⊗**Iskra**®

User 's Manual

EN

Multifunction Transducer iMT440

Contents

iMT440 MEASURING TRANSDUCER

SECURITY ADVICE AND WARNINGS

Please read this chapter carefully and examine the equipment carefully for potential damages which might arise during transport and to become familiar with it before continue to install, energize and work with a measuring instrument.

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

Everyone using the product should become familiar with the contents of chapter »Security Advices and Warnings«.

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

⚠ **PLEASE NOTE**

ISKRA d.o.o. assumes no responsibility in connection with installation. This booklet contains instructions for installation and use of measuring instrument. Installation and use of a device also includes handling with dangerous currents and voltages therefore should be installed, operated, serviced and maintained by qualified persons only. If there is any doubt regarding installation and use of the system in which the device is used for measuring or supervision, please contact a person who is responsible for installation of such system.

Warnings, information and notes regarding designation of the product

Used symbols:

⚠	See product documentation.
▣	Double insulation in compliance with the EN 61010−1 standard.
⏚	Functional ground potential. Note: This symbol is also used for marking 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.
CE	Compliance of the product with European CE directives.
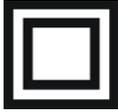
Before switching the device on

Check the following before switching on the device:
- Nominal voltage,
- Supply voltage,
- Nominal frequency,
- Voltage ratio and phase sequence,
- Current transformer ratio and terminals integrity,
- Protection fuse for voltage inputs (recommended maximal external fuse size is 6 A),
- Proper connection and voltage level of I/O modules.

Important: A current transformer secondary should be short circuited before connecting the device.

⚠ **WARNING**

A current transformer secondary should be short circuited before connecting the transducer.

Device switch-of 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 having completely disconnected auxiliary supply (both poles of any DC supply).

Disposal

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

BASIC DESCRIPTION AND OPERATION

The following chapter presents basic information about measuring transducers, required to understand its purpose, applicability and basic features connected to its operation.

Besides that, this chapter contains navigational tips, description of used symbols and other useful information for understandable navigation through this manual.

Regarding the options of a measuring transducer, different chapters should be considered since it might vary in functionality and design. More detailed description of device functions is given in chapter Main Features, supported options and functionality.

Measuring instrument is available in housing for DIN rail mounting. Specifications of housing and DIN rail type are specified in chapter Dimensions.

Contents

Contents and size of a packaging box can slightly vary depending on type of consignment.

Single device shipment or a very small quantity of devices is shipped in a larger cardboard box, which offers better physical protection during transport.

This type of contents contains:

- Measuring instrument
- Fixation screws
- CD with full version of this document, installation of setting software MiQen, required drivers for -USB (if device is equipped with USB communication)
- Short installation manual

When larger amount of devices is sent they are shipped in a smaller cardboard box for saving space and thus reducing shipment costs. This type of contents contains:

- Measuring instrument
- Fixation screws
- Short installation manual

This document and settings software MiQen can also be found on our web page www.iskra.eu.

ⓘ CAUTION

Please examine the equipment carefully for potential damages which might arise during transport!

Description

Measuring transducer is intended for measuring, analysing and monitoring single-phase or three-phase electrical power network. It measures RMS value by means of fast sampling of voltage and current signals, which makes instrument suitable for acquisition of transient events.

Appearance

Measuring transducer can differ from yours depending on the type and functionality.

iMT440

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

Communication ports and LED indicators

Serial communication can be connected by using screw-in connector (RS232 or RS485). USB can be connected through USB-mini type connector at the bottom of transducer.
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 unconnected to aux. supply AND power inputs!

I/O modules

Four I/O module slots are intended for various I/O modules, which should be chosen at placing the order. Analogue outputs, fast analogue outputs, relay outputs (alarm, general-purpose digital outputs) and solid-state relay outputs (alarm, general-purpose digital outputs).

Universal auxiliary supply

Auxiliary supply is connected by two screw-in connectors. For safety purposes it is important that all wires are firmly fastened. Auxiliary supply is wide range (20 VDC – 300 VDC; 48 VAC – 276 VAC).

Voltage inputs

Each voltage input is connected to measuring circuit through 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 measuring circuit through 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. Most common abbreviations and expressions are explained in the following table:

Term	Explanation
RMS	Root Mean Square value
MODBUS	Industrial protocol for data transmission
MiQen	Setting Software for ISKRA d.o.o. instruments
AC	Alternating voltage
PA total	Angle calculated from total active and apparent power
PA1, PA2, PA3	Angle between fundamental phase voltage and phase current
PF	Power factor
THD	Total harmonic distortion
MD	Measurement of average values in time interval
M_v – 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.
PO	Pulse output module
RO	Relay output module
AL	Alarm output module
AO	Analogue output module
FAO	Fast analogue output module
DO	Digital output module

List of common abbreviations and expressions

Purpose and use of different type of measuring transducer

⚠ **PLEASE NOTE**

Described in chapter below are main differences between different types of measuring transducers. Please note that in flowing chapters, these differences may not be specifically pointed out.

Multifunctional transducer iMT440

iMT440 Multifunctional transducer is intended for measuring and monitoring single-phase or three-phase electrical power network. iMT440 measures true RMS value by means of fast sampling of voltage and current signals, which makes instruments suitable for acquisition of transient events. A built-in microcontroller calculates measurements (voltage, current, frequency, energy, power, power factor, THD phase angles, etc.) from the measured signals.

Type differences

Different types differ on functionality and equipment as shown in the following table.

Differences in hardware

Feature		iMT440
Real time clock (RTC) with battery		●
Communication interface USB / USB + RS232 / USB + RS485		●/○/○
I/O 1	AO / FAO / PO / RO	○/○/○/○
I/O 2	AO / FAO / PO / RO	○/○/○/○
I/O 3	AO / FAO / PO / RO	○/○/○/○
I/O 4	AO / FAO / PO / RO	○/○/○/○
Automatic voltage / current range		●/●
Universal power supply		○
Fixed AC power supply 63.5 / 110 / 230 / 240 / 400 V		○/○/○/○/○

● – serial   ○ – option   × – not supported

AO-analogue out, FAO-fast analogue out, PO-pulse out, RO-relay out

Software functions

Functions	iMT440
MODBUS protocol	●
Programmable alarms	32
Alarms recording	×
Measurements recording	×

● – serial   × – not supported

Supported measurements

	Basic measurements	iMT440
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 $\phi^\sim$	●
	THD of phase voltage U_{f1}, U_{f2} and U_{f3}	●
	THD of power angle I_1, I_2 and I_3	●
	Voltage harmonics 1 - 31	●
	Current harmonics 1 - 31	●
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	●
	Harmonics in phase-to-phase voltage 1 - 31	●
Energy	Counter 1	●
	Counter 2	●
	Counter 3	●
	Counter 4	●
	Active tariff	●
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	●
	Other measurements	
Measurement	Frequency	●
	Internal temperature	●

● – serial   × – not supported

CONNECTION

This chapter deals with the instructions for measuring instrument connection. Both the use and connection of the device includes handling with dangerous currents and voltages. Connection shall therefore be performed ONLY a by a qualified person using an appropriate equipment. *ISKRA d.o.o.* does not take any responsibility regarding the use and connection. If any doubt occurs regarding connection and use in the system which device is intended for, please contact a person who is responsible for such installations.

A person qualified for installation and connection of a device should be familiar with all necessary precaution measures described in this document prior to its connection.

Before use please check the following:
- Nominal voltage (U_{P-Pmax} = 1000 V_{ACrms}; U_{P-Nmax} = 600 V_{ACrms}),
- Supply voltage,
- Nominal frequency,
- Voltage ratio and phase sequence,
- Current transformer ratio and terminals integrity,
- Protection fuse for voltage inputs (recommended maximal external fuse size is 6 A),
- 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 short period of time (<1 ms). Please choose an appropriate MCB for disconnection of aux. Supply.

⚠ PLEASE NOTE
After connection, settings have to be performed via communication (connection mode, current and voltage transformers ratio …).

Mounting

iMT4xx measuring transducer is designed for DIN rail mounting. It should be mounted on a 35 mm DIN rail by means of two plastic fasteners. Before installation fasteners should be in open position (pulled). After device is on place, fasteners are locked (pushed) to close position.
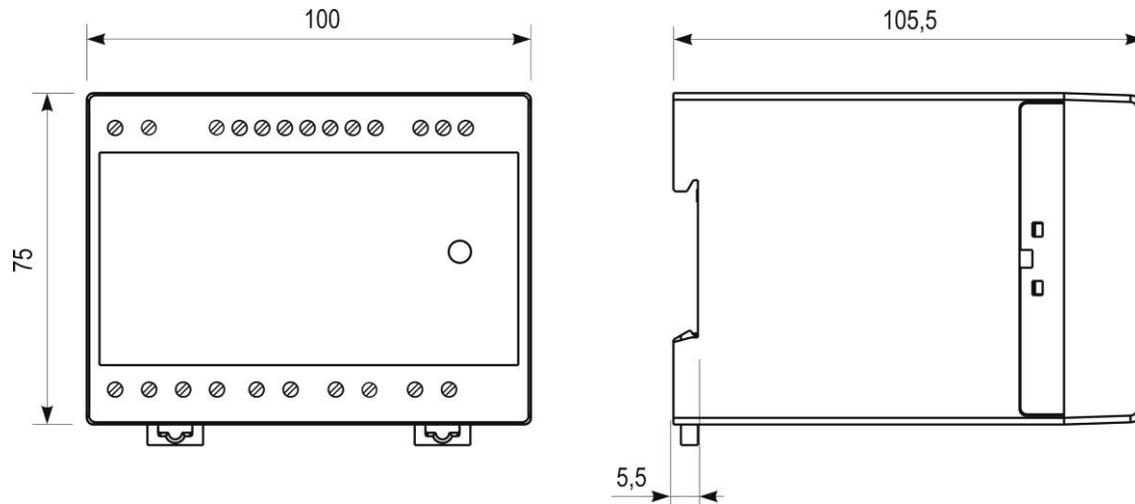
Electrical connection

Voltage inputs of measuring transducer can be connected directly to low-voltage network or via appropriate voltage measuring transformer to medium or high voltage network.

Current inputs of measuring transducer can be connected directly to 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 characteristics is given in chapter Inputs page 366.

⚠ **WARNING**

Before using tool for accessing interior or any other part of the transducer which in normal use may be hazardous live (aux. supply and measuring input terminals), transducer MUST BE ISOLATED OR DISCONNECTED from hazardous live voltage.

⚠ **PLEASE NOTE**

For proper connection wire diameters and other wiring requirements see chapter Connection.

Multifunctional transducer iMT440

System/connection	Terminal assignment
Connection 1b (1W) Single phase connection	
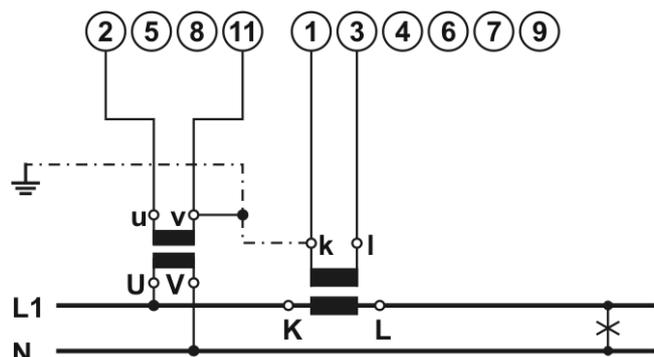
System/connection	Terminal assignment
Connection 3b (1W3b) Three phase, three wire connection with balanced load	
Connection 3u (2W3u) Three phase, three wire connection with unbalanced load	
Connection 4b (1W4b) Three phase, four wire connection with balanced load	
Connection 4u (3W4u) Three phase, four wire connection with unbalanced load	
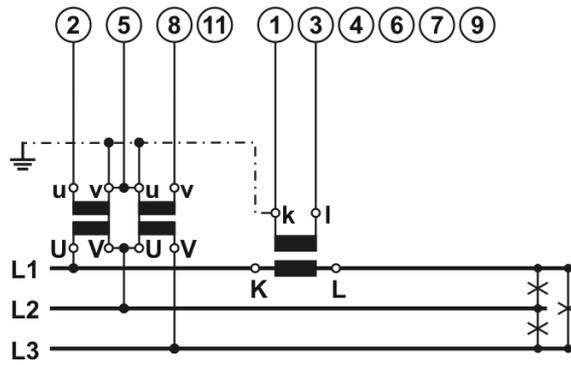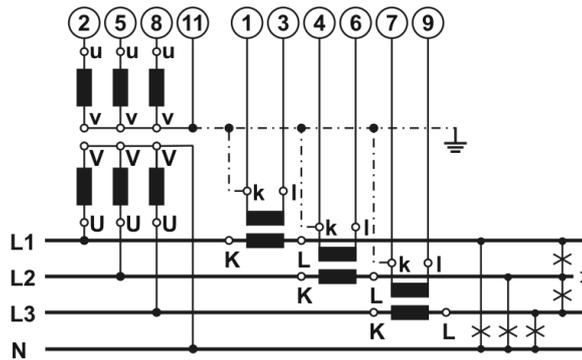
Connection of input/output modules

⚠ WARNING

Check the module features that are specified on the label, before connecting module contacts. Wrong connection can cause damage or destruction of module and/or device.

Connect module contacts as specified on the label. Examples of labels are given below and describe modules built in the device. Information on electrical properties of modules is given in chapter Modules.

Label	Description
I/O 1 — Relay output, 48 V DC/AC, 1000 mA, +/I 15, −/I 16	Electromechanical relay output module. (Example of alarm module as I/O module 1)
I/O 1 — Solid-state output, 40 V DC/AC, 30 mA, +/I 15, −/I 16	Solid-state relay module output. (Example of pulse module as I/O module 1)
I/O 1 — Analogue output, −20...0...20 mA + 15, −10...0...10 V − 16	Analogue output module with analogue output, proportional to measured quantities. The outputs may be either short or open-circuited. They are electrically insulated from each other and from all other circuits. (Example of analogue output module as I/O module 1)
I/O 1 — Fast analogue output, −20...0...20 mA + 15, −10...0...10 V − 16	Fast analogue output module with analogue output, proportional to measured quantities. The outputs may be either short or open-circuited. They are electrically insulated from each other and from all other circuits. (Example of analogue output module as I/O module 1)

Communication connection

Both voltage and current transducers have one isolated communication port, which can be equipped with RS232 or RS485 or left open (to be specified with order). Additionally, iMT4xx measuring transducer has a USB communication port, located on the bottom under small circular plastic cover. It is intended for settings ONLY and requires NO auxiliary power supply. When connected to this communication port transducer is powered by USB.

⚠ WARNING

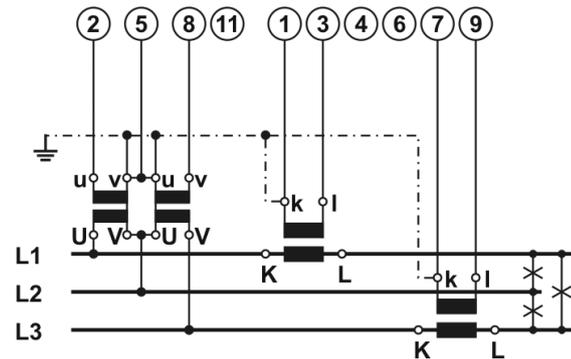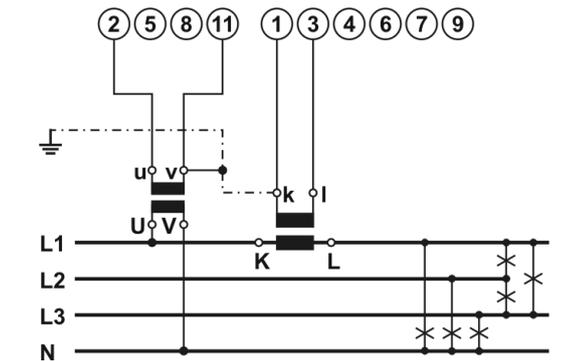USB communication port is provided with only BASIC insulation and can ONLY be used unconnected to aux. supply and power inputs!

Connect a communication line by means of corresponding terminals. Connection information is stated on the instrument label. Connector terminals are marked on the label on the upper side of the instrument.
USB connector is positioned on the bottom side of an instrument under removable plastic cover. For driver installation see Note on the next page. Instrument will establish USB connection with PC approx. 3 seconds after physical connection to USB port.
More detailed information about communication is given in chapter Communication.

Label	Description
COM — RS232, Rx 23, E 24, Tx 25	COM1 serial communication port (RS232)
COM — RS485, A 23, NC 24, B 25	COM1 serial communication port (RS485)

	SERVICE communication port (USB)

RS232

RS232 communication is intended for direct connection of the Device to the personal computer. For proper operation it is necessary to assure the corresponding connection of individual terminals (see table: Survey of communication connection).

RS485

RS485 communication is intended for connection of multiple devices to a network where devices with RS485 communication are connected to a common communication interface. We suggest using one of the *ISKRA d.o.o.* communication interfaces!

For proper operation it is necessary to assure the corresponding connection of individual terminals (see table: Survey of communication connection).

USB

Additionally, there is a USB communication port, located on the bottom under small circular plastic cover. It is intended for settings ONLY and requires NO auxiliary power supply. When connected to this communication port iMT4xx measuring transducer is powered by USB.

> ⚠ **WARNING**
>
> USB communication port is provided with only BASIC insulation and can ONLY be used unconnected to aux. supply AND power inputs.

> ⚠ **WARNING**
>
> Do not remove USB cover permanently!

The USB port should not remain open. It should be closed immediately after the initial setting through USB port was done and should remain closed during all time of storing & operation. In case the customer has not put the cover on the USB after the initial setting was done, before putting to store, mounting the unit on the DIN rail or the unit operates without USB cover the warranty is void.

Also unit returned back 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.

> ⚠ **PLEASE NOTE**
>
> When iMT4xx is connected to a PC through USB communication for the first time, a user is prompted to install a driver. The driver is automatically installed during MiQen software installation. MiQen software can be downloaded on ISKRA d.o.o. website (www.iskra.eu/download/software). With driver installed, USB is redirected to a serial port, which should be selected when using MiQen software.

Survey of communication connection

Connector	Terminals	Position	RS232	RS485
Screw terminal	25 B / 24 C / 23 A	23	Rx	A
		24	GND	NC
		25	Tx	B
USB-mini B	Mini-USB Type A/B 1 2 3 4 5	Standard USB 2.0 compatible cable recommended (Type mini B plug)		
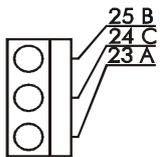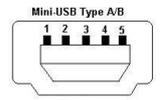
Connection of auxiliary power supply

Measuring transducer can have universal auxiliary power supply or fixed AC power supply. Information on electric consumption is given in chapter Technical data. Auxiliary supply is connected through screw terminal connector.

AUX		
20...300 V DC	+/I	13
48...276 V AC	−/I	14
45...65 Hz		
< 8 VA		

Connection of universal power supply to terminals 13 and 14

> ⚠ **WARNING**
>
> For safety purposes it is important that both wires (Line and Neutral) are firmly connected.

SETTINGS

Instrument settings can be remotely modified with communication (COM1 and/or USB if available) and MiQen software when connected to a PC.

MiQen software

MiQen software is a tool for a complete programming and monitoring of *ISKRA d.o.o.* measuring instruments. Remote operation is possible by means of serial (RS485/RS232) or USB communication (depending on device equipment). A user-friendly interface consists of six segments: Connection, Settings, Measurements, Analysis, My devices and Upgrades. These segments are easily accessed by means of six icons on the left side (see picture below).
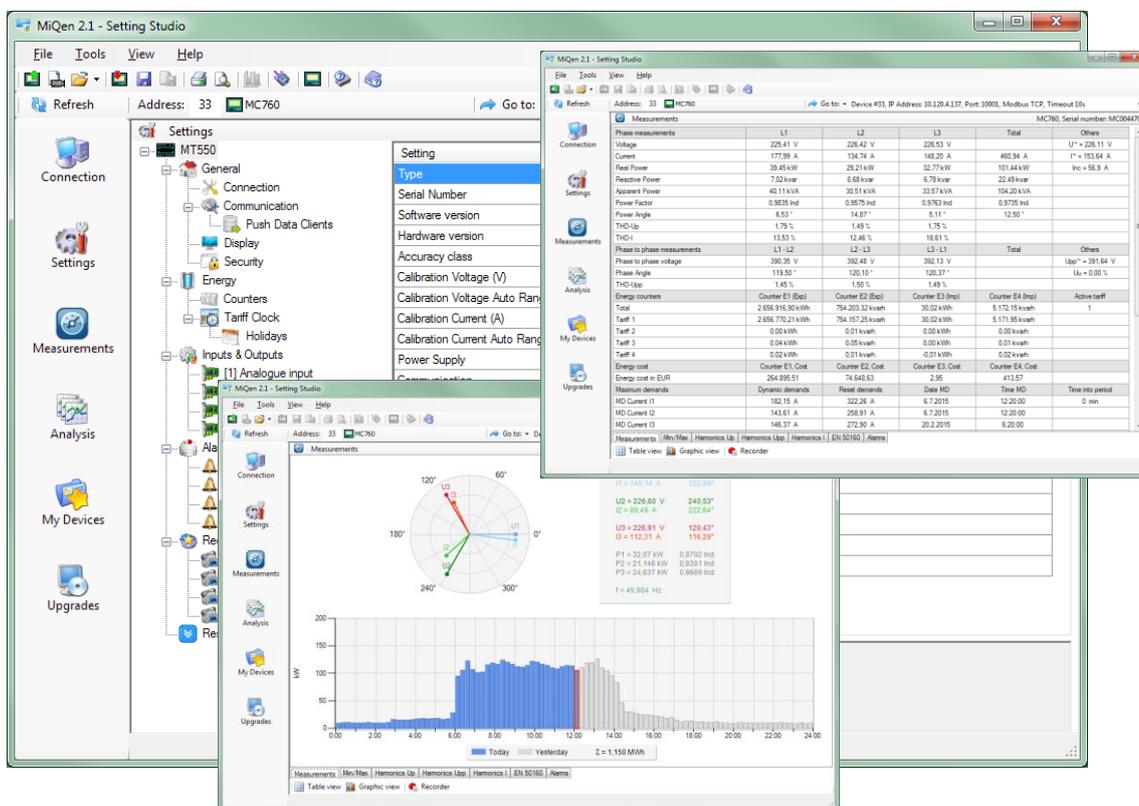
Latest version of MiQen software can be downloaded from *ISKRA d.o.o.* website - www.iskra.eu/download/software.

⚠ **PLEASE NOTE**

MiQen has very intuitive help system. All functions and settings are described in Info window on the bottom of MiQen window. In MiQen Help file, detailed instructions about software usage, connection and communication with different type of devices, driver installation,… are described.

Connection

Select the instrument in a favorite's line. Use the network explorer to set and explore the devices network. Communication parameters of all devices and their addresses in network can be easily set.

Settings

Multi Register Edit technology assures a simple modification of settings that are organized in a tree structure. Besides transferring settings into the instrument, storing and reading from the setting files are also available.

Measurements

All supported measurements can be captured in real time in a table form. For further processing of the results of measurements, copying via a clipboard into standard Windows formats is supported.

Analysis

MiQen enables also analysis of the historical data stored in device internal memory (for devices with built in memory only). In order to perform analysis data source has to be defined first. Data source can be one of the selected.

My Devices

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

Upgrades

In Upgrades section latest software, both for MiQen and *ISKRA d.o.o.* measuring devices can be found. The latest version should always be used to assure full functionality. Manual or automatic checking for upgrades is available. Internet connection is required.

List of available updates is divided in to various sections for easier navigation. Each section is named by software or family of devices (MiQen software, Measuring centres, Measuring transducers...). History file with data about corrections and added functionality is also available.

Setting procedure

A setting structure that is similar to a file structure in an explorer is displayed in the left part of the MiQen setting window. Available settings of that segment are displayed in the right part by clicking any of the stated parameters.

⚠ **PLEASE 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 four additional sublevels (Connection, Communication, Display and Security).

Description & Location

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

Average interval

The averaging interval defines a refresh rate of measurements on display, communication. It is used also as averaging interval for actual alarm value calculation for alarm triggering.
Interval can be set from 8 periods to 256 periods. Default value is 64 periods.

- Shorter average interval means better resolution in minimum and maximum value and faster alarm response. Also data presented in display will refresh faster.
- Longer average interval means lower minimum and maximum value and slower alarm response (alarm response can be delayed also with Compare time delay setting – See chapter Alarms). Also data on display will refresh slower.

Temperature unit

Choose a unit for temperature display. Degrees Celsius or degrees Fahrenheit are available.

Maximum demand calculation (MD mode)

The instrument provides maximum demand values using thermal function. A thermal function assures exponent thermal characteristic based on simulation of bimetal meters. Maximal values are stored in device. A time constant (t. c.) can be set from 1 to 255 minutes and is 6 – time thermal time constant (t. c. = 6 * thermal time constant).

Example:

Mode:	Thermal function
Time constant:	8 min.
Current MD and maximal MD:	Reset at 0 min.

Thermal function

Time [min.]

- - · Present MD   ---·--- MD peak   ⸻ Input
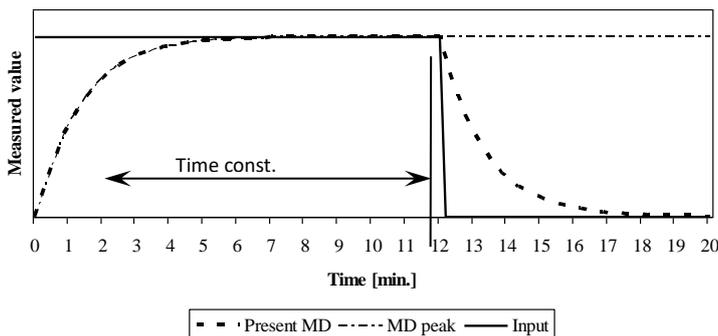
Starting current for PF and PA (mA)

At all measuring inputs noise is usually present. It is constant and its influence on the accuracy is increased by decreasing measuring signals. It is present also when measuring signals are not connected and it occurs at all further calculations as very sporadic measurements. By setting a common starting current, a limit of input signal is defined where measurements and all other calculations are still performed.

Starting current for all powers (mA)

Noise is limited with a starting current also at measurements and calculations of powers.

Starting voltage for sync

Device needs to synchronize its sampling with measuring signals period to accurately determine its frequency. For that purpose, input signal has to large enough to be distinguished from a noise.

If all phase voltages are smaller than this (noise limit) setting, instrument uses current inputs for synchronization. If also all phase currents are smaller than Starting current for PF and PA setting, synchronization is not possible and frequency displayed is 0.

The value for starting voltage should be set according to conditions in a system (level of noise, random voltage fluctuation …).

Harmonics calculation

Relative harmonic values can be different according to used base unit. According to requirements relative harmonics can be calculated as:
percentage of RMS signal value (current, voltage) or
percentage of the fundamental (first harmonic).

Reactive power and energy calculation

Two different principles of reactive power and energy calculation are used
- *Standard method*
  With this method a reactive power and energy are calculated based on assumption that all power (energy) that is not active is reactive.
  $Q^2 = S^2 - P^2$
  This means also that all higher harmonics will be measured as reactive power (energy).
- *Delayed current method*

With this method, reactive power (energy) is calculated by multiplication of voltage samples and delayed current samples (see chapter Appendix B - *Equations*):

$Q = U \times I|_{+90°}$

With this method, reactive power (energy) represents only true reactive component of apparent power (energy).

Connection

ⓘ CAUTION

Settings of connections shall reflect actual state otherwise measurements could not be valid.

Connection mode

When connection is selected, load connection and the supported measurements are defined. (see chapter Survey of supported measurements regarding Connection mode).

Setting of current and voltage ratios

Before setting current and voltage ratios it is necessary to be familiar with the conditions in which device will be used. All other measurements and calculations depend on these settings. Up to five decimal places can be set.

Settings range	VT primary	VT secondary	CT primary	CT secondary
Maximal value	1638,3 kV	13383 V	1638,3 kA	13383 A
Minimal value	0,1 V	1 mV	0,1 A	1 mA

Used voltage/current range (V/A)

Setting of the range is connected with all settings of alarms, analogue outputs and a display (calculation) of energy and measurements recording, where 100% represents 500V, 5A. In case of subsequent change of the range, alarms settings shall be correspondingly changed, as well.

ⓘ CAUTION

In case of subsequent change of those ranges shall be alarm and analogue output settings correspondingly changed as well.

Already recorded values will not be valid after change of used voltage and current range!

Nominal frequency

A valid frequency measurement is within the range of nominal frequency ±32 Hz. This setting is used for alarms.

Energy flow direction

This setting allows manual change of energy flow direction (IMPORT to EXPORT or vice versa) in readings tab. It has no influence on readings sent to communication.

CT connection

If this setting is set to REVERSED it has the same influence as if CT's would be reversely connected. All power readings will also change its sign.

This setting is useful to correct wrong CT connections.

Communication

Communication parameters (COM 1)

iMT4xx has one galvanically separated communication port, which can be equipped with RS232/RS485 or left open (to be specified with order).

Different configurations are possible (to be specified with order):

Configuration	COM 1
WO	USB
RS232	USB + RS232
RS485	USB + RS485

Communication parameters (only for main communication port COM1), which are important for the operation in RS485 network or connections with PC via RS232 communication:

Serial communication	RS232	RS485
Connection type	Direct	Network
Connection terminals	Screw terminals	
Function	Settings, measurements and firmware upgrade	
Insulation	Protection class II, 3.3 kV$_{ACRMS}$, 1 min	
Max. connection length	3 m	1000 m
Transfer mode	Asynchronous	
Protocol	MODBUS RTU	
Transfer rate	2.4 kBaud to 115.2 kBaud	
Default settings	#33 \ 115200 \ N \ 8 \ 2	
Number of bus stations	/	≤ 32

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	

Modbus table

Modbus is enabled via RS232/RS485 or USB. The response is the same type as the request. See chapter Appendix A - Modbus communication protocol.

USB Communication

Additionally, iMT4xx has a USB communication port, located on the bottom under small circular plastic cover. It is intended for settings ONLY and requires NO auxiliary power supply. When connected to this communication port transducer is powered by USB.

Instrument will establish USB connection with PC approx. 3 seconds after physical connection to USB port.

Service USB Communication

Has no setting. Device is automatically recognized in Windows environment if device driver has been correctly installed. Instrument will establish USB connection with PC approx. 3 seconds after physical connection to USB port. For more detailed information how to handle device with USB communication use Help section in MiQen software.

⚠ PLEASE NOTE

Service USB is intended only for parameterisation of the meter and is not galvanic separated. Advantage is that in this case meter does not need a power supply to communicate. Communication via service port is time limited.

⚠ PLEASE NOTE

Service USB communication is not galvanic separated!

When using service USB communication, power supply and measuring voltages need to be disconnected!

Security

Settings parameters are divided into four groups regarding security level: PL0 >password level 0), PL1 >password level 1), PL2 >password level 2) and BP >a backup password).

⚠ PLEASE NOTE

A serial number of device is stated on the label and is also accessible with MiQen software.

Password-Level 0 >PL0)

Password is not required.

Available settings:

- language
- contrast

Password-Level 1 >PL1)

Password for first level is required.

Available settings:

- RTC settings
- Energy meters reset
- Max. Demand reset

Password-Level 2 >PL2)

Password for second level is required.

Available settings:

- All settings are available

A Backup Password->BP)

A backup password >BP) is used if passwords at levels 1 >PL1) and 2 >PL2) have been forgotten, and it is different for each device >depending on a serial number of the device). The BP password is available in the user support department in ISKRA d.o.o. and is entered instead of the password PL1 or/and PL2. Do not forget to state the device serial number when contacting the personnel in ISKRA d.o.o..

Password locks time >min)

Defines the time in minutes for the instrument to activate password protection. Enter 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. When setting a password, only the letter being set is visible while others are hidden.

A password of the first >PL1) and the second >PL2) level is entered, and time of automatic activation is set.

Password modification

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

Password disabling

A password is disabled by setting the "AAAA" password.

⚠ **PLEASE NOTE**

A factory set password is "AAAA" at both access levels >L1 and L2). This password does not limit access.

Energy

⚠ **WARNING**

After modification of energy parameters, the energy meters must be reset otherwise all further energy measurements could be incorrect.

Active tariff

When active tariff is set, one of the tariffs (up to four) is defined as active.

Common energy exponent

Common energy exponent defines minimal 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 in setting a number of impulses for energy of pulse output or alarm output functioning as an energy meter.

Define common energy exponent as recommended in table below, where counter divider is at default value 10. Values of primary voltage and current determine proper Common energy exponent.

Current / Voltage	1 A	5 A	50 A	100 A	1000 A
110 V	−1	0	1	1	2
230 V	0	0	1	2	3
1000 V	0	1	2	3	4
30 kV	2	2	3	4	4*

* − Counter divider should be at least 100

Counter divider

The counter divider additionally defines precision of a certain counter, according to settings of common energy exponent. An example for 12.345kWh of consumed active energy:

Common energy exponent	0	2	2
Counter divider	1	1	100
Example of result, displayed	12.345 kWh	12.3 kWh	0.01 MWh

Inputs and outputs

Module settings depend on built-in modules.

Analogue output module

Each of up to four analogue outputs is fully programmable and can be set to any of 6 full-scale ranges. Within each of those 6 ranges, other required output ranges can be set. For example, 4 … 20 mA range can be set when ± 20 mA full-scale range is selected:
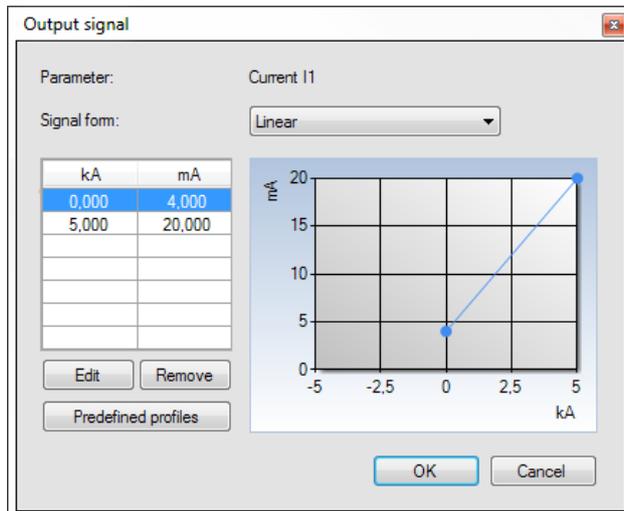
Output parameter

Set the measured parameter to be transformed onto the analogue output.

Output range

Defines analogue output full-scale ranges:

DC current output	DC voltage output
-1 … 0 … 1 mA	-1 … 0 … 1 V
-5 … 0 … 5 mA	
-10 … 0 … 10 mA	-10 … 0 … 10 V
-20 … 0 … 20 mA	

Intrinsic-error (for analogue outputs)

Defines the shape and up to 5 break points of an analogue output. For intrinsic-error for analogue outputs with bent or linear zoom characteristic multiply accuracy class with correction factor (c). Correction factor c (the highest value applies).

Linear characteristic	Bent characteristic
$$c = \frac{1-\frac{y_0}{y_e}}{1-\frac{x_0}{x_e}} \; or \; c = 1$$	$x_{b-1} \leq x \leq x_b$ b – number of break points (1 to 5) $$c = \frac{y_b - y_{b-1}}{x_b - x_{b-1}} \times \frac{x_e}{y_e} \; or \; c = 1$$

Example of settings with linear and bent characteristic:
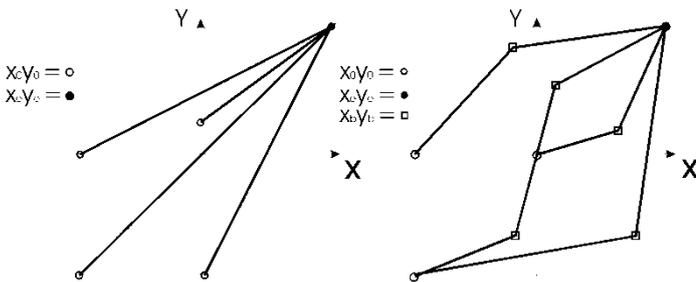
Limit of the output range

Average interval for analogue output

Defines the average interval for measurements on the analogue output. Available settings are from 1 period (0.02 sec by 50 Hz) up to 128 periods (2.56 sec by 50 Hz).

Fast analogue output module

Functionality of fast analogue output module is the same as with standard analogue output module.

The only difference is its faster response time (≤ 60 ms), and consequential higher ripple. For a proper behavior of fast analogue output module (fast response), average interval shall be set to minimum (1 period).

Relay output module

Relay output module as well as Solid state output module can be assigned different functions.
- Alarm notification functionality (alarm output)
- Pulse output for energy measurement (pulse output)
- General purpose digital output (digital output)

Pulse output functionality

A corresponding energy counter (up to 4) can be assigned to a pulse output. A number of pulses per energy unit, pulse length, and a tariff in which output is active are set.

> ⚠️ **WARNING**
>
> Pulse parameters are defined by SIST EN 62053−31 standard. In sub-chapter *Calculation of recommended pulse parameters* below a simplified rule is described to assist you in setting the pulse output parameters.

Calculation of recommended pulse parameters:

Number of pulses per energy unit should be in certain limits according to expected power. If not so the measurement from pulse output can be incorrect. Settings of current and voltage transformers can help in estimation of expected power.

Principle described below for pulse setting, where e is prefix, satisfies SIST EN 62053−31: 2001 standards pulse specifications:

$$1,5 \ldots 15 \, eW \rightarrow 100 \, p/1 \, eWh$$

Examples:

Expected power		Pulse output settings
150 − 1500 kW	→	1 p/1 kWh
1,5 − 15 MW	→	100 p/1 MWh
15 − 150 MW	→	10 p/1 MWh
150 − 1500 MW	→	1 p/1 MWh

Alarm notification functionality

An alarm notification function can also be assigned to output. In case of any alarm occurrence, alarm output will trigger passive electromechanical relay or passive solid-state relay.

Two parameters should be defined for each alarm output:

- The source for assigned alarm (alarm group 1, 2 or both)
- Type of output signal when alarm is detected.

General purpose digital output

This functionality allows user to enable / disable output relay (electromechanical or solid-state) by software settings (when appropriate values are set in MODBUS table).

Module number	Modbus register	Register value	
Module 1 (if installed)	40722	3 - ON	4 - OFF
Module 2 (if installed)	40725	3 - ON	4 - OFF
Module 3 (if installed)	40728	3 - ON	4 - OFF
Module 4 (if installed)	40731	3 - ON	4 - OFF

Alarms

Alarms are used for alarming exceeded set values of the measured quantities.

Alarms setting

iMT440 supports setting up to 32 alarms in four alarm groups. Alarms can be set for any of measured parameters by setting condition and a limit value.

A time constant of maximum demand values in a thermal mode, a delay time and switch-off hysteresis are defined for each group of alarms.

To each of two alarm groups an alarm output (solid-state or electromechanical relay) can be dedicated.

⚠ **WARNING**

New values of alarms are calculated in percentage at modification of connection settings. If Used voltage, current range is changed, limit values of alarms will change proportionally.

Reset

During normal operation of a device different values need to be reset from time to time.

Reset energy counters (E1, E2, E3, E4)

All or individual energy meters are reset.

Reset MD values

Current and stored MDs are reset.

Reset the last MD period

Current MD value is reset.

Reset Min / Max values

Min / Max values are reset.

Reset alarm output

All alarms are reset.

MEASUREMENTS

iMT4xx are intended for measuring and monitoring single-phase or three-phase electrical power network. They measure true RMS value by means of fast sampling of voltage and current signals.

Measurements (online)

Online measurements are available with setting and monitoring software MiQen.

Readings refresh rate of readings monitored with MiQen is fixed at approx. one second.

For better overview over numerous readings, they are divided into several groups, which contain:

- Measurements, Min/Max. values, Alarms, Harmonics (presented groups depend on measurements and function supported in selected device).

Each group can represent data in visually favoured graphical form or detailed tabelaric form. Latter allows freezing readings and/or copying data into various report generation software tools.

Daily energy consumption profile

In the graphical form, the measurements of total energy and daily consumption profile of energy of all three phases are represented. The daily energy consumption profile measures a 15-minute average of the active power.

Press the System symbol to observe the measurements of total energy. Press the L1, L2, or L3 symbols to observe the consumption profile of energy of the first, second, or third phase (see picture below, the symbols are surrounded by red).
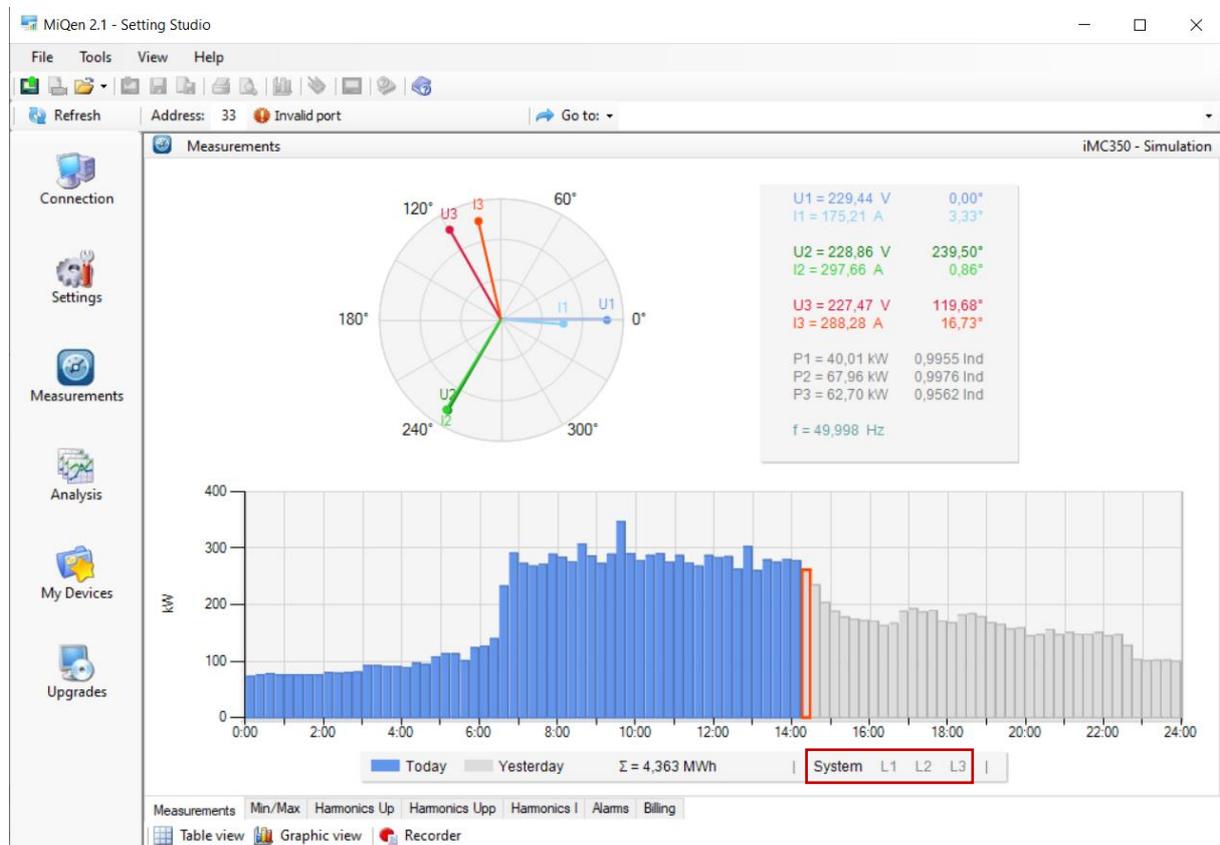
Available connections

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

- Connection 1b (1Wb) – Single phase connection
- Connection 3b (1W3b) – Three phase, three wire connection with balanced load
- Connection 4b (1W4b) – Three phase, four wire connection with balanced load
- Connection 3u (2W3u) – Three phase, three wire connection with unbalanced load
- Connection 4u (3W4u) – Three phase, four wire connection with unbalanced load

---

⚠ **PLEASE NOTE**

Measurements support depends on connection mode and device type. Calculated measurements (for example voltages U1 and U2 when 3-phase, 4-wire connection with a balanced load is used) are only informative.

Survey of supported measurements regarding connection mode

	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 Ia	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/ePF1		●	×	×	●	●
	Power factor PF2	PF2/ePF2		×	×	×	○	●
	Power factor PF3	PF3/ePF3		×	×	×	○	●
	Total power factor PF~	PF/ePF		●	●	●	○	●
	Power angle φ1	φ1	°	●	×	×	●	●
	Power angle φ2	φ2	°	×	×	×	○	●
	Power angle φ3	φ3	°	×	×	×	○	●
	Total power angle φ~	φ	°	●	●	●	○	●
	THD of phase voltage Uf1	U1%	%THD	●	×	×	●	●
	THD of phase voltage Uf2	U2%	%THD	×	×	×	○	●
	THD of phase voltage Uf3	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 (Uff)	U	V	×	●	●	○	●
	Phase-to-phase angle ɸ12	ɸ12	°	×	×	×	○	●
	Phase-to-phase angle ɸ23	ɸ23	°	×	×	×	○	●
	Phase-to-phase angle ɸ31	ɸ31	°	×	×	×	○	●
	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, E3, E4	Wh, VAh, varh	●	●	●	●	●
	Active tariff	Atar		●	●	●	●	●
Max. values MD	MD current I1	I1	A	●	●	●	●	●
	MD current I2	I2	A	×	○	●	○	●
	MD current I3	I3	A	×	○	●	○	●
	MD active power P (positive)	P+	W	●	●	●	●	●
	MD active power P (negative)	P−	W	●	●	●	●	●
	MD reactive power Q−L	Q	var	●	●	●	●	●
	MD reactive power Q−C	Q	var	●	●	●	●	●
	MD apparent power S	S	VA	●	●	●	●	●

● – supported   ○ – calculated   × – not supported

⚠ **PLEASE NOTE**

For 3b and 3u connection mode, only phase to phase voltages are measured. Because of that factor √3 is applied to calculation of quality considering nominal phase voltage.
For 4u connection mode measurements support is same as for 1b.

Explanation of basic concepts

Sample factor Mv

A meter measures all primary quantities with sample frequency which cannot exceed a certain number of samples in a time period. Based on these limitations (128 sample/per at 65Hz) 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 THD calculations.

Average interval Mp

Due to readability of measurements from communication or LCD (where available), an Average interval (MP) is calculated with regard to the measured signal frequency. The Average interval (see chapter Average interval) defines refresh rate of displayed measurements based on a sampling factor.

Power & energy flow

Figures below show a flow of active power, reactive power and energy for 4u connection.
Display of energy flow direction can be adjusted to connection and operation requirements by changing the Energy flow direction settings.

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, all of them are shown in a chapter Appendix B – Equations with additional descriptions and explanations.

⚠ PLEASE NOTE

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

Present values

All measuring instruments may not support all the measurements. Please see chapter Purpose and use of different type of measuring transducer, for supported measurements.

Voltage

Instrument measures true RMS values of all phase voltages (U1, U2, U3), connected to the meter. Phase-to-phase voltages (U12, U23, U31), average phase voltage (Uf) and average phase-to-phase voltage (Ua) are calculated from measured phase voltages (U1, U2, U3).

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

All voltage measurements are available via communication.

Current

Instrument measures true RMS values of phase currents, connected to current inputs. Neutral current (I_n), average current (I_a) and a sum of all phase currents (I_t) are calculated from phase currents.

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

All current measurements are available via communication.

Active, reactive and apparent power

Active power is calculated from instantaneous phase voltages and currents.
Two different principles of reactive power calculation are used:

Standard method:

With this method a reactive power is calculated based on assumption that all power that is not active is reactive.
$Q^2 = S^2 - P^2$
This means also that all higher harmonics will be measured as reactive power.

Delayed current method:

With this method, reactive power (energy) is calculated by multiplication of voltage samples and delayed current samples (see chapter Appendix B - Equations).
$Q = U \times I|_{+90°}$
With this method, reactive power (energy) represents only true reactive component of apparent power (energy).

All measurements are seen via communication. For more detailed information about calculation see chapter Appendix B - Equations.

Power factor and power angle

Power factor is calculated as quotient of active and apparent power for each phase separately ($\cos\varphi_1$, $\cos\varphi_2$, $\cos\varphi_3$) and total power angle ($\cos\varphi_t$). For correct display of PF via analogue output and application of the alarm, ePF (extended power factor) is applied. It illustrates power factor with one value as described in the table below. For a display on the remote display both of them have equal display function: between −1 and −1 with the icon for inductive or capacitive load.

Presentation of extended PF (ePF)

Load	C	$\rightarrow$		$\leftarrow$	L
Angle [°]	−180	−90	0	+90	+180 (179.99)
PF	−1	0	1	0	−1
ePF	−1	0	1	2	3

Example of analogue output for PF and ePF:
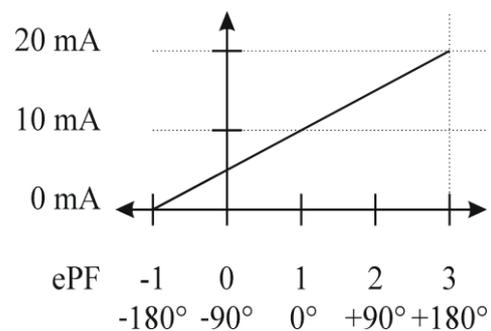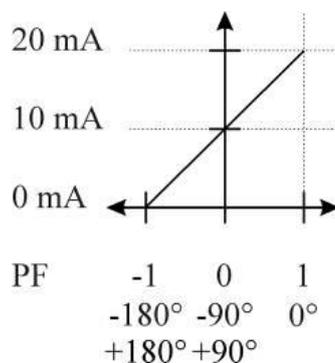
Power angle represents angle between first voltage harmonic and first current harmonic for each individual phase. Total power angle is calculated from total active and reactive power (see equation for Total power angle, chapter Appendix B - Equations). A positive sign shows inductive load, and a negative sign shows capacitive load.

Frequency

Network frequency is calculated from time periods of measured voltage. Frequency is an average of number of periods set in General settings/average interval.

Energy counters

Three ways of Energy - counters presentations are available:
- by individual counter,
- by tariffs for each counter separately and
- energy cost by counter

There are two different methods of calculating reactive energy. See chapter Reactive power and energy calculation. Additional information, how to set and define a counter quantity is explained in chapter ENERGY.

MD values

MD values and time stamp of occurrence are shown for:
- Three phase currents
- Active powers (import and export)
- Reactive power (ind. and cap.)
- Apparent power

Dynamic demands are continuously calculated according to set time constants and other parameters.
Reset demands are max. values of Dynamic demands since last reset.

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.
Instrument uses measuring technique of true RMS values that assures exact measurements with the presence of high harmonics up to 31st harmonic.

Harmonic analysis

Power monitoring device iMT440 measures harmonics up to 31st and evaluates the following harmonic parameters:

- Phase Voltage/Current harmonic signals
- Phase-to-phase Voltage harmonic signals.

Information about harmonic parameters, especially individual harmonic values, can be obtained when the device is connected through communication by using the MiQen software.
Representation of individual harmonics consists of:

- Absolute value
- Relative value
- Phase angle between base and observed harmonic

Relative value can be calculated as a percentage of the base unit or as a percentage of the RMS value. Setting of this relative factor is available under General settings (see Harmonic calculation setting)

TEHNICAL DATA

In following chapter all technical data regarding operation of device is presented.

Accuracy

Total accuracy (measurements and analogue output) according to IEC/EN 60 688 is presented as percentage of range except when it is stated as an absolute value.

Measured values	Range		Accuracy class
RMS current (I_1, I_2, I_3, I_{avg}, I_n)	Auto (1, 5, 10 A)		0.3
Maximum current	12.5 A		0.3
RMS phase voltage (U_1, U_2, U_3, Uavg)	Auto (62.5, 125, 250, 500 V L-N)		0.3
Maximum voltage	600 V L-N		0.3
RMS phase-to-phase voltage (U_{12}, U_{23}, U_{31}, U_{avg})	800 V L-L		0.3
Frequency (f) – actual	50 / 60Hz		10 mHz
Nominal frequency range	16 … 400 Hz		10 mHz
Power angle (φ)	−180 … 0 … 180°		0.2°
Power factor (PF)	−1 … 0 … +1 U = 50 … 120 % U_n I = 2 % … 20 % I_n I = 20 % … 200 % I_n		0.5 0.2
THD	5…500 V 0…400 %		0.5
Active power	75 120	375 600	0.5
Reactive power	250 500	1250 2500	0.5
Apparent power	[W/var/VA] I_n = 1 A	[W/var/VA] I_n = 5 A	0.5
Active energy			Class 1 (EN 62053-21)
Reactive energy			Class 2 (EN 62053-23)

Inputs

Voltage input		
	Nominal range values	62.5, 125, 250, 500 V_{LN}
	Nominal voltage(U_N)	500 V_{LN}
	Minimal measurement	2 V sinusoidal
	Frequency range	50/60, 400 Hz
	Max. measured value (cont.)	600 V_{LN}; 1000 V_{LL}
	Max. allowed value	$2 \times U_N$; 10 s
	(acc. to IEC/EN 60 688)	
	Consumption	$< U^2 / 3.3$ MΩ per phase
	Input impedance	3.3 MΩ per phase
Current input		
	Nominal range values	1, 5, 10 A
	Nominal current (I_N)	5 A
	Min. measurement	Settings from starting current for all powers*
	Frequency range	50/60, 400 Hz
	Max. measured value	12.5 A sinusoidal
	Max. allowed value (thermal)	15 A cont.
	(acc. to IEC/EN 60 688)	$20 \times I_N$; $5 \times 1s$
	Consumption	$< I^2 \times 0.01Ω$ per phase
Frequency		
	Nominal frequency (f_N)	50, 60, 400 Hz
	Measuring range	16 … 400 Hz**
Power supply Universal		
	Nominal voltage AC	48 … 276 V
	Nominal frequency	45 … 65 Hz
	Nominal voltage DC	20 … 300 V
	Consumption	< 8 VA
	Power-on transient current	< 20 A; 1 ms

* Starting current is set by setting software MiQen
** For frequency measurement only

Connection

Permitted conductor cross-sections

Terminals	Max. conductor cross-sections
Voltage inputs (4)	2.5 mm^2 with pin terminal 4 mm^2 solid wire
Current inputs (6)	2.5 mm^2 with pin terminal 4 mm^2 solid wire
Supply (2)	2.5 mm^2 with pin terminal 4 mm^2 solid wire
Modules & Com (8 + 3)	2.5 mm^2 with pin terminal 4 mm^2 solid wire

I/O modules

Electromechanical relay output module		
	Purpose	alarm, pulse, general purpose digital output
	Type	Electromechanical Relay switch
	Rated voltage	48 V AC/DC (+40% max)
	Max. switching current	1000 mA
	Contact resistance	≤ 100 mΩ (100 mA, 24V)
	Pulse	Max. 4000 imp/hour
	(if used as pulse output)	Min. length 100 ms
	Insulation voltage	
	Between coil and contact	4000 VDC
	Between contacts	1000 VDC
Solid-state relay output module		
	Purpose	alarm, pulse, general purpose digital output
	Type	Optocoupler open collector solid-state switch
	Rated voltage	40 V AC/DC
	Max. switching current	30 mA ($R_{ONmax} = 8Ω$)
	Pulse length	programmable
	(if used as pulse output)	1 … 999 ms
Analogue output General		
	Max. voltage on output	35 V
	(open circuit current output)	
	Max. current on output	35 mA
	(short circuit voltage output)	
	Linearization	Linear, Quadratic
	No. of break points	5
	Output value limits	± 120 % of nominal output
	Response time	< 100 ms (standard analogue output)
		≤50 ms (FAST analogue output)
	Residual ripple	< 1 % p.p. (standard analogue output)
		< 2 % p.p. (FAST analogue output)
DC Current output		
	Output range values	−100 … 0 … 100 %
	-1 … 0 … 1 mA	Range 1
	-5 … 0 … 5 mA	Range 2
	-10 ... 0 ... 10 mA	Range 3
	-20 ... 0 ... 20 mA	Range 4
	Other ranges	possible by MiQen software
	Burden voltage	10 V
	External resistance	$RB_{max} = 10 V / I_{outN}$
DC Voltage output		
	Output range values	−100 … 0 … 100 %
	-1 … 0 … 1 V	Range 5
	-10 … 0 … 10 V	Range 6
	Other ranges	possible by MiQen software
	Burden current	20 mA
	External resistance	$RB_{min} = U_{outN} / 20 mA$

Communication

Type	RS232	RS485	USB
Connection type	Direct	Network	Direct
Max. connection length	3 m	1000 m	-
Number of bus stations	-	≤ 32	-
Connection terminals	Screw terminals		USB mini
Insulation	Protection class II, 3.3 kV$_{ACRMS}$ 1 min		Basic isolation only
Transfer mode	Asynchronous		
Protocol	MODBUS RTU		
Transfer rate	2.4 kBaud to 115.2 kBaud		USB 2.0

iMT4xx has a USB communication port, located on the bottom under small circular plastic cover. It is intended for settings ONLY and requires NO auxiliary power supply. When connected to this communication port iMT4xx is powered by USB.

⚠ **WARNING**

USB communication port is provided with only BASIC insulation and can ONLY be used unconnected to aux. supply AND power inputs.

Electronic features

Response time

Input → communication	All calculations are averaged over an interval of between 8 to 256 periods. Preset interval is 64 periods, which is 1.28 second at 50 Hz.

Status LEDs

PWR	Red → Instrument power ON

Safety features

Protection	Protection class II
Pollution degree	2
Installation category	CAT III; 600 V meas. Inputs Acc. to EN 61010-1 CAT III; 300 V aux. supply Acc. to EN 61010-1
Test voltages Acc. to EN 61010-1	UAUX↔I/O, COM: 3320 VACrms UAUX↔U, I inputs: 3320 VACrms U, I in↔I/O,COM: 3320 VACrms U in↔I in: 3320 VACrms
EMC	Directive on electromagnetic compatibility 2014/30/EU Acc. to EN 61326-1
Enclosure material	PC/ABS
Flammability	Acc. to UL 94 V-0
Weight	370 g

Mechanical

Dimensions (WxHxD)	100 × 75× 105 mm
Max. conductor cross section for terminals	2.5 mm² with pin terminal
	4 mm² solid wire
Vibration withstand	7 g, 3 … 100 Hz, 1 oct/min
	10 cycles in each of three axes
Shock withstand	300 g, 8 ms pulse
	6 shocks in each of three axes
Mounting	Rail mounting 35 × 15 mm
	acc. to DIN EN 50 022
Enclosure material	PC/ABS
Flammability	Acc. to UL 94 V-0
Housing protection	IP20
Weight	370 g

Environmental conditions

Ambient temperature	usage group II
	-10 … 0 … 45 … 55 °C
	Acc. to IEC/EN 60 688
Operating temperature	-30 to +70 °C
Storage temperature	-40 to +70 °C
Average annual humidity	≤ 93% r.h.
Altitude	≤ 2000 m

Dimensions
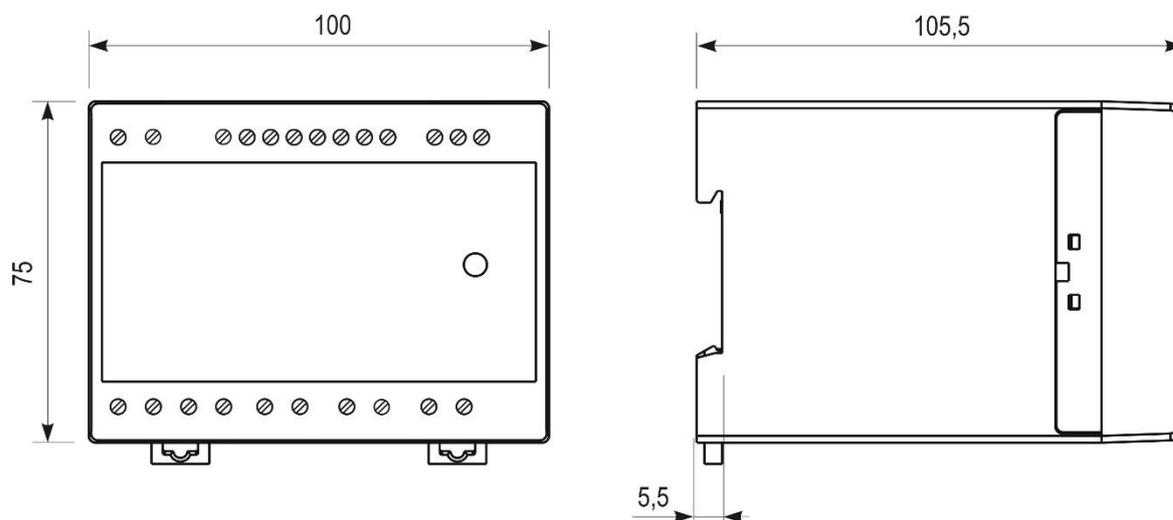
Connection table

Function			Connection
Inputs / outputs	I/O 1	⊖→ +	15
		⊖→ —	16
	I/O 2	⊖→ +	17
		⊖→ —	18
	I/O 3	⊖→ +	19
		⊖→ —	20
	I/O 4	⊖→ +	21
		⊖→ —	22
Auxiliary power supply		+ / AC (L)	13
		− / AC (N)	14
Communication	RS232 / RS485	Rx / A	23
		GND / NC	24
		Tx / B	25

APPENDICES

Appendix A

Modbus communication protocol
Modbus is enabled via RS232 and RS485 or USB. The response is the same type as the request.

Two versions of MODBUS register tables are available:
- VERSION 1: Compatibility with advanced family of transducers (iMT500)
- VERSION 2: Compatibility with previous family of transducers (MI400)

Modbus
Modbus protocol enables operation of device on Modbus networks. For device with serial communication the Modbus protocol enables point to point (for example Device to PC) communication via RS232 communication and multi drop communication via RS485 communication. Modbus protocol is a widely supported open interconnect originally designed by Modicon.

The memory reference for input and holding registers is 30000 and 40000 respectively.

VERSION 1:
Register table for the actual measurements

Parameter	MODBUS		Type
	Register		
	Start	**End**	
Reserved	30101	30104	
Frequency	30105	30106	T5
U1	30107	30108	T5
U2	30109	30110	T5
U3	30111	30112	T5
Uavg (phase to neutral)	30113	30114	T5
φ 12 (angle between U1 and U2)	30115		T17
φ 23 (angle between U2 and U3)	30116		T17
φ 31 (angle between U3 and U1)	30117		T17
U12	30118	30119	T5
U23	30120	30121	T5
U31	30122	30123	T5
Uavg (phase to phase)	30124	30125	T5
I1	30126	30127	T5
I2	30128	30129	T5
I3	30130	30131	T5
INc	30132	30133	T5
INm - reserved	30134	30135	T5
Iavg	30136	30137	T5
Σ I	30138	30139	T5
Active Power Total (Pt)	30140	30141	T6
Active Power Phase L1 (P1)	30142	30143	T6
Active Power Phase L2 (P2)	30144	30145	T6
Active Power Phase L3 (P3)	30146	30147	T6

| Parameter | MODBUS | | |
| | Register | | Type |
	Start	End	
Reactive Power Total (Qt)	30148	30149	T6
Reactive Power Phase L1 (Q1)	30150	30151	T6
Reactive Power Phase L2 (Q2)	30152	30153	T6
Reactive Power Phase L3 (Q3)	30154	30155	T6
Apparent Power Total (St)	30156	30157	T5
Apparent Power Phase L1 (S1)	30158	30159	T5
Apparent Power Phase L2 (S2)	30160	30161	T5
Apparent Power Phase L3 (S3)	30162	30163	T5
Power Factor Total (PFt)	30164	30165	T7
Power Factor Phase 1 (PF1)	30166	30167	T7
Power Factor Phase 2 (PF2)	30168	30169	T7
Power Factor Phase 3 (PF3)	30170	30171	T7
Power Angle Total (atan2(Pt,Qt))	30172		T17
φ 1 (angle between U1 and I1)	30173		T17
φ 2 (angle between U2 and I2)	30174		T17
φ 3 (angle between U3 and I3)	30175		T17
Internal Temperature	30181		T17
THD HARMONIC DATA			
U1 THD%	30182		T16
U2 THD%	30183		T16
U3 THD%	30184		T16
U12 THD%	30185		T16
U23 THD%	30186		T16
U31 THD%	30187		T16
I1 THD%	30188		T16
I2 THD%	30189		T16
I3 THD%	30190		T16
I/O STATUS			
Alarm Status Flags (No. 1 … 16)	30191		T1
I/O 1 Value	30193		T17
I/O 2 Value	30194		T17
I/O 3 Value	30195		T17
I/O 4 Value	30196		T17
ENERGY			
Energy Counter 1 Exponent	30401		T2
Energy Counter 2 Exponent	30402		T2
Energy Counter 3 Exponent	30403		T2
Energy Counter 4 Exponent	30404		T2
Current Active Tariff	30405		T1
Energy Counter 1	30406	30407	T3
Energy Counter 2	30408	30409	T3
Energy Counter 3	30410	30411	T3
Energy Counter 4	30412	30413	T3

Actual counter value is calculated:
Counter $* 10^{\text{Exponent}}$

Parameter	MODBUS		
	Register		
	Start	End	Type
DEMAND VALUES			
DYNAMIC DEMAND VALUES			
Time Into Period (minutes)	30501		T1
I1	30502	30503	T5
I2	30504	30505	T5
I3	30506	30507	T5
Apparent Power Total (St)	30508	30509	T5
Active Power Total (Pt) - (positive)	30510	30511	T6
Active Power Total (Pt) - (negative)	30512	30513	T6
Reactive Power Total (Qt) - L	30514	30515	T6
Reactive Power Total (Qt) - C	30516	30517	T6
MAX DEMAND SINCE LAST RESET			
I1	30518	30519	T5
I2	30524	30525	T5
I3	30530	30531	T5
Apparent Power Total (St)	30536	30537	T5
Active Power Total (Pt) - (positive)	30542	30543	T6
Active Power Total (Pt) - (negative)	30548	30549	T6
Reactive Power Total (Qt) - L	30554	30555	T6
Reactive Power Total (Qt) - C	30560	30561	T6

Register table for the normalized actual measurements

Parameter	MODBUS		100%
	Register	Type	value
U1	30801	T16	Un
U2	30802	T16	Un
U3	30803	T16	Un
Uavg (phase to neutral)	30804	T16	Un
U12	30805	T16	Un
U23	30806	T16	Un
U31	30807	T16	Un
Uavg (phase to phase)	30808	T16	Un
I1	30809	T16	In
I2	30810	T16	In
I3	30811	T16	In
Σ I	30812	T16	It
I neutral (calculated)	30813	T16	In
I neutral (measured)	30814	T16	In
Iavg	30815	T16	In
Active Power Phase L1 (P1)	30816	T17	Pn
Active Power Phase L2 (P2)	30817	T17	Pn
Active Power Phase L3 (P3)	30818	T17	Pn
Active Power Total (Pt)	30819	T17	Pt
Reactive Power Phase L1 (Q1)	30820	T17	Pn
Reactive Power Phase L2 (Q2)	30821	T17	Pn

Parameter	MODBUS		100% value
	Register	Type	
Reactive Power Phase L3 (Q3)	30822	T17	Pn
Reactive Power Total (Qt)	30823	T17	Pt
Apparent Power Phase L1 (S1)	30824	T16	Pn
Apparent Power Phase L2 (S2)	30825	T16	Pn
Apparent Power Phase L3 (S3)	30826	T16	Pn
Apparent Power Total (St)	30827	T16	Pt
Power Factor Phase 1 (PF1)	30828	T17	1
Power Factor Phase 2 (PF2)	30829	T17	1
Power Factor Phase 3 (PF3)	30830	T17	1
Power Factor Total (PFt)	30831	T17	1
CAP/IND P. F. Phase 1 (PF1)	30832	T17	1
CAP/IND P. F. Phase 2 (PF2)	30833	T17	1
CAP/IND P. F. Phase 3 (PF3)	30834	T17	1
CAP/IND P. F. Total (PFt)	30835	T17	1
φ 1 (angle between U1 and I1)	30836	T17	100°
φ 2 (angle between U2 and I2)	30837	T17	100°
φ 3 (angle between U3 and I3)	30838	T17	100°
Power Angle Total (atan2(Pt,Qt))	30839	T17	100°
φ 12 (angle between U1 and U2)	30840	T17	100°
φ 23 (angle between U2 and U3)	30841	T17	100°
φ 31 (angle between U3 and U1)	30842	T17	100°
Frequency	30843	T17	Fn+10Hz
I1 THD%	30845	T16	100%
I2 THD%	30846	T16	100%
I3 THD%	30847	T16	100%
U1 THD%	30848	T16	100%
U2 THD%	30849	T16	100%
U3 THD%	30850	T16	100%
U12 THD%	30851	T16	100%
U23 THD%	30852	T16	100%
U31 THD%	30853	T16	100%
MAX DEMAND SINCE LAST RESET			
Active Power Total (Pt) - (positive)	30854	T16	Pt
Active Power Total (Pt) - (negative)	30855	T16	Pt
Reactive Power Total (Qt) - L	30856	T16	Pt
Reactive Power Total (Qt) - C	30857	T16	Pt
Apparent Power Total (St)	30858	T16	Pt
I1	30859	T16	In
I2	30860	T16	In
I3	30861	T16	In

Parameter	MODBUS		100% value
	Register	Type	
DYNAMIC DEMAND VALUES			
Active Power Total (Pt) - (positive)	30862	T16	Pt
Active Power Total (Pt) - (negative)	30863	T16	Pt
Reactive Power Total (Qt) - L	30864	T16	Pt
Reactive Power Total (Qt) - C	30865	T16	Pt
Apparent Power Total (St)	30866	T16	Pt
I1	30867	T16	In
I2	30868	T16	In
I3	30869	T16	In
ENERGY			
Energy Counter 1	30870	T17	
Energy Counter 2	30871	T17	Actual counter value MOD 20000 is returned
Energy Counter 3	30872	T17	
Energy Counter 4	30873	T17	
Active Tariff	30879	T1	
Internal Temperature	30880	T17	100°

VERSION 2:
Register table for the actual measurements

Parameter	MODBUS		
	Register		Type
	Start	End	
Frequency	30049	30050	T5
U1	30057	30058	T5
U2	30059	30060	T5
U3	30061	30062	T5
Uavg (phase to neutral)	30063	30064	T5
φ 12 (angle between U1 and U2)	30065		T17
φ 23 (angle between U2 and U3)	30066		T17
φ 31 (angle between U3 and U1)	30067		T17
U12	30068	30069	T5
U23	30070	30071	T5
U31	30072	30073	T5
Uavg (phase to phase)	30074	30075	T5
I1	30076	30077	T5
I2	30078	30079	T5
I3	30080	30081	T5
INc	30082	30083	T5
INm - reserved	30084	30085	T5
Iavg	30086	30087	T5
Σ I	30088	30089	T5
Active Power Total (Pt)	30090	30091	T6
Active Power Phase L1 (P1)	30092	30093	T6
Active Power Phase L2 (P2)	30094	30095	T6
Active Power Phase L3 (P3)	30096	30097	T6

| Parameter | MODBUS | | |
| | Register | | Type |
	Start	End	
Reactive Power Total (Qt)	30098	30099	T6
Reactive Power Phase L1 (Q1)	30100	30101	T6
Reactive Power Phase L2 (Q2)	30102	30103	T6
Reactive Power Phase L3 (Q3)	30104	30105	T6
Apparent Power Total (St)	30106	30107	T5
Apparent Power Phase L1 (S1)	30108	30109	T5
Apparent Power Phase L2 (S2)	30110	30111	T5
Apparent Power Phase L3 (S3)	30112	30113	T5
Power Factor Total (PFt)	30114	30115	T7
Power Factor Phase 1 (PF1)	30116	30117	T7
Power Factor Phase 2 (PF2)	30118	30119	T7
Power Factor Phase 3 (PF3)	30120	30121	T7
Power Angle Total (atan2(Pt,Qt))	30122		T17
φ 1 (angle between U1 and I1)	30123		T17
φ 2 (angle between U2 and I2)	30124		T17
φ 3 (angle between U3 and I3)	30125		T17
Internal Temperature	30126		T17
THD HARMONIC DATA			
U1 THD%	30639		T16
U2 THD%	30640		T16
U3 THD%	30641		T16
U12 THD%	30642		T16
U23 THD%	30643		T16
U31 THD%	30644		T16
I1 THD%	30645		T16
I2 THD%	30646		T16
I3 THD%	30647		T16
ENERGY			
Energy Counter 1 Exponent	30037		T2
Energy Counter 2 Exponent	30038		T2
Energy Counter 3 Exponent	30039		T2
Energy Counter 4 Exponent	30040		T2
Current Active Tariff	30133		T1
Energy Counter 1	30134	30135	T3
Energy Counter 2	30136	30137	T3
Energy Counter 3	30138	30139	T3
Energy Counter 4	30140	30141	T3

Actual counter value is calculated: $\text{Counter} * 10^{\text{Exponent}}$

Parameter	MODBUS		Type
	Register		
	Start	End	
DEMAND VALUES			
DYNAMIC DEMAND VALUES			
Time Into Period (minutes)	30174		T1
I1	30175	30176	T5
I2	30177	30178	T5
I3	30179	30180	T5
Apparent Power Total (St)	30181	30182	T5
Active Power Total (Pt) - (positive)	30183	30184	T6
Active Power Total (Pt) - (negative)	30185	30186	T6
Reactive Power Total (Qt) - L	30187	30188	T6
Reactive Power Total (Qt) - C	30189	30190	T6
MAX DEMAND SINCE LAST RESET			
I1	30207	30208	T5
I2	30213	30214	T5
I3	30219	30220	T5
Apparent Power Total (St)	30225	30226	T5
Active Power Total (Pt) - (positive)	30231	30232	T6
Active Power Total (Pt) - (negative)	30237	30238	T6
Reactive Power Total (Qt) - L	30243	30244	T6
Reactive Power Total (Qt) - C	30249	30250	T6

Register table for the normalized actual measurements

Parameter	MODBUS		100% value
	Register	Type	
U1	30801	T16	Un
U2	30802	T16	Un
U3	30803	T16	Un
Uavg (phase to neutral)	30804	T16	Un
U12	30805	T16	Un
U23	30806	T16	Un
U31	30807	T16	Un
Uavg (phase to phase)	30808	T16	Un
I1	30809	T16	In
I2	30810	T16	In
I3	30811	T16	In
Σ I	30812	T16	It
I neutral (calculated)	30813	T16	In
I neutral (measured)	30814	T16	In
Iavg	30815	T16	In
Active Power Phase L1 (P1)	30816	T17	Pn
Active Power Phase L2 (P2)	30817	T17	Pn
Active Power Phase L3 (P3)	30818	T17	Pn
Active Power Total (Pt)	30819	T17	Pt
Reactive Power Phase L1 (Q1)	30820	T17	Pn
Reactive Power Phase L2 (Q2)	30821	T17	Pn

| Parameter | MODBUS | | 100% |
	Register	Type	value
Reactive Power Phase L3 (Q3)	30822	T17	Pn
Reactive Power Total (Qt)	30823	T17	Pt
Apparent Power Phase L1 (S1)	30824	T16	Pn
Apparent Power Phase L2 (S2)	30825	T16	Pn
Apparent Power Phase L3 (S3)	30826	T16	Pn
Apparent Power Total (St)	30827	T16	Pt
Power Factor Phase 1 (PF1)	30828	T17	1
Power Factor Phase 2 (PF2)	30829	T17	1
Power Factor Phase 3 (PF3)	30830	T17	1
Power Factor Total (PFt)	30831	T17	1

All other MODBUS registers are a subject to change. For the latest MODBUS register definitions go to ISKRA d.o.o.'s web page www.iskra.eu.

100% values calculations for normalized measurements

Un =	(R40147 / R40146) * R30015 * R40149
In =	(R40145 / R40144) * R30017 * R40148
Pn =	Un*In
It =	In Connection Mode: 1b
It =	3*In Connection Modes: 3b, 4b, 3u, 4u
Pt =	Pn Connection Mode: 1b
Pt =	3*Pn Connection Modes: 3b, 4b, 3u, 4u
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 (<u>Type T4</u>) = 10^2 × 40 = **8028**$_{(16)}$ –> **4000 A/10 = 400 A**
CT Secondary   = R40144 (<u>Type T4</u>) = 10^2 × 50 = **8032**$_{(16)}$ –> **5000 mA**
Cal. Current   = R30017 (<u>Type T4</u>) = 10^2 × 50 = **8032**$_{(16)}$ –> **5000 mA**
Input range   = R40148 (<u>Type T16</u>) = 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 CD15(16)
T4	bits # 15…14 bits # 13…00	Short Unsigned float (16 bit) Decade Exponent(Unsigned 2 bit) Binary Unsigned Value (14 bit) Example: $10000*10^2$ = 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)
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

Calculations

Definitions of symbols

No	Symbol	Definition
1	M_v	Sample factor
2	M_P	Average interval
3	U_f	Phase voltage (U_1, U_2 or U_3)
4	U_{ff}	Phase-to-phase voltage (U_{12}, U_{23} or U_{31})
5	N	Total number of samples in a period
6	n	Sample number ($0 \leq n \leq N$)
7	x, y	Phase number (1, 2 or 3)
8	i_n	Current sample n
9	u_{fn}	Phase voltage sample n
10	u_{ffn}	Phase-to-phase voltage sample n
11	φ_f	Power angle between current and phase voltage f (φ_1, φ_2 or φ_3)
12	U_c	Agreed supply voltage

Equations

Voltage

$$U_f = \sqrt{\frac{\sum_{n=1}^{N} u_n^2}{N}}$$

Phase voltage (TRMS)

N – 128 samples in one period (up to 65 Hz)
N – 128 samples in M_v periods (above 65 Hz)
Example: 400 Hz $\rightarrow$ N = 7

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

Phase-to-phase voltage (TRMS)

u_x, u_y – phase voltages (U_f)
N – a number of samples in a period

Current

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

Phase current (TRMS)

N – 128 samples in a period (up to 65 Hz)
N – 128 samples in more periods (above 65 Hz)

$$I_n = \sqrt{\frac{\sum_{n=1}^{N} (i_{1n} + i_{2n} + i_{3n})^2}{N}}$$

Phase current

N – 128 samples in a period (up to 65 Hz)
N – 128 samples in more periods (above 65 Hz)

Power

$$P_f = \frac{1}{N}\sum_{n=1}^{N}(u_{fn}\times i_{fn})$$

Active power by phases
N – a number of samples in a period
n – sample number ($0 \le n \le N$)
f – phase designation

$$P_t = P_1 + P_2 + P_3$$

Total active power
t – total power
1, 2, 3 – phase designation

$$\text{SignQ}_f(\varphi)$$
$$\varphi \in [0° - 180°] \rightarrow \text{SignQ}_f(\varphi) = +1$$
$$\varphi \in [180° - 360°] \rightarrow \text{SignQ}_f(\varphi) = -1$$

Reactive power sign
Q_f – reactive power (by phases)
φ – power angle

$$S_f = U_f \times I_f$$

Apparent power by phases
U_f – phase voltage
I_f – phase current

$$S_t = S_1 + S_2 + S_3$$

Total apparent power
S_f – apparent power by phases

$$Q_f = \text{SignQ}_f(\varphi) \times \sqrt{S_f^2 - P_f^2}$$

Reactive power by phases (standard)
S_f – apparent power by phases
P_f – active power by phases

$$Q_f = \frac{1}{N}\sum_{n=1}^{N}(u_{f\,n}\times i_{f\,[n+N/4]})$$

Reactive power by phases (delayed current method)
N – a number of samples in a period
n – sample number ($0 \le n \le N$)
f – phase designation

$$Q_t = Q_1 + Q_2 + Q_3$$

Total reactive power
Q_f – reactive power by phases

$$\varphi_s = \text{arctan2}\,(P_t, Q_t)$$
$$\varphi_s = [-180°, 179,99°]$$

Total power angle
P_t – total active power
S_t – total apparent power

$$PF_t = \frac{P_t}{S_t}$$

3 phase power factor
P_t - total active power
S_t - total apparent power

$$PF_f = \frac{P_f}{S_f}$$

Power factor by phases
P_f - phase active power
S_f - phase apparent power

THD

$$I_f THD(\%) = \frac{\sqrt{\sum_{n=2}^{63} I_n^2}}{I_1} \times 100$$

Current THD
I_1 – value of first harmonic
n – number of harmonic

$$U_f THD(\%) = \frac{\sqrt{\sum_{n=2}^{63} U_{fn}^2}}{U_{f1}} \times 100$$

Phase voltage THD
U_1 – value of first harmonic
n – number of harmonic

$$U_{ff} THD(\%) = \frac{\sqrt{\sum_{n=2}^{63} U_{ffn}^2}}{U_{ff1}} \times 100$$

Phase-to-phase voltage THD
U_1 – value of first harmonic
n – number of harmonic

Energy

$$Price\,in\,tariff = Price \times 10^{Tarif\,price\,exponent}$$

Total exponent of tariff price and energy price in all tariffs

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