

# Firmware version 2

- IOMOD 4Cs4Vs User Manual

# IOMOD 4Cs4Vs User Manual

## 1. Introduction

IOMod 4Cs4Vs is a compact-sized stand-alone power meter for measuring analog AC input signals from low-power current and voltage sensors. It measures three AC voltages and current phases with additional inputs for neutral/residual voltage and current. The measured and calculated values are transmitted to the host system via communication protocol **IEC 60870-5-103**, **IEC 60870-5-101** or **Modbus RTU**.

### 1.1 Features

- 4 AC sensor inputs according to IEC 60044-8 (nominal value 225mV);
- 4 AC voltage sensor inputs according to IEC 60044-7 (nominal value  $3.25/\sqrt{3}$  V);
- 32 samples per cycle;
- FFT-based calculation with harmonic information;
- Configurable using the IOMod Utility app for user-friendly setup;
- Firmware upgrade over USB or RS485;
- RS485 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

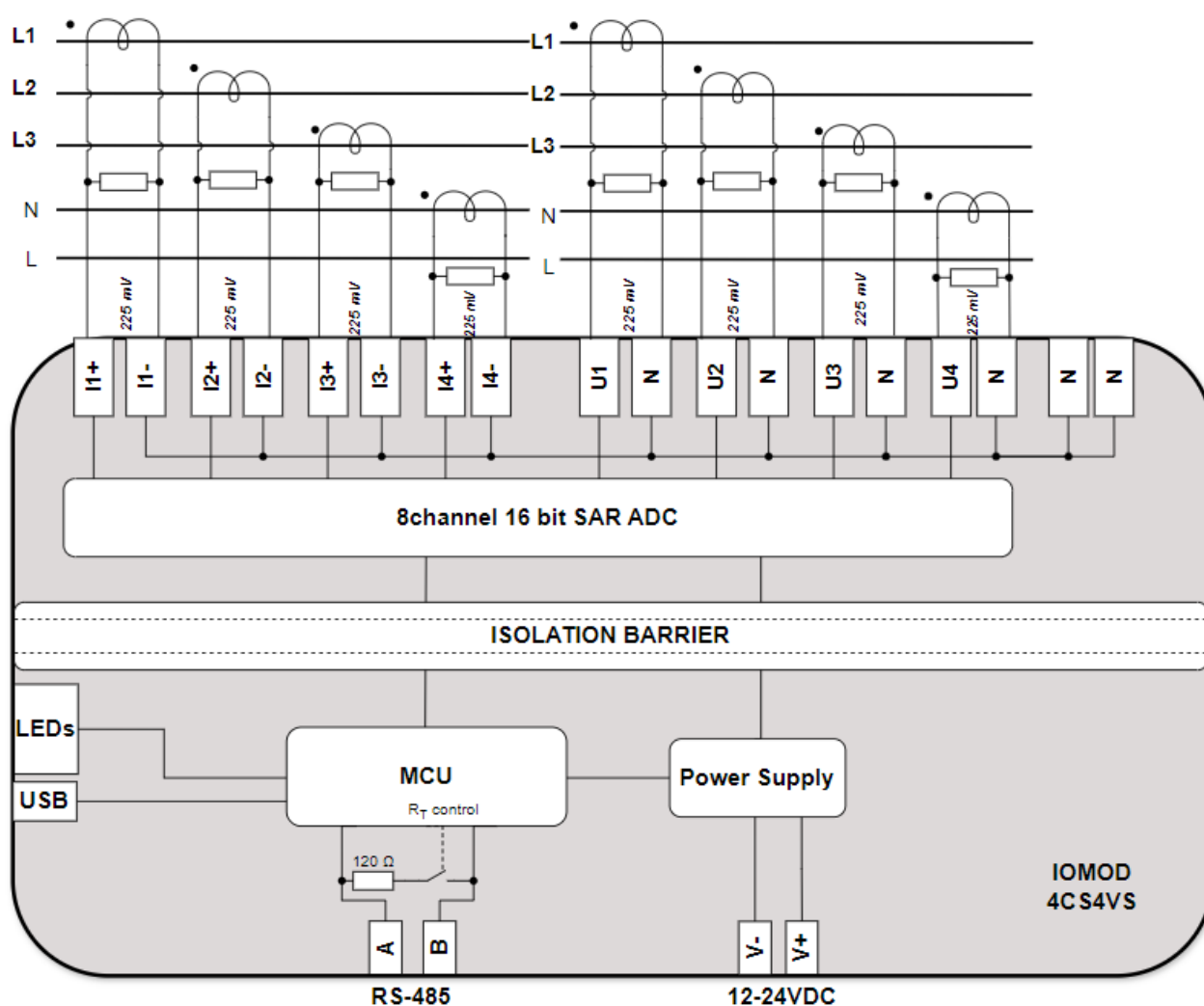


Fig. 1.2.1 IOMod 4Cs4Vs internal structure and block diagram

## 2. Hardware data

### 2.1 Mechanical drawings

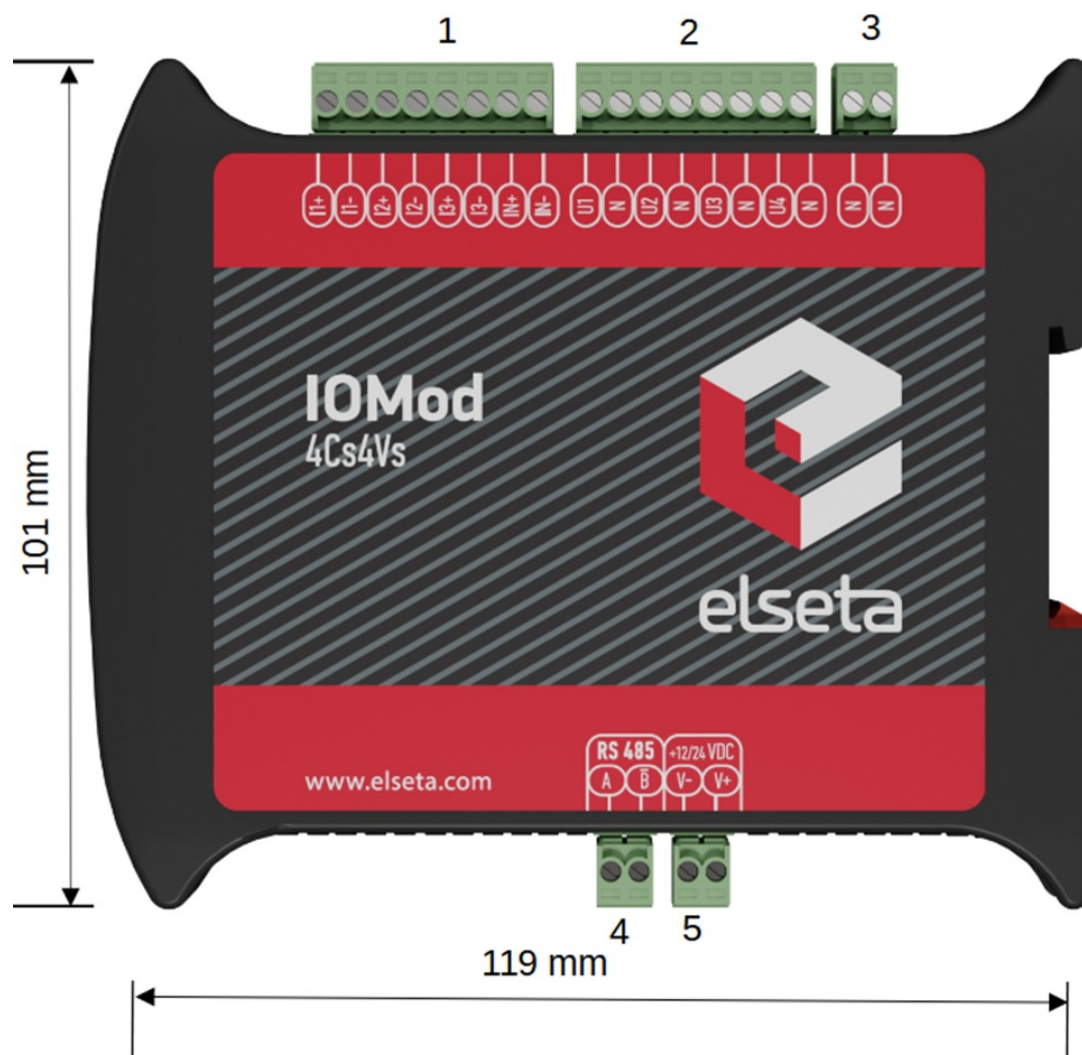


Fig. 2.1.1 IOMod 4Cs4Vs side view with dimensions and terminal description.  
 1 - current measurement inputs; 2 - voltage measurement inputs;  
 3 - ground input for analogue measurements; 4 - RS485 interface;  
 5 - power supply input



Fig. 2.1.2 IOMod 4Cs4Vs front view with dimensions

## 2.2 Terminal Connections

IOMod 4Cs4Vs has 22 terminals, which are depicted below:

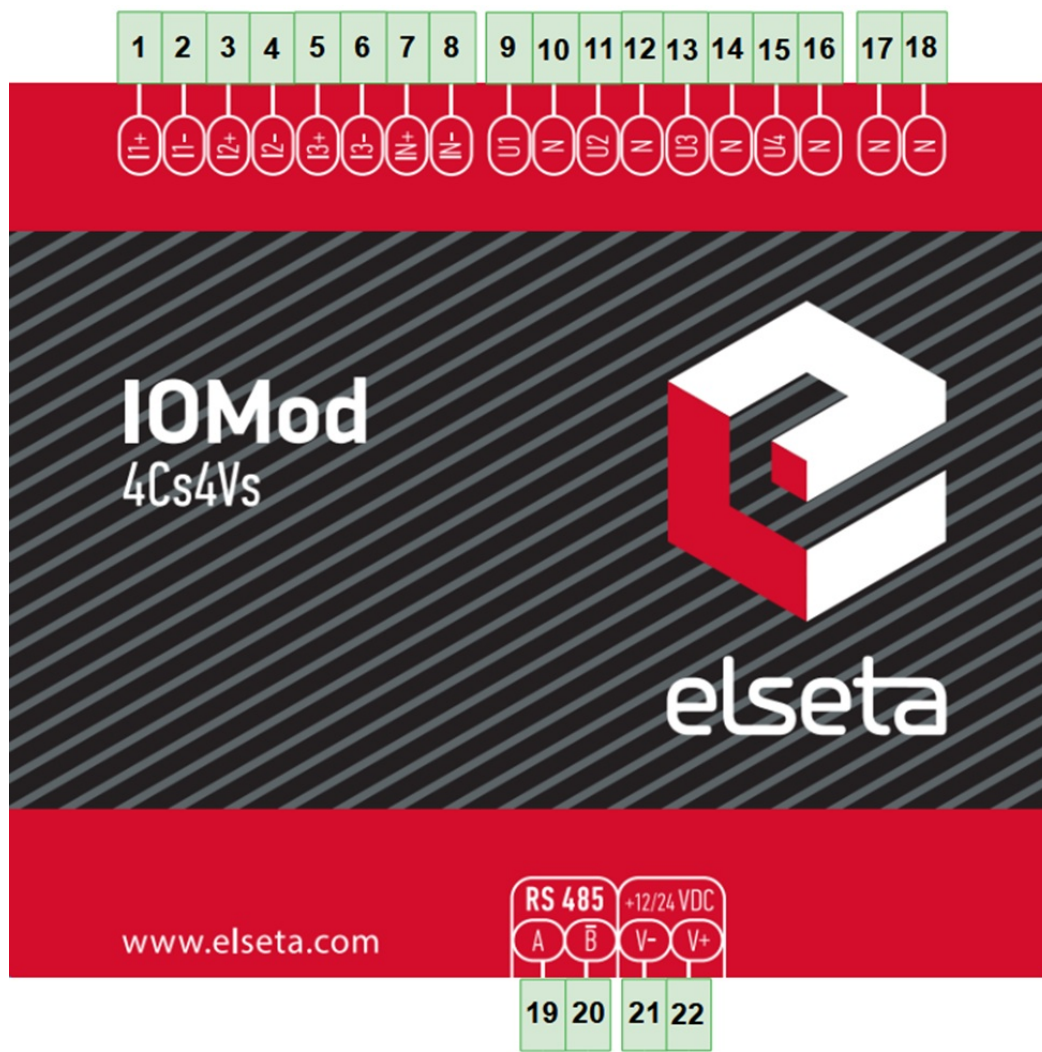


Fig. 2.2.1 IOMod 4Cs4Vs terminal diagram

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

Table 2.2.1 Terminal Specifications

Terminal number	Terminal name	Description
1	I1+	Current inputs
2	I1-	
3	I2+	
4	I2-	
5	I3+	
6	I3-	
7	IN+	
8	IN-	
9	U1	
10	N	

11	U2	Voltage inputs
12	N	
13	U3	
14	N	
15	U4	
16	N	
17	N	Common
18	N	
19	A	RS485 input
20	B̄	
21	V-	Power source input
22	V+	

## 2.3 Status indication

IOMod 4Cs4Vs have 2 LEDs (Fig. 2.3.1), which indicate communication and power statuses.



Fig. 2.3.1 IOMod 4Cs4Vs LEDs physical location

The description of each IOMod 4Cs4Vs 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 RS485 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		
1.	Dimension	101 x 119 x 17.5 mm
2.	Case	ABS, black
3.	Working environment	Indoor
4.	Working temperature	From -40°C to +85°C
5.	Recommended operating conditions	5 – 60°C and 20 – 80%RH
6.	Configuration	USB – configuration via IOMod Utility RS485 – configuration via IOMod Utility
7.	Firmware upgrade	USB – IOMod Utility RS485 – IOMod Utility
Electrical specifications		
8.	Inputs	<p>16-bit resolution, Input resistance: ~1 MOhm Input capacitance: ~170 pF Input Ranges: <math>\pm 10</math> V (amplitude); Nominal values:</p> <ul style="list-style-type: none"> <li>Current input: <ul style="list-style-type: none"> <li>225 mV (RMS);</li> </ul> </li> <li>Voltage input: <ul style="list-style-type: none"> <li>1.876 V (RMS);</li> </ul> </li> </ul> <p>Overvoltage protection of all inputs up to <math>\pm 20</math> V (amplitude)</p>
Power		
9.	Power Supply	9 V to 33 V
10.	Current consumption	40 mA @ 12 VDC, 20 mA @ 24 VDC

# 4. Mounting and Installation

## 4.1 Connection Diagrams

This chapter discusses the various options for connecting the device to medium-voltage systems.

### 4.1.1 IOMod 4Cs4Vs connection for two feeders

The special feature of IOMod 4Cs4Vs is the ability to be used for two feeders (Fig 4.1.1.1). In this case, the 4I4I connection mode needs to be enabled in IOMod Utility (Fig. 4.1.1.2).

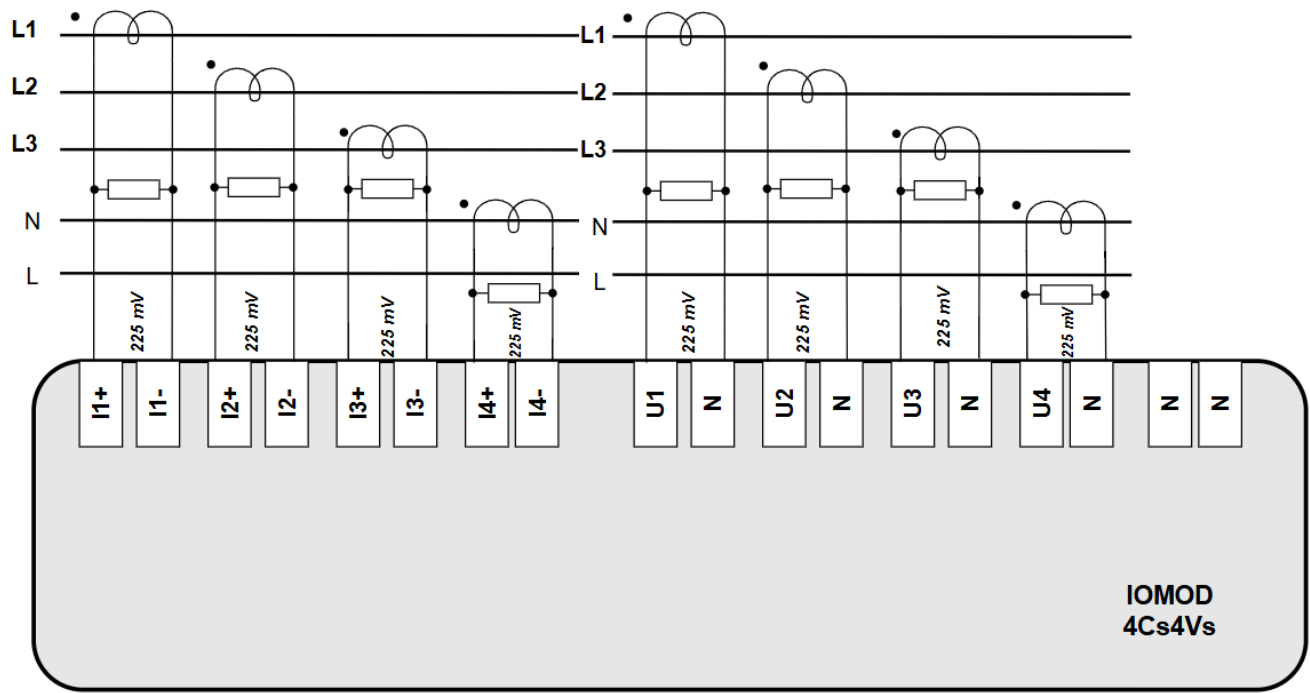


Fig. 4.1.1.1 IOMod 4Cs4Vs connection diagram for feeders

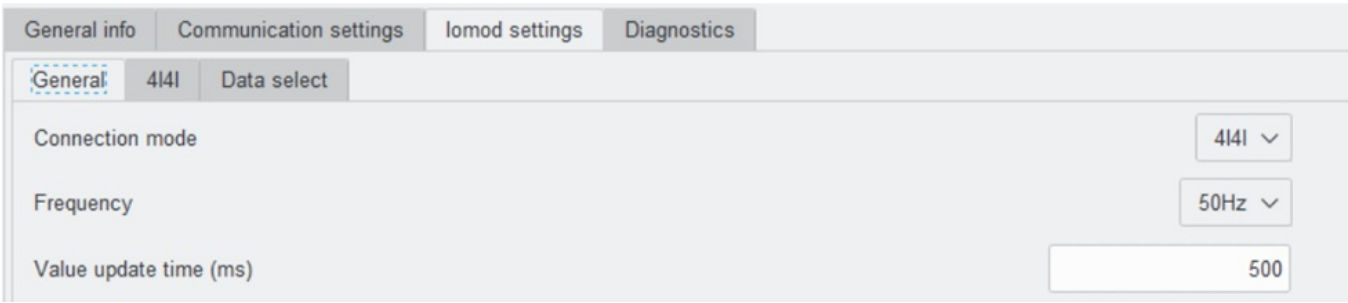


Fig. 4.1.1.2 IOMod Utility General settings tab with Connection mode set to 4I4I

This mode allows us to use IOMod 4Cs4Vs voltage inputs for current measurements so that the currents of both feeders are measured simultaneously. In the connection scheme above (Fig. 4.1.1.1) IOMod 4Cs4Vs current inputs are connected to the pair of feeders via low-power current sensors.

### 4.1.2 3 Low-Power Voltage Sensor, 2-Phase Current, and Core Balance Current Transformer

IOMod 4Cs4Vs allow directly measuring the neutral current. To use this feature  $I_0$  current acquiring mode needs to be switched in IOMod Utility from calculated to metered (Fig. 4.1.2.1).



General info		Communication settings		Iomod settings		Diagnostics	
General		4I4U		Data select			
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. 4.1.2.1 IOMod Utility 4I4U settings view with  $I_0$  mode switched to metered

After enabling  $I_0$  metered mode IOMod 4Cs4Vs second phase input (I2+/I2-) 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 the neutral current is being metered directly, the second phase measurements are being calculated by taking a vector sum of the measured currents. In the scheme below (Fig. 4.1.2.2) current and voltage measurements are taken by using low-power current and low-power voltage sensors. The second input (I2+/I2-) is connected to a low-power current sensor which is placed on the neutral line.

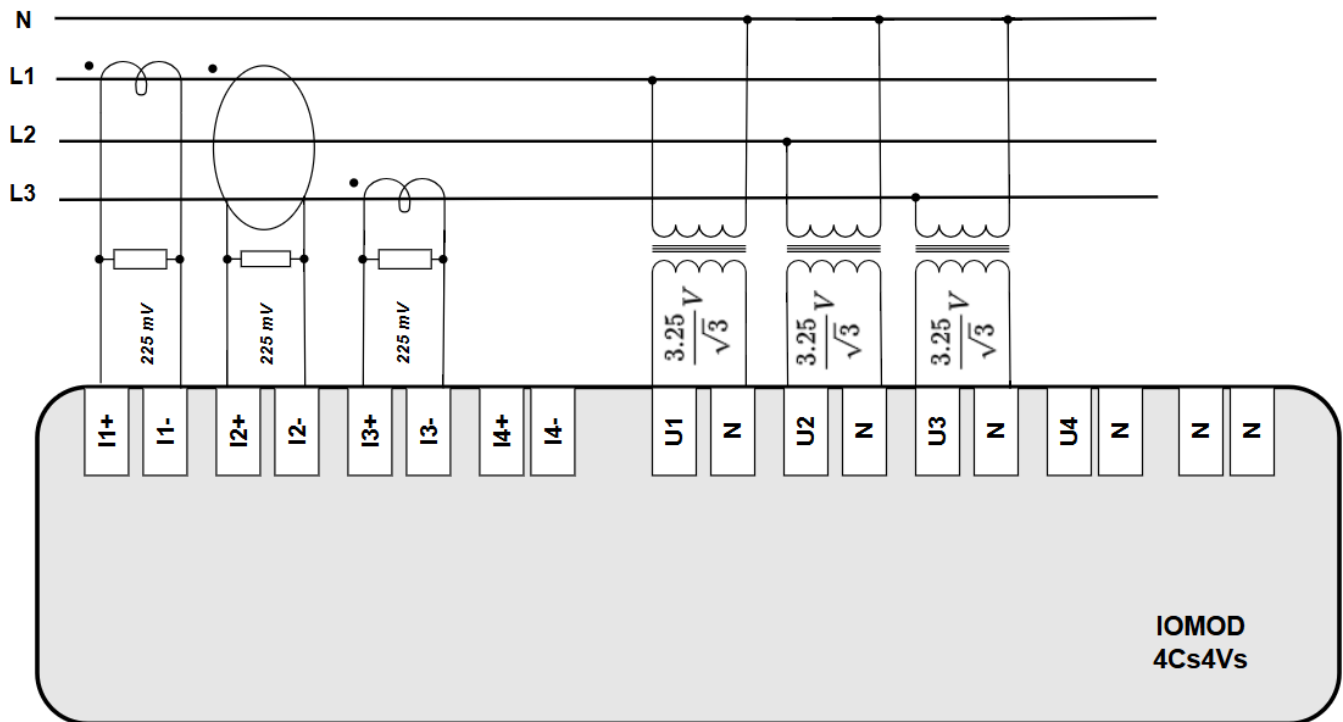


Fig. 4.1.2.2 IOMod 4Cs4Vs  $I_0$  metered mode connection diagram

### 4.1.3 2 Phase Current, and Core Balance Current Transformer

Similarly to the  $I_0$  calculated mode, IOMod 4Cs4Vs can take solely current measurements via low-power current sensors (Fig. 4.1.3.1). However, this connection scheme restricts IOMod FPI fault detection capabilities only to the current-related faults. Also, the absence of voltage measurements results in an inability to provide the directional fault information.

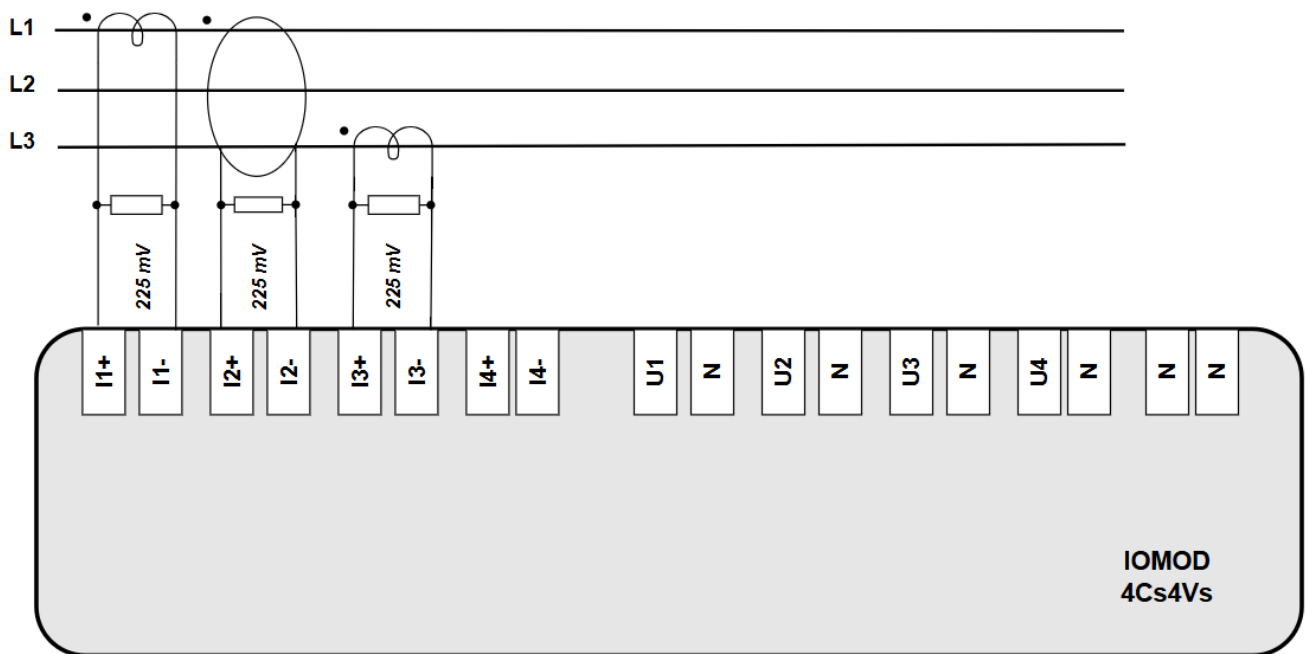


Fig. 4.1.3.1 IOMod 4Cs4Vs  $I_0$  metered mode connection diagram without voltage measurements

## 4.2 Power Supply

IOMod 4Cs4Vs need to be powered by a 9–33 V power source. IOMod 4Cs4Vs power supply inputs are located next to RS485 interface inputs (Fig 4.3.1).

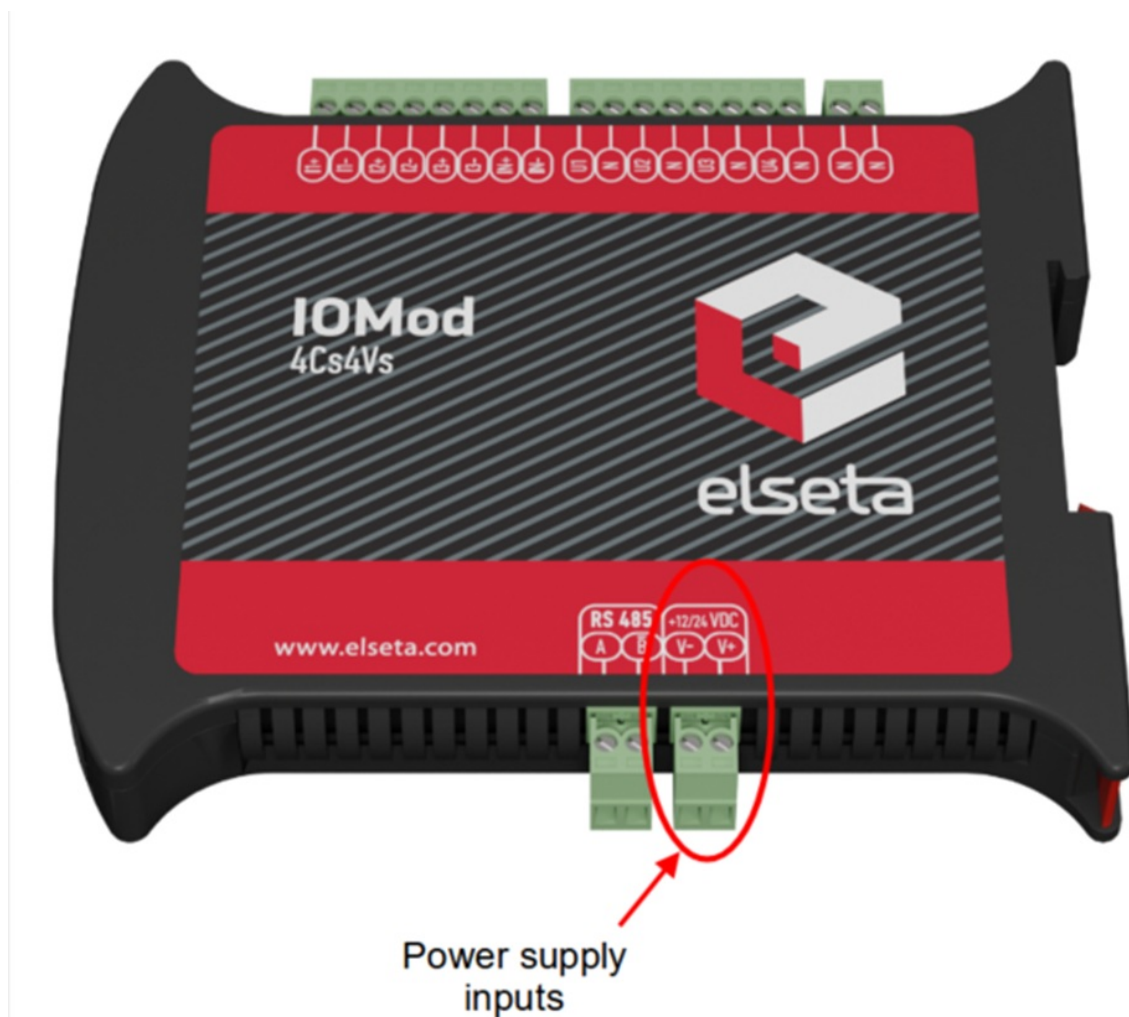


Fig. 4.3.1 Power supply inputs physical location

## 4.3 USB Connection

IOMod 4Cs4Vs 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.

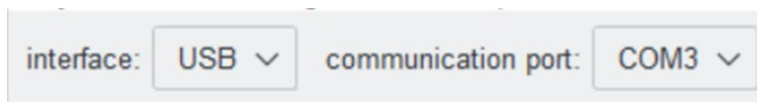


Fig. 4.4.1 IOMod Utility interface and communication port parameters



Fig. 4.4.2 IOMod 4Cs4Vs USB connection port physical location

## 5. Parametrization

In this section, the IOMod 4Cs4Vs settings configuration is described. IOMod 4Cs4Vs 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).

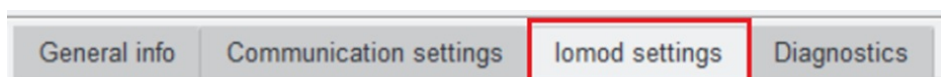


Fig. 5.1 IOMod settings tab

### 5.1 General Parameters

To configure IOMod 4Cs4Vs general settings open the "IOMod settings" tab in IOMod Utility. After clicking on "IOMod

settings", the "General" section opens (Fig. 5.1.1).

General infoCommunication settingsIomod settingsDiagnostics

General4I4IData select

Connection mode4I4I

Frequency50Hz

Value update time (ms)500

Fig. 5.1.1 IOMod Utility with IOMod 4Cs4Vs 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 4Cs4Vs general parameter ranges and default values.

Parameter	Range	Default value
Connection mode	4I4I, 4I4U	4I4I
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 9–16, 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 4I4U designation. 4I4U designation means – "4 currents and 4 voltages" meaning that both current and voltage measurements are being taken from a feeder. 4I4U connection mode parameters can be found in a separate settings section which is labelled with communication mode designation (connection mode settings are described in the next section).

Selecting 4I4I connection mode in IOMod Utility changes IOMod Setting sections – 4I4U changes to 4I4I. IOMod 4Cs4Vs, in 4I4I connection mode, interprets the values measured with voltage inputs (terminals 9–16, see Fig. 2.2.1) as current measurements. 4I4I designation means – "4 currents and 4 currents" meaning that the voltage inputs become the second channel current inputs. The 4I4I 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 IOMod 4Cs4Vs 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 early IOMod 4Cs4Vs supports two connection modes – 4I4U and 4I4I. 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 certain connection mode are going to be described.

5.2.1 4I4U connection mode parameters

The 4I4U connection mode parameters section has six parameters (Table 5.2), which are going to be described below.

Table 5.2 4I4U 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 4I4I connection mode parameters

The 4I4I connection mode parameters section has eight parameters (Table 5.3), which are going to be described below.

Table 5.3 4I4I 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 info		Communication settings		Iomod settings		Diagnostics			
General	4141	Data select							
I1 (0)	<input checked="" type="checkbox"/>	I2 (1)	<input checked="" type="checkbox"/>	I3 (2)	<input checked="" type="checkbox"/>	I0 (3)	<input checked="" type="checkbox"/>	U12 (4)	<input checked="" type="checkbox"/>
U23 (5)	<input checked="" type="checkbox"/>	U31 (6)	<input checked="" type="checkbox"/>	U1 (7)	<input checked="" type="checkbox"/>	U2 (8)	<input checked="" type="checkbox"/>	U3 (9)	<input checked="" type="checkbox"/>
U0 (10)	<input checked="" type="checkbox"/>	U1 angle (11)	<input type="checkbox"/>	U2 angle (12)	<input type="checkbox"/>	U3 angle (13)	<input type="checkbox"/>	S (14)	<input checked="" type="checkbox"/>
P (15)	<input checked="" type="checkbox"/>	Q (16)	<input checked="" type="checkbox"/>	PF (17)	<input checked="" type="checkbox"/>	S1 (18)	<input checked="" type="checkbox"/>	S2 (19)	<input checked="" type="checkbox"/>
S3 (20)	<input checked="" type="checkbox"/>	P1 (21)	<input checked="" type="checkbox"/>	P2 (22)	<input checked="" type="checkbox"/>	P3 (23)	<input checked="" type="checkbox"/>	Q1 (24)	<input checked="" type="checkbox"/>
Q2 (25)	<input checked="" type="checkbox"/>	Q3 (26)	<input checked="" type="checkbox"/>	PF1 (27)	<input checked="" type="checkbox"/>	PF2 (28)	<input checked="" type="checkbox"/>	PF3 (29)	<input checked="" type="checkbox"/>
Frequency (30)	<input checked="" type="checkbox"/>	THD U1 (31)	<input type="checkbox"/>	THD U2 (32)	<input type="checkbox"/>	THD U3 (33)	<input type="checkbox"/>	THD I1 (34)	<input type="checkbox"/>
THD I2 (35)	<input type="checkbox"/>	THD I3 (36)	<input type="checkbox"/>	I1 H3 (37)	<input type="checkbox"/>	I1 H5 (38)	<input type="checkbox"/>	I1 H7 (39)	<input type="checkbox"/>
I1 H9 (40)	<input type="checkbox"/>	I2 H3 (41)	<input type="checkbox"/>	I2 H5 (42)	<input type="checkbox"/>	I2 H7 (43)	<input type="checkbox"/>	I2 H9 (44)	<input type="checkbox"/>
I3 H3 (45)	<input type="checkbox"/>	I3 H5 (46)	<input type="checkbox"/>	I3 H7 (47)	<input type="checkbox"/>	I3 H9 (48)	<input type="checkbox"/>	U1 H3 (49)	<input type="checkbox"/>
U1 H5 (50)	<input type="checkbox"/>	U1 H7 (51)	<input type="checkbox"/>	U1 H9 (52)	<input type="checkbox"/>	U2 H3 (53)	<input type="checkbox"/>	U2 H5 (54)	<input type="checkbox"/>
U2 H7 (55)	<input type="checkbox"/>	U2 H9 (56)	<input type="checkbox"/>	U3 H3 (57)	<input type="checkbox"/>	U3 H5 (58)	<input type="checkbox"/>	U3 H7 (59)	<input type="checkbox"/>
U3 H9 (60)	<input type="checkbox"/>	I4 (61)	<input checked="" type="checkbox"/>	U4 (62)	<input checked="" type="checkbox"/>	I1 angle (63)	<input type="checkbox"/>	I2 angle (64)	<input type="checkbox"/>
I3 angle (65)	<input type="checkbox"/>	I0 angle (66)	<input type="checkbox"/>	U0 angle (67)	<input type="checkbox"/>	U12 angle (68)	<input type="checkbox"/>	U23 angle (69)	<input type="checkbox"/>
U31 angle (70)	<input type="checkbox"/>	I4 angle (71)	<input type="checkbox"/>	U4 angle (72)	<input type="checkbox"/>	Ip (73)	<input type="checkbox"/>	In (74)	<input type="checkbox"/>
Ip angle (75)	<input type="checkbox"/>	In angle (76)	<input type="checkbox"/>	Up (77)	<input type="checkbox"/>	Un (78)	<input type="checkbox"/>	Up angle (79)	<input type="checkbox"/>
Un angle (80)	<input type="checkbox"/>	I1 H2 (81)	<input type="checkbox"/>	I2 H2 (82)	<input type="checkbox"/>	I3 H2 (83)	<input type="checkbox"/>	I1 ch2 (84)	<input type="checkbox"/>
I2 ch2 (85)	<input type="checkbox"/>	I3 ch2 (86)	<input type="checkbox"/>	I0 ch2 (87)	<input type="checkbox"/>	I4 ch2 (88)	<input type="checkbox"/>	I1 angle ch2 (89)	<input type="checkbox"/>
I2 angle ch2 (90)	<input type="checkbox"/>	I3 angle ch2 (91)	<input type="checkbox"/>	I0 angle ch2 (92)	<input type="checkbox"/>	I4 angle ch2 (93)	<input type="checkbox"/>	Ip ch2 (94)	<input type="checkbox"/>
In ch2 (95)	<input type="checkbox"/>	Ip angle ch2 (96)	<input type="checkbox"/>	In angle ch2 (97)	<input type="checkbox"/>	I1 H2 ch2 (98)	<input type="checkbox"/>	I2 H2 ch2 (99)	<input type="checkbox"/>
I3 H2 ch2 (100)	<input type="checkbox"/>	THD I1 ch2 (101)	<input type="checkbox"/>	THD I2 ch2 (102)	<input type="checkbox"/>	THD I3 ch2 (103)	<input type="checkbox"/>	I1 H3 ch2 (104)	<input type="checkbox"/>
I1 H5 ch2 (105)	<input type="checkbox"/>	I1 H7 ch2 (106)	<input type="checkbox"/>	I1 H9 ch2 (107)	<input type="checkbox"/>	I2 H3 ch2 (108)	<input type="checkbox"/>	I2 H5 ch2 (109)	<input type="checkbox"/>
I2 H7 ch2 (110)	<input type="checkbox"/>	I2 H9 ch2 (111)	<input type="checkbox"/>	I3 H3 ch2 (112)	<input type="checkbox"/>	I3 H5 ch2 (113)	<input type="checkbox"/>	I3 H7 ch2 (114)	<input type="checkbox"/>
I3 H9 ch2 (115)	<input type="checkbox"/>								

Fig. 5.3.1 IOMod 4Cs4Vs Data select tab view

## 5.4 Diagnostics

The IOMod Utility Diagnostics tab allows real-time monitoring of IOMod 4Cs4Vs 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						
<div>Connect</div> <div>Offline <span style="color: red;">●</span></div>								
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

General info		Communication settings		Iomod settings		Diagnostics	
Measurements		Harmonics					
<div>Connect</div> <div>Offline <span style="color: black;">●</span></div>							
Total harmonic distortion							
I1	<input type="text" value="0"/>	I2/I0	<input type="text" value="0"/>	I3	<input type="text" value="0"/>		
U1	<input type="text" value="0"/>	U2	<input type="text" value="0"/>	U3	<input type="text" value="0"/>		
Channel 2 I1	<input type="text" value="0"/>	Channel 2 I2/I0	<input type="text" value="0"/>	Channel 2 I3	<input type="text" value="0"/>		
2nd Harmonics							
I1	<input type="text" value="0"/>	I2	<input type="text" value="0"/>	I3	<input type="text" value="0"/>		
Channel 2 I1	<input type="text" value="0"/>	Channel 2 I2	<input type="text" value="0"/>	Channel 2 I3	<input type="text" value="0"/>		
3rd Harmonics							
I1	<input type="text" value="0"/>	I2/I0	<input type="text" value="0"/>	I3	<input type="text" value="0"/>		
U1	<input type="text" value="0"/>	U2	<input type="text" value="0"/>	U3	<input type="text" value="0"/>		
Channel 2 I1	<input type="text" value="0"/>	Channel 2 I2/I0	<input type="text" value="0"/>	Channel 2 I3	<input type="text" value="0"/>		
5th Harmonics							
I1	<input type="text" value="0"/>	I2/I0	<input type="text" value="0"/>	I3	<input type="text" value="0"/>		
U1	<input type="text" value="0"/>	U2	<input type="text" value="0"/>	U3	<input type="text" value="0"/>		
Channel 2 I1	<input type="text" value="0"/>	Channel 2 I2/I0	<input type="text" value="0"/>	Channel 2 I3	<input type="text" value="0"/>		
7th Harmonics							
I1	<input type="text" value="0"/>	I2/I0	<input type="text" value="0"/>	I3	<input type="text" value="0"/>		
U1	<input type="text" value="0"/>	U2	<input type="text" value="0"/>	U3	<input type="text" value="0"/>		
Channel 2 I1	<input type="text" value="0"/>	Channel 2 I2/I0	<input type="text" value="0"/>	Channel 2 I3	<input type="text" value="0"/>		
9th Harmonics							
I1	<input type="text" value="0"/>	I2/I0	<input type="text" value="0"/>	I3	<input type="text" value="0"/>		
U1	<input type="text" value="0"/>	U2	<input type="text" value="0"/>	U3	<input type="text" value="0"/>		
Channel 2 I1	<input type="text" value="0"/>	Channel 2 I2/I0	<input type="text" value="0"/>	Channel 2 I3	<input type="text" value="0"/>		

Fig. 5.4.2 IOMod Utility Dlganostics 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 4Cs4Vs parameters. To turn off Diagnostics real-time monitoring mode, the "Disconnect" button needs to be pressed.

## 6. Communication Protocols



IOMod 4Cs4Vs 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 IOMod Utility (IOMod Utility manual can be accessed [here](#)).

## 6.1 Modbus RTU operational information

When the Modbus RTU protocol is selected IOMod 4Cs4Vs 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. Request with an unsupported function code or register number out of range will be answered with the corresponding exception. Measurement results in nominal values having 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 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 <sub>12</sub> angle	0.1 deg	INT16	R
67	Line voltage U <sub>23</sub> angle	0.1 deg	INT16	R
68	Line voltage U <sub>31</sub> 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 I0 angle	0.1 deg	UINT16	R
74	Current I4 angle	0.1 deg	UINT16	R
75	Voltage U0 angle	0.1 deg	UINT16	R
76	Voltage U4 angle	0.1 deg	UINT16	R
77	Current Ip angle	0.1 deg	UINT16	R
78	Current In angle	0.1 deg	UINT16	R
79	Current Up angle	0.1 deg	UINT16	R
80	Current Un angle	0.1 deg	UINT16	R
81	Current I1 2nd harmonic	% x10	UINT16	R
82	Current I2 2nd harmonic	% x10	UINT16	R
83	Current I3 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 harmonic channel 2	%	UINT16	R
111	Current I2 9th harmonic channel 2	%	UINT16	R

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 $\Sigma$ 3 phase	VA	FLOAT	R
230 - 231	Active power $\Sigma$ 3 phase	W	FLOAT	R
232 - 233	Reactive power $\Sigma$ 3 phase	Var	FLOAT	R
234 - 235	Power factor $\Sigma$ 3 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).

IOMod 4Cs4Vs via IEC101 protocol transmit various measurement signals in a standardized format. These signals are predefined in the IOMod and mapped to corresponding Information Object Addresses (IOA).

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

Time synchronization is critical for logging events. To synchronize time, the master sends a Time Sync command C\_CS\_NA\_1 (103) with Cause of Transmission (COT) 6. According to the IEC 60870-5-101 protocol specification, time synchronization can be performed for multiple devices using broadcast messages. A master device sends a broadcast timesync command with a broadcast link address. This ensures consistent time-stamping for event recording and fault detection across the network.

All the measurements are represented in absolute values without any scaling and using standard units. Almost every measurement can be sent using TI 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-bit". The necessity in other data formats for the energy measurements comes from the fact that they are saved in 32-bit unsigned integer data type. The usage of integer type instead of float ensures better precision.

Table 6.2.1 List of signals

IOA	Description	Units	TI
0	Current I1	A	13 (M_ME_NC_1)
1	Current I2	A	13 (M_ME_NC_1)
2	Current I3	A	13 (M_ME_NC_1)
3	Current I0	A	13 (M_ME_NC_1)
4	Voltage U12	U	13 (M_ME_NC_1)
5	Voltage U23	U	13 (M_ME_NC_1)
6	Voltage U31	U	13 (M_ME_NC_1)
7	Voltage U1	U	13 (M_ME_NC_1)
8	Voltage U2	U	13 (M_ME_NC_1)
9	Voltage U3	U	13 (M_ME_NC_1)
10	Voltage U0	U	13 (M_ME_NC_1)
11	Voltage U1 angle	°	13 (M_ME_NC_1)
12	Voltage U2 angle	°	13 (M_ME_NC_1)
13	Voltage U3 angle	°	13 (M_ME_NC_1)
14	Apparent power $\Sigma$ 3 phase	VA	13 (M_ME_NC_1)
15	Active power $\Sigma$ 3 phase	W	13 (M_ME_NC_1)
16	Reactive power $\Sigma$ 3 phase	Var	13 (M_ME_NC_1)
17	Power factor $\Sigma$ 3 phase		13 (M_ME_NC_1)
18	Apparent power S1	VA	13 (M_ME_NC_1)
19	Apparent power S2	VA	13 (M_ME_NC_1)
20	Apparent power S3	VA	13 (M_ME_NC_1)
21	Active power P1	W	13 (M_ME_NC_1)
22	Active power P2	W	13 (M_ME_NC_1)
23	Active power P3	W	13 (M_ME_NC_1)
24	Reactive power Q1	Var	13 (M_ME_NC_1)
25	Reactive power Q2	Var	13 (M_ME_NC_1)
26	Reactive power Q3	Var	13 (M_ME_NC_1)
27	Power factor PF1		13 (M_ME_NC_1)
28	Power factor PF2		13 (M_ME_NC_1)
29	Power factor PF3		13 (M_ME_NC_1)
30	Frequency	Hz	13 (M_ME_NC_1)
31	THD Voltage U1		13 (M_ME_NC_1)
32	THD Voltage U2		13 (M_ME_NC_1)
33	THD Voltage U3		13 (M_ME_NC_1)
34	THD Current I1		13 (M_ME_NC_1)
35	THD Current I2		13 (M_ME_NC_1)
36	THD Current I3		13 (M_ME_NC_1)
37	Current I1 3rd harmonic		13 (M_ME_NC_1)
38	Current I1 5th harmonic		13 (M_ME_NC_1)
39	Current I1 7th harmonic		13 (M_ME_NC_1)
40	Current I1 9th harmonic		13 (M_ME_NC_1)
41	Current I2 3rd harmonic		13 (M_ME_NC_1)

42	Current I2 5th harmonic		13 (M_ME_NC_1)
43	Current I2 7th harmonic		13 (M_ME_NC_1)
44	Current I2 9th harmonic		13 (M_ME_NC_1)
45	Current I3 3rd harmonic		13 (M_ME_NC_1)
46	Current I3 5th harmonic		13 (M_ME_NC_1)
47	Current I3 7th harmonic		13 (M_ME_NC_1)
48	Current I3 9th harmonic		13 (M_ME_NC_1)
49	Voltage U1 3rd harmonic		13 (M_ME_NC_1)
50	Voltage U1 5th harmonic		13 (M_ME_NC_1)
51	Voltage U1 7th harmonic		13 (M_ME_NC_1)
52	Voltage U1 9th harmonic		13 (M_ME_NC_1)
53	Voltage U2 3rd harmonic		13 (M_ME_NC_1)
54	Voltage U2 5th harmonic		13 (M_ME_NC_1)
55	Voltage U2 7th harmonic		13 (M_ME_NC_1)
56	Voltage U2 9th harmonic		13 (M_ME_NC_1)
57	Voltage U3 3rd harmonic		13 (M_ME_NC_1)
58	Voltage U3 5th harmonic		13 (M_ME_NC_1)
59	Voltage U3 7th harmonic		13 (M_ME_NC_1)
60	Voltage U3 9th harmonic		13 (M_ME_NC_1)
61	Current I4	A	13 (M_ME_NC_1)
62	Voltage U4	U	13 (M_ME_NC_1)
63	Current I1 angle	°	13 (M_ME_NC_1)
64	Current I2 angle	°	13 (M_ME_NC_1)
65	Current I3 angle	°	13 (M_ME_NC_1)
66	Current I0 angle	°	13 (M_ME_NC_1)
67	Voltage U0 angle	°	13 (M_ME_NC_1)
68	Voltage U12 angle	°	13 (M_ME_NC_1)
69	Voltage U23 angle	°	13 (M_ME_NC_1)
70	Voltage U31 angle	°	13 (M_ME_NC_1)
71	Current I4 angle	°	13 (M_ME_NC_1)
72	Voltage U4 angle	°	13 (M_ME_NC_1)
73	Current positive seq Ip	A	13 (M_ME_NC_1)
74	Current negative seq In	A	13 (M_ME_NC_1)
75	Current Ip angle	°	13 (M_ME_NC_1)
76	Current In angle	°	13 (M_ME_NC_1)
77	Voltage positive seq Up	U	13 (M_ME_NC_1)
78	Voltage negative seq Un	U	13 (M_ME_NC_1)
79	Voltage Up angle	°	13 (M_ME_NC_1)
80	Voltage Un angle	°	13 (M_ME_NC_1)
81	Current I1 2nd harmonic		13 (M_ME_NC_1)
82	Current I2 2nd harmonic		13 (M_ME_NC_1)
83	Current I3 2nd harmonic		13 (M_ME_NC_1)
84	Current I1 channel 2	A	13 (M_ME_NC_1)
85	Current I2 channel 2	A	13 (M_ME_NC_1)
86	Current I3 channel 2	A	13 (M_ME_NC_1)
87	Current I0 channel 2	A	13 (M_ME_NC_1)
88	Current I4 channel 2	A	13 (M_ME_NC_1)
89	Current I1 channel 2 angle	°	13 (M_ME_NC_1)
90	Current I2 channel 2 angle	°	13 (M_ME_NC_1)
91	Current I3 channel 2 angle	°	13 (M_ME_NC_1)



92	Current I0 channel 2 angle	°	13 (M_ME_NC_1)
93	Current I4 channel 2 angle	°	13 (M_ME_NC_1)
94	Current Ip channel 2	A	13 (M_ME_NC_1)
95	Current In channel 2	A	13 (M_ME_NC_1)
96	Current Ip channel 2 angle	°	13 (M_ME_NC_1)
97	Current In channel 2 angle	°	13 (M_ME_NC_1)
98	Current I1 2nd harmonic ch2		13 (M_ME_NC_1)
99	Current I2 2nd harmonic ch2		13 (M_ME_NC_1)
100	Current I3 2nd harmonic ch2		13 (M_ME_NC_1)
101	THD Current I1 ch2		13 (M_ME_NC_1)
102	THD Current I2 ch2		13 (M_ME_NC_1)
103	THD Current I3 ch2		13 (M_ME_NC_1)
104	Current I1 3rd harmonic ch2		13 (M_ME_NC_1)
105	Current I1 5th harmonic ch2		13 (M_ME_NC_1)
106	Current I1 7th harmonic ch2		13 (M_ME_NC_1)
107	Current I1 9th harmonic ch2		13 (M_ME_NC_1)
108	Current I2 3rd harmonic ch2		13 (M_ME_NC_1)
109	Current I2 5th harmonic ch2		13 (M_ME_NC_1)
110	Current I2 7th harmonic ch2		13 (M_ME_NC_1)
111	Current I2 9th harmonic ch2		13 (M_ME_NC_1)
112	Current I3 3rd harmonic ch2		13 (M_ME_NC_1)
113	Current I3 5th harmonic ch2		13 (M_ME_NC_1)
114	Current I3 7th harmonic ch2		13 (M_ME_NC_1)
115	Current I3 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 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.

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.

When this initialization is complete, the master should poll the IOMod device 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.

As IOMod 4Cs4Vs does not have any digital inputs, only analog ones, therefore 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  $2.4 \times U_n$ , the measurand value 0.5 corresponds to  $1.2 \times I_n$ , and so on. If the measurand value, in this case, exceeds  $2.4 \times U_n$ , 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 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 4I4U 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 4I4I 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	$I_1^{(ch1)}, I_2^{(ch1)}, I_3^{(ch1)},$ $I_0^{(ch1)}, I_1^{(ch2)}, I_2^{(ch2)},$ $I_3^{(ch2)}, I_0^{(ch2)}, f,$ $THD_{I1}^{(ch1)}, THD_{I2}^{(ch1)},$ $THD_{I3}^{(ch1)}, I_1^{(h3, ch1)},$ $I_1^{(h5, ch1)}, I_1^{(h7, ch1)},$ $I_1^{(h9, ch1)}, I_2^{(h3, ch1)},$ $I_2^{(h5, ch1)}, I_2^{(h7, ch1)},$ $I_2^{(h9, ch1)}, I_3^{(h3, ch1)},$ $I_3^{(h5, ch1)}, I_3^{(h7, ch1)},$ $I_3^{(h9, ch1)}, THD_{I1}^{(ch2)},$ $THD_{I2}^{(ch2)}, THD_{I3}^{(ch2)},$ $I_1^{(h3, ch2)}, I_1^{(h5, ch2)},$ $I_1^{(h7, ch2)}, I_1^{(h9, ch2)},$ $I_2^{(h3, ch2)}, I_2^{(h5, ch2)},$ $I_2^{(h7, ch2)}, I_2^{(h9, ch2)},$ $I_3^{(h3, ch2)}, I_3^{(h5, ch2)},$ $I_3^{(h7, ch2)}, I_3^{(h9, ch2)}$
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The 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 IEC103 protocol is calculated by multiplying the nominal value by 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 of the allowed range, then the scaled value, which is going to be sent by means of IEC103 signal, is calculated by multiplying it by 4096 and dividing it by the maximum measurement value:

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

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

In the special case, where 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.