-power in control

INSTALLATION INSTRUCTIONS

Multi-functional Protection Relay, MTR-4P

- 13 protection functions
- Marine approval from GL/DNV
- Power accuracy class 0.5
- Fast and simple commissioning from M-Set
- Two-stage trip setting
- Start-up delay
- Typical response time below 50 ms
- Modbus RS-485 communication
- Password protection

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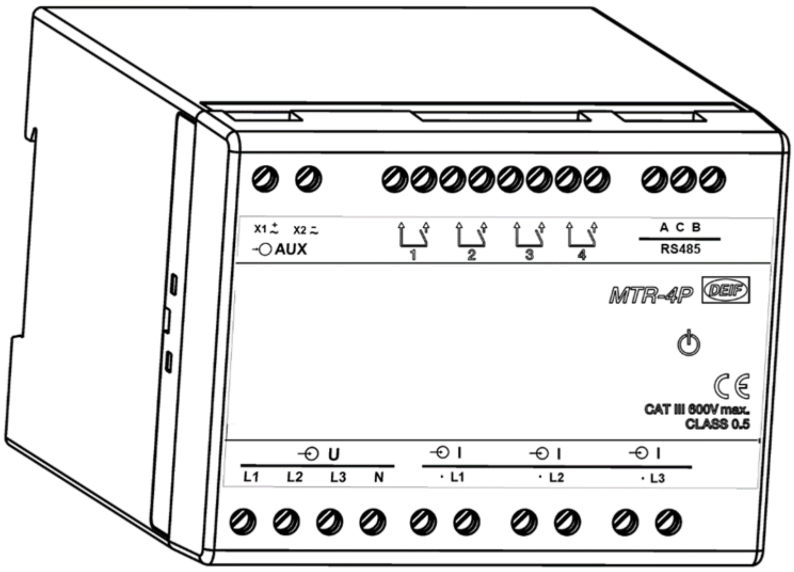
Document no.: 4189341144A

Table of content

MULTI-FUNCTIONAL PROTECTION RELAY, MTR-4P



SECURITY ADVICE AND WARNINGS

Read this chapter carefully to acquaint yourself with the measuring instrument before you continue to install, energise and work with it, and examine the equipment carefully for potential damages which might arise during transport.

This chapter deals with important information and warnings that should be considered for safe installation and handling of a device in order to assure its correct use and continuous operation.

Users of the product should acquaint themselves with the contents of chapter »Security Advice and Warnings«.

If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

NOTE

Installation and use of devices also includes work with dangerous currents and voltages, therefore such work must be carried out by qualified persons only. DEIF A/S does not assume any responsibility in connection with installation and use of the product. If there is any doubt regarding installation and use of the system, in which the instrument is used for measuring or protection, contact the person who is responsible for installation of the system.

WARNINGS, INFORMATION AND NOTES REGARDING DESIGNATION OF PRODUCT

Used symbols:

⓿	See product documentation.
⑩	Double insulation in compliance with the EN 61010−1 standard.
🖌	Functional ground potential. Note: This symbol is also used to mark a terminal for protective ground potential if it is used as a part of connection terminal or auxiliary supply terminals.
+	Compliance of the product with directive 2002/96/EC, as first priority, the prevention of waste electrical and electronic equipment (WEEE), and in addition, the reuse, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste. It also seeks to improve the environmental performance of all operators involved in the life cycle of electrical and electronic equipment.
⑨	Compliance of the product with European CE directives.

BEFORE SWITCHING THE DEVICE ON

Check the following before you switch the device on:

- Nominal voltage
- Supply voltage
- Nominal frequency
- Voltage ratio and phase sequence
- Current transformer ratio and terminals' integrity
- Protection fuse for voltage inputs (recommended maximum external fuse size is 6 A)
- External switch or circuit breaker must be included in the installation for disconnection of the devices' aux. power supply. It must be suitably located and properly marked for reliable disconnection of the device when needed
- Integrity of earth terminal
- Proper connection and voltage level of I/O modules

WARNING

A current transformer secondary should be short-circuited before you connect the device.

DEVICE SWITCH OFF WARNING

Auxiliary supply circuits for (external) relays can include capacitors between supply and ground. In order to prevent electrical shock hazard, the capacitors should be discharged via external terminals after the auxiliary supply has been completely disconnected (both poles of any DC supply).

HEALTH AND SAFETY

The purpose of this chapter is to provide the user with information on safe installation and handling of the product in order to assure its correct use and continuous operation.
We expect that anyone using the product will be acquainted with the contents of chapter »Security Advice and Warnings«.

If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

REAL TIME CLOCK

As a backup power supply for real time clock, super-cap, is built in. Support time is up to two days (after the auxiliary power supply is disconnected).

DISPOSAL

It is strongly recommended that electrical and electronic equipment is not deposited as municipal waste. The manufacturer or provider must take waste electrical and electronic equipment free of charge. The complete procedure after lifetime expiry should comply with the Directive 2002/96/EC about restrictions on the use of certain hazardous substances in electrical and electronic equipment.

BASIC DESCRIPTION AND OPERATION

This chapter presents all relevant information about the instrument, which is required to understand its purpose, applicability and basic features related to its operation.

In addition, it also contains navigational tips, description of used symbols and other useful information for understandable navigation through this manual.

As regards the options of this instrument, different chapters should be considered since a particular sub-variant might vary in functionality. More detailed description of device functions is given in chapters »Main Features«, »Supported options« and »Functionality«.

The protection relay MTR-4P is available in DIN rail mounting enclosure. Specifications of housing are given in chapter »Connection« > Mounting on page 10.

Contents

The packaging contains the following items:

- Protection unit
- Quick start guide

All related documentation on this product is available at www.DEIF.com/products/. The instrument desktop-based setting software, M-set, together with accompanying drivers are available on our web page http://www.DEIF.com/software/. For environmental reasons, all this information is no longer provided on a separate CD.

CAUTION

Examine the equipment carefully for potential damage, which might have occurred during transport.

Description of the MTR-4P Protection relay

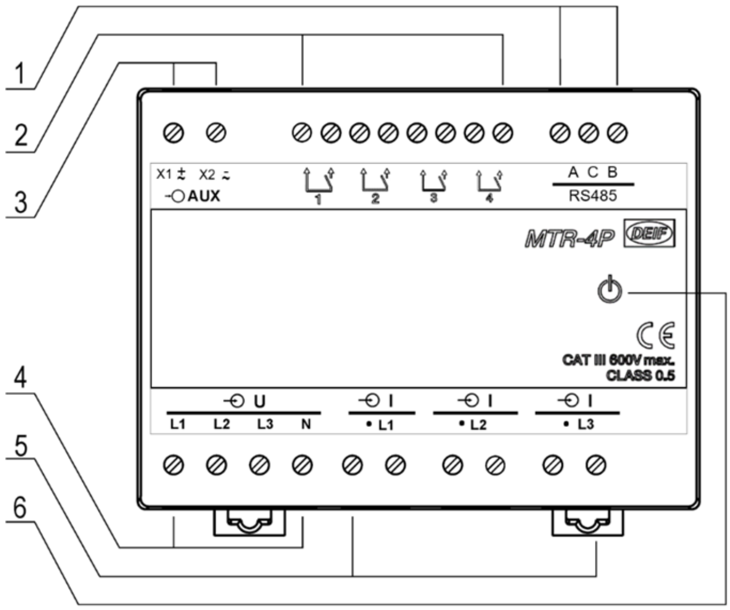
MTR-4P is intended for measuring and protection of single-phase or three-phase electrical power networks. It measures RMS network values and all significant deviations from the nominal values by means of fast sampling of voltage and current signals. There is an option in the M-set Settings Studio software to also select the measurements based only on positive sequence fundamental wave, which does not include harmonics measurements. This option can be found under the M-set Settings menu. With this option included, all corresponding values are replaced by IEC 61400-21 Annex C measurements. This makes MTR-4P suitable for acquisition and validation of fast changes in the network. A built-in microcontroller calculates measured values (voltage, current, frequency, energy, power, power factor, THD phase angles, and deviations) and sends these data over the RS-485 communication interface.

Lack of information regarding supplied voltage quality can lead to unexplained production problems and malfunction or can even damage equipment that is used during factory production process. Therefore MTR-4P can be used to detect predefined faults. With measuring of 13 different network deviations, MTR-4P can be used as a simple but efficient protection relay. MTR-4P is delivered un-configured for customer configuration with the user-friendly setting software, M-set. MTR-4P supports Modbus RS-485 with speed up to 115200 Baud, which is perfect for integration into large systems.

Additional USB 2.0 interface can only be used for a fast setup without the need for auxiliary power supply. This interface is provided with only **basic** insulation and can **only** be used when disconnected from all power inputs.

Appearance

1 – Communication ports
2 – I/O modules
3 – Auxiliary supply
4 – Voltage inputs
5 – Current inputs
6 – Power ON LED



Communication ports and LED indicators

Serial communication can be connected by using a screw-in connector (RS-485). USB can be connected through a USB-mini type connector at the bottom of the transducer.
The LED indicator is intended for POWER ON signalling (red LED).

WARNING

USB communication port is provided with only **basic** insulation and can **only** be used when disconnected from aux. supply **and** power inputs!

I/O modules
Four I/O module slots are intended for electromechanical relay output I/O modules.
Universal auxiliary supply
Auxiliary supply is connected by means of two screw-in connectors. For safety purposes it is important that all wires are firmly fastened. Auxiliary supply is wide range (20 to 300 V DC; 48 to 276 V AC).
Voltage inputs
Each voltage input is connected to the measuring circuit through an input resistor chain (3.3 MΩ per phase). Maximum value of input voltage is 600 V_{L-N} (1000 V_{L-L}).
Current inputs
Each current input is connected to the measuring circuit through a current transformer (0.01 Ω per phase). Maximum allowed thermal value of input current is 15 A (cont.).

Abbreviation/glossary

Abbreviations are explained within the text where they appear the first time. The most common abbreviations and expressions are explained in the following table:

Term	Explanation
RMS	Root mean square value
Flash	A type of memory module that keeps its content in case of power supply failure
MODBUS / DNP3	Industrial protocol for data transmission
M-set	Setting software for DEIF instruments
PA total	Power angle calculated from total active and apparent power
PA_{phase}	Angle between fundamental phase voltage and phase current
PF_{phase}	Power factor, calculated from apparent and active power (affected by harmonics)
THD (U, I)	Total harmonic distortion
TDD (I)	Total demand distortion (according to IEEE Std. 519-1992). Indicates harmonic distortion at full load
MD	Max. demand; measurement of average values in time interval
FFT graphs	Graphical display of presence of harmonics
Harmonic voltage − harmonic	Sinusoidal voltage with frequency equal to integer multiple of basic frequency
InterHarmonic voltage − interharmonics	Sinusoidal voltage with frequency **not** equal to integer multiple of basic frequency
RTC	Real time clock
Sample factor	Defines a number of periods for measuring calculation on the basis of measured frequency
M_p − average interval	Defines frequency of refreshing displayed measurements
Hysteresis [%]	Percentage specifies increase or decrease of a measurement from a certain limit after exceeding it
RO	Relay output module

List of common abbreviations and expressions

Purpose and use of MTR-4P

The MTR-4P protection relay is used for measuring and monitoring of all single-phase or three-phase values and for detecting predefined faults. With measuring of ten different network deviations, MTR-4P can be used as a simple but efficient protection relay. MTR-4P is delivered unconfigured for customer configuration with the user-friendly setting software, M-set. MTR-4P supports Modbus RS-485 with speed up to 115200 Baud, which is perfect for integration into large systems.

Additional USB 2.0 interface can only be used for a fast setup without the need for auxiliary power supply. This interface is provided with only **basic** insulation and can be used **only** when disconnected from power inputs.

Supported measurements

	Basic measurements
Phase	Voltage U_1, U_2, U_3 and $U^{\sim}$
	Current I_1, I_2, I_3, I_n, I_t and I_a
	Active power P_1, P_2, P_3, and P_t
	Reactive power Q_1, Q_2, Q_3, and Q_t
	Apparent power S_1, S_2, S_3, and S_t
	Power factor PF_1, PF_2, PF_3 and $PF^{\sim}$
	Power angle φ_1, φ_2, φ_3 and $\varphi^{\sim}$
	THD of phase voltage U_{f1}, U_{f2} and U_{f3}
	THD of power angle I_1, I_2 and I_3
Phase-to-phase	Phase-to-phase voltage U_{12}, U_{23}, U_{31}
	Average phase-to-phase voltage U_{ff}
	Phase-to-phase angle φ_{12}, φ_{23}, φ_{31}
	THD of phase−to−phase voltage
Energy	Counter 1
	Counter 2
	Counter 3
	Counter 4
	Active tariff

	Other measurements
MD values	Phase current I_1, I_2, I_3
	Active power P (positive)
	Active power P (negative)
	Reactive power Q − L
	Reactive power Q − C
	Apparent power S
Measurements	Frequency
	Internal temperature

CONNECTION

This chapter deals with the instructions for connection of the measuring instrument. Both the use and connection of the device include handling of dangerous currents and voltages. Connection must therefore be performed **only** by a qualified person using appropriate equipment. DEIF A/S does not take any responsibility regarding the use and connection. If any doubt occurs regarding connection and use in the system, for which the device is intended, contact a person who is responsible for such installations.
A person qualified for installation and connection of a device should be acquainted with all necessary precaution measures described in this document prior to its connection.

Check the following before use:

- Nominal voltage ($U_{P\text{-}Pmax}$ = 1000 V_{ACrms}; $U_{P\text{-}Nmax}$ = 600 V_{ACrms})
- Supply voltage (rated value)
- Nominal frequency
- Voltage ratio and phase sequence
- Current transformer ratio and terminals' integrity
- Protection fuse for voltage inputs (recommended maximum external fuse size is 6 A)
- External switch or circuit breaker must be included in the installation for disconnection of the devices' aux. power supply. It must be suitably located and properly marked for reliable disconnection of the device when needed. See CAUTION below
- Integrity of earth terminal
- Proper connection and voltage level of I/O modules

WARNING

Wrong or incomplete connection of voltage or other terminals can cause non-operation or damage to the device.

CAUTION

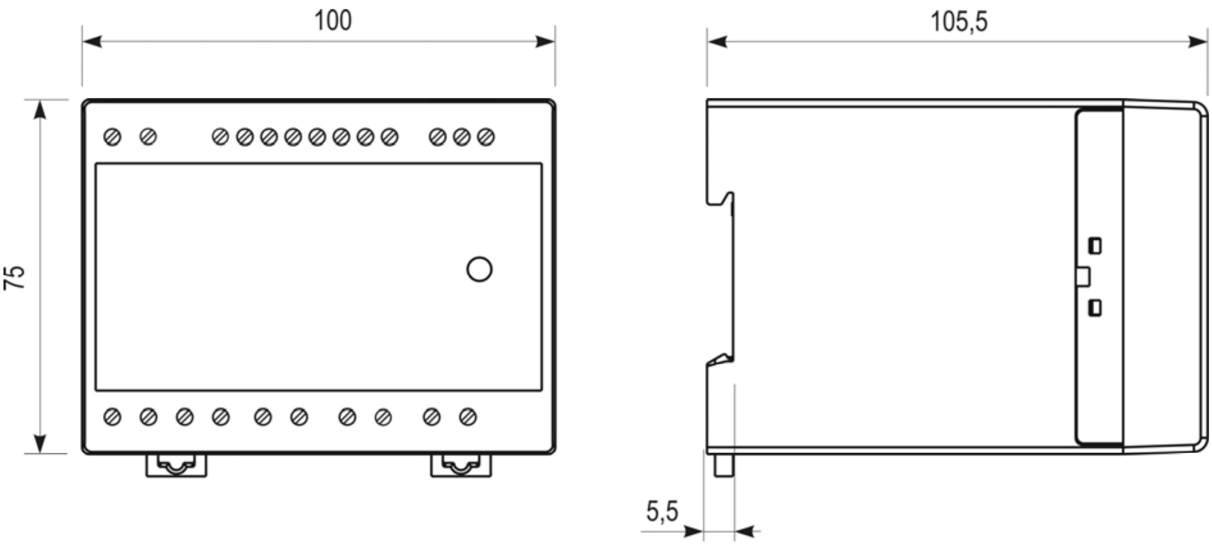
Aux. supply inrush current can be as high as 20 A for a short period of time (<1 ms). Choose an appropriate MCB for disconnection of aux. supply.

NOTE

After connection, settings must be performed via communication using the M-set software.

Mounting

The MTR-4P protection relay is designed for DIN rail mounting. It should be mounted on a 35 mm DIN rail by means of two plastic fasteners. Before installation, the fasteners should be in open position (pulled). Once the device is in place, the fasteners are locked (pushed) to close position.



Dimensional drawing

Electrical connection for MTR-4P

Voltage inputs of a device can be connected directly to a low-voltage network or via a voltage measuring transformer to a high-voltage network.

Current inputs of a measuring transducer can be connected directly to a low-voltage network or via a corresponding current transformer.

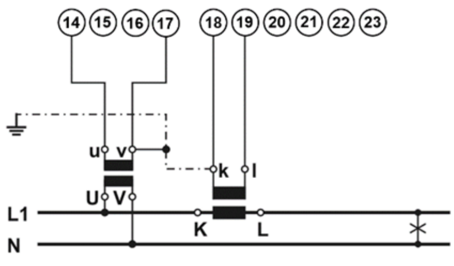
Choose corresponding connection from the figures below and connect corresponding voltages and currents. Information on electrical consumption of current and voltage inputs is given in the data sheet, section »Technical Data«.

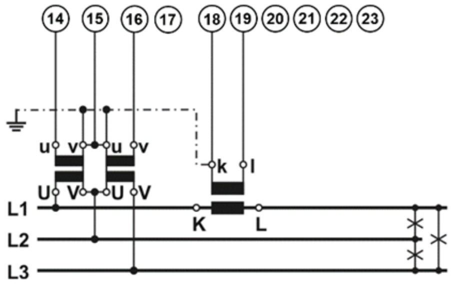
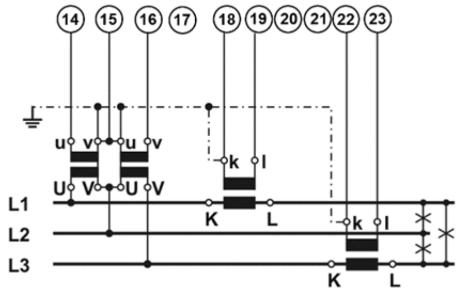
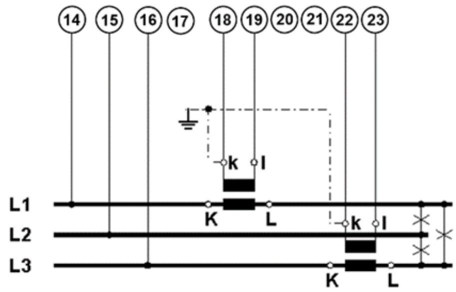
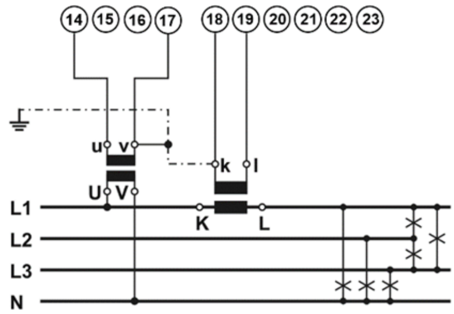
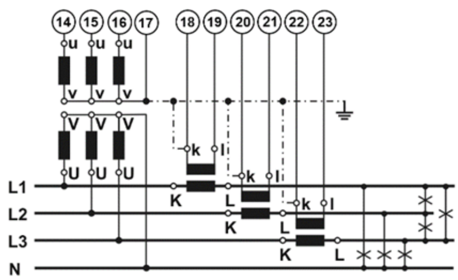
CAUTION

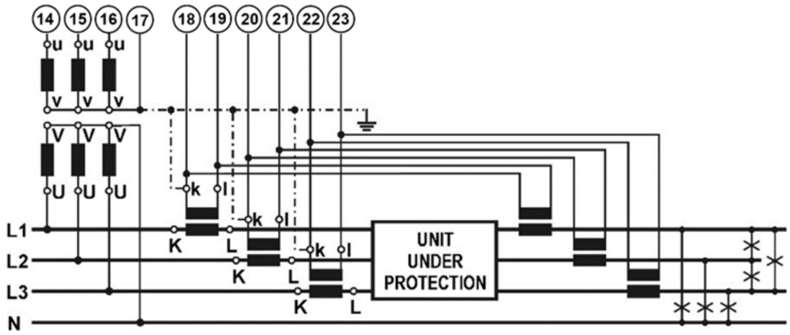
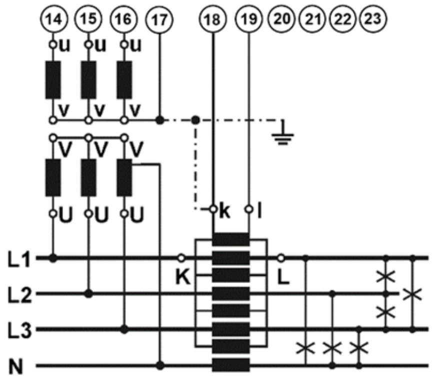
For accurate operation and to avoid measuring signal crosstalk it is important to avoid driving voltage measuring wires close to current measuring transformers.

NOTE

For proper connection, wire diameters and other wiring requirements, see section »Technical data« > Connection in the data sheet.

System/connection	Terminal assignment
Connection 1b (**1W**) Single-phase connection	

System/connection	Terminal assignment
Connection 3b (**1W3b**) Three-phase, three-wire connection with balanced load	
Connection 3u (**2W3u**) Three-phase, three-wire connection with unbalanced load	
Direct connection 3u (**2W3u**) Three-phase, three-wire direct connection	
Connection 4b (**1W4b**) Three-phase, four-wire connection with balanced load	
Connection 4u (**3W4u**) Three-phase, four wire-connection with unbalanced load	

System/connection	Terminal assignment
Connection I_{diff} Three-phase, four-wire connection with unbalanced load	
Connection I_E Three-phase, four-wire connection with unbalanced load	

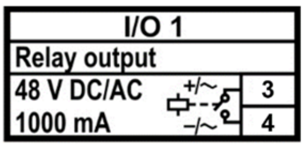
Connection of input/output modules

WARNING

Check the module features that are specified on the label before you connect module contacts. Wrong connection may cause damage or destruction of module and/or device.

Connect module contacts as specified on the label. Examples of labels are given below, they describe modules built in the device. Information on electrical properties of modules is given in section »Technical Data« in the data sheet.

I/O module 1

	Electromechanical relay output module. (Example of alarm module as I/O module 1).

Communication connection

The MTR-4P protection relay is equipped with one service communication port (USB) and optionally with one standard (COM1) RS-485 communication port.

WARNING

The USB communication port is provided with only **basic** insulation and can **only** be used when disconnected from aux. supply **and** power inputs!

Connect a communication line by means of corresponding terminals. Connection information is given on the instrument label. Connector terminals are marked on the label on the upper side of the instrument.
The USB connector is positioned at the bottom of the instrument, under the removable plastic cover. The instrument will establish USB connection with the PC approximately 3 seconds after physical connection to the USB port.
More detailed information about communication is given in chapter »Communication« on page 25.

RS-485

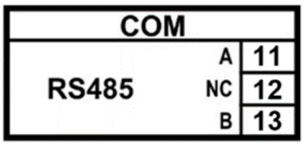
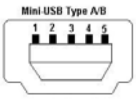
Additionally, MTR-4P has RS-485 communication intended for connection of multiple devices to a network where devices with RS-485 communication are connected to a common communication interface. We suggest using one of the DEIF A/S communication interfaces! For proper operation it is necessary to assure the corresponding connection of individual terminals. See table »Survey of communication connection« on page 14.

Service USB

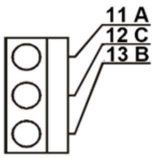
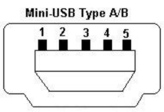
MTR-4P has a USB communication port, located at the bottom under a small circular plastic cover. It is intended for settings **only** and requires **no** auxiliary power supply. When connected to this communication port, MTR-4P is powered by USB.
The USB port should not remain open. It should be closed immediately after the initial setting through the USB port has been done and should always remain closed during storing and operation. Always remember to put the USB cover back on after initial setting. The warranty will be void if the unit is put into storage, mounted on the DIN rail or operated without USB cover.
Also, if the unit is returned without USB cover or with clear indications that it was stored or operated without USB cover on the USB port, it will be treated as out of the warranty.

⚠ WARNING

The USB communication port is provided with only **basic** insulation and can **only** be used when disconnected from aux. supply **and** power inputs!

	COM1 serial communication port (RS-485)
	SERVICE communication port (USB)

Survey of communication connection

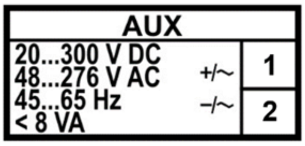
Connector	Terminals	Position	RS-485
Screw terminals		11	A
		12	NC
		13	B
USB-mini B		Standard USB 2.0 compatible cable recommended (type mini B plug)	

Connection of aux. power supply

The device can be equipped with either of two types of universal (AC/DC) switching power supply.

Auxiliary power supply: 20 to 300 V DC
48 to 276 V AC
45 to 65 Hz

Regarding power supply voltage specification on the label, choose and connect the power supply voltage:



Connection of auxiliary power supply type to terminals 1 and 2.

CAUTION

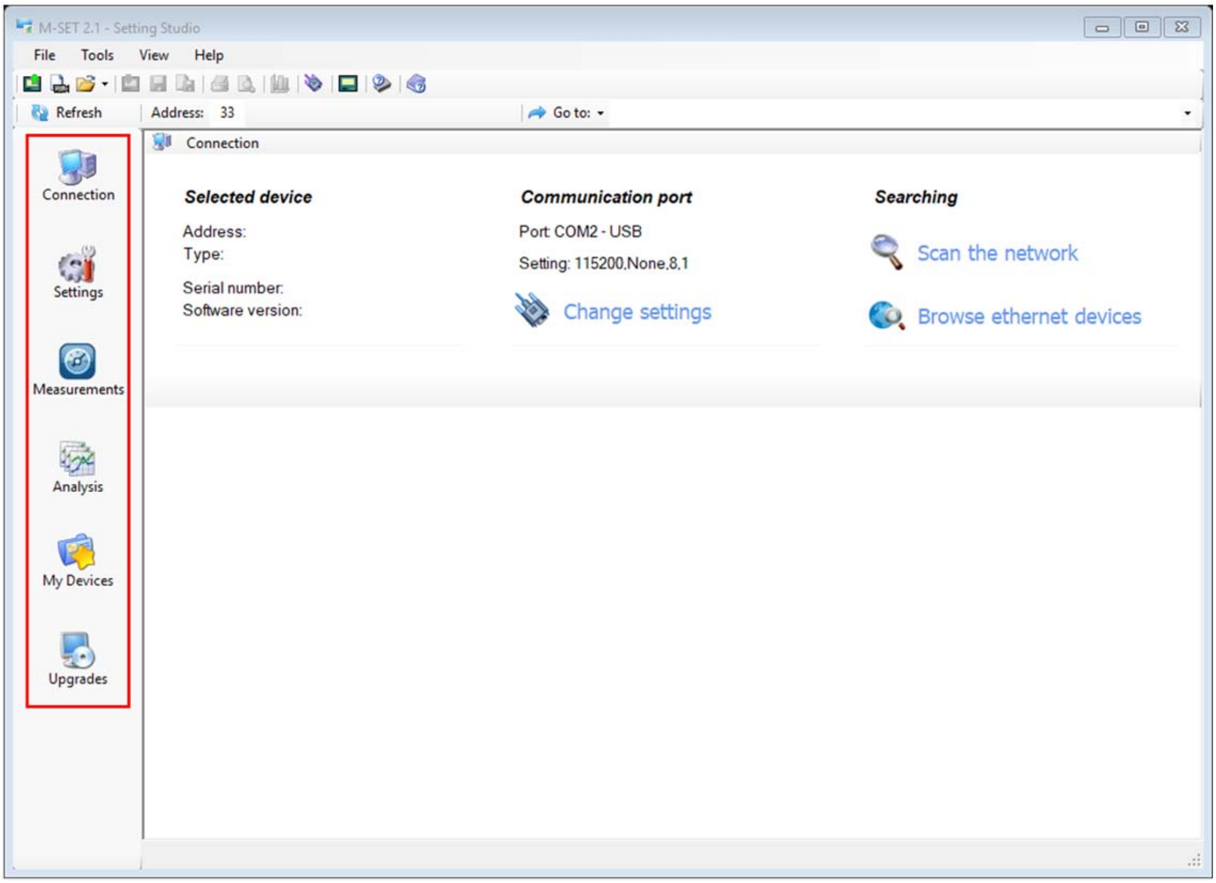
Aux. supply inrush current can be as high as 20 A for a short period of time (<1 ms). Choose an appropriate MCB for connection of aux. supply.

SETTINGS

Setting of the device can be performed via communication with the M-set software. Complete setting of the device can be done using the M-set software.

M-set software

The M-set software is a tool for complete programming and monitoring of DEIF measuring instruments. Remote operation is possible by means of serial RS-485. The user-friendly interface consists of six segments: Connection, settings, measurements, analysis, my devices and upgrades. These segments are easily accessed by means of the six icons to the left:

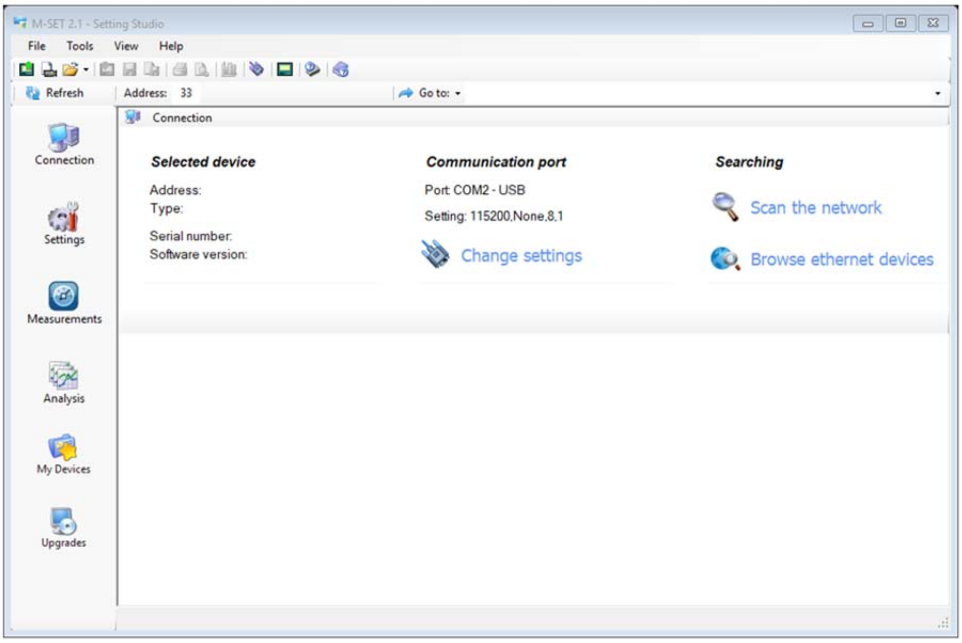


The latest version of the M-set software can be downloaded from the DEIF A/S website, www.DEIF.com

NOTE

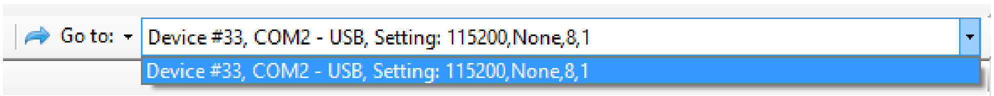
M-set has a very intuitive help system. All functions and settings are described in an info window at the bottom of the M-set window. In the M-set Help file, detailed instructions about software usage, connection and communication with different types of devices, driver installation, and so on, are described.

Device management



M-set device management window

With M-set it is very easy to manage devices. If you are dealing with a device that has been accessed before, it can easily be selected from a favourites line.

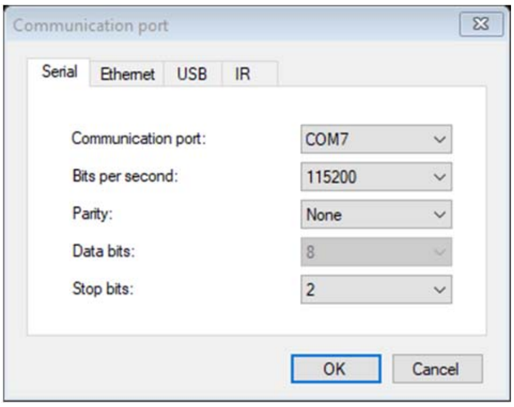


In this way, the communication port is automatically set as it was when it was last accessed.
Follow the instructions below to communicate with the new device:
Connect the device to a communication interface (depending on type of device):

- To comm. adapter RS-485
- Directly to a PC using USB cable

Set communication port parameters

Current communication parameters are displayed under communication port. To change those parameters, click the Change settings button. A communication port window opens with settings for different communication interfaces.



To activate the desired communication, select the proper communication tab, set the communication parameters and confirm your selections with the OK button.

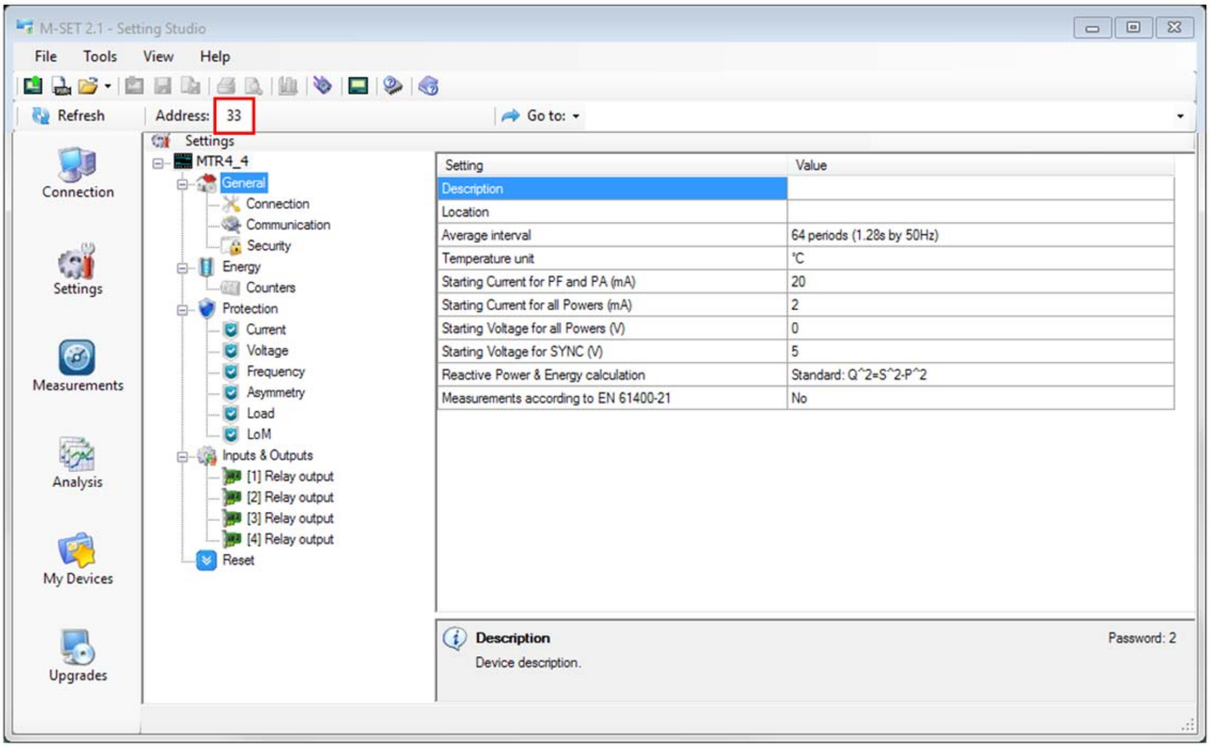
NOTE

The first time a device with USB communication is connected to a computer, a device driver will be installed automatically. If the installation is correct, the device presents itself in an operating system (Device manager > COM Ports) as a measuring device. If the device is not recognised automatically, or if a wrong driver is installed, valid installation drivers are located in the M-set installation directory, subdirectory Drivers.
With this driver installed, the USB is redirected to a serial port which should be selected when using the M-set software.

For more information regarding communication parameters, see chapter »Communication« on page 25.

Set device Modbus address number

Each device that is connected to a network has its unique Modbus address number. In order to communicate with that device, an appropriate address number should be set.



The factory default Modbus address for all devices is 33. If devices are connected to a communication network, they should all have the same communication parameters, but each of them should have its own unique address.

Start communicating with a device

Click the Refresh button to display device information:

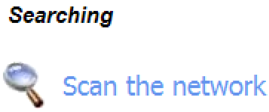
Selected device

Address: 33
Type: MTR3-0

Serial number: M4T09191
Software version: 0.19

When devices are connected to a network, and a certain device is required, it is possible to browse a network for devices. For this purpose you must choose:

- **Scan the network** when the device is connected to an RS-485 bus

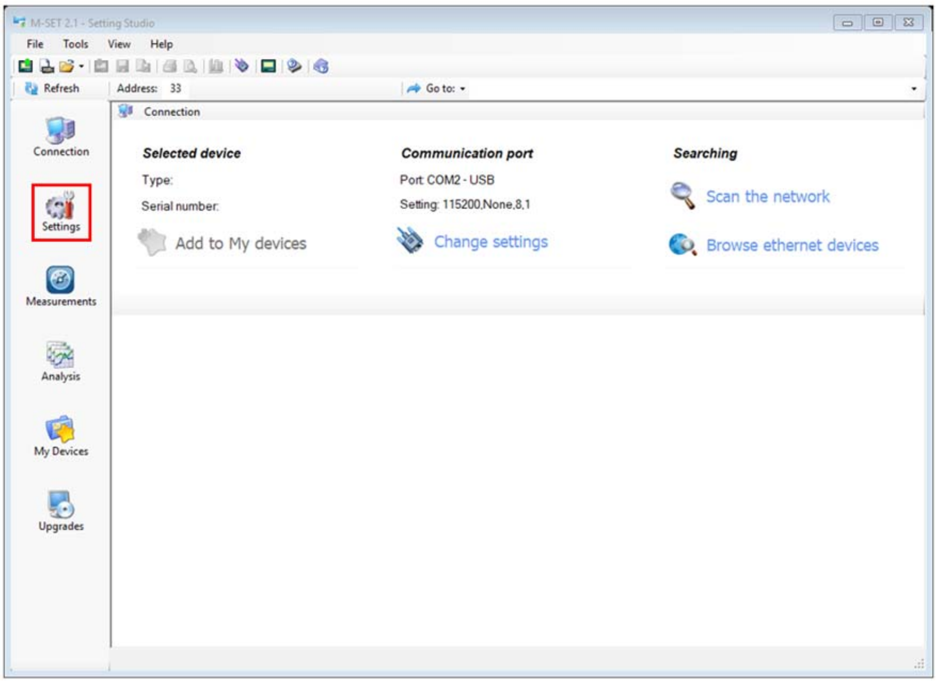


Settings

Programming of devices can be performed **online** when the device is connected to aux. power supply and communicates with M-set. When the device is not connected, it is possible to adjust the settings **offline**.

Online programming

When communication with a device has been established, choose the icon Settings from the list of M-set functions to the left.
M-set device setting window:



Choose the (Read settings) button to display the settings of all devices, and adjust them according to project requirements.

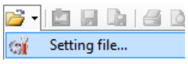
NOTE

When you have finished programming, you should confirm the changes by pressing the (Download settings) button in the M-set menu bar, or with the mouse right-click menu.

NOTE

When you have finished programming, all settings can be saved in a setting file (*.msf file). In this way it is possible to archive settings in combination with a date. It is also possible to use saved settings for offline programming, or to programme other devices with the same settings. For more information, see »Offline programming«.

Offline programming

When a device is not physically present, or it is unable to communicate, it is still possible to perform **offline** programming. Choose the Open icon and select 

(Setting file) from the M-set device setting window.

From a list of *.msf files, choose either a previously stored file (a setting file that has been used for another device and stored) or an MXxxx.msf file, which holds default settings for this device.

When confirmed, all device settings are displayed in the same way as with **online** programming.

When you have finished programming, all settings can be saved in a setting file with a meaningful name (for example *MXxxx_location_date*.msf). If the file is to be used to set the device via memory card (only for devices with memory card support), a special name format must be used.

Settings are stored in the Setting directory, using two recording modes:

- With a type designation and a sequence number between 1 and 9
- With a device serial number

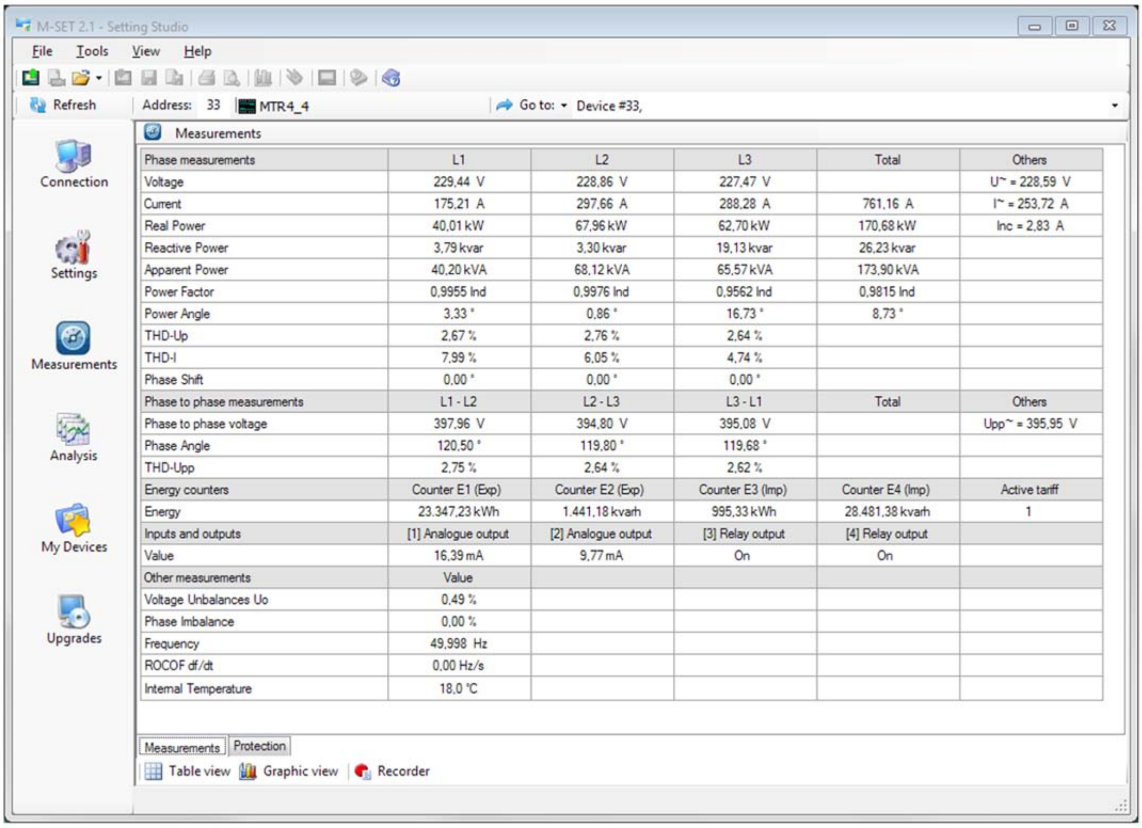
CAUTION

An MXxxx.msf file or any other original device setting file should not be modified, as it contains device default settings. Save the setting file under another name before you adjust it with your own project requirements.

Measurements

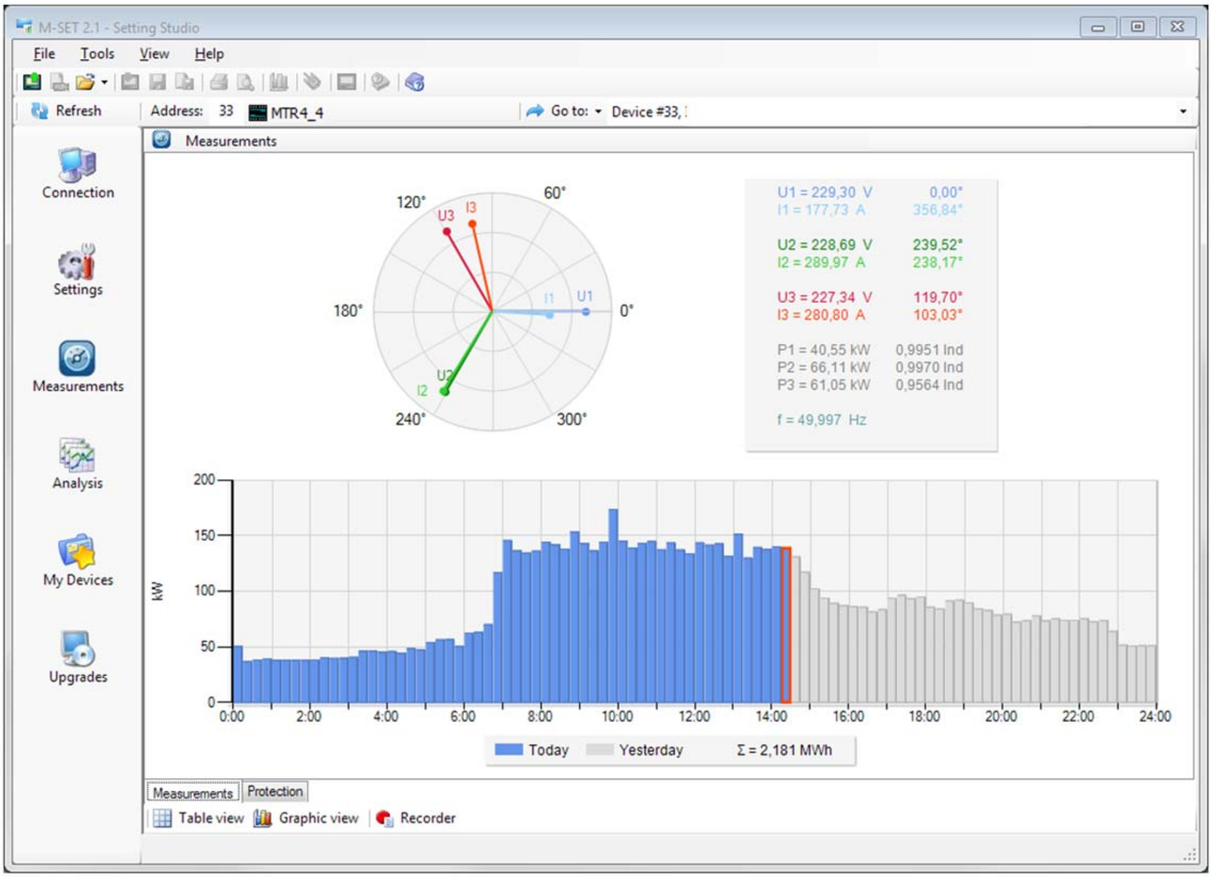
Measurements can be seen **online** when the device is connected to aux. power supply and communicates with M-set. When the device is not connected, it is possible to see **offline** measurement simulation. The latter is useful for presentations and visualisation of measurements without presence of the actual device.

In **online** mode, all supported measurements and alarms can be seen in real time in a table view. Also, for some devices, presentation in graphical form is supported.



Phase measurements	L1	L2	L3	Total	Others
Voltage	229,44 V	228,86 V	227,47 V		U~ = 228,59 V
Current	175,21 A	297,66 A	288,28 A	761,16 A	I~ = 253,72 A
Real Power	40,01 kW	67,96 kW	62,70 kW	170,68 kW	Inc = 2,83 A
Reactive Power	3,79 kvar	3,30 kvar	19,13 kvar	26,23 kvar	
Apparent Power	40,20 kVA	68,12 kVA	65,57 kVA	173,90 kVA	
Power Factor	0,9955 Ind	0,9976 Ind	0,9562 Ind	0,9815 Ind	
Power Angle	3,33 °	0,86 °	16,73 °	8,73 °	
THD-Up	2,67 %	2,76 %	2,64 %		
THD-I	7,99 %	6,05 %	4,74 %		
Phase Shift	0,00 °	0,00 °	0,00 °		
Phase to phase measurements	L1 - L2	L2 - L3	L3 - L1	Total	Others
Phase to phase voltage	397,96 V	394,80 V	395,08 V		Upp~ = 395,95 V
Phase Angle	120,50 °	119,80 °	119,68 °		
THD-Upp	2,75 %	2,64 %	2,62 %		
Energy counters	Counter E1 (Exp)	Counter E2 (Exp)	Counter E3 (Imp)	Counter E4 (Imp)	Active tariff
Energy	23.347,23 kWh	1.441,18 kvarh	995,33 kWh	28.481,38 kvarh	1
Inputs and outputs	[1] Analogue output	[2] Analogue output	[3] Relay output	[4] Relay output	
Value	16,39 mA	9,77 mA	On	On	
Other measurements	Value				
Voltage Unbalances Uo	0,49 %				
Phase Imbalance	0,00 %				
Frequency	49,998 Hz				
ROCOF df/dt	0,00 Hz/s				
Internal Temperature	18,0 °C				

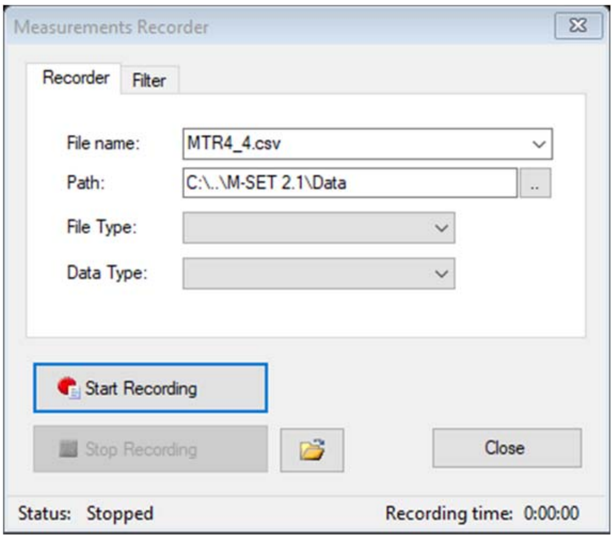
Online measurements in Table view



Online measurements in graphical form – phasor diagram and daily total active power consumption histogram

Different measuring data can be accessed by means of the Measurements and Protection tabs in the lower part of the M-set window.

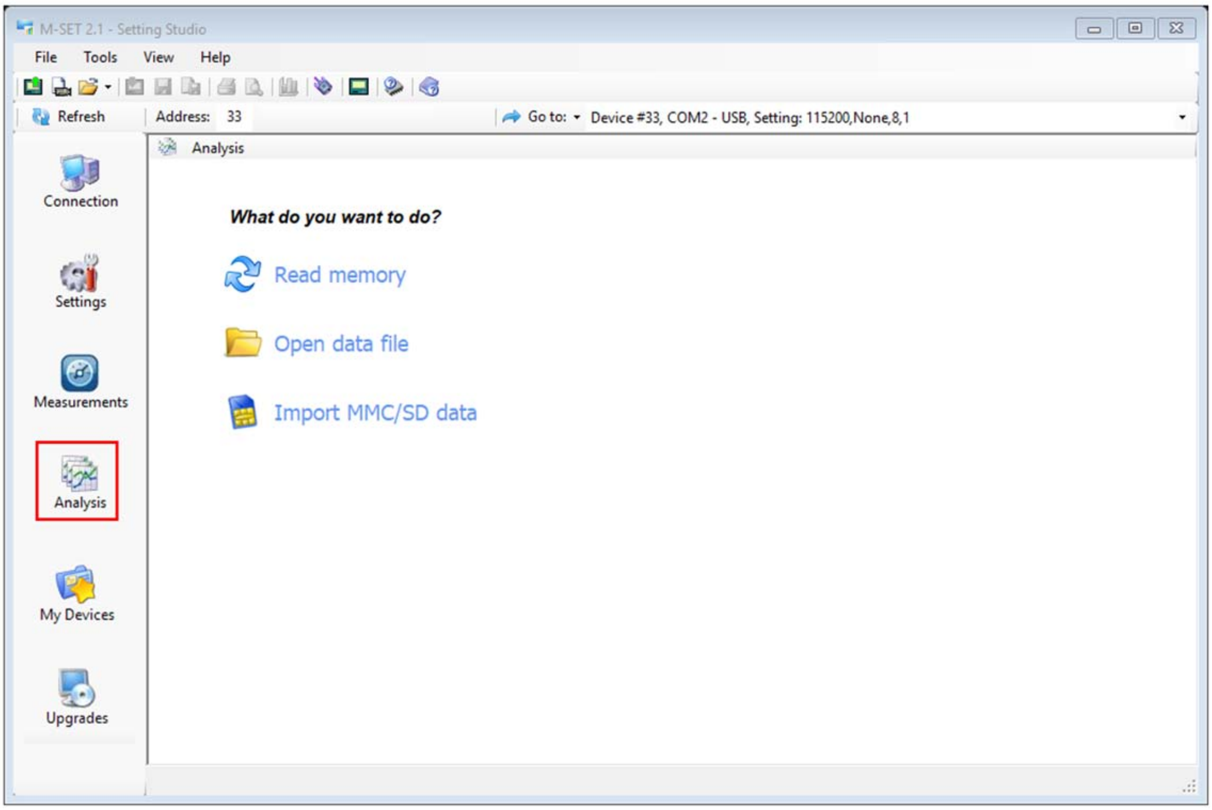
For further processing of real time measurement results, it is possible to set a recorder (with the Recorder button) on an active device, to record and save selected measurements to MS Excel .csv file format. Data can then be analysed and processed in any program that supports files in .csv format.



Window for setting of local database recording parameters

Data analysis

M-set also enables analysis of the historical data stored in the device's internal memory (only for devices with built-in memory). In order to perform an analysis, the data source must be defined first. The data source can be one of the following (selected):



Read memory

This option is selected to download and analyse data from a currently active device. Data is read directly from a device's internal memory.

Open data file

This option is selected to analyse data that is already stored on the computer. Data is read from a local database.

My Devices

In My Devices the user can store connections to devices that are frequently used. Each device can be assigned to a user-defined group and equipped with user-defined description and location for easier recognition. By selecting the device from the list, access to the device settings plus downloaded and recorded files is much easier.

Upgrades

In the Upgrades section the latest software, for M-set as well as DEIF measuring devices, can be found. To assure full functionality, you should always use the latest version. Manual or automatic checking for upgrades is available. Internet connection is required.

The list of available updates is divided into various sections for easier navigation. Each section is named by software or type of devices (M-set software, Measuring centres, Measuring transducers, and so on). A history file with data on corrections and added functionality is also available.

Software upgrading

NOTE

M-set cannot be used for execution of firmware upgrade of devices. It only indicates that a new version is available and provides a link to downloading it from the server. Software for execution of firmware upgrades is included in the downloaded zip file together with the upgrade file, upgrade procedure description and revision history.

Setting procedure

Before you configure a device with the M-set software, current settings should be read. Reading is available either via communication or from a file (stored on a local disk). A setting structure that is similar to a file structure in an Explorer is displayed in the left part of the M-set setting window. Available settings of that segment are displayed in the right part when you click any of the stated parameters.

NOTE

Some settings may not be available due to unsupported measurements and/or functions that depend on the device type.

General settings

General settings are essential for measuring instruments. They are divided into three sublevels (Connection, Communication and Security).

Description and location

Description is intended for easier recognition of a certain unit in a network. It is used chiefly for identification of the device on which measurements are performed.

Average interval

The average interval defines a refresh rate of measurements on display and communication. It is also used as average interval for minimum and maximum values stored in the recorder and actual alarm value calculation for alarm triggering.

Average interval for measurements

The average interval defines a refresh rate of measurements on display and communication. It also defines the response time for alarms set to Normal response (see chapter »Alarms«).

- Shorter average interval means better resolution in minimum and maximum value in the recorded period detection. Also, data presented on the display will refresh faster.
- Longer average interval means lower minimum and maximum value in the recorded period detection and slower alarm response (the alarm response can also be delayed with the Compare time delay setting, see chapter »Alarms«). Also, data on display will refresh slower.

The interval can be set from 8 to 256 periods. The default value is 64 periods.

NOTE

This setting only applies to the minimum and maximum values displayed on the LCD and accessible from communication. These values are not used for storing into the internal recorder.

Temperature unit

Choose a unit for displaying of temperature. Degrees Celsius and degrees Fahrenheit are available.

Starting current for PF and PA (mA)

All measuring inputs are influenced by noise of various frequencies. It is more or less constant and its influence on the accuracy is increased by decreasing measuring signals. It is also present when measuring signals are not present or very low. It causes very sporadic measurements.
This setting defines the lowest current that allows regular calculation of power factor (PF) and power angle (PA).
The value of the starting current should be set according to the conditions in a system (level of noise, random current fluctuation, and so on).

Starting current for all powers (mA)

Noise is limited with a starting current also at measurements and calculations of powers. The value of the starting current should be set according to the conditions in a system (level of noise, random current fluctuation, and so on).

Starting voltage for all powers (V)

Noise is limited with a starting voltage also at measurements and calculations of powers. Until the voltage reaches the user-defined starting voltage threshold, all powers are set to 0. When three-wire electrical connections are used, virtual phase voltage is used in calculations.

Starting voltage for SYNC

The device needs to synchronise its sampling with the measuring signal periods to accurately determine its frequency. For that purpose, the input signal bust be large enough to be distinguished from a noise.
If all phase voltages are smaller than this (noise limit) setting, the instrument uses current inputs for synchronisation. Also, if all phase currents are smaller than the starting current for PF and PA settings, synchronisation is not possible and the frequency displayed is 0.
The value of the starting voltage should be set according to the conditions in a system (level of noise, random voltage fluctuation, and so on).

Reactive power and energy calculations

Harmonic distortion can significantly influence the reactive power and energy calculation. In absence of harmonic distortion, both described methods will offer the same result. In reality, harmonics are always present. Therefore it depends on the project requirements, which method is applicable.
The user can select between two different principles of reactive power and energy calculation:

Standard method

With this method, reactive power and energy are calculated based on the assumption that all power (energy), which is not active, is reactive.
Q2 = S2 – P2
This also means that all higher harmonics (out of phase with base harmonic) will be measured as reactive power (energy).

Displacement method

With this method, reactive power (energy) is calculated by multiplication of voltage samples and by 90 ° displaced current samples.
Q = U × I|+90 °
With this method, reactive power (energy) represents only true reactive component of apparent power (energy).

Connection

CAUTION

Settings of connections must reflect the actual state, otherwise measurements will not be valid.

Connection mode

When connection is selected, load connection and the supported measurements are defined.

Setting of current and voltage ratios

Before setting the current and voltage ratios, it is necessary to know in which conditions the device will be used. All other measurements and calculations depend on these settings. Aux. CT transformer ratios can be set separately from phase CT ratios, since aux. CT may differ from phase CTs.
Range of CT and VT ratios:

Settings range	VT primary	VT secondary	CT, aux. CT primary	CT, aux. CT secondary
Max. value	1638.3 kV	13383 V	1638.3 kA	13383 A
Min. value	0.1 V	0.1 V	0.1 A	0.1 A

Energy flow direction

This setting allows manual change of energy flow direction (**import** to **export** or vice versa) in the readings tab. It has no influence on readings sent to communication or to memory.

CT connection

If this setting is set to **reversed**, it has the same influence as if CTs would be reversely connected. All power readings will also change their sign.
This setting is useful to correct wrong CT connections.

Communication

Communication parameters (COM1)

MTR-4P has one optional galvanically separated communication port (COM1), which in some variants is equipped with RS-485, or left open.

Configuration	**COM**
Without	Service USB
RS-485	RS-485 + service USB

Serial communication:	**RS-485**
Connection type	Network
Connection terminals	Screw terminals
Function	Settings, measurements and FW upgrade
Insulation	Protection class II, 3.3 kV_{ACRMS} 1 min
Max. connection length	2000 m
Transfer mode	Asynchronous
Protocol	Modbus RTU
Transfer rate	2.4 kBaud to 115.2 kBaud
Number of nodes	≤ 32

Serial communication

Communication parameters (only for main communication port COM1), which are important for the operation in RS-485 networks.
Factory settings for serial communication are:

Modbus address	#33	Address range is 1 to 247
Comm. speed	115200	Speed range is 2400 to 115200
Parity	none	
Data bits	8	
Stop bits	2	

Service USB communication

There is no setting. The device is automatically recognised in Windows environments if the device driver has been correctly installed. For more detailed information on how to handle devices with USB communication, see the Help section in the M-set software.

NOTE

The USB communication port is provided with only **basic** insulation and can **only** be used when disconnected from aux. supply **and** power inputs!
The service USB is intended only for parameterisation of the meter and is not galvanically separated. The advantage is that, in this case, the meter does not need a power supply to communicate. Communication via service port is time-limited.

Security

Setting parameters are divided into three groups regarding security level: PL0 >password level 0), PL1 >password level 1) and PL2 >password level 2).

Password - level 0 >PL0)

Password is not required.
Available setting:

- Language

Password - level 1 >PL1)

Password for first level is required.
Available settings:

- RTC settings
- Energy meters reset
- Max. demand reset
- Active tariff setting

Password - level 2 >PL2)

Password for second level is required.
Available settings:

- All settings are available

Password lock time >min)

Defines the time in minutes for the instrument to activate password protection. Enter the value 0 if you want to use manual password activation.

Password setting

A password consists of four letters taken from the British alphabet from A to Z. Passwords of the first >PL1) and the second >PL2) levels are entered, and time of automatic activation is set.

Password modification

A password can be modified; however, only that password can be modified to which the access is currently unlocked.

Password disabling

A password is disabled by setting it to "AAAA".

NOTE

The factory-set password is "AAAA" at both access levels >PL1) and >PL2). This password does not limit access.

Energy

WARNING

Before modification, all energy counters should be read with the M-set software to assure that old data is not lost.

After modification of energy parameters, the energy meters (counters) should be reset. Previously recorded measurements might have wrong values, so they should not be transferred to any system for data acquisition and analysis. Data stored before modification should be used for this purpose.

Active tariff

When active tariff is set, one of the tariffs is defined as active; switching between tariffs is done either with a tariff clock or a tariff input. For the operation of the tariff clock, other parameters of the tariff clock that are accessible only via communication must be set correctly.

Common energy counter resolution

A common energy exponent defines the minimum energy that can be displayed on the energy counter. On the basis of this and a counter divider, a basic calculation prefix for energy is defined (−3 is 10^{-3}Wh = mWh, 4 is 10^{4}Wh = 10 kWh). A common energy exponent also influences the setting of a number of impulses for energy of a pulse output or alarm output that functions as an energy meter.
Define common energy exponents as recommended in the table below, where the default value of the counter divider is 10. Values of primary voltage and current determine a proper common energy exponent.

Voltage \ Current	1 A	5 A	50 A	100 A	1000 A
110 V	100 mWh	1 Wh	10 Wh	10 Wh	100 Wh
230 V	1 Wh	1 Wh	10 Wh	100 Wh	1 kWh
1000 V	1 Wh	10 Wh	100 Wh	1 kWh	10 kWh
30 kV	100 Wh	100 Wh	1 kWh	10 kWh	10 kWh *

** − Individual counter resolution should be at least 100.*

Counters

Measured energy

For each of four (4) counters, different measured quantities can be selected. The user can select from a range of predefined options referring to measured total energy or energy on a single phase, or can even select his own option by selecting the appropriate quantity, quadrant, absolute or inverse function.
A pulse/digital input can also be attached to the energy counter. In this case, the energy counter counts pulses from an outside source (water-, gas- or energy meter).

Individual counter resolution

Additionally, the individual counter resolution defines precision of a certain counter, according to the settings of common energy counter resolution.

Tariff selector

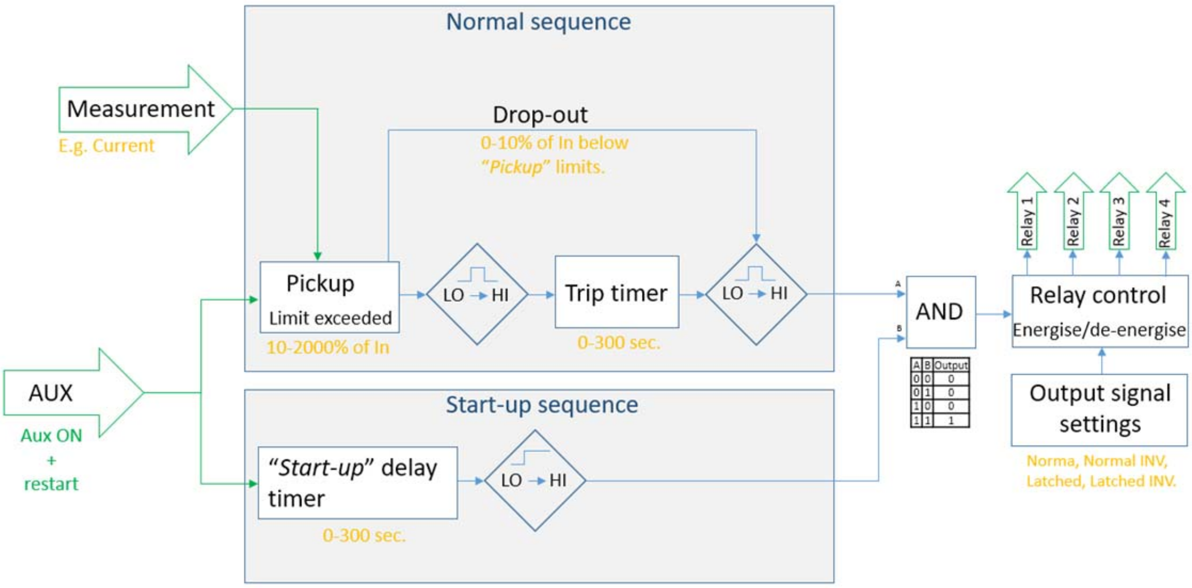
Defines tariffs where the counter is active.

Inputs and outputs

MTR-4P can be equipped with four relay output I/O modules. For relay output technical specifications, see section »Technical data« in the data sheet.

Start-up delay for outputs

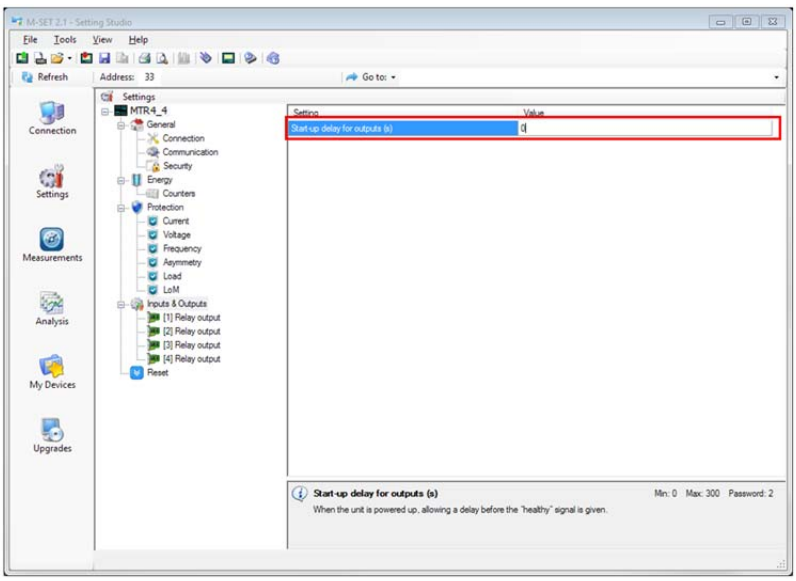
MTR-4P has a start-up delay (0 to 300 s), which inhibits the output relays when the auxiliary supply is powered on. The protection functions start simultaneously with the start-up delay, but the relay outputs stay in OFF state until expiry of the start-up delay time. After expiry of the start-up delay time, the modules are set according to the present network conditions. If a fault is detected and the comparison time delay has run out during the start-up delay, it will change into fault condition when the start-up timer has run out. See the diagram below for detailed explanation:



– input/output simulations

Yellow – setting range examples

– "answer"



M-set setting – MTR-4P > Inputs & Outputs > Start-up delay for outputs

Options for I/O module 1/2/3/4

Outputs:

- Relay output
- Without

See variant configuration in the MTR-4P datasheet.

Relay output module

The relay output module has an alarm notification function. In case of any alarm occurrences, the alarm output will trigger a passive electromechanical relay.
When an alarm is detected, a type of output signal (normal, normal inverse, latched, latched inverse, pulsed, pulsed inverse, always ON, always OFF) should be defined for each alarm output.

Protection functions

MTR-4P supports 13 different protection functions in six different logical categories:

Current protection functions:

- Over-current I 1 & 2 **ANSI [50]** (>I, >>I)
- Over-current IE 1 & 2 **ANSI [50 N/G]** (>IE)
- Over-current Idiff 1 & 2 **ANSI [87]** (>I'))

Voltage protection functions:

- Over-voltage 1 & 2 **ANSI [59]** (>U, >>U)
- Under-voltage 1 & 2 **ANSI [27]** (<U, <<U)

Frequency protection functions:

- Over-frequency 1 & 2 **ANSI [81O]** (>f, >>f)
- Under-frequency 1 & 2 **ANSI [81U]** (<f, <<f)

Asymmetry protection functions:

- Voltage unbalances **ANSI [47]** (>UUn)
- Phase imbalance 1 & 2 **ANSI [46]** (>I_{im}, >>I_{im})

Load protection functions:

- Directional power 1 & 2 **ANSI [32]** (>P, >>P)
- Power underrun 1 & 2 **ANSI [32R/U]** (<P, <<P)

LoM (Loss of Mains) protection functions:

- Phase shift **ANSI [78]** (> dPhi/dt)
- Rate Of Change Of Frequency (ROCOF) protection **ANSI [81R]** (> df/dt))

The general parameters that are presented in the table below can be defined in the setting and acquisition software M-set to define the overall functioning of the protection functions that MTR-4P provides:

Settings	*Definition*
Connection mode	Defines the connection mode for the voltage monitoring.
Nominal voltage (V)	Defines the nominal voltage for all voltage-related protection functions.
Nominal frequency	Defines the nominal frequency for all frequency-related protection functions.
Rated current (A)	Defines the rated current for all current-related protection functions.
Rated active power (W)	Defines the rated active power for all power-related protection functions.
Phase rotation	Defines the phase rotation direction for correct phase imbalance monitoring. Clockwise (L1-L2-L3); anticlockwise (L1-L3-L2).
Phase shift monitoring mode	Defines the phase shift monitoring mode. '1- in 3 phase' – tripping occurs if the phase shift exceeds the threshold value (1 phase) in at least one phase or exceeds the threshold value (3 phase) in all three phases: '3 phase' – tripping occurs if the phase shift exceeds the threshold value (3 phase) in all three phases.
Monitoring**	Defines if the monitoring parameter protection function is enabled or not.
Parameter limit (%)*	Defines the threshold value for tripping. If the threshold value is reached or fallen below for the period of at least the compare delay time, the alarm will be activated.
Compare time delay (s)* (In this document it is marked as: t_{cd})	Defines the compare time delay for tripping. If the threshold value is reached or fallen below for the period of at least the compare delay time, the alarm will be activated.
Hysteresis (%)*	Defines the hysteresis for tripping. The hysteresis is calculated from the nominal value and is used when the output is switched off.
Assigned group**	Defines the logical group assigned with the protection function. Use the enabled protection groups' setting (relay output) to assign logical groups to physical outputs.
Parameter limit – 1-phase ( )***	Defines the threshold value for tripping. If the threshold value is reached or fallen below for the period of at least the compare delay time, the alarm will be activated.
Parameter limit – 3-phase ( )***	Defines the threshold value for tripping. If the threshold value is reached or fallen below for the period of at least the compare delay time, the alarm will be activated.

** Under every particular protection category except phase shift*

*** Under every particular protection category*

**** Under category phase shift*

See the M-set settings overview for MTR-4P in chapter »Protection Functions in M-set - Setting and Acquisition Software«.

NOTE

MTR-4P response time:
Time from error detection until the relay switches on/off is typically below 50 ms.

Over-current I 1 & 2 ANSI [50] (>I, >>I)

NOTE

The over-current protection function (>I, >>I) must be used with *Three phase, four wire connection with unbalanced load (4u)* – refer to chapter »Electrical connection for MTR-4P« on page 10. Since other current protection functions use a different electrical connection mode, it is not possible to use them simultaneously.

If >I and >>I are chosen (4u electrical connection), monitoring of >IE and >I´ is not possible.

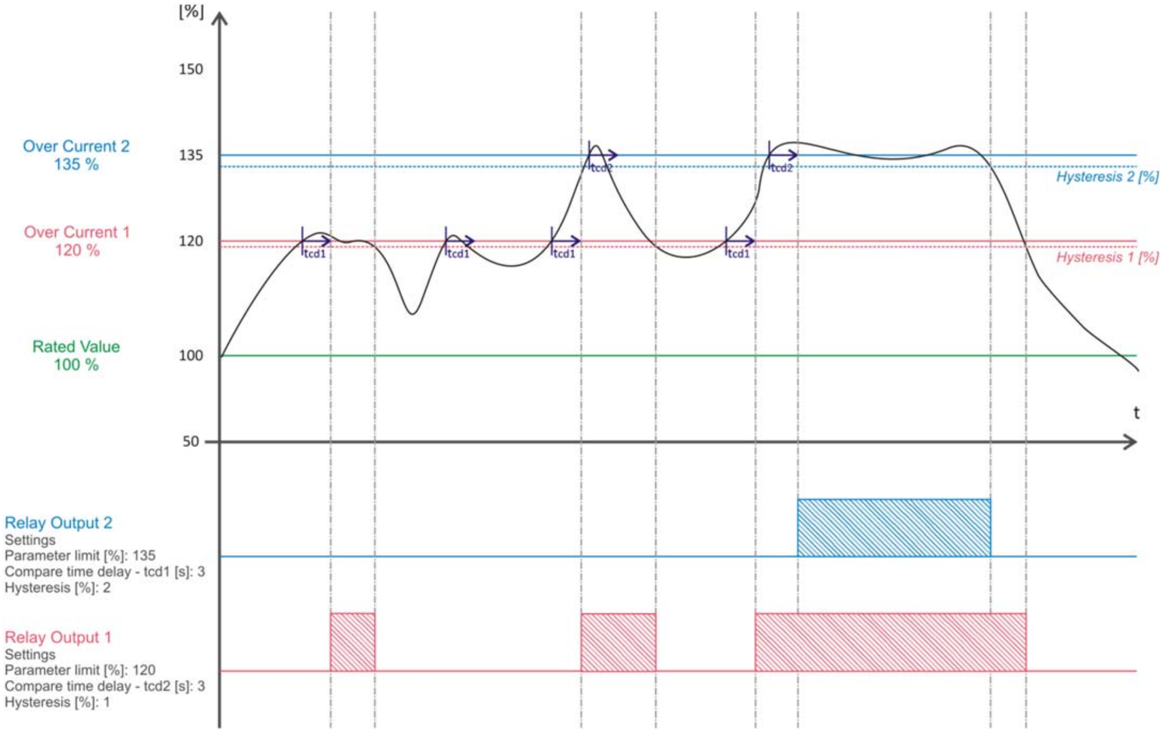
ANSI 50 – Over-current protection function detects abnormally high network current on each individual phase. If the current exceeds the predefined parameter limit, the protection function will trigger the relay. It is possible to define up to two over-current (>I, >>I) relay output limits with up to 2000 % of nominal current.

The parameters that are presented in the table below can be defined in the setting and acquisition software M-set (see M-set: MTR-4P > Protection > Current > Over Current 1/2 protection functions; the description is identical for all limits; the limits may differ only in their setting ranges):

Limit	Text	Setting range	Standard value
Over-current 1	Monitoring	Yes/No	No
	Parameter limit (%)	10.00 – 2000.00	108
	Compare time delay (s)	0.00 – 300.00	0
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection group 1, Protection group 2, Protection group 3, Protection group 4	Protection group 1
Over-current 2	Monitoring	Yes/No	Yes
	Parameter limit (%)	10.00 – 2000.00	112
	Compare time delay (s)	0.00 – 300.00	0.3
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 2

Monitoring – Over-current (>I, >>I)

The figure below graphically presents the behaviour of this particular protection function:



Monitoring – Over-current (>I, >>I)

Over-current IE 1 & 2 ANSI [50 N/G] (>IE)

NOTE

The over-current protection function (>IE) must be used with *IE electrical connection* – refer to chapter »Electrical connection for MTR-4P« on page 10. Since other current protection functions use a different electrical connection mode, it is not possible to use them simultaneously.

If >IE is chosen (IE electrical connection), monitoring of >I, >>I and >I´ is not possible.

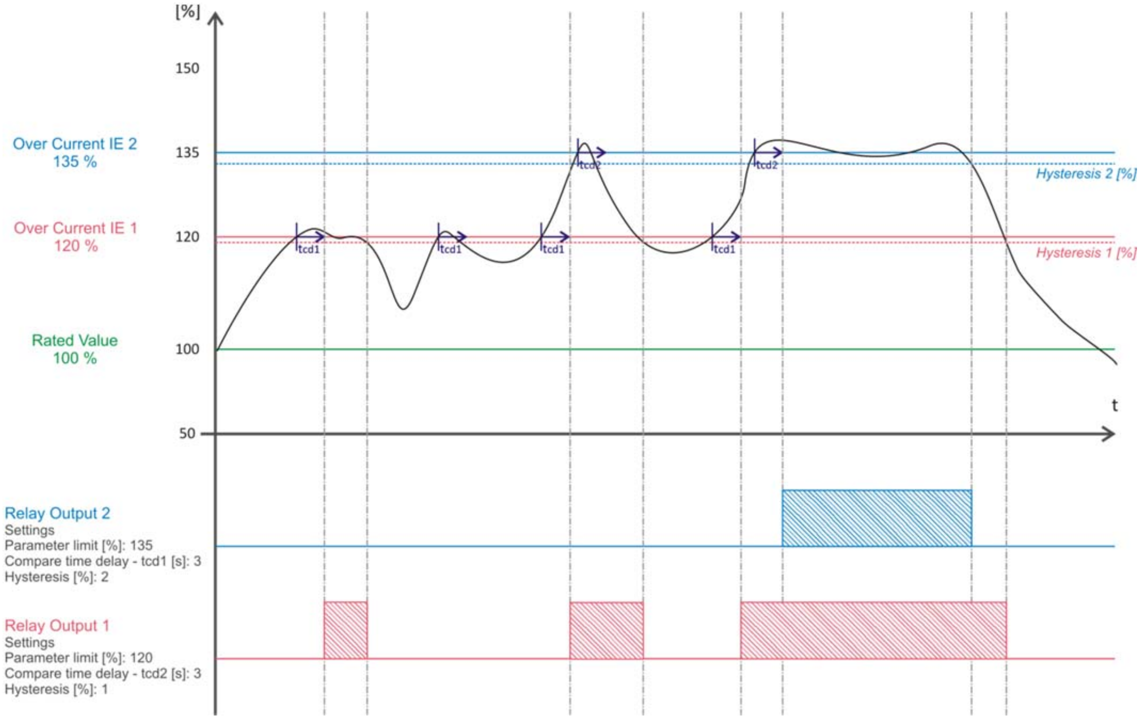
ANSI 50 N/G – Earth fault protection function (>IE) detects earth faults. >IE measurement is performed in a way that sums up external currents. In normal operation, the summation equals 0. Earth fault on one or more phases will result in abnormally high network current, which will trigger the earth fault function. It is possible to define up to two over-current (>IE) relay output limits with up to 550 % of nominal current.

The parameters that are presented in the table below can be defined in the setting and acquisition software M-set (see M-set: MTR-4P > Protection > Current > Over Current IE 1/2 protection functions; the description is identical for all limits; the limits may differ only in their setting ranges):

Limit	Text	Setting range	Standard value
Over-current 1	Monitoring	Yes/No	No
	Parameter limit (%)	0.40 – 550.00	108
	Compare time delay (s)	0.00 – 300.00	0
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection group 1, Protection group 2, Protection group 3, Protection group 4	Protection group 1
Over-current 2	Monitoring	Yes/No	Yes
	Parameter limit (%)	0.40 – 550.00	112
	Compare time delay (s)	0.00 – 300.00	0.3
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 2

Monitoring – Over-current (>IE)

The figure below graphically presents the behaviour of this particular protection function:



Monitoring – Over-current (>IE)

Over-current Idiff 1 & 2 ANSI [87] (>I'))

NOTE

The over-current protection function (>I') must be used with *Idiff electrical connection* – refer to chapter »Electrical connection for MTR-4P« on page 10. Since other current protection functions use a different electrical connection mode, it is not possible to use them simultaneously.

If >I´ is chosen (Idiff electrical connection), monitoring of >I, >>I and >IE is not possible.

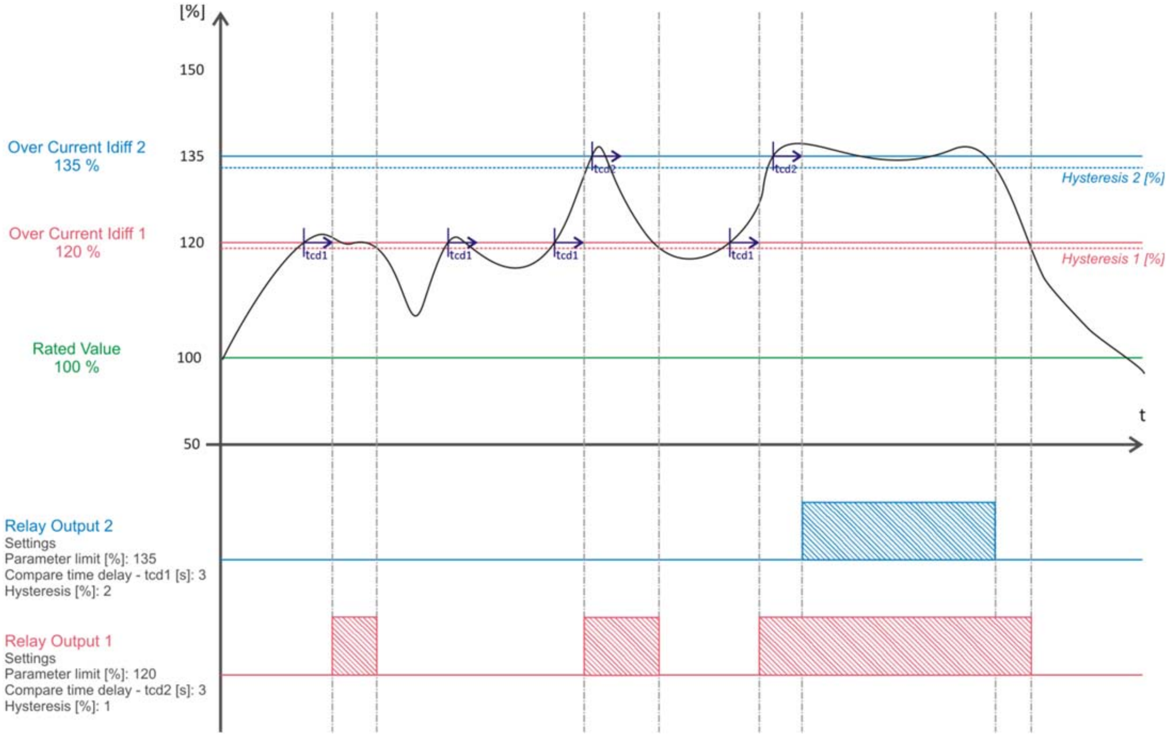
ANSI 87 – Over-current Idiff protection function compares the differential current of each of the three phases, providing an RMS measurement at sinusoidal currents. When the measurement exceeds the predefined parameter limit, the Idiff protection function triggers the relay. It is possible to define up to two over-current (>I') relay output limits with up to 200 % of nominal current.

The parameters that are presented in the table below can be defined in the setting and acquisition software M-set (see M-set: MTR-4P > Protection > Current > Over Current Idiff 1/2 protection functions; the description is identical for all limits; the limits may differ only in their setting ranges):

Limit	Text	Setting range	Standard value
Over-current 1	Monitoring	Yes/No	No
	Parameter limit (%)	0.80 – 200.00	108
	Compare time delay (s)	0.00 – 300.00	0
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection group 1, Protection group 2, Protection group 3, Protection group 4	Protection group 1
Over-current 2	Monitoring	Yes/No	Yes
	Parameter limit (%)	0.80 – 200.00	112
	Compare time delay (s)	0.00 – 300.00	0.3
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 2

Monitoring – Over-current (>I')

The figure below graphically presents the behaviour of this particular protection function:



Monitoring – Over-current (>I')

Over-voltage 1 & 2 ANSI [59] (>U, >>U)

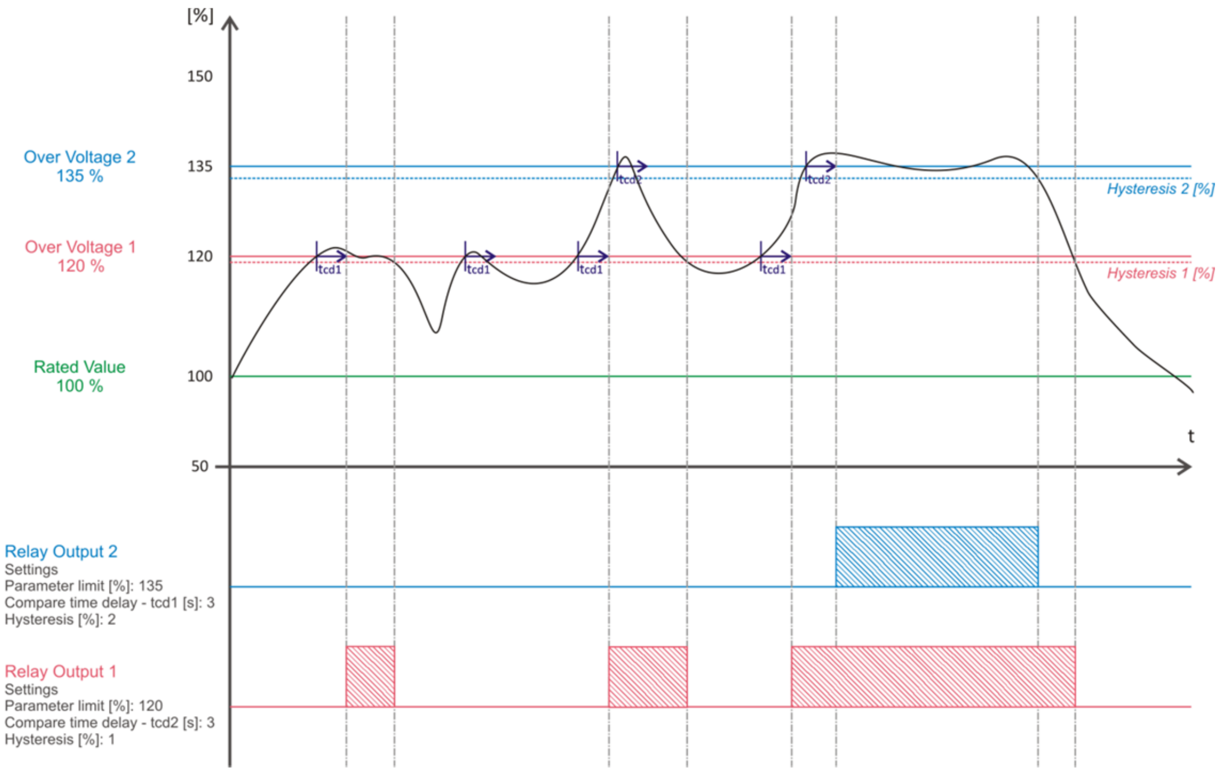
ANSI 59 – Over-voltage protection function detects abnormally high network voltage or checks for sufficient voltage to enable source transfer. This function works with phase-to-phase or phase-to-neutral voltage, each voltage being monitored separately. It is possible to define up to two over-voltage relay output limits with up to 150 % of nominal voltage.

The parameters that are presented in the table below can be defined in the setting and acquisition software M-set (see M-set: MTR-4P > Protection > Voltage > Over Voltage 1/2 protection functions; the description is identical for all limits; the limits may differ only in their setting ranges):

Limit	Text	Setting range	Standard value
Over-voltage 1	Monitoring	Yes/No	Yes
	Parameter limit (%)	100.00 - 150.00	108
	Compare time delay (s)	0.00 – 300.00	5
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 1
Over-voltage 2	Monitoring	Yes/No	Yes
	Parameter limit (%)	100.00 - 150.00	112
	Compare time delay (s)	0.00 – 300.00	0.3
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 2

Monitoring – Over-voltage

The figure below graphically presents the behaviour of this particular protection function:



Monitoring – Over-voltage

Under-voltage 1 & 2 ANSI [27] (<U, <<U)

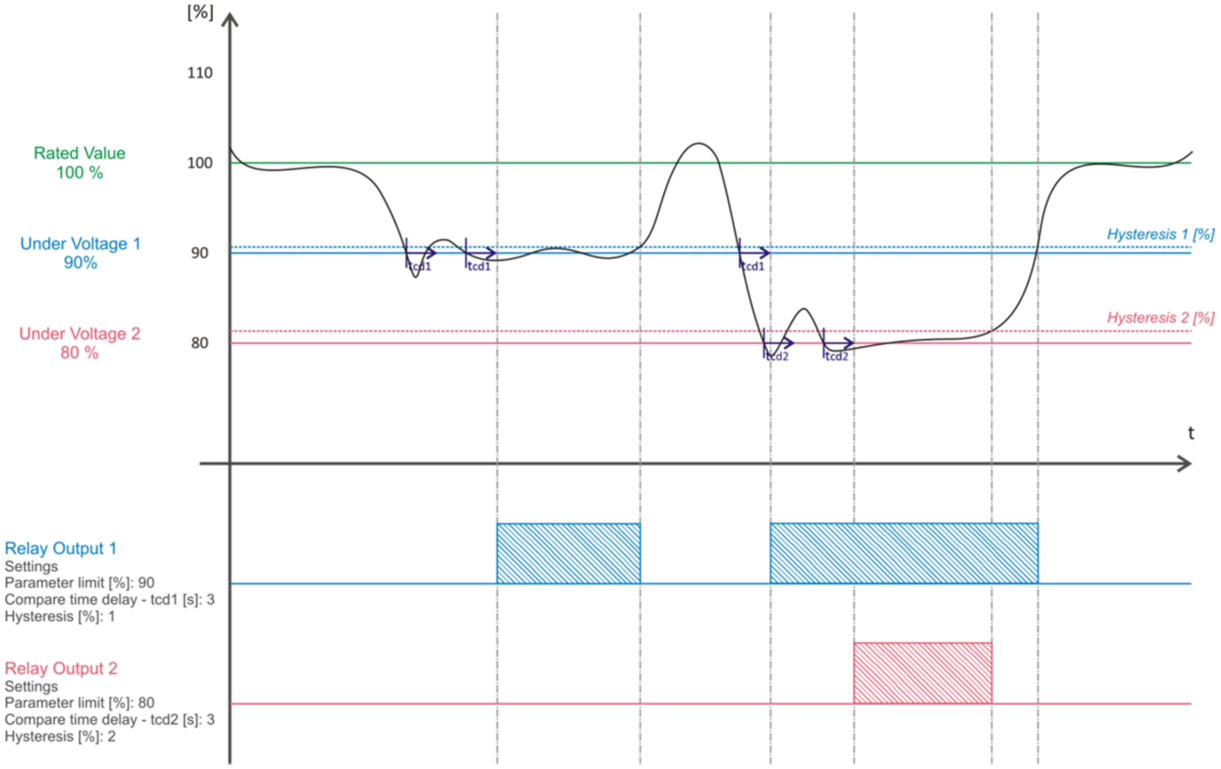
ANSI 27 – Under-voltage protection function is used for protection of motors against voltage sags or for detection of abnormally low network voltage to trigger automatic load shedding or source transfer. It works with phase-to-phase or phase-to-neutral voltage, each voltage being monitored separately. It is possible to define up to two under-voltage relay output limits with down to 50 % of nominal voltage.

The parameters that are presented in the following table can be defined in the setting and acquisition software M-set (see M-set: MTR-4P > Protection > Voltage > Under voltage 1/2 protection functions; the description is identical for all limits; the limits may differ only in their setting ranges):

Limit	Text	Setting range	Standard value
Under-voltage 1	Monitoring	Yes/No	Yes
	Parameter limit (%)	50.00 – 100.00	92
	Compare time delay (s)	0.00 – 300.00	5
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 1
Under-voltage 2	Monitoring	Yes/No	Yes
	Parameter limit (%)	50.00 - 100.00	88
	Compare time delay (s)	0.00 – 300.00	0.3
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 2

Monitoring – Under-voltage

The figure below graphically presents the behaviour of this particular protection function:



Monitoring – Under-voltage

Over-frequency 1 & 2 ANSI [81O] (>f, >>f)

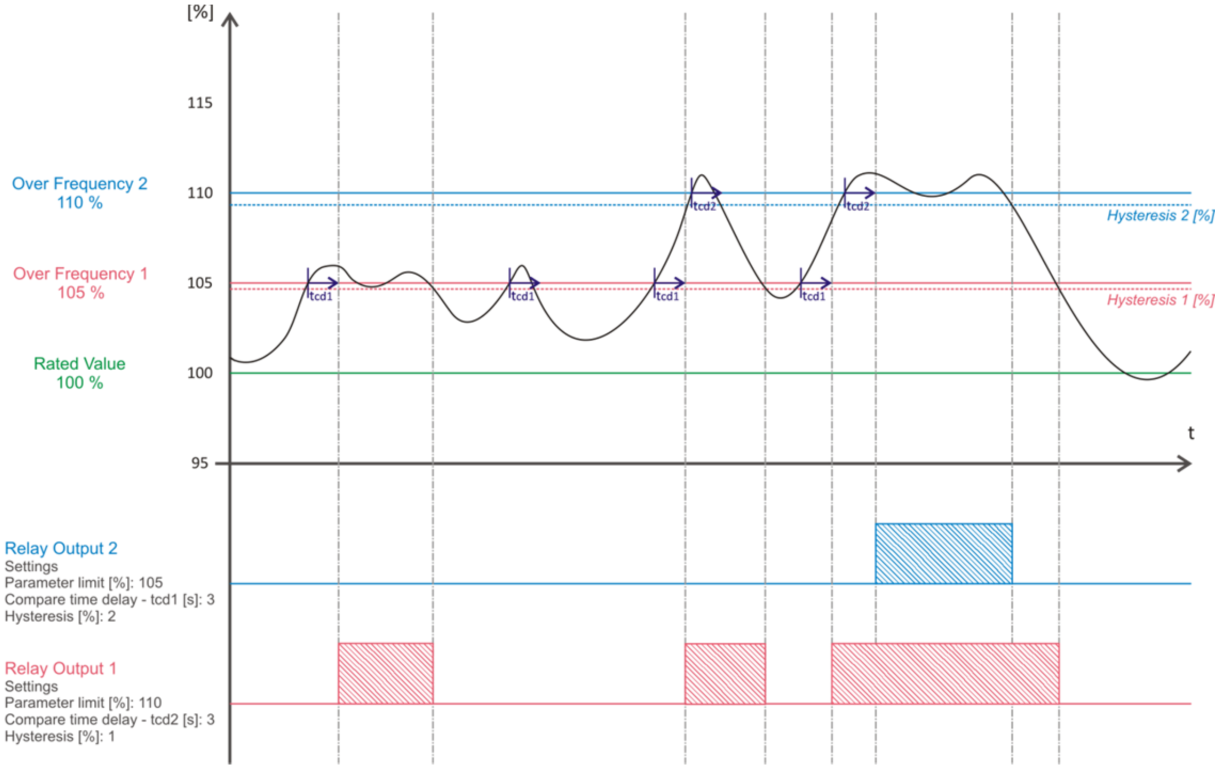
ANSI 81O – Over-frequency protection function detects abnormally high frequency compared to the rated frequency, to monitor the power supply quality. Monitoring of the frequency is accomplished in two steps. It is possible to define up to two over-frequency relay output limits with up to 150 % of nominal frequency.

The parameters that are presented in the following table can be defined in the setting and acquisition software M-set (see M-set: MTR-4P > Protection > Frequency > Over Frequency 1/2 protection functions; the description is identical for all limits; the limits may differ only in their setting ranges):

Limit	Text	Setting range	Standard value
Over-frequency 1	Monitoring	Yes/No	Yes
	Parameter limit (%)	100.00 – 150.00	110
	Compare time delay (s)	0.00 – 300.00	1.5
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 1
Over-frequency 2	Monitoring	Yes/No	Yes
	Parameter limit (%)	100.00 - 150.00	115
	Compare time delay (s)	0.00 – 300.00	0.3
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 2

Monitoring – Over-frequency

The figure below graphically presents the behaviour of this particular protection function:



Monitoring – Over-frequency

Under-frequency 1 & 2 ANSI [81U] (<f, <<f)

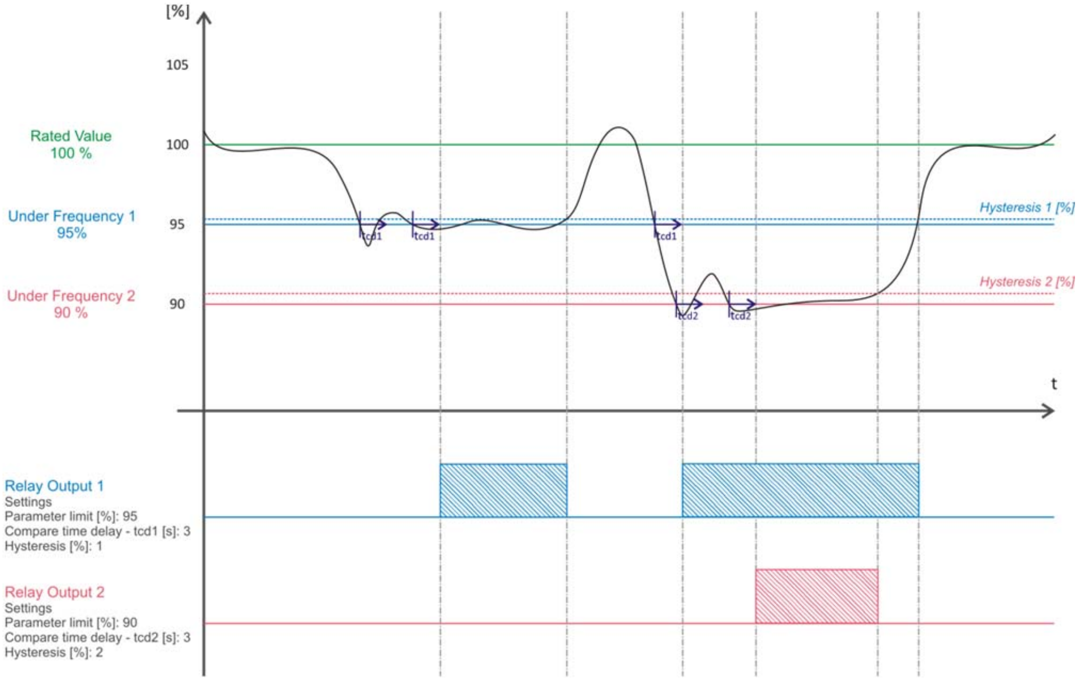
ANSI 81U – Under-frequency protection function is detection of abnormally low frequency compared to the rated frequency, to monitor the power supply quality. The protection may be used for overall tripping or load shedding. Protection stability is ensured by the protection function loss of mains, and presence of remnant voltage by a restraint in the event of a continuous decrease of the frequency. This is activated by parameter setting. Monitoring of the frequency is performed in two steps. It is possible to define up to two under-frequency relay output limits with down to 50 % of nominal frequency.

The parameters that are presented in the following table can be defined in the setting and acquisition software M-set (see M-set: MTR-4P > Protection > Frequency > Under Frequency 1/2 protection functions; the description is identical for all limits; the limits may differ only in their setting ranges):

Limit	Text	Setting range	Standard value
Under-frequency 1	Monitoring	Yes/No	Yes
	Parameter limit (%)	50.00 – 100.00	90
	Compare time delay (s)	0.00 – 300.00	5
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 1
Under-frequency 2	Monitoring	Yes/No	Yes
	Parameter limit (%)	50.00 – 100.00	84
	Compare time delay (s)	0.00 – 300.00	0.3
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 2

Monitoring – Under-frequency

The figure below graphically presents the behaviour of this particular protection function:



Monitoring – Under-frequency

Voltage unbalances ANSI [47] (>UUn)

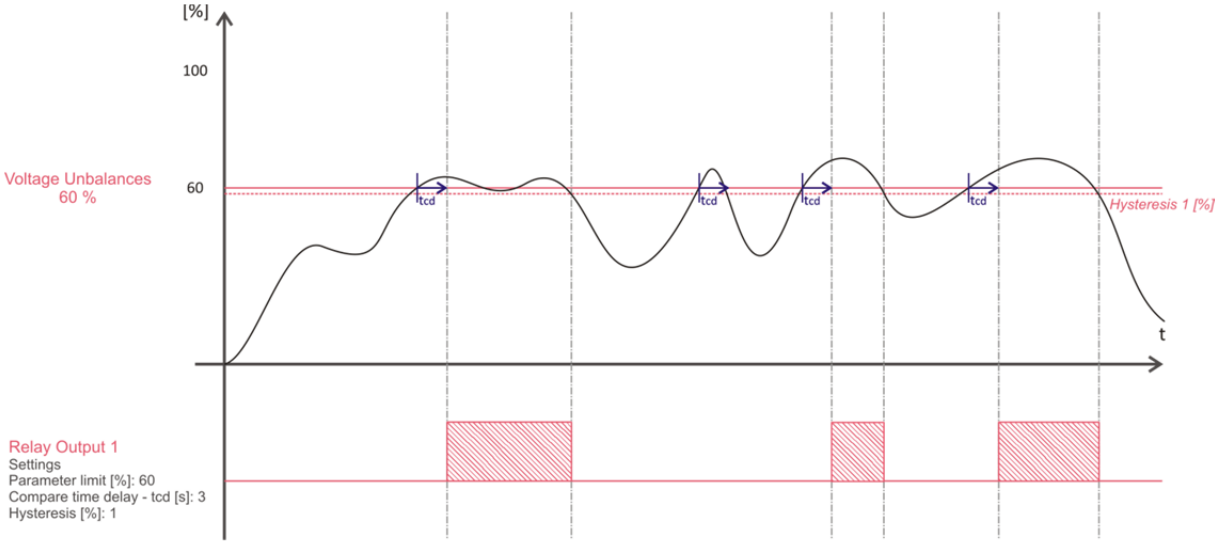
Voltage unbalance is regarded as a power quality problem of significant concern at the electricity distribution level. Although the voltages are quite well balanced at the generator and transmission levels, the voltages at the utilisation level can become unbalanced due to the unequal system impedances and the unequal distribution of single-phase loads. An excessive level of voltage unbalance can have serious impacts on mains connected induction motors. The level of current unbalance that is present is several times the level of voltage unbalance.
With this protection function, voltage unbalance is supervised over phase resulting from phase inversion, unbalanced supply or distant fault, detected by the measurement of negative sequence voltage components of a three phase system. This parameter has a range of 0 to 100 % of the rated nominal voltage.

The parameters that are presented in the following table can be defined in the setting and acquisition software M-set (see M-set: MTR-4P > Protection > Asymmetry > Voltage unbalances protection functions; the description is identical for all limits; the limits may differ only in their setting ranges):

Limit	Text	Setting range	Standard value
Voltage unbalances	Monitoring	Yes/No	Yes
	Parameter limit (%)	0.00 – 100.00	100
	Compare time delay (s)	0.00 – 300.00	5
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 1

Monitoring – Voltage unbalances

The figure below graphically presents the behaviour of this particular protection function:



Monitoring – Voltage unbalances

Phase imbalance 1 & 2 ANSI [46] (>Iim, >>Iim)

ANSI 46 represents protection against phase unbalance, detected by the measurement of negative sequence currents. It can be used in the following practical examples:

- Sensitive protection to detect 2-phase faults at the end of long lines
- Protection of equipment against temperature build-up, caused by an unbalanced power supply, phase inversion or loss of phase, and against phase current unbalance

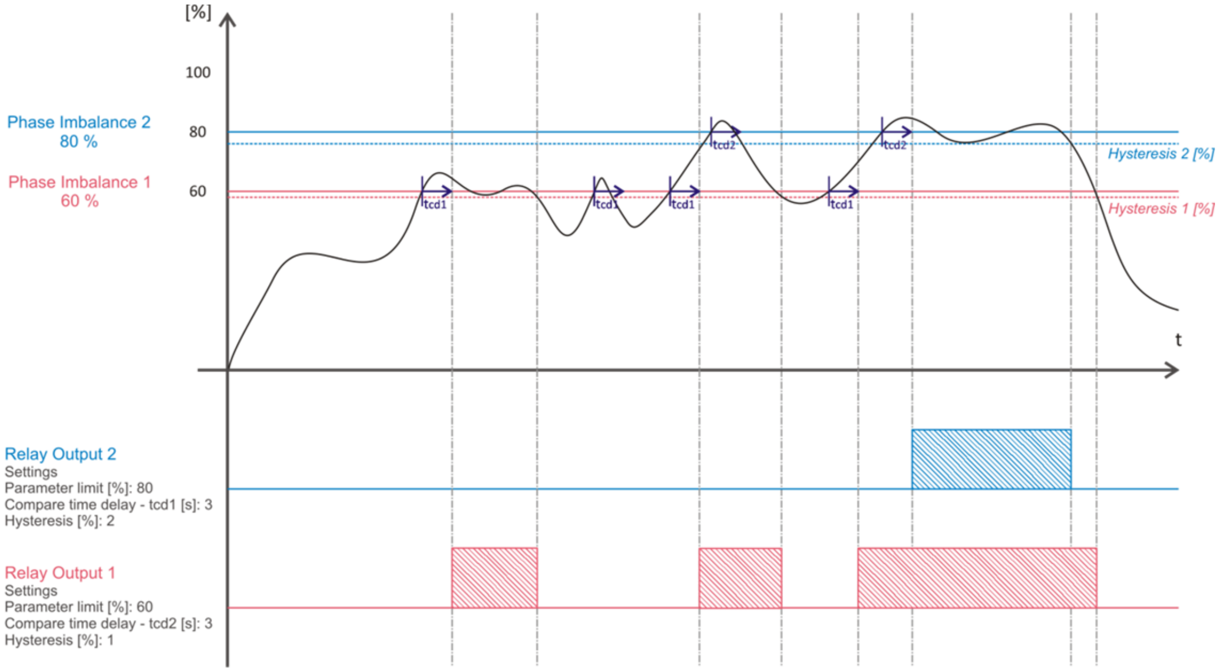
The phase imbalance protection function is used for protection against over-phase imbalance resulting from phase inversion, unbalanced supply or distant fault, detected by the measurement of negative sequence voltage. This threshold is defined relative to the rated current and has a range between 0 and 100 %.

The parameters that are presented in the following table can be defined in the setting and acquisition software M-set (see M-set: MTR-4P > Protection > Asymmetry > Phase Imbalance 1/2 protection functions; the description is identical for all limits; the limits may differ only in their setting ranges):

Limit	Text	Setting range	Standard value
Phase imbalance 1	Monitoring	Yes/No	Yes
	Parameter limit (%)	0.00 – 100.00	10
	Compare time delay (s)	0.00 – 300.00	10
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 1
Phase imbalance 2	Monitoring	Yes/No	Yes
	Parameter limit (%)	0.00 – 100.00	15
	Compare time delay (s)	0.00 – 300.00	1
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 2

Monitoring – Phase imbalance

The figure below graphically presents the behaviour of this particular protection function:



Monitoring – Phase imbalance

Directional power 1 & 2 ANSI [32] (>P, >>P)

This protection function is a two-way protection based on calculated active power, for the following applications:

- Active over-power protection to detect overloads and allow load shedding
- Reverse active power protection:
  - against generators running like motors when the generators consume active power
  - against motors running like generators when the motors supply active power

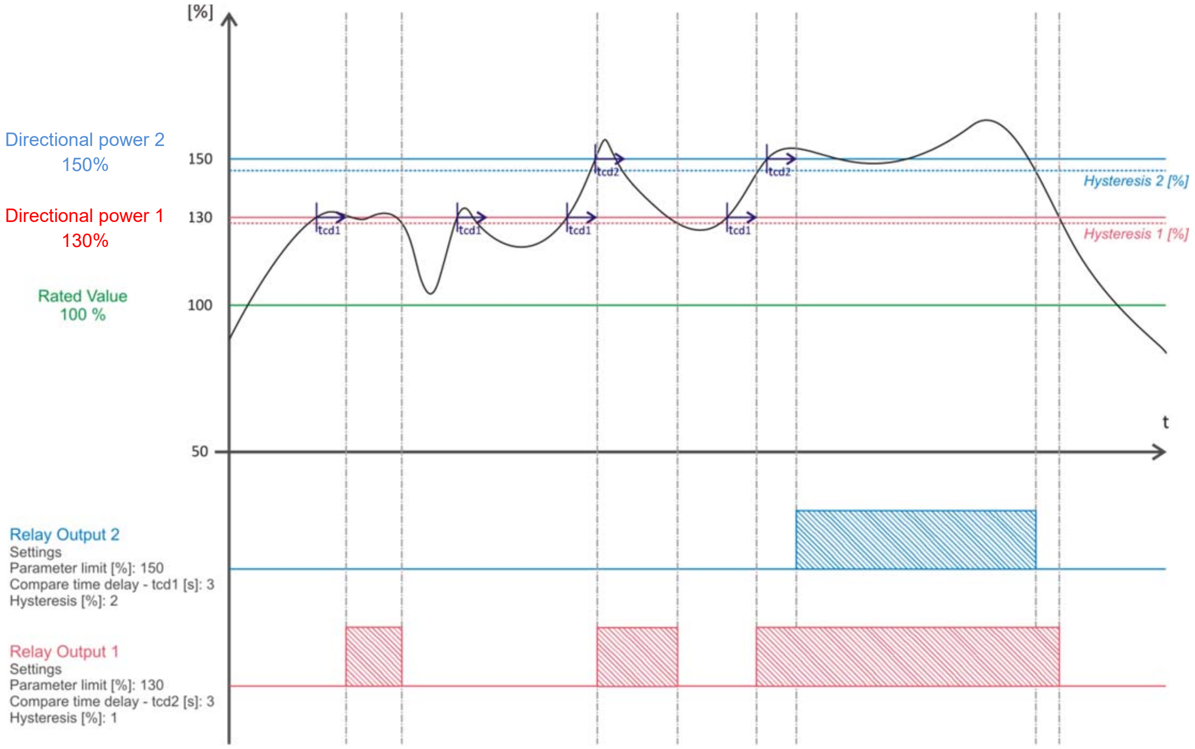
The directional power protection is based on calculated active power. Active over-power monitoring is used to detect over-powers and allow power shedding. It is possible to define up to two relay output limits in the range between -300 % and 300 % of the rated active power.

The parameters that are presented in the following table can be defined in the setting and acquisition software M-set (see M-set: MTR-4P > Protection > Load > Load Overrun 1/2 protection functions; the description is identical for all limits; the limits may differ only in their setting ranges):

Limit	Text	Setting range	Standard value
Directional power 1	Monitoring	Yes/No	Yes
	Parameter limit (%)	-300.00 – 300.00	110
	Compare time delay (s)	0.00 – 300.00	11
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 1
Directional power 2	Monitoring	Yes/No	Yes
	Parameter limit (%)	-300.00 – 300.00	120
	Compare time delay (s)	0.00 – 300.00	0.1
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 2

Monitoring – Directional power

The figure below graphically presents the behaviour of this particular protection function:



Monitoring – Directional power

Power underrun 1 & 2 ANSI [32R/U] (<P, <<P)

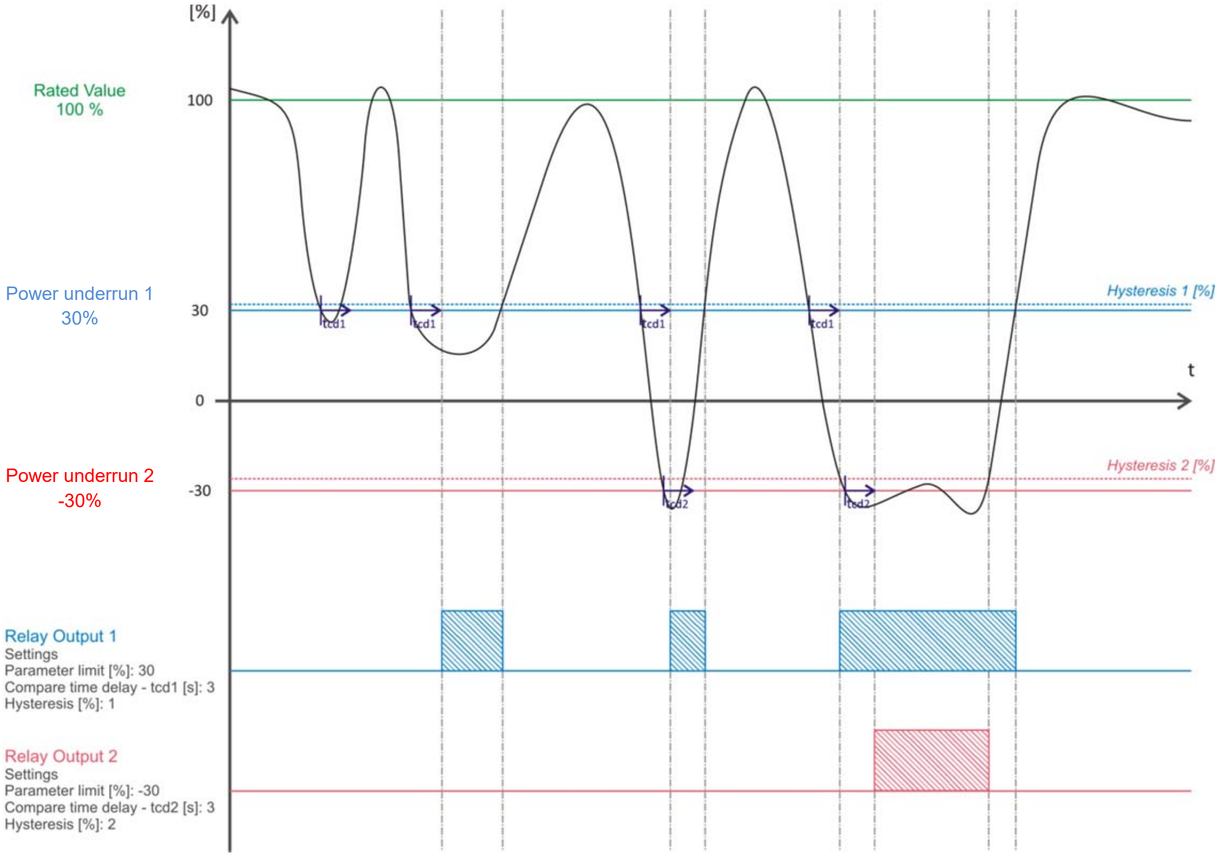
Power underrun protection is based on calculated active power. This user-defined limit defines the permissible deviation of the load from defined thresholds. The function is triggered if the measured value drops below the rated active power limit, and it can be set between -300 % and 300 %.

The parameters that are presented in the following table can be defined in the setting and acquisition software M-set (see M-set: MTR-4P > Protection > Load > Load Underrun 1/2 protection functions; the description is identical for all limits; the limits may differ only in their setting ranges):

Limit	Text	Setting range	Standard value
Power underrun 1	Monitoring	Yes/No	Yes
	Parameter limit (%)	-300.00 – 300.00	-3
	Compare time delay (s)	0.00 – 300.00	5
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 1
Power underrun 2	Monitoring	Yes/No	Yes
	Parameter limit (%)	-300.00 – 300.00	-5
	Compare time delay (s)	0.00 – 300.00	3
	Hysteresis (%)	0.00 – 10.00	0
	Assigned group	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 2

Monitoring – Power underrun

The figure below graphically presents the behaviour of this particular protection function:



Monitoring – Power underrun

Phase shift ANSI [78] (> dPhi/dt)

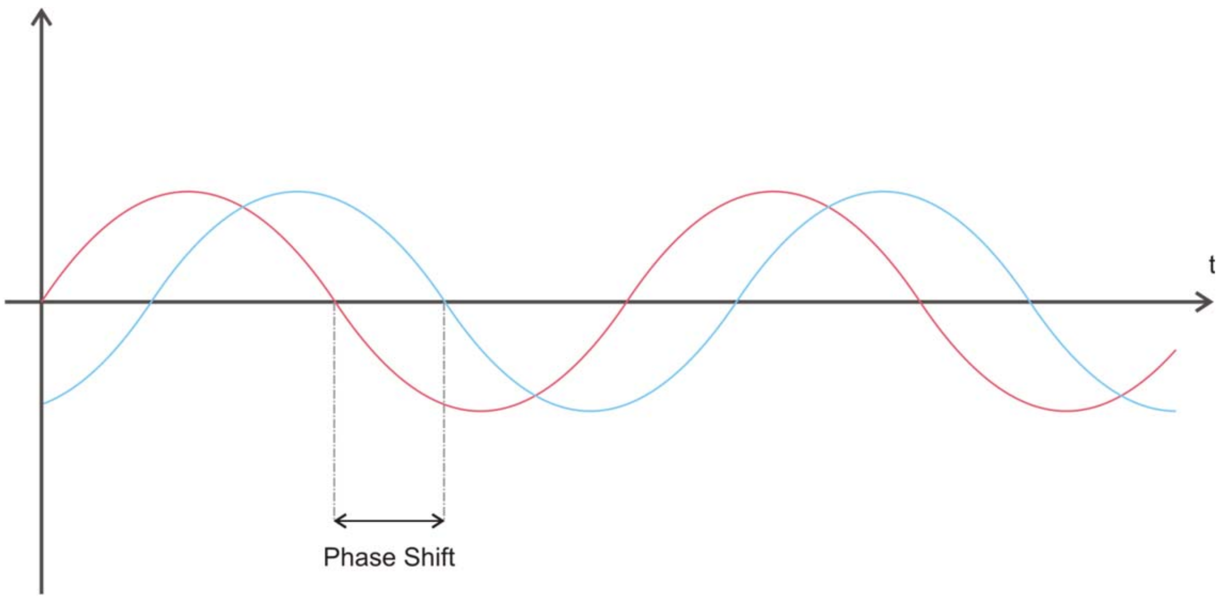
Loss of Mains occurs when part of the public utility network loses connection with the rest of the system. If LoM is not detected, the generator could remain connected, causing a safety hazard within the network. Automatic reconnection of the generator to the network may occur, causing damage to the generator and the network.
One of the LoM detection methods is voltage vector shift/phase shift. The vector shift protection algorithm is based on voltage angle measurements performed on all three phase voltages. A measurement is taken from each of the three phase voltages after every half-cycle, and the evaluation is made after a full cycle. The use of three phases makes the algorithm less exposed to harmonic distortion, interference and imbalanced faults. This improves the protection stability and decreases the probability of spurious tripping during non-symmetrical faults. This limit for phases 1 and 3 can be set in the range between 0 and 90 %.
The monitoring may be carried out in three-phase or one-phase mode. The monitoring can be configured in different ways. The vector/phase shift monitoring can also be used as an additional method to decouple from the grid. Vector/phase shift monitoring is only enabled when the monitored voltage exceeds 50 % of the PT secondary rated voltage.

The parameters that are presented in the following table can be defined in the setting and acquisition software M-set (see M-set: MTR-4P > Protection > LoM > Phase Shift protection functions; the description is identical for all limits; the limits may differ only in their setting ranges):

Limit	Text	Setting range	Standard value
Phase shift	Monitoring	Yes/No	Yes
	Parameter limit – 1 phase (°)	0.00 – 90.00	20
	Parameter limit – 3 phase (°)	0.00 – 90.00	8
	Assigned output	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 1

Monitoring – Phase shift

The figure below graphically presents the behaviour of this particular protection function:



Monitoring – Phase shift

Rate Of Change Of Frequency (ROCOF) protection ANSI [81R] (> df/dt)

Loss of Mains occurs when part of the public utility network loses connection with the rest of the system. If LoM is not detected, the generator could remain connected, causing a safety hazard within the network. Automatic reconnection of the generator to the network may occur, causing damage to the generator and the network.
One of the LoM detection methods is ROCOF (Rate Of Change Of Frequency). The ROCOF method is based on the local measurement of the generator voltage and estimation of the rate of change of frequency. The rate of change of frequency following a LoM event is directly proportional to the amount of active power imbalance between local load and the generator output. The ROCOF value is calculated in moving 60 ms windows, and two consecutive calculations are required to assess if this is a permanent change. When both give a result above the set threshold, the trip signal is initiated. To provide additional stability against normal load switching events and other small-scale system transients, an additional time delay can be applied.
The ROCOF parameter has a permissible limit range between 0 and 10 Hz/s. The frequency of a source will vary due to changing loads and other effects. The rate of these frequency changes due to the load variances is relatively high compared to those of a large network. The control unit calculates a value of change of frequency per time unit. The df/dt is measured over four sine waves to ensure that it is differentiated from a phase shift. This results in a minimum response time of approximately 100 ms.

The parameters that are presented in the following table can be defined in the setting and acquisition software M-set (see M-set: MTR-4P > Protection > LoM > ROCOF df/dt protection functions; the description is identical for all limits; the limits may differ only in their setting ranges):

Limit	Text	Setting range	Standard value
ROCOF df/dt	Monitoring	Yes/No	Yes
	Parameter limit (Hz/s)	0.00 – 10.00	2.6
	Compare time delay (s)	0.00 – 300.00	0.1
	Hysteresis (%)	0.00 – 10.00	0
	Assigned output	Protection output 1, Protection output 2, Protection output 3, Protection output 4	Protection output 1

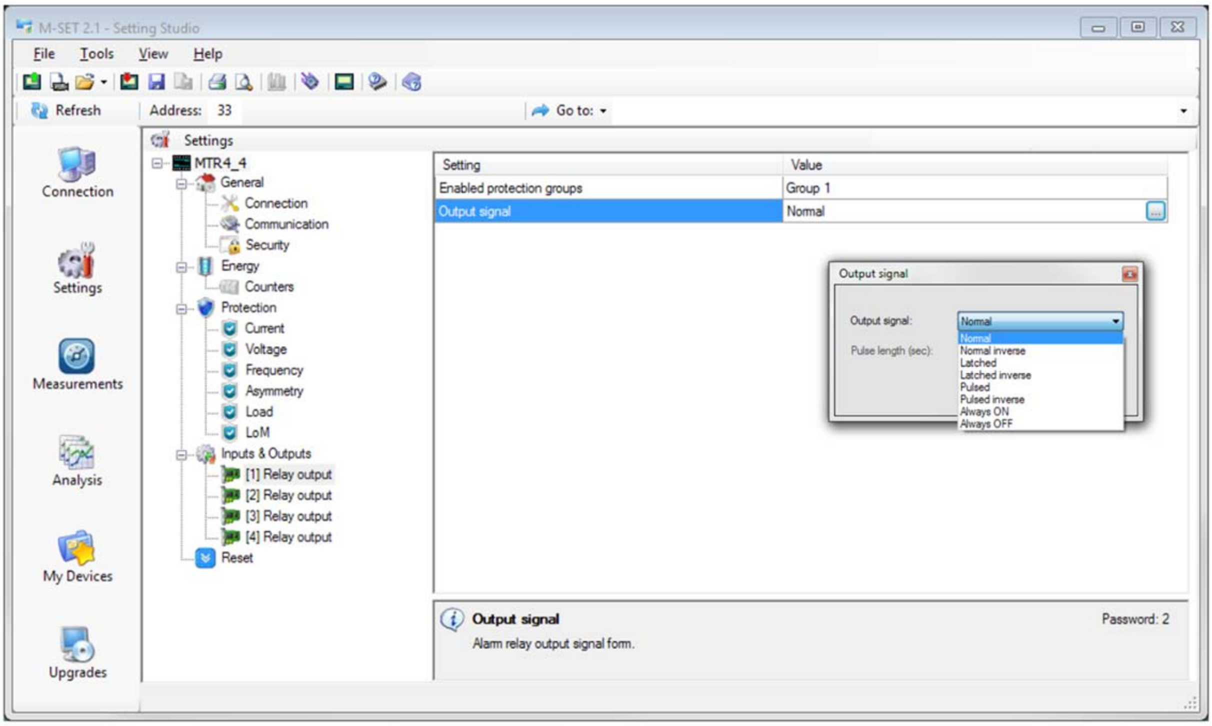
Monitoring – ROCOF

Protection functions in M-set - setting and acquisition software

The M-set software is intended for setting up the MTR-4P and many other instruments through a PC. Network- and protection settings as well as displaying of measured values are possible via the serial communication. The information and measurements can be exported in standard Windows formats. The software runs on Windows XP, Vista, Win7, Win8 and Win10 operating systems.

Main features of the M-set setting studio software:

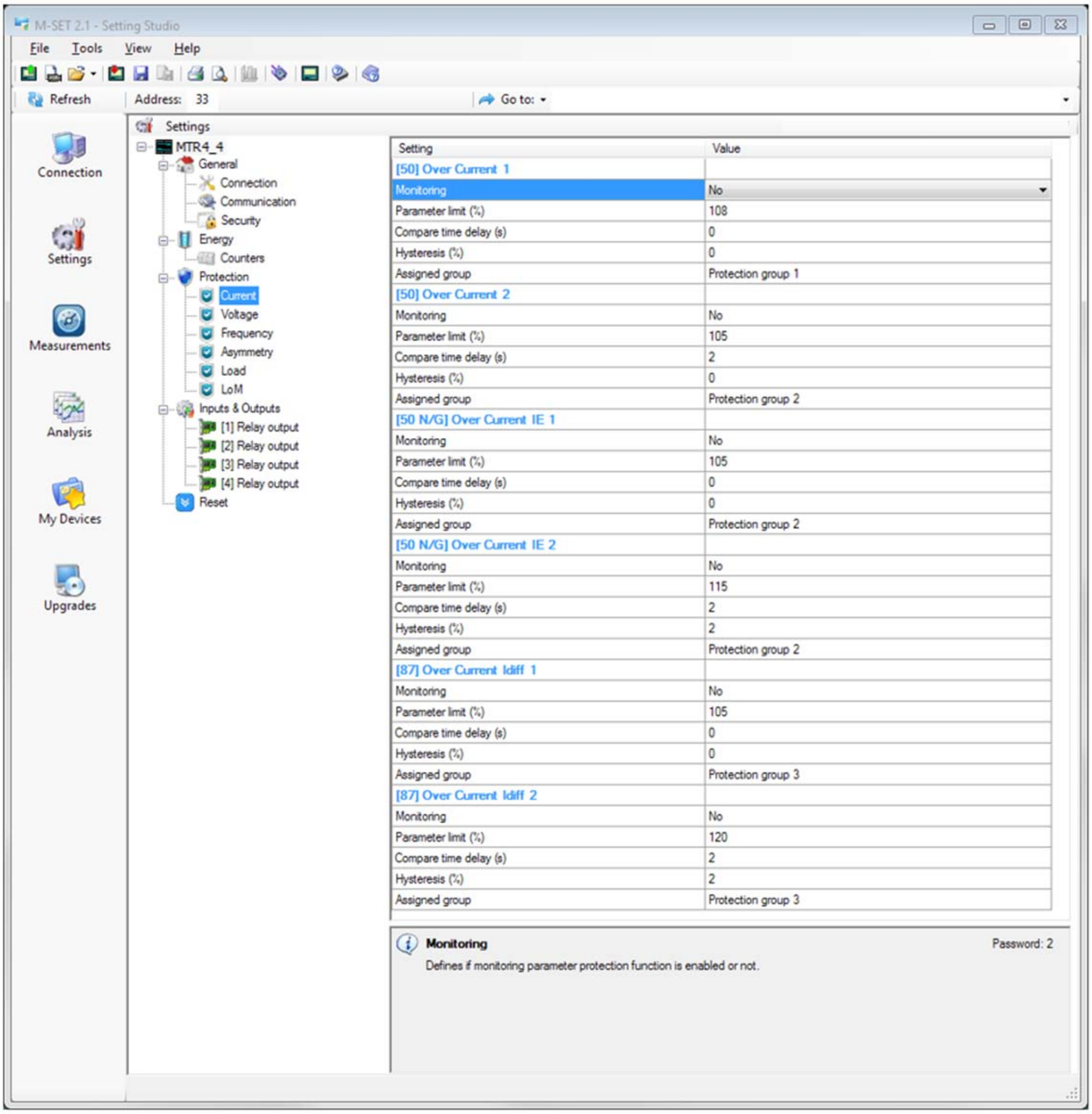
- Setting of all of the instrument's parameters (online and offline)
- Viewing current measured readings
- Setting and resetting of energy counters
- Complete relay output modules configuration
- Searching the network for devices
- Virtual interactive instrument
- Comprehensive help support



M-set settings overview for MTR-4P (example shows relay output module signal options)

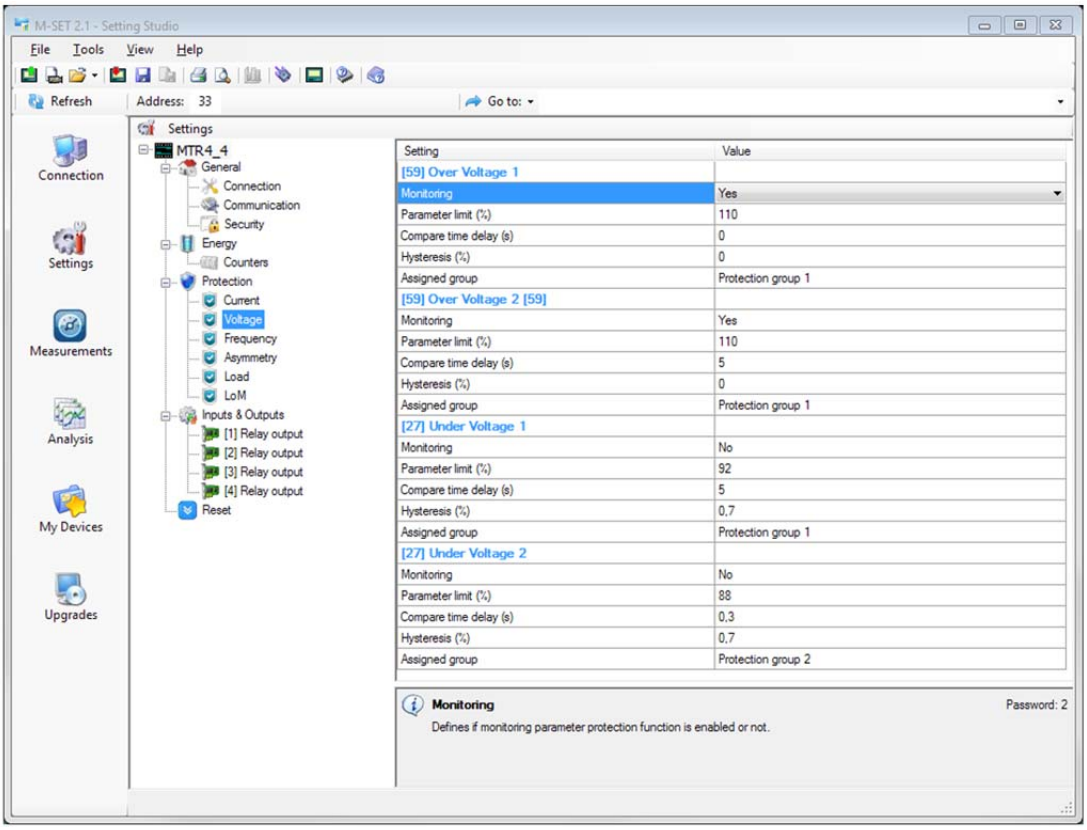
Protection functions

Current protection functions:



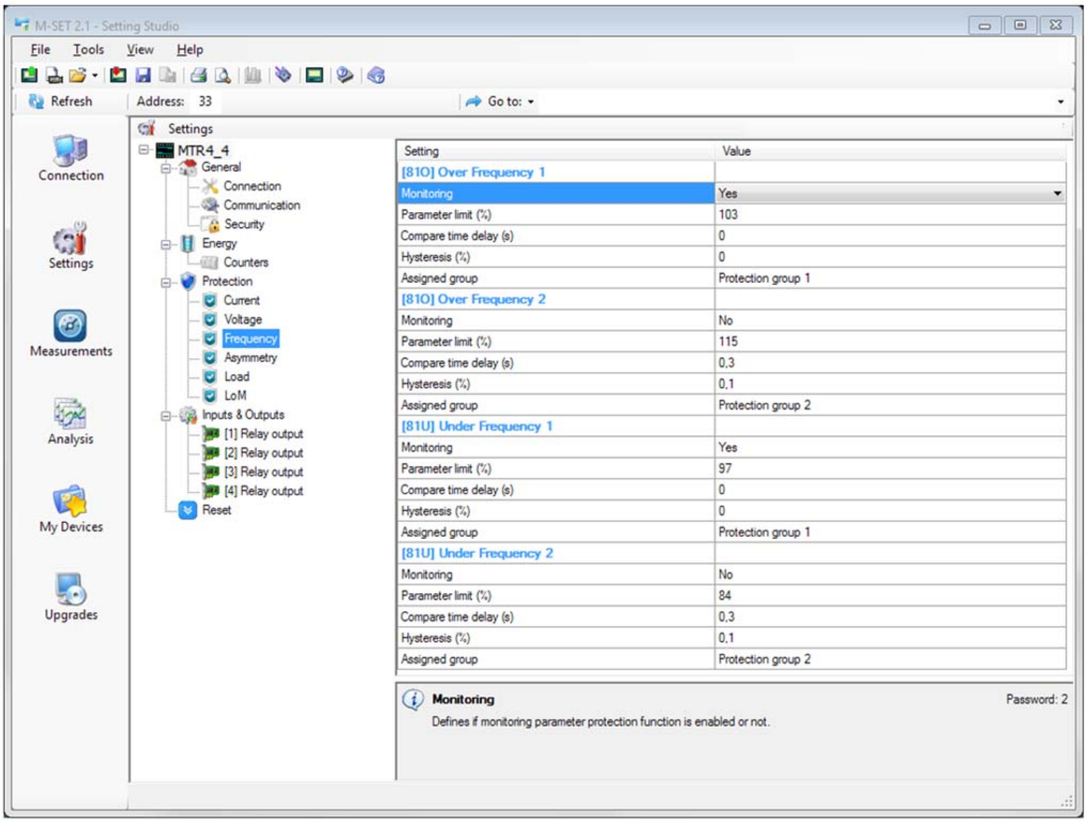
M-set: Setting – Current protection functions

Voltage protection functions:



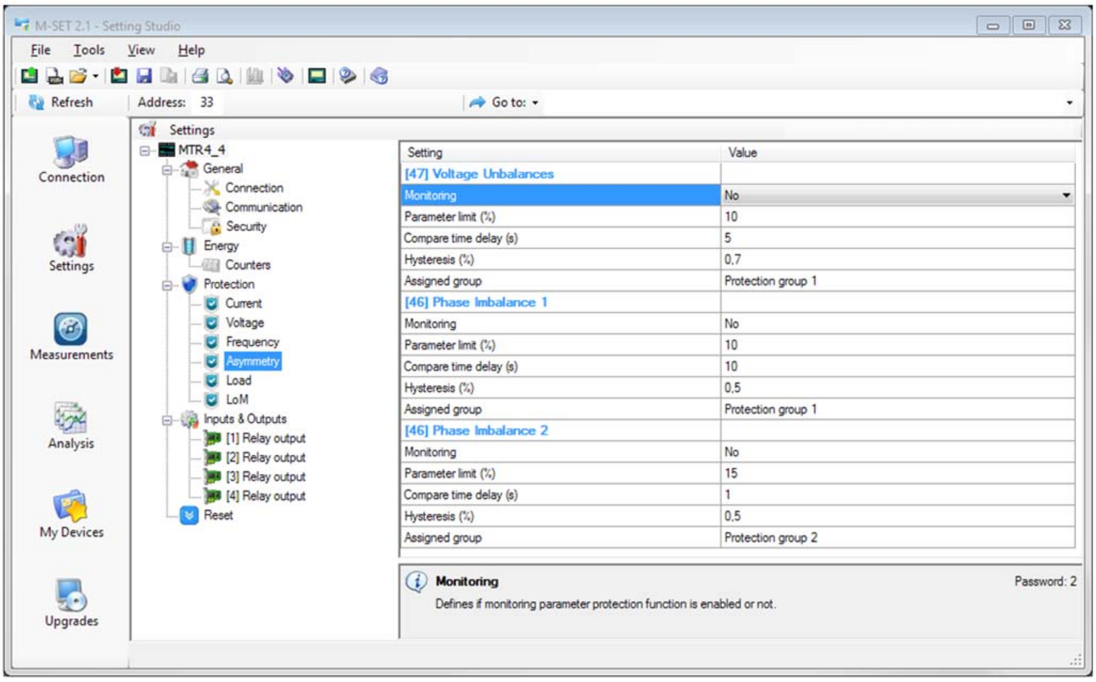
M-set: Setting – Voltage protection functions

Frequency protection functions:



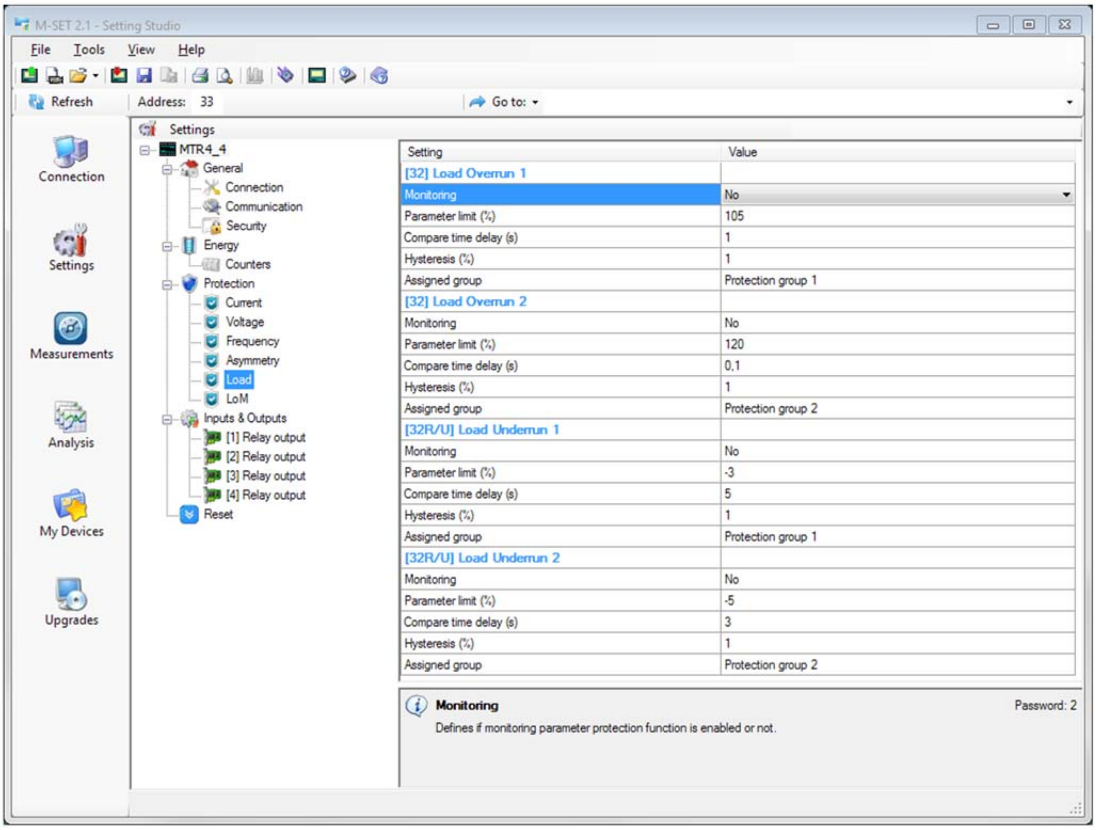
M-set: Setting – Frequency protection functions

Asymmetry protection functions:



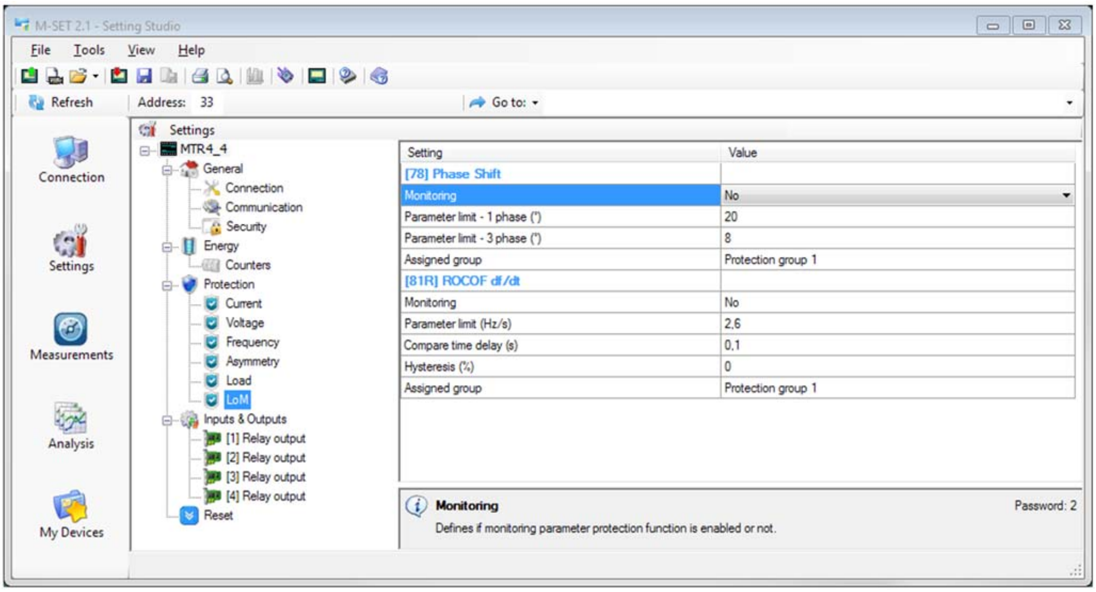
M-set: Setting – Asymmetry protection functions

Load protection functions:



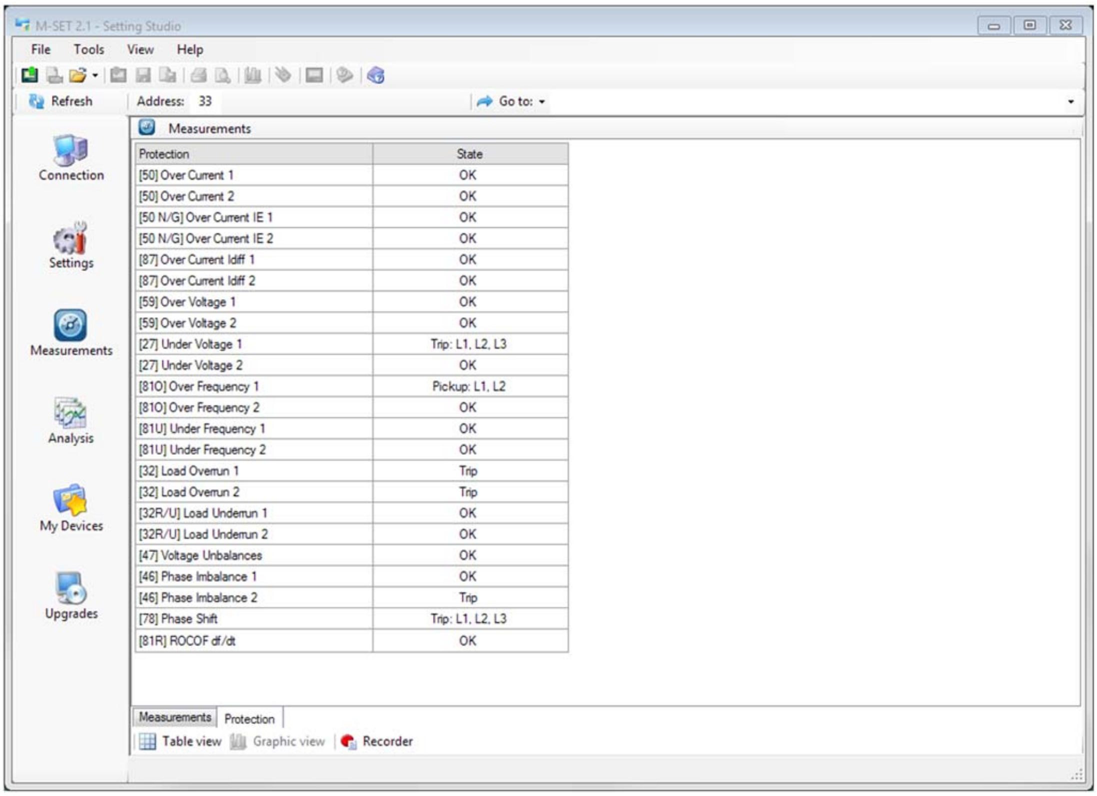
M-set: Setting – Load protection functions

LoM protection functions:



M-set: Setting – LoM protection functions

Online data monitoring



Online data monitoring in MTR-4P with M-set (example shows actual protection states)

Online data monitoring for MTR-4P with M-set provides us with states of protection functions. Three different states are possible over communication (not over relay):

- Ok – normal operation without alarms
- Pickup – parameter limit has been reached
- Trip – alarm

Pickup state example:

- Over-voltage parameter limit is set to 110 %; time delay is set to 3 s.
- When the voltage reaches a parameter limit of 110 %, pickup state is displayed in M-set.
- After 3 s (time delay), pickup state changes to trip (presuming that the voltage stayed over 110 % the entire time).

Reset

During normal operation of a device, different counter values must be reset from time to time.

Reset energy counter [E1/E2/E3/E4]

All or individual energy meters (counters) are reset.

Reset MD values

Set maximum demand values to zero. At the same time, MD synchronisation is performed.

Reset last period MD

Set maximum demand last period values to zero. At the same time, MD synchronisation is performed.

Alarm relay [1/2/3/4] off

When using M-set, each alarm output can be reset separately.

Reset alarm statistics

Clears alarm statistics. It can be done in the M-set software, under alarm settings. This setting is only for resetting online alarm statistics displayed in the M-set software.

MEASUREMENTS

Online measurements

Online measurements can be monitored with the setting and monitoring software M-set.

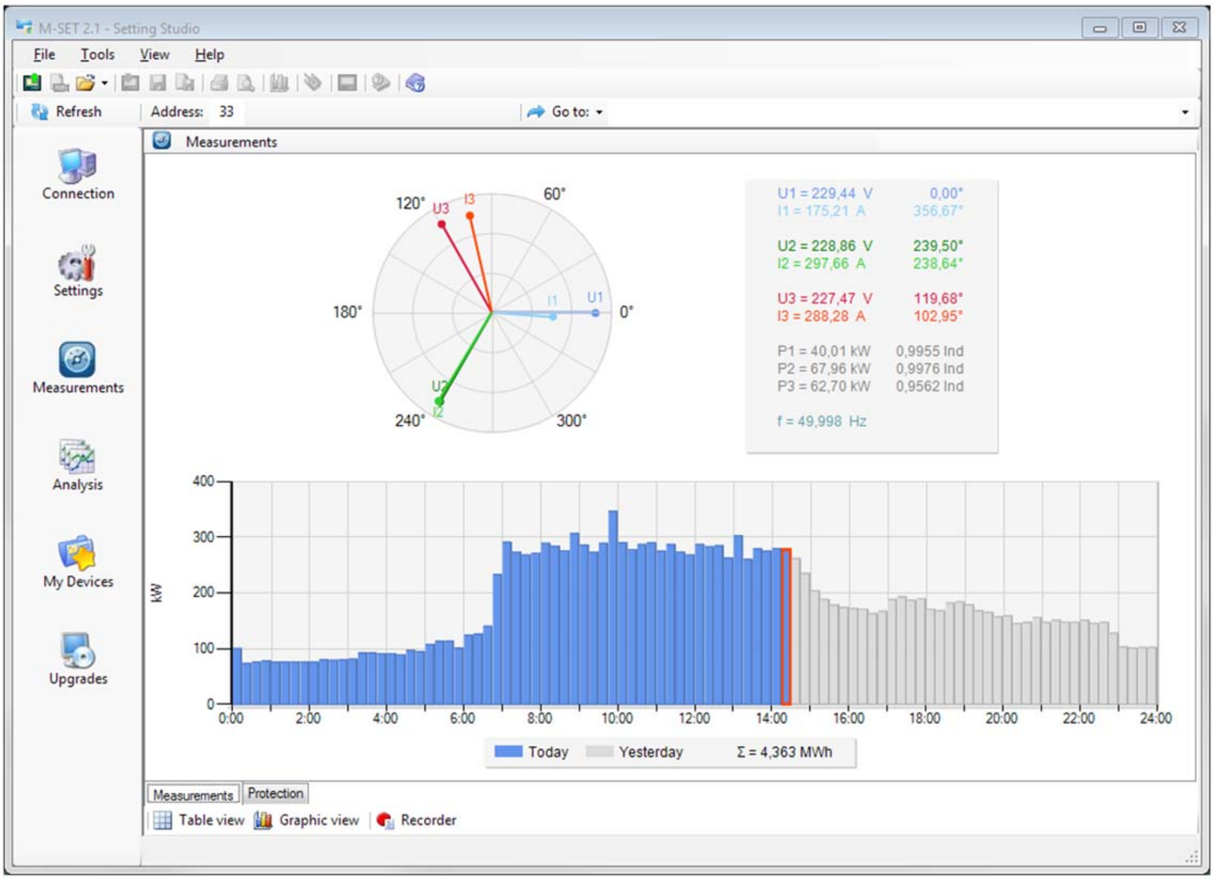
Refresh rate of readings is fixed to approximately one second in M-set.

To provide a better overview of numerous readings, they are divided into two groups:

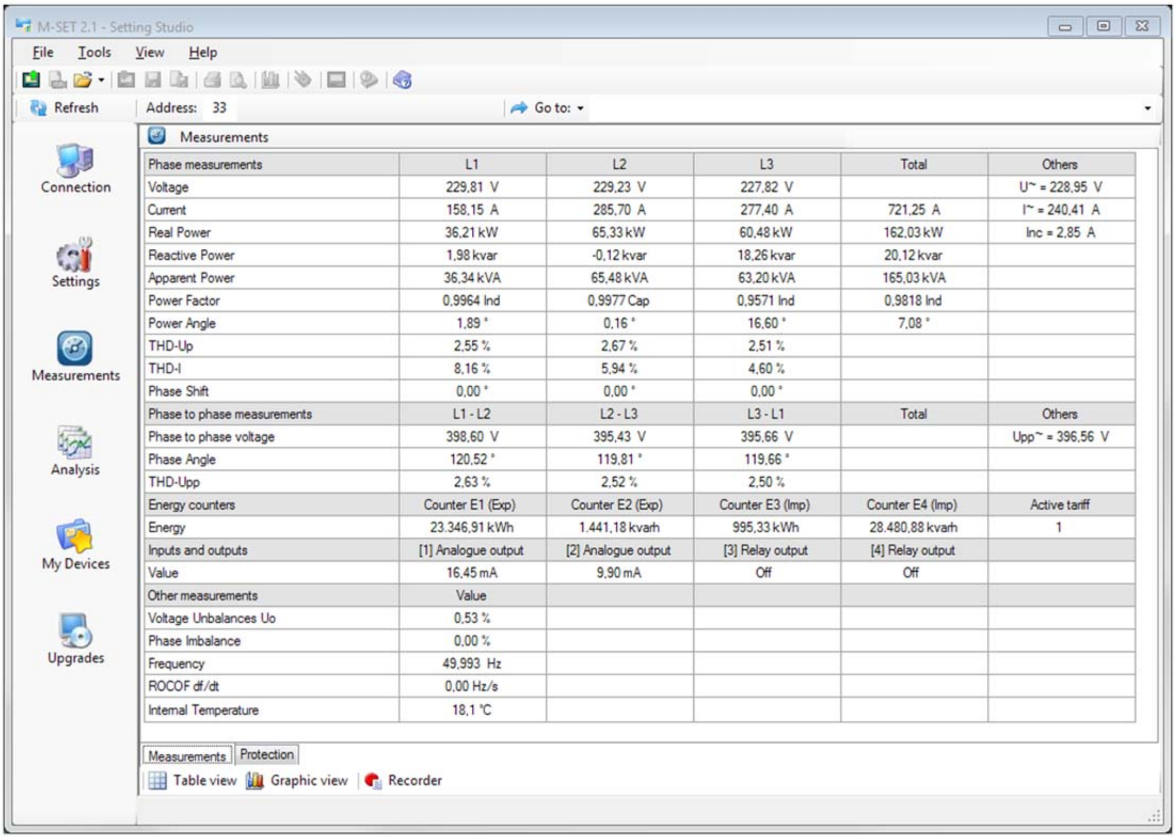
- Measurements
- Protection

The measurements group can present data in the visually favoured graphical form or in detailed tabular form. The latter allows freezing of readings and/or copying of data into various report generation software tools.

The protection group can only present data in tabular form.



Example: Online measurements in graphical form - phasor diagram and daily total active power consumption histogram

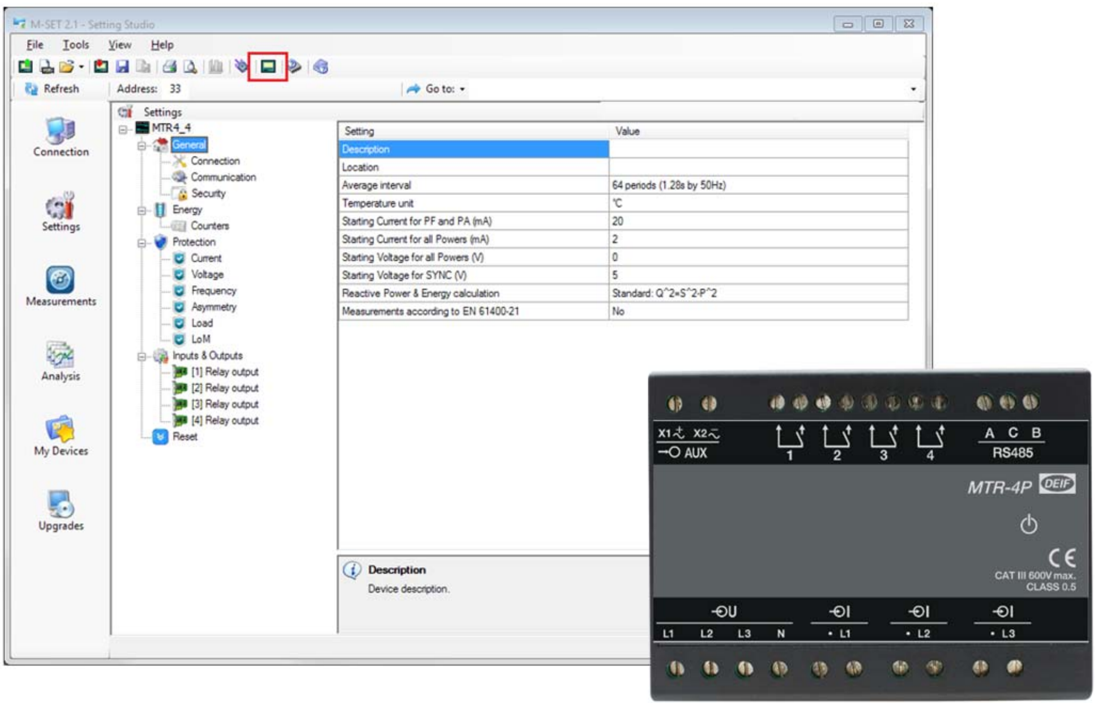


Example: Online measurements in tabular form

Interactive instrument

An additional communication feature of the device allows interactive handling of a non-existing device as if it was operational in front of the user.
This feature is useful for presentations or product training.

MTR-4P – interactive instrument:



Available connections

Different electric connections are described in more detail in chapter »Electrical connection«.
Connections are marked as follows:

- Connection 1b (1W) – Single-phase connection
- Connection 3b (1W3) – Three-phase, three-wire connection with balanced load
- Connection 4b (1W4) – Three-phase, four-wire connection with balanced load
- Connection 3u (2W3) – Three-phase, three-wire connection with unbalanced load
- Connection 4u (3W4) – Three-phase, four-wire connection with unbalanced load
- Connection IE – Three-phase, four-wire connection with unbalanced load
- Connection Idiff – Three-phase, four-wire connection with unbalanced load

NOTE

Support of measurements and protection functions depends on connection mode. Each current protection function uses different electrical connection modes. When a specific current protection function is used in correlation to its connection mode, it is not possible to activate the other two current protection functions.

If >I and >>I are chosen (4u electrical connection), monitoring of >IE and >I´ is not possible.
If >IE is chosen (IE electrical connection), monitoring of >I, >>I and >I´ is not possible.
If >I´ is chosen (Idiff electrical connection), monitoring of >I, >>I and >IE is not possible.

Refer to chapter »Electrical connection for MTR-4P« on page 10 for more information/details regarding electrical wiring.

Supported measurements

Selection of supported measurements and protection functions of the individual instrument is changed in the connection settings. All supported measurements can be read via communication (through M-set) or displayed on the device display (not supported in MTR-4P).

Selection of available quantities

Available online measuring quantities and their appearance can vary according to the set type of power network and other settings, such as average interval, maximum demand mode and reactive power calculation method. A complete list of available online measuring quantities is shown in the table below.

NOTE

Support of measurements depends on connection mode as well as the device type (built-in options). Calculated measurements (for example voltages U_1 *and* U_2 when 3-phase, 4-wire connection with a balanced load is used) are only informative.

NOTE

For the 3b and 3u connection modes, only phase-to-phase voltages are measured. The factor √3 is then applied to calculate the nominal phase voltage. For the 4u connection mode, the same measurements are supported as for 1b.

	Basic measurements	Designat.	Unit	1b	3b	3u	4b	4u
Phase	Voltage U1	U1	V	●	×	×	●	●
	Voltage U2	U2	V	×	×	×	○	●
	Voltage U3	U3	V	×	×	×	○	●
	Average voltage U~	U	V	×	×	×	○	●
	Current I1	I1	A	●	●	●	●	●
	Current I2	I2	A	×	○	●	○	●
	Current I3	I3	A	×	○	●	○	●
	Current In	Inc	A	×	○	○	○	●
	Total current It	I	A	●	○	○	○	●
	Average current I~	Iavg	A	×	○	○	○	●
	Frequency	F	Hz	●	●	●	●	●
	Active power P1	P1	W	●	×	×	●	●
	Active power P2	P2	W	×	×	×	○	●
	Active power P3	P3	W	×	×	×	○	●
	Total active power Pt	P	W	●	●	●	○	●
	Reactive power Q1	Q1	var	●	×	×	●	●
	Reactive power Q2	Q2	var	×	×	×	○	●
	Reactive power Q3	Q3	var	×	×	×	○	●
	Total reactive power Qt	Q	var	●	●	●	○	●
	Apparent power S1	S1	VA	●	×	×	●	●
	Apparent power S2	S2	VA	×	×	×	○	●
	Apparent power S3	S3	VA	×	×	×	○	●
	Total apparent power St	S	VA	●	●	●	○	●
	Power factor PF1	PF1		●	×	×	●	●
	Power factor PF2	PF2		×	×	×	○	●
	Power factor PF3	PF3		×	×	×	○	●
	Total power factor PFt	PF		●	●	●	○	●
	Power angle φ1	φ1	°	●	×	×	●	●
	Power angle φ2	φ2	°	×	×	×	○	●
	Power angle φ3	φ3	°	×	×	×	○	●
	Total power angle φt	φ	°	●	●	●	○	●
	THD of phase voltage Up1	U1%	%THD	●	×	×	●	●
	THD of phase voltage Up2	U2%	%THD	×	×	×	○	●
	THD of phase voltage Up3	U3%	%THD	×	×	×	○	●
	THD of phase current I1	I1%	%THD	●	●	●	●	●
	THD of phase current I2	I2%	%THD	×	○	●	○	●
	THD of phase current I3	I3%	%THD	×	○	●	○	●

● – supported ○ − calculated × − not supported

	Basic measurements	Designat.	Unit	1b	3b	3u	4b	4u
Phase-to-phase	Phase-to-phase voltage U12	U12	V	×	●	●	○	●
	Phase-to-phase voltage U23	U23	V	×	●	●	○	●
	Phase-to-phase voltage U31	U31	V	×	●	●	○	●
	Average phase-to-phase voltage Upp~	U	V	×	●	●	○	●
	Phase-to-phase angle φ12	φ12	°	×	×	×	○	●
	Phase-to-phase angle φ23	φ23	°	×	×	×	○	●
	Phase-to-phase angle φ31	φ31	°	×	×	×	○	●
	THD of phase-to-phase voltage THDU12	U12%	%THD	×	●	●	○	●
	THD of phase-to-phase voltage THDU23	U23%	%THD	×	●	●	○	●
	THD of phase-to-phase voltage THDU31	U31%	%THD	×	●	●	○	●
Energy	Counters 1−4	E1, E2,	Wh	●	●	●	●	●
		E3, E4	varh					
	Active tariff	Atar		●	●	●	●	●

● – supported ○ − calculated × − not supported

Explanation of basic concepts

Sample factor M_V

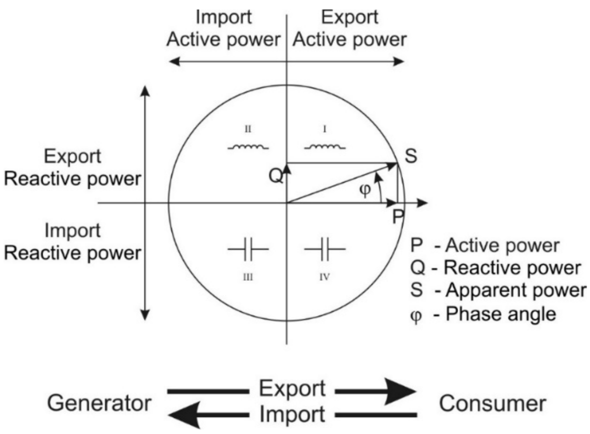
A meter measures all primary quantities with a sample frequency that cannot exceed a certain number of samples in a time period. Based on these limitations (128 samples/per. at 65 Hz), a sample factor is calculated. A sample factor (M_V), depending on frequency of a measured signal, defines a number of periods for a measurement calculation and thus a number of harmonics considered in calculations.

Average interval MP

Due to readability of measurements from communication or LCD (not supported in MTR-4P), an average interval (MP) is calculated with regard to the measured signal frequency. The average interval (see chapter »Average interval«) defines the refresh rate of displayed measurements based on a sampling factor.

Power and energy flow

The figure below shows the flow of active power, reactive power and energy for the 4u connection. Display of energy flow direction can be adjusted according to connection and operation requirements by changing the energy flow direction settings.



Explanation of energy flow direction

Calculation and display of measurements

This chapter deals with capture, calculation and display of all supported quantities of measurement. Only the most important equations are described; however, they are all shown in chapter »Equations« with additional descriptions and explanations.

NOTE

Calculation and display of measurements depend on the connection used. For more detailed information, see chapter »Survey of supported measurements«.

Present values

NOTE

Since measurement support depends on connection mode, some display groups can be combined into one in the measurements menu.

NOTE

Display of present values depends on connection mode. Therefore the display organisation differs slightly from one connection mode to another.

All measuring instruments may not support all the measurements. For overview of supportive instruments, see chapter »Selection of available quantities« on page 54.

Voltage

The device measurements:

- Real effective (rms) value of all phase voltages (U1, U2, U3), phase-to-phase voltages (U12, U23, U31) and neutral to earth voltage (Un)
- Average phase voltage (U⅄) and average phase-to-phase voltage (U△)
- Negative and zero sequence unbalance ratio (Uu, U0)
- Phase and phase-to-phase voltage angles (φ1-3, φ12, φ13, φ23)

$$U_f = \sqrt{\frac{\sum_{n=1}^{N} u_n^2}{N}} \qquad U_{xy} = \sqrt{\frac{\sum_{n=1}^{N} \left(u_{xn} - u_{yn}\right)^2}{N}}$$

All voltage measurements are available over communication.

Current

The device measurements:
- Real effective (rms) value of phase currents and neutral measured current (Inm), connected to current inputs
- Neutral calculated current (Inc), neutral error current (Ie = |Inm – Inc|),
- Phase angle between neutral voltage and neutral current (φIn), average current (Ia) and a sum of all phase currents (It)

$$I_{RMS} = \sqrt{\frac{\sum_{n=1}^{N} i_n^2}{N}}$$

All current measurements are available over communication.

Active, reactive and apparent power

Active power is calculated from instantaneous phase voltages and currents. All measurements are seen over communication. For more detailed information about calculation, see chapter »Appendix B - Equations« on page 83.
There are two different methods of calculating reactive power, see chapter »Reactive power and energy calculation« on page 24.

Power factor and power angle

Power angle (or displacement power factor) is calculated as a quotient of active and apparent power for each phase separately ($\cos\varphi_1$, $\cos\varphi_2$, $\cos\varphi_3$) and total power angle ($\cos\varphi_T$). It represents the angle between first (base) voltage harmonic and first (base) current harmonic for each individual phase. Total power angle is calculated from total active and reactive power (see equation for total power angle, chapter »Equations«). A symbol for a coil (positive sign) represents inductive load, and a symbol for a capacitor (negative sign) represents capacitive load.

Presentation of PF:

Load	*C*	→		←	*L*
Angle [°]	−180	−90	0	+90	+180 (179.99)
PF	−1	0	1	0	−1

Frequency

Network frequency is calculated from time periods of measured voltage. The instrument uses the synchronisation method, which is highly immune to harmonic disturbances.
The device always synchronises to a phase voltage *U1*. If the signal on that phase is too low, it (re)synchronises to the next phase. If all phase voltages are low (for example due to short circuit), the device synchronises to phase currents. If there is no signal present on any voltage or current channels, the device shows frequency 0 Hz.

Energy counters

Three ways of displaying energy counters are available:

- By individual counter
- By tariffs for each counter separately
- Energy cost by counter

The sum in the upper line depends on the tariffs set in the instrument.
There are two different methods of calculating reactive energy. See chapter »Reactive power and energy calculation« on page 24.
Additional information on how to set and define a counter quantity is explained in chapter »Energy« on page 28.

THD − total harmonic distortion

THD is calculated for phase currents, phase and phase-to-phase voltages and is expressed as percent of high harmonic components regarding RMS value or relative to first harmonic.
The instrument uses the measuring technique of true RMS values that assures exact measurements with the presence of high harmonics up to 63rd harmonic.

Average interval for min. max. values

Minimum and maximum values often require a special averaging period, which enables or disables detection of short measuring spikes. With this setting it is possible to set averaging from 1 period to 256 periods.

APPENDICES

Appendix A

Modbus communication protocol
Modbus is enabled via RS-485 on MTR-4P. The response is the same type as the request.

Modbus

Modbus protocol enables operation of the device on Modbus networks. For devices with serial communication, the Modbus protocol enables point-to-point (for example device to PC) multi-drop communication via RS-485 communication. A Modbus protocol is a widely supported open interconnection originally designed by Modicon.

The memory reference for input and holding registers is 300001 and 400001 respectively.

The register tables on the next pages show both the PLC address and Modbus address to read from the desired register.

Example for reading of frequency parameter:
PLC: Read address 300106-300107
Modbus: Read address 105-106 with function 4

The Modbus address will always be 1 lower than the PLC address, because PLC addresses start with 1 whereas Modbus addresses start with 0.

MEASUREMENTS (IEEE 754)

Parameter	PLC		Modbus reading			
	Address		Address		Function	Type
	Start	End	Start	End		
Frequency (fast response)	302483	302484	2482	2483	04	T_float
Uavg (phase to neutral)	302485	302486	2484	2485	04	T_float
Uavg (phase to phase)	302487	302488	2486	2487	04	T_float
Sum I	302489	302490	2488	2489	04	T_float
Active Power Total (Pt)	302491	302492	2490	2491	04	T_float
Reactive Power Total (Qt)	302493	302494	2492	2493	04	T_float
Apparent Power Total (St)	302495	302496	2494	2495	04	T_float
Power Factor Total (PFt)	302497	302498	2496	2497	04	T_float
Frequency	302499	302500	2498	2499	04	T_float
U1	302501	302502	2500	2501	04	T_float
U2	302503	302504	2502	2503	04	T_float
U3	302505	302506	2504	2505	04	T_float
Uavg (phase to neutral)	302507	302508	2506	2507	04	T_float
U12	302509	302510	2508	2509	04	T_float
U23	302511	302512	2510	2511	04	T_float
U31	302513	302514	2512	2513	04	T_float
Uavg (phase to phase)	302515	302516	2514	2515	04	T_float
I1	302517	302518	2516	2517	04	T_float
I2	302519	302520	2518	2519	04	T_float
I3	302521	302522	2520	2521	04	T_float
Sum I	302523	302524	2522	2523	04	T_float
I neutral (calculated)	302525	302526	2524	2525	04	T_float
I neutral (measured)	302527	302528	2526	2527	04	T_float
Iavg	302529	302530	2528	2529	04	T_float
Active Power Phase L1 (P1)	302531	302532	2530	2531	04	T_float
Active Power Phase L2 (P2)	302533	302534	2532	2533	04	T_float
Active Power Phase L3 (P3)	302535	302536	2534	2535	04	T_float
Active Power Total (Pt)	302537	302538	2536	2537	04	T_float
Reactive Power Phase L1 (Q1)	302539	302540	2538	2539	04	T_float
Reactive Power Phase L2 (Q2)	302541	302542	2540	2541	04	T_float
Reactive Power Phase L3 (Q3)	302543	302544	2542	2543	04	T_float
Reactive Power Total (Qt)	302545	302546	2544	2545	04	T_float
Apparent Power Phase L1 (S1)	302547	302548	2546	2547	04	T_float
Apparent Power Phase L2 (S2)	302549	302550	2548	2549	04	T_float
Apparent Power Phase L3 (S3)	302551	302552	2550	2551	04	T_float
Apparent Power Total (St)	302553	302554	2552	2553	04	T_float
Power Factor Phase 1 (PF1)	302555	302556	2554	2555	04	T_float
Power Factor Phase 2 (PF2)	302557	302558	2556	2557	04	T_float
Power Factor Phase 3 (PF3)	302559	302560	2558	2559	04	T_float
Power Factor Total (PFt)	302561	302562	2560	2561	04	T_float
CAP/IND P. F. Phase 1 (PF1)	302563	302564	2562	2563	04	T_float
CAP/IND P. F. Phase 2 (PF2)	302565	302566	2564	2565	04	T_float
CAP/IND P. F. Phase 3 (PF3)	302567	302568	2566	2567	04	T_float
CAP/IND P. F. Total (PFt)	302569	302570	2568	2569	04	T_float
φ1 (angle between U1 and I1)	302571	302572	2570	2571	04	T_float
φ2 (angle between U2 and I2)	302573	302574	2572	2573	04	T_float
φ3 (angle between U3 and I3)	302575	302576	2574	2575	04	T_float
Power Angle Total atan2(Pt,Qt))	302577	302578	2576	2577	04	T_float

MEASUREMENTS (IEEE 754)

Parameter	PLC		Modbus reading			
	Address		Address		Function	Type
	Start	End	Start	End		
φ12 (angle between U1 and U2)	302579	302580	2578	2579	04	T_float
φ23 (angle between U2 and U3)	302581	302582	2580	2581	04	T_float
φ31 (angle between U3 and U1)	302583	302584	2582	2583	04	T_float
Frequency	302585	302586	2584	2585	04	T_float
Reserved	302587	302588	2586	2587		
I1 THD%	302589	302590	2588	2589	04	T_float
I2 THD%	302591	302592	2590	2591	04	T_float
I3 THD%	302593	302594	2592	2593	04	T_float
U1 THD%	302595	302596	2594	2595	04	T_float
U2 THD%	302597	302598	2596	2597	04	T_float
U3 THD%	302599	302600	2598	2599	04	T_float
U12 THD%	302601	302602	2600	2601	04	T_float
U23 THD%	302603	302604	2602	2603	04	T_float
U31 THD%	302605	302606	2604	2605	04	T_float
MAX DEMAND SINCE LAST RESET						
Active Power Total (Pt) - (positive)	302607	302608	2606	2607	04	T_float
Active Power Total (Pt) - (negative)	302609	302610	2608	2609	04	T_float
Reactive Power Total (Qt) - L	302611	302612	2610	2611	04	T_float
Reactive Power Total (Qt) - C	302613	302614	2612	2613	04	T_float
Apparent Power Total (St)	302615	302616	2614	2615	04	T_float
I1	302617	302618	2616	2617	04	T_float
I2	302619	302620	2618	2619	04	T_float
I3	302621	302622	2620	2621	04	T_float
DYNAMIC DEMAND VALUES						
Active Power Total (Pt) - (positive)	302623	302624	2622	2623	04	T_float
Active Power Total (Pt) - (negative)	302625	302626	2624	2625	04	T_float
Reactive Power Total (Qt) - L	302627	302628	2626	2627	04	T_float
Reactive Power Total (Qt) - C	302629	302630	2628	2629	04	T_float
Apparent Power Total (St)	302631	302632	2630	2631	04	T_float
I1	302633	302634	2632	2633	04	T_float
I2	302635	302636	2634	2635	04	T_float
I3	302637	302638	2636	2637	04	T_float
ENERGY						
Energy Counter 1	302639	302640	2638	2639	04	T_float
Energy Counter 2	302641	302642	2640	2641	04	T_float
Energy Counter 3	302643	302644	2642	2643	04	T_float
Energy Counter 4	302645	302646	2644	2645	04	T_float
Reserved	302647	302656	2646	2655		
Active Tariff	302657	302658	2656	2657	04	T_float
Internal Temperature	302659	302660	2658	2659	04	T_float

PROTECTION STATUS PARAMETERS

PROTECTION							
	PLC		Modbus reading				
	Address		Address		Type	Ind	Values/descriptions
	Start	End	Start	End			
Protection							
Voltage Unbalances Uo	307002		7001		T16		%
Phase Imbalance	307003		7002		T16		%
Phase Shift L1	307004		7003		T17		°
Phase Shift L2	307005		7004		T17		°
Phase Shift L3	307006		7005		T17		°
ROCOF df/dt	307007		7006		T17		Hz/S
Reserved	307008	307020	7007	7019			
Protection states							
Protection Outputs	307021		7020		T1	Bit 0	Relay output 1 Active
						Bit 1	Relay output 2 Active
						Bit 3	Relay output 3 Active
						Bit 4	Relay output 4 Active
Overvoltage 1	307022		7021		T1	Bit 0	0 = OK, 1 = Active phase L1
						Bit 1	0 = OK, 1 = Active phase L2
						Bit 2	0 = OK, 1 = Active phase L3
						Bit 8	0 = OK, 1 = Pickup phase L1
						Bit 9	0 = OK, 1 = Pickup phase L2
						Bit10	0 = OK, 1 = Pickup phase L3
Overvoltage 2	307023		7022		T1	Bit 0	0 = OK, 1 = Active phase L1
						Bit 1	0 = OK, 1 = Active phase L2
						Bit 2	0 = OK, 1 = Active phase L3
						Bit 8	0 = OK, 1 = Pickup phase L1
						Bit 9	0 = OK, 1 = Pickup phase L2
						Bit10	0 = OK, 1 = Pickup phase L3
Undervoltage 1	307024		7023		T1	Bit 0	0 = OK, 1 = Active phase L1
						Bit 1	0 = OK, 1 = Active phase L2
						Bit 2	0 = OK, 1 = Active phase L3
						Bit 8	0 = OK, 1 = Pickup phase L1
						Bit 9	0 = OK, 1 = Pickup phase L2
						Bit10	0 = OK, 1 = Pickup phase L3
Undervoltage 2	307025		7024		T1	Bit 0	0 = OK, 1 = Active phase L1
						Bit 1	0 = OK, 1 = Active phase L2
						Bit 2	0 = OK, 1 = Active phase L3
						Bit 8	0 = OK, 1 = Pickup phase L1
						Bit 9	0 = OK, 1 = Pickup phase L2
						Bit10	0 = OK, 1 = Pickup phase L3
Overfrequency 1	307026		7025		T1	Bit 0	0 = OK, 1 = Active
						Bit 8	0 = OK, 1 = Pickup
Overfrequency 2	307027		7026		T1	Bit 0	0 = OK, 1 = Active
						Bit 8	0 = OK, 1 = Pickup
Underfrequency 1	307028		7027		T1	Bit 0	0 = OK, 1 = Active
						Bit 8	0 = OK, 1 = Pickup
Underfrequency 2	307029		7028		T1	Bit 0	0 = OK, 1 = Active
						Bit 8	0 = OK, 1 = Pickup
Directional power 1	307030		7029		T1	Bit 0	0 = OK, 1 = Active
						Bit 8	0 = OK, 1 = Pickup
Directional power 2	307031		7030		T1	Bit 0	0 = OK, 1 = Active
						Bit 8	0 = OK, 1 = Pickup

PROTECTION STATUS PARAMETERS

	PLC		Modbus reading				
	Address		Address		Type	Ind	Values/descriptions
Power underrun 1	307032		7031		T1	Bit 0	0 = OK, 1 = Active
						Bit 8	0 = OK, 1 = Pickup
Power underrun 2	307033		3032		T1	Bit 0	0 = OK, 1 = Active
						Bit 8	0 = OK, 1 = Pickup
Voltage unbalances	307034		7033		T1	Bit 0	0 = OK, 1 = Active
						Bit 8	0 = OK, 1 = Pickup
Phase imbalance 1	307035		7034		T1	Bit 0	0 = OK, 1 = Active
						Bit 8	0 = OK, 1 = Pickup
Phase imbalance 2	307036		7035		T1	Bit 0	0 = OK, 1 = Active
						Bit 8	0 = OK, 1 = Pickup
Phase shift	307037		7036		T1	Bit 0	0 = OK, 1 = Active phase L1
						Bit 1	0 = OK, 1 = Active phase L2
						Bit 2	0 = OK, 1 = Active phase L3
						Bit 4	0 = OK, 1 = 3-phase
ROCOF df/dt	307038		7037		T1	Bit 0	0 = OK, 1 = Active phase
						Bit 8	0 = OK, 1 = Pickup
Over-current 1	307039		7038		T1	Bit 0	0 = OK, 1 = Active phase L1
						Bit 1	0 = OK, 1 = Active phase L2
						Bit 2	0 = OK, 1 = Active phase L3
						Bit 8	0 = OK, 1 = Pickup phase L1
						Bit 9	0 = OK, 1 = Pickup phase L2
						Bit10	0 = OK, 1 = Pickup phase L3
Over-current 2	307040		7039		T1	Bit 0	0 = OK, 1 = Active phase L1
						Bit 1	0 = OK, 1 = Active phase L2
						Bit 2	0 = OK, 1 = Active phase L3
						Bit 8	0 = OK, 1 = Pickup phase L1
						Bit 9	0 = OK, 1 = Pickup phase L2
						Bit10	0 = OK, 1 = Pickup phase L3
Over-current IE 1	307041		7040		T1	Bit 0	0 = OK, 1 = Active phase L1
						Bit 1	0 = OK, 1 = Active phase L2
						Bit 2	0 = OK, 1 = Active phase L3
						Bit 8	0 = OK, 1 = Pickup phase L1
						Bit 9	0 = OK, 1 = Pickup phase L2
						Bit10	0 = OK, 1 = Pickup phase L3
Over-current IE 2	307042		7041		T1	Bit 0	0 = OK, 1 = Active phase L1
						Bit 1	0 = OK, 1 = Active phase L2
						Bit 2	0 = OK, 1 = Active phase L3
						Bit 8	0 = OK, 1 = Pickup phase L1
						Bit 9	0 = OK, 1 = Pickup phase L2
						Bit10	0 = OK, 1 = Pickup phase L3
Over-current Idiff 1	307043		7042		T1	Bit 0	0 = OK, 1 = Active phase L1
						Bit 1	0 = OK, 1 = Active phase L2
						Bit 2	0 = OK, 1 = Active phase L3
						Bit 8	0 = OK, 1 = Pickup phase L1
						Bit 9	0 = OK, 1 = Pickup phase L2
						Bit10	0 = OK, 1 = Pickup phase L3
Over-current Idiff 2	307044		7043		T1	Bit 0	0 = OK, 1 = Active phase L1
						Bit 1	0 = OK, 1 = Active phase L2
						Bit 2	0 = OK, 1 = Active phase L3
						Bit 8	0 = OK, 1 = Pickup phase L1
						Bit 9	0 = OK, 1 = Pickup phase L2
						Bit10	0 = OK, 1 = Pickup phase L3

Register table for the actual measurements

Parameter	PLC		Modbus reading			
	Address		Address		Function	Type
	Start	End	Start	End		
Frequency	300106	300107	105	106	04	T5
U1	300108	300109	107	108	04	T5
U2	300110	300111	109	110	04	T5
U3	300112	300113	111	112	04	T5
Uavg (phase to neutral)	300114	300115	113	114	04	T5
φ12 (angle between U1 and U2)	300116		115		04	T17
φ23 (angle between U2 and U3)	300117		116		04	T17
φ31 (angle between U3 and U1)	300118		117		04	T17
U12	300119	300120	118	119	04	T5
U23	300121	300122	120	121	04	T5
U31	300123	300124	122	123	04	T5
Uavg (phase to phase)	300125	300126	124	125	04	T5
I1	300127	300128	126	127	04	T5
I2	300129	300130	128	129	04	T5
I3	300131	300132	130	131	04	T5
INc	300133	300134	132	133	04	T5
INm - reserved	300135	300136	134	135	04	T5
Iavg	300137	300138	136	137	04	T5
∑I	300139	300140	138	139	04	T5
Active Power Total (Pt)	300141	300142	140	141	04	T6
Active Power Phase L1 (P1)	300143	300144	142	143	04	T6
Active Power Phase L2 (P2)	300145	300146	144	145	04	T6
Active Power Phase L3 (P3)	300147	300148	146	147	04	T6
Reactive Power Total (Qt)	300149	300150	148	149	04	T6
Reactive Power Phase L1 (Q1)	300151	300152	150	151	04	T6
Reactive Power Phase L2 (Q2)	300153	300154	152	153	04	T6
Reactive Power Phase L3 (Q3)	300155	300156	154	155	04	T6
Apparent Power Total (St)	300157	300158	156	157	04	T5
Apparent Power Phase L1 (S1)	300159	300160	158	159	04	T5
Apparent Power Phase L2 (S2)	300161	300162	160	161	04	T5
Apparent Power Phase L3 (S3)	300163	300164	162	163	04	T5
Power Factor Total (PFt)	300165	300166	164	165	04	T7
Power Factor Phase 1 (PF1)	300167	300168	166	167	04	T7
Power Factor Phase 2 (PF2)	300169	300170	168	169	04	T7
Power Factor Phase 3 (PF3)	300171	300172	170	171	04	T7
Power Angle Total atan2(Pt,Qt))	300173	300173	172	172	04	T17
φ1 (angle between U1 and I1)	300174		173		04	T17
φ2 (angle between U2 and I2)	300175		174		04	T17
φ3 (angle between U3 and I3)	300176		175		04	T17
Internal Temperature	300182		181		04	T17

Register table for the actual measurements

Parameter	PLC Address Start	PLC Address End	Modbus reading Address Start	Modbus reading Address End	Function	Type
Reactive Power Total (Qt)	300149	300150	148	149	04	T6
Reactive Power Phase L1 (Q1)	300151	300152	150	151	04	T6
Reactive Power Phase L2 (Q2)	300153	300154	152	153	04	T6
Reactive Power Phase L3 (Q3)	300155	300156	154	155	04	T6
Apparent Power Total (St)	300157	300158	156	157	04	T5
Apparent Power Phase L1 (S1)	300159	300160	158	159	04	T5
Apparent Power Phase L2 (S2)	300161	300162	160	161	04	T5
Apparent Power Phase L3 (S3)	300163	300164	162	163	04	T5
Power Factor Total (PFt)	300165	300166	164	165	04	T7
Power Factor Phase 1 (PF1)	300167	300168	166	167	04	T7
Power Factor Phase 2 (PF2)	300169	300170	168	169	04	T7
Power Factor Phase 3 (PF3)	300171	300172	170	171	04	T7
Power Angle Total (atan2(Pt,Qt))	300173		172		04	T17
φ1 (angle between U1 and I1)	300174		173		04	T17
φ2 (angle between U2 and I2)	300175		174		04	T17
φ3 (angle between U3 and I3)	300176		175		04	T17
Internal Temperature	300182		181		04	T17
THD HARMONIC DATA						
U1 THD%	300183		182		04	T16
U2 THD%	300184		183		04	T16
U3 THD%	300185		184		04	T16
U12 THD%	300186		185		04	T16
U23 THD%	300187		186		04	T16
U31 THD%	300188		187		04	T16
I1 THD%	300189		188		04	T16
I2 THD%	300190		189		04	T16
I3 THD%	300191		190		04	T16
I/O STATUS						
Alarm Status Flags (No. 1…16)	300192		191		04	T1
I/O 1 Value (0=Off, 100=On)	300194		193		04	T17
I/O 2 Value (0=Off, 1=On)	300195		194		04	T17
I/O 3 Value (0=Off, 1=On)	300196		195		04	T17
I/O 4 Value (0=Off, 1=On)	300197		196		04	T17
ENERGY (see note)						
Energy Counter 1 Exponent	300401		400		04	T2
Energy Counter 2 Exponent	300402		401		04	T2
Energy Counter 3 Exponent	300403		402		04	T2
Energy Counter 4 Exponent	300404		403		04	T2
Current Active Tariff	300405		404		04	T1
Energy Counter 1	300406	300407	405	406	04	T3
Energy Counter 2	300408	300409	407	408	04	T3
Energy Counter 3	300410	300411	409	410	04	T3
Energy Counter 4	300412	300413	411	412	04	T3

Note: Energy counters' actual value is calculated: Counter * $10^{Exponent}$

Register table for the actual measurements

Parameter	PLC		Modbus reading			
	Address		Address		Function	Type
	Start	End	Start	End		
DYNAMIC DEMAND VALUES						
Time Into Period (minutes)	300502		501		04	T1
I1	300503	300504	502	503	04	T5
I2	300505	300506	504	505	04	T5
I3	300507	300508	506	507	04	T5
Apparent Power Total (St)	300509	300510	508	509	04	T5
Active Power Total (Pt) - (positive)	300511	300512	510	511	04	T6
Active Power Total (Pt) - (negative)	300513	300514	512	513	04	T6
Reactive Power Total (Qt) - L	300515	300516	514	515	04	T6
Reactive Power Total (Qt) - C	300517	300518	516	517	04	T6
MAX DEMAND SINCE LAST RESET						
I1	300519	300520	518	519	04	T5
I2	300525	300526	524	525	04	T5
I3	300531	300532	530	531	04	T5
Apparent Power Total (St)	300537	300538	536	537	04	T5
Active Power Total (Pt) - (positive)	300543	300544	542	543	04	T6
Active Power Total (Pt) - (negative)	300549	300550	548	549	04	T6
Reactive Power Total (Qt) - L	300555	300556	554	555	04	T6
Reactive Power Total (Qt) - C	300561	300562	560	561	04	T6

Register table for the normalised actual measurements (in %)

Parameter	PLC Address Start	PLC Address End	Modbus reading Address Start	Modbus reading Address End	Function	Type	100 % value
U1	300802		801		04	T16	Un
U2	300803		802		04	T16	Un
U3	300804		803		04	T16	Un
Uavg (phase to neutral)	300805		804		04	T16	Un
U12	300806		805		04	T16	Un
U23	300807		806		04	T16	Un
U31	300808		807		04	T16	Un
Uavg (phase to phase)	300809		808		04	T16	Un
I1	300810		809		04	T16	In
I2	300811		810		04	T16	In
I3	300812		811		04	T16	In
∑I	300813		812		04	T16	It
I neutral (calculated)	300814		813		04	T16	In
I neutral (measured)	300815		814		04	T16	In
Iavg	300816		815		04	T16	In
Active Power Phase L1 (P1)	300817		816		04	T17	Pn
Active Power Phase L2 (P2)	300818		817		04	T17	Pn
Active Power Phase L3 (P3)	300819		818		04	T17	Pn
Active Power Total (Pt)	300820		819		04	T17	Pt
Reactive Power Phase L1 (Q1)	300821		820		04	T17	Pn
Reactive Power Phase L2 (Q2)	300822		821		04	T17	Pn
Reactive Power Phase L3 (Q3)	300823		822		04	T17	Pn
Reactive Power Total (Qt)	300824		823		04	T17	Pt
Apparent Power Phase L1 (S1)	300825		824		04	T16	Pn
Apparent Power Phase L2 (S2)	300826		825		04	T16	Pn
Apparent Power Phase L3 (S3)	300827		826		04	T16	Pn
Apparent Power Total (St)	300828		827		04	T16	Pt
Power Factor Phase 1 (PF1)	300829		828		04	T17	1
Power Factor Phase 2 (PF2)	300830		829		04	T17	1
Power Factor Phase 3 (PF3)	300831		830		04	T17	1
Power Factor Total (PFt)	300832		831		04	T17	1
CAP/IND P. F. Phase 1 (PF1)	300833		832		04	T17	1
CAP/IND P. F. Phase 2 (PF2)	300834		833		04	T17	1
CAP/IND P. F. Phase 3 (PF3)	300835		834		04	T17	1
CAP/IND P. F. Total (PFt)	300836		835		04	T17	1
φ1 (angle between U1 and I1)	300837		836		04	T17	100°
φ2 (angle between U2 and I2)	300838		837		04	T17	100°
φ3 (angle between U3 and I3)	300839		838		04	T17	100°
Power Angle Total (atan2(Pt,Qt))	300840		839		04	T17	100°
φ12 (angle between U1 and U2)	300841		840		04	T17	100°
φ23 (angle between U2 and U3)	300842		841		04	T17	100°
φ31 (angle between U3 and U1)	300843		842		04	T17	100°
Frequency	300844		843		04	T17	Fn+10 Hz
I1 THD%	300845		844		04	T16	100%
I2 THD%	300846		845		04	T16	100%
I3 THD%	300847		846		04	T16	100%
U1 THD%	300848		847		04	T16	100%
U2 THD%	300849		848		04	T16	100%
U3 THD%	300850		849		04	T16	100%

Register table for the normalised actual measurements (in %)

	PLC		Modbus reading				
Parameter	**Address**		**Address**		**Function**	**Type**	**100 % value**
	Start	**End**	**Start**	**End**			
U12 THD%	300851		850		04	T16	100%
U23 THD%	300852		851		04	T16	100%
U31 THD%	300853		852		04	T16	100%
MAX DEMAND SINCE LAST RESET							
Active Power Total (Pt) - (positive)	300854		853		04	T16	Pt
Active Power Total (Pt) - (negative)	300855		854		04	T16	Pt
Reactive Power Total (Qt) - L	300856		855		04	T16	Pt
Reactive Power Total (Qt) - C	300857		856		04	T16	Pt
Apparent Power Total (St)	300858		857		04	T16	Pt
I1	300859		858		04	T16	In
I2	300860		859		04	T16	In
I3	300861		860		04	T16	In
DYNAMIC DEMAND VALUES							
Active Power Total (Pt) - (positive)	300862		861		04	T16	Pt
Active Power Total (Pt) - (negative)	300863		862		04	T16	Pt
Reactive Power Total (Qt) - L	300864		863		04	T16	Pt
Reactive Power Total (Qt) - C	300865		864		04	T16	Pt
Apparent Power Total (St)	300866		865		04	T16	Pt
I1	300867		866		04	T16	In
I2	300868		867		04	T16	In
I3	300869		868		04	T16	In
ENERGY							
Energy counter 1	300870		869		04	T17	Actual counter value MOD 20000 is returned
Energy counter 2	300871		870		04	T17	
Energy counter 3	300872		871		04	T17	
Energy counter 4	300873		872		04	T17	
Active tariff	300879		878		04	T1	
Internal temperature	300880		879		04	T17	100°

Register table for the fast response of normalised actual measurements (in %)

The measurements in the registers below are not averaged, and therefore the response time is less than 50 mS.

Parameter	PLC Address Start	PLC Address End	Modbus reading Address Start	Modbus reading Address End	Function	Type	100 % value
U1	300902		901		04	T16	Un
U2	300903		902		04	T16	Un
U3	300904		903		04	T16	Un
Uavg (phase to neutral)	300905		904		04	T16	Un
U12	300906		905		04	T16	Un
U23	300907		906		04	T16	Un
U31	300908		907		04	T16	Un
Uavg (phase to phase)	300909		908		04	T16	Un
I1	300910		909		04	T16	In
I2	300911		910		04	T16	In
I3	300912		911		04	T16	In
∑I	300913		912		04	T16	It
I neutral (calculated)	300914		913		04	T16	In
I neutral (measured)	300915		914		04	T16	In
Iavg	300916		915		04	T16	In
Active Power Phase L1 (P1)	300917		916		04	T17	Pn
Active Power Phase L2 (P2)	300918		917		04	T17	Pn
Active Power Phase L3 (P3)	300919		918		04	T17	Pn
Active Power Total (Pt)	300920		919		04	T17	Pt
Reactive Power Phase L1 (Q1)	300921		920		04	T17	Pn
Reactive Power Phase L2 (Q2)	300922		921		04	T17	Pn
Reactive Power Phase L3 (Q3)	300923		922		04	T17	Pn
Reactive Power Total (Qt)	300924		923		04	T17	Pt
Apparent Power Phase L1 (S1)	300925		924		04	T16	Pn
Apparent Power Phase L2 (S2)	300926		925		04	T16	Pn
Apparent Power Phase L3 (S3)	300927		926		04	T16	Pn
Apparent Power Total (St)	300928		927		04	T16	Pt
Power Factor Phase 1 (PF1)	300929		928		04	T17	1
Power Factor Phase 2 (PF2)	300930		929		04	T17	1
Power Factor Phase 3 (PF3)	300931		930		04	T17	1
Power Factor Total (PFt)	300932		931		04	T17	1
CAP/IND P. F. Phase 1 (PF1)	300933		932		04	T17	1
CAP/IND P. F. Phase 2 (PF2)	300934		933		04	T17	1
CAP/IND P. F. Phase 3 (PF3)	300935		934		04	T17	1
CAP/IND P. F. Total (PFt)	300936		935		04	T17	1
φ1 (angle between U1 and I1)	300937		936		04	T17	100°
φ2 (angle between U2 and I2)	300938		937		04	T17	100°
φ3 (angle between U3 and I3)	300939		938		04	T17	100°
Power Angle Total (atan2(Pt,Qt))	300940		939		04	T17	100°
φ12 (angle between U1 and U2)	300941		940		04	T17	100°
φ23 (angle between U2 and U3)	300942		941		04	T17	100°
φ31 (angle between U3 and U1)	300943		942		04	T17	100°
Frequency	300944		943		04	T17	Fn+10 Hz
Reserved	300945		944				
I1 THD%	300946		945		04	T16	100%
I2 THD%	300947		946		04	T16	100%
I3 THD%	300948		947		04	T16	100%
U1 THD%	300949		948		04	T16	100%

U2 THD%	300950		949		04	T16	100%
U3 THD%	300951		950		04	T16	100%
U12 THD%	300952		951		04	T16	100%
U23 THD%	300953		952		04	T16	100%
U31 THD%	300954		953		04	T16	100%

Register settings table

Parameter	PLC Address Start	PLC Address End	Modbus reading Address Start	Modbus reading Address End	Type	Ind	Values/dependencies
SYSTEM COMMANDS							
User Password (L1, L2)	400002	400003	1	2	T_Str4	A...Z	Password to attempt user access level upgrade
Factory Password (FAC)	400004	400006	3	5	T_Str6	A...Z	Password to attempt factory access level upgrade
Level 1 - User password	400007	400008	6	7	T_Str4	A...Z	
Level 2 - User password	400009	400010	8	9	T_Str4	A...Z	
Active Access Level	400011		10		T1	0	Full protection
						1	Access up to level 1 user password
						2	Access up to level 2 user password
						3	Access up to level 2 (backup pass.)
						4	Factory access level
Manual password activation	400012		11		T1	1	Lock instrument
Operator Command Register	400013		12		T1	1	Save Settings
						2	Abort Settings
						3	Restart Instrument
Reset command register 1	400014		13		T1	Bit-0	Reset counter 1
						Bit-1	Reset counter 2
						Bit-2	Reset counter 3
						Bit-3	Reset counter 4
						Bit-10	Reset last period MD
						Bit-11	Reset MD values
Reserved	400016	400100	15	99			
GENERAL SETTINGS							
Description	400102	400120	101	119	T-Str40		
Location	400123	400140	122	139	T-Str40		
Password activation	400142		141				Reserved
Password lock time	400143		142		T1		Minutes, 0 = No lock
Connection Mode	400144		143		T1	0	No mode
						1	1b - Single Phase
						2	3b - 3 phase 3 wire balanced
						3	4b - 3 phase 4 wire balanced
						4	3u - 3 phase 3 wire unbalanced
						5	4u - 3 phase 4 wire unbalanced
CT Secondary	400145		144		T4		mA
CT Primary	400146		145		T4		A/10
VT Secondary	400147		146		T4		mV
VT Primary	400148		147		T4		V/10
Current input range (%)	400149		148		T16		10000 for 100%
Voltage input range (%)	400150		149		T16		10000 for 100%
Frequency nominal value	400151		150		T1		Hz
CT Connection	400152		151		T1	Bit-0	Disable display "Wrong connection"
						Bit-1	Reverse Energy flow direction
						Bit-2	Reverse CT connection

Register settings table

MD Time constant	400153		152		T1		Minutes (0=disabled)
Reserved	400154		153				
Starting total current for PFt & Pat	400155		154		T16		2000 for 20 mA
Starting current for all powers	400156		155		T16		200 for 2 mA
Reserved	400157	400159	156	158			
Temperature unit	400160		159		T1	0	°C
						1	°F
Reserved	400161	400167	160	166			
Starting voltage for SYNC.	400168		167		T1		5000 for 5 V (for R30015 = 500 V)
Reserved	400168	400169	168	169			
Comm. average interval	400171		170		T1	0	1 period (0.02 s @50 Hz) default
						1	2 periods (0.04 s @50 Hz)
						2	4 periods (0.08 s @50 Hz)
						3	8 periods (0.16 s @50 Hz)
						4	16 periods (0.32 s @50 Hz)
						5	32 periods (0.64 s @50 Hz)
						6	64 periods (1.28 s @50 Hz) default
						7	128 periods (2.56 s @50 Hz)
						8	256 periods (5.12 s @50 Hz)
Reserved	400172	400201	171	200			
	400189		188		T1	0	Disabled
						1	Enabled
COMMUNICATION							
Res. for Port 1: Device Address (DNP3)	400201		200				
Port 1: Device Address (Modbus)	400203		202		T1		
Port 1: Baud Rate	400204		203		T1	0	Baud rate 1200
						1	Baud rate 2400
						2	Baud rate 4800
						3	Baud rate 9600
						4	Baud rate 19200
						5	Baud rate 38400
						6	Baud rate 57600
						7	Baud rate 115200
Port 1: Stop Bit	400205		204		T1	0	1 Stop bit
						1	2 Stop bits
Port 1: Parity	400206		205		T1	0	No parity
						1	Odd parity
						2	Even parity
Port 1: Data Bits	400207		206		T1	0	8 bits
						1	7 bits
Reserved	400208	400400	207	399			

Register settings table

Parameter	PLC Address Start	PLC Address End	Modbus reading Address Start	Modbus reading Address End	Type	Ind	Values/dependencies
ENERGY							
Active Tariff	400402		401		T1	0	Tariff input (Tariff 1, if input not available)
						1..4	Tariff 1..4
Common Energy Counter Exponent	400402		402		T2		
Reserved	400404	400420	403	419			
Reactive power calculation	400421		420		T1	0	Standard calculation (Q2=S2-P2)
						1	Delayed Current method
Energy Counter 1 Parameter	400422		421		T1	0	No Parameter
						1	Active Power
						2	Reactive Power
						3	Apparent Power
						5	Active Power Phase 1
						6	Reactive Power Phase 1
						7	Apparent Power Phase 1
						9	Active Power Phase 2
						10	Reactive Power Phase 2
						11	Apparent Power Phase 2
						13	Active Power Phase 3
						14	Reactive Power Phase 3
						15	Apparent Power Phase 3
						16	Pulse input 1 (reg.40402 not used)
						17	Pulse input 2 (reg.40402 not used)
						18	Pulse input 3 (reg.40402 not used)
						19	Pulse input 4 (reg.40402 not used)
Energy Counter 1 Configuration	400423		422		T1	Bit-0	Quadrant I Enabled
						Bit-1	Quadrant II Enabled
						Bit-2	Quadrant III Enabled
						Bit-3	Quadrant IIII Enabled
						Bit-4	Absolute Value
						Bit-5	Invert Value
Energy Counter 1 Divider	400424		423		T1	0	1
						1	10
						2	100
						3	1000
						4	10000
Energy Counter 1 Tarif Selector	400425		424		T1	Bit-0	Tarif 1 Enabled
						Bit-1	Tarif 2 Enabled
						Bit-2	Tarif 3 Enabled
						Bit-3	Tarif 4 Enabled
Reserved	400426	400431	425	430			
Energy Counter 2 Parameter	400432		431		T1		see Energy Counter 1 Param.
Energy Counter 2 Configuration	400433		432		T1		see Energy Counter 1 Config.
Energy Counter 2 Divider	400434		433		T1		see Energy Counter 1 Divider
Energy Counter 2 Tarif Selector	400435		434		T1		see Energy Counter 1 Tarif Selector
Reserved	400436	400441	435	440			
Energy Counter 3 Parameter	400442		441		T1		see Energy Counter 1 Param.
Energy Counter 3 Configuration	400443		442		T1		see Energy Counter 1 Config.
Energy Counter 3 Divider	400444		443		T1		see Energy Counter 1 Divider
Energy Counter 3 Tarif Selector	400445		444		T1		see Energy Counter 1 Tarif Selector
Reserved	400446	400451	445	450			
Energy Counter 4 Parameter	400452		451		T1		see Energy Counter 1 Param.
Energy Counter 4 Configuration	400453		452		T1		see Energy Counter 1 Config.
Energy Counter 4 Divider	400454		453		T1		see Energy Counter 1 Divider
Energy Counter 4 Tarif Selector	400455		454		T1		see Energy Counter 1 Tarif Selector
Reserved	400456	400700	455	699			

Register settings table

INPUTS/OUTPUTS							
Start-up output delay	400701		700		T1		Seconds
PULSE OUTPUTS							
Pulse Output 1 Energy Counter	400702		701		T1	0	Alarm output
						1	Counter 1
						2	Counter 2
						3	Counter 3
						4	Counter 4
Pulse Output 1 No. Of pulses	400703		702		T1		
Pulse Output 1 Energy unit	400704		703		T1		* 10^(Common Energy Counter Exponent)
Pulse Output 1 Pulse length	400705		704		T1		ms
Pulse Output 1 Tariff Selector	400706		705		T1	Bit-0	Tarif 1 enabled
						Bit-1	Tarif 2 enabled
						Bit-2	Tarif 3 enabled
						Bit-3	Tarif 4 enabled
Pulse Output 2 Energy Counter	400707		706		T1		
Pulse Output 2 No. Of pulses	400708		707		T1		
Pulse Output 2 Energy unit	400709		708		T1		* 10^(Common Energy Counter Exponent)
Pulse Output 2 Pulse length	400710		709		T1		ms
Pulse Output 2 Tariff Selector	400711		710		T1		
Pulse Output 3 Energy Counter	400712		711		T1		
Pulse Output 3 No. Of pulses	400713		712		T1		
Pulse Output 3 Energy unit	400714		713		T1		* 10^(Common Energy Counter Exponent)
Pulse Output 3 Pulse length	400715		714		T1		ms
Pulse Output 3 Tariff Selector	400716		715		T1		
Pulse Output 4 Energy Counter	400717		716		T1		
Pulse Output 4 No. Of pulses	400718		717		T1		
Pulse Output 4 Energy unit	400719		718		T1		* 10^(Common Energy Counter Exponent)
Pulse Output 4 Pulse length	400720		719		T1		ms
Pulse Output 4 Tariff Selector	400721		720		T1		
PROTECTION OUTPUTS							
PROTECTION OUTPUT 1							
Enabled Alarm groups	400722		721		T1	Bit-4	Protection Output 1
						Bit-5	Protection Output 2
						Bit-6	Protection Output 3
						Bit-7	Protection Output 4
Output signal	400723		722		T1	0	Normal
						1	Permanent
						2	Pulsed
						3	Always ON
						4	Always OFF
						5	Normal inverse
						6	Permanent inverse
						7	Pulsed inverse
Output pulse length	400724		723		T1		Seconds
PROTECTION OUTPUT 2	400725	400727	724	726			See ALARM OUTPUT 1
PROTECTION OUTPUT 3	400728	400730	727	729			See ALARM OUTPUT 1
PROTECTION OUTPUT 4	400731	400733	730	732			See ALARM OUTPUT 1

Register settings table

PROTECTION								
System								
Nominal Voltage (%)	406002		6001		T16		% of VT Primary
Connection mode	406003		6002		T1	0	Phase to neutral
						1	Phase to phase
Nominal Frequency	406004		6003		T1	0	50 Hz
						1	60 Hz
Phase rotation	406005		6004		T1	0	Clockwise
						1	Anticlockwise
Rated Current	406006		6005		T16		% of CT Primary
Rated Active Power	406007		6006		T16		% of VT * CT Primary
Phase Shift monitoring mode	406008		6007		T1	0	1- and 3 phase
						1	3 phase
Reserved	406009	406021	6008	6020			
Overvoltage 1							
Monitoring	406022		6021		T1	0	No
						1	Yes
Parameter limit (%)	406023		6022		T16		% of Nominal Voltage
Compare time delay (s)	406024		6023		T16		
Hysteresis (%)	406025		6024		T16		
Assigned Output	406026		6025		T1	0	None
						1-4	Protection Group 1-4
Reserved	406027	406028	6026	6027			
Overvoltage 2							
Monitoring	406029		6028		T1	0	No
						1	Yes
Parameter limit (%)	406030		6029		T16		% of Nominal Voltage
Compare time delay (s)	406031		6030		T16		
Hysteresis (%)	406032		6031		T16		
Assigned Output	406033		6032		T1	0	None
						1-4	Protection Group 1-4
Reserved	406034	406035	6033	6034			
Undervoltage 1							
Monitoring	406036		6035		T1	0	No
						1	Yes
Parameter limit (%)	406037		6036		T16		% of Nominal Voltage
Compare time delay (s)	406038		6037		T16		
Hysteresis (%)	406039		6038		T16		
Assigned Output	406040		6039		T1	0	None
						1-4	Protection Group 1-4
Reserved	406041	406042	6040	6041			
Undervoltage 2							
Monitoring	406043		6042		T1	0	No
						1	Yes
Parameter limit (%)	406044		6043		T16		% of Nominal Voltage
Compare time delay (s)	406045		6044		T16		
Hysteresis (%)	406046		6045		T16		
Assigned Output	406047		6046		T1	0	None
						1-4	Protection Group 1-4
Reserved	406048	406049	6047	6048			

Overfrequency 1							
Monitoring	406050		6049		T1	0	No
						1	Yes
Parameter limit (%)	406051		6050		T16		% of Nominal Frequency
Compare time delay (s)	406052		6051		T16		
Hysteresis (%)	406053		6052		T16		
Assigned Output	406054		6053		T1	0	None
						1-4	Protection Group 1-4
Reserved	406055	406056	6054	6055			
Overfrequency 2							
Monitoring	406057		6056		T1	0	No
						1	Yes
Parameter limit (%)	406058		6057		T16		% of Nominal Frequency
Compare time delay (s)	406059		6058		T16		
Hysteresis (%)	406060		6059		T16		
Assigned Output	406061		6060		T1	0	None
						1-4	Protection Group 1-4
Reserved	406062	406061	6061	6062			
Underfrequency 1							
Monitoring	406064		6063		T1	0	No
						1	Yes
Parameter limit (%)	406065		6064		T16		% of Nominal Frequency
Compare time delay (s)	406066		6065		T16		
Hysteresis (%)	406067		6066		T16		
Assigned Output	406068		6067		T1	0	None
						1-4	Protection Group 1-4
Reserved	406069	406070	6068	6069			
Underfrequency 2							
Monitoring	406071		6070		T1	0	No
						1	Yes
Parameter limit (%)	406072		6071		T16		% of Nominal Frequency
Compare time delay (s)	406073		6072		T16		
Hysteresis (%)	406074		6073		T16		
Assigned Output	406075		6074		T1	0	None
						1-4	Protection Group 1-4
Reserved	406076	406077	6075	6076			

Directional power 1							
Monitoring	406078		6077		T1	0	No
						1	Yes
Parameter limit (%)	406079		6078		T17		% of Rated Active Power
Compare time delay (s)	406080		6079		T16		
Hysteresis (%)	406081		6080		T16		
Assigned Output	406082		6081		T1	0	None
						1-4	Protection Group 1-4
Reserved	406083	406084	6082	6083			
Directional power 2							
Monitoring	406085		6084		T1	0	No
						1	Yes
Parameter limit (%)	406086		6085		T17		% of Rated Active Power
Compare time delay (s)	406087		6086		T16		
Hysteresis (%)	406088		6087		T16		
Assigned Output	406089		6088		T1	0	None
						1-4	Protection Group 1-4
Reserved	406090	406091	6089	6090			
Power underrun 1							
Monitoring	406092		6091		T1	0	No
						1	Yes
Parameter limit (%)	406093		6092		T17		% of Rated Active Power
Compare time delay (s)	406094		6093		T16		
Hysteresis (%)	406095		6094		T16		
Assigned Output	406096		6095		T1	0	None
						1-4	Protection Group 1-4
Reserved	406097	406098	6096	6097			
Power underrun 2							
Monitoring	406099		6098		T1	0	No
						1	Yes
Parameter limit (%)	406100		6099		T17		% of Rated Active Power
Compare time delay (s)	406101		6100		T16		
Hysteresis (%)	406102		6101		T16		
Assigned Output	406103		6102		T1	0	None
						1-4	Protection Group 1-4
Reserved	406104	406105	6103	6104			

Voltage unbalances							
Monitoring	406106		6105		T1	0	No
						1	Yes
Parameter limit (%)	406107		6106		T16		%
Compare time delay (s)	406108		6107		T16		
Hysteresis (%)	406109		6108		T16		
Assigned Output	406110		6109		T1	0	None
						1-4	Protection Group 1-4
Reserved	406111	406112	6110	6111			
Phase imbalance 1							
Monitoring	406113		6112		T1	0	No
						1	Yes
Parameter limit (%)	406114		6113		T16		% of Rated Current
Compare time delay (s)	406115		6114		T16		
Hysteresis (%)	406116		6115		T16		
Assigned Output	406117		6116		T1	0	None
						1-4	Protection Group 1-4
Reserved	406118	406119	6117	6118			
Phase imbalance 2							
Monitoring	406120		6119		T1	0	No
						1	Yes
Parameter limit (%)	406121		6120		T16		% of Rated Current
Compare time delay (s)	406122		6121		T16		
Hysteresis (%)	406123		6122		T16		
Assigned Output	406124		6123		T1	0	None
						1-4	Protection Group 1-4
Reserved	406125	406126	6124	6125			
Phase shift							
Monitoring	406127		6126		T1	0	No
						1	Yes
Parameter limit 1 phase (°)	406128		6127		T16		Degrees
Parameter limit 3 phase (°)	406129		6128		T16		Degrees
Reserved Hysteresis (%)	406130		6129		T16		
Assigned Output	406131		6130		T1	0	None
						1-4	Protection Group 1-4
Reserved	406132	406133	6131	6132			
LoM - ROCOF							
Monitoring	406134		6133		T1	0	No
						1	Yes
Parameter limit (Hz/s)	406135		6134		T16		Hz/s
Compare time delay (s)	406136		6135		T16		
Hysteresis (%)	406137		6136		T16		
Assigned Output	406138		6137		T1	0	None
						1-4	Protection Group 1-4
Reserved	406139	406140	6138	6139			

Over-current 1								
Monitoring	406141		6140		T1	0	No
						1	Yes
Parameter limit (%)	406142		6141		T19		% of Rated Current
Compare time delay (s)	406143		6142		T16		
Hysteresis (%)	406144		6143		T16		
Assigned Output	406145		6144		T1	0	None
						1-4	Protection Group 1-4
Reserved	406146	406147	6145	6146			
Over-current 2							
Monitoring	406148		6147		T1	0	No
						1	Yes
Parameter limit (%)	406149		6148		T19		% of Rated Current
Compare time delay (s)	406150		6149		T16		
Hysteresis (%)	406151		6150		T16		
Assigned Output	406152		6151		T1	0	None
						1-4	Protection Group 1-4
Reserved	406153	406154	6152	6153			
Over-current IE 1							
Monitoring	406155		6154		T1	0	No
						1	Yes
Parameter limit (%)	406156		6155		T17		% of Rated Current
Compare time delay (s)	406157		6156		T16		
Hysteresis (%)	406158		6157		T16		
Assigned Output	406159		6158		T1	0	None
						1-4	Protection Group 1-4
Reserved	406160	406161	6159	6160			
Over-current IE 2							
Monitoring	406162		6161		T1	0	No
						1	Yes
Parameter limit (%)	406163		6162		T17		% of Rated Current
Compare time delay (s)	406164		6163		T16		
Hysteresis (%)	406165		6164		T16		
Assigned Output	406166		6165		T1	0	None
						1-4	Protection Group 1-4
Reserved	406167	406168	6166	6167			
Over-current Idiff 1							
Monitoring	406169		6168		T1	0	No
						1	Yes
Parameter limit (%)	406170		6169		T17		% of Rated Current
Compare time delay (s)	406171		6170		T16		
Hysteresis (%)	406172		6171		T16		
Assigned Output	406173		6172		T1	0	None
						1-4	Protection Group 1-4
Reserved	406174	406175	6173	6174			
Over-current Idiff 2							
Monitoring	406176		6175		T1	0	No
						1	Yes
Parameter limit (%)	406177		6176		T17		% of Rated Current
Compare time delay (s)	406178		6177		T16		
Hysteresis (%)	406179		6178		T16		
Assigned Output	406180		6179		T1	0	None
						1-4	Protection Group 1-4
Reserved	406181	406182	6180	6181			

All other Modbus registers are subject to changes. For the latest Modbus register definitions, go to DEIF's web page www.deif.com

100 % values calculations for normalised measurements

Un =	(R40147 / R40146) * R30015 * R40149
In =	(R40145 / R40144) * R30017 * R40148
Pn =	Un * In
It =	In
It =	3 * In
Pt =	Pn
Pt =	3 * Pn
Fn =	R40150

Parameter	Modbus		Values/dependencies
	Register	Type	
Calibration voltage	30015	T4	mV
Calibration current	30017	T4	mA

Register table for the basic settings

Register	Content	Type	Ind	Values/dependencies	Min.	Max.	P. level
40143	Connection Mode	T1	0	No mode	1	5	2
			1	1b - Single Phase			
			2	3b - 3 phase 3 wire balanced			
			3	4b - 3 phase 4 wire balanced			
			4	3u - 3 phase 3 wire unbalanced			
			5	4u - 3 phase 4 wire unbalanced			
40144	CT Secondary	T4		mA			2
40145	CT Primary	T4		A/10			2
40146	VT Secondary	T4		mV			2
40147	VT Primary	T4		V/10			2
40148	Current input range (%)	T16		10000 for 100%	5.00	200.00	2
40149	Voltage input range (%)	T16		10000 for 100%	2.50	100.00	2
40150	Frequency nominal value	T1		Hz	10	1000	2

Example of calculation using Modbus registers and their data types:

CT primary = R40145 (Type T4) = 10^2 × 40 = **8028**$_{(16)}$ –> **4000 A/10 = 400 A**
CT secondary = R40144 (Type T4) = 10^2 × 50 = **8032**$_{(16)}$ –> **5000 mA**
Cal. current = R30017 (Type T4) = 10^2 × 50 = **8032**$_{(16)}$ –> **5000 mA**
Input range = R40148 (Type T16) = 10000 = **2710**$_{(16)}$ –> **100.00 %**

In = (R40145 / R40144) * R30017 * R40148 = (400 / 5) * 5A * 100% = 400A

Data types decoding

Type	Bit mask	Description
T1		Unsigned Value (16 bit) Example: 12345 = 3039(16)
T2		Signed Value (16 bit) Example: -12345 = CFC7(16)
T3		Signed Long Value (32 bit) Example: 123456789 = 075B CD 15(16)
T4	bits # 15…14 bits # 13…00	Short Unsigned float (16 bit) Decade Exponent(Unsigned 2 bit) Binary Unsigned Value (14 bit) Example: 10000*102 = A710(16)
T5	bits # 31…24 bits # 23…00	Unsigned Measurement (32 bit) Decade Exponent(Signed 8 bit) Binary Unsigned Value (24 bit) Example: 123456*10-3 = FD01 E240(16)
T6	bits # 31…24 bits # 23…00	Signed Measurement (32 bit) Decade Exponent (Signed 8 bit) Binary Signed value (24 bit) Example: - 123456*10-3 = FDFE 1DC0(16)
T7	bits # 31…24 bits # 23…16 bits # 15…00	Power Factor (32 bit) Sign: Import/Export (00/FF) Sign: Inductive/Capacitive (00/FF) Unsigned Value (16 bit), 4 decimal places Example: 0.9876 CAP = 00FF 2694(16)
T9	bits # 31…24 bits # 23…16 bits # 15…08 bits # 07…00	Time (32 bit) 1/100s 00 - 99 (BCD) Seconds 00 - 59 (BCD) Minutes 00 - 59 (BCD) Hours 00 - 24 (BCD) Example: 15:42:03.75 = 7503 4215(16)
T10	bits # 31…24 bits # 23…16 bits # 15…00	Date (32 bit) Day of month 01 - 31 (BCD) Month of year 01 - 12 (BCD) Year (unsigned integer) 1998..4095 Example: 10, SEP 2000 = 1009 07D0(16)
T16		Unsigned Value (16 bit), 2 decimal places Example: 123.45 = 3039(16)
T17		Signed Value (16 bit), 2 decimal places Example: -123.45 = CFC7(16)
T19		Unsigned Value (16 bit), 1 decimal place Example: 1234.5 stored as 12345 = 3039(16)
T_Str4		Text: 4 characters (2 characters for 16 bit register)
T_Str6		Text: 6 characters (2 characters for 16 bit register)
T_Str8		Text: 8 characters (2 characters for 16 bit register)
T_Str16		Text: 16 characters (2 characters for 16 bit register)
T_Str40		Text: 40 characters (2 characters for 16 bit register)

APPENDIX B

Equations

Definition of symbols:

No.	Symbol	Definition
1	MP	Average interval
2	Uf	Phase voltage (U1, U2 or U3)
3	Uff	Phase-to-phase voltage (U12, U23 or U31)
4	N	Total number of samples in a period
5	n	Sample number ($0 \le n \le N$)
6	x, y	Phase number (1, 2 or 3)
7	in	Current sample n
8	ufn	Phase voltage sample n
9	ufFn	Phase-to-phase voltage sample n
10	ϕ_f	Power angle between current and phase voltage f (ϕ_1, ϕ_2 or ϕ_3)
11	Uu	Voltage unbalance
12	Uc	Agreed supply voltage

Voltage

$$U_f = \sqrt{\frac{\sum_{n=1}^{N} u_n^2}{N}}$$	**Phase voltage** N − samples in averaging interval (up to 65 Hz)
$$U_{xy} = \sqrt{\frac{\sum_{n=1}^{N} \left(u_{xn} - u_{yn}\right)^2}{N}}$$	**Phase-to-phase voltage** u_x, u_y − phase voltages (U_f) N − a number of samples in averaging interval
$$U_u = \sqrt{\frac{1-\sqrt{3-6\beta}}{1+\sqrt{3-6\beta}}} \cdot 100\%$$ $$\beta = \frac{U_{12fund}^4 + U_{23fund}^4 + U_{31fund}^4}{\left(U_{12fund}^2 + U_{23fund}^2 + U_{31fund}^2\right)^2}$$	**Voltage unbalance** U_{fund} − first harmonic of phase-to-phase voltage

Current

$$I_{RMS} = \sqrt{\frac{\sum_{n=1}^{N} i_n^2}{N}}$$	**Phase current** N − samples in averaging interval (up to 65 Hz)
$$I_n = \sqrt{\frac{\sum_{n=1}^{N} \left(i_{1n} + i_{2n} + i_{3n}\right)^2}{N}}$$	**Neutral current** i − n sample of phase current (1, 2 or 3) N − samples in averaging interval (up to 65 Hz)

Power

$P_f = \frac{1}{N} \cdot \sum_{n=1}^{N} (u_{fn} \cdot i_{fn})$	**Active power by phases** N − a number of periods n − index of samples in a period f − phase designation
$P_t = P_1 + P_2 + P_3$	**Total active power** t − total power 1, 2, 3 − phase designation
$\mathrm{SignQ}_f(\varphi)$ $\varphi \in [0° - 180°] \Rightarrow \mathrm{SignQ}_f(\varphi) = +1$ $\varphi \in [180° - 360°] \Rightarrow \mathrm{SignQ}_f(\varphi) = -1$	**Reactive power sign** Q_f − reactive power (by phases) φ − power angle
$S_f = U_f \cdot I_f$	**Apparent power by phases** U_f − phase voltage I_f − phase current
$S_t = S_1 + S_2 + S_3$	**Total apparent power** S_t − apparent power by phases
$Q_f = \mathrm{SignQ}_f(\varphi) \cdot \sqrt{S_f^2 - P_f^2}$	**Reactive power by phases** S_f − apparent power by phases P_f − active power by phases
$Q_f = \frac{1}{N} \cdot \sum_{n=1}^{N} \left(u_{f\,n} \times i_{f\,[n+N/4]} \right)$	**Reactive power by phases (displacement method)** N − a number of samples in a period n − sample number (0 ≤ n ≤ N) f − phase designation
$Q_t = Q_1 + Q_2 + Q_3$	**Total reactive power** Q_t − reactive power by phases
$D = \sqrt{S^2 - P^2 - Q_{fund}^2}$	**Distortion power** S – apparent power P – active power Q_{fund} – fundamental reactive power
$\varphi_s = \arctan 2(P_t, Q_t)$ $\varphi_s = [-180°, 179{,}99°]$	**Total power angle** P_t − total active power Q_t − total reactive power
$PF = \frac{\lvert P \rvert}{S}$	**Distortion power factor** P − active power S − apparent power

THD, TDD

$$I_f THD(\%) = \frac{\sqrt{\sum_{n=2}^{63} I_n^{\ 2}}}{I_1} \cdot 100$$	**Current THD** I_1 − value of first harmonic n − number of harmonic
$$U_f THD(\%) = \frac{\sqrt{\sum_{n=2}^{63} U_{fn}^{\ 2}}}{U_{f1}} \cdot 100$$	**Phase voltage THD** U_1 − value of first harmonic n − number of harmonic
$$U_{ff} THD(\%) = \frac{\sqrt{\sum_{n=2}^{63} U_{ffn}^{\ 2}}}{U_{ff1}} \cdot 100$$	**Phase-to-phase voltage THD** U_1 − value of first harmonic n − number of harmonic

Energy

$\text{Price in tariff} = \text{Price} \cdot 10^{\text{Tarif price exponent}}$	Total exponent of tariff price and energy price in all tariffs