

3.14 Illuminance

1



Select item **Lux** to call up the measurement screen.

2



Connect the optical probe.

3

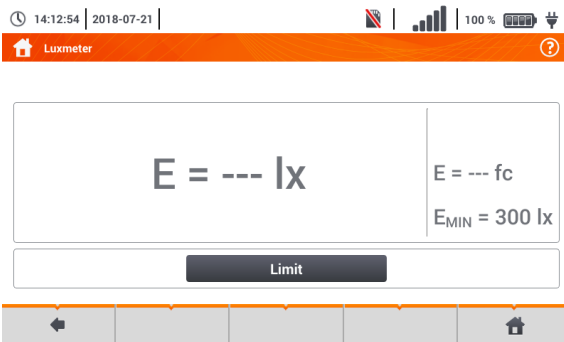


- Select **Limit** to set the criterion of minimum illuminance.
- Select unit.
- Delete the previous value and enter a new one from the range of 0...20 000 lx.

Functions of icons

- reject changes and exit to the previous screen
- accept changes

4



The meter is ready for light measurement.

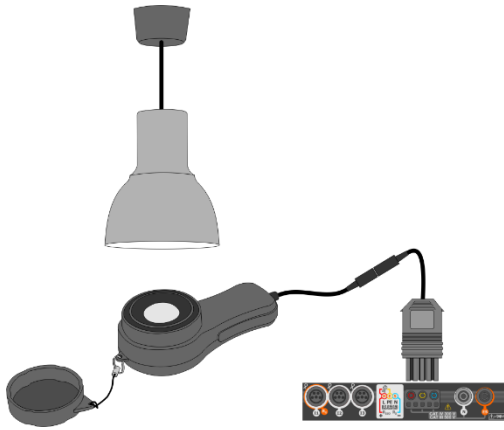
Live mode

E [lx] – illumination expressed in lux (lm/m²)

E [fc] – illumination expressed in lm/ft² (lumen per square foot)

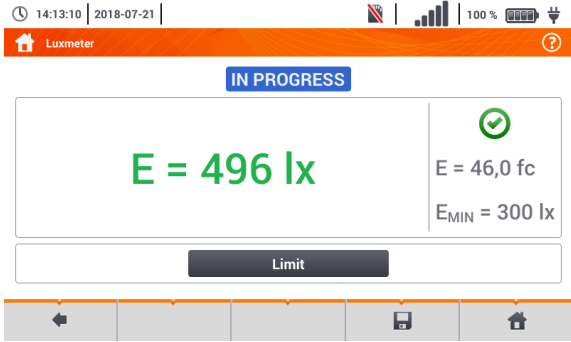
E_{MIN} – limit set in steps **3** **4**

5



Place the probe in the test work plane.

6



Read out the result.

- Signal lights for the limit (step 3)
- the result is within the set limit
 - the result is outside the set limit
 - assessment not possible

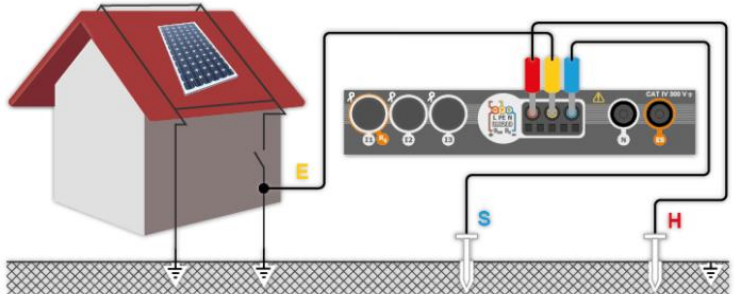
7

Save the measurement to the meter memory using the icon. A detailed description of memory management is contained in **section 6.1.3**.

3.15 MPI-540-PV Resistance-to-earth (PV)



Connect the measuring system. The measurement is performed similarly as in **section 3.6**.



3.16 MPI-540-PV *Insulation resistance (PV)*



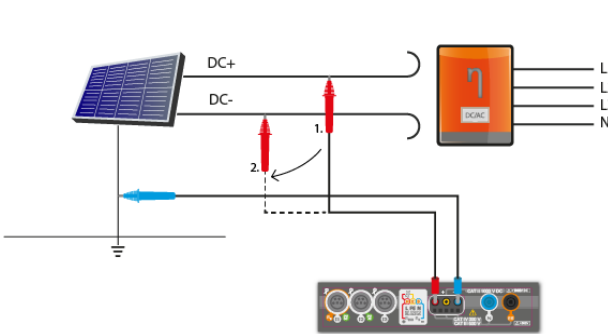
WARNING

- During measurements of insulation resistance, dangerous voltage up to 1 kV occurs at the ends of test leads of the meter.
- **It is forbidden** to disconnect test leads before the measurement is completed. Failure to obey the above instruction will lead to **electric shock with high voltage** and make it impossible to discharge the tested object.



The measurement is performed similarly as in **sec. 3.10**. Measure the insulation resistance between the positive pole (DC+) and grounding, as well as between the negative pole (DC-) and grounding. For this purpose:

- connect the grounding with R_{ISO-} socket of the meter, connect DC+ line with R_{ISO+} meter, select R_{ISO+} method in the instrument and start the measurement,
- connect DC- line with R_{ISO+} socket, select R_{ISO-} method in the instrument and start the measurement.



After selecting the bar ◀ on the right side, a menu will slide out with additional measurement results.

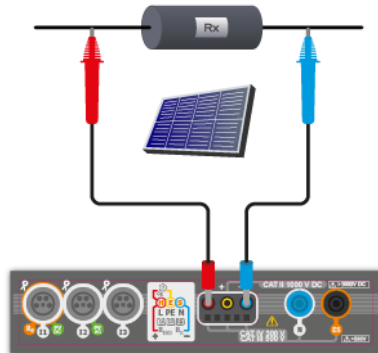
$U_{ISO L-N}$ – measurement voltage

Selecting the ▶ bar hides the menu.

3.17 MPI-540-PV *Continuity of connections (PV)*



Connect the measuring system. The measurement is performed similarly as in **sec. 3.11.2**.



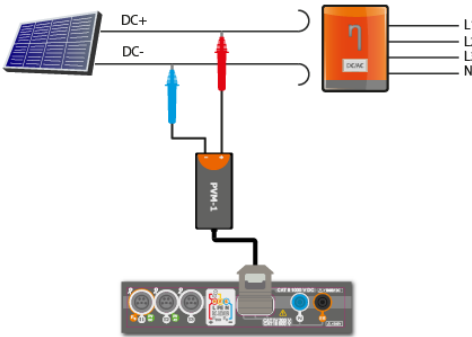
3.18 MPI-540-PV Open circuit DC voltage U_{OC}

1



Select item U_{OC} to call up the measurement screen.

2



Turn off the inverter or disconnect it from the tested object. Connect the meter to the chain of PV modules using PVM-1 adapter and adapters of MC4 connectors. The following parameters will be measured:

U_{OC} – open circuit voltage,
 $U_{OC:STC}$ – open circuit voltage after conversion to STC* conditions,
 ΔU_{OC} – difference in open circuit voltage (measured and converted to STC conditions) and the same voltage declared by the producer of the panel, also converted to STC conditions.

*STC (Standard Test Conditions) – reference conditions, for which the manufacturer provides all the parameters of the modules.



WARNING

Do not disconnect MC4 connectors when the load current of working inverter flows through them. This may cause arcing and danger to the user!

3



Enter the test parameters:

T_A – ambient temperature, if the source of temperature measurement = air (**sec. 2.2.1**),

T_{PV} – module temperature, if the source of temperature measurement = module (**sec. 2.2.1**),

E – irradiance,

Limit – setting of $\Delta U_{OC MAX}$ values,

M – photovoltaic module selected from the meter database (**sec. 2.2.3**).

In addition, the screen displays the following:

$U_{OC:STC(R)}$ – open circuit voltage in STC conditions, declared by the manufacturer,

$\Delta U_{OC MAX}$ – limit ΔU_{OC} set.



Parameters T_A , T_{PV} , E come from the irradiance meter, if it is connected to the meter. See also **sec. 3.22**.

4



Press **START** to start the measurement.

5 **Signal lights for the limit (step 3)**

- the result is within the set limit
- the result is outside the set limit
- assessment not possible

After selecting bar, a pop-up menu is displayed on the right side of the screen, containing the parameters of the measured PV object.

M – number of modules in series,

N – number of modules connected in parallel,

T_{PV} – temperature of the module.

Selecting the bar hides the menu.

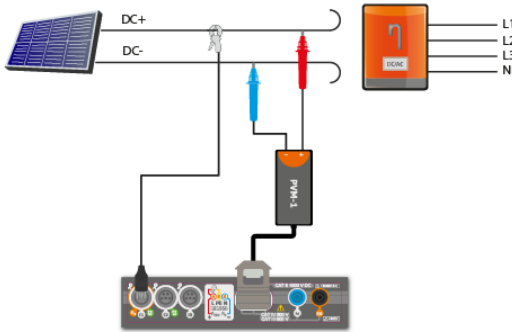
3.19 MPI-540-PV Short circuit DC current I_{sc}

1



Select item I_{sc} , to call up the measurement screen. Then reset the clamp (sec. 3.21).

2



Turn off the inverter or disconnect it from the tested object. Connect the meter to the chain of PV modules using PVM-1 adapter and adapters of MC4 connectors. The following parameters will be measured:

- I_{sc} – short-circuit current
- $I_{sc:STC}$ – short circuit current after conversion for STC* conditions,
- ΔI_{sc} – difference of short-circuit current (measured and converted to STC conditions) and the same current declared by the producer of the panel, also converted to STC.

*STC (Standard Test Conditions) – reference conditions, for which the manufacturer provides all the parameters of the modules.



WARNING

Do not disconnect MC4 connectors when the load current of working inverter flows through them. This may cause arcing and danger to the user!

3



Enter the test parameters:

- T_A – ambient temperature, if the source temperature measurement = air (sec. 2.2.1),
- T_{PV} – module temperature, if the source of temperature measurement = module (sec. 2.2.1),
- E – irradiance,
- Limit** – setting of $\Delta I_{sc MAX}$ values,
- M – photovoltaic module selected from the meter database (sec. 2.2.3).

In addition, the screen displays the following:

- $I_{sc:STC(R)}$ – short-circuit current in STC conditions, as declared by the manufacturer,
- $\Delta I_{sc MAX}$ – limit ΔI_{sc} set.



Parameters T_A , T_{PV} , E come from the irradiance meter, if it is connected to the meter. See also sec. 3.22.

4



If necessary, reset the clamps again. Press **START** to start the measurement.

5

Signal lights for the limit (step 3)

- the result is within the set limit
- the result is outside the set limit
- assessment not possible

After selecting bar, a pop-up menu is displayed on the right side of the screen, containing the parameters of the measured PV object.

- M – number of modules in series,
 - N – number of modules connected in parallel,
 - T_{PV} – temperature of the module.
- Selecting the bar hides the menu.

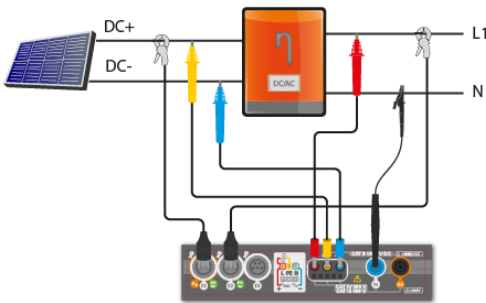
3.20 MPI-540-PV Test of the inverter panel η , P , I

1



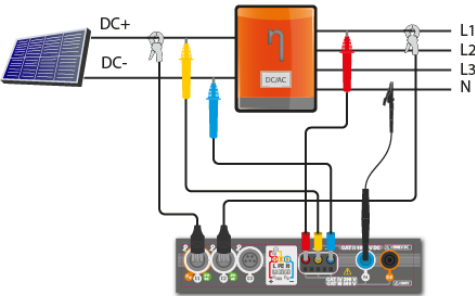
Select item η , P , I , to call up the measurement screen. Then reset the clamps (sec. 3.21).

2



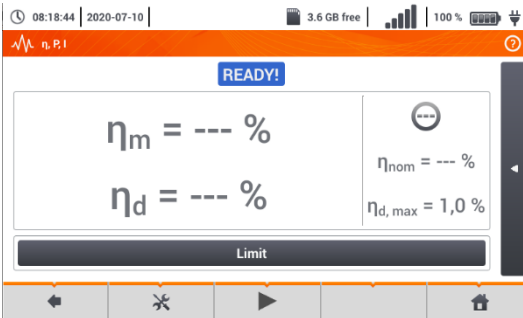
Connect the meter to the tested object. The following parameters will be measured:

- at the inverter input (DC)
- at the inverter output (AC).



◀ In the case of 3-phase inverter, the measurement is made assuming the symmetry of the output currents and voltages on the AC side.

3



You may use icon, to select the data presented on the screen.

- ⇒ currents at input (I_{DC}) and output (I_{AC}),
- ⇒ power values at input (P_{DC}) and output (P_{AC}),
- ⇒ inverter efficiency (η_m) and the difference between the efficiencies of the inverter: measured and declared by the manufacturer (η_d).

Select **Limit**, to set the criterion of the maximum difference between the efficiencies of the inverter: measured and declared by the manufacturer.

If necessary, reset the clamp again.

Use icon to go to the measurement configuration. See sec. 3.20.1, 3.20.2.

4



Press **START**. The live mode readings will be captured and displayed in the main screen.

5 Signal lights for the limit (step 3)

- the result is within the set limit
- the result is outside the set limit
- assessment not possible

After selecting the bar on the right side, a menu will slide out with additional measurement results.

η_m – the efficiency value of the inverter as the ratio of the active power of AC side to active power of DC side

η_{nom} – efficiency of the inverter declared by the manufacturer

η_d – difference between the efficiencies of the inverter: measured and declared by the manufacturer

U_{AC} – voltage measured on AC side

U_{DC} – voltage measured on DC side

I_{AC} – current measured on AC side

I_{DC} – current measured on DC side

Selecting the bar hides the menu.

3.20.1 Measurement configuration

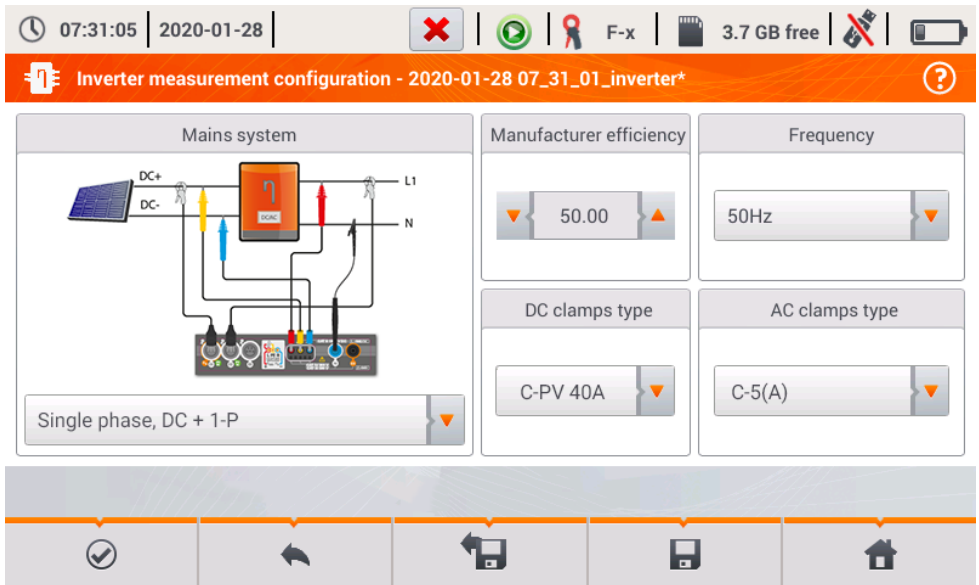


Fig. 3.10. Configuration screen of inverter efficiency measurement

Set the parameters of the tested inverter on the displayed configuration screen:

- **Mains system** – there are two types to choose from:
 - **Single phase, DC + 1-P**

Select this system type for inverters with single-phase AC output. The screen will show a simplified diagram of the meter connection to the tested circuit:

 - DC+ voltage input of the inverter must be connected to L2 input of the meter
 - DC- input of the inverter must be connected to L3 input,
 - AC voltage side of the inverter must be connected to inputs: L1 (phase wire) and N (neutral wire),
 - current of DC side of the inverter is measured with DC clamps connected to I1 input of the clamps.



It is necessary to use clamps for DC measurements

- current of AC side of the inverter is measured with clamps connected to I2 input of the meter. The user may specify any type of clamps compatible with the meter.
- **Three phase, DC + 4-P**

It is possible to measure only the efficiency of three-phase, 4-wire inverters (star configuration with neutral wire). Please note that due to the limited number of voltage inputs in the meter, it is not possible to directly measure all phase-to-phase voltages. Therefore, the measured parameters on AC side are presented as approximate values, with accuracy depending on the symmetry of the output voltages and currents of the inverter. If it works in such systems, verify voltage asymmetry before the efficiency measurement (negative sequence unbalance U_2/U_1 should be less than 1%). This verification should be carried out by configuring and connecting the meter in a standard way to a three-phase network 4-P (sec. 5.6.3, 5.6.4).

How to connect the meter:

- DC+ voltage input of the inverter must be connected to L2 input of the meter
- DC- input of the inverter must be connected to L3 input,
- AC voltage side of the inverter must be connected to inputs: L1 (phase wire) and N (neutral wire),
- current of DC side of the inverter is measured with DC clamps connected to I1 input of the clamps.









It is necessary to use clamps for DC measurements

- current of AC side of the inverter is measured with clamps connected to I2 input of the meter. The user may specify any type of clamps compatible with the meter.
- **Manufacturer efficiency** – efficiency of the inverter declared by the manufacturer. This value is used to compare the measured efficiency with the declared value.
- **DC clamps type** – the user may use the list to select the type of clamps used for current measurements on DC side of the inverter.
- **AC clamps type** – the user may use the list to select the type of clamps used for current measurements on AC side of the inverter.
- **Frequency** – nominal frequency of the AC output of the inverter.

After setting the required parameters, you can go directly to the required measurements.

Menu bar functions

-  entering the measurement screen (live values in a tabular view) with the specified settings (without saving the configuration).
-  saving the configuration of inverter efficiency to a file with an option to start the measurement directly after saving (field **Go to Live mode** in the pop-up window).
-  entering the list of saved configurations of inverter efficiency and creating a new configuration. Configurations are presented similarly to the measuring configurations, they have their own icon . Double-tap on a selected configuration will open it automatically and entering the screen with inverter efficiency settings (**Fig. 3.11**). The button in the menu bar  is used for adding new configurations starting of the inrush current (a window is displayed, as shown in **Fig. 3.12** with default settings). Icon  is used to edit the chosen configuration.

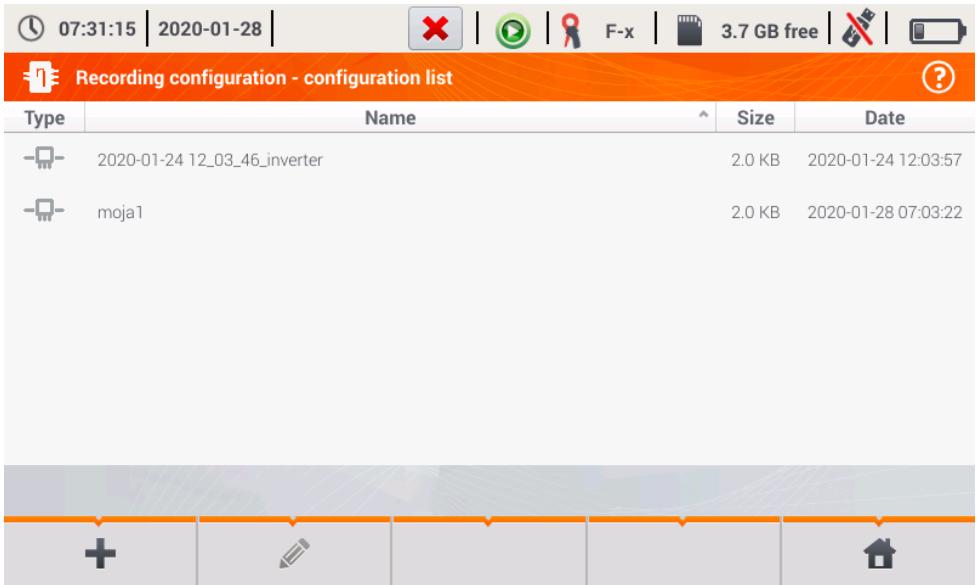


Fig. 3.11. Menu of recording configuration

3.20.2 Live mode

After entering the live mode screen, all the parameters of the measured inverter circuit are shown in a tabular view.

	η_m [%]	η_d [%]	U [V]	U_{ho1} [V]	U_{DC} [mV]	f [Hz]	I [A]
AC/DC	16.03	33.97	---	---	---	---	---
DC	---	---	3.282	---	-3.235	---	1.464
L1	---	---	0.057	---	14.73	0.000	0.624
L2	---	---	---	---	---	---	---
L3	---	---	---	---	---	---	---
N	---	---	---	---	---	---	---
L1-2	---	---	---	---	---	---	---
L2-3	---	---	---	---	---	---	---

Fig. 3.12. Live mode in tabular view for the inverter efficiency measurement mode

- **AC/DC** line:
 - column η_m displays the efficiency value η_m of the inverter as the ratio of the active power of AC side to active power of DC side:

$$\eta_m[\%] = \frac{P_{AC}[W]}{P_{DC}[W]} \cdot 100\%$$

- column η_d shows the difference between the measured and declared efficiency of the inverter:

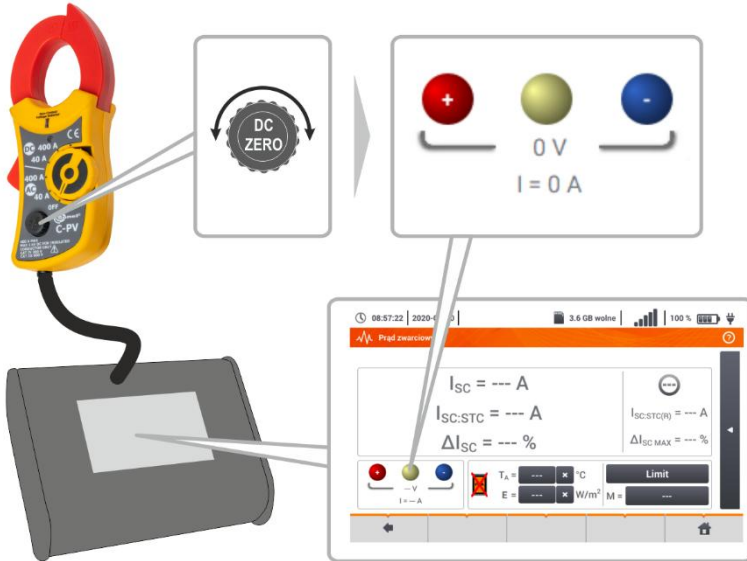
$$\eta_d[\%] = \eta_{nom}[\%] - \eta_m[\%]$$

where η_{nom} is the declared efficiency of the inverter entered to the configuration screen.

- line **DC** presents the parameters of DC side of the inverter such as voltage, current, active power, active energy.
- values related to AC side are displayed in lines: **L1** and **Σ**.

3.21 **MPI-540-PV** *Resetting C-PV clamp*

Before the I_{SC} measurement and testing the inverter (**sec. 3.19, 3.20**) reset C-PV clamp. To do this, connect the clamp to the meter. Set the **DC ZERO** knob on the housing of the clamp to make the voltage and current readings as close to zero as possible. Only then you can connect the clamp to the tested object.



3.22 **MPI-540-PV** *Irradiance and temperature*

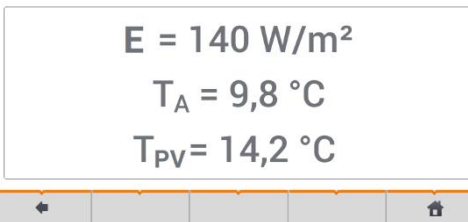
1 Pair the instrument and the irradiance meter according to **sec. 2.3.3**.



Select item **Irr**, to display the measurement screen.



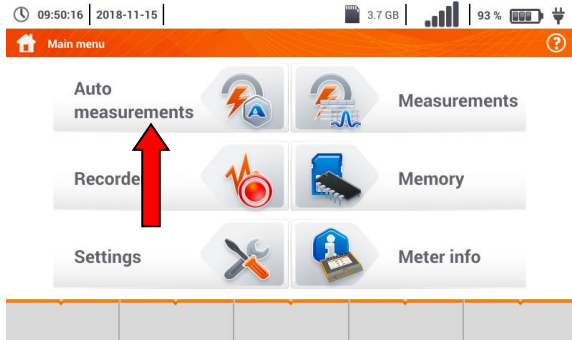
Connect the irradiance meter to the tested object. The screen shows the current readings:



E – irradiance,
T_A – ambient temperature,
T_{PV} – PV module temperature.

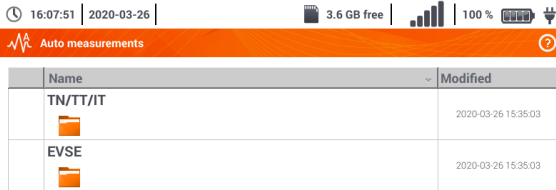
4 Auto measurements

The meter includes automated test procedures.



4.1 Proceeding auto measurements

1



The measurement sequences are grouped into two folders:

- ⇒ measurements in TN/TT/IT networks,
- ⇒ measurements dedicated for electric vehicles charging stations.

Select the measuring sequence from the list.

2



Connect the meter to the measuring system.

In each setting field, enter the type of measuring accessory, installation parameters and other required data.

Description of function icons

- assistance for a particular measurement
- collapsing setting fields
- expanding setting fields
- saving entered measurement data

3



Press **START**. The automatic measurement sequence will start.

4



◀ The screen after completion of one of sequence measurements.

Description of function icons

- stopping the procedure and going to summary
- ↺ repeating the measurement with overwriting its result
- ↻ repeating the measurement without losing its previous result
- ⏸ stopping the procedure
- ▶▶ going to the next step of the procedure or to the summary. Time remaining to the next step is set according to **sec. 2.2.1.**

5



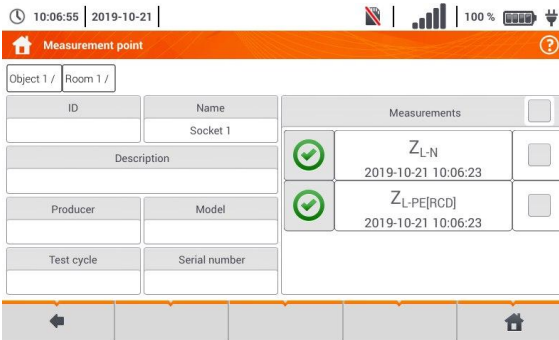
◀ Summary screen.

The procedure can be restarted with the ↺ icon.

Each measurement in a sequence hides partial results. To call them, touch the **label of such measurement**. A window as for a single measurement will be opened. Enter it with the use of the ⬅ icon.

Save the measurement to the meter memory using the 💾 icon. A detailed description of memory management is contained in **section 6.1.3.**

6



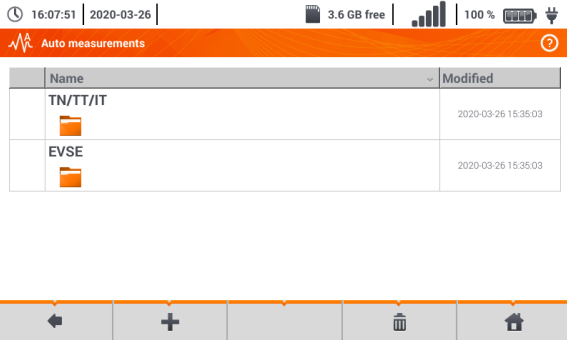
All sequence measurements will be saved in one measuring point.

Signal lights for reaching the limit

- ✔ the result is within the set limit
- ✘ the result is outside the set limit
- ⋯ assessment not possible
- no measurement was made

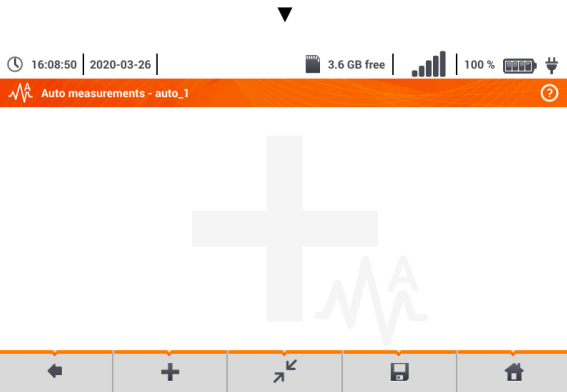
4.2 Creating measurement procedures

1

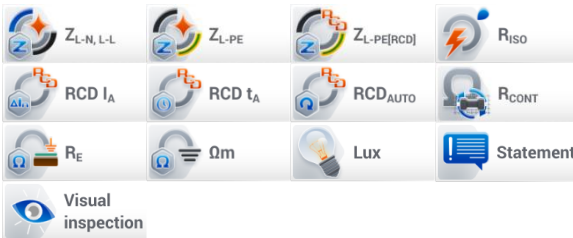


- Select **+**, to go to the sequence wizard.

- Select **+**, to add the desired measurement procedure.



2



From the available items select the one, which is to be a part of the procedure. In addition to standard measurements, the following are also available:

- ⇒ text message,
- ⇒ visual test.

3



After each selection, the menu with step parameters will be shown.

If the tests contain measurements in electric vehicle charging stations, then **EV** box should be selected.

Description of function icons

- assistance for a particular measurement
- collapsing setting fields
- expanding setting fields
- saving entered measurement data

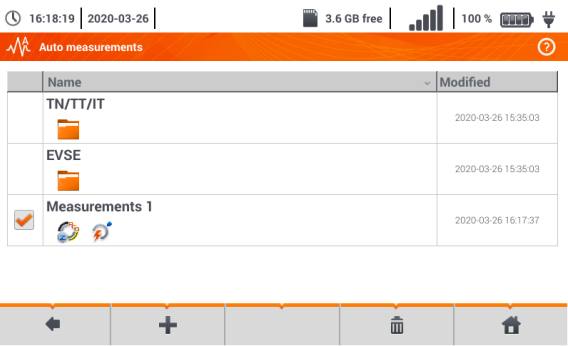
4



- Changing the order of the steps is performed by using icons. Delete the step by using icon.

- Save the procedure by using icon. A window will be shown requesting the name of the procedure.

5



The procedure will be available from the main menu of auto-procedures. To remove it, select it with and choose .

5 Recorder

5.1 Functional Description

MPI-540 meter can be used as a 3-phase recorder of power supply parameters. It allows measurement and recording of parameters of 50/60 Hz power networks such as voltage, current, power, harmonics values, etc. To switch to the meter to power supply quality analyzer mode, select **Recorder** on the main screen.

In this mode it is possible to view the current network parameters (i.a. waveforms, component vectors, tabular data), recording of average parameter values according to the user settings and analysis of the recorded data (time diagrams, harmonics, etc.).

The analyzer module uses the following input sockets of the meter:

- three sockets of **current** clamps I1, I2, I3,
- three **voltage** banana sockets L1, L2, L3 in the multifunctional socket, to which individual voltage phases are connected (max. 550 V relative to earth),
- separate banana socket marked N.



Fig. 5.1 Measuring inputs

Four sockets for current clamps allow the user to connect several types of clamps to measure currents. The following clamps may be connected to them:

- flexible clamps F-1A, F-2A, F-3A of nominal range of 3000 A AC (different only in terms of the coil perimeter),
- CT clamps: C-4A (range 1000 A AC), C-5A (range 1000 A AC/DC), C-6A (range 12 A AC) and C-7A (range 100 A AC).

The measuring range may be changed by using additional transducers – for example, using a transducer of 10 000 A / 5 A with C-6A clamps the user may measure currents up to 10 000 A.

The recorded data is stored on a removable microSD memory card. The meter also has an internal memory, which is used for storing i.a. configuration files. A detailed description of memory management is contained in **section 5.5.3**.

Configuration of the recorder consists in that the user only sets the basic parameters: type of network, type of clamps, frequency, averaging period. All data that the meter is able to measure is always recorded. All parameters of the power supply network measured by the meter in the recorder mode are listed below:

- RMS voltage,
- DC components of voltages,
- RMS currents,
- DC components of currents (only using C-5A clamps),
- mains frequency within the range of 40..70 Hz,
- harmonics of voltages and currents (up to 40th),

- total harmonic distortion (THD) THD_F for currents and voltages,
- active, reactive, apparent and distortion power,
- active positive and negative energies,
- passive energies consumed and returned,
- apparent energies,
- power factors (PF)
- unbalance factors of voltages and currents

Some of the parameters are aggregated (averaged) according to the time selected by the user (available settings: 1 s, 3 s, 10 s, 30 s, 1 min, 10 min, 15 min, 30 min) and may be stored on a memory card.

The meter is compatible with PC software *Sonel Analysis*, which also supports other analyzers produced by Sonel. This software allows analysis of the recorded data. The data may be read using the USB cable or directly from a microSD card after inserting it to an external memory card reader connected to PC.

Tab. 5.1 presents a summary of parameters measured by MPI-540, depending on the mains type.

Tab. 5.1. Measured parameters for different network configurations

Parameter		Network type, channel		1-phase			2-phase			3-phase 4-wire				3-phase 3-wire			
		L1	N	L1	L2	N	Σ	L1	L2	L3	N	Σ	L12	L23	L31	Σ	
U	Effective voltage	•		•	•	•		•	•	•			•	•	•		
U _{DC}	Voltage constant component	•		•	•	•		•	•	•			•	•	•		
I	Effective current	•		•	•	•		•	•	•	•		•	•	•		
I _{DC}	Current constant component	•	•	•	•	•		•	•	•	•		•	•	•		
F	Frequency	•		•				•					•				
P	Active power	•		•	•	•	•	•	•	•	•	•				•	
Q ₁	Reactive power	•		•	•	•	•	•	•	•	•	•				• ⁽¹⁾	
D, S _N	Distortion power	•		•	•	•	•	•	•	•	•	•					
S	Apparent power	•		•	•	•	•	•	•	•	•	•				•	
PF	Power Factor	•		•	•	•	•	•	•	•	•	•				•	
tanφ	Factor tangent φ	•		•	•	•	•	•	•	•	•	•				• ⁽¹⁾	
THD _F U	Total harmonic distortion voltage	•		•	•	•		•	•	•			•	•	•		
THD _F I	Total harmonic distortion current	•	•	•	•	•		•	•	•	•		•	•	•		
E _{P+} , E _{P-}	Active energy (consumed and supplied)	•		•	•	•	•	•	•	•	•	•				•	
E _{Q1+} , E _{Q1-} , E _{Q3+} , E _{Q3-}	Reactive energy (consumed and supplied)	•		•	•	•	•	•	•	•	•	•				• ⁽¹⁾	
E _S	Apparent energy	•		•	•	•	•	•	•	•	•	•				•	
U _{h1..h40}	Voltage harmonic amplitudes	•		•	•	•		•	•	•			•	•	•		
I _{h1..h40}	Current harmonic amplitudes	•	•	•	•	•		•	•	•	•		•	•	•		
Unbalance U, I	Symmetrical components and unbalance factors												•			•	

Explanations: L1, L2, L3 (L12, L23, L31) indicate subsequent phases,

N is a measurement of I_N current depending on the parameter type,

Σ is the total value for the system.

(1) In 3-wire networks, the total reactive power is calculated as inactive power N.

(2) Only consumed energy E_{P+}.



- During recording the **HV LED / REC / CONT.** diode flashes **red** at 2-second intervals.
- In order to avoid ambiguity in the calculating power values, attach clamps with their arrows indicating the point of connecting L terminal of the meter to the tested object.
- If they are attached in the other direction, an appropriate correction may be introduced in the meter before recording starts (**section 5.5.1**).

5.2 Main elements of the screen

After entering the recorder mode the **Main menu** is displayed. It is available:


- after switching the meter on,
- at any time after the  icon has been selected on the display.



Fig. 5.2 Main elements of the recorder screen

1 Top bar

2 Name of the active menu

The fact of introducing a change that has not been saved yet is indicated by the * symbol in the screen header.



3 Main window

4 Information bar on current network configuration ,

5 Function icons bar

6 Active menu help

- Visualisation of connection systems
- Explanation of icons

5.2.1 Top bar

At the top of the screen there is a bar with status controls (Fig. 5.3).

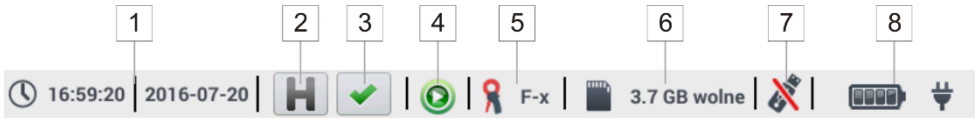


Fig. 5.3. Elements of the top bar

1 Current time and date

2 HOLD function control

Selecting this icon on the screens of LIVE mode (preview of the current network, see **sec. 5.6**) will stop the refreshing of image displayed in the main window. Press it again to return to normal mode.

3 Verifying the connection control

The icon on this button informs the user about the correctness or potential problem with the configuration or connection of the recorder (symbols , or may be displayed). Pressing this icon will display a window with more detailed information about possible errors in connecting the recorder to the mains and with the compliance of mains parameters with the current measurement configuration. More information can be found in **section 5.3.2**.

4 Recording status icon

- recording inactive
- recording active

5 Information on connected or configured current clamps

- If the measurement configuration has **no clamps indicated** - the field displays **dashes "---**".
- When a **specific type of clamps** is selected, their **name** will be displayed.

6 Memory card icon with information about free space

If the card is not in the slot, the icon on the screen is crossed out.

7 USB external memory icon (flash drive)

If no external memory is connected, the icon is crossed out.

8 The icon of battery charge status and mains power supply

5.2.2 Title bar

The title bar (Fig. 5.2, element **2**) displays the name of the current main window with the name of the section. It allows the user to quickly see which part of the interface is displayed.

5.2.3 Main window

In the central part of the screen, the main window of the recorder is displayed. The default window (shown in Fig. 5.2) contains the following items:






- **Recording configuration** – this part of the interface is used to configure the measurement system and all aspects related to the recording of network parameters such as: network type (e.g. single-phase, three-phase) or clamps type (**section 5.4**),
- **Recording analysis** – provides an analysis of the recorded data and 'live' view of the recording process (**section 5.7**),
- **Analyzer settings** – a series of the recorder configuration options can be found here (more: **section 5.5**),
- **Energy loss calculator** – in this mode the user can estimate financial losses due to poor quality of power supply,
- **Exit** – go to the main menu.

5.2.4 Information bar on the parameters of the current network


Below the main screen a bar is displayed, which shows the main parameters of the active measurement system (Fig. 5.2, element 4):

- nominal voltage,
- network frequency,
- network layout,
- name of the current recording configuration.

The network layout is symbolized by icons:

-  1-phase system,
-  2-phase system,
-  3-phase 4-wire system,
-  3-phase 3-wire system,
-  3-phase 3-wire system with the measurement of currents using Aron's method,

5.2.5 Help

On the right side of the title bar the help icon  is seen (Fig. 5.2, element 6). After its selection, a context help is displayed, which describes interface elements visible on the screen.

5.3 Connecting the measuring system

5.3.1 Measuring arrangements

The recorder may be connected directly to the following types of AC networks:

- single-phase (Fig. 5.4)
- 2-phase (split-phase) with split-winding of the transformer) (Fig. 5.5),
- 3-phase 4-wire (Fig. 5.6),
- 3-phase 3-wire (Fig. 5.7 ,Fig. 5.8).

In three-wire AC systems, current may be measured by the Aron method (Fig. 5.8), which uses only two clamps that measure linear currents I_{L1} and I_{L3} . I_{L2} current is then calculated using the following formula:

$$I_{L2} = -I_{L1} - I_{L3}$$

Pay attention to the direction of current clamps (flexible and hard). The clamps should be installed with the indicating the load direction. It may be verified by conducting an active power measurement - in most types of passive receivers active power is positive. When clamps are inversely connected, it is possible to change their polarity using in software (**Analyzer settings**→ **Clamps**)

The following figures show schematically how to connect the analyzer to the tested network depending on its type.

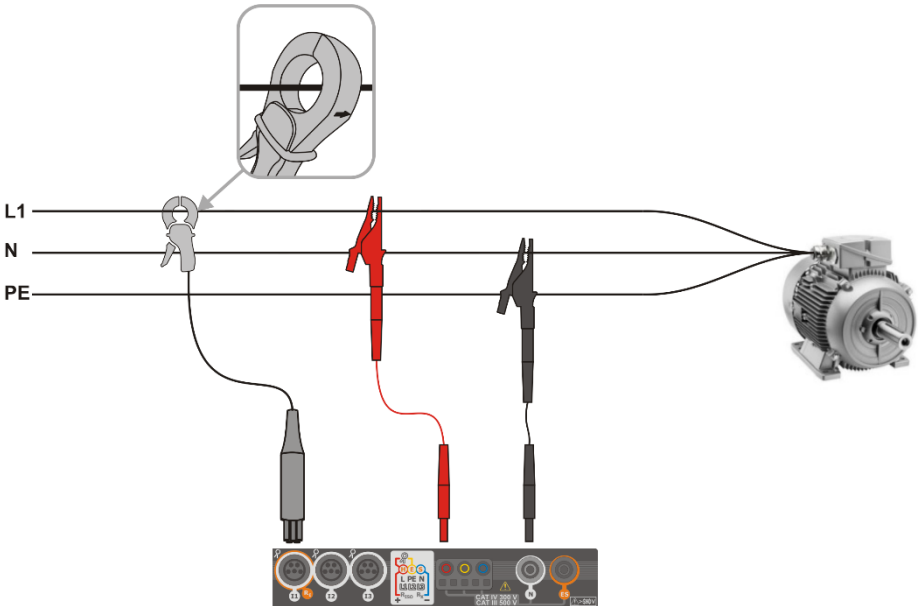


Fig. 5.4 Wiring diagram – single phase

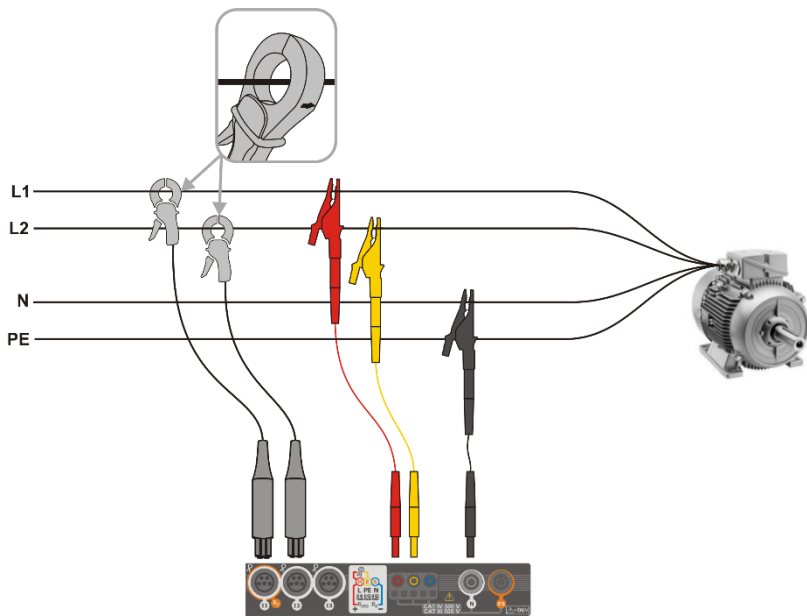


Fig. 5.5 Wiring diagram – 2-phase

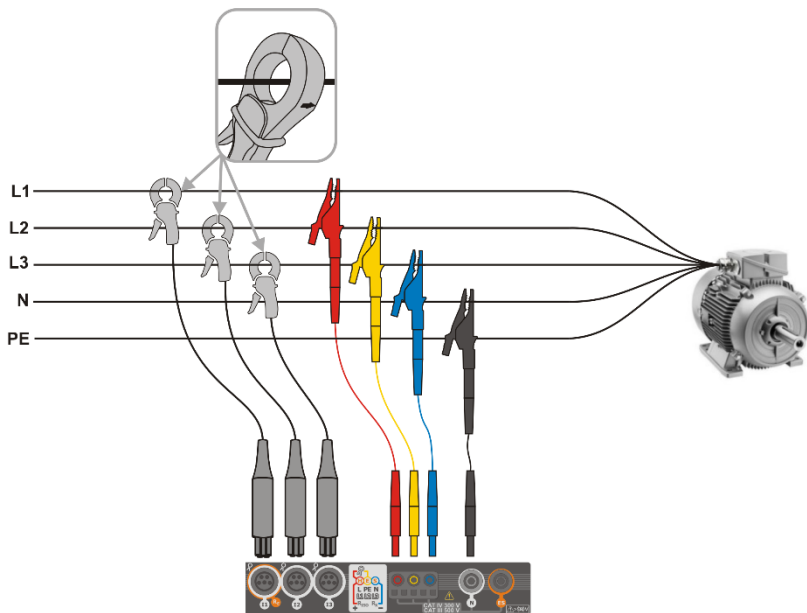


Fig. 5.6 Wiring diagram – 3-phase with four operating wires

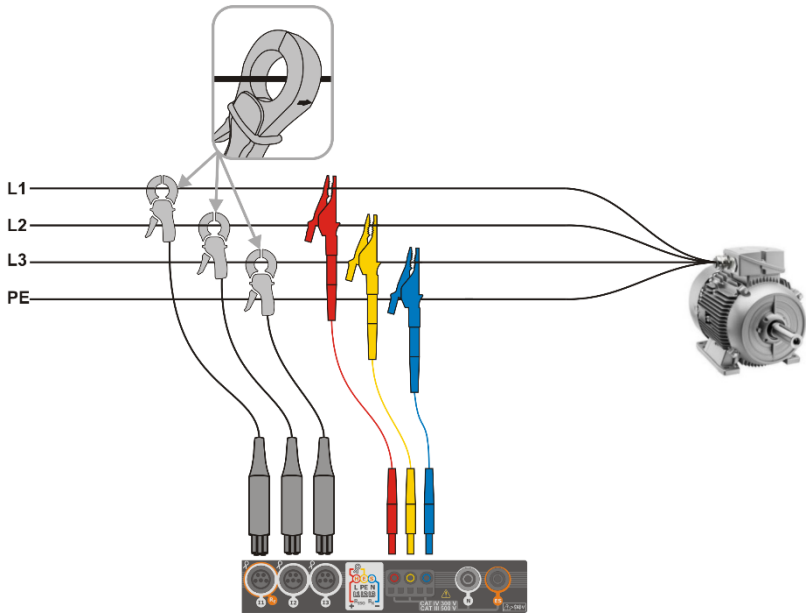


Fig. 5.7 Wiring diagram – 3-phase with three operating wires

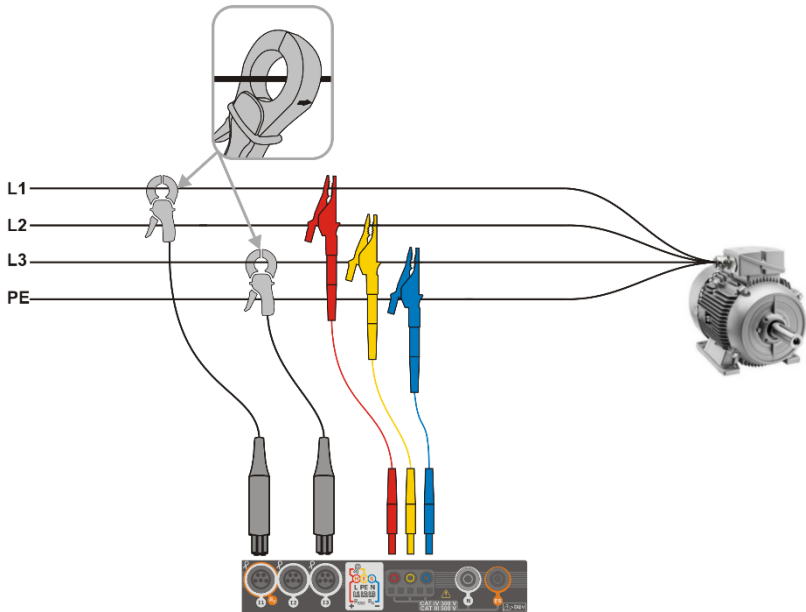



Fig. 5.8 Wiring diagram – 3-phase with three operating wires (measurement of currents using Aron method)

5.3.2 Verifying the connection

Selecting the top bar icon signalling the correct connection of the recorder (Fig. 5.3 element ) a window is displayed showing some important information on the connection of the recorder to the tested network. This information **helps the user to verify the compliance** of the current configuration of the recorder with the parameters of the measured network.

- **Voltage values** – two possible icons:
 - ✓ RMS voltages are correct, they are within the tolerance range \pm of 15% of the nominal voltage,
 - ✗ RMS values are outside the range of $U_{nom} \pm 15\%$.
- **Current values** – four options:
 - ✓ RMS currents are in the range of $0.3\% I_{nom} \dots 115\% I_{nom}$,
 - ? RMS currents are lower than $0.3\% I_{nom}$,
 - ✗ RMS currents are higher than $115\% I_{nom}$,
 - dashes are displayed when the current measurement is disabled in the configuration.
- **Voltage vectors** – the recorder verifies the correctness of the basic angles and displays the corresponding icon:
 - ✓ the vectors have correct angles in the range of $\pm 30^\circ$ of the theoretical value for a resistive load and symmetrical circuit (in 3-phase systems),
 - ? the accuracy of angles cannot be verified, because the RMS voltage value is too low (less than 1% of U_{nom}),
 - ✗ incorrect angles of vectors. In three-phase systems, this icon is displayed, among others, in case of reversed sequence of voltage phases.
- **Current vectors** – correctness of vector angles is verified for the components of main currents in relation to the voltage vectors. The following icons are displayed:
 - ✓ vectors are within $\pm 55^\circ$ in relation to angles corresponding to the voltage vectors,
 - ? the accuracy of current vector angles cannot be verified, because the RMS current values are too low (below 0.3% of I_{nom}),
 - ✗ vectors are outside the acceptable range of angles ($\pm 55^\circ$),
 - dashes are displayed when the current measurement is disabled in the configuration
- **Frequency:**
 - ✓ the measured grid frequency is in the range of $f_{nom} \pm 10\%$,
 - ? the RMS value of reference voltage phase is lower than 10V or there is no PLL synchronization,
 - ✗ the measured frequency is outside of $f_{nom} \pm 10\%$.

The icon is displayed in the top control bar in the following way:

- ✗ if the table includes is at least one ✗,
- ? if the table includes is at least one ?, but there is no error (no ✗),
- ✓ if all measured parameters are correct.

5.4 Recording configuration

Before any measurement it is necessary to properly configure the recorder in accordance with the requirements of the user. Configuration changes are made from the meter level.

5.4.1 Configuration using the meter

To access the configuration module on the main screen, select section **Recording configuration**. The list is displayed with measurement configurations saved in the recorder memory (Fig. 5.9).

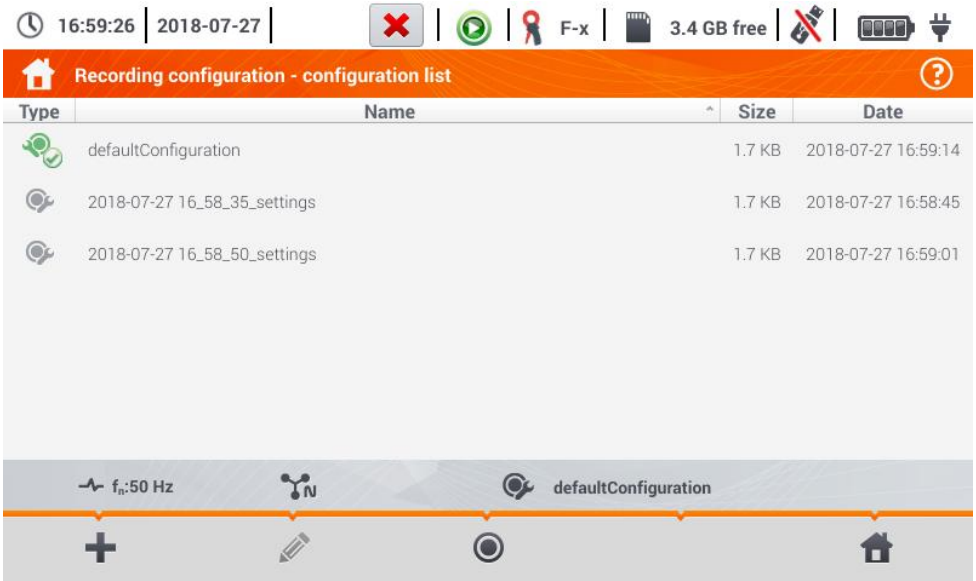






Fig. 5.9. Recording configuration – configuration list.


The table consists of columns:


- **Type** – displayed icon determines the type of measurement configuration:
 -  recording according to user configuration (inactive – grey)
 -  recording according to user configuration (active – green)
- **Name** – the name of the configuration given by the user,
- **Size** – the size of the configuration file,
- **Date** – Date - date and time of creating the configuration.

The list can be **scrolled** by moving a finger across the window.

Item sorting is performed by tapping the header. The first row of the table contains the active configuration. In the next rows the item will be sorted:





- in ascending order (symbol  next to the header),
- in descending order (symbol  next to the header).

To **activate the desired configuration**, select its line, and then on the bottom bar select icon  (activating the configuration).


To **modify the selected configuration**, on the bottom bar select icon  (editing) or double-tap the line of this configuration.

To **add a new configuration**, select icon  (add).

Description of function icons

-  adding a new configuration
-  editing the active configuration
-  activating the selected configuration
-  returning to the main menu of the recorder mode

5.4.2 Recording configuration

After the  icon has been selected, a new window will be displayed as shown in Fig. 5.10. The default name of the new configuration will be displayed in the title bar, created from the current date and time in the "YYYY-MM-DD hh_mm_ss_settings" format, which may be modified.





An asterisk after the name indicates that the configuration has been **modified** but **not saved**.

The screenshot displays the 'Recording configuration' screen. At the top, the status bar shows the time 11:45:03, date 2022-11-24, and various system icons. Below this is an orange title bar with the configuration name 'Recording configuration - 2022-11-24 11_44_23_settings*' and a help icon. The main content area is divided into several sections:


- Mains system:** A diagram showing a 3-phase 4-wire system with phases L1, L2, L3, and N connected to a device. A dropdown menu below the diagram is set to '3-phase 4-wire'.
- Frequency:** A dropdown menu set to '50Hz'.
- Nominal voltage:** A dropdown menu set to '230/400' V.
- Period time:** A dropdown menu set to '10s'.
- Clamps type:** A dropdown menu set to 'F-1(A), F-2(A), F-3(A)'.

At the bottom, there is a navigation bar with icons for back, forward, home, and a save icon. The bottom-most bar shows the current frequency $f_n: 50 \text{ Hz}$, a neutral line icon, and the configuration name '2022-11-16 13_41_48_settings'.

Fig. 5.10. Recording configuration – general settings

Buttons  and  at the bottom menu bar are used to switch between successive screens.

At this point, you may define:

- **Mains system.** By selecting the icon from drop-down list  or on the network name, you can select the following types:
 - ⇒ **1-phase,**
 - ⇒ **split-phase,**
 - ⇒ **3-phase 4-wire** – systems with neutral wire, e.g. star with N,
 - ⇒ **3-phase 3-wire** – systems without neutral wire – star without N and delta,
 - ⇒ **3-phase 3-wire Aron** – as standard 3-wire system, but with the current measurement using two clamps (I_1 i I_3). The third current (I_2) is determined by calculation from the relationship $I_2 = -I_1 - I_3$.
- **Frequency** – mains nominal frequency. The following options are available:
 - ⇒ **50 Hz,**
 - ⇒ **60 Hz.**
- **Averaging period** - specifies the time of averaging recorded parameters and also the time between successive recorded data on a memory card (except events). The following settings are available:
 - ⇒ 1 s,
 - ⇒ 3 s,
 - ⇒ 10 s,
 - ⇒ 30 s,
 - ⇒ 1 min,
 - ⇒ 10 min,
 - ⇒ 15 min,
 - ⇒ 30 min.
- **Nominal voltage.** The following settings are available: 58/100, 64/110, 110/190, 115/200, 120/208, 127/220, 133/230, 220/380, 230/400, 240/415, 254/440, 290/500, 400/690 V
- **Clamps type** - here you can enable or disable the measurement of currents and determine the type of clamps. If the current measurement is required, indicate clamps to be used from the following list:
 - ⇒ **No** – clamps not applied,
 - ⇒ **F-1(A), F-2(A), F-3(A)** – flexible clamps (Rogowski coil) with a nominal range of 3000 A AC,
 - ⇒ **C-4** – clamps CT (with core) with a range of 1000 A AC,
 - ⇒ **C-5** – clamps with a Hall sensor with a range of 1000 A AC/DC,
 - ⇒ **C-6** – clamps CT (with core) with a range of 12 A AC,
 - ⇒ **C-7** – clamps CT (with core) with a range of 100 A AC.
- **Voltage events: Log events** – ticking this box enables voltage event detection: swells, dips, interruptions. Three field with values allow the user to introduce own thresholds for these three types of events. Thresholds may be entered in volts or as a percentage values referenced to the nominal voltage of the network, e.g. setting the threshold of swell as +10% at nominal voltage of 230 V triggers the detection of swell after exceeding 253 V voltage ($RMS_{1/2}$). The event ends when the voltage drops to the threshold value reduced by hysteresis. If the hysteresis in the described case is 2%, then the end of the event will occur if when voltage ($RMS_{1/2}$) is lower than 248.4 V (253 V – 4.6 V).

- **Current events: Log events** – ticking this box enables current event detection. Entering "0" disables a given event. The entered values may be from range 0 ... I_n (where I_n is the current measurement range after taking into account current transformers).
 - **L max [A]** - maximum value threshold for current L1, L2, L3 (depending on the network). An event is detected when the value of $RMS_{1/2}$ current exceeds the specified threshold.
 - **L min [A]** – minimum value threshold for current L1, L2, L3. An event is detected when the value of $RMS_{1/2}$ current drops below the specified threshold.
 - **N max [A]** – similarly to L max, but it relates to N current channel (neutral current).
 - **N min [A]** – similarly to L min, but it relates to N current channel (neutral current).
- **Settings: Hysteresis** - percentage value in the range from 0.1 to 10, to be used for detecting events. Higher values allow to limit the number of detected events if the parameter value fluctuates around the threshold. The typical value of the hysteresis is 2%.

Description of function icons



returning to configuration list without saving changes



saving changes Additional window will appear, where it is possible to:

⇒ change the name of configuration,

⇒ set the saved configuration as active () or inactive (),

⇒ accept the selection (**Ok**),

⇒ cancel the selection (**Cancel**)

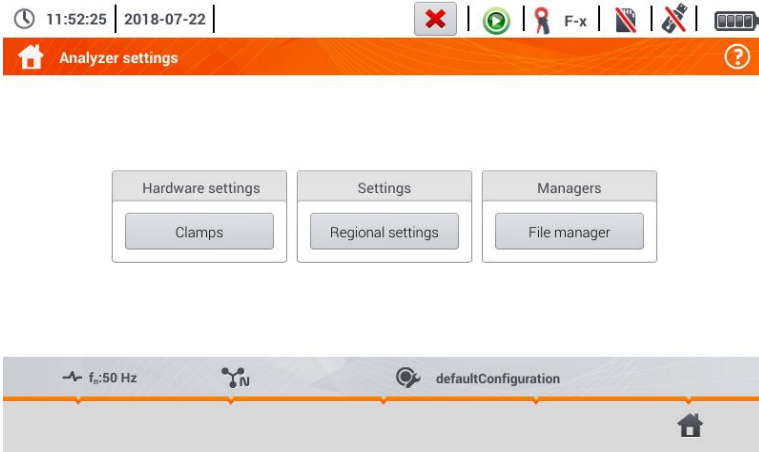


return to the main menu of the recorder mode

5.5 Analyzer settings

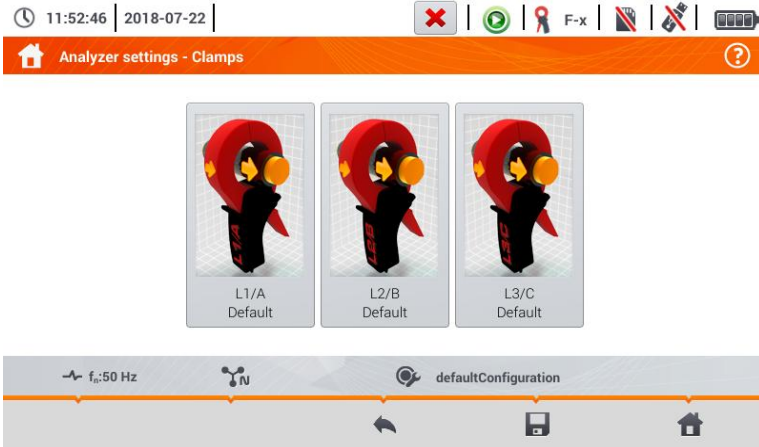
On the **Analyzer settings** screen it is possible to:

- specify the manner of clamps fastening,
- change the phase identification,
- view files stored in the recorder mode.



5.5.1 Hardware settings – clamps (manner of connecting)

If the clamps have not been attached in accordance with the direction of the current flow, this information can be entered into the meter. Then the recorder readings will be automatically corrected. This is useful in situations where the physical reversing of clamps is impossible or difficult.





To **enter information** on the manner of attaching the clamps, tap the corresponding icon. The manner of connecting (forward/reverse) will change to the opposite (reverse/forward).



Phase of clamps can not be changed during the recording process.

Description of function icons

 returning to the recorder settings menu

 saving changes Additional window will appear, where it is possible to:
 ⇒ accept the selection (**Yes**)
 ⇒ cancel the selection (**No**)

 return to the main menu of the recorder mode


5.5.2 Settings – Regional settings

On the **Regional settings** screen it is possible to change:

- **identification of phases.** Available options:
 - ⇒ L1, L2, L3,
 - ⇒ A, B, C,
- **phase colours.** Wire colouring schemes are available for:
 - ⇒ the European Union,
 - ⇒ Australia,
 - ⇒ India,
 - ⇒ China,
 - ⇒ the United States,
 - ⇒ plus two additional schemes (U1, U2), configurable by the user.






Fig. 5.11 Regional settings

1  If option U₁ or U₂ has been selected, a screen of colour selection for a specific phase current or voltage waveforms will appear.

The 'Set phase colors' screen features a 10x10 color grid. Below the grid are eight circular color selection buttons labeled U_{L1}, U_{L2}, U_{L3}, U_N, I_{L1}, I_{L2}, I_{L3}, and I_N. At the bottom right are 'Ok' and 'Cancel' buttons.

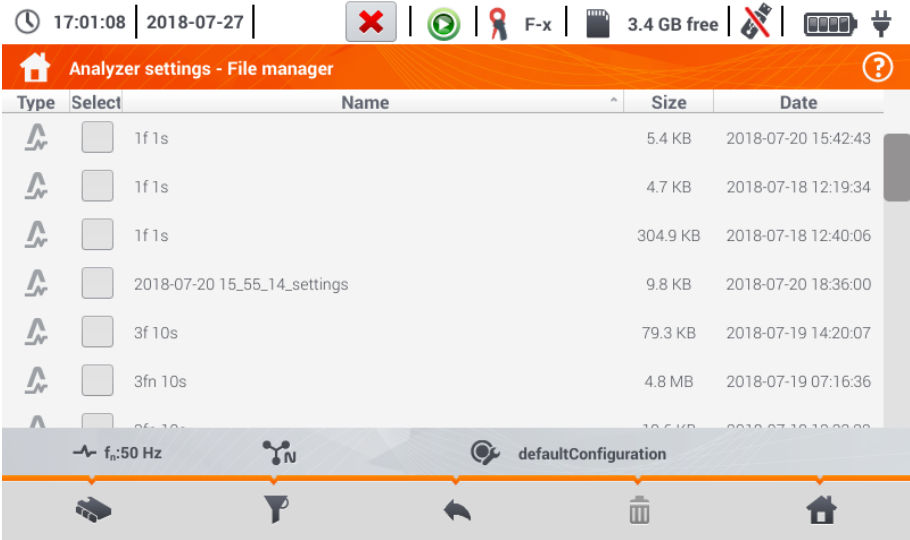
- 2 Tap the control of the required variable.
- 3 Tap the required colour in the colour selection area.
- 4 Repeat the 2 3 as many times as required.
- 5 **Ok** - confirming changes and returning to the previous screen
Cancel - rejecting the selection and returning to the previous screen

Description of function icons

-  returning to the **Analyzer setting** menu
-  saving changes
-  returning to the main menu of the recorder mode

5.5.3 Managers – file manager

On the **Analyzer settings – file manager** screen recordings saved to the memory of the meter can be viewed.




a. Data viewing

In the **Type** column icons are contained defining the type of record (waveform , screenshot , configuration file). Checkbox in the **Select** column lets the user activate the required entry (→).

Description of function icons

- selection of the location to be searched. After selecting, the menu with the following options appears:
 - microSD card selection
 - selection of the internal memory of the meter
 - saving active () files to a flash drive (option active if there is a flash drive in the USB slot)
 - activating/deselecting all records
 - closing the menu
- filtering the list of files. After the icon has been selected, filtering options appear (possibility of multiple selection, the active filter icon is **orange**):
 - saved waveforms
 - configuration file
 - screenshots with waveforms
- returning to the **Analyzer setting** menu
- removing active () record.
- returning to the main menu of the recorder mode

b. Data preview

From the file manager level the content of screenshots can be opened (symbol ). To do this, double-tap the required item (Fig. 5.12).

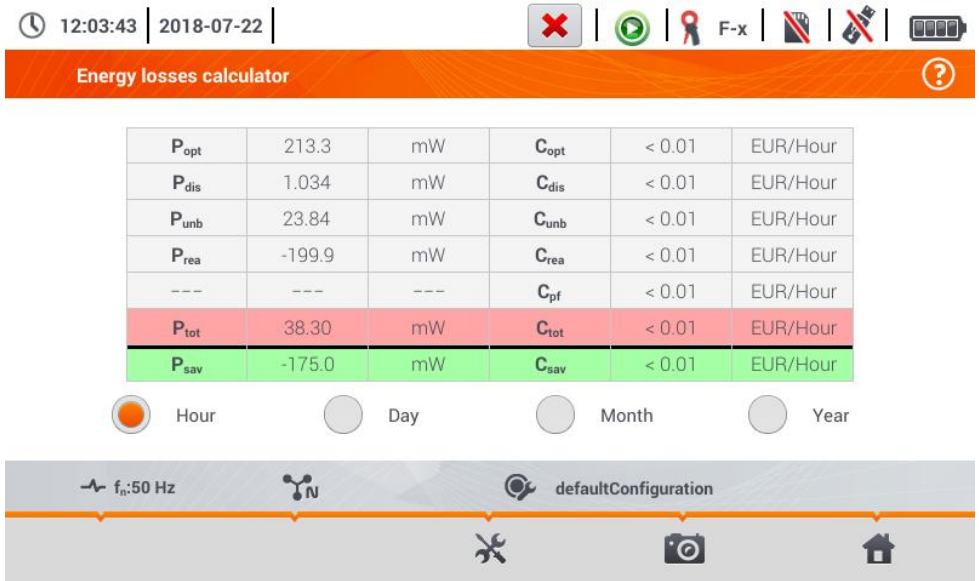











Fig. 5.12 Preview of a sample screenshot

Description of function icons

-  previous screenshot
-  next screenshot
-  return to the file manager
-  return to the main menu of the recorder mode

5.6 LIVE mode of the network


The recorder allows the user to preview network parameters in real time (LIVE mode). The icons of available views are displayed in the main recorder menu, in the bottom part:

-  view of waveforms of currents and voltages
-  timeplot view,
-  view of the table of measurements ,
-  view of the phasor diagram,
-  view of harmonics.

Screen refreshing in the LIVE mode can be temporarily blocked using the **HOLD** function (see description of the top bar in **section 5.2.1**).

- To pause refreshing, select the button on the top bar (the colour of the icon changes to **red**).
- To resume screen refreshing, select the icon again (the colour of the icon will change to **black**).

5.6.1 Transient waveforms of current and voltages (waveforms)

After the  icon has been selected the view of waveforms of currents and voltages is displayed. They show two periods of network waveforms for active channels (depending on the measurement configuration).

A sample screen is shown in Fig. 5.13 Use **labels** on the right side of the window to **switch on** and **off** individual measuring channels (at least one waveform must be always visible). Each label includes the **name of the channel** (for example "U L1") and its **effective value**.




Fig. 5.13. "Live" mode - waveforms

Description of function icons



menu of active channels. After touching, an additional menu bar is opened with buttons for enabling or disabling the display of a phase or current and voltage. The active channel is indicated by **orange** colour of the icon. Remember that the screen must **always display at least one waveform** (you can not turn off all of them). The menu displays only the buttons of channels that exist in the network layout. From this menu you can turn off:

- U collectively all voltage waveforms
- I collectively all current waveforms
- L1 collectively all phase L1 waveforms
- L2 collectively all phase L2 waveforms
- L3 collectively all phase L3 waveforms
-  selecting this icon closes the menu



zooming of the displayed waveform. After the icon has been selected, a menu expands with the following options:




after selecting this icon, use your finger to circle the area which is to be zoomed in. The graph is then enlarged; it may be moved with a finger up, down and to the sides



after selecting this icon graph will be zoomed out in steps



selecting this icon closes the zooming menu (also, the  may be selected)



icon for selecting the view type. An additional menu appears, where type of view of the LIVE mode can be changed



screenshot Selecting it saves the current contents of the main window to a graphic file. The file name is automatically created basing on the view name and the current date, for example "*Current Readings - waveforms – 2016-08-01 12_00_00*". The files are saved to the internal memory of the meter




return to the main menu of the recorder mode



- The diagram can be scaled with gestures. To **zoom in, move apart** the two fingers touching the screen in the opposite directions). To **zoom out – bring together** the two fingers touching the screen).
- Waveforms return to their default size after turning on/off any channel (buttons on the right side).

5.6.2 Timeplot of effective values

After the  icon has been selected, the view of timeplot is displayed (Fig. 5.14). This view displays a graph of the effective values of voltages and currents in time. The whole window covers time of approx. 110 seconds. After filling the entire window, the chart moves to the left by 30 seconds.

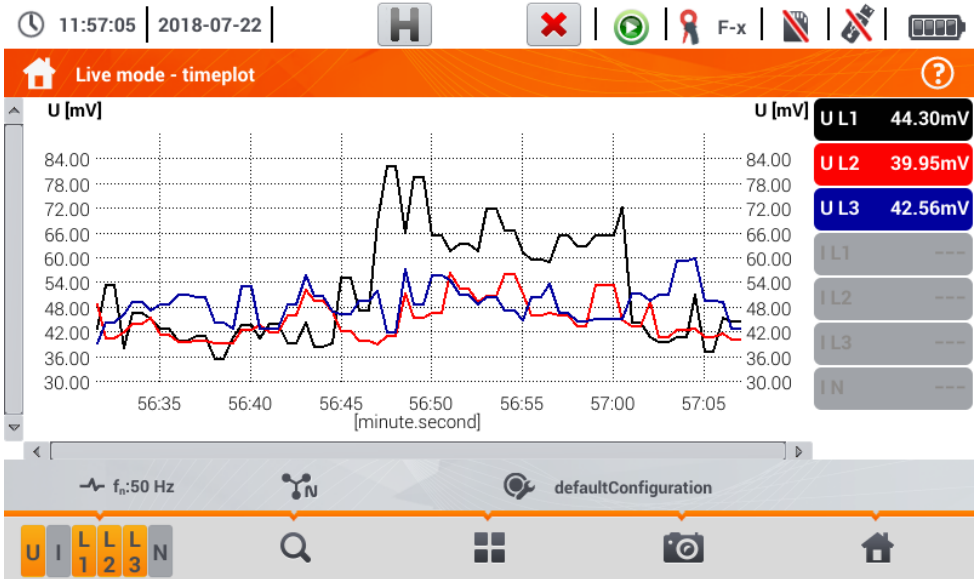









Fig. 5.14. "Live" mode - timeplot




Description of function icons

 Menu of active channels. After touching, an additional menu bar is opened with buttons for enabling or disabling the display of a phase or current and voltage. The active channel is indicated by **orange** colour of the icon. Remember that the screen must **always display at least one waveform** (you can not turn off all of them). The menu displays only the buttons of channels that exist in the network layout. From this menu you can turn off:

- U collectively all voltage waveforms
- I collectively all current waveforms
- L1 collectively all phase L1 waveform
- L2 collectively all phase L2 waveforms
- L3 collectively all phase L3 waveforms
-  selecting this icon closes the menu

 zooming of the displayed waveform. After the icon has been selected, a menu expands with the following options:

-  after selecting this icon, use your finger to circle the area which is to be zoomed in. The graph will be enlarged. After zooming in it may be moved with a finger up, down and to the sides
-  after selecting this icon graph will be zoomed out in steps.
-  selecting this icon closes the zooming menu (also, the  may be selected)

-  icon for selecting the view type. An additional menu appears, where type of view of the LIVE mode can be changed
-  screenshot Selecting it saves the current contents of the main window to a graphic file. The file name is automatically created basing on the view name and the current date, for example "Current Readings - waveforms – 2016-08-01 12_00_00". The files are saved to the internal memory of the meter
-  return to the main menu of the recorder mode



- The diagram can be scaled with gestures. To **zoom in**, spread the two fingers touching the screen in the opposite directions). To **zoom out** – bring together the two fingers touching the screen).
- Waveforms return to their default size after turning on/off any channel (buttons on the right side).

5.6.3 "Live" mode - tabular view


After the  icon has been selected a summary table with the values of network parameters is displayed. The table is refreshed in real time. A sample screen is shown in Fig. 5.15



Fig. 5.15. Live mode - measurements

The next lines were determined as follows:


- L1 phase values L1,
- L2 phase values L2,
- L3 phase values L3,
- N voltage values of the current channel I_N,
- L1-2 phase-to-phase values L1-L2,
- L2-3 phase-to-phase values L2-L3,
- L3-1 phase-to-phase values L3-L1,
- Σ total values.

The next column show the values of individual parameters:


U [V]	RMS voltage,
U_{h01} [V]	RMS of the fundamental voltage component,
U_{DC} [V]	voltage constant component,
f [Hz]	network frequency,
I [A]	RMS current,
I_{h01} [A]	RMS of the fundamental current component,
I_{DC} [A]	current constant component,
P [W]	active power,
Q1 or QB [var]	reactive power of the fundamental component or reactive power, according to Budeanu (depending on the method of calculating reactive power),
S [VA]	apparent power,
S_N [VA] or D [var]	apparent distortion power or Budeanu distortion power (depending on the method of calculating the reactive power),
E_{P+} [Wh]	active energy consumed,
E_{P-} [Wh]	active energy returned,
E_{CL+} [varh]	inductive reactive energy consumed,
E_{CC-} [varh]	capacitive reactive energy supplied,
E_{CL-} [varh]	inductive reactive energy supplied,
E_{CC+} [varh]	capacitive reactive energy consumed,
E_s [VAh]	apparent energy,
PF	Power Factor,
cosφ	displacement power factor,
tanφL+	tangent φ inductive reactive energy consumed,
tanφC-	tangent φ capacitive reactive energy supplied,
tanφL-	tangent φ inductive reactive energy supplied,
tanφC+	tangent φ capacitive reactive energy consumed,
Pst	short-term flicker factor,
PIt	long-term flicker factor,
U₀ [V]	zero symmetric voltage component,
U₁ [V]	positive sequence symmetrical component of voltage,
U₂ [V]	negative sequence symmetrical component of voltage,
U₂/U₁ [%]	voltage unbalance factor for negative sequence,
U₀/U₁ [%]	unbalance factor for zero component of voltage,
I₀ [A]	current zero symmetrical component,
I₁ [A]	current positive sequence symmetrical component,
I₂ [A]	current negative sequence symmetrical component,
I₂/I₁ [%]	current unbalance factor for negative sequence,
I₀/I₁ [%]	current unbalance factor for zero sequence.

Description of function icons


 scrolling the table to the left/right (can also be moved using a finger)

 icon for selecting the view type. An additional menu appears, where type of view of the LIVE mode can be changed

 screenshot

 return to the main menu of the recorder mode

5.6.4 Vector diagram of fundamental components (phasor)


After the  icon has been selected the phasor diagram appears (example in Fig. 5.16). It shows the basic layout of component vectors of voltages and currents. It may be used to quickly verify the correctness of connecting the recorder to the network.


The following tables are next to the diagram:

the first, containing information on basic component values and their angles,

the second, containing the unbalance coefficients of negative components (the coefficients are only displayed for 3-phase networks).

The nature of the load is signalled by the icon of:

 the coil (inductive load) if the angle between the fundamental components of the voltage and current ($\varphi_{U_{h1}, I_{h1}}$) is greater than zero (voltage is ahead of current),

 the capacitor (capacitive load) if the angle $\varphi_{U_{h1}, I_{h1}}$ is negative (current is ahead of voltage).

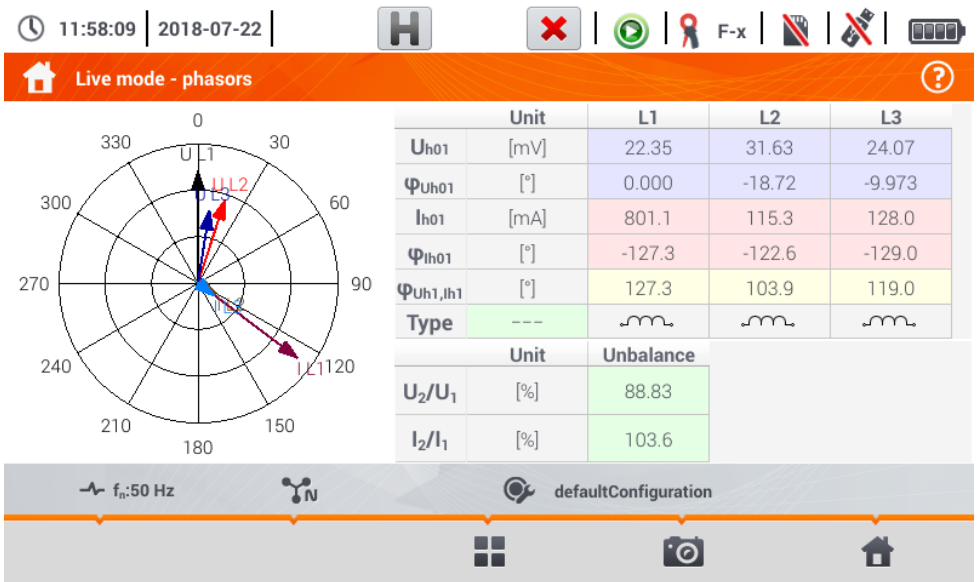




Fig. 5.16. "Live" mode - phasor graph


Description of function icons

 icon for selecting the view type. An additional menu appears, where type of view of the LIVE mode can be changed

 screenshot

 return to the main menu of the recorder mode

5.6.5 Harmonics graph/table

After the  icon has been selected the mode of harmonics display is displayed. This screen allows you to view the harmonics of voltages and currents, angles between the current and voltage harmonics, $\cos\phi$ factors of these currents and THD factors. Harmonics are displayed graphically in a bar graph (default) or in a table.

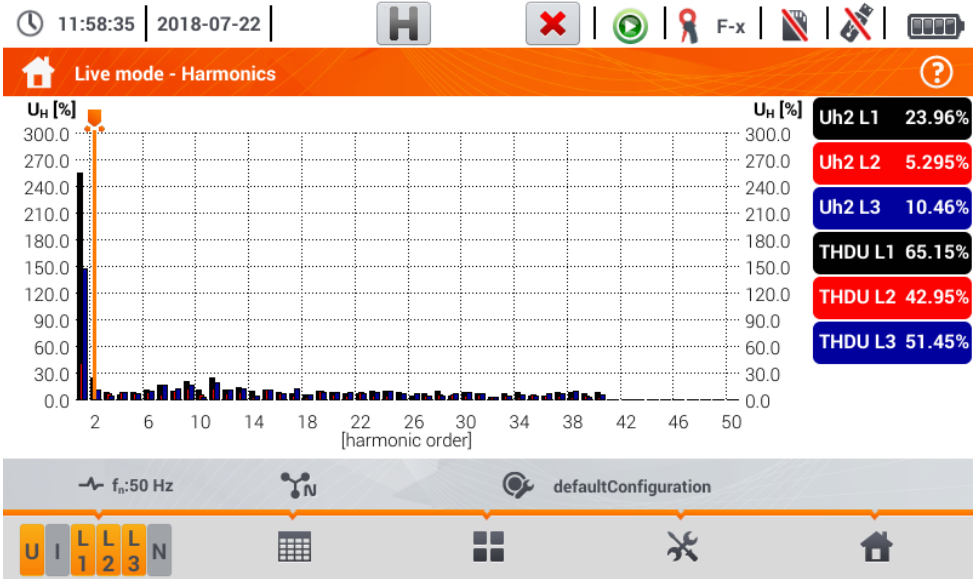






Fig. 5.17 Live mode - harmonics - bar graph


The graph includes:
 graphs for the harmonics selected from the menu **Graph data selection**,
 slider  - indicator of actual values. The user can slide it to any graph point.







Labels of individual waveforms are located on the right side of the screen. They display the participation of harmonics in the basic signal for these harmonics, which are indicated by the slider . In addition, tapping the label hides its corresponding graph (in graph mode only).

Description of function icons

 menu of active channels. After clicking, an additional menu bar is opened with icons for enabling or disabling the data and to switch between current and voltage harmonics. The active channel is indicated by **orange** colour of the icon

 switching to tabular view of harmonics (Fig. 5.18). The table in each row displays the harmonic values (from DC harmonic to the harmonic of 40th order) or the angles between the current and voltage harmonics. In case of harmonics, the values may be displayed in absolute units (V/A), or as percentage related to the fundamental harmonic

 switching to histogram view

-  icon for selecting the view type. An additional menu appears, where type of view of the LIVE mode can be changed
-  options menu for a chart or table. After selecting it, an additional menu bar is displayed, which provides several new options:
 -  hide/show the fundamental harmonic (not available in tabular view)
 - [V,A]** displaying values in absolute units (volts and amps)
 - [%]** displaying values as percent in relation to the fundamental component.
 -  screenshot
 -  closing the menu
-  return to the main menu of the recorder mode

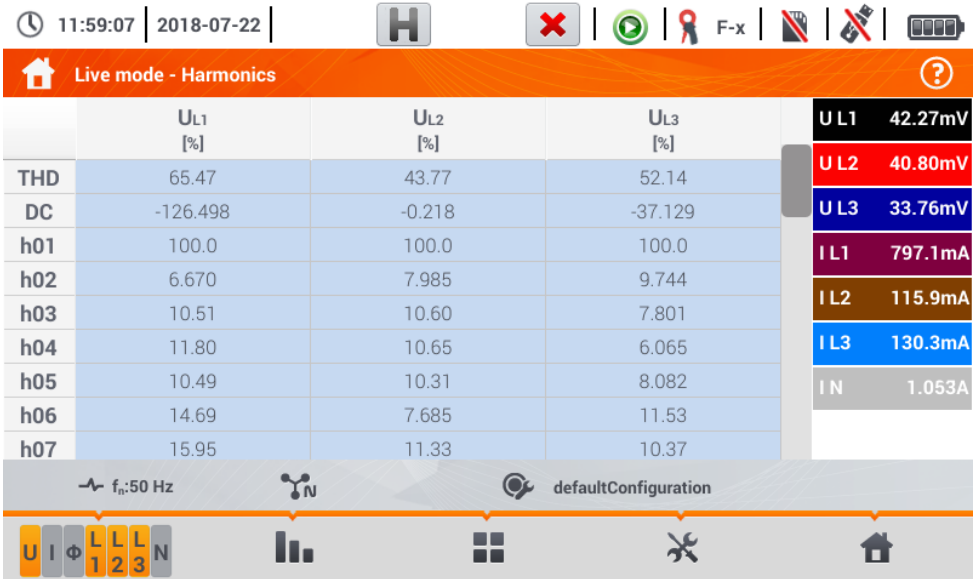




Fig. 5.18. Live mode - harmonics - tabular view

5.7 Switching the recording on/off

After correct configuration you can **trigger recording** by pressing the **START** button. Recording in-progress is signalled by icon  on the top bar and flashing red LED.

To **stop recording**, press the **START** button and confirm your intention to stop in the pop-up window. Stopping the recording will be **confirmed by sounds** (three long and three short signals) and the colour of the recording icon will change into , and the red LED will stop flashing.



Recording ends automatically when the memory card is **full**, recording terminates **automatically**.

5.7.1 Approximate recording times

The maximum recording time depends on several factors, such as:

- memory card capacity,
- averaging time,
- network type,

A few selected configurations are given in Tab. 5.2. The last column specifies the approximate recording times when the memory card is almost completely empty and has approx. 3.6 GB of free space. If the averaging time is different than the one chosen for the sample user configuration of 1 second, the approximate time of recording is proportionally extended, e.g. for 10-second averaging, the recording time will be 10 times the specified recording time at 1-second averaging.

Tab. 5.2. Approximate recording times for a few typical configurations.

Averaging period	System type (current measurement on)	Current Measurement	Approximate recording time with 3.6 GB allocated space
10 minutes	3-phase 4-wire	•	> 10 years
10 minutes	1-phase	•	> 10 years
1 second	3-phase 4-wire	•	90 days
1 second	3-phase 4-wire		144 days
1 second	1-phase	•	250 days
1 second	1-phase		330 days
1 second	3-phase 3-wire	•	125 days
1 second	3-phase 3-wire		144 days

5.7.2 Recording guidelines

Before starting the recording, pay attention to the following issues:


- Verify time of the instrument. If the date or time are incorrect, correct data must be entered in accordance with **section 2.1.1**.
- Verify connections of the analyzer with the tested network. If the icon for the correct connection of the analyzer on the top bar is **?** or **✘**, then before recording parameters, an additional window is displayed warning about a potential problem with the connection. The user must:
confirm the start of recording despite this or
resign from the start.
- For more information about the potential problem:
call up the connection correctness window (section 5.3.2).
It may also be helpful to check the phasor diagram (section 5.6.4) - vectors of voltages and currents; rotation sequence of phases in 3-phase system should be such that phase UL1 (UL1-2) is at 0°, UL2 (UL2-3) approx. -120°, UL3 (UL3-1) approx. -240°. Both unbalance factor (for voltage and current) shown on this screen should be low (typically less than 10%).
The display of waveforms may be checked for the shape of the waveforms and the effective values of voltages and currents.
The correct connection of current clamps may be verified by checking the mark(s) of active power - in most cases of operation of receivers this sign will be positive.
- If the recording is longer, ensure the continuity of power supply by connecting an external 12 V power supply adapter to the socket of the meter (the bar in the upper right corner will show an electric plug icon).
- The memory card must be inserted into the socket, and have enough free space (which is indicated on the top bar). If the card has not enough free space for the expected records (which depends e.g. on the averaging time, recording time, network type), you must ensure a free space by deleting previous records (go to **Analyzer settings → File manager**).
- Recording takes the name of measurement configuration, which is active at the time of its triggering and there is no possibility to change it later. Therefore, it may be helpful to name the configuration before that, using a name which describes the measurements to facilitate finding it on the list of records (the name of the configuration can be modified before the start, entering the edition of active configuration).

5.8 Recording analysis


Analysis of the recorded data is possible directly using the meter itself, without additional software. The scope of the analysis includes:

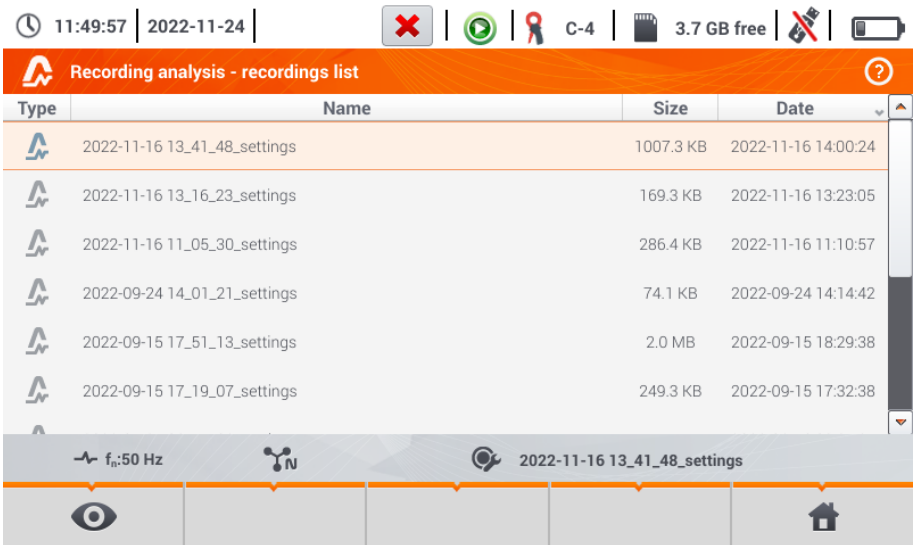
- general preview of the recording - start and end time, average values of voltages and currents,
- preview the average value of voltage across the whole recording range,
- preparing timelines of any recorded parameters (limited to 1100 points and 4 parameters on a single graph) with zoom-in option and time-point marker.
- preview of bar graph for harmonics (average value for the whole recording period).







It is possible to analyse records completed and saved on the memory card and on-going records.


The list of recording (entries on the symbol ) stored in the meter memory can be found on the **Recording analysis – recording list** screen. The list can be scrolled by moving your finger up and down within the visible summary.







① To open the contents of the file:





- double-tap the desired item or
- activate the required item and select the  icon with one tap.



11:49:57 | 2022-11-24 |    C-4 |  3.7 GB free |  

Recording analysis - recordings list 

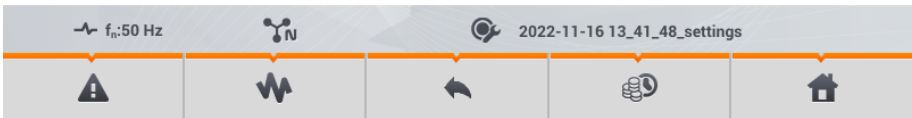
Type	Name	Size	Date
	2022-11-16 13_41_48_settings	1007.3 KB	2022-11-16 14:00:24
	2022-11-16 13_16_23_settings	169.3 KB	2022-11-16 13:23:05
	2022-11-16 11_05_30_settings	286.4 KB	2022-11-16 11:10:57
	2022-09-24 14_01_21_settings	74.1 KB	2022-09-24 14:14:42
	2022-09-15 17_51_13_settings	2.0 MB	2022-09-15 18:29:38
	2022-09-15 17_19_07_settings	249.3 KB	2022-09-15 17:32:38

   2022-11-16 13_41_48_settings 



Recording configuration: 2022-11-16 13_41_48_settings

Start:	2022-11-16 13:43:08		$U_{AVG\ MIN}$	U_{AVG}	$U_{AVG\ MAX}$
Stop:	2022-11-16 14:00:24	L1:	2.714V (1.18%Un)	232.1V (100.91%Un)	248.0V (107.82%Un)
Duration:	0d 0h 17m 16s	L2:	1.034V (0.45%Un)	231.9V (100.82%Un)	242.7V (105.54%Un)
		L3:	2.931V (1.27%Un)	231.7V (100.72%Un)	243.0V (105.64%Un)
Swells: 140	Interruptions: 6	N:	-- (-%Un)	-- (-%Un)	-- (-%Un)
Dips: 44	Other: 4				
All: 194					
		L1:	$I_{AVG\ MIN}$	I_{AVG}	$I_{AVG\ MAX}$
		L2:	131.5mA	306.4mA	627.1mA
		L3:	257.9mA	291.5mA	338.3mA
		N:	244.3mA	398.4mA	722.6mA
			---	---	---



The record content will appear (recording summary). The following parameters will be shown on the screen:

Start – time of starting the recording process,
Stop – time of stopping the recording process,
Duration (of the recording process).

In addition, the parameters of voltage and current in the phase conductor and the neutral conductor are shown:

$U_{AVG\ MIN}$ minimum average voltage; the percentage relative to rated voltage U_n is shown in brackets,

U_{AVG} average voltage; the percentage relative to rated voltage U_n is shown in brackets,

$U_{AVG\ MAX}$ maximum average voltage; the percentage relative to rated voltage U_n is shown in brackets,

$I_{AVG\ MIN}$ minimum average current,

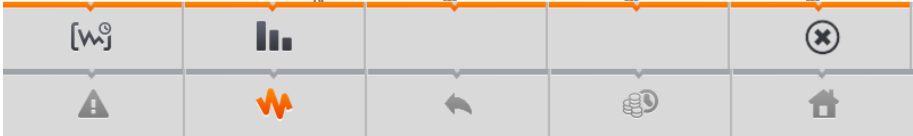
I_{AVG} average current,

$I_{AVG\ MAX}$ maximum average current.



Recording configuration: 2022-11-16 13_41_48_settings

Start:	2022-11-16 13:43:08		$U_{AVG\ MIN}$	U_{AVG}	$U_{AVG\ MAX}$
Stop:	2022-11-16 14:00:24	L1:	2.714V (1.18%Un)	232.1V (100.91%Un)	248.0V (107.82%Un)
Duration:	0d 0h 17m 16s	L2:	1.034V (0.45%Un)	231.9V (100.82%Un)	242.7V (105.54%Un)
		L3:	2.931V (1.27%Un)	231.7V (100.72%Un)	243.0V (105.64%Un)
Swells: 140	Interruptions: 6	N:	-- (-%Un)	-- (-%Un)	-- (-%Un)
Dips: 44	Other: 4				
All: 194					
		L1:	$I_{AVG\ MIN}$	I_{AVG}	$I_{AVG\ MAX}$
		L2:	--	--	--
		L3:	--	--	--
		N:	--	--	--



Description of function icons


- event list (**section 5.8.3**)
- expanding graphical analysis options:
 - recording timeplot (**section 5.8.1**)
 - harmonics waveform graph (**section 5.8.2**)
- closing the menu
- return to the file manager
- energy costs calculator (**section 5.8.4**)
- return to the main menu of the recorder mode



- **Minimum and maximum voltage values** are determined from the recorded **average values** (these are not minimum and maximum RMS_{1/2} values). In addition to the values in volts, in brackets you can see the percentage value related to the nominal voltage. If a channel has not been measured in a given configuration, dashes are displayed.
- **Minimums and maximums of currents** are determined **from the average currents**. If a channel has not been measured in a given configuration, dashes are displayed.

5.8.1 Recording timeplot

a. Functional Description

If in section 5.8 step ③ the  icon has been selected, the screen shown in Fig. 5.19 will appear.

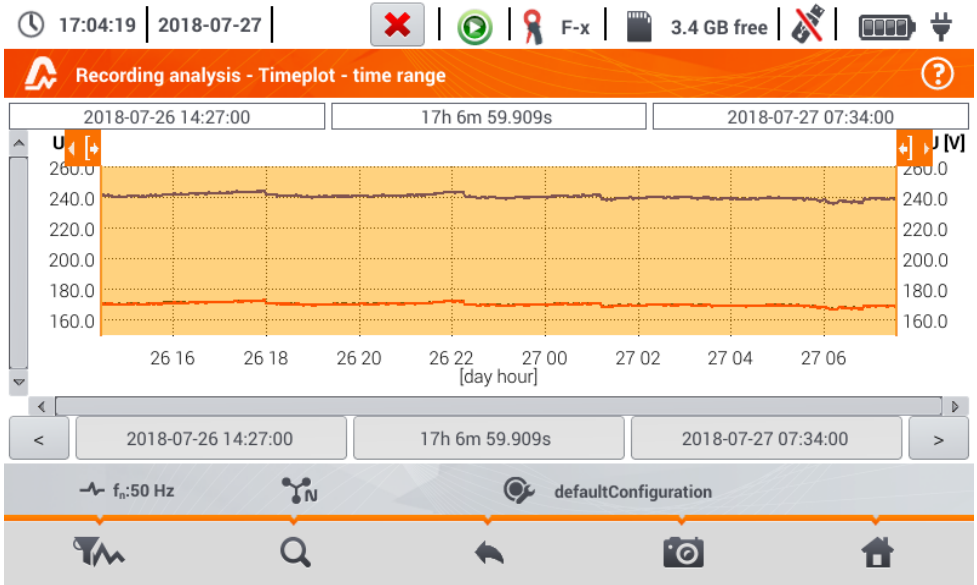


Fig. 5.19. Recording timeplot

The range of data to be analysed may be determined in two ways:



- by dragging the   icons above the graph or
- by manually entering boundary values of date and time and the interval for analysis.

Fig. 5.20 Setting the beginning of the analysis range

Fig. 5.21 Setting the width of the analysis range

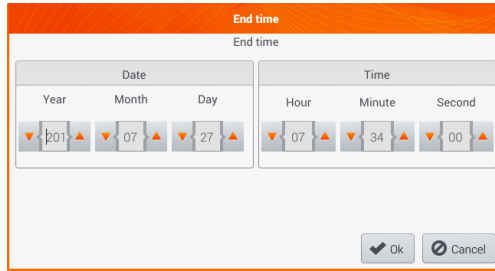












Fig. 5.22 Setting the end of the analysis range

The   icons reset the analysis range to initial settings.


Description of function icons

-  opens the **Selecting data for the plot** menu. The parameters to be analysed can be selected on this screen. A detailed description is provided in point **b**.
-  zooming of the displayed waveform. After tapping, an additional menu expands with icons:
 -  after selecting this icon, use your finger to circle the area which is to be zoomed in. The graph will be enlarged. After zooming in it may be moved with a finger up, down and to the sides
 -  after selecting this icon graph will be zoomed out in steps
 -  selecting this icon closes the zooming menu
 -  returning to **Recording analysis – recording summary** menu
-  performing the screenshot
-  return to the main menu of the recorder mode



The diagram can be scaled with gestures. To **zoom in**, move apart the two fingers touching the screen in the opposite directions). To **zoom out** – bring together the two fingers touching the screen).

b. Selecting parameters for the timeplot

After selecting the  icon, the **Selecting data for the plot** screen opens. The parameters to be analysed can be selected here. Types of readings are assigned to each of the categories, and the parameters which may be selected are assigned to these.



Available option (differing depending on the network layout)

- **Un voltage**
 - U RMS (effective voltage) – for phases L1, L2, L3 (A, B, C)
 - U L-L (phase-to-phase voltage)
 - f (frequency) – for phase L1 (A)
- **Current**
 - I RMS (effective current) – for phases L1, L2, L3 (A, B, C)
- **Power**
 - P (active power) – for phases L1, L2, L3 (A, B, C) and Σ sum
 - Q1 (reactive power) – for phases L1, L2, L3 (A, B, C) and Σ sum
 - S_n (distortion power) – for phases L1, L2, L3 (A, B, C) and Σ sum
 - S (apparent power) – for phases L1, L2, L3 (A, B, C) and Σ sum
 - cos ϕ – for phases L1, L2, L3 (A, B, C) and Σ sum
 - PF (power factor) – for phases L1, L2, L3 (A, B, C) and Σ sum
- **Energies**
 - EP+ (active energy consumed from network) – for phases L1, L2, L3 (A, B, C) and Σ sum
 - EP- (active energy supplied to network) – for phases L1, L2, L3 (A, B, C) and Σ sum
 - EQ+ (reactive energy consumed from network) – for phases L1, L2, L3 (A, B, C) and Σ sum
 - EQ- (reactive energy supplied to network) – for phases L1, L2, L3 (A, B, C) and Σ sum
 - ES (apparent energy) – energy for phases L1, L2, L3 (A, B, C) and in total Σ
- **Harmonics U**
 - THD U (total harmonic distortion) – for phases L1, L2, L3 (A, B, C)
 - U h1...U h40 (1...40. voltage harmonic) – for phases L1, L2, L3 (A, B, C)



- In the window for selecting the parameters, only those parameters are displayed which were recorded.
- For better orientation, the fields with parameters selected for the chart, the fields of category and type are surrounded by orange border, if they contain any selected parameters.
- If you have already ticked four parameters, any attempt to select another will result in displaying a message on limited number of parameters in the chart.

Description of function icons

- calling up the time graph
- deselecting all variables
- returning to menu **Timeplot – time interval** (pointa)
- return to the main menu of the recorder mode

c. Creating and managing a timeplot

1 17:05:54 | 2018-07-27 | F-x | 3.4 GB free |

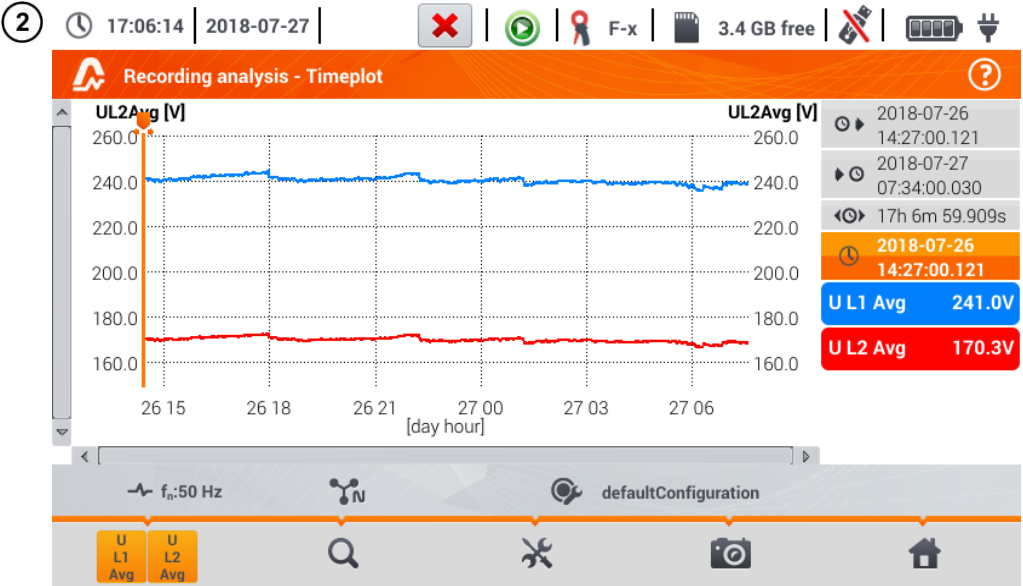
Recording analysis - timeplot - plot data selection

Category	Type	Max	Avg	Min	Inst
Voltage Un	U RMS		<input checked="" type="checkbox"/>		
Current	f		<input checked="" type="checkbox"/>		
Powers					
Energy					
Voltage harmonics					

$f_n: 50 \text{ Hz}$ defaultConfiguration

Select the data to be displayed on the plot on the **Selecting data for the plot** screen. For this purpose:

- in the **Category** column select the required item, in the **Type** column select the required parameter, and in the last column select the required variable (→)
- select the icon.



The timeplot appears. It includes:
 waveforms for the values selected in the menu **Selecting data for the plot**,
 slider - indicator of actual values. The user can slide it to any graph point.

On the right side of the screen you can see:

- time of starting the recording process,
- time of stopping the recording process,
- duration of the recording process.
- time corresponding to the position of the slider .

labels for individual waveforms. They display instantaneous values of the readings, corresponding to the position of the slider on the plot. In addition, tapping the label hides the graph that it represents.

Description of function icons

menu of active channels. After this icon has been selected, an additional menu bar opens with buttons to enable and disable the display of waveforms set for step **1**. The active channel is indicated by **orange** colour of the button.

zooming of the displayed waveform. After the icon has been selected, a menu expands with the following options:

- after selecting this icon, use your finger to circle the area which is to be zoomed in. The graph is then enlarged; it may be moved with a finger up, down and to the sides
- after selecting this icon graph will be zoomed out in steps
- selecting this icon closes the zooming menu (also, the may be selected)



options menu for a chart or table. After the selection has been made, an additional menu bar appears which enables selection of a scale description on the right side and on the left side of the graph. To do this, click on the icon with the name of the parameter.



The icon with the unit name is displayed when the graph has at least two parameters with the same unit. **Select** this icon to **rescale waveforms** having the same unit to a **common scale** (described by one of the common parameters). Remember that when scales are not unified, only one waveform with unit assigned to the axis is scaled to the indicated scale and its plot is adjusted to the size of the window - other waveforms, even having the same unit, are not scaled.



returning to the **Selecting data for the plot** menu




performing the screenshot



The diagram can be scaled with gestures. To **zoom in, move apart** the two fingers touching the screen in the opposite directions). To **zoom out – bring together** the two fingers touching the screen).

5.8.2 Harmonics waveform graph

If in **section 5.8** step ③ the  icon has been selected, the screen shown in Fig. 5.23 will appear. The workspace consists of a graph, the labels menu and function icons menu. This screen allows you to view the harmonics of voltages and currents, angles between the current and voltage harmonics, $\cos\phi$ factors of these currents and THD factors. Harmonics are displayed graphically in a bar graph (default) or in a table.

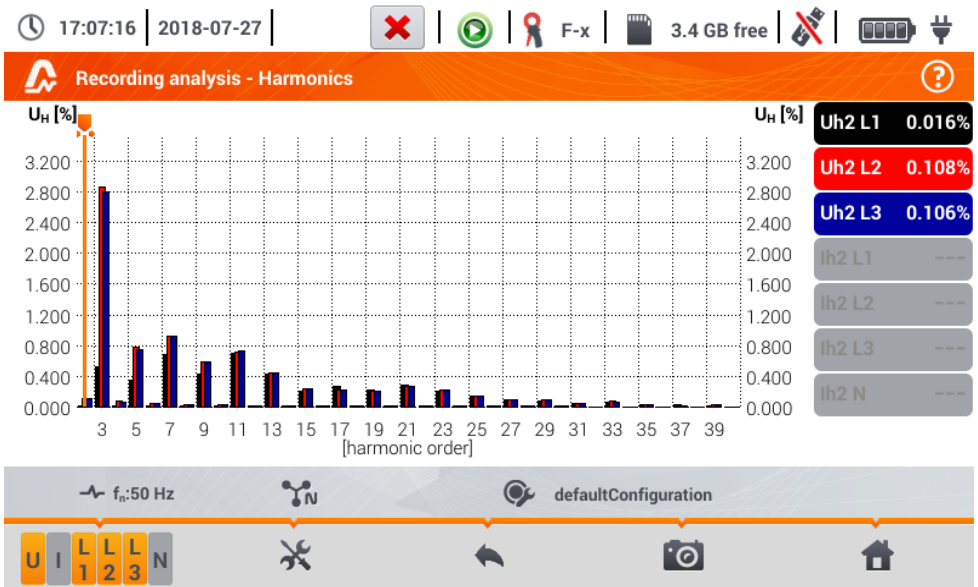


Fig. 5.23. Live mode - harmonics - bar graph

The graph includes:
 graphs for the harmonics selected from the menu **Graph data selection**,
 slider - indicator of actual values. The user can slide it to any graph point.

Labels of individual waveforms are located on the right side of the screen. They display the **name of the harmonic** and its **participation** in the basic signal for these harmonics, which are indicated by the slider . In addition, tapping the label hides its corresponding graph.

Description of function icons

menu of active channels. After selecting the icon, an additional bar is opened with buttons for enabling or disabling the data and to switch between current and voltage harmonics. The active channel is indicated by **orange** colour of the icon.

options menu for a chart or table. After selecting it, an additional menu bar is displayed, which provides several new options:

- hide/show the fundamental harmonic
- displaying values in absolute units (volts and amps)
- displaying values as percent in relation to the fundamental component.
- switching to tabular view of harmonics (Fig. 5.24). Each row in the table displays the values of harmonics (harmonics up to the 40th and additionally for the [%] mode – also THD)

closing the menu

returning to the previous screen

performing the screenshot

returning to the main menu of the recorder mode

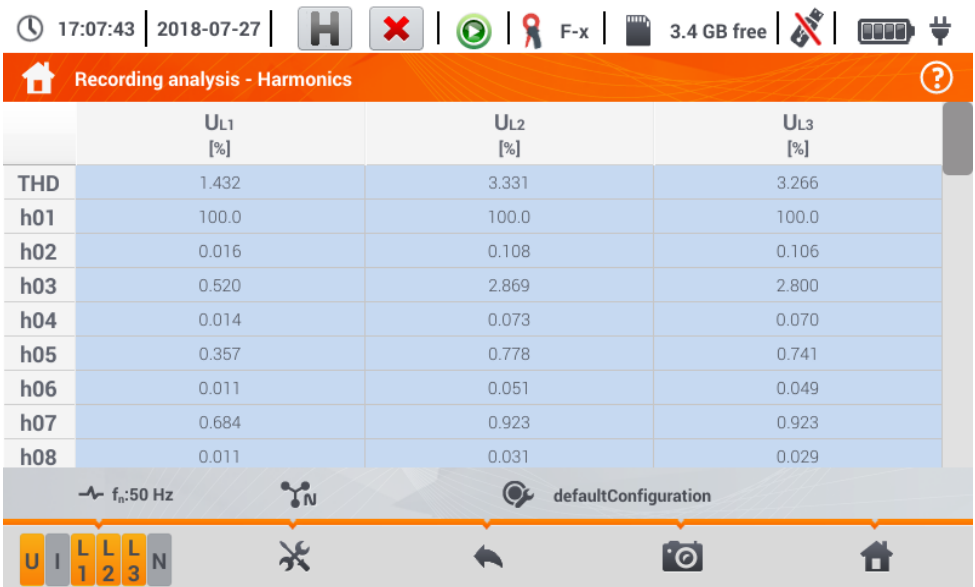



Fig. 5.24. Live mode - harmonics - tabular view

5.8.3 Event list

Selecting option  from the recording summary screen (in the bottom menu) will display a window with a list of recorded events. The analyzer may detect the following types of events:

In 50/60Hz systems:

- voltage dips,
- voltage swells,
- voltage interruptions,
- exceeding the maximum current threshold ($I > \text{max.}$), separate thresholds for $I_{1,2,3}$ and I_N
- dropping below the minimum current threshold ($I < \text{min.}$), separate thresholds for $I_{1,2,3}$ and I_N

In DC systems:

- exceeding the absolute maximum DC voltage threshold ($|U_{DC}| > \text{max.}$)
- exceeding the absolute maximum DC current threshold ($|I_{DC}| > \text{max.}$)

If the user selected detection of any of the events listed above in the measurement configuration screen, and if these events have been recorded, the list will include all of them. An example of the event window is shown in Fig. 5.25.

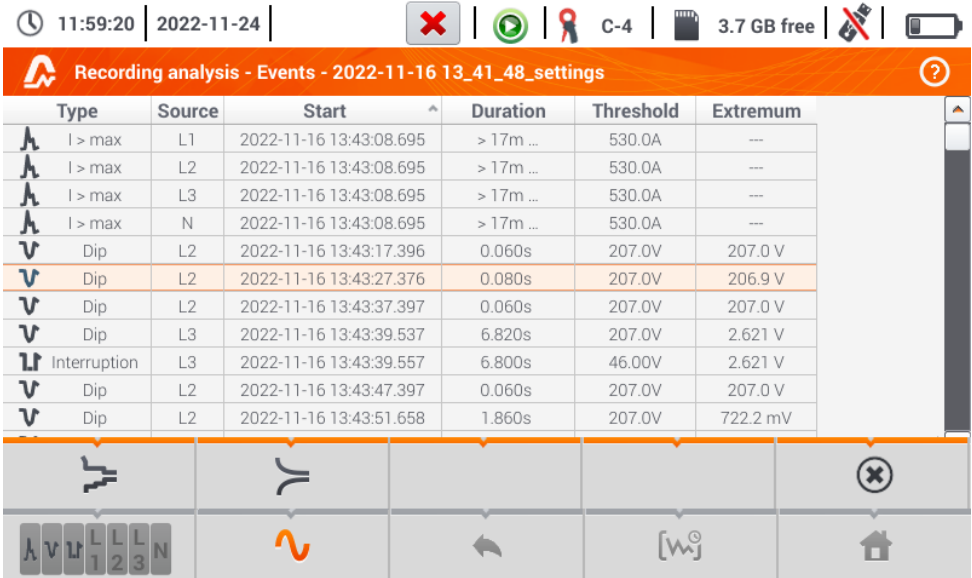


Fig. 5.25. Recording analysis – list of events


The table contains the following columns:


- **Type** of event: dip, interruption, swell, I > max, I < min, $U_{DC} > \text{max.}$, $I_{DC} > \text{max.}$
- **Source** of event: channel where the event occurred,
- **Start**: date and time of beginning of event,
- **Duration** of the event (if the event was in progress when recording was ended, an additional sign ">" is displayed, which means that the event has not been ended),
- **Threshold**: threshold value that has been set in the recording configuration,
- **Extremum**: parameter limit value (maximum or minimum, depending on the event type), which was recorded during the event. For example, in case of voltage dip, it is a residual voltage, which is the lowest $U_{RMS1/2}$ value recorded during the dip.

The table may be sorted by selected column after clicking its header. Next to the column name, a small arrow is present to show the direction of sorting.

Menu bar functions

After selecting a specific event in the table (by clicking its line), you can perform additional operations by selecting the following options from the menu bar:

 - opens additional menu of waveforms:

 - ANSI chart. It shows the graph of voltage events according to ANSI criteria. Dots represent individual events and their location indicates the duration (horizontal axis) and peak (*extremum* in the event table) related to the nominal voltage on the vertical axis. Arrow icons on the right side of the graph may be used to select individual events. By touching the screen in the graph area, the user may move the marker to the indicated place. Information about the specified event (type, duration, extreme value) are shown on the right side of the screen. An example of screen with similar diagram is shown in Fig. 5.26.

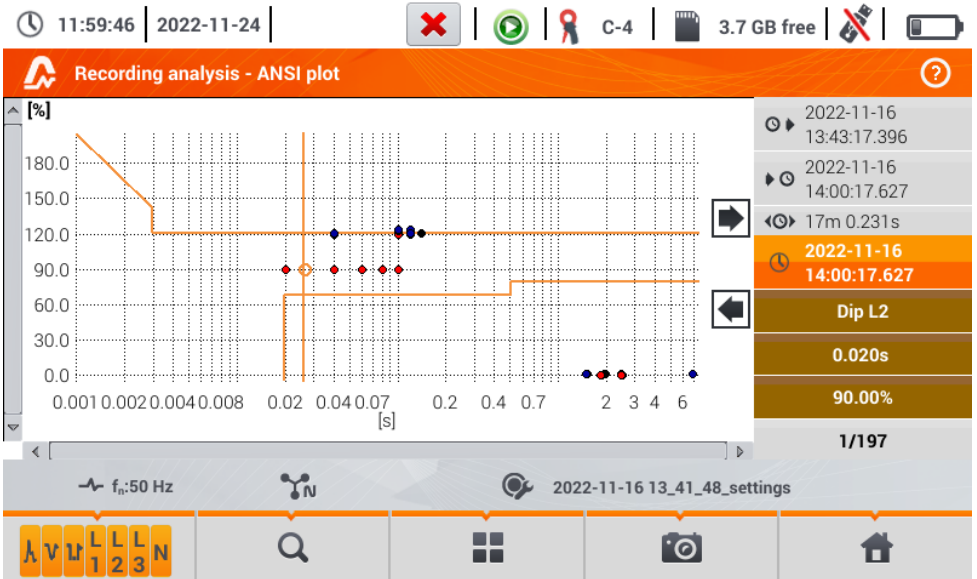


Fig. 5.26. Recording analysis – ANSI graph


☞ - CBEMA graph. It shows the graph of voltage events according to CBEMA criteria. Description of the graph and its properties are similar to ANSI chart (see above). An example of screen with similar diagram is shown in Fig. 5.27.







Fig. 5.27. Recording analysis – CBEMA graph

5.8.4 Energy costs calculator

a. Functional Description

When the parameters recorded by the recorder include active energy E_p , it is possible to calculate the energy costs according to the cost calculator set by the user. To enter the screen of the energy cost calculator, use the bar on the recording summary window (section 5.7 step ③) and select icon .

The screen with energy costs will be displayed as shown in Fig. 5.28. The following sections present:

- **Recording time** –  start,  end and  duration of the recording. The last line shows the  duration which is analysed by the algorithm of the cost calculator (full aggregation periods). The algorithm enables the calculation of the energy costs for the whole recording period and there is no option to select a different time interval.
- **Energy** – this field displays the total active energy in kilowatt-hours measured in the reporting time interval.
- **Single zone tariff** – this section displays the total cost of energy in the selected currency for single-zone variant. The tariff of this type has a single flat rate per kWh, regardless of the time of day and day of the week. **Tariff type** (may be modified by the user) is displayed **in the upper part**.
- **Multi-zone tariff** – shows the total cost of energy in the chosen currency in the multi-zone variant. This tariff allows you to define two continuous time intervals in 24 hours, which have different cost rates per kWh, and the third the rate for other times of the day. **Tariff type** (may be modified by the user) is displayed **in the upper part**. Configuration of rates and zones is carried out in the control panel of the energy cost calculator.






If you have not used or have not changed the settings of the cost calculator, the recorder will use the default settings. The settings of the cost calculator may be modified by selecting from the menu bar the  icon.



Fig. 5.28. Screen with indications of the energy cost calculator

Description of function icons


-  entering the settings of the energy cost calculator.
-  returning to the previous screen
-  performing the screenshot
-  returning to the main menu of the recorder mode

b. Settings of the energy cost calculator.

The settings of the cost calculator may be easily modified to fit individual needs. The calculator allows you to calculate costs for two tariffs:

- **Single zone tariff** – this is the simplest form of tariffs - a single rate for each kilowatt is taken into account throughout the analysed interval, regardless of time of day or day of the week,
- **Multi-zone tariff** – more extensive tariff. It allows you to set three different rates that apply in different time intervals:
 - ⇒ **Zone A billing rate** – you may enter the cost of 1 kWh for the first time interval of the day (e.g. daytime rate),
 - ⇒ **Zone B billing rate** – you may enter the cost of 1 kWh for the second time interval of the day (e.g. night-time rate),
 - ⇒ **Zone C billing rate** (not included in zones A and B).

Settings of the cost calculator are divided into two screens (**Fig. 5.29** and **Fig. 5.30**). The first screen allows you to configure the following parameters:

- **Currency** – you can choose from a list of several predefined currencies (PLN, EUR, USD, RUB, INR) or set your own (up to four characters), which will be shown on the list as the last position and marked with an asterisk (*).
- For **single zone tariff**:
 - ⇒ **Name of the single zone tariff** (C11 as default) – after clicking the name field a panel is displayed for editing.
 - ⇒ **Single zone rate** – the cost of 1 kWh of energy for the single zone tariff. The panel for editing will be displayed after the value field has been selected. The value may also be changed using the  icons. Rate values may be entered with an accuracy of four decimal places.

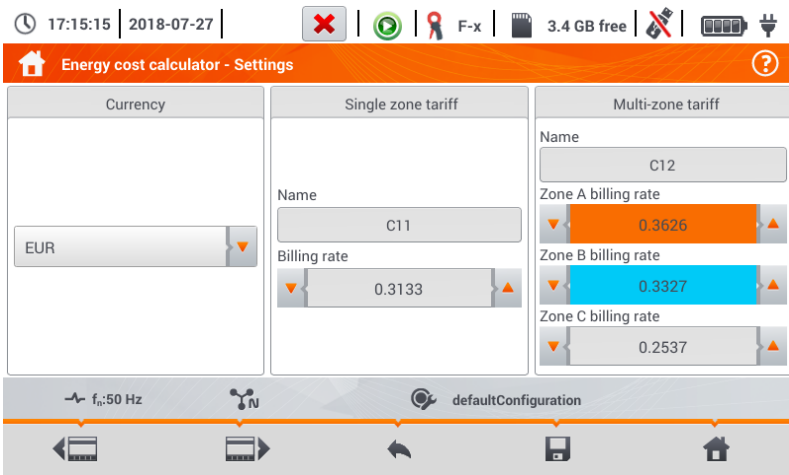


Fig. 5.29 Energy cost calculator – Settings

- For **Multi-zone tariff**:

- Name of the zone (C12 as default),
- Zone A billing rate for 1 kWh (colour: orange),
- Zone B billing rate for 1 kWh (colour: blue),
- Zone C billing rate for 1 kWh (for other times of the day).

Time intervals of the day corresponding to A, B and C zones are set on the second screen with cost calculator settings (Fig. 5.30). The main elements are the bars representing the entire day, divided into 15-minute blocks.

In the **simpler variant**, the same zone settings are valid for all days of the week (only the set marked with icon 1¹). If you need to configure **other time intervals** for the selected days (e.g. for Saturdays and Sundays), then selecting the box at the bottom left of the window unlocks the second set of time intervals marked with icon 2². Select weekdays for the second set by indicating the selection boxes for desired week days.

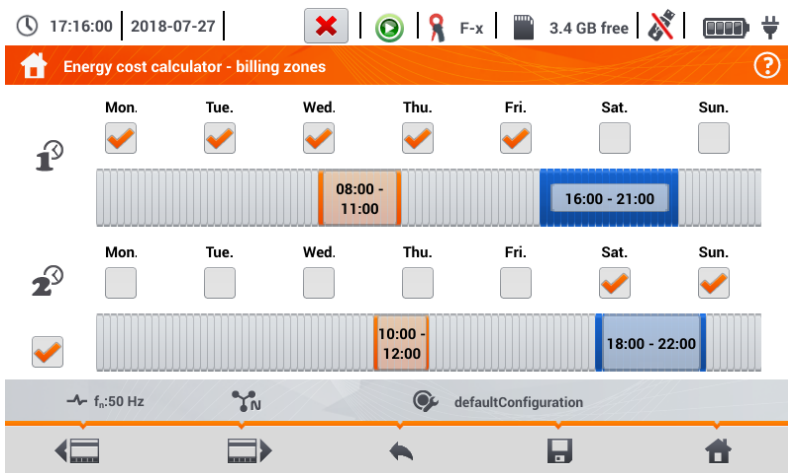


Fig. 5.30 Energy cost calculator – Billing zones in multi-zone tariff

Intervals for zones A and B (respective colours: orange and blue) may be modified by:

- touching the centre of the time interval and moving it sideways,
- touching and moving the left or the right edge of the interval, changing the limits of the tariff zone.

Start and end time is visible in the middle of the time interval. The **resolution** of time intervals is **15 minutes**. The **minimum duration** of an interval is **2 hours**.

Description of function icons

- switching between the two setting screens of the cost calculator.
- returning to the results indicated by the cost calculator. If the settings have been modified and saved, the energy costs will be automatically calculated and displayed.
- saving the settings in the analyzer memory.
- returning to the main menu of the recorder mode



The settings are global for the entire recorder (not related to a specific recording).

5.9 Energy loss calculator

5.9.1 Functional Description

In this mode, you can estimate the loss of active power and associated costs due to poor power supply quality. The loss analysis screen is shown in **Fig. 5.31**. Analysis can be performed in terms of the desired time.

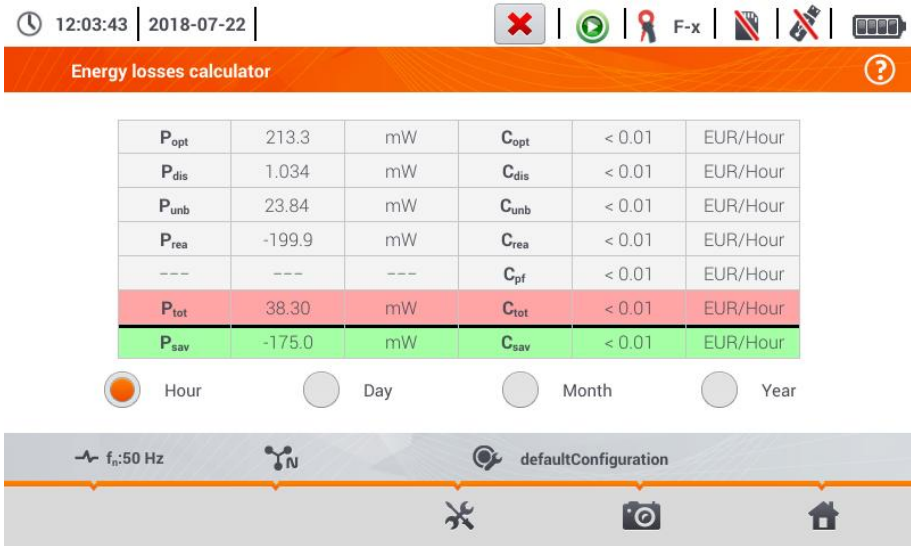


Fig. 5.31 Energy loss analysis

Parameters to analyse




P_{opt}	power loss due to wire resistance (assuming the absence of higher harmonics, unbalance and reactive power)	C_{opt}	cost related to P_{opt} losses
P_{dis}	losses due to higher harmonics	C_{dis}	cost related to P_{dis} losses
P_{unb}	power losses due to network unbalance	C_{unb}	cost related to P_{unb} losses
P_{rea}	power loss due to the presence of reactive power	C_{rea}	cost related to P_{rea} losses
P_{tot}	total losses (the sum of the above)	C_{pf}	cost related to a low power factor (large share of reactive power)
P_{sav}	losses which can be reduced by improving the quality parameters (e.g. compensation of harmonics, elimination of unbalance), arising from the relationship:	C_{tot}	cost related to P_{rea} losses
	$P_{sav} = P_{tot} - P_{opt}$	C_{sav}	cost related to P_{sav} losses

The financial loss can be estimated based on the current readings in terms of:




- ⇒ one hour,
- ⇒ one day,
- ⇒ one month
- ⇒ one year.

When one of the above options is activated ( → ), the table will display data relevant to the selection.

Description of function icons

-  going to the configuration panel of the loss calculator (**section 5.9.2**)
-  performing the screenshot
-  returning to the main menu of the recorder mode

5.9.2 Configuration of the loss calculator

After the  icon has been selected, the calculator configuration panel appears, shown in **Fig. 5.32** and **Fig. 5.33**. It is possible to switch between screens using the   icons.

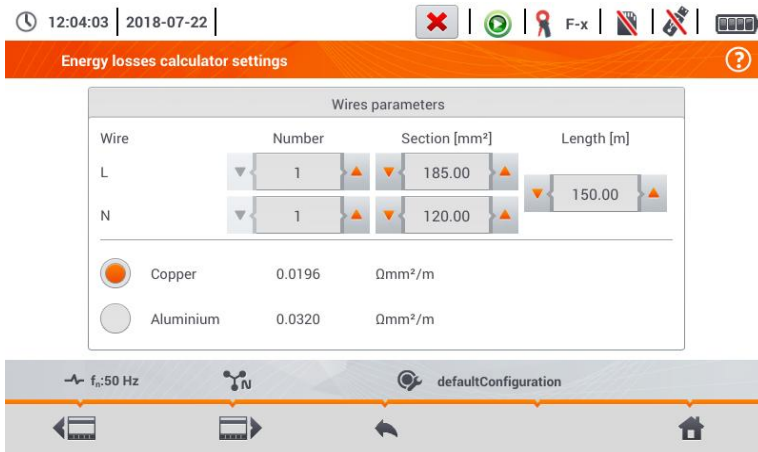


Fig. 5.32 Energy loss analysis – configuration screen 1

On the first screen, set the parameters of the wire, to which the analysis applies, namely:

- for phase conductors **L**:
 - **number of wires** in the phase,
 - **cross section** of cores in mm²,
- for neutral conductors **N**:
 - **number** of neutral wires,
 - **cross section** of cores in mm²,
- **the length** of the analysed line in metres,
- **line** material – copper or aluminium.

Based on the above parameters, the calculator will calculate the power loss in the analysed line.

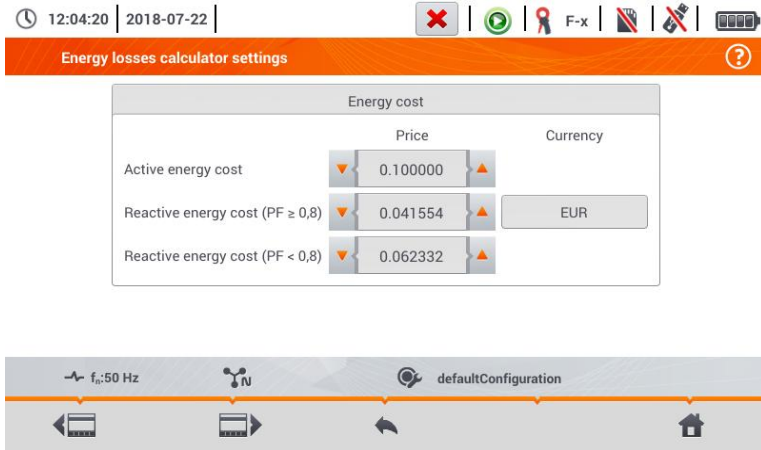


Fig. 5.33 Energy loss analysis – configuration screen 2



On the second screen, set the parameters defining the financial loss, i.e:


- cost of 1 kWh of active energy,
- cost of 1 kWh reactive energy at power factor $PF \geq 0.8$,
- cost of 1 kWh of reactive energy at power factor $PF < 0.8$,
- currency.


To change the currency:


- tap the field with the current unit,
- enter a new unit using the on-screen keyboard.

Description of function icons

  switching between the two setting screens of the calculator.

 returning to the results indicated by the calculator. If the settings have been modified and saved, the results will be automatically calculated and displayed.

 recording calculator settings

 returning to the main menu of the recorder mode

5.10 Inverter efficiency

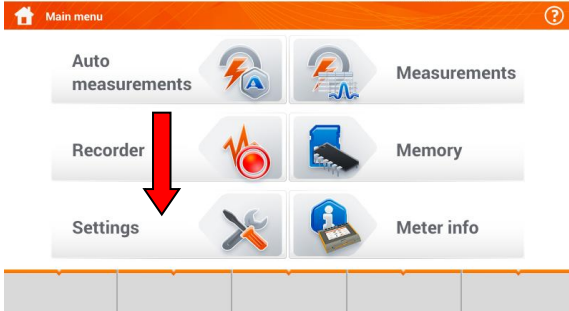
See **sec. 3.20.1, 3.20.2.**

6 Memory of the meter

6.1 Memory of measurements

6.1.1 Memory settings

1 09:50:16 | 2018-11-15 | 3.7 GB | | 93% In the main menu select **Settings**.

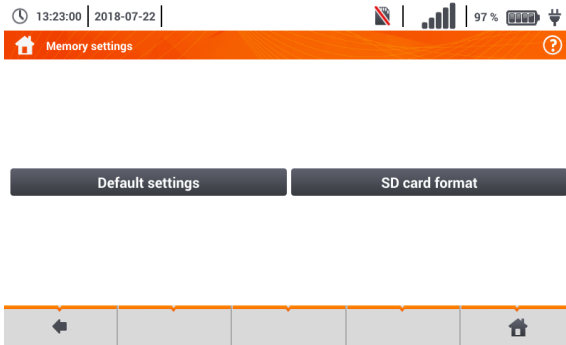


2



Select **Memory settings**.

3



Two options will appear.

- **Default settings** – restores the meter memory to default memory settings. When this option has been selected, a prompt will appear asking to confirm the selection.
- **SD card format**. When this option has been selected, a prompt will appear asking to confirm that the user wants to format the SD card.

Description of function icons

- return to the previous screen
- return to the main menu

6.1.2 Structure of the memory

The memory of measurement results is of a tree structure (**Fig. 6.1**). The user can record an unlimited number of clients. Any number of objects with sub-objects can be created in each client.

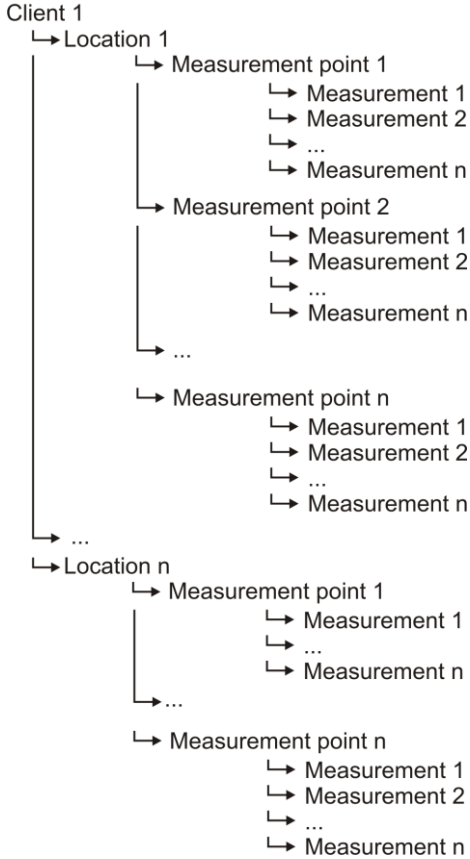


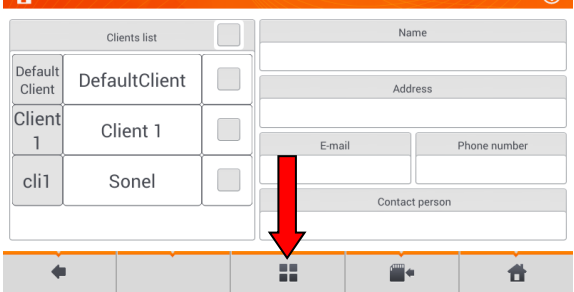
Fig. 6.1. Structure of meter memory for a single client

a. Fundamentals of navigating the Memory menu

1 09:50:16 | 2018-11-15 | 3.7 GB | 93% | Select **Memory** in the main menu.



2 13:25:51 | 2018-07-22 | 98% | Memory management panel will appear.



Description of function icons

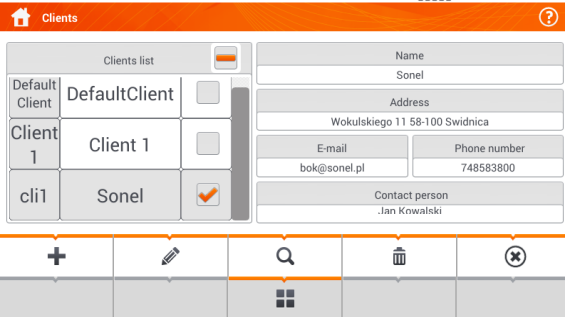
- item inactive
- item active
- ← returning to the previous screen
- ➡ going to a lower level of the active (✓) item
- ✓ going to the folder tree of the active (✓) client
- 🏠 returning to the main menu
- 📁 recording the active item to the SD card
- ⊞ expanding the active item management menu

3

13:27:10 | 2018-07-22



Description of icons in the edit menu



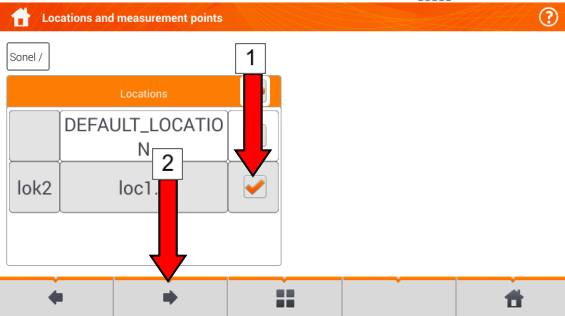
- + adding a new client
- editing the active client
- search mode (**section 6.1.4**)
- removing the active client
- closing the menu

4

13:27:35 | 2018-07-22



To go to a lower level of the folder tree:

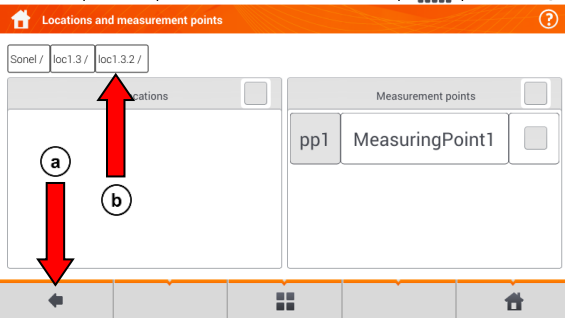


- activate the required item (→)
- select the icon.

13:28:17 | 2018-07-22



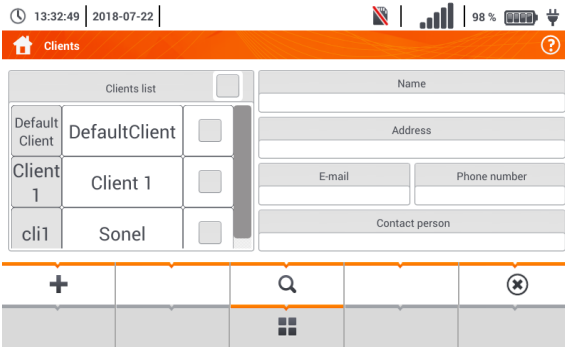
To go to a higher level of the folder tree, select the icon.



- (b)** To move **several levels up**, select the name of the required folder on the top navigation bar.

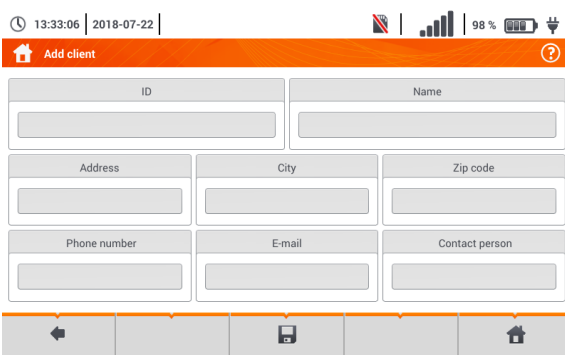
b. Adding a new measurements tree

1



Add a new client using the + icon.

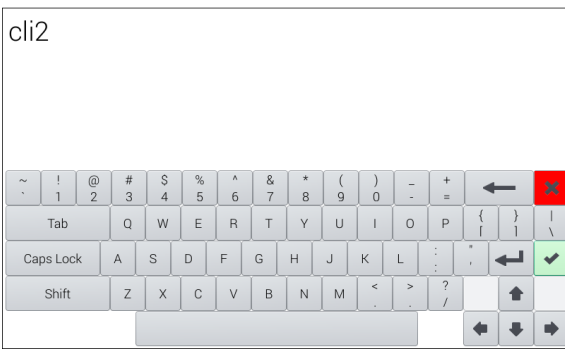
2



Tap and complete the required fields using the on-screen keyboard:

- ⇒ Client ID,
- ⇒ name,
- ⇒ address:
- ⇒ city,
- ⇒ postal code,
- ⇒ phone number,
- ⇒ e-mail,
- ⇒ contact person.

3

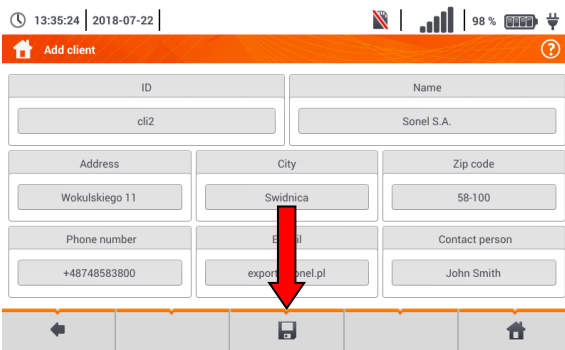



Enter the name from the touch keypad (holding certain buttons for a longer time triggers Polish characters).

Functions of icons

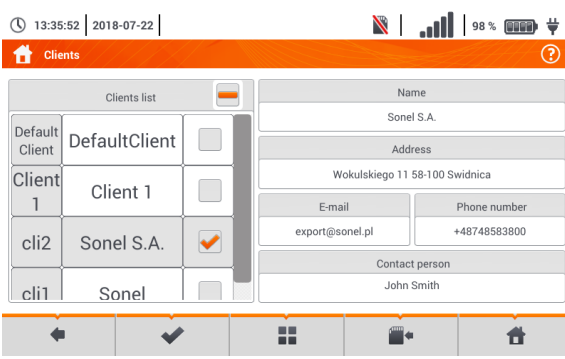
- rejecting changes and returning to step 2
- accepting changes and going to step 4






4



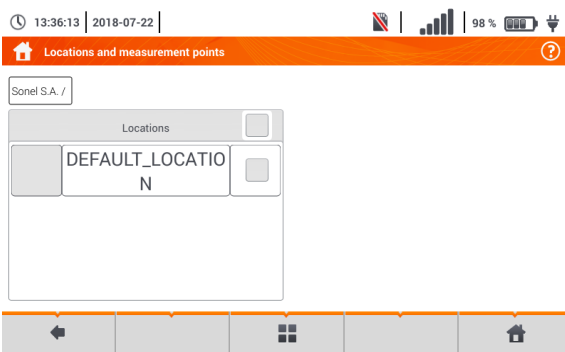
- Save changes using the  icon.
- The display will return to the client management menu.

5



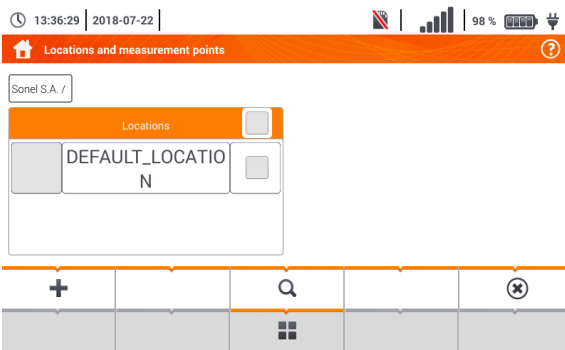
- Tap to activate the selected client ( → .
- Select icon  and  to edit data.
- Further actions are the same as in steps 2, 3, 4.
- To go to the lower level of the tree:
 - ⇒ tap the label of the required item,
 - ⇒ activate the required item and select .

6




Creating a new client results in creating a default location for the measurements.

7



To add a new location:

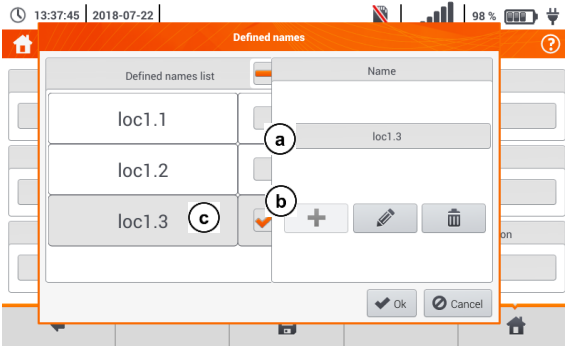
- tap to activate the **Location** column,
- expand the edit menu using the  icon and select **+**,
- proceed as in steps 2 3.



8





In the **Name** field the list of names for further use may be defined.

9



- a) Tap the name creation field and add a new name, the same as in step 3.
- b) Using the **+** icon add the created item to the list of names.
- c) Select the required item and using the icons:
 -  edit the name,
 -  remove the name.

Tap to assign a location from the list to a required location of the tree ( → .

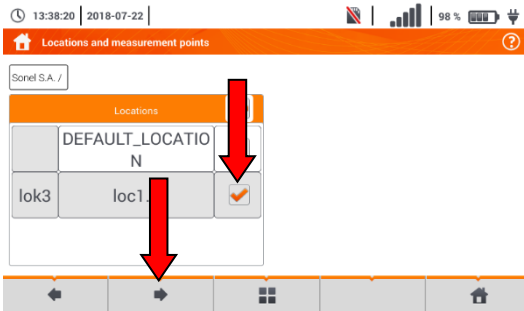
Ok – accept all changes.
Cancel – cancel changes.

10



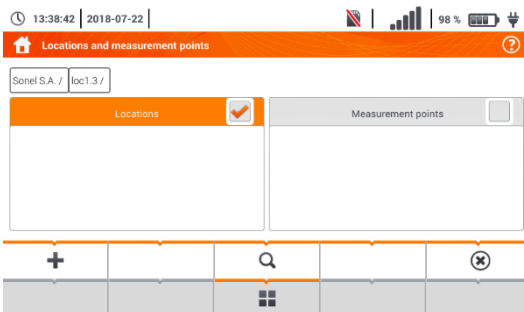
- Save changes using the icon.
- The display will return to the location management menu.

11



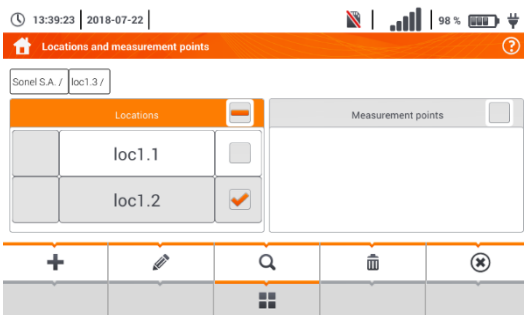
- Activate the required location (→).
- Select to go to the lower level of the tree.

12



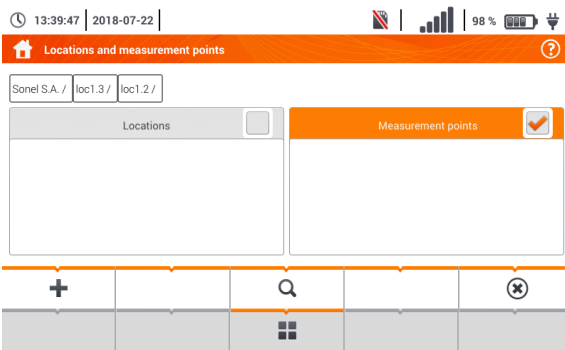
- The screen for locations and measuring points will appear.
- Tap to activate the **Location** column.
 - Expand the edit menu using the and select .
 - Proceed as in steps [2](#) [3](#) [4](#) and [8](#) [9](#) [10](#).

13



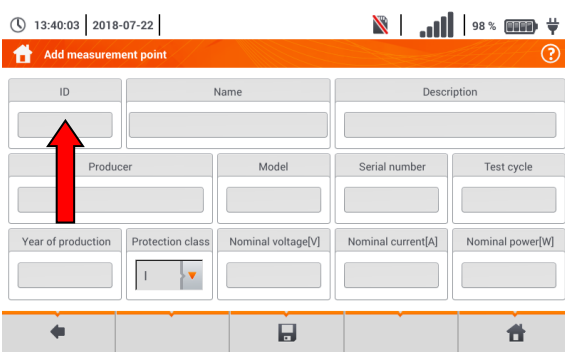
- Activate the required location (→).
- Using the , go to a lower level of the menu.
- If necessary, repeat steps [12](#) [13](#).
- Using the icon expand the edit menu and select:
 - to edit location (as in steps [8](#) [9](#) [10](#)),
 - to enter the search mode ([section 6.1.4](#)),
 - remove.

14



- Activate the column **Measurement points** (☐ → ☑).
- Using the ☐ icon expand the edit menu and select + to add a new measurement point (step 15).

15

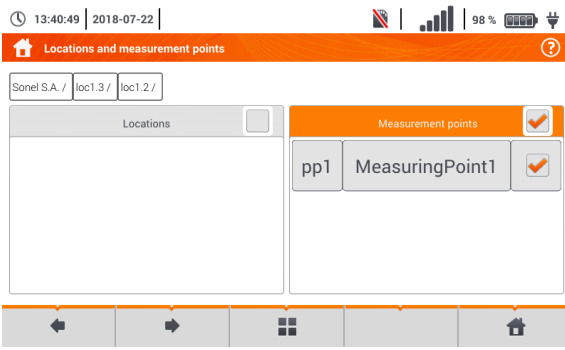


- Tap and complete the required fields using the on-screen keyboard:
- ⇒ point ID,
 - ⇒ name,
 - ⇒ description,
 - ⇒ manufacturer,
 - ⇒ model,
 - ⇒ serial number,
 - ⇒ measuring cycle,
 - ⇒ year of manufacture,
 - ⇒ safety class,
 - ⇒ nominal voltage,
 - ⇒ nominal current,
 - ⇒ nominal power.

Description of function icons

- ← returning to the previous screen
- 💾 saving changes
- 🏠 returning to the main menu

16



The measuring point has been saved.

Description of icons in the edit menu


- + adding a new point
- ✎ editing the active point
- Q search mode (section 6.1.4)
- 🗑 removing the active point.
- ⊗ closing the menu



- The results of measurements performed for all measuring functions can be stored in one cell of the **Measurement points** column.
- Only the results of measurements activated by pressing the **START** button can be stored in the memory (except autozeroing in low-voltage measurement of resistance).
- Complete set of results (main result and supplementary results) for a given measuring function, preset measurement settings, date and time of the measurement are stored in the memory.

6.1.3 Entering the measurement result



1

- After the measurement, select the  icon.
- The menu Entering the measurement result will appear (the menu and control the same as in **section 6.1.1**).

2

- If necessary, create a new location in accordance with **section 6.1.2b**.

3

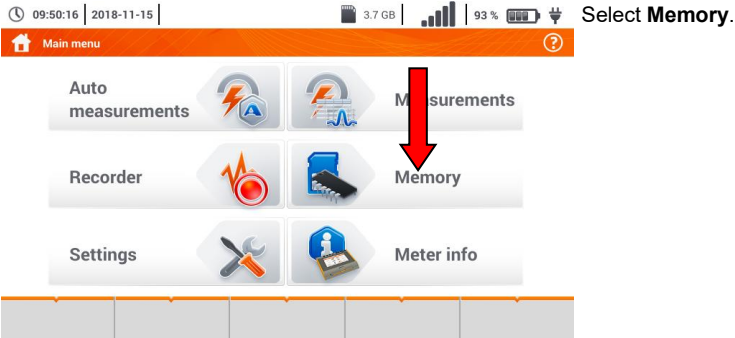
- Select the required measurement point from the location or create a new point in accordance with **section 6.1.2b** step (14)(15)(16).
- Tap  to save the result to memory.
- In case of cancellation, return to the measurement menu using the  icon.



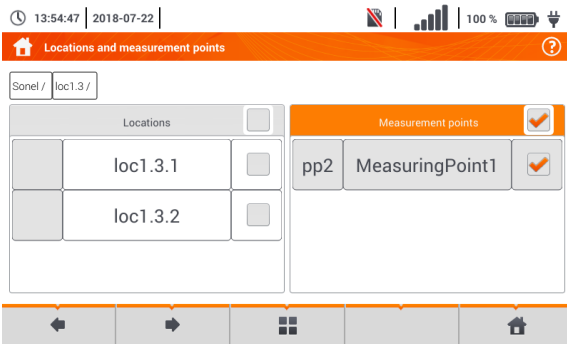
Management of objects and sub-objects is possible both in the saving to memory mode and memory viewing (**section 6.1.4**).

6.1.4 Viewing saved measurements

1

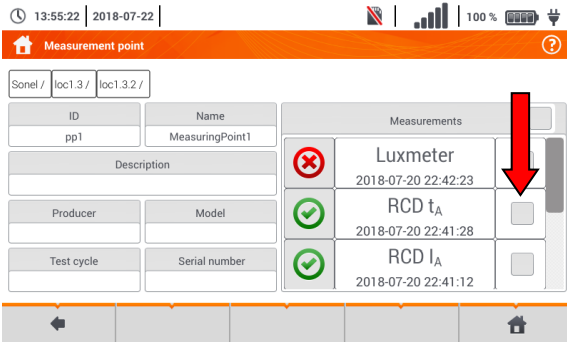


2



- Go to a location with a measuring point to which the measurement results were saved.
- Activate the required measuring point (→).
- Using the icon, go to the contents of the measuring point.

3

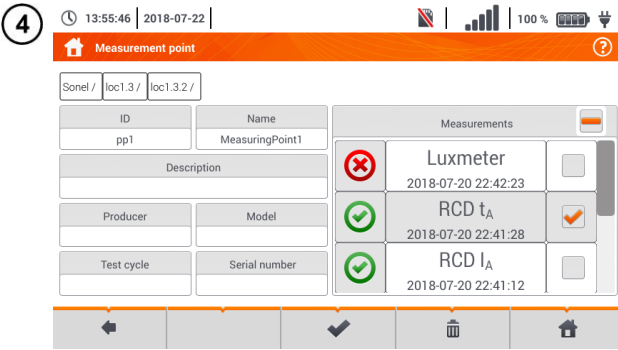


The list of measuring points contained in the active point will be displayed.

Description of controls signaling that the set limit has been reached.

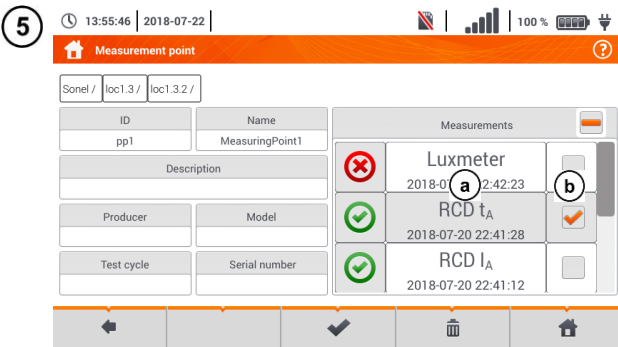
- condition fulfilled
- condition unfulfilled
- limit not defined

To call up the measurements management menu, activate the required records (→).



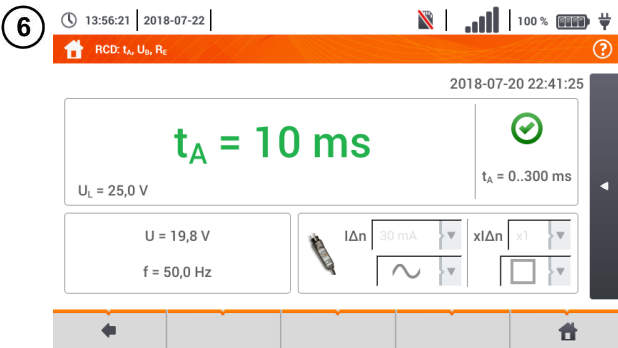
Description of function icons

- returning to the previous screen
- going to details (step 5)
- removing the active record.
- returning to the main menu



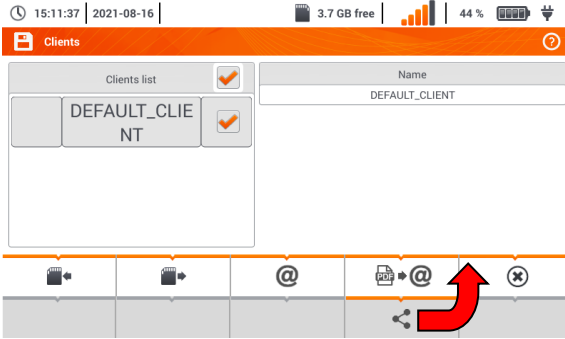
To go to the selected measurement result:


- a) tap the record label,
- b) activate the record (→) and select .







The value of the required measurement will be displayed.


6.1.5 Sharing recorded measurements







- Select . The following options are available:

-   import of all clients from the memory card to the meter,

-   export of selected clients to a memory card,

-  sending selected customers via e-mail,

-   generating a report in PDF format and sending it by e-mail.

- If necessary, select the customer ( → ) , which is to be subject to the requested action.

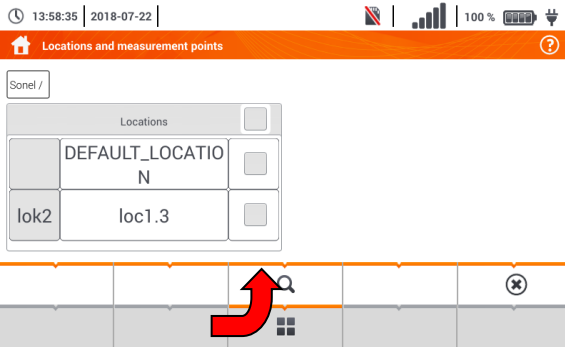
- Select the icon with the desired action.



Before sending data by e-mail, the Outbox must be configured. See **sec. 2.3.4**.

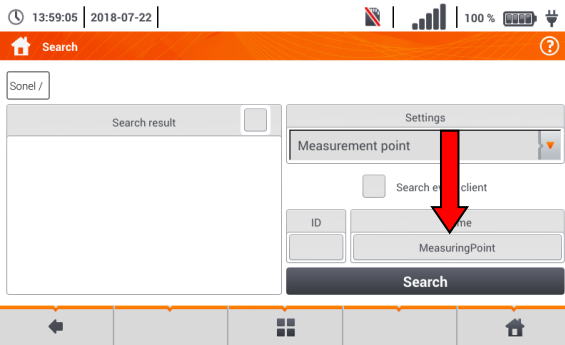
6.1.6 Searching the meter memory

1



- From anywhere in the browse menu select and .

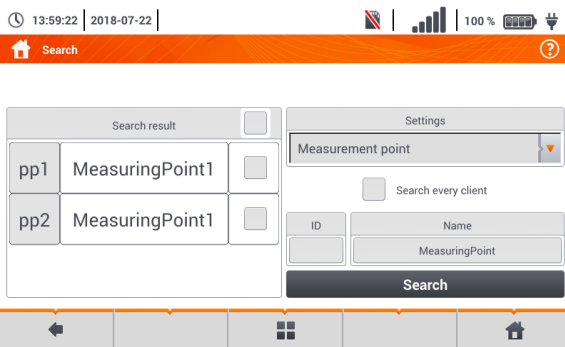
2



- The search menu will be displayed.
- In the **Settings** field, select the type of the searched object: **location** or **measuring point**.
- If necessary, select **Search all clients** (→)
- In the **Name** field, enter the searched phrase from the on-screen keyboard.

- Select **Search**.

3



- Activate the required result (→)
- Go to details using the icon.
- After the icon has been selected, the option of record editing is also available in accordance with **section 6.1.2b**, steps **8** **9** **10**.

Description of other function icons

- returning to the previous screen
- returning to the main menu

6.2 Recorder memory

6.2.1 microSD Memory Card

Removable microSD HC card is the primary place of data storage. The following are saved on it:

- recorded measurement data,
- screenshot files.

The top bar shows the status of the card and its free space available.

To ensure proper operation of the meter and prevent data loss, do not:

- remove the memory card during recording. Removal of the card may result in **ending the recording process**, **damage** of data recorded, and in some cases, **damage to the entire structure of files** saved on the card.
- modify or delete files stored on the card or store your own files on it. If after inserting the card the meter detects an error in the file system, the memory format panel is shown to perform formatting of the card. Only after formatting (which removes all files) it will be possible to reuse the card in the device.

In addition, before removing the card from the meter (e.g. to read the data by *Sonel Analysis*) it is recommended to turn the meter off, to save all cached data.

MicroSD memory card may be formatted from the user interface level. Go to **Analyser settings**, and then select the **Memory** section, where the user can format the selected memory (see also **section 6.1.1**).

6.2.2 USB external memory (flash drive)

Connecting an external USB stick allows user to:

- copy selected files with screenshot from microSD memory card to the memory stick,
- save the log file of the meter, in case of an error in the device in order to perform an analysis in the service of the manufacturer,
- update the firmware of the device.

Supported file systems are FAT32. When a memory formatted in a different file system is inserted, the device will display a window informing about detecting unformatted media carrier. From this window, the user may directly enter the formatting screen.

The data on the memory stick are stored in the folder named "MPI-540_DATA".

6.2.3 Compatibility with *Sonel Analysis* software



Sonel Analysis is an application used to work with MPI-540 meter and power analyzers of PQM series. In combination with the above devices it enables to:

- read data from the device,
- present data in the tabular form,
- present data in the form of graphs,
- updating firmware of analyzer to new and updating the application itself.

The software operates with Windows XP, Windows Vista, Windows 7, Windows 8 and Windows 10. Detailed manual for "*Sonel Analysis*" is available in a separate document (also downloadable from the manufacturer's website).

6.2.4 PC connection and data transmission

Connection to a computer (PC mode), ensures transmission of data stored in the recorder memory – it is possible to read data from all completed recordings.


- When connected to a PC, the display shows message "PC Connection"
- When connected to a PC, all buttons are locked except  button, unless the recorder operates with key lock mode (e.g. during recording) – then all the buttons are locked. The  icon whose selection interrupts the connection with the PC is displayed on the screen on the bottom bar.
- When within 10 seconds of connecting a PC to the device no data exchange occurs between the device and the computer, the device exits data exchange mode and terminates the connection.







Sonel Analysis software also allows you to read data directly from a microSD card using an external memory card reader. This method allows for the fastest reading of the recorded data. To use this mode, remove the memory card from the meter and put it into the reader connected to a computer (when removing the card, follow the rules described in **sec. 6.2.1**; it is safe to turn the meter off earlier).

7 Power supply

7.1 Monitoring of the battery charge status

The device is equipped with a Li-Ion battery pack 11.1 V 3.4 Ah. The battery pack includes a circuit monitoring its charge status, which provides precise level of battery pack charge and a temperature sensor.

The charging level of the battery pack is indicated by icon on the top bar of the screen on the right side (section 2 element ).

	charging level 80...100%
	charging level 60...80%
	charging level 40...60%
	charging level 20...40%
	charging level 0...20%
	<ul style="list-style-type: none">• batteries fully discharged.• no battery• no communication with the battery pack

7.2 Replacing rechargeable batteries

MPI-540 meter is powered from SONEL Li-Ion rechargeable battery pack.

Battery charger is installed inside the meter and cooperates only with the manufacturer's rechargeable battery pack. The charger is powered by external power supply adapter. It can be also powered from the car cigarette lighter socket. Both the rechargeable battery pack and the adapter are standard components of the meter.



WARNING

If the test leads are left in the terminals during replacement of the batteries, there is a risk of electric shock.

The internal real time clock is supplied from the battery pack, therefore to avoid deleting the clock settings, the battery pack replacement may be performed with connected power supply of 12 V DC.

In order to replace the battery pack it is necessary to:

- remove all the test leads from the sockets and turn the meter off,
- connect the external power supply 12 V DC (to prevent deleting date and time settings)
- remove the four screws of the battery compartment (in the lower part of the casing, **Fig. 7.1**),
- remove the battery compartment,
- remove the compartment cover and remove the batteries,
- insert a new battery pack,
- Insert (snap) the compartment cover,
- Insert the compartment in the meter,
- screw the 4 screws of the battery compartment.

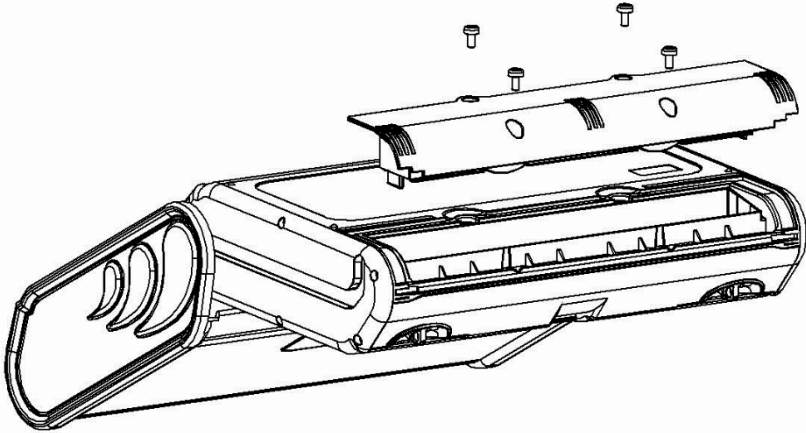


Fig. 7.1. Replacing the battery pack




NOTE!

Do not use the meter when the accumulator compartment is removed or open or power it from other sources than those mentioned in this manual.

7.3 Charging the rechargeable batteries

Charging the battery pack of the device is started automatically after connecting:



- 2 V DC power supply adapter,
- charging cable for the car cigarette lighter.

Charging is indicated by the  icon next to the battery symbol on the top bar and by the **H.V./REC/CONT.** diode. The temperature of the battery and the ambient temperature influence the charging process. If the battery temperature is below 0°C or higher than 45°C, the charging process is stopped.

Indication of charging status


- charging

meter off – diode **H.V./REC/CONT.** is lit **green**  

meter on – charging signalled only by an icon on the display  

- damage

meter off – diode **H.V./REC/CONT.** flashes **green** every 0.5 second  

meter on – error signalled by an icon on the display 



Due to interferences in the network or to high ambient temperature, the charging process of rechargeable batteries may finish prematurely. When charging time is too short, turn off the meter and start charging again.

7.4 General rules for using Li-Ion rechargeable batteries

- Store the half-charged battery pack in a plastic container placed in a dry, cool and well ventilated place and protect them from direct sunlight. The battery pack may be damaged if stored when fully discharged. The ambient temperature for prolonged storage should be maintained within the range of 5°C...25°C.
- Charge the batteries in a cool, well-ventilated place at a temperature of 10°C ... 28°C. Modern fast chargers detect both too low and too high temperature of rechargeable batteries and react to the situation adequately. When the temperature is too low, charging should be prevented as it may irreparably damage the batteries. The increase in temperature of the battery pack may cause electrolyte leakage and even its ignition or explosion.
- Do not exceed the charging current, as it may result in ignition or "swelling" of the battery pack. "Swollen" battery pack must not be used.
- Do not charge or use the batteries in extreme temperatures. Extreme temperatures reduce the lifetime of rechargeable batteries. Always observe the rated operating temperature. Do not dispose the battery pack into fire.
- Li-Ion cells are sensitive to mechanical damage. This kind of damage may cause their permanent damage and thus - ignition or explosion.
- Any interference in the structure of Li-ion battery pack may cause its damage. This may result in the ignition or explosion.
- A short-circuit of the battery poles "+" and "-" may permanently damage the battery pack or even cause its fire or explosion.
- Do not immerse Li-Ion battery in liquids and do not store in humid conditions.
- If the electrolyte contained in the Lithium-Ion battery pack, contacts eyes or skin, immediately rinse the affected place with plenty of water and consult a doctor. Protect the battery against unauthorised persons and children.
- When you notice any changes in the Lithium-Ion battery pack (e.g. changes in colour, swelling, excessive temperature), stop using the battery pack. Li-Ion batteries that are mechanically damaged, overcharged or excessively discharged are not suitable for use.
- Any misuse of the battery may cause its permanent damage. This may result in the ignition. The seller and the manufacturer shall not be liable for any damages resulting from improper handling Li-Ion battery pack.

8 Cleaning and maintenance



NOTE!

Use only the maintenance methods specified by the manufacturer in this manual.

The meter has been designed for many years of reliable use, provided that the following recommendations are observed for its maintenance and care:

1. **THE METER MUST BE DRY.** Wipe the dampened meter.
2. **THE METER MUST BE USED AND STORED IN NORMAL TEMPERATURES.** Extreme temperatures may shorten the life of electronic components and distort or melt plastic parts.
3. **THE METER MUST BE HANDLED CAREFULLY AND GENTLY.** Dropping the meter may damage its electronic elements or the housing.
4. **THE METER MUST BE KEPT CLEAN.** From time to time wipe the housing with a damp cloth. DO NOT use chemicals, solvents or detergents.
5. **CLEAN THE PROBES WITH WATER AND DRY THEM** Before the probe is stored for a prolonged period of time it is recommended to grease it with any machine lubricant.
6. The reels and test leads should be cleaned with water and detergents, and then dried.



The electronic system of the meter does not require maintenance.

9 Storage

In the case of storage of the device, the following recommendations must be observed:

- Disconnect all the test leads from the meter.
- Clean the meter and all its accessories thoroughly.
- Wind the long test leads onto the reels.
- In the case the meter is to be stored for a prolonged period of time, the batteries must be removed from the device.
- In order to prevent a total discharge of the rechargeable batteries in the case of a prolonged storage, charge them from time to time.

10 Dismantling and utilisation

Worn-out electric and electronic equipment should be gathered selectively, i.e. it must not be placed with waste of another kind.

Worn-out electronic equipment should be sent to a collection point in accordance with the law of waste electrical and electronic equipment.

Before the equipment is sent to a collection point, do not dismantle any elements. Observe the local regulations concerning disposal of packages and used batteries/rechargeable batteries.

11 Technical data

11.1 Basic data

⇒ Abbreviation "m.v." used in the specification of accuracy means standard measured value

11.1.1 Measurement of alternating voltages (True RMS)

Range	Resolution	Accuracy
0.0 V...299.9 V	0.1 V	±(2% m.v. + 4 digits)
300 V...500 V	1 V	±(2% m.v. + 2 digits)

- Frequency range: 45...65 Hz

11.1.2 Frequency measurement

Range	Resolution	Accuracy
45.0 Hz...65.0 Hz	0.1 Hz	±(0.1% m.v. + 1 digit)

- Voltage range: 50 ... 500V

11.1.3 Measurement of fault loop impedance Z_{L-PE} , Z_{L-N} , Z_{L-L}

Measurement of fault loop impedance Z_s

Test range according to IEC 61557-3:

Test lead	Test range Z_s
1.2 m	0.130 Ω ...1999.9 Ω
5 m	0.170 Ω ...1999.9 Ω
10 m	0.210 Ω ...1999.9 Ω
20 m	0.290 Ω ...1999.9 Ω
WS-03, WS-04	0.190 Ω ...1999.9 Ω

Display range:

Display range	Resolution	Accuracy
0.000...19.999 Ω	0.001 Ω	±(5% m.v. + 0.03 Ω)
20.00...199.99 Ω	0.01 Ω	±(5% m.v. + 0.3 Ω)
200.0...1999.9 Ω	0.1 Ω	±(5% m.v. + 3 Ω)

- Rated operating voltage U_{nL-N} / U_{nL-L} : 110/190 V, 115/200 V, 127/220 V, 220/380 V, 230/400 V, 240/415 V
- Operating voltage range: 95 V...270 V (for Z_{L-PE} and Z_{L-N}) and 95 V...440 V (for Z_{L-L})
- Rated mains frequency f_n : 50 Hz, 60 Hz
- Operating frequency range: 45 Hz...65 Hz
- Maximum test current (for 415 V): 41.5 A (10 ms)
- Control of correctness of PE terminal connection by means of a touch electrode

Indications of fault loop resistance R_S and fault loop reactance X_S

Display range	Resolution	Accuracy
0...19.999 Ω	0.001 Ω	$\pm(5\% + 0.05 \Omega)$ of Z_S value

- Calculated and displayed for $Z_S < 20 \Omega$

Indications of short-circuit current I_k

Test range according to IEC 61557-3 can be calculated on the basis of test ranges for Z_S and nominal voltages.

Display range	Resolution	Accuracy
0.055 ... 1.999 A	0.001 A	Calculated on the basis of accuracy for fault loop
2.00...19.99 A	0.01 A	
20.0...199.9 A	0.1 A	
200...1999 A	1 A	
2.00...19.99 kA	0.01 kA	
20.0 ... 40.0 kA	0.1 kA	

- Prospective fault current calculated and displayed by the meter may slightly differ from the value calculated by the user with a calculator, basing on the displayed value of the impedance, because the meter calculates the current from unrounded value of fault loop impedance (which is used for displaying). As the correct value, consider I_k current value, displayed by the meter or by firmware.

11.1.4 Measurement of fault loop impedance $Z_{L-PE[RCD]}$ (without triggering of RCD)

Measurement of fault loop impedance Z_S

Test range according to IEC 61557-3:

- 0.50...1999 Ω for 1.2 m leads, WS-03 and WS-04
- 0.51...1999 Ω for 5 m, 10 m and 20 m leads

Display range	Resolution	Accuracy
0...19.99 Ω	0.01 Ω	$\pm(6\% \text{ m.v.} + 10 \text{ digits})$
20.0...199.9 Ω	0.1 Ω	$\pm(6\% \text{ m.v.} + 5 \text{ digits})$
200...1999 Ω	1 Ω	

- It will not trip RCDs of $I_{\Delta n} \geq 30 \text{ mA}$
- Rated operating voltage U_n : 110 V, 115 V, 127 V, 220 V, 230 V, 240 V
- Operating voltage range: 95 V...270 V
- Rated mains frequency f_n : 50 Hz, 60 Hz
- Operating frequency range: 45...65 Hz
- Control of correctness of PE terminal connection by means of a touch electrode

Indications of fault loop resistance R_S and fault loop reactance X_S

Display range	Resolution	Accuracy
0...19.99 Ω	0.01 Ω	$\pm(6\% + 10 \text{ digits})$ of Z_S value

- Calculated and displayed for $Z_S < 20 \Omega$

Indications of short-circuit current I_k

Test range according to IEC 61557-3 can be calculated on the basis of test ranges for Z_s and nominal voltages.

Display range	Resolution	Accuracy
0.055 ... 1.999 A	0.001 A	Calculated on the basis of accuracy for fault loop
2.00...19.99 A	0.01 A	
20.0...199.9 A	0.1 A	
200...1999 A	1 A	
2.00...19.99 kA	0.01 kA	
20.0 ...40.0 kA	0.1 kA	

- Prospective fault current calculated and displayed by the meter may slightly differ from the value calculated by the user with a calculator, basing on the displayed value of the impedance, because the meter calculates the current from unrounded value of fault loop impedance (which is used for displaying). As the correct value, consider I_k current value, displayed by the meter or by firmware.

11.1.5 Measurement of parameters of RCD

- Measurement of RCDs type: AC, A, B, B+, F, EV
- Rated operating voltage U_n : 110 V, 115 V, 127 V, 220 V, 230 V, 240 V
- Operating voltage range: 95 V...270 V
- Rated mains frequency f_n : 50 Hz, 60 Hz
- Operating frequency range: 45...65 Hz

RCD trigger and response time test t_A (for measurement function t_A)

Test range according to IEC 61557-6: 0ms ... to the upper limit of displayed value

Type of RCD	Setting of multiple values	Test range	Resolution	Accuracy
<ul style="list-style-type: none"> • General type • Short-time delay type • AC module in EV type 	0.5 $I_{\Delta n}$	0..300 ms (TN/TT)	1 ms	$\pm(2\% \text{ m.v.} + 2 \text{ digits})^1)$
	1 $I_{\Delta n}$	0..400 ms (IT)		
	2 $I_{\Delta n}$	0..150 ms		
	5 $I_{\Delta n}$	0..40 ms		
Selective	0.5 $I_{\Delta n}$	0..500 ms		
	1 $I_{\Delta n}$			
	2 $I_{\Delta n}$	0..200 ms		
	5 $I_{\Delta n}$	0..150 ms		
<ul style="list-style-type: none"> • EV 6 mA DC • RCM 	1 $I_{\Delta n}$	0.0..10.0 s	0.1 s	$\pm(2\% \text{ m.v.} + 3 \text{ digits})$
	10 $I_{\Delta n}$	0..300 ms	1 ms	
	33 $I_{\Delta n}$ ²⁾	0..100 ms		
	50 $I_{\Delta n}$ ³⁾	0..40 ms		

1) for $I_{\Delta n} = 10 \text{ mA}$ and $0.5 I_{\Delta n}$ accuracy is $\pm(2\% \text{ m.v.} + 3 \text{ digits})$

2) for measurements acc. to IEC 62955









3) for measurements acc. to IEC 62752









- Accuracy of differential current setting:

for $1 \cdot I_{\Delta n}$, $2 \cdot I_{\Delta n}$, $5 \cdot I_{\Delta n}$ 0..8%

for $0.5 \cdot I_{\Delta n}$ -8..0%

Effective value of forced leakage current at measurement of RCD disconnection time (does not apply to RCD EV 6 mA DC and RCM) [mA]

$I_{\Delta n}$	Multiplication factor setting							
	0.5				1			
								
10	5	3.5	3.5	5	10	20	20	20
30	15	10.5	10.5	15	30	42	42	60
100	50	35	35	50	100	140	140	200
300	150	105	105	150	300	420	420	600
500	250	175	175	—	500	700	700	1000*
1000	500	—	—	—	1000	—	—	—

$I_{\Delta n}$	Multiplication factor setting							
	2				5			
								
10	20	40	40	40	50	100	100	100
30	60	84	84	120	150	210	210	300
100	200	280	280	400	500	700	700	1000*
300	600	840	840	—	—	—	—	—
500	1000	—	—	—	—	—	—	—
1000	—	—	—	—	—	—	—	—

* - does not apply to $U_n = 110$ V, 115 V and 127 V and IT network

Effective value of forced leakage current at measurement of RCD disconnection time (applies to RCD EV 6 mA DC and RCM) [mA]

$I_{\Delta n}$	Multiplication factor setting			
	1	10	33	50
6 mA DC acc. to IEC 62955	6	60	200	—
6 mA DC acc. to IEC 62752	6	60	—	300

Measurement of resistance-to-earth R_E (for TT)

Selected nominal current of RCD	Test range	Resolution	Test current	Accuracy
10 mA	0.01...5.00 k Ω	0.01 k Ω	4 mA	0..+10% m.v. ± 8 digits
30 mA	0.01...1.66 k Ω		12 mA	0..+10% m.v. ± 5 digits
100 mA	1...500 Ω	1 Ω	40 mA	0..+5% m.v. ± 5 digits
300 mA	1...166 Ω		120 mA	
500 mA	1...100 Ω		200 mA	
1000 mA	1...50 Ω		400 mA	

Measurement of touch voltage U_B in relation to nominal differential current

Test range according to IEC 61557-6: 10.0 V...99.9 V

Test range	Resolution	Test current	Accuracy
0...9.9 V	0.1 V	0.4 x $I_{\Delta n}$	0%...10% m.v. ± 5 digits
10.0...99.9 V			0%...15% m.v.

Measurement of RCD disconnection current I_A for sinusoidal differential current

Test range according to IEC 61557-6: $(0.3...1.0)I_{\Delta n}$

Selected nominal current of RCD	Test range	Resolution	Test current	Accuracy
10 mA	3.0..10.0 mA	0.1 mA	$0.3 \times I_{\Delta n}..1.0 \times I_{\Delta n}$	$\pm 5\% I_{\Delta n}$
30 mA	9.0 .. 30.0 mA			
100 mA	30..100 mA	1 mA		
300 mA	90..300 mA			
500 mA	150..500 mA			
1000 mA	300..1000 mA			

- it is possible to start the measurement from the positive of the negative half of forced leakage current
- test current duration..... max. 8.8 s

Measurement of RCD disconnection current I_A for differential unidirectional pulsed current and unidirectional pulsed current with 6mA direct current offset

Test range according to IEC 61557-6: $(0.35...1.4)I_{\Delta n}$ for $I_{\Delta n} \geq 30$ mA and $(0.35...2)I_{\Delta n}$ for $I_{\Delta n} = 10$ mA

Selected nominal current of RCD	Test range	Resolution	Test current	Accuracy
10 mA	3.5..20.0 mA	0.1 mA	$0.35 \times I_{\Delta n}..2.0 \times I_{\Delta n}$	$\pm 10\% I_{\Delta n}$
30 mA	10.5..42.0 mA			
100 mA	35..140 mA	1 mA	$0.35 \times I_{\Delta n}..1.4 \times I_{\Delta n}$	
300 mA	105..420 mA			
500 mA	175..700 mA			

- measurement may be performed for positive or negative half-periods of forced leakage current
- test current duration..... max. 8.8 s

Measurement of RCD disconnection current I_A for differential direct current

Test range according to IEC 61557-6: $(0.2...2)I_{\Delta n}$

Selected nominal current of RCD	Test range	Resolution	Current	Accuracy
6 mA ¹⁾	1.0..6.0 mA	0.1 mA	1.0..6.0 mA	$\pm 6\% I_{\Delta n}$
10 mA	2.0..20.0 mA	0.1 mA	$0.2 \times I_{\Delta n}..2.0 \times I_{\Delta n}$	$\pm 10\% I_{\Delta n}$
30 mA	6..60 mA	1 mA		
100 mA	20..200 mA			
300 mA	60..600 mA			
500 mA	100..1000 mA			

- measurement can be performed for positive or negative forced leakage current
- test current duration (does not apply to RCD EV and RCM)..... max. 5.2 s
- 1) test current duration (applies to RCD EV and RCM)
 - acc. to IEC 62955..... 30 s
 - acc. to IEC 62752..... 40 s

11.1.6 Measurement of resistance-to-earth R_E

Test range according to IEC 61557-5: 0.50 Ω ...1.99 k Ω for test voltage of 50 V and 0.56 Ω ...1.99 k Ω for test voltage of 25 V

Range	Resolution	Accuracy
0.00...0.35 Ω	0.01 Ω	$\pm(2\% \text{ m.v.} + 10 \text{ digits})$
0.35...9.99 Ω	0.01 Ω	$\pm(2\% \text{ m.v.} + 4 \text{ digits})$
10.0...99.9 Ω	0.1 Ω	$\pm(2\% \text{ m.v.} + 3 \text{ digits})$
100...999 Ω	1 Ω	
1.00...1.99 k Ω	0.01 k Ω	

- test voltage: 25 V or 50 V rms
- test current: 20 mA, sinusoidal rms 125 Hz (for $f_n=50$ Hz) and 150 Hz (for $f_n=60$ Hz)
- blocking of measurement at interference voltage of $U_N > 24$ V
- maximum measured voltage of interferences $U_{Nmax}=100$ V
- maximum resistance of auxiliary earth electrodes 50 k Ω

Measurement of resistance of auxiliary earth electrodes R_H , R_S

Display range	Resolution	Accuracy
000...999 Ω	1 Ω	$\pm(5\% (R_S + R_E + R_H) + 3 \text{ digits})$
1.00...9.99 k Ω	0.01 k Ω	
10.0...50.0 k Ω	0.1 k Ω	

Measurement of interference voltages

Internal resistance: approx. 8 M Ω

Range	Resolution	Accuracy
0...100 V	1 V	$\pm(2\% \text{ m.v.} + 3 \text{ digits})$

Selective measurement of earthing with clamps

Range	Resolution	Accuracy*
0.00...0.35 Ω	0.01 Ω	$\pm(8\% \text{ m.v.} + 10 \text{ digits})$
0.35...9.99 Ω	0.01 Ω	$\pm(8\% \text{ m.v.} + 4 \text{ digits})$
10.0...99.9 Ω	0.1 Ω	
100...999 Ω	1 Ω	
1.00...1.99 k Ω	0.01 k Ω	

* – at maximum interference current of 1 A

- Measurement with additional current clamps C-3,
- The range of interference current is up to 9.99 A.

Selective measurement of earthing with two clamps

Range	Resolution	Accuracy*
0.00...0.35 Ω	0.01 Ω	$\pm(10\% \text{ m.v.} + 10 \text{ digits})$
0.35...9.99 Ω	0.01 Ω	$\pm(10\% \text{ m.v.} + 4 \text{ digits})$
10.0...19.9 Ω	0.1 Ω	
20.0...99.9 Ω		$\pm(20\% \text{ m.v.} + 4 \text{ digits})$

* – at maximum interference current of 1 A

- Measurement with transmitting clamps N-1 and receiving clamps C-3.
- The range of interference current is up to 9.99 A.

Measuring soil resistivity (ρ)

Range	Resolution	Accuracy
0.0...99.9 Ω m	0.1 Ω m	Depending on the accuracy of the measurement R_E
100...999 Ω m	1 Ω m	
1.00...9.99 k Ω m	0.01 k Ω m	
10.0...99.9 k Ω m	0.1 k Ω m	

- Measurement with Wenner method,
- Option for setting the distance in meters or feet,
- Selecting a distance: 1 m ... 30 m (1 ft ... 90 ft).

11.1.7 Low-voltage measurement of continuity of circuit and resistance

Measurement of continuity of protective conductors and equipotential bonding with 200 mA \pm current

Measurement range according to IEC 61557-4: 0.12...400 Ω

Range	Resolution	Accuracy
0.00...19.99 Ω	0.01 Ω	$\pm(2\% \text{ m.v.} + 3 \text{ digits})$
20.0...199.9 Ω	0.1 Ω	
200...400 Ω	1 Ω	

- Voltage at open terminals: 4 V...9 V
- Output current at $R < 2 \Omega$: min. 200 mA (I_{sc} : 200 mA...250 mA)
- Compensation of test leads resistance
- Measurements for both current polarizations

Measurement of resistance with low current

Range	Resolution	Accuracy
0.0...199.9 Ω	0.1 Ω	$\pm(3\% \text{ m.v.} + 3 \text{ digits})$
200...1999 Ω	1 Ω	

- Voltage at open terminals: 4 V...9 V
- Output current < 8 mA
- Audio signal for measured resistance < 30 $\Omega \pm 50\%$
- Compensation of test leads resistance

11.1.8 Measurement of insulation resistance

Measurement range, according to IEC 61557-2 for $U_N = 50 \text{ V}$: 50 k Ω ...250 M Ω

Display range for $U_N = 50 \text{ V}$	Resolution	Accuracy
0 k Ω ...1999 k Ω	1 k Ω	$\pm(3\% \text{ m.v.} + 8 \text{ digits})$, $[\pm(5\% \text{ m.v.} + 8 \text{ digits})]^*$
2.00 M Ω ...19.99 M Ω	0.01 M Ω	
20.0 M Ω ...199.9 M Ω	0.1 M Ω	
200 M Ω ...250 M Ω	1 M Ω	

* – for WS-03 and WS-04 leads

Test range according to IEC 61557-2 for $U_N = 100 \text{ V}$: 100 k Ω ...500 M Ω

Display range for $U_N = 100 \text{ V}$	Resolution	Accuracy
0 k Ω ...1999 k Ω	1 k Ω	$\pm(3\% \text{ m.v.} + 8 \text{ digits})$ $[\pm(5\% \text{ m.v.} + 8 \text{ digits})]^*$
2.00 M Ω ...19.99 M Ω	0.01 M Ω	
20.0 M Ω ...199.9 M Ω	0.1 M Ω	
200 M Ω ...500 M Ω	1 M Ω	

* – for WS-03 and WS-04 leads

Test range according to IEC 61557-2 for $U_N = 250 \text{ V}$: 250 k Ω ...999 M Ω

Display range for $U_N = 250 \text{ V}$	Resolution	Accuracy
0 k Ω ...1999 k Ω	1 k Ω	$\pm(3\% \text{ m.v.} + 8 \text{ digits})$ $[\pm(5\% \text{ m.v.} + 8 \text{ digits})]^*$
2.00 M Ω ...19.99 M Ω	0.01 M Ω	
20.0 M Ω ...199.9 M Ω	0.1 M Ω	
200 M Ω ...999 M Ω	1 M Ω	

* – for WS-03 and WS-04 leads

Test range according to IEC 61557-2 dla $U_N = 500 \text{ V}$: 500 k Ω ...2.00 G Ω

Display range for $U_N = 500 \text{ V}$	Resolution	Accuracy
0...1999 k Ω	1 k Ω	$\pm(3\% \text{ m.v.} + 8 \text{ digits})$ $[\pm(5\% \text{ m.v.} + 8 \text{ digits})]^*$
2.00...19.99 M Ω	0.01 M Ω	
20.0...199.9 M Ω	0.1 M Ω	
200...999 M Ω	1 M Ω	
1.00...2.00 G Ω	0.01 G Ω	$\pm(4\% \text{ m.v.} + 6 \text{ digits})$ $[\pm(6\% \text{ m.v.} + 6 \text{ digits})]^*$

* – for WS-03 and WS-04 leads

Test range according to IEC 61557-2 for $U_N = 1000 \text{ V}$: 1000 k Ω ...4.99 G Ω

Display range for $U_N = 1000 \text{ V}$	Resolution	Accuracy
0...1999 k Ω	1 k Ω	$\pm(3\% \text{ m.v.} + 8 \text{ digits})$
2.00...19.99 M Ω	0.01 M Ω	
20.0...199.9 M Ω	0.1 M Ω	
200...999 M Ω	1 M Ω	
1.00...4.99 G Ω	0.01 G Ω	$\pm(4\% \text{ m.v.} + 6 \text{ digits})$
5.00...9.99 G Ω	0.01 G Ω	unspecified

- Test voltage: 50 V, 100 V, 250 V, 500 V i 1000 V
- Accuracy of generated voltage (Robc [Ω] $\geq 1000 \cdot U_N$ [V]): -0% +10% from the set value
- Detection of a dangerous voltage before commencing a measurement
- Discharging the object tested

- Measurement of insulation resistance with the use of UNI-Schuko plug (WS-03, WS-04) between all three terminals (for $U_N=1000$ V is not available)
- Insulation resistance measurement for multi-wire cables (max. 5) using an optional external AutoISO-1000c adapter
- Measurement of voltage on terminals $+R_{ISO}$, $-R_{ISO}$ within the range of: 0 V...440 V
- Test current < 2 mA

11.1.9 Light measurements

Measuring ranges of LP-1 probe

Range [lx]	Resolution [lx]	Spectral uncertainty	Accuracy*
0...399.9	0.1	f1<6%	±(5% m.v. + 5 digits)
400...3999	1		
4.00 k...19.99 k	0.01 k		

Range [fc]	Resolution [fc]	Spectral uncertainty	Accuracy*
0...39.99	0.01	f1<6%	±(5% m.v. + 5 digits)
40.0...399.9	0.1		
400...1999	1		

- Probe class B

* above a reading of 6000 lx / 600 fc, accuracy is not specified

Measuring ranges of LP-10B probe

Range [lx]	Resolution [lx]	Spectral uncertainty	Accuracy
0...39.99	0.01	f1<6%	±(5% m.v. + 5 digits)
40.0...399.9	0.1		
400...3999	1		
4.00 k...39.99 k	0.01 k		
40.0 k...399.9 k	0.1 k		

Range [fc]	Resolution [fc]	Spectral uncertainty	Accuracy
0...3.999	0.001	f1<6%	±(5% m.v. + 5 digits)
4.00...39.99	0.01		
40.0...399.9	0.1		
400...3999	1		
4.00 k...39.99 k	0.01 k		

- Probe class B

Measuring ranges of LP-10A probe

Range [lx]	Resolution [lx]	Spectral uncertainty	Accuracy
0...3.999	0.001	f1<2%	±(2% m.v. + 5 digits)
4.00...39.99	0.01		
40.0...399.9	0.1		
400...3999	1		
4.00 k...39.99 k	0.01 k		
40.0 k...399.9 k	0.1 k		

Range [fc]	Resolution [fc]	Spectral uncertainty	Accuracy
0...3.999	0.001	f1 < 2%	±(2% m.v. + 5 digits)
4.00...39.99	0.01		
40.0...399.9	0.1		
400...3999	1		
4.00 k...39.99 k	0.01 k		

- Probe class A

11.1.10 Phase sequence

- Phase sequence indication: in the same direction (correct), opposite direction (incorrect)
- Range of network voltages U_{LL} : 95 V...500 V (45 Hz...65 Hz)
- Display of phase-to-phase voltages

11.1.11 Motor rotation

- EMF motor voltage ranges: 1 V + 500 V AC
- Test current (per phase): < 3.5 mA

11.1.12 **MPI-540-PV** Measurement of open circuit DC voltage U_{OC}

Range	Resolution	Accuracy
0.0 V...299.9 V	0.1 V	±(3% m.v. + 5 digits)
300 V...1000 V	1 V	±(3% m.v. + 2 digits)

11.1.13 **MPI-540-PV** Measurement of short circuit DC current I_{sc}

Range	Resolution	Accuracy
0.00 A...20.00 A	0.01 A	±(3% m.v. + 0,10 A)

- Before the measurement reset the clamp

11.2 Recorder data

Recorder class: compliance with EN 61000-4-30:2015 class S.

11.2.1 Inputs

Voltage input terminals

Number of inputs	5 (L1, L2, L3, N - 3 measuring channels) not galvanically insulated
Maximum input voltage	L1, L2, L3, N: 500 V _{RMS} relative to earth.
Peak input voltage (without cutting)	1150 V (L-N)
Analogue transmission band (-3 dB)	12 kHz
Transformers	defined by user
Impedance of measurement inputs	14 MΩ (L-L, L-N)
CMRR	>70 dB (50 Hz)

Current input terminals

Number of inputs	3 (L1, L2, L3) not galvanically insulated from one another
Maximum peak input voltage	5 V relative to earth
Nominal input voltage (hard clamps)	1 V _{RMS}
Peak input voltage (hard clamps, without cutting)	3.6 V
Analogue transmission band (-3dB)	12 kHz
Input Impedance	Path for hard clamps: 100 kΩ Path for flexible clamps: 12.4 kΩ
Measurement range (without transformers)	Flexible clamps F-1(A)/F-2(A)/F-3(A): 1..3000 A (10000 A peak, 50 Hz) Hard clamps C-4(A), C-5(A): 1..1000 A (3600 A peak) Hard clamps C-6(A): 0.01..12 A (36 A peak) Hard clamps C-7(A): 0..100 A (360 A peak)
Transformers	defined by user
CMRR	60 dB (50 Hz)

11.2.2 Sampling and RTC

A/C converter	16-bit
Sampling rate	5.12 kHz for 50 Hz and 60 Hz Simultaneous sampling in all channels
Samples per period	102.4 for 50 Hz; 85.33 for 60 Hz
PLL synchronization	40..70 Hz
Reference channel for PLL	L1-N, L1-L2 (depending on the type of network)
Real-time clock	±30 ppm (approx. ±2.6 s/day)

11.2.3 Voltage measurement

Voltage	Range and conditions	Resolution	Accuracy
U _{RMS} (AC+DC)	20% U _{nom} ≤ U _{RMS} ≤ 120% U _{nom} for U _{nom} ≥ 100 V	0.1% U _{nom}	±0,5% U _{nom}
Crest Factor	1..10 (1..2.2 for voltage 500 V) for U _{RMS} ≥ 10% U _{nom}	0.01	±5%

11.2.4 Measurement of current (True RMS)

Current	Range and conditions	Resolution	Accuracy
I _{RMS} (AC+DC)	Accuracy of the device		
	10% I _{nom} ≤ I _{RMS} < 100% I _{nom}	0.01% I _{n-om}	±2%
	Flexible clamps F-1A/F-2A/F-3A		
	0..3000 A (10 kA _{p-p} @ 50Hz)	0.01% I _{n-om}	Additional uncertainty ±1% (±2% taking into account additional error due to the position)
	Hard clamps C-4A		
	0..1000 A (3600 A _{p-p})	0.01% I _{n-om}	Additional uncertainty 0.1..10 A: ± (3% + 0.1 A) 10 A: ±3% 50 A: ±1.5% 200 A: ±0.75% 1000..1200 A: ±0.5%
	Hard clamps C-5A		
	0..1000 A (3600 A _{p-p})	0.01% I _{n-om}	Additional uncertainty 0.5..100 A: ≤ (1.5% + 1 A) 100..800 A: ≤ 2.5% 800..1000 A AC: ≤ 4% 1000..1400 A DC: ≤ 5%
	Hard clamps C-6A		
0..12 A (36 A _{p-p})	0.01% I _{n-om}	Additional uncertainty 0.01..0.1 A: ± (3% + 1 mA) 0.1..1 A: ±2.5% 1..12 A: ±1%	
Hard clamps C-7A			
0..100 A (360 A _{p-p})	0.01% I _{n-om}	Additional uncertainty 0..100 A: ± (0,5% + 0,02 A) (45..65 Hz) 0..100 A: ± (1,0% + 0,04 A) (40..1000 Hz)	
Crest Factor	1..10 (max. 3.6 for I _{nom}) for I _{RMS} ≥ 1% I _{nom}	0.01	±5%

11.2.5 Frequency measurement

Frequency	Range and conditions	Resolution	Accuracy
f	40..70 Hz 15% U _{nom} ≤ U _{RMS} ≤ 120% U _{nom}	0.01 Hz	±0,05 Hz

11.2.6 Measuring harmonics

Harmonics	Range and conditions	Resolution	Accuracy
Harmonic (n)	DC, 1..40, grouping: harmonics sub-groups according to EN 61000-4-7		
U _{RMS} amplitude	0..200% U _{nom}	0.01% U _{nom}	±0.15% U _{nom} if m.v.<3% U _{nom} ±(5% + 0,1% × n) m.v. if m.v.≥ 3% U _{nom}
I _{RMS} amplitude	Depending clamps used (see specifications for I _{RMS})	0.01% I _{nom}	±0.5% I _{nom} if m.v.<10% I _{nom} ±(5% + 0,1% × n) m.v. if m.v.≥ 10% I _{nom}
Voltage THD-F (n = 2..40)	0.0...100.0% for U _{RMS} ≥ 1% U _{nom}	0.1%	±5%
current THD-F (n = 2..40)	0.0...100.0% for I _{RMS} ≥ 1% I _{nom}	0.1%	±5%

11.2.7 Unbalance

Unbalance (voltage and current)	Range and conditions	Resolution	Accuracy
Unbalance factor for positive, negative and zero sequence	0.0% ... 10.0% for 80% U _{nom} ≤ U _{RMS} < 150% U _{nom}	0.1%	±0.15% (absolute error)

11.2.8 Power and energy measurement

Power and energy	Conditions (for power and energy 80% U _{nom} ≤ U _{RMS} < 120% U _{nom})	Resolution	Accuracy ⁽¹⁾
Active power Active energy	2% I _{nom} ≤ I _{RMS} < 5% I _{nom} cosφ = 1	depending on U _{nom} and I _{nom}	± √(2,5 ² + δ _{ph} ²) %
	5% I _{nom} ≤ I _{RMS} ≤ I _{nom} cosφ = 1		± √(2,0 ² + δ _{ph} ²) %
	5% I _{nom} ≤ I _{RMS} < 10% I _{nom} cosφ = 0.5		± √(2,5 ² + δ _{ph} ²) %
	10% I _{nom} ≤ I _{RMS} ≤ I _{nom} cosφ = 0.5		± √(2,0 ² + δ _{ph} ²) %
Reactive power Reactive energy	2% I _{nom} ≤ I _{RMS} < 5% I _{nom} sinφ = 1	depending on U _{nom} and I _{nom}	± √(4,0 ² + δ _{ph} ²) %
	5% I _{nom} ≤ I _{RMS} < I _{nom} sinφ = 1		± √(3,0 ² + δ _{ph} ²) %
	5% I _{nom} ≤ I _{RMS} < 10% I _{nom} sinφ = 0.5		± √(4,0 ² + δ _{ph} ²) %
	10% I _{nom} ≤ I _{RMS} < I _{nom} sinφ = 0.5		± √(3,0 ² + δ _{ph} ²) %
	10% I _{nom} ≤ I _{RMS} < I _{nom} sinφ = 0.25		± √(4,0 ² + δ _{ph} ²) %
Apparent power Apparent energy	2% I _{nom} ≤ I _{RMS} < 5% I _{nom}	depending on U _{nom} and I _{nom}	±2.5%
	5% I _{nom} ≤ I _{RMS} ≤ I _{nom}		±2.0%
Power factor (PF)	0...1 50% U _{nom} ≤ U _{RMS} < 150% U _{nom} 10% I _{nom} ≤ I _{RMS} < I _{nom}	0.01	±0.03
Displacement power factor (cosφ/ DPF)	0...1 50% U _{nom} ≤ U _{RMS} < 150% U _{nom} 10% I _{nom} ≤ I _{RMS} < I _{nom}	0.01	±0.03

(1) See section 11.2.9 Estimated measurement uncertainty values for power and energy

11.2.9 Estimated measurement uncertainty values for power and energy

The total measurement uncertainty for power, active and reactive energy (fundamental component) is based on the following relation (for energy we ignore the additional uncertainty due to time measurement, as it is much smaller than other uncertainties):

$$\delta_{P,Q} \cong \sqrt{\delta_{U_h}^2 + \delta_{I_h}^2 + \delta_{ph}^2}$$

where: $\delta_{P,Q}$ – measurement uncertainty for active or reactive power,
 δ_{U_h} – total measurement uncertainty of voltage harmonic amplitude (recorder, transducers, clamps),
 δ_{I_h} – total measurement uncertainty of current harmonic amplitude (recorder, transducers, clamps),
 δ_{ph} – additional uncertainty of error in the measurement of the phase between voltage and current harmonics.

The δ_{ph} uncertainty may be calculated when the phase angle is known for the considered frequency band. **Tab. 11.1** describes error of the phase difference between the voltage and harmonics for MPI-540 recorder (without clamps and transducers).

Tab. 11.1. Phase error of MPI-540 recorder, depending on the frequency.

Frequency range	0..200 Hz	200..500 Hz	500 Hz..1 kHz	1..2 kHz	2..2.4 kHz
Phase error	≤1°	≤2.5°	≤5°	≤10°	≤15°

Phase error introduced by transducers and clamps may be usually found in their technical documentation. In this case, we need to estimate the resultant phase error between the voltage and the current for a given frequency caused by all elements of the measuring circuit: current and voltage transducers, clamps, and the recorder.

The uncertainty of the specific harmonics active power measurements may be calculated according to the following formula:

$$\delta_{ph} = 100 \left(1 - \frac{\cos(\varphi + \Delta\varphi)}{\cos\varphi} \right) [\%], \cos\varphi \neq 0$$

On the other hand, the uncertainty of the harmonics reactive power measurement may be calculated according to the following formula:

$$\delta_{ph} = 100 \left(1 - \frac{\sin(\varphi - \Delta\varphi)}{\sin\varphi} \right) [\%], \sin\varphi \neq 0$$

In both formulas, φ means the actual phase shift angle between the current and voltage components, and $\Delta\varphi$ means the total phase error for a given frequency.

11.3 Other technical data

- a) type of insulation acc. to EN 61010-1 and IEC 61557 double
- b) measurement category acc. to EN 61010-2-030 IV 300 V, III 500 V, **MPI-540-PV** II 1000 V DC
- c) housing degree of protection for the housing acc. to EN 60529 IP51 (with closed sealing plug)
- d) meter power supply Li-Ion 11,1 V 3,4 Ah 37,7 Wh
- e) parameters of AC adapter for the battery charge 12 V DC / 2.5 A
 100 V...240 V, 50 Hz...60 Hz (mains)
- f) dimensions 288 mm x 223 mm x 75 mm
- g) weight of the meter with batteries approx. 2.5 kg
- h) storage temperature -20°C...+60°C
- i) operating temperature 0°C...+45°C
- j) temperature range suitable for initiating battery charging +10°C...+40°C
- k) temperatures at which the charging process is interrupted <+5 °C and ≥ +50°C
- l) humidity 20%...90%
- m) reference temperature +23°C ± 2°C
- n) reference humidity 40%...60%
- o) altitude (above sea level): <2000 m
- p) time until Auto-OFF 2 min, 5 min or off
- q) number of measurements Z or RCD (for batteries) >3000 (6 measurements/minute)
- r) number of measurements R_{ISO} or R (for charged batteries) >1000
- s) recording time (for batteries) 16 h
- t) display colour LCD TFT, touchscreen
 800 x 480 pixels
 diagonal 7"
- u) memory of measurement results unlimited
- v) recorder memory unlimited
- w) data transmission USB
- x) quality standard design, construction and manufacturing are ISO 9001, ISO 14001, ISO 45001 compliant
- y) the device meets the requirements of IEC 61557 standard
- z) the product meets EMC requirements (immunity for industrial environment) according to the following standards EN 61326-1 and EN 61326-2-2



EN 55022 Compliance statement

MPI-540 / MPI-540-PV is a class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures (e.g. increasing the distance between affected products).



SONEL S.A. hereby declares that the radio device type MPI-540 / MPI-540-PV complies with Directive 2014/53/EU. The full text of the EU Declaration of Conformity is available at the following website address: <https://sonel.pl/en/download/declaration-of-conformity/>

11.4 Bluetooth specification

- a) version v4.2 Classic, BLE
- b) frequency range 2412 MHz...2472 MHz
- c) modulation method GFSK/π/4DQPSK/8DPSK/LE
- d) receiver sensitivity down to -92 dBm
- e) maximum radio frequency power (EIRP) 8.3 dBm (ca. 6.8 mW)

11.5 Additional data

Data on additional uncertainties are useful mainly when the meter is used in non-standard conditions and for metrological laboratories for the purpose of calibration.

11.5.1 Additional uncertainties according to IEC 61557-2 (R_{ISO})

Significant parameter	Designation	Additional uncertainty
Position	E ₁	0%
Supply voltage	E ₂	0%
Temperature 0°C...35°C	E ₃	2%

11.5.2 Additional uncertainties according to IEC 61557-3 (Z)

Significant parameter	Designation	Additional uncertainty
Position	E ₁	0%
Supply voltage	E ₂	0%
Temperature 0°C...35°C	E ₃	1.2 m lead – 0 Ω 5 m lead – 0.011 Ω 10 m lead – 0.019 Ω 20 m lead – 0.035 Ω WS-03 and WS-04 lead – 0.15 Ω
Phase angle 0°...30°	E _{6,2}	0.6%
Frequency 99%..101% f _n	E ₇	0%
Mains voltage 85%..110% U _n	E ₈	0%
Harmonic	E ₉	0%
DC component	E ₁₀	0%

11.5.3 Additional uncertainties according to IEC 61557-4 (R ±200 mA)

Significant parameter	Designation	Additional uncertainty
Position	E ₁	0%
Supply voltage	E ₂	0.5%
Temperature 0 °C...35 °C	E ₃	1.5%

11.5.4 Additional uncertainties of earth resistance measurement (R_E)

Additional uncertainties according to IEC 61557-5

Significant parameter	Designation	Additional uncertainty
Position	E ₁	0%
Supply voltage	E ₂	0%
Temperature 0 °C...35 °C	E ₃	0% for 50 V ± 2 digits for 25 V
Serial interference voltage	E ₄	±(6.5% + 5 digits)
Resistance of electrodes	E ₅	2.5%
Frequency 99%...101% f _n	E ₇	0%
Mains voltage 85%...110% U _n	E ₈	0%

Additional uncertainty caused by serial interference voltage for 3p, 4p, 3p+clamps functions

(for 25 V and 50 V)

R _E	Additional uncertainty
<10 Ω	$\pm(((-32 \cdot 10^{-5} \cdot R_E + 33 \cdot 10^{-4}) \cdot U_Z^2 + (-12 \cdot 10^{-3} \cdot R_E + 13 \cdot 10^{-3}) \cdot U_Z) \cdot 100\% + 0,026 \cdot \sqrt{U_Z \Omega})$
≥10 Ω	$\pm(((-46 \cdot 10^{-9} \cdot R_E + 1 \cdot 10^{-4}) \cdot U_Z^2 + (14 \cdot 10^{-8} \cdot R_E + 19 \cdot 10^{-5}) \cdot U_Z) \cdot 100\% + 0,26 \sqrt{U_Z \Omega})$

Additional uncertainty caused by resistance of electrodes

$$\delta_{\text{dod}} = \pm \left(\frac{R_S}{R_S + 10^6} \cdot 300 + \frac{R_H^2}{R_E \cdot R_H + 200} \cdot 3 \cdot 10^{-3} + \left(1 + \frac{1}{R_E} \right) \cdot R_H \cdot 5 \cdot 10^{-4} \right) [\%]$$

Formula is valid for $R_S > 200 \Omega$ and/or $R_H \geq 200 \Omega$.

Additional uncertainty due to interference current for 3p + clamps function

(for 25 V and 50 V)

R_E	Uncertainty [Ω]
$\leq 50 \Omega$	$\pm (4 \cdot 10^{-2} \cdot R_E^2 \cdot I_{\text{zakl}}^2)$
$> 50 \Omega$	$\pm (25 \cdot 10^{-5} \cdot R_E^2 \cdot I_{\text{zakl}}^2)$

Additional uncertainty due to interference current for double clamps function

R_E	Uncertainty [Ω]
$< 5 \Omega$	$\pm (5 \cdot 10^{-2} \cdot R_E^2 \cdot I_{\text{zakl}}^2)$
$\geq 5 \Omega$	$\pm (2,5 \cdot 10^{-2} \cdot R_E^2 \cdot I_{\text{zakl}}^2)$

Additional uncertainty for the ratio of the resistance measured with clamps on a branch of a multiple earthing, to the resultant resistance the as a function of 3p + clamps.

R_C	Uncertainty [Ω]
$\leq 99.9 \Omega$	$\pm (5 \cdot 10^{-3} \cdot \frac{R_C}{R_W^2})$
$> 99.9 \Omega$	$\pm (9 \cdot 10^{-2} \cdot \frac{R_C}{R_W^2})$

$R_C[\Omega]$ is a value of resistance measured with clamps on the branch displayed by the device, whereas $R_W[\Omega]$ is a value of resultant resistance of multiply earthing.

11.5.5 Additional uncertainties according to IEC 61557-6 (RCD)

I_A, t_A, U_B




Significant parameter	Designation	Additional uncertainty
Position	E ₁	0%
Supply voltage	E ₂	0%
Temperature 0°C...35°C	E ₃	0%
Resistance of electrodes	E ₅	0%
Mains voltage 85%...110% U_n	E ₈	0%








11.6 List of reference standards

EN 61010-1:2010
 EN 61010-2-030:2010
 EN 61557-1:2007,-2, 3, 4, 5, 7:2007, -6:2007, -10:2013
 EN 60529:1991/A2:2013
 EN 61326-1:2013
 EN 61326-2-2:2013
 IEC 62752
 IEC 62955

12 Optional accessories

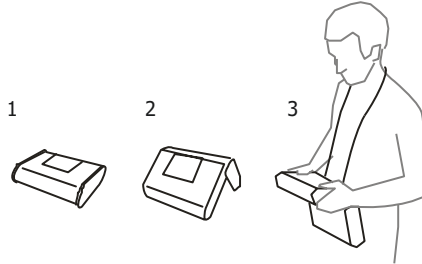
The full list of accessories can be found on the manufacturer's website.

			
	N-1	C-3	MPI-540-PV C-PV
	WACEGN1BB	WACEGC3OKR	WACEGCPVOKR
Rated current	1000 A AC	1000 A AC	40 A DC, 400 A DC 40 A AC, 400 A AC
Frequency	30 Hz...5 kHz	30 Hz...5 kHz	—
Max. diameter of measured conductor	52 mm	52 mm	30 mm
Minimum accuracy	—	≤0.3%	2.5% + 0.1 A
Battery power	—	—	√
Lead length	2 m	2 m	0.9 m
Measurement category	III 600 V	III 600 V	IV 300 V III 600 V
Ingress protection	IP40		

							
	C-4A	C-5A	C-6A	C-7A	F-1A	F-2A	F-3A
	WACEGC4AOKR	WACEGC5AOKR	WACEGC6AOKR	WACEGC7AOKR	WACEGF1AOKR	WACEGF2AOKR	WACEGF3AOKR
Rated current	1000 A AC	1000 A AC 1400 A DC	12 A AC	100 A AC	3000 A AC		
Frequency	30 Hz...5 kHz	DC...5 kHz	40 Hz...10 kHz	40 Hz...1 kHz	40 Hz...10 kHz		
Max. diameter of measured conductor	52 mm	39 mm	20 mm	24 mm	380 mm	250 mm	140 mm
Minimum accuracy	≤0.5%	≤1.5%	≤1%	0.5%	0.5%		
Battery power	—	√	—	—	—		
Lead length	2.2 m	2.2 m	2.2 m	3 m	2.5 m		
Measurement category	III 600 V IV 300 V	IV 300 V	III 600 V IV 300 V	III 300 V	III 1000 V IV 600 V		
Ingress protection	IP40				IP67		

13 Positions of the meter's cover

The movable cover enables using the meter in various positions.



1 – Cover as the bottom of the meter

2 – Cover used as a support

3 – Cover in the position that enables convenient use of the meter suspended on the neck by means of hanging straps

14 Manufacturer

The manufacturer of the device and provider of guarantee and post-guarantee service:

SONEL S.A.

Wokulskiego 11

58-100 Świdnica

Poland

tel. +48 74 884 10 53 (Customer Service)

e-mail: customerservice@sonel.com

web page: www.sonel.com



NOTE!

Service repairs must be performed only by the manufacturer.

NOTES

NOTES

NOTES

MEASURING MESSAGES



NOTE!

The meter is designed for operation at rated phase voltages of 110 V, 115 V, 127 V, 220 V, 230 V and 240 V and phase-to-phase voltages of 190 V, 200 V, 220 V, 380 V, 400 V, 415 V.

Connecting voltage higher than allowed between any of the test terminals may damage the meter and cause a hazard to the user.

Z_s measurement

L-N!

U_{L-N} voltage is incorrect for making a measurement.

L-PE!

U_{L-PE} voltage is incorrect for making a measurement.

N-PE!

U_{N-PE} voltage exceeds allowable value of 50 V.



Phase connected to N terminal instead of L terminal (for example, exchange of L and N in the mains socket).

TEMPERATURE!

Maximum temperature of the meter is exceeded.

f!

Network frequency is outside the range of 45 Hz...65 Hz.

ERROR!

Measurement error. Correct result cannot be displayed.

Loop circuit malfunction!

The meter should be serviced.

U>500V!

and continuous audio signal

Before measurement, voltage at test terminals exceeds 500 V.

VOLTAGE!

The voltage on the tested object is not within the limits specified for the set rated voltage of the network U_n.

LIMIT!

Too low value of the prospective short circuit current I_k for the pre-set fuse and time of its triggering.

R_E measurement

VOLTAGE!

Too high voltage at the meter terminals.

H!

Interruption in the test probe circuit.

S!

Interruption in the voltage probe circuit.

R_E>1.99 kΩ

Measuring range is exceeded.

NOISE!

Signal / noise ratio is too low (interfering signal too large).

LIMIT!

Measurement uncertainty R_E due to the resistance of electrodes >30 %. (For calculating uncertainty, measured values are taken into account).



Interruption in measuring circuit or resistance of test probes is higher than 60 kΩ.

RCD measurement

U_B>U_L!

The touch voltage exceeds a preset U_L threshold value.

!

displayed on the right side of the result indicates a fault of RCD.

PE!

and continuous audio signal

Voltages between the contact electrode and PE conductor exceeds the allowable limit value of U_L.

R_{ISO} measurement



and continuous audio signal

Voltage detected on terminals of the meter. Measurement is not possible.

NOISE!

Interference voltage occurs on the tested object. Measurement is possible but may be burdened with additional uncertainty.

LIMIT!

Current limit tripped. The symbol displayed during the measurement is accompanied by a continuous beep. If it is displayed after the measurement, it means that the measurement result was obtained during operation with a current limiting device (e.g. short circuit of the test object).



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