Firmware version 2

- IOMod Meter User Manual

IOMod Meter User Manual

1. Introduction

IOMod Meter is a compact-sized, stand-alone power meter for measuring analog AC input signals from low-power current and voltage sensors. It measures three phases of AC voltage and current amplitudes and phase shifts. Unlike IOMod 4Cs4Vs IOMod Meter only has three inputs for each phase current and voltage measurements. The measured and calculated values are transmitted to the host system via the communication protocol **Modbus RTU, IEC 60870-5-101 or IEC 60870-5-103**.

1.1 Features

- 3 AC current sensor inputs according to IEC 60044-8 (nominal value 225 mV);
- 3 AC voltage sensor inputs according to IEC 60044-7 (nominal value 3.25/√3 V);
- 32 samples per cycle;
- FFT-based calculation with harmonic information;
- Additional measurements of:
  - Frequency (Nominal frequencies: 50 and 60 Hz; Frequency range: 45–65 Hz);
  - Active, reactive, and apparent power;
  - Neutral voltage, neutral current;
  - Power factor;
  - Phase angle;
- Firmware upgrade over USB, RS485;
- Configurable using the IOMOD Utility app for user-friendly setup;
- RS-485 interface with a switchable terminating resistor;
- Compact case with a removable transparent front panel;
- DIN rail mounting for seamless integration into industrial systems;

1.2 Block diagram
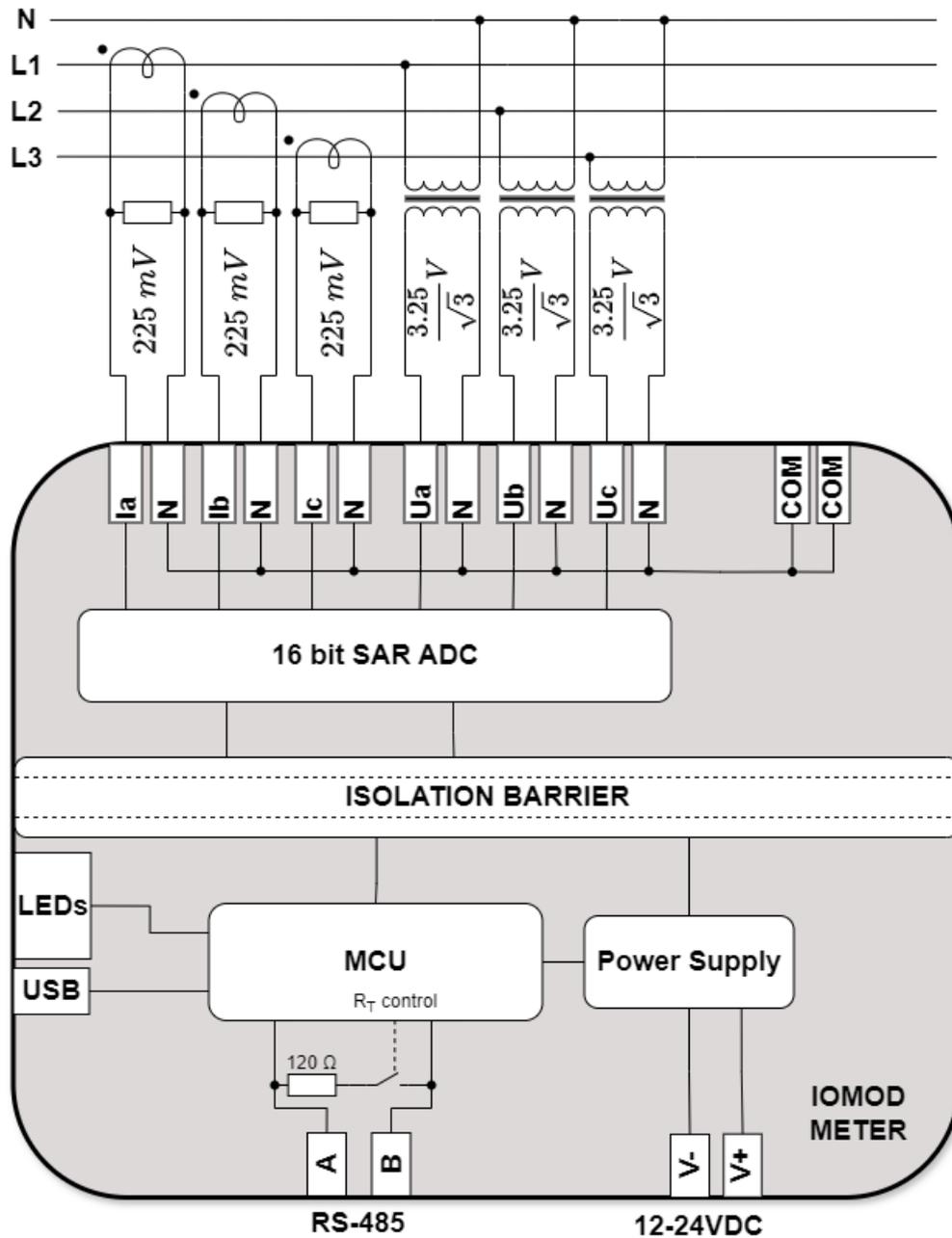
Fig. 1.2.1. IOMOD Meter internal structure and block diagram

2. Hardware data

2.1 Mechanical drawings
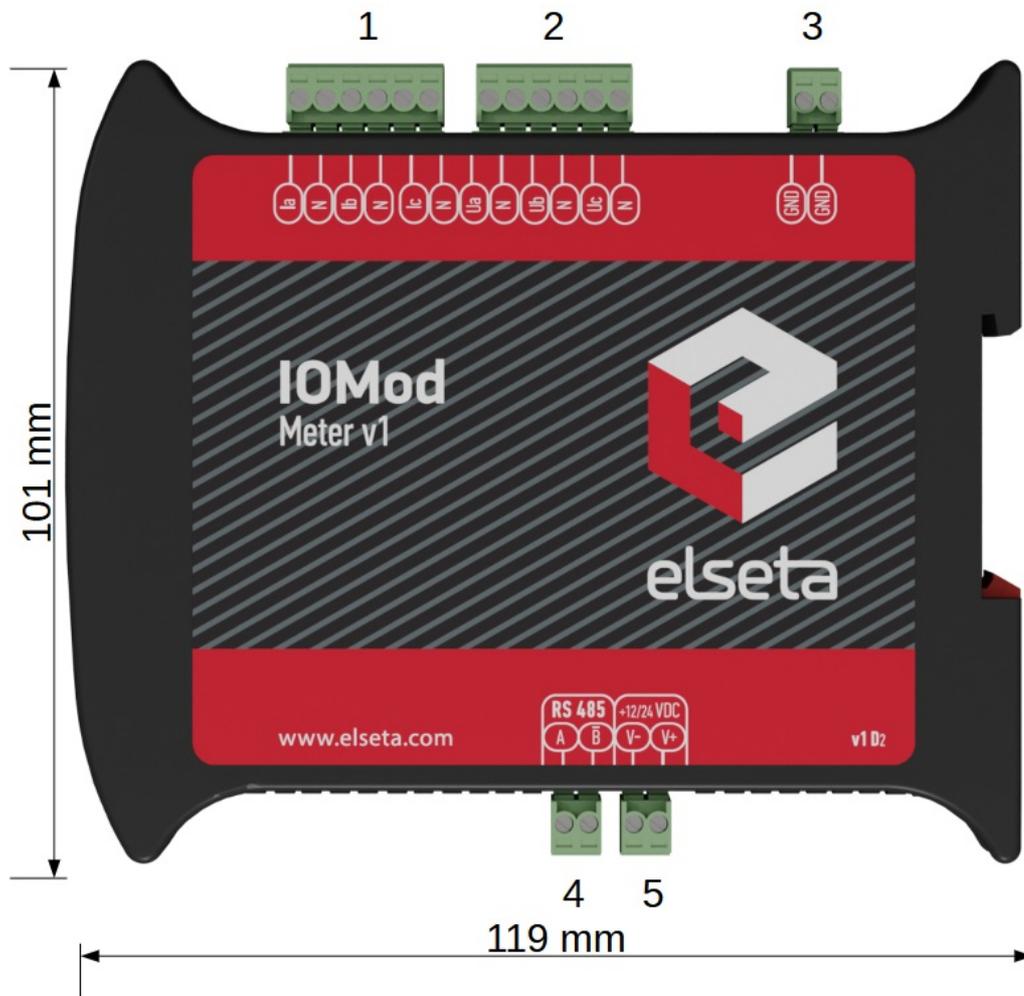
Fig. 2.1.1. IOMod Meter side view with dimensions and terminal description. 1 – current measurement inputs; 2 – voltage measurement inputs; 3 – ground input for analogue measurements; 4 - RS485 interface; 5 - power supply input

Fig. 2.1.2 IOMOD Meter front view with measurements

2.2 Terminal Connections

IOMod Meter has 18 terminals, which are depicted below:
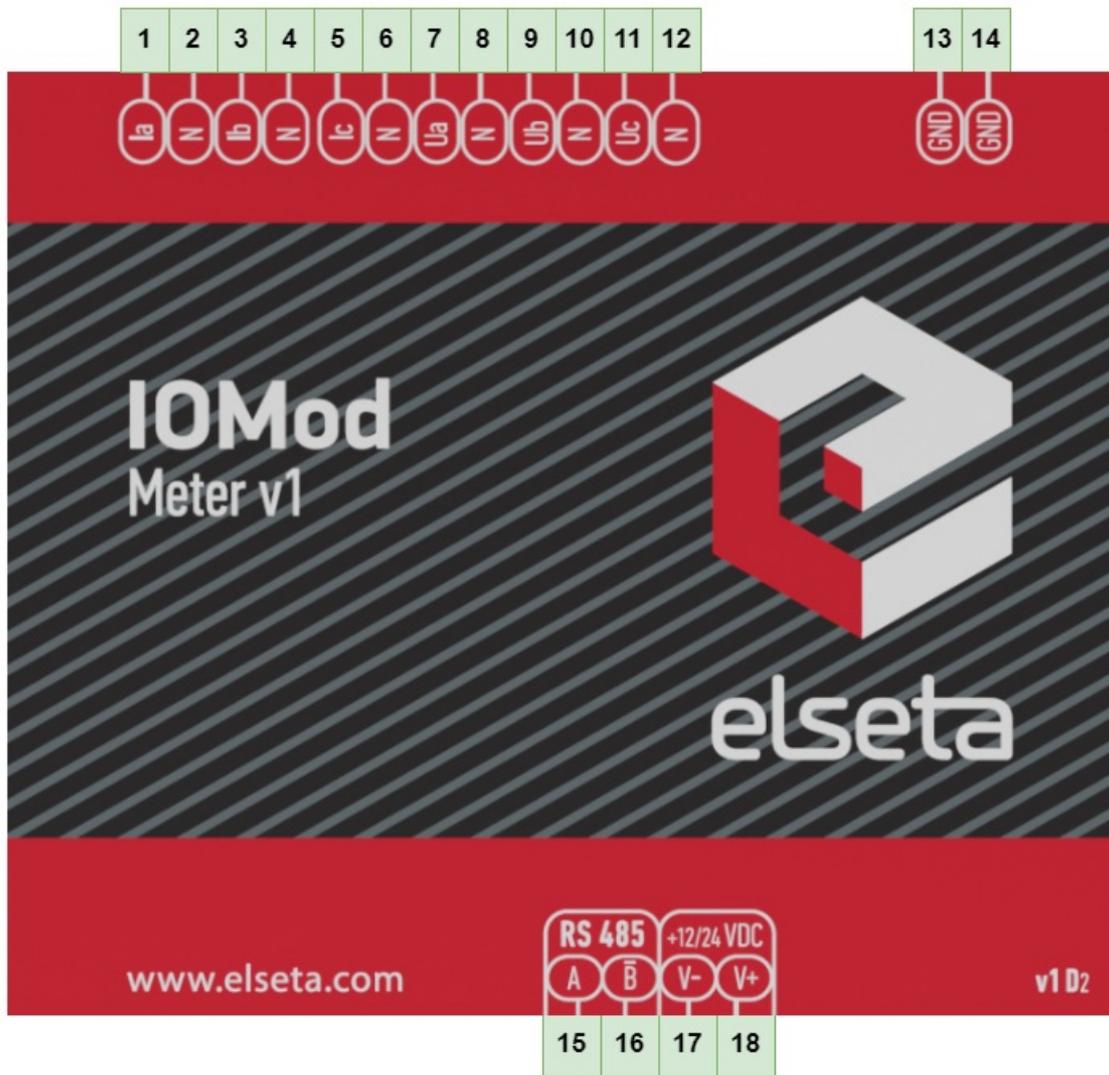
Fig. 2.2.1 IOMod Meter terminal diagram

The description of each terminal can be found in the table below:

Table 2.2.1 Terminal Specifications

Terminal number	Terminal name	Description
1	Ia	Phase current 1
2	N	
3	Ib	Phase current 2 or neutral current in case of ∂ metered mode
4	N	
5	Ic	Phase current 3
6	N	
7	Ua	Phase voltage 1 or phase current 1 in case of 3I3I connection mode
8	N	
9	Ub	Phase voltage 2 or phase current 2 in case of 3I3I connection mode, or neutral current in

10	N	case of 3I3I connection mode, along with I_0 metered mode
11	Uc	Phase voltage 3 or phase current 3 in case of 3I3I connection mode
12	N	
13	COM	Analogue measurements common neutral terminals
14	COM	
15	A	RS-485 interface port
16	B̄	
17	V-	Power source inputs
18	V+	

2.3 Status indication

IOMod Meter have 2 LEDs (Fig. 2.3.1), which indicate communication and power statuses.

Fig. 2.3.1. IOMod Meter LEDs physical location

The description of each IOMod Meter LED can be found in the table below:

Table 2.3.1. Description of LEDs.

Name	LED color	Description

RX/TX	⬛ (green)	A blinking green light indicates active communication via the RS-485 interface.
STAT	⬛ (green)	The power source is connected to the power supply input.
	⬛ (blue)	IOMod Meter is connected to an external device via a USB mini cable.

3. Technical information

Table 3.1. Technical specifications.

System	
Dimension	101 x 119 x 17.5 mm
Case	ABS, black
Working environment	Indoor
Operating temperature	-40°C … +85°C
Recommended operating conditions	5–60°C and 20–80%RH;
Configuration	USB, RS485
Firmware upgrade	USB, RS485
Electrical specifications		
Inputs	Resolution	16 bits
	Input resistance	~1 MΩ
	Input capacitance	< 170 pF
	Input ranges	±10 V (amplitude)
	Nominal values	Current input: 225 mV (rms) Voltage input: 1.876 V (rms)
	Overvoltage protection for all inputs	up to ±20 V (amplitude)
Power	
Power Supply	9–33 VDC (full range)
Current consumption	40 mA @ 12 VDC, 20 mA @ 24 VDC

4. Mounting and Installation

4.1 Connection Diagrams

In this chapter the various options of connecting the device to medium-voltage systems are discussed.

4.1.1 3 Low-Power Current Sensor, 3 Low-Power Voltage Sensors

In the case of 3I3U connection mode, IOMod Meter can be connected to a medium-voltage system by using low-power current and low-power voltage sensors (Fig. 4.1.1.1). In this scenario, the neutral current I_0 and the neutral voltage U_0 are calculated by taking a vector sum of appropriate measurements. IOMod Meter GND inputs are not required to be connected to the neutral line because they are interconnected with signal neutral inputs (Fig. 1.2.1).
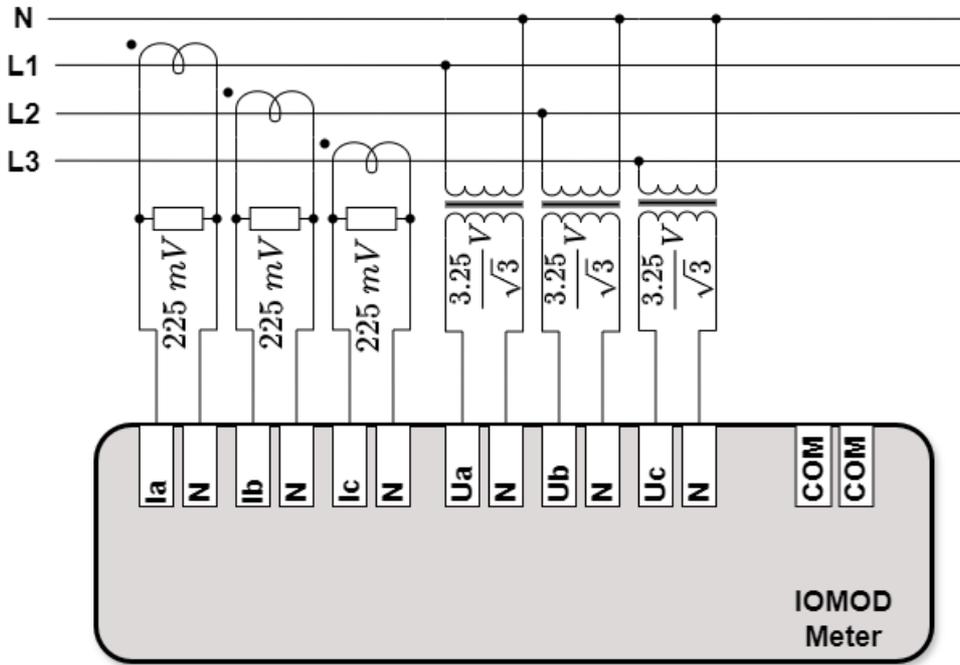
Fig. 4.1.1.1. Connection diagram with 3 low-power current and 3 low-power voltage sensors

4.1.2 Fault Passage Indicator for two feeders

The special feature of IOMod Meter is the ability to perform the metering of two feeders (Fig. 4.1.2.1). In this case, 3I3I connection mode needs to be enabled in the IOMod Utility (Fig. 4.1.2.2).
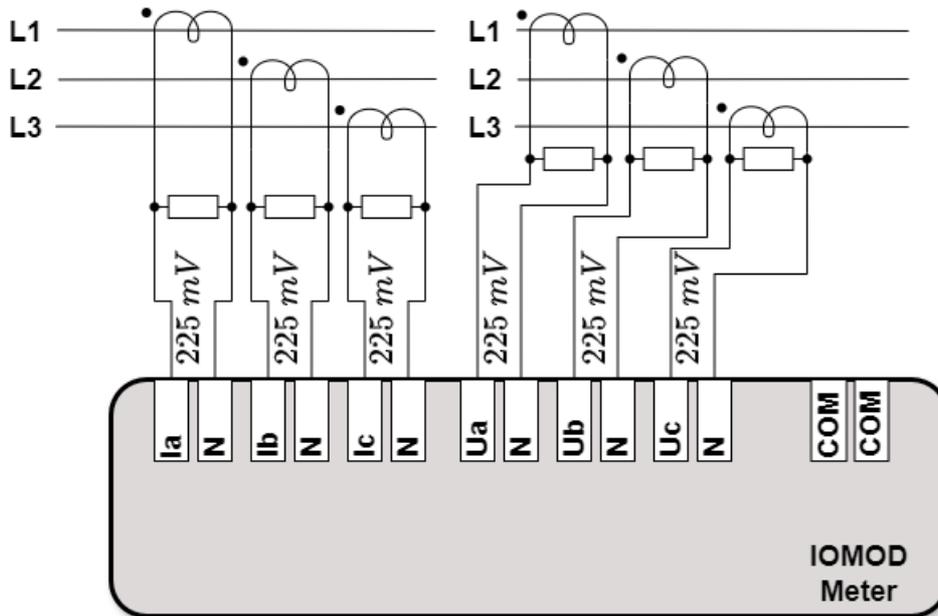

Fig. 4.1.2.1. IOMod Meter connection diagram for two feeders
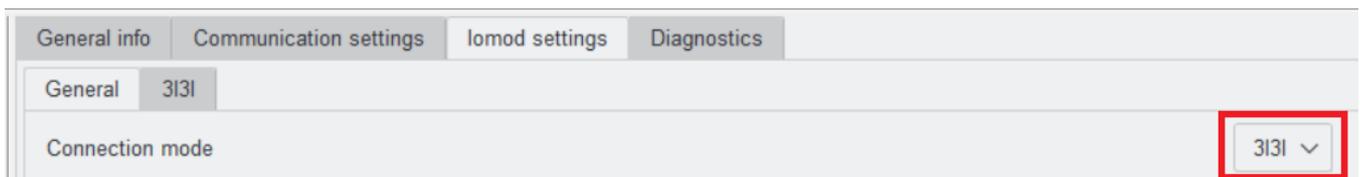
Fig. 4.1.2.2. IOMod Utility General settings tab with Connection mode set to 3I3I

This mode allows us to use IOMod Meter voltage inputs for current measurements, so that the currents of both feeders are measured simultaneously. In the connection scheme above (Fig. 4.1.2.1), IOMod Meter, each input is connected to the pair of feeders via low-power current sensors.

4.1.3 3 Low-Power Voltage Sensor, 2 Phase Current, and Core Balance Current

Transformer

IOMod Meter allows direct measurement of the neutral current. To use this feature, I_0 current acquiring mode needs to be switched in **IOMod Utility** from calculated to metered (Fig. 4.1.3.1).

General info	Communication settings	Iomod settings	Diagnostics	

General	3I3U	

Primary current (A)	100
Primary voltage (kV)	10.0
Current sensor (mV)	225
Voltage sensor (V)	1.876
I0 mode	metered ⌄
Primary current I0	100
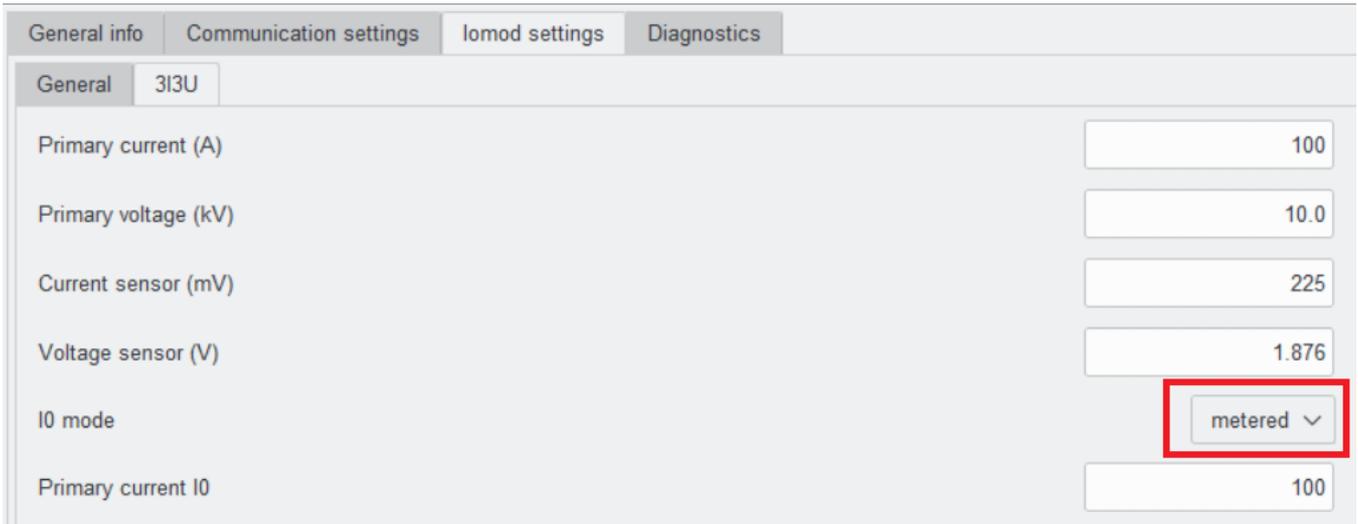
Fig. 4.1.3.1. IOMod Utility 3I3U settings view with I_0 mode switched to metered

After enabling I_0 metered mode IOMod Meter second phase input (Ib+/N) becomes neutral current input. Since neutral current measurements are performed directly instead of being calculated, it allows to achieve much higher precision and sensitivity. While neutral current is being metered directly, the second phase measurements are calculated by taking a vector sum of the measured currents. In the scheme below (Fig. 4.1.3.2), current and voltage measurements are taken by using low-power current and low-power voltage sensors. The second input (Ib+/N) is connected to a low-power current sensor, which is placed on the neutral line.
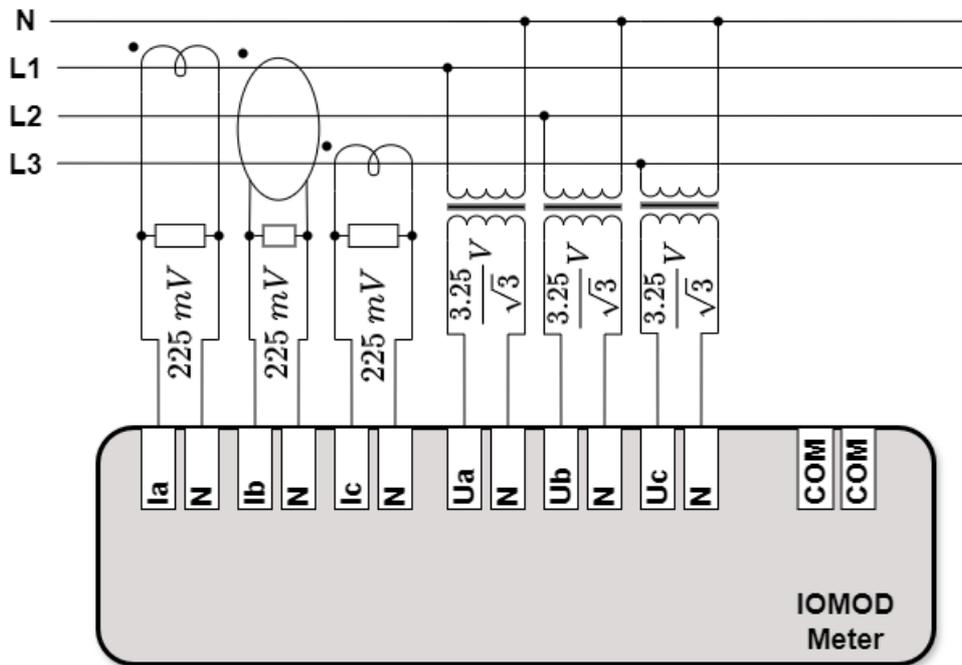

Fig. 4.1.3.2. IOMod Meter I_0 metered mode connection diagram

4.1.4 2-Phase Current and Core Balance Current Transformer for two feeders

IOMod Meter operating in I_0 metered mode preserves the ability of monitoring the currents of two feeders (Fig. 4.1.4.1). In this case, 3I3I connection mode needs to be enabled in **IOMod Utility** (Fig. 4.1.4.2). 3I3I connection mode allows using voltage inputs as second channel current inputs.
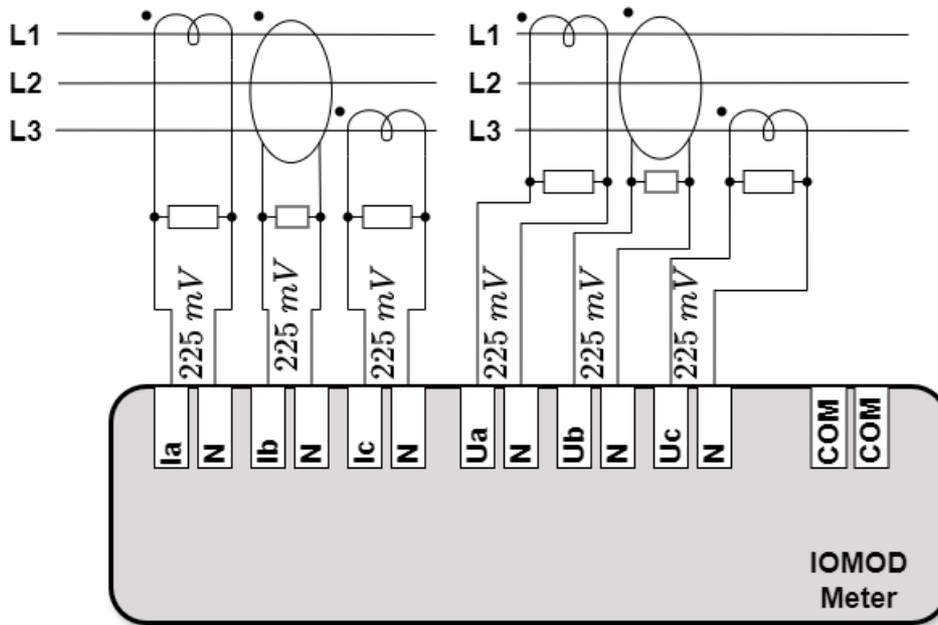
Fig. 4.1.4.1. IOMod Meter connection diagram for two feeders
with both channels I_0 metered mode

In the connection scheme above (Fig. 4.1.4.1), IOMod Meter current inputs are connected to the pair of feeders via low-power current sensors. Moreover, in **IOMod Utility** I_0 mode of both current input channels needs to be changed from calculated to metered (Fig. 4.1.4.2).
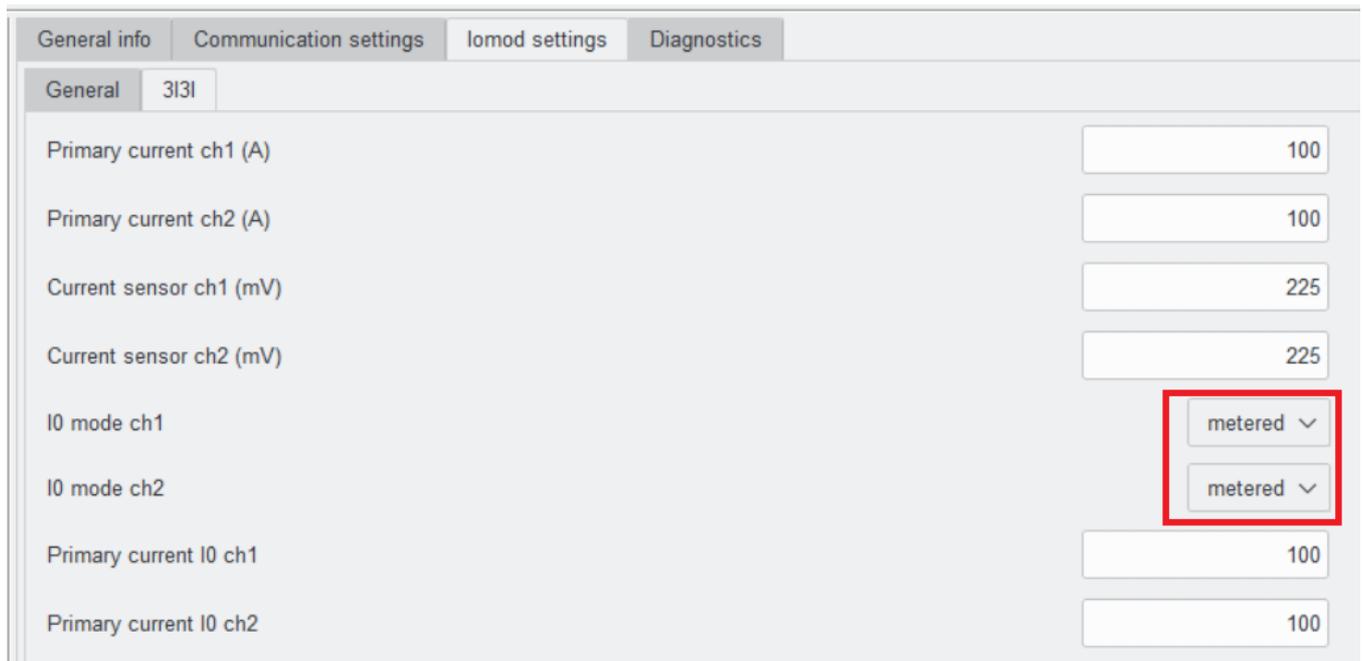
Fig. 4.1.4.2. IOMod Utility 3I3I settings view with I_0 mode of both channels set to metered.

4.1.5 Conventional Current transformers (CT) connection via CT adapters.

IOMod Meter can take current measurements via a current transformer adapter (Fig. 4.1.5.1). Contrary to the current sensors, current transformers are usually intended for transforming priorly lowered currents from secondary distribution networks.
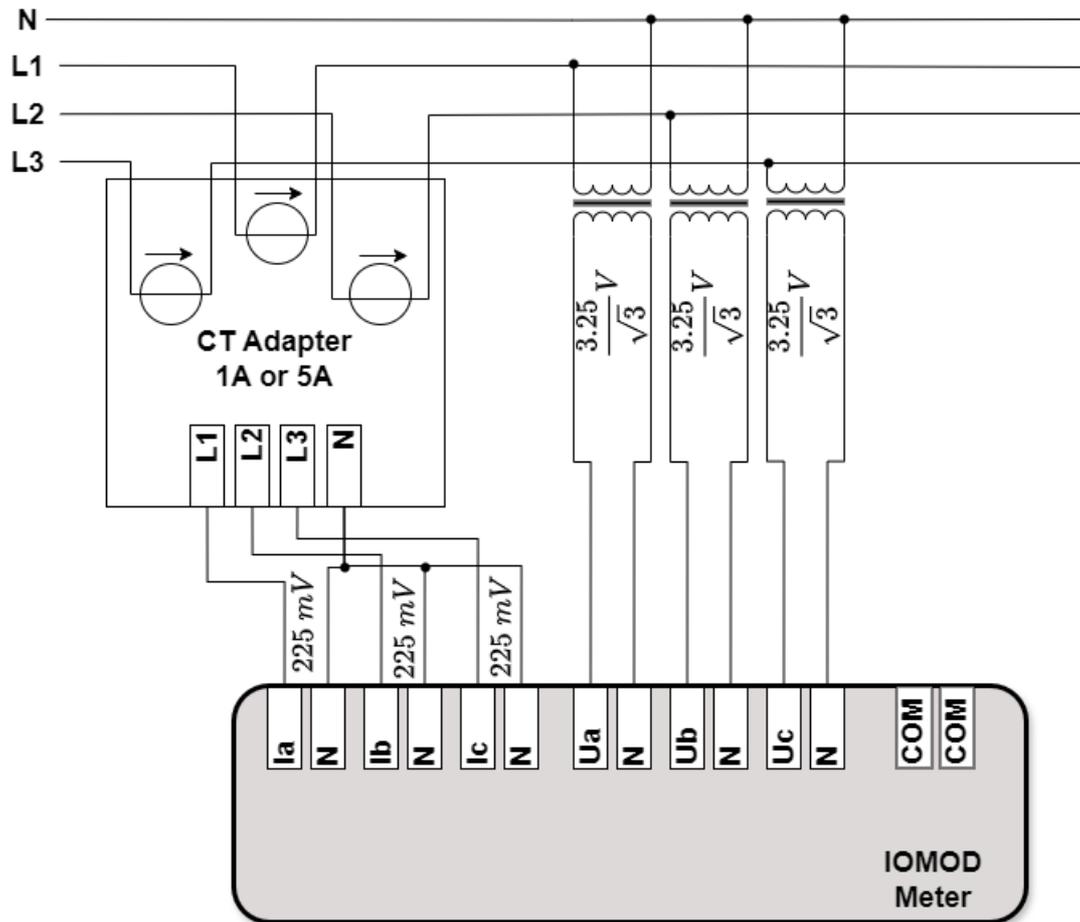
Fig. 4.1.5.1. IOMod Meter connection diagram with current transformer adapter and low-power voltage sensors

4.1.6 Conventional Voltage transformers (VT) connection via VT adapters.

IOMod Meter can take voltage measurements via a voltage transformer adapter (Fig. 4.1.6.1). Contrary to the voltage sensors, voltage transformers are usually intended for transforming priorly lowered voltages from secondary distribution networks.
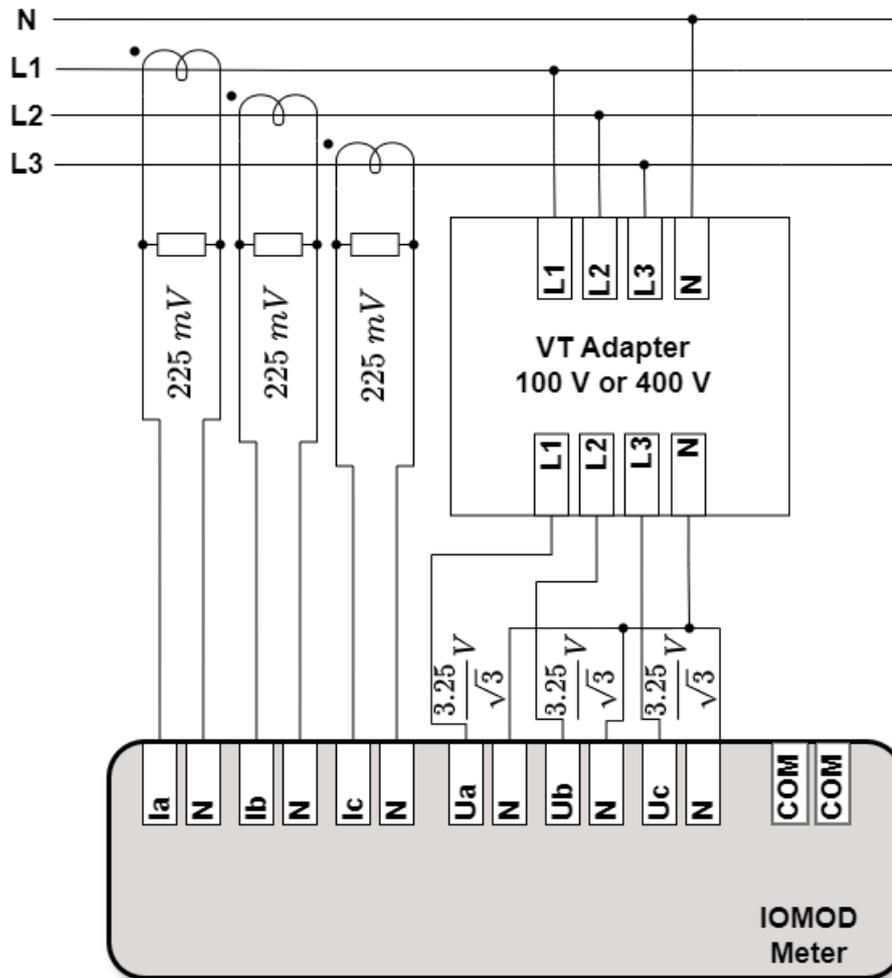
Fig. 4.1.6.1. IOMod Meter connection diagram with low-power current sensors and voltage transformer adapter

4.2 RS485 Interface

IOMod Meter has an integrated 120 Ω termination resistor, which can be enabled or disabled via the configuration terminal. It is recommended that termination be used at each end of the RS-485 cable. IOMod Meter has a 1/8 Unit load receiver, allowing up to 255 units on a single line (compared to the standard 32 units). To reduce reflections, keep the stubs (cable distance from the main RS485 bus line) as short as possible.

4.3 Power Supply

IOMod Meter need to be powered by a 9–33 V power source. IOMOD Meter power supply inputs are located next to RS485 interface inputs (Fig. 4.3.1).

Power supply
inputs

Fig. 4.3.1. Power supply inputs physical location

4.4 USB Connection

IOMod Meter device has a USB mini connection port. Its primary function is the physical connection establishment between the IOMod and a PC. By selecting the USB interface and correct communication port in IOMod Utility (Fig. 4.4.1), a user can connect to the IOMod to control its parameters and monitor its measured data and the status of fault detection functions. Also, this connection can be used for powering the module.
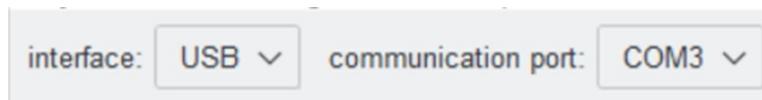

Fig. 4.4.1. IOMOD Utility interface and communication port parameters

USB-mini
connection port

Fig. 4.4.2. IOMOD Meter USB connection port physical location

5. Parametrization

In this section, the IOMod Meter settings configuration is described. IOMod Meter configuration is performed via IOMod Utility (the manual can be accessed here). All IOMod-related settings can be found in the "Iomod settings" tab (Fig. 5.1).
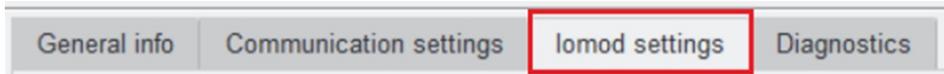

Fig. 5.1. IOMod settings tab

5.1 General Parameters

To configure IOMod Meter general settings, open the "Iomod settings" tab in IOMod Utility. After clicking on "Iomod settings", the "General" section opens (Fig. 5.1.1).
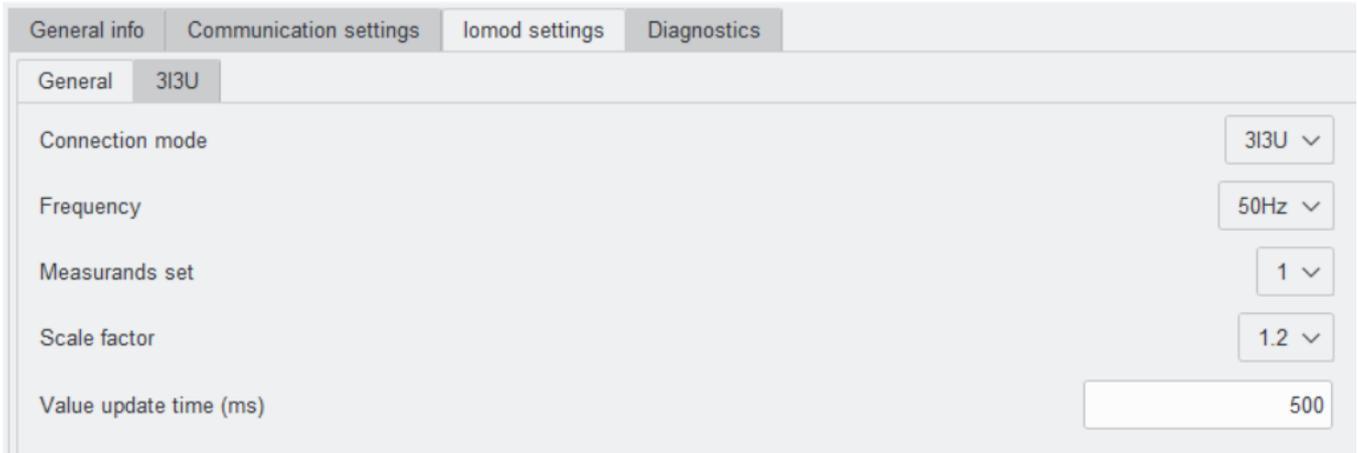

Fig. 5.1.1. IOMod Utility with IOMod Meter general settings window opened.

The general settings consist of two parameters, which apply to all communication protocols (Table 5.1.1). "Measurands set" and "Scale factor" are defined only in the context of the IEC 60870-5-103 communication protocol. The last parameter, "Value update time (ms)", is defined only in the context of IEC 60870-5-101 and IEC 60870-5-103 communication protocols.

Table 5.1.1. IOMOD Meter general parameter ranges and default values.

Parameter	Range	Default value
Connection mode	3I3I, 3I3U	3I3U
Frequency	50 Hz, 60 Hz	50 Hz
Value update time (ms) *	20-60000	500
Measurands set **	1-4	1
Scale factor **	1.2, 1.4	1.2

The parameter is defined only for IEC 60870-5-101 and IEC 60870-5-103 communication protocols.

*** The parameters are defined only for the IEC 60870-5-103 communication protocol.*

The first parameter "Connection mode" allows us to define how the values measured with voltage inputs (terminals 7–12, see Fig. 2.2.1) are supposed to be interpreted. The values are interpreted as voltage measurements by default. This connection mode is denoted by the 3I3U designation. 3I3U designation means "3 currents and 3 voltages", meaning that both current and voltage measurements are being taken from a feeder. 3I3U connection mode parameters can be found in a separate settings section, which is labelled with the communication mode designation (connection mode settings are described in the next section).

Selecting 3I3I connection mode in IOMod Utility changes IOMod Setting sections – 3I3U changes to 3I3I. IOMod Meter, in 3I3I connection mode, interprets the values measured with voltage inputs (terminals 7–12, see Fig. 2.2.1) as current measurements. 3I3I designation means – "3 currents and 3 currents", meaning that the voltage inputs become the second channel current inputs. The 3I3I settings section allows us to modify connection mode parameters (described in the next section).

The "Frequency" parameter allows us to set the nominal frequency of the power line to which the IOMod Meter is connected.

If the IEC 60870-5-103 communication protocol is selected, the "Measurands set" parameter sets one of the lists of

measurements (Table 6.3.2, Table 6.3.3), which is going to be sent to a master device.

If the IEC 60870-5-103 communication protocol is selected, the "Scale factor" parameter sets a value by which all measurements are going to be multiplied.

The value update time (ms) parameter defines how frequently the updated values are going to be sent to a controlling station via IEC 60870-5-101 or IEC 60870-5-103 communication protocols.

5.2 Connection mode settings

As was described earlier IOMod Meter supports two connection modes – 3I3U and 3I3I. After selecting one of them in General settings (Fig. 5.1.1), a new respectively named section appears. In this subsection, the parameters of a specific connection mode are going to be described.

5.2.1 3I3U connection mode parameters

The 3I3U connection mode parameters section has six parameters (Table 5.2), which are going to be described below.

Table 5.2.1.1 3I3U connection mode parameters.

Parameter	Range	Default value
Primary current (A)	1–2000	100
Primary voltage (kV)	0.2–60.0	10.0
Current sensor (mV)	100–300	225
Voltage sensor (V)	1.0–3.0	1.876
I0 mode	Calculated, Metered	Calculated
Primary current I0	1–2000	100

- The "Primary current (A)" parameter defines the nominal input current of a current sensor or a current transformer.
- The "Primary voltage (kV)" parameter sets the nominal input line voltage of a voltage sensor or a voltage transformer. If instead of the line voltage, the sensor or adapter converts the phase voltage, still, the value of the line voltage must be used. For example, if a voltage sensor declares the primary voltage of $10/\sqrt{3}$ kV, then 10 kV must be used for the "Primary voltage (kV)" parameter, for it is the line voltage of the network.
- The "Current sensor (mV)" parameter defines the nominal output voltage of a current sensor or a current transformer.
- The "Voltage sensor (V)" parameter defines the nominal output phase voltage of a voltage sensor or a voltage transformer. Contrary to the Primary Voltage, the phase voltage must be used for this parameter. For example, if a voltage sensor declares the secondary voltage of $3.25/\sqrt{3}$ V, then the approximate phase voltage value must be used. It means, that the given expression must be evaluated ($3.25/\sqrt{3} \approx 1.876$ V) and the result must be entered into the "Voltage sensor (V)" parameter (1.876 V).
- The "I0 mode" parameter defines the way of obtaining the neutral current values. The default parameter value is "Calculated", meaning that the value of the neutral current is going to be calculated by taking the phase current measurements. If "Metered" is selected, then the neutral current values are expected to be measured directly.
- The "Primary current I0" parameter defines the nominal input neutral current which is being measured by a Core Balance Current Transformer.

5.2.2 3I3I connection mode parameters

The 3I3I connection mode parameters section has eight parameters (Table 5.3), which are going to be described below.

Table 5.2.2.1 3I3I connection mode parameters.

Parameter	Range	Default value
Primary current ch1 (A)	1–2000	100
Primary current ch2 (A)	1–2000	100
Current sensor ch1 (mV)	100–300	225
Current sensor ch2 (mV)	100–300	225
I0 mode ch1	Calculated, Metered	Calculated
I0 mode ch2	Calculated, Metered	Calculated
Primary current I0 ch1	1–2000	100
Primary current I0 ch2	1–2000	100

- The "Primary current ch1 (A)" parameter sets the nominal input current of a current sensor or a current transformer which is connected to the first channel current inputs.
- The "Primary current ch2 (A)" parameter sets the nominal input current of a current sensor or a current transformer which is connected to the second channel current inputs.

- The "Current sensor ch1 (mV)" parameter defines the nominal output voltage of a current sensor or a current transformer which is connected to the first channel current inputs.
- The "Current sensor ch2 (mV)" parameter defines the nominal output voltage of a current sensor or a current transformer which is connected to the second channel current inputs.
- The "I0 mode ch1" parameter defines the way of obtaining the neutral current values with the first channel current inputs. The default parameter value is "Calculated", meaning that the value of the neutral current is going to be calculated by taking the phase current measurements. If "Metered" is selected, then the neutral current values are expected to be measured directly.
- The "I0 mode ch2" parameter defines the way of obtaining the neutral current values with the second channel current inputs. The default parameter value is "Calculated", meaning that the value of the neutral current is going to be calculated by taking the phase current measurements. If "Metered" is selected, then the neutral current values are expected to be measured directly.
- The "Primary current I0 ch1" parameter defines the nominal input neutral current which is being measured by a Core Balance Current Transformer connected to the first channel current inputs.
- The "Primary current I0 ch2" parameter defines the nominal input neutral current which is being measured by a Core Balance Current Transformer connected to the second channel current inputs.

5.3 Data Select

The data select tab (Fig. 5.3.1) is the last IOMod settings section, which provides a way to control the data being sent via the IEC 60870-5-101 communication protocol. The IOA (Information Object Address) of each data unit is specified in the brackets to the right of a parameter's name. To include a parameter to a set of parameters which are sent via IEC 60870-5-101 communication protocol a checkbox to the right of a parameter's name needs to be checked.

General | 3I3U | Data select

Item		Item		Item		Item		Item	
I1 (0)	☑	I2 (1)	☑	I3 (2)	☑	I0 (3)	☑	U12 (4)	☑
U23 (5)	☑	U31 (6)	☑	U1 (7)	☑	U2 (8)	☑	U3 (9)	☑
U0 (10)	☑	U1 angle (11)	☐	U2 angle (12)	☐	U3 angle (13)	☐	S (14)	☑
P (15)	☑	Q (16)	☑	PF (17)	☑	S1 (18)	☑	S2 (19)	☑
S3 (20)	☑	P1 (21)	☑	P2 (22)	☑	P3 (23)	☑	Q1 (24)	☑
Q2 (25)	☑	Q3 (26)	☑	PF1 (27)	☑	PF2 (28)	☑	PF3 (29)	☑
Frequency (30)	☑	THD U1 (31)	☐	THD U2 (32)	☐	THD U3 (33)	☐	THD I1 (34)	☐
THD I2 (35)	☐	THD I3 (36)	☐	I1 H3 (37)	☐	I1 H5 (38)	☐	I1 H7 (39)	☐
I1 H9 (40)	☐	I2 H3 (41)	☐	I2 H5 (42)	☐	I2 H7 (43)	☐	I2 H9 (44)	☐
I3 H3 (45)	☐	I3 H5 (46)	☐	I3 H7 (47)	☐	I3 H9 (48)	☐	U1 H3 (49)	☐
U1 H5 (50)	☐	U1 H7 (51)	☐	U1 H9 (52)	☐	U2 H3 (53)	☐	U2 H5 (54)	☐
U2 H7 (55)	☐	U2 H9 (56)	☐	U3 H3 (57)	☐	U3 H5 (58)	☐	U3 H7 (59)	☐
U3 H9 (60)	☐	I4 (61)	☑	U4 (62)	☑	I1 angle (63)	☐	I2 angle (64)	☐
I3 angle (65)	☐	I0 angle (66)	☐	U0 angle (67)	☐	U12 angle (68)	☐	U23 angle (69)	☐
U31 angle (70)	☐	I4 angle (71)	☐	U4 angle (72)	☐	Ip (73)	☐	In (74)	☐
Ip angle (75)	☐	In angle (76)	☐	Up (77)	☐	Un (78)	☐	Up angle (79)	☐
Un angle (80)	☐	I1 H2 (81)	☐	I2 H2 (82)	☐	I3 H2 (83)	☐	I1 ch2 (84)	☐
I2 ch2 (85)	☐	I3 ch2 (86)	☐	I0 ch2 (87)	☐	I4 ch2 (88)	☐	I1 angle ch2 (89)	☐
I2 angle ch2 (90)	☐	I3 angle ch2 (91)	☐	I0 angle ch2 (92)	☐	I4 angle ch2 (93)	☐	Ip ch2 (94)	☐
In ch2 (95)	☐	Ip angle ch2 (96)	☐	In angle ch2 (97)	☐	I1 H2 ch2 (98)	☐	I2 H2 ch2 (99)	☐
I3 H2 ch2 (100)	☐	THD I1 ch2 (101)	☐	THD I2 ch2 (102)	☐	THD I3 ch2 (103)	☐	I1 H3 ch2 (104)	☑
I1 H5 ch2 (105)	☑	I1 H7 ch2 (106)	☑	I1 H9 ch2 (107)	☑	I2 H3 ch2 (108)	☑	I2 H5 ch2 (109)	☐
I2 H7 ch2 (110)	☐	I2 H9 ch2 (111)	☐	I3 H3 ch2 (112)	☐	I3 H5 ch2 (113)	☐	I3 H7 ch2 (114)	☐
I3 H9 ch2 (115)	☐								

Fig. 5.3.1. IOMOD Meter Data select tab view

5.4 Diagnostics

The IOMod Utility Diagnostics tab allows real-time monitoring of IOMod Meter measurements and harmonics statuses. The diagnostics mode of both measurements and harmonics is turned off by default. This is indicated by the red "Offline" word designation and by the unchanging black circle (Fig. 5.4.1, Fig. 5.4.2).

| General info | Communication settings | Iomod settings | Diagnostics |

| Measurements | Harmonics |

| | | Connect | Offline ● |

| P | 0.00kW | Q | 0.00kVAr | S | 0.00kVA |

| PF | 0.000 | Frequency | 0.00Hz |

| Active energy import | 0kWh | Reactive energy import | 0kVArh |
| Active energy export | 0kWh | Reactive energy export | 0kVArh |

I1	0A	0°	I2	0A	0°	I3	0A	0°
U1	0	0°	U2	0	0°	U3	0	0°
U12	0	0°	U23	0	0°	U31	0	0°

I0	0A	0°	U0	0	0°
Ip	0A	0°	Up	0	0°
In	0A	0°	Un	0	0°
I4	0A	0°	U4	0	0°

P1	0.0kW	P2	0.0kW	P3	0.0kW
Q1	0.0kVAr	Q2	0.0kVAr	Q3	0.0kVAr
S1	0.0kVA	S2	0.0kVA	S3	0.0kVA
PF1	0.000	PF2	0.000	PF3	0.000

——————————— Current channel 2 ———————————

I1	0A	0°	I2	0A	0°	I3	0A	0°
I0	0A	0°	I4	0A	0°
Ip	0A	0°	In	0A	0°

Fig. 5.4.1. IOMod Utility Diagnostics tab, Measurements section in offline mode

Measurements | Harmonics

Connect   Offline ●

Total harmonic distortion

I1	0	I2/I0	0	I3	0
U1	0	U2	0	U3	0
Channel 2 I1	0	Channel 2 I2/I0	0	Channel 2 I3	0

2nd Harmonics

I1	0	I2	0	I3	0
Channel 2 I1	0	Channel 2 I2	0	Channel 2 I3	0

3rd Harmonics

I1	0	I2/I0	0	I3	0
U1	0	U2	0	U3	0
Channel 2 I1	0	Channel 2 I2/I0	0	Channel 2 I3	0

5th Harmonics

I1	0	I2/I0	0	I3	0
U1	0	U2	0	U3	0
Channel 2 I1	0	Channel 2 I2/I0	0	Channel 2 I3	0

7th Harmonics

I1	0	I2/I0	0	I3	0
U1	0	U2	0	U3	0
Channel 2 I1	0	Channel 2 I2/I0	0	Channel 2 I3	0

9th Harmonics

I1	0	I2/I0	0	I3	0
U1	0	U2	0	U3	0
Channel 2 I1	0	Channel 2 I2/I0	0	Channel 2 I3	0

Fig. 5.4.2 IOMod Utility Diagnostics tab Harmonics section in offline mode

To turn on real-time monitoring of both Diagnostics sections, the "Connect" button to the left of the "Offline" word designation needs to be pressed. The button can be pressed in either the Diagnostics sections (Measurements or Harmonics). After pressing the "Connect" button, the word designation of Diagnostics mode changes to "Online", the black circle starts blinking, and the button name changes to "Disconnect".

It is advisable to turn off Diagnostics mode before setting new IOMod Meter parameters. To turn off Diagnostics real-time monitoring mode, the "Disconnect" button needs to be pressed.

6. Communication Protocols

IOMod Meter supports three communication protocols: Modbus RTU, IEC 60870-5-101 and IEC 60870-5-103. Using these communication protocols, a user via a master device can read the measured data from the device. The communication protocol can be selected using the IOMod Utility (the IOMod Utility manual can be accessed here).

6.1 Modbus RTU operational information

When the Modbus RTU protocol is selected IOMod Meter acts as a slave device and waits for requests from the Modbus master. For reading the measurements, a master can send a Read Input Register (FC 04) request. A request with an unsupported function code or register number out of range will be answered with the corresponding exception. Measurement results in nominal values have an integer type, while results in primary values are 32-bit float type.

Table 6.1.1 Nominal values in integer format. The data can be read using a Modbus FC4 request.

Address (Dec)	Description	Units	Data type	Access
0	Phase L1 current	% x10	UINT16	R
1	Phase L2 current	% x10	UINT16	R
2	Phase L3 current	% x10	UINT16	R
3	Calculated neutral current	% x10	UINT16	R
4	Calculated line voltage U_{12}	% x10	UINT16	R
5	Calculated line voltage U_{23}	% x10	UINT16	R
6	Calculated line voltage U_{31}	% x10	UINT16	R
7	Calculated zero sequence voltage	% x10	UINT16	R
8	Total 3-phase apparent power (S1+S2+S3)	% x10	UINT16	R
9	Total 3-phase active power (P1+P2+P3)	% x10	INT16	R
10	Total 3-phase reactive power (Q1+Q2+Q3)	% x10	INT16	R
11	Total 3-phase power factor	x1000	INT16	R
12	Total harmonic distortions of U1 voltage		UINT16	R
13	Total harmonic distortions of U2 voltage		UINT16	R
14	Total harmonic distortions of U3 voltage		UINT16	R
15	Total harmonic distortions of I1 current		UINT16	R
16	Total harmonic distortions of I2 current		UINT16	R
17	Total harmonic distortions of I3 current		UINT16	R
18	3rd harmonic level of the I1 current	%	UINT16	R
19	5th harmonic level of I1 current	%	UINT16	R
20	7th harmonic level of I1 current	%	UINT16	R
21	9th harmonic level of I1 current	%	UINT16	R
22	3rd harmonic level of the I2 current	%	UINT16	R
23	5th harmonic level of I2 current	%	UINT16	R
24	7th harmonic level of I2 current	%	UINT16	R
25	9th harmonic level of I2 current	%	UINT16	R
26	3rd harmonic level of the I3 current	%	UINT16	R
27	5th harmonic level of I3 current	%	UINT16	R
28	7th harmonic level of I3 current	%	UINT16	R

29	9th harmonic level of I3 current	%	UINT16	R
30	3rd harmonic level of U1 voltage	%	UINT16	R
31	5th harmonic level of U1 voltage	%	UINT16	R
32	7th harmonic level of U1 voltage	%	UINT16	R
33	9th harmonic level of U1 voltage	%	UINT16	R
34	3rd harmonic level of U2 voltage	%	UINT16	R
35	5th harmonic level of U2 voltage	%	UINT16	R
36	7th harmonic level of U2 voltage	%	UINT16	R
37	9th harmonic level of U2 voltage	%	UINT16	R
38	3rd harmonic level of U3 voltage	%	UINT16	R
39	5th harmonic level of U3 voltage	%	UINT16	R
40	7th harmonic level of U3 voltage	%	UINT16	R
41	9th harmonic level of U3 voltage	%	UINT16	R
42	Phase L1 active power	% x10	INT16	R
43	Phase L2 active power	% x10	INT16	R
44	Phase L3 active power	% x10	INT16	R
45	Phase L1 reactive power	% x10	INT16	R
46	Phase L2 reactive power	% x10	INT16	R
47	Phase L3 reactive power	% x10	INT16	R
48	The phase angle of U1 voltage	0.1 deg	INT16	R
49	The phase angle of U2 voltage	0.1 deg	INT16	R
50	The phase angle of U3 voltage	0.1 deg	INT16	R
51	Phase L1 voltage	% x10	UINT16	R
52	Phase L2 voltage	% x10	UINT16	R
53	Phase L3 voltage	% x10	UINT16	R
54	Frequency of phase L1 voltage	Hz x100	UINT16	R
55	Input I4 current	% x10	UINT16	R
56	Input U4 voltage	% x10	UINT16	R
57	S1 phase apparent power	% x10	INT16	R
58	S2 phase apparent power	% x10	INT16	R
59	S3 phase apparent power	% x10	INT16	R
60	L1 phase power factor	% x10	INT16	R
61	L2 phase power factor	% x10	INT16	R
62	L3 phase power factor	% x10	INT16	R
63	The angle of the I1 current	0.1 deg	INT16	R
64	The angle of the I2 current	0.1 deg	INT16	R
65	The angle of the I3 current	0.1 deg	INT16	R
66	Line voltage U_{12} angle	0.1 deg	INT16	R
67	Line voltage U_{23} angle	0.1 deg	INT16	R
68	Line voltage U_{31} angle	0.1 deg	INT16	R
69	Current positive sequence	Data * 10	UINT16	%

70	Current negative sequence	% x10	UINT16	R
71	Voltage positive sequence	% x10	UINT16	R
72	Voltage negative sequence	% x10	UINT16	R
73	Current I_0 angle	0.1 deg	UINT16	R
74	Current I_4 angle	0.1 deg	UINT16	R
75	Voltage U_0 angle	0.1 deg	UINT16	R
76	Voltage U_4 angle	0.1 deg	UINT16	R
77	Current I_p angle	0.1 deg	UINT16	R
78	Current I_n angle	0.1 deg	UINT16	R
79	Current U_p angle	0.1 deg	UINT16	R
80	Current U_n angle	0.1 deg	UINT16	R
81	Current I_1 2nd harmonic	% x10	UINT16	R
82	Current I_2 2nd harmonic	% x10	UINT16	R
83	Current I_3 2nd harmonic	% x10	UINT16	R
84	Current I1 channel 2	% x10	UINT16	R
85	Current I2 channel 2	% x10	UINT16	R
86	Current I3 channel 2	% x10	UINT16	R
87	Current I0 channel 2	% x10	UINT16	R
88	Current I4 channel 2	% x10	UINT16	R
89	Current Ip channel 2	% x10	UINT16	R
90	Current In channel 2	% x10	UINT16	R
91	Current I1 channel 2 angle	0.1 deg	UINT16	R
92	Current I2 channel 2 angle	0.1 deg	UINT16	R
93	Current I3 channel 2 angle	0.1 deg	UINT16	R
94	Current I0 channel 2 angle	0.1 deg	UINT16	R
95	Current I4 channel 2 angle	0.1 deg	UINT16	R
96	Current Ip channel 2 angle	0.1 deg	UINT16	R
97	Current In channel 2 angle	0.1 deg	UINT16	R
98	Current I1 2nd harmonic channel 2	0.1 deg	UINT16	R
99	Current I2 2nd harmonic channel 2	0.1 deg	UINT16	R
100	Current I3 2nd harmonic channel 2	0.1 deg	UINT16	R
101	THD of current I1 channel 2		UINT16	R
102	THD of current I2 channel 2		UINT16	R
103	THD of current I3 channel 2		UINT16	R
104	Current I1 3rd harmonic channel 2	%	UINT16	R
105	Current I1 5th harmonic channel 2	%	UINT16	R
106	Current I1 7th harmonic channel 2	%	UINT16	R
107	Current I1 9th harmonic channel 2	%	UINT16	R
108	Current I2 3rd harmonic channel 2	%	UINT16	R
109	Current I2 5th harmonic channel 2	%	UINT16	R
110	Current I2 7th hamonic channel 2	%	UINT16	R
111	Current I2 9th harmonic channel 2	%	UINT16	R

Address (Dec)	Description	Units	Data type	Access
112	Current I3 3rd harmonic channel 2	%	UINT16	R
113	Current I3 5th harmonic channel 2	%	UINT16	R
114	Current I3 7th harmonic channel 2	%	UINT16	R
115	Current I3 9th harmonic channel 2	%	UINT16	R
116-117	Active import energy	kWh	UINT32	R
118-119	Active export energy	kWh	UINT32	R
120-121	Reactive import energy	kVArh	UINT32	R
122-123	Reactive export energy	kVArh	UINT32	R

Table 6.1.2 Primary values in float format. The data can be read using Modbus FC4.

Address (Dec)	Description	Units	Data type	Access
200 - 201	Current I1	A	FLOAT	R
202 - 203	Current I2	A	FLOAT	R
204 - 205	Current I3	A	FLOAT	R
206 - 207	Current I0	A	FLOAT	R
208 - 209	Voltage U12	U	FLOAT	R
210 - 211	Voltage U23	U	FLOAT	R
212 - 213	Voltage U31	U	FLOAT	R
214 - 215	Voltage U1	U	FLOAT	R
216 - 217	Voltage U2	U	FLOAT	R
218 - 219	Voltage U3	U	FLOAT	R
220 - 221	Voltage U0	U	FLOAT	R
222 - 223	Voltage U1 angle	°	FLOAT	R
224 - 225	Voltage U2 angle	°	FLOAT	R
226 - 227	Voltage U3 angle	°	FLOAT	R
228 - 229	Apparent power Σ3 phase	VA	FLOAT	R
230 - 231	Active power Σ3 phase	W	FLOAT	R
232 - 233	Reactive power Σ3 phase	Var	FLOAT	R
234 - 235	Power factor Σ3 phase		FLOAT	R
236 - 237	Apparent power S1	VA	FLOAT	R
238 - 239	Apparent power S2	VA	FLOAT	R
240 - 241	Apparent power S3	VA	FLOAT	R
242 - 243	Active power P1	W	FLOAT	R
244 - 245	Active power P2	W	FLOAT	R
246 - 247	Active power P3	W	FLOAT	R
248 - 249	Reactive power Q1	Var	FLOAT	R
250 - 251	Reactive power Q2	Var	FLOAT	R
252 - 253	Reactive power Q3	Var	FLOAT	R
254 - 255	Power factor PF1		FLOAT	R
256 - 257	Power factor PF2		FLOAT	R
258 - 259	Power factor PF3		FLOAT	R
260 - 261	Frequency	Hz	FLOAT	R
262 - 263	THD Voltage U1		FLOAT	R
264 - 265	THD Voltage U2		FLOAT	R
266 - 267	THD Voltage U3		FLOAT	R
268 - 269	THD Current I1		FLOAT	R
270 - 271	THD Current I2		FLOAT	R

272 - 273	THD Current I3		FLOAT	R
274 - 275	Current I1 3rd harmonic		FLOAT	R
276 - 277	Current I1 5th harmonic		FLOAT	R
278 - 279	Current I1 7th harmonic		FLOAT	R
280 - 281	Current I1 9th harmonic		FLOAT	R
282 - 283	Current I2 3rd harmonic		FLOAT	R
284 - 285	Current I2 5th harmonic		FLOAT	R
286 - 287	Current I2 7th harmonic		FLOAT	R
288 - 289	Current I2 9th harmonic		FLOAT	R
290 - 291	Current I3 3rd harmonic		FLOAT	R
292 - 293	Current I3 5th harmonic		FLOAT	R
294 - 295	Current I3 7th harmonic		FLOAT	R
296 - 297	Current I3 9th harmonic		FLOAT	R
298 - 299	Voltage U1 3rd harmonic		FLOAT	R
300 - 301	Voltage U1 5th harmonic		FLOAT	R
302 - 303	Voltage U1 7th harmonic		FLOAT	R
304 - 305	Voltage U1 9th harmonic		FLOAT	R
306 - 307	Voltage U2 3rd harmonic		FLOAT	R
308 - 309	Voltage U2 5th harmonic		FLOAT	R
310 - 311	Voltage U2 7th harmonic		FLOAT	R
312 - 313	Voltage U2 9th harmonic		FLOAT	R
314 - 315	Voltage U3 3rd harmonic		FLOAT	R
316 - 317	Voltage U3 5th harmonic		FLOAT	R
318 - 319	Voltage U3 7th harmonic		FLOAT	R
320 - 321	Voltage U3 9th harmonic		FLOAT	R
322 - 323	Current I4	A	FLOAT	R
324 - 325	Voltage U4	U	FLOAT	R
326 - 327	Current I1 angle	°	FLOAT	R
328 - 329	Current I2 angle	°	FLOAT	R
330 - 331	Current I3 angle	°	FLOAT	R
332 - 333	Current I0 angle	°	FLOAT	R
334 - 335	Voltage U0 angle	°	FLOAT	R
336 - 337	Voltage U12 angle	°	FLOAT	R
338 - 339	Voltage U23 angle	°	FLOAT	R
340 - 341	Voltage U31 angle	°	FLOAT	R
342 - 343	Current I4 angle	°	FLOAT	R
344 - 345	Voltage U4 angle	°	FLOAT	R
346 - 347	Current positive seq Ip	A	FLOAT	R
348 - 349	Current negative seq In	A	FLOAT	R
350 - 351	Current Ip angle	°	FLOAT	R
352 - 353	Current In angle	°	FLOAT	R
354 - 355	Voltage positive seq Up	U	FLOAT	R
356 - 357	Voltage negative seq Un	U	FLOAT	R
358 - 359	Voltage Up angle	°	FLOAT	R
360 - 361	Voltage Un angle	°	FLOAT	R
362 - 363	Current I1 2nd harmonic		FLOAT	R
364 - 365	Current I2 2nd harmonic		FLOAT	R
366 - 367	Current I3 2nd harmonic		FLOAT	R
368 - 369	Current I1 channel 2	A	FLOAT	R
370 - 371	Current I2 channel 2	A	FLOAT	R

372 - 373	Current I3 channel 2	A	FLOAT	R
374 - 375	Current I0 channel 2	A	FLOAT	R
376 - 377	Current I4 channel 2	A	FLOAT	R
378 - 379	Current I1 channel 2 angle	°	FLOAT	R
380 - 381	Current I2 channel 2 angle	°	FLOAT	R
382 - 383	Current I3 channel 2 angle	°	FLOAT	R
384 - 385	Current I0 channel 2 angle	°	FLOAT	R
386 - 387	Current I4 channel 2 angle	°	FLOAT	R
388 - 389	Current Ip channel 2	A	FLOAT	R
390 - 391	Current In channel 2	A	FLOAT	R
392 - 393	Current Ip channel 2 angle	°	FLOAT	R
394 - 395	Current In channel 2 angle	°	FLOAT	R
396 - 397	Current I1 2nd harmonic ch2		FLOAT	R
398 - 399	Current I2 2nd harmonic ch2		FLOAT	R
400 - 401	Current I3 2nd harmonic ch2		FLOAT	R
402 - 403	THD Current I1 ch2		FLOAT	R
404 - 405	THD Current I2 ch2		FLOAT	R
406 - 407	THD Current I3 ch2		FLOAT	R
408 - 409	Current I1 3rd harmonic ch2		FLOAT	R
410 - 411	Current I1 5th harmonic ch2		FLOAT	R
412 - 413	Current I1 7th harmonic ch2		FLOAT	R
414 - 415	Current I1 9th harmonic ch2		FLOAT	R
416 - 417	Current I2 3rd harmonic ch2		FLOAT	R
418 - 419	Current I2 5th harmonic ch2		FLOAT	R
420 - 421	Current I2 7th harmonic ch2		FLOAT	R
422 - 423	Current I2 9th harmonic ch2		FLOAT	R
424 - 425	Current I3 3rd harmonic ch2		FLOAT	R
426 - 427	Current I3 5th harmonic ch2		FLOAT	R
428 - 429	Current I3 7th harmonic ch2		FLOAT	R
430 - 431	Current I3 9th harmonic ch2		FLOAT	R

6.2 IEC 60870-5-101 operational information

IEC 60870-5-101 (IEC101) is a communication protocol designed for telecontrol applications in power systems, enabling communication between a master station and slave devices (e.g., Remote Terminal Units or RTUs). The implementation of IEC101 protocol allows for a data transfer to be initiated only by a master (unbalanced mode).

IOMod Meter via IEC101 protocol transmits various measurement signals in a standardized format. These signals are predefined in the IOMod and mapped to corresponding Information Object Addresses (IOA).

Using IOMod devices along with WCC Lite allows sending broadcast time synchronization messages to multiple IOMod devices simultaneously.

The protocol distinguishes between **Type Identifiers (TI)**, which, according to the standard, define the format, structure and type of the data being sent. The measurement signals are assigned to two different Type Identifiers, 7 and 13.

All the measurements are represented in absolute values without any scaling and using standard units. Almost every measurement can be sent using 13 ("measured value, short floating-point number"). The measurements which are

sent with TI 13 signals are not marked with timestamps. This is because these signals are not intended for spontaneous transmission upon a change, but rather are to be polled by a controlling (master) station. All energy measurements are assigned to the signals with TI 7, which stands for "bitstring of 32 bits". The necessity for other data formats for the energy measurements comes from the fact that they are saved in a 32-bit unsigned integer data type. The usage of an integer type instead of a float ensures better precision.

Table 6.2.1 List of IEC101 measurement signals

IOA	Description	Units	TI
0	Current I_1	A	13 (M_ME_NC_1)
1	Current I_2	A	13 (M_ME_NC_1)
2	Current I_3	A	13 (M_ME_NC_1)
3	Current I_0	A	13 (M_ME_NC_1)
4	Voltage U_{12}	U	13 (M_ME_NC_1)
5	Voltage U_{23}	U	13 (M_ME_NC_1)
6	Voltage U_{31}	U	13 (M_ME_NC_1)
7	Voltage U_1	U	13 (M_ME_NC_1)
8	Voltage U_2	U	13 (M_ME_NC_1)
9	Voltage U_3	U	13 (M_ME_NC_1)
10	Voltage U_0	U	13 (M_ME_NC_1)
11	Voltage U_1 angle	°	13 (M_ME_NC_1)
12	Voltage U_2 angle	°	13 (M_ME_NC_1)
13	Voltage U_3 angle	°	13 (M_ME_NC_1)
14	Apparent power Σ 3-phase	VA	13 (M_ME_NC_1)
15	Active power Σ 3-phase	W	13 (M_ME_NC_1)
16	Reactive power Σ 3-phase	Var	13 (M_ME_NC_1)
17	Power factor Σ 3-phase		13 (M_ME_NC_1)
18	Apparent power S_1	VA	13 (M_ME_NC_1)
19	Apparent power S_2	VA	13 (M_ME_NC_1)
20	Apparent power S_3	VA	13 (M_ME_NC_1)
21	Active power P_1	W	13 (M_ME_NC_1)

22	Active power P_2	W	13 (M_ME_NC_1)
23	Active power P_3	W	13 (M_ME_NC_1)
24	Reactive power Q_1	Var	13 (M_ME_NC_1)
25	Reactive power Q_2	Var	13 (M_ME_NC_1)
26	Reactive power Q_3	Var	13 (M_ME_NC_1)
27	Power factor PF_1		13 (M_ME_NC_1)
28	Power factor PF_2		13 (M_ME_NC_1)
29	Power factor PF_3		13 (M_ME_NC_1)
30	Frequency	Hz	13 (M_ME_NC_1)
31	THD Voltage U_1		13 (M_ME_NC_1)
32	THD Voltage U_2		13 (M_ME_NC_1)
33	THD Voltage U_3		13 (M_ME_NC_1)
34	THD Current I_1		13 (M_ME_NC_1)
35	THD Current I_2		13 (M_ME_NC_1)
36	THD Current I_3		13 (M_ME_NC_1)
37	Current I_1 3rd harmonic		13 (M_ME_NC_1)
38	Current I_1 5th harmonic		13 (M_ME_NC_1)
39	Current I_1 7th harmonic		13 (M_ME_NC_1)
40	Current I_1 9th harmonic		13 (M_ME_NC_1)
41	Current I_2 3rd harmonic		13 (M_ME_NC_1)
42	Current I_2 5th harmonic		13 (M_ME_NC_1)
43	Current I_2 7th harmonic		13 (M_ME_NC_1)
44	Current I_2 9th harmonic		13 (M_ME_NC_1)
45	Current I_3 3rd harmonic		13 (M_ME_NC_1)
46	Current I_3 5th harmonic		13 (M_ME_NC_1)

47	Current I_3 7th harmonic		13 (M_ME_NC_1)
48	Current I_3 9th harmonic		13 (M_ME_NC_1)
49	Voltage U_1 3rd harmonic		13 (M_ME_NC_1)
50	Voltage U_1 5th harmonic		13 (M_ME_NC_1)
51	Voltage U_1 7th harmonic		13 (M_ME_NC_1)
52	Voltage U_1 9th harmonic		13 (M_ME_NC_1)
53	Voltage U_2 3rd harmonic		13 (M_ME_NC_1)
54	Voltage U_2 5th harmonic		13 (M_ME_NC_1)
55	Voltage U_2 7th harmonic		13 (M_ME_NC_1)
56	Voltage U_2 9th harmonic		13 (M_ME_NC_1)
57	Voltage U_3 3rd harmonic		13 (M_ME_NC_1)
58	Voltage U_3 5th harmonic		13 (M_ME_NC_1)
59	Voltage U_3 7th harmonic		13 (M_ME_NC_1)
60	Voltage U_3 9th harmonic		13 (M_ME_NC_1)
61	Current I_4	A	13 (M_ME_NC_1)
62	Voltage U_4	U	13 (M_ME_NC_1)
63	Current I_1 angle	°	13 (M_ME_NC_1)
64	Current I_2 angle	°	13 (M_ME_NC_1)
65	Current I_3 angle	°	13 (M_ME_NC_1)
66	Current I_0 angle	°	13 (M_ME_NC_1)
67	Voltage U_0 angle	°	13 (M_ME_NC_1)
68	Voltage U_{12} angle	°	13 (M_ME_NC_1)
69	Voltage U_{23} angle	°	13 (M_ME_NC_1)
70	Voltage U_{31} angle	°	13 (M_ME_NC_1)
71	Current I_4 angle	°	13 (M_ME_NC_1)

72	Voltage U_4 angle	°	13 (M_ME_NC_1)
73	Current positive seq I_p	A	13 (M_ME_NC_1)
74	Current negative seq I_n	A	13 (M_ME_NC_1)
75	Current I_p angle	°	13 (M_ME_NC_1)
76	Current I_n angle	°	13 (M_ME_NC_1)
77	Voltage positive seq U_p	U	13 (M_ME_NC_1)
78	Voltage negative seq U_n	U	13 (M_ME_NC_1)
79	Voltage U_p angle	°	13 (M_ME_NC_1)
80	Voltage U_n angle	°	13 (M_ME_NC_1)
81	Current I_1 2nd harmonic		13 (M_ME_NC_1)
82	Current I_2 2nd harmonic		13 (M_ME_NC_1)
83	Current I_3 2nd harmonic		13 (M_ME_NC_1)
84	Current I_1 channel 2	A	13 (M_ME_NC_1)
85	Current I_2 channel 2	A	13 (M_ME_NC_1)
86	Current I_3 channel 2	A	13 (M_ME_NC_1)
87	Current I_0 channel 2	A	13 (M_ME_NC_1)
88	Current I_4 channel 2	A	13 (M_ME_NC_1)
89	Current I_1 channel 2 angle	°	13 (M_ME_NC_1)
90	Current I_2 channel 2 angle	°	13 (M_ME_NC_1)
91	Current I_3 channel 2 angle	°	13 (M_ME_NC_1)
92	Current I_0 channel 2 angle	°	13 (M_ME_NC_1)
93	Current I_4 channel 2 angle	°	13 (M_ME_NC_1)
94	Current I_p channel 2	A	13 (M_ME_NC_1)
95	Current I_n channel 2	A	13 (M_ME_NC_1)
96	Current I_p channel 2 angle	°	13 (M_ME_NC_1)

97	Current I_n channel 2 angle	°	13 (M_ME_NC_1)
98	Current I_1 2nd harmonic ch2		13 (M_ME_NC_1)
99	Current I_2 2nd harmonic ch2		13 (M_ME_NC_1)
100	Current I_3 2nd harmonic ch2		13 (M_ME_NC_1)
101	THD Current I_1 ch2		13 (M_ME_NC_1)
102	THD Current I_2 ch2		13 (M_ME_NC_1)
103	THD Current I_3 ch2		13 (M_ME_NC_1)
104	Current I_1 3rd harmonic ch2		13 (M_ME_NC_1)
105	Current I_1 5th harmonic ch2		13 (M_ME_NC_1)
106	Current I_1 7th harmonic ch2		13 (M_ME_NC_1)
107	Current I_1 9th harmonic ch2		13 (M_ME_NC_1)
108	Current I_2 3rd harmonic ch2		13 (M_ME_NC_1)
109	Current I_2 5th harmonic ch2		13 (M_ME_NC_1)
110	Current I_2 7th harmonic ch2		13 (M_ME_NC_1)
111	Current I_2 9th harmonic ch2		13 (M_ME_NC_1)
112	Current I_3 3rd harmonic ch2		13 (M_ME_NC_1)
113	Current I_3 5th harmonic ch2		13 (M_ME_NC_1)
114	Current I_3 7th harmonic ch2		13 (M_ME_NC_1)
115	Current I_3 9th harmonic ch2		13 (M_ME_NC_1)
400	Active import energy	kWh	7 (M_BO_NA_1)
401	Active export energy	kWh	7 (M_BO_NA_1)
402	Reactive import energy	kVArh	7 (M_BO_NA_1)
403	Reactive export energy	kVArh	7 (M_BO_NA_1)

6.3 IEC 60870-5-103 operational information

When the IEC-60870-5-103 protocol is selected, IOMod Meter uses a standard communication scheme. Initiation, control messages, and queries are initiated by a master (controlling station), while the IOMod device (controlled station) only answers requests and sends values. The first message sent by the master should be RESET CU to restart communication. When an *acknowledge* (ACK) packet is sent from a slave device, a master may proceed with acquiring *General Interrogation* and sending *Time synchronization* packets.

When this initialization is complete, the master should poll the IOMod Meter with Class 1 and Class 2 requests. Class 2 is used when the master polls for cyclic data. The controlled device responds when spontaneous data exists and the master then sends a request for Class 1. The controlled station responds with a time-tagged message.

Time synchronization is critical for logging events. To synchronize time, the master sends a Time Sync command with function 0 and Cause of Transmission (COT) 8. According to the IEC 60870-5-103 protocol specification, time synchronization can be performed for multiple devices using broadcast messages. For broadcast time synchronization, the master device sends a periodic signal with a time stamp to synchronize the system time of slave devices. If synchronization fails, devices default to their local system time until they successfully resynchronize.

As IOMod Meter does not have any digital inputs, only analog ones, the general interrogation returns nothing. Values of measurements are returned cyclically as a response to Class 2 data requests.

Specific settings for the IEC 60870-5-103 protocol:

1. Measurand set selection. A user can select which predefined measurand set will be transmitted to the host system. Available measurand sets are presented in Table 6.3.1.
2. Scale factor. The communication protocol IEC 60870-5-103 only lets 13-bit signed values in the range of -1...+1. When an IEC 60870-5-103 measurand, for example, phase voltage, is scaled as 2.4, it means that the measurand value 1 corresponds to 2.4 multiplied by Un, the measurand value 0.5 corresponds to 1.2 multiplied by In, and so on. If the measurand value, in this case, exceeds 2.4 multiplied by Un, the IEC 60870-5-103 object value saturates at its maximum value, and an overflow flag is set in the IEC 60870-5-103 object transmission.
3. Device function type. By default, IOMod has the IEC 60870-5-103 Function Type set to 253. If this Function type, for some reason, is not suitable, a user can define any other type

Table 6.3.1. Data sets for 3I3U connection mode

Set Nr.	TYPE	FUN*	INF	Qty of data	Information elements (measurands)
1	9	253	148	9	I_1, I_2, I_3, U_1, U_2, U_3, P, Q, f
2	9	253	149	23	I_1, I_2, I_3, I_4, U_1, U_2, U_3, U_4, P_1, P_2, P_3, Q_1, Q_2, Q_3, S_1, S_2, S_3, PF_1, PF_2, PF_3, $U_{12}^{(angle)}$, $U_{23}^{(angle)}$, $U_{13}^{(angle)}$
3	9	253	150	60	I_1, I_2, I_3, I_N, U_1, U_2, U_3, U_N, P_1, P_2, P_3, Q_1, Q_2, Q_3, S_1, S_2, S_3, PF_1, PF_2, PF_3, U_{12}, U_{23}, U_{13}, f, THD_{U1}, THD_{U2}, THD_{U3}, THD_{I1}, THD_{I2}, THD_{I3}, $I_1^{(h2)}$, $I_1^{(h3)}$, $I_1^{(h5)}$, $I_1^{(h7)}$, $I_1^{(h9)}$, $I_2^{(h2)}$, $I_2^{(h3)}$, $I_2^{(h5)}$, $I_2^{(h7)}$, $I_2^{(h9)}$, $I_3^{(h2)}$, $I_3^{(h3)}$, $I_3^{(h5)}$, $I_3^{(h7)}$, $I_3^{(h9)}$, $U_1^{(h2)}$, $U_1^{(h3)}$, $U_1^{(h5)}$, $U_1^{(h7)}$, $U_1^{(h9)}$, $U_2^{(h2)}$, $U_2^{(h3)}$, $U_2^{(h5)}$, $U_2^{(h7)}$, $U_2^{(h9)}$, $U_3^{(h2)}$, $U_3^{(h3)}$, $U_3^{(h5)}$, $U_3^{(h7)}$, $U_3^{(h9)}$
4	9	253	151	54	I_1, I_2, I_3, I_N, U_{12}, U_{23}, U_{13}, U_N, S, P, Q, PF, THD_{U1}, THD_{U2}, THD_{U3}, THD_{I1}, THD_{I2}, THD_{I3}, $I_1^{(h3)}$, $I_1^{(h5)}$, $I_1^{(h7)}$, $I_1^{(h9)}$, $I_2^{(h3)}$, $I_2^{(h5)}$, $I_2^{(h7)}$, $I_2^{(h9)}$, $I_3^{(h3)}$, $I_3^{(h5)}$, $I_3^{(h7)}$, $I_3^{(h9)}$, $U_1^{(h3)}$, $U_1^{(h5)}$, $U_1^{(h7)}$, $U_1^{(h9)}$, $U_2^{(h3)}$, $U_2^{(h5)}$, $U_2^{(h7)}$, $U_2^{(h9)}$, $U_3^{(h3)}$, $U_3^{(h5)}$, $U_3^{(h7)}$, $U_3^{(h9)}$, P_1, P_2, P_3, Q_1, Q_2, Q_3, $U_1^{(angle)}$, $U_2^{(angle)}$, $U_3^{(angle)}$, U_1, U_2, U_3

6.3.2 Data sets for 3I3I connection mode

Set Nr.	TYPE	FUN*	INF	Qty of data	Information elements (measurands)
1	9	253	148	7	$I_1^{(ch1)}, I_2^{(ch1)}, I_3^{(ch1)}, I_1^{(ch2)}, I_2^{(ch2)}, I_3^{(ch2)}, f$
2	9	253	149	8	$I_1^{(ch1)}, I_2^{(ch1)}, I_3^{(ch1)}, I_4^{(ch1)}, I_1^{(ch2)}, I_2^{(ch2)}, I_3^{(ch2)}, I_4^{(ch2)}$
3	9	253	150	45	$I_1^{(ch1)}, I_2^{(ch1)}, I_3^{(ch1)}, I_0^{(ch1)}, I_1^{(ch2)}, I_2^{(ch2)}, I_3^{(ch2)}, I_0^{(ch2)}, f, THD_{I1}^{(ch1)}, THD_{I2}^{(ch1)}, THD_{I3}^{(ch1)}, I_1^{(h3, ch1)}, I_1^{(h5, ch1)}, I_1^{(h7, ch1)}, I_1^{(h9, ch1)}, I_2^{(h3, ch1)}, I_2^{(h5, ch1)}, I_2^{(h7, ch1)}, I_2^{(h9, ch1)}, I_3^{(h3, ch1)}, I_3^{(h5, ch1)}, I_3^{(h7, ch1)}, I_3^{(h9, ch1)}, THD_{I1}^{(ch2)}, THD_{I2}^{(ch2)}, THD_{I3}^{(ch2)}, I_1^{(h3, ch2)}, I_1^{(h5, ch2)}, I_1^{(h7, ch2)}, I_1^{(h9, ch2)}, I_2^{(h3, ch2)}, I_2^{(h5, ch2)}, I_2^{(h7, ch2)}, I_2^{(h9, ch2)}, I_3^{(h3, ch2)}, I_3^{(h5, ch2)}, I_3^{(h7, ch2)}, I_3^{(h9, ch2)}$

A certain set of measurements can be configured in IOMod Utility General settings (see Table 5.1.1, Fig. 6.3.1).

Measurands set	1 ⌄
Scale factor	1.2 ⌄
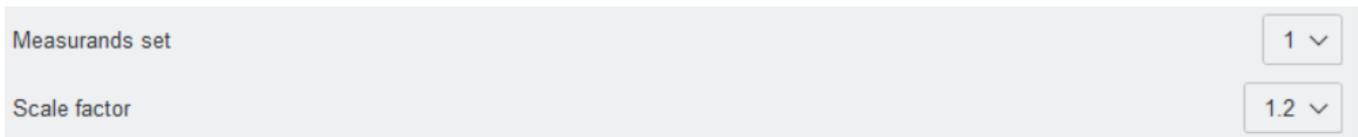
Fig. 6.3.1. IOMod Utility General settings IEC 60870-5-103 protocol parameters

Type 9 signals allocate only 13 bits for measurement values, which is not enough for float values to be transferred. For that reason, all measurement data are being scaled. However, not all values are scaled the same. All currents, voltages and power measurements are scaled using the same algorithm. The range of the maximum and the minimum measurement values, which can be transferred with the IEC103 protocol, is calculated by multiplying the nominal value by the scale factor:

$$MMV = SF \cdot NV \quad (6.3.1)$$

- MMV – maximum measurement value;
- NV – nominal value;
- SF – scale factor;

The scale factor of most measurements can be selected in IOMod Utility General settings (Table 5.1.1, Fig. 6.3.1). The maximum measurement value (MMV) is only the upper limit of the allowed range. The full allowed range goes from -MMV up to +MMV. Since the first bit is used to denote the sign, the maximum absolute value, which can be sent via IEC 60870-5-103 communication protocol, is $2^{12} = 4096$. The MMV is mapped to this value, so that if the measured value is equal to the MMV, 4096 is going to be sent to a controlling station via IEC103 protocol. If a measurement value exceeds MMV, then the overflow is going to be indicated by the signal and 4096 is going to be sent. If a measured value is inside the allowed range, then the scaled value, which is going to be sent using the IEC103 signal, is calculated by multiplying it by 4096 and dividing it by the maximum measurement value:

$$SV = \frac{MV \cdot 4096}{MMV}, \text{ where } -MMV \le MV \le +MMV \quad (6.3.2)$$

- SV – scaled value, which is going to be sent using IEC103 protocol;
- MV – measured value, which must be in the allowed range;
- MMV – maximum measurement value;

In the special case where the measured value is equal to the nominal value, the scaled value formula can be simplified as:

$$SV = \frac{NV \cdot 4096}{SF \cdot NV} = \frac{4096}{SF} \quad (6.3.3)$$

The scaled values of other measurands are calculated by using different scaling techniques. The scaled frequency is

calculated by multiplying the measured frequency by 50. All angle measurements are scaled by a factor of 10.