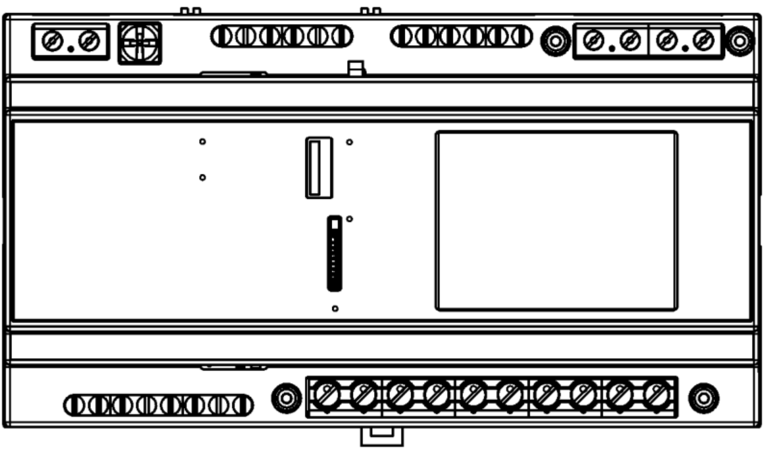

USER MANUAL

POWER QUALITY ANALYZER

PQM-750

USER MANUAL

POWER QUALITY ANALYZER
PQM-750

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Version 1.01 12.02.2025

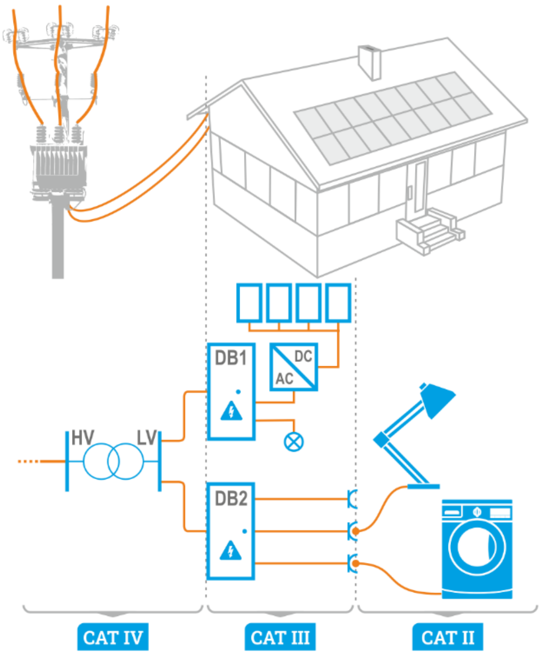
- Due to continuous product development, the manufacturer reserves the right to make changes to functionality, features and technical parameters of the analyzers. The manufacturer provides long-term support for the product, adding new functionalities and fixing noticed errors.
- This manual describes the firmware version 1.01.

CONTENTS

1 General information

The following international symbols are used on the analyzer and in this manual:

⚠	Refer to the user manual for additional information and explanations	♲	Recycling information	CE	Declaration of Conformity with EU directives (*Conformité Européenne*)
⎓	DC current/voltage		Do not dispose of with other household waste		Conforms to relevant Australian standards
∼	AC current/voltage	⏚	Protective earth terminal		



Measurement categories according to EN IEC 61010-2-030:

- **CAT II** – concerns measurements performed in circuits directly connected to low voltage installations,
- **CAT III** – concerns measurements performed in buildings installations,
- **CAT IV** – concerns measurements performed at the source of low voltage installation.

1.1 Safety

To avoid electric shock or fire, you must observe the following guidelines:

- Before you proceed to operate the analyzer, acquaint yourself thoroughly with the present manual and observe the safety regulations and specifications provided by the producer.
- Any application that differs from those specified in the present manual may result in damage to the device and constitute a source of danger for the user.
- Analyzers must be operated only by appropriately qualified personnel with relevant certificates authorizing the personnel to perform works on electric systems. Operating the analyzer by unauthorized personnel may result in damage to the device and constitute a source of danger for the user.
- The device must not be used for networks and devices in areas with special conditions, e.g. fire-risk and explosive-risk areas.
- Before starting the work, check the analyzer, wires, and other accessories for any sign of mechanical damage. Pay special attention to the connectors.
- It is unacceptable to operate the device when:
  - ⇒ it is damaged and completely or partially out of order,
  - ⇒ its cords and cables have damaged insulation,
  - ⇒ of the device and accessories mechanically damaged.
- Always connect the Protective Earth Terminal to local ground. Use an eyelet or spade terminal and tighten the screw. Do not leave this terminal floating! Class I protection device.
- A switch or circuit-breaker must be included in the installation. It must be suitably located and easily reached. The switch or circuit-breaker must be marked as the disconnecting device for the analyzer.
- Do not power the analyzer from sources other than those listed in this manual.
- Do not connect inputs of the analyzer to voltages higher than the rated values.
- Use accessories and probes with a suitable rating and measuring category for the tested circuit.
- Do not exceed the rated parameters of the lowest measurement category (CAT) of the used measurement set consisting of the analyzer, probes and accessories. When the product is used with other devices or accessories, the lowest measurement category of the connected devices applies.
- If possible, connect the analyzer to the de-energized circuits.
- Use the ground (earth) terminal only for connecting the local ground, do not connect it to any voltage.
- Do not handle or move the device while holding it only by its cables.
- Repairs may be performed only by an authorized service point.

The analyzer is equipped with an internal Li-Ion battery, which has been tested by an independent laboratory and is quality-certified for compliance with the standard *UN Manual of Tests and Criteria Part III Subsection 38.3 (ST/SG/AC.10/11/Rev.5).* Therefore, the analyzer is approved for air, maritime and road transport.

1.2 General characteristics

Fixed mounted Power Quality Analyzer PQM-750 (Fig. 1) is an advanced device providing its users with a comprehensive features for measuring, analyzing and recording parameters of 50/60 Hz power networks and power quality in accordance with the European Standard EN 50160. Analyzer is fully compliant with the requirements of IEC 61000-4-30:2015, Class A and IEC 62586 (PQI-A-FI1 classification).

The device is equipped with four voltage measurement inputs installed as terminal blocks marked as U1, U2, U3 and N. These measurement channels are referenced to ground (earth) terminal. The range of voltages measured directly by these four measurement channels is up to 1000 V_{RMS} referred to ground. This range may be increased by using additional external voltage transformers.

Measurements are carried out using five current inputs installed as terminal blocks. The nominal current range for all of the inputs is 5 $A_{RMS.}$

High sampling frequency in the main path (81.92 kHz) provides a wide bandwidth, which translates into the ability to capture high-frequency disturbances, and also allows for the measurement of harmonics and interharmonics up to the order of 256, and monitoring of emissions in the 2-9 kHz frequency band.

The additional voltage measurement path is designed to monitor conducted emissions in the 8-150 kHz frequency band.

In one variant the analyzer can be equipped with an optional internal module for measuring fast voltage transients, which allows for the capture and recording of overvoltages in the range of ±6 kV with a sampling frequency of up to 10 MHz.

The analyzer meets class 0.2S according to the IEC 62053-22 standard for active energy measurement accuracy, and class 0.5S according to the IEC 62053-24 standard for reactive energy measurement accuracy.

The voltage and current inputs can be sealed to prevent manipulation and access to the input terminals by unauthorized persons.

The device has two memory cards: a built-in 8 GB memory card and external removable 8 GB memory card (microSD type).

Recorded parameters are divided into groups that may be independently turned on/off for recording purposes and this solution facilitates the rational management of the space on the memory card. Parameters that are not recorded, leave more memory space for further measurements.

Measurement results can be converted to the PQDIF format and sent to the control system using the FTP/FTPS protocol.

Analyzer configuration and measurement parameterization can be performed using the built-in web server or using one of the implemented communication protocols (e.g. Modbus RTU, Modbus TCP, IEC 61850).

The user interface includes a color 2.4" LCD display with a resolution of 320x240 pixels and a resistive touchpanel.

Another advantage of the device is a possibility to connect external modules using the expansion connector on the right side of the enclosure. Three modules can be connected to the base analyzer:

- GPS-1 module – a GPS receiver module with a SMA antenna connector. Three length options are available for antennas: 10 / 20 / 30 meters. The GPS receiver ensures the synchronization with UTC (Universal Time Clock), and provides measurement accuracy in the order of microseconds.
- GSM-1 module – a GSM (LTE) modem with a SMA antenna connector.
- IOM-1 module – an Input/Output expansion module with digital inputs and outputs and 4-20 mA current loop inputs / outputs.

Fig. 1. PQM-750 Power Quality Analyzer. General view.

Fig. 2 and Fig. 3 shows side views of the analyzer with description of the terminal blocks input/outputs. The third row in the tables shows the strip number assigned to given terminal. See also Table 1. PQM-750 terminal block connectors.

Watchdog relay, digital outputs							
WR		DO1			DO2		
1	2	3	4	5	6	7	8

Current inputs									
I1		I2		I3		I4		I5	
9	10	11	12	13	14	15	16	17	18

Fig. 2. PQM-750 Power Quality Analyzer. Bottom side view The RJ-45 LAN1 input is also visible.

Voltage inputs			
N	U3	U2	U1
19	20	21	22

Temperature and digital inputs					
DQ	GND	DI2		DI1	
23	24	25	26	27	28

RS-485-2			RS-485-1		
A	B	SH	A	B	SH
29	30	31	32	33	34

⏚	Power supply	
PE	N	L
35	36	37

Fig. 3. PQM-750 Power Quality Analyzer. Top side view. The RJ-45 LAN2 input and the RTC clock backup battery socket are also visible.

1.3 Mounting of the analyzer

1.3.1 Mounting on the DIN rail

The analyzer is a device adapted and mounted on a 35 mm DIN EN 60715 rail. First, the analyzer is hung on the upper hooks and then snapped into place using the lower hook. This is shown in Fig. 4. To dismantle the analyzer, use a tool to pull the lower hook down and then pull the bottom of the analyzer towards you.

Fig. 4 Mounting the analyzer on the DIN EN 60715 35 mm rail.

1.3.2 Mounting on the wall

The analyzer can be mounted on a wall or other flat surface using additional brackets (included). The brackets are pressed into both sides of the bottom part of the housing and then screwed to the surface using the supplied or other screws. This is shown in Fig. 5.

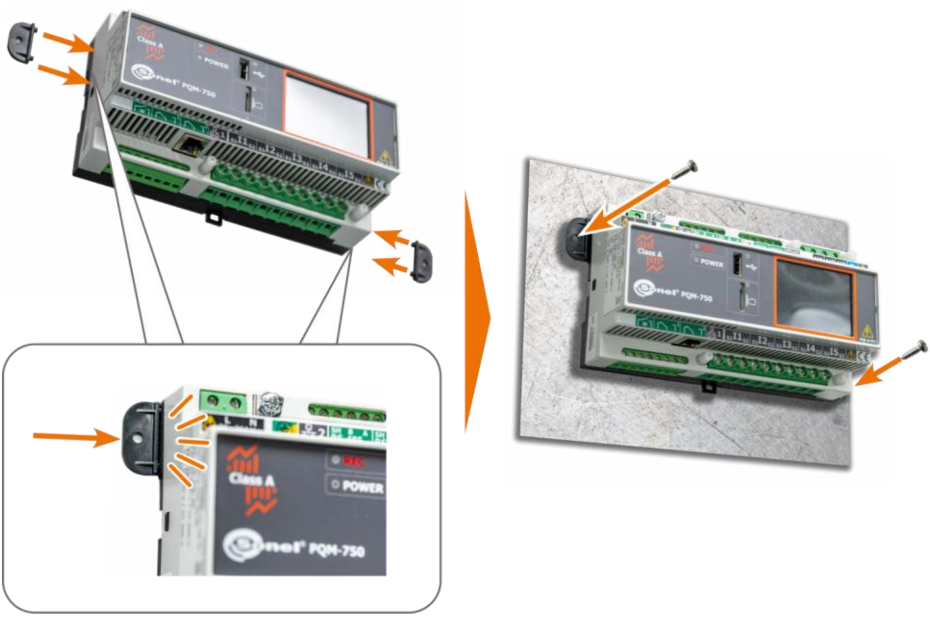


Fig. 5. Mounting the analyzer to the wall using the supplied brackets.

1.3.3 Sealing of the measurement terminals

In order to protect the measuring terminals of the voltage and current inputs from unauthorized interference and manipulation, they can be sealed using the supplied sealing strips. This is shown in Fig. 6. After installing the strips, a sealing wire should be fed through the holes in the posts on both sides of the strips.

Fig. 6. Sealing of the measurement terminals.

1.4 Terminal block connections

Table 1 list all the terminal block connectors used on PQM-750 analyzer.

Table 1. PQM-750 terminal block connectors.

Connector name	Connector strip number	Designation	Cable cross section in mm²	Stripped length in mm
Watchdog relay (WR)	1	NO contact	0.5 – 3.3	6
	2	NO contact		
Digital output relay 1 (DO1)	3	NC contact	0.5 – 3.3	6
	4	COM		
	5	NO contact		
Digital output relay 2 (DO2)	6	NC contact	0.5 – 3.3	6
	7	COM		
	8	NO contact		
Current I1	9	S1	0.5 – 6 (solid) 0.5 – 4 (flexible)	8
	10	S2		
Current I2	11	S1	0.5 – 6 (solid) 0.5 – 4 (flexible)	8
	12	S2		
Current I3	13	S1	0.5 – 6 (solid) 0.5 – 4 (flexible)	8
	14	S2		
Current I4 / I_N/ neutral	15	S1	0.5 – 6 (solid) 0.5 – 4 (flexible)	8
	16	S2		
Current I5 / I_E/ leakage	17	S1	0.5 – 6 (solid) 0.5 – 4 (flexible)	8
	18	S2		
Voltage neutral	19	N	0.5 – 4 (solid) 0.5 – 2.5 (flexible)	8
Voltage U3	20	U3	0.5 – 4 (solid) 0.5 – 2.5 (flexible)	8
Voltage U2	21	U2	0.5 – 4 (solid) 0.5 – 2.5 (flexible)	8
Voltage U1	22	U1	0.5 – 4 (solid) 0.5 – 2.5 (flexible)	8
Temperature Input (TI)	23	DQ	0.5 – 3.3	6
	24	GND		
Digital Input 2 (DI2)	25	-/+ (no polarity)	0.5 – 3.3	6
	26	+/- (no polarity)		
Digital Input 1 (DI1)	27	-/+ (no polarity)	0.5 – 3.3	6
	28	+/- (no polarity)		
RS-485 Port 2 (RS-485-1)	29	A/+	0.5 – 3.3	6
	30	B/-		
	31	shield		
RS-485 Port 1 (RS-485-2)	32	A/+	0.5 – 3.3	6
	33	B/-		
	34	shield		
Protective Earth	35	PE	Use spade or eyelet terminal	–
Power supply neutral	36	N	0.5 – 4 (solid) 0.5 – 2.5 (flexible)	8
Power supply phase	37	L		

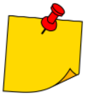
1.5 Power supply of the analyzer

The analyzer has a built-in power adapter with nominal voltage range of 85…264 V AC / 120…300 V DC (option "AC") or 18…60 V DC (option "DC"). The power adapter has independent terminal block inputs.

The analyzer has also a PoE input on the LAN1 RJ-45 port, and can be powered with IEEE 802.3 at/af compatible ethernet switches. The PoE power supply can serve as a primary or backup power.

To maintain power supply to the device during power outages (no AC/DC or PoE power), the internal rechargeable battery is used. It is charged when the voltage is present at terminals of the AC or DC internal power supply module or the PoE supply is present. The battery is able to maintain power supply up to 1 h hour at temperatures of -20...+55°C. After the battery is discharged the meter stops its current operations (e.g. recording) and switches off in the emergency mode. When the power supply from mains returns, the analyzer resumes interrupted recording.

The presence of the main AC/DC and PoE power supply can be verified on the analyzer screen by selecting **SETTINGS→POWER** supply from the menu.



The battery may be replaced only by the manufacturer's service department.

1.6 Measured parameters

The analyzer is designed to measure and record the following parameters:

- RMS phase and phase-to-phase voltages – up to 1000 V referred to ground (peak voltages up to ±1500 V),
- transient voltages (overvoltages) in the range up to ±6 kV (optional internal module),
- emission voltages in the 2-9 kHz and 8-150 kHz frequency range,
- RMS currents with nominal range 5 A (peak measurable values up to ±70 A) using internal isolated current transformers (other nominal ranges possible),
- Crest Factors for current and voltage,
- mains frequency within the range of 40..70 Hz,
- active, reactive and apparent power and energy, distortion power,
- harmonics of voltages and currents (up to 256th),
- Total Harmonic Distortion THD_F and THD_R for current and voltage,
- Total Demand Distortion for currents (TDD),
- K-Factor (loss factor in transformers caused by higher harmonics),
- Transformer derating Factor K according to HD 538.3.S1 standard,
- active and reactive powers of harmonics,
- the angles between voltage and current harmonics,
- Power Factor, cosφ (DPF), 4-quadrant tangentφ,
- unbalance factors and symmetrical components for three-phase mains,
- flicker severity P_{ST} and P_{LT} ,
- interharmonics of voltages and currents (up to 256th),
- Total Interharmonic Distortion TID_F and TID_R for current and voltage,
- mains signaling voltage in the frequency band of 5...30000 Hz,
- Rapid Voltage Changes (RVC),
- other not mentioned here.

Selected parameters are aggregated (averaged) according to the time selected by the user and may be stored on a memory card. In addition to average value, it is also possible to record minimum and maximum values during the averaging period.

The module for event detection is also powerful. According to EN 50160, typical events include voltage dip (reduction of RMS voltage to less than 90% of nominal voltage), swell (exceeding 110% of the nominal value) and interruption (reduction of the supplied voltage below 5 % of the nominal voltage) The user does not have to enter the settings defined in EN 50160, as the software provides an automatic configuration of the device to obtain power quality measurement mode compliant with EN 50160 The user may also perform manual configuration - the software is fully flexible in this area. Voltage is only one of many parameters for which the limits of event detection may be defined. For example, the analyzer may be configured to detect Power Factor drop below a defined value, THD exceeding another threshold, and the 9th voltage harmonic exceeding a user-defined percentage value. Each event is recorded along with the time of occurrence. For selected events the recorded information may also include a waveform for voltage and current. It is possible to record from 5 mains cycles of up to 60 seconds, with adjustable pre-triggering time up to 1 second. Together with the waveform, half-cycle RMS values ($RMS_{1/2}$) may be also recorded with time adjustable from 1 s to 60 s.

Additionally, the analyzer has the ability to detect events caused by the change of the shape of voltage envelope and voltage phase angle, by comparing consecutive successive periods of the mains voltage with each other.

A very wide range of configurations, including a multitude of measured parameters make the analyzer an extremely useful and powerful tool for measuring and analyzing all kinds of power supply systems and interferences occurring in them. Some of the unique features of this device make it distinguishable from other similar analyzers available in the market.

Table 2 presents a summary of parameters measured by analyzer, depending on the mains type.

Table 2. Measured parameters for different network configurations.

Parameter	Mains type, channel	1-phase			split-phase						3-phase 4-wire									3-phase 3-wire							
		U_{1N} I_1 L1	U_{NE} I_N	I_E	U_{1N} I_1 L1	U_{2N} I_2 L2	U_{12}	U_{NE} I_N	I_E	TOT	U_{1N} I_1 L1	U_{2N} I_2 L2	U_{3N} I_3 L3	U_{12}	U_{23}	U_{31}	U_{NE} I_N	I_E	TOT	U_{12}	U_{23}	U_{31}	U_{1E} I_1 L1	U_{2E} I_2 L2	U_{3E} I_3 L3	I_E	TOT
U	RMS voltage	✓	✓		✓	✓		✓			✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		
U_{DC}	DC voltage	✓	✓		✓	✓		✓			✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		
I	RMS current	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓				✓	✓					✓	✓	✓	✓	
f	Frequency	✓			✓						✓									✓							
CF U	Voltage crest factor	✓	✓		✓	✓		✓			✓	✓	✓				✓			✓	✓	✓					
CF I	Current crest factor	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓				✓	✓					✓	✓	✓	✓	
P	Active power	✓			✓	✓				✓	✓	✓	✓						✓				✓	✓	✓		✓
Q_1, Q_B	Reactive power	✓			✓	✓				✓	✓	✓	✓						✓				✓	✓	✓		✓(1)
D, S_N	Distortion power	✓			✓	✓				✓	✓	✓	✓						✓				✓	✓	✓		✓
S	Apparent power	✓			✓	✓				✓	✓	✓	✓						✓				✓	✓	✓		✓
PF	Power Factor	✓			✓	✓				✓	✓	✓	✓						✓				✓	✓	✓		✓
cosφ	Displacement power factor	✓			✓	✓				✓	✓	✓	✓						✓				✓	✓	✓		✓
$\tan\varphi_{C-}$, $\tan\varphi_{L+}$ $\tan\varphi_{L-}$, $\tan\varphi_{C+}$	tangent φ (4-quadrant)	✓			✓	✓				✓	✓	✓	✓						✓				✓	✓	✓		✓(1)
THD U	Voltage total harmonic distortion	✓	✓		✓	✓		✓			✓	✓	✓				✓			✓	✓	✓					
THD I	Current total harmonic distortion	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓				✓	✓					✓	✓	✓	✓	
TDD I	Total Demand Distortion	✓	✓		✓	✓		✓			✓	✓	✓				✓						✓	✓	✓		
K-Factor	Transformer loss K-Factor	✓	✓		✓	✓		✓			✓	✓	✓				✓						✓	✓	✓		
Factor K	Transformer derating Factor K	✓	✓		✓	✓		✓			✓	✓	✓				✓						✓	✓	✓		
E_{P+}, E_{P-}	Active energy (imported and exported)	✓			✓	✓				✓	✓	✓	✓						✓				✓	✓	✓		✓
E_{QC-}, E_{QL+} E_{QL-}, E_{QC+}	Reactive energy (4-quadrant)	✓			✓	✓				✓	✓	✓	✓						✓				✓	✓	✓		✓(1)
E_S	Apparent energy	✓			✓	✓				✓	✓	✓	✓						✓				✓	✓	✓		✓
U_{h1}..U_{h256}	Voltage harmonic amplitudes	✓	✓		✓	✓		✓			✓	✓	✓				✓			✓	✓	✓					
I_{h1}..I_{h256}	Current harmonic amplitudes	✓	✓		✓	✓		✓			✓	✓	✓				✓						✓	✓	✓		
φ_{UI1}.. φ_{UI256}	Angles between voltage and current harmonics	✓			✓	✓					✓	✓	✓										✓	✓	✓		
φ_{Uh}	Absolute voltage harmonics angles	✓	✓		✓	✓		✓			✓	✓	✓				✓						✓	✓	✓		
φ_{Ih}	Absolute current harmonics angles	✓	✓		✓	✓		✓			✓	✓	✓				✓						✓	✓	✓		
P_{h1}..P_{h256}	harmonics active power	✓			✓	✓					✓	✓	✓										✓	✓	✓		
Q_{h1}..Q_{h256}	harmonics reactive power	✓			✓	✓					✓	✓	✓										✓	✓	✓		

Unbalance U, I	Symmetrical components and unbalance factors																		✓								✓
P_{st}, P_{lt}	Flicker	✓			✓	✓					✓	✓	✓							✓	✓	✓					
TID-F U, TID-R U	Voltage total interharmonic distortion	✓	✓		✓	✓		✓			✓	✓	✓				✓			✓	✓	✓					
TID-F I TID-R I	Current total interharmonic distortion	✓	✓		✓	✓		✓			✓	✓	✓				✓						✓	✓	✓		
U_{ih0}..U_{ih256}	Voltage interharmonics amplitudes	✓	✓		✓	✓		✓			✓	✓	✓				✓			✓	✓	✓					
I_{ih0}..I_{ih256}	Current interharmonics amplitudes	✓	✓		✓	✓		✓			✓	✓	✓				✓						✓	✓	✓		
U_{R1}, U_{R2}	Mains signalling in voltage	✓			✓	✓					✓	✓	✓							✓	✓	✓					
U_{2-9k}	Conducted voltage emmissions 2-9 kHz	✓			✓	✓					✓	✓	✓							✓	✓	✓					
U_{8-150k}	Conducted voltage emmissions 8-150 kHz	✓			✓	✓					✓	✓	✓										✓	✓	✓		
U_t	Voltage transients(2)	✓	✓		✓	✓		✓			✓	✓	✓				✓						✓	✓	✓		

Explanations: TOT is the total value for the polyphase system.

(1) In 3-phase 3-wire networks the total reactive power is calculated as inactive power $N = \sqrt{S_e^2 - P^2}$ (see discussion on reactive power in Power Quality Guide document).

(2) Voltage transients are measured when optional transient module is installed (option "TR").

2 Operation of the analyzer

2.1 Touchscreen

The analyzer can be navigated with simplified GUI displayed on the embedded LCD touchscreen. With this GUI the user can do basic configuration of the analyzer and view some of the measured parameters.

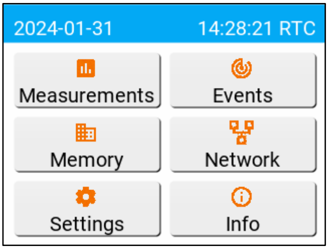


Fig. 7. Main screen.

The main screen is shown on Fig. 7. The top bar shows the date and time of analyzer, and also the current time source (RTC / GPS / NTP / IRIG).

Six buttons are displayed on the main screen:

- **Measurements** – real time measurement data can be viewed from there.
- **Events** – allows checking recent voltage events count and details.
- **Memory** – shows analyzer's memory cards size and occupied size.
- **Network** – allows checking current Ethernet network parameters.
- **Settings** – this option can be used to perform basic analyzer configuration.
- **Info** – shows version and vendor information.

2.2 Switching the analyzer on/off

There is no power button on the analyzer. It starts operation immediately when it is powered via main power supply input (AC or DC) or when Power over Ethernet source is connected to LAN1 port.

After powering a welcome screen is displayed, showing the name of the meter, the internal software version (firmware) and hardware version. Then, the analyzer performs a self-test and in case of detecting errors, the display shows an error message, accompanied by a long beep.

While the analyzer is initializing, the green POWER led will blink once per second. Once the analyzer is fully initialized and functional, the POWER led will be on continuously.

When an error occurs during memory card launching, the following message is displayed Memory card error. If the file system on the card is damaged (e.g. when the user manually formatted the card) the analyzer will suggest formatting the memory (message **Format SD card?**) and pressing OK button on the touchpanel will trigger the process of formatting. After the formatting is completed, the analyzer will repeat initialization of the card.

When you start the meter for the first time, the setup wizard is activated, which allows the user to specify the basic network parameters: network type, nominal frequency, nominal voltage, voltage and current transducers ratio, and the profile of the recorded standard (see also sec. 2.8.3). You can also then enable GUI protection against unauthorized use and set PIN codes (sec. 2.3).

After switching on, the analyzer is activated with the last measurement configuration.

To switch the analyzer off the main power supply and PoE should be deactivated first. The analyzer will then switch to battery power. Only in such state the option to power off the analyzer will activate on the screen. The user has to navigate from the main menu: **SETTINGS**→ › →**POWER OFF**, and confirm the displayed message. After few seconds the analyzer will turn off.

2.3 Restricting access to GUI

It is possible to limit access to the analyzer's GUI so that it is not possible to change settings and/or view parameters. For this purpose, two users with different levels of authorization have been created, each of whom can be assigned a PIN code consisting of 4 to 8 digits.

- 'Administrator' has full access to settings and data viewing in the GUI.
- 'User' has access only to data viewing and cannot make any changes to the configuration.

By default, PIN codes are disabled for both of the above-mentioned users. For security reasons, it is recommended to enable the PIN code of the user 'Administrator' and set your own PIN code, so that it is not possible to change the analyzer settings by unauthorized persons.

Enabling the PIN of the 'User' forces the activation of the PIN for the 'Administrator'.

To go to the PIN code settings, select **SETTINGS**→**SECURITY** from the main menu. The screen shown in Fig. 8 will be displayed. To enable the Administrator PIN, press the switch to the '**ON**' position. Pressing the 'PIN' button will take you to the personal PIN settings screen (Fig. 9). You must enter a 4 to 8-digit code twice.

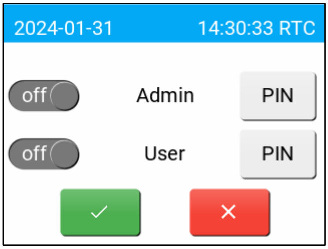


Fig. 8. GUI security settings screen.

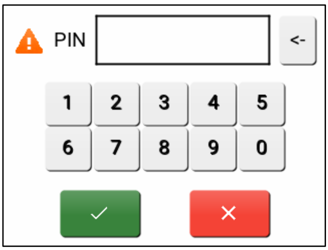


Fig. 9. Entering PIN code.

After activating the Administrator PIN code, moving from the main menu to the **SETTINGS**, **NETWORK** and **MEMORY** sections requires entering the Administrator PIN code.

The same procedure is followed with the User PIN code. After additionally activating the User PIN code, all other sections available from the main menu are blocked: **MEASUREMENTS**, **EVENTS**, **INFO**.

Entering the Administrator PIN code gives access to all GUI options. The method of regaining access to the meter GUI in the event of forgetting the Administrator PIN code is given in sec. 3.2.

2.4 Verifying the connection

Next to the phasor diagram there are connection correctness indicators (see Fig. 10), which give some relevant information on connecting the analyzer to the tested network. This information helps user verify the compliance of the current configuration of the analyzer with the parameters of the measured network.

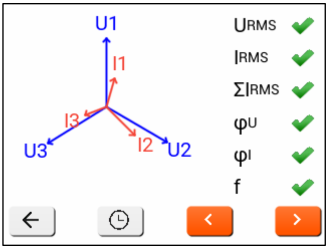


Fig. 10. Phasor diagram with connection correctness indicators.

The indicators are sequentially marked as: $\mathbf{U_{RMS}}$, $\mathbf{I_{RMS}}$, $\mathbf{\Sigma I_{RMS}}$, $\boldsymbol{\varphi_U}$, $\boldsymbol{\varphi_I}$, **f**.

$\mathbf{U_{RMS}}$: effective values of voltages – two possible icons:

- – RMS voltages are correct, they are within the tolerance range of ±15% of the nominal voltage,
- – RMS values are outside the range of U_{NOM} ±15%.

$\mathbf{I_{RMS}}$: effective values of current values – four options:

- – RMS currents are in the range of 0.3% I_{NOM}...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.

  In all systems where it is possible the analyzer also calculates the sum of all the currents (instantaneous values) and checks if it totals to zero. This helps in determining if all current probes are connected correctly (i.e. arrows on current probes facing to the load). If the calculated current sum RMS value is higher than 0.3% of I_{nom}, it is treated as an error and the icon is displayed.

$\mathbf{\Sigma I_{RMS}}$: The analyzer verifies the correctness of the currents connection on the basis of the instantaneous sum of all currents. In a closed system, the RMS value of the instantaneous sum of the current should be close to zero. The verification is only performed when the RMS of at least one measured current exceeds 0.3% of I_{nom}. In measuring systems with analytical calculation of the I_n current and in Aron circuits, this checking is disabled.

- – currents connected correctly – the instantaneous sum of currents is close to zero,
- – the correctness of summing the currents cannot be verified due to too low current values,
- – the calculated RMS value of the instantaneous sum of the currents exceeds 0.3% of I_{nom} and at the same time it exceeds 25% of the maximum value of all measured currents. Such a situation may occur, e.g. when the I_N current is connected in reverse direction.

$\boldsymbol{\varphi_U}$: vectors – the analyzer verifies the correctness of the fundamental component angles and displays the corresponding icon:

- – the vectors have correct angles in the range of ±30° 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.

φ_I: current vectors – correctness of current vector angles is verified in relation to the voltage vectors. The following icons are displayed:

- – vectors are within ±55° 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 (±55°),
- **---** dashes are displayed when the current measurement is disabled in the configuration.

f: frequency:

- – the measured grid frequency is in the range of f_{NOM} ±10%,
- – the RMS value of reference voltage phase is lower than 10V (the analyzer operates on internal generator) or there is no PLL synchronization,
- – the measured frequency is outside of f_{NOM} ±10%.

2.5 Communication and data transmission

The analyzer provides different ways of communication with a PC. They are as follows:

- communication via Modbus RTU protocol and RS-485-1 port (by default),
- communication via Modbus TCP/IP protocol and ethernet port (LAN1, LAN2),
- communication via IEC 61850 protocol suite (ethernet protocol),
- communication via HTTPS protocol and web browser using embedded webserver (ethernet),
- communication via proprietary Sonel S.A. protocol SonelFrame (ethernet).

Each of these communication means has its own properties and set of features. These features are discussed in separate sections.

2.6 Network configuration

The PQM-750 has two separate LAN connectors: LAN1 and LAN2. Both are connected internally to the same ethernet switch. The analyzer supports single IP address on both physical connectors. The second LAN port can be used to simplify network connections when other device needs ethernet connection, or can be used to connect an external panel display that interfaces with the PQM-750 webserver.

To be able to communicate with the analyzer via ethernet network, its IP address, Gateway address and network mask needs to be configured. The user can assign the IP manually or if there is active DHCP server on the network, the analyzer can obtain the required network parameters automatically.

By default the analyzer is pre-set to the static IP address 192.168.75.2, gateway 192.168.75.1, and network mask 255.255.255.0.

To change the network settings from the main menu select **SETTINGS→ →NETWORK.**

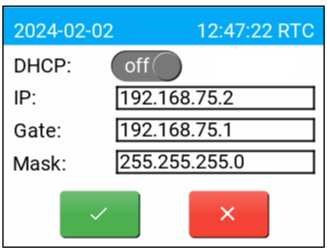


Fig. 11. Default network settings.

The default network settings shown on Fig. 11 can be changed by interacting with the fields. By pressing the DHCP slider the user can turn on and turn off DHCP. When DHCP is active then there must be active DHCP server on the network. The obtained IP address can be checked by choosing **NETWORK** button on the main screen.

If the user wants to assign the addresses manually, than each of the fields must be pressed and the addresses have to be entered with the keypad displayed on the screen.

When the network configuration has succeeded then it allows communication with the analyzer via different means: by using the internal webserver via web browser, via Modbus TCP/IP or by using IEC 61850 protocol.

2.7 Viewing real time measurement data

The LCD display allows you to view measurement results in real time. This is possible by selecting **MEASUREMENTS** from the main menu. The real time data is divided into several separate screens:

- **U, THDU, F** – phasor diagram, correctness indicators, RMS voltages, voltage THD, frequency,
- **I, THDI, HARM** – RMS currents, current THD, voltage and current harmonics (bar view up to 50th order),
- **UNBALANCE** – voltage and current unbalance and symmetrical components,
- **FLICKER** – Pst, Plt and Pinst,
- **P,Q,S** – active, reactive, apparent, and nonactive apparent powers,
- **COSΦ, PF** – displacement power factor (cosφ) and power factor,
- **TANΦ** – four quadrant tangentφ: tanφL+, tanφC-, tanφL-, tanφC+,
- **ENERGY** – active energy (imported and exported), four quadrant reactive energy, apparent energy,
- **2-150 KHZ** – gives information about the maximum emission frequency in 2-9 kHz and 8-150 kHz with frequency and channel,
- **I/O** – quick review of the states of digital inputs and outputs.

The right and left orange arrows allows switching between all the real time data screen in a circular manner.

Example screens are shown on Fig. 12, Fig. 13, Fig. 14 and Fig. 15.

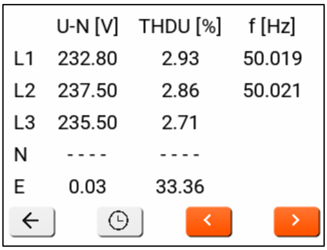


Fig. 12. “U, THDU, f” screen. The upper frequency is 10/12-cycle frequency, and the bottom is 10-second frequency.

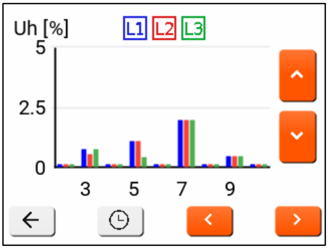


Fig. 13. Voltage harmonics screen. Nine harmonics are shown on each screen, and pressing up and down arrows allows switching to next or previous nine harmonics. Pressing right arrow switches to the current harmonics.

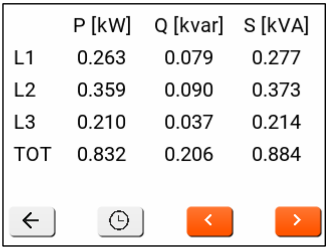


Fig. 14. Powers screen.

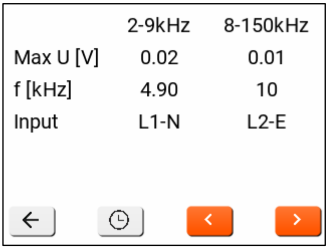


Fig. 15. 2-150 kHz screen.

2.8 Taking measurements

2.8.1 Start / stop of recording

In the PQM-750 analyzer, recording starts automatically after starting the meter if no errors preventing recording are detected (e.g. missing memory card).

When recording is active, the red **REC** LED lights up continuously.

Stopping recording is possible in several cases:

- When the user uses the option of ejecting an external memory card when the recording data is saved on this card – from the main screen, select **MEMORY→EJECT CARD**. After reinserting the card, recording will continue.
- When the entire memory card is full in linear memory organization.
- When the battery in the analyzer running on battery power is completely discharged. In such a situation, the analyzer will stop recording and turn off. After applying external voltage, the meter will turn on again and continue recording.

Advanced control over the recording process is possible using remote protocols.

2.8.2 Recording configuration

Before you start recording, it is necessary to configure the measurement, to perform the recording process according to your requirements. Basic configuration via GUI is described in sec. 2.8.3. The full configuration is carried out remotely via one of the protocols or via embedded webserver.

In the full configuration process, in addition to the basic settings, the user can also indicate, among others, the averaging time and parameters that are to be recorded in the user configuration, activate events detection, etc.

Recording for compliance with the indicated standard may be followed by a compliance report, which is used to assess the quality of power supply in the tested network point.

In cases when the user only wants recording for compliance with the Standard and does not want the analyzer to record additionally any other parameters (and thus increase unnecessarily the size of recorded data), turn off (by unchecking in settings) all other parameters, or choose a long averaging time from the list (even if the parameters are to be recorded, it will take relatively little space). However, this does not includes events, so the best solution is to disable unnecessary parameters.

2.8.3 Basic measurement settings with GUI

One of the most important configuration options is to set the mains system parameters. This basic configuration can be performed using the GUI on the analyzer's LCD.

From the main menu select **SETTINGS** and then **MEASUREMENT** to start a few steps configuration wizard. Use left / right arrows to switch between screens.

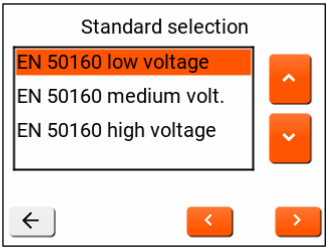


Fig. 16

1. Standard selection. From the list select the appropriate power quality standard, for example a variant of the EN 50160. This will allow the analyzer to generate report files based on the chosen profile parameters.

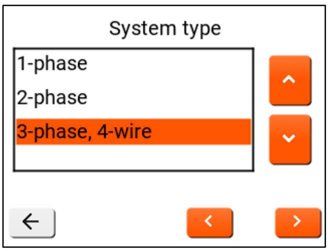


Fig. 17

2. System type. On this screen you may select the mains type.

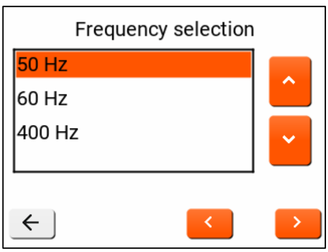


Fig. 18

3. Frequency selection. Select nominal frequency of the system: 50 / 60 Hz.

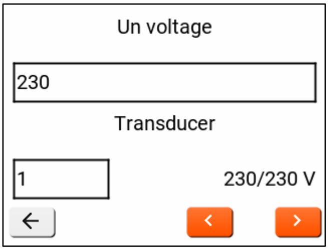


Fig. 19

4. Nominal voltage and Transducer configuration. By pressing on the values the keypad will appear that will allow entering custom nominal voltage and voltage transducer ratio (the ratio between primary and secondary transducer voltages).

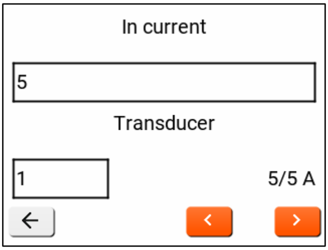


Fig. 20

5. This screen allow setting of current transducers. It is divided. The transducers for I1-I3, In/I4 and Ie/I5 channels are set independently. The nominal current is calculated as the product of the entered ratios and the nominal range of current inputs installed in the analyzer.

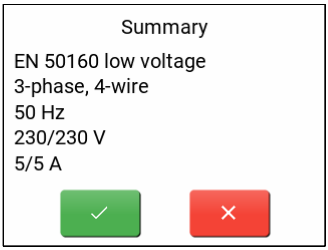


Fig. 21

6. The last screen of the configuration wizard is the summary. If all the configuration parameters are correct, confirm the settings by pressing accept button.

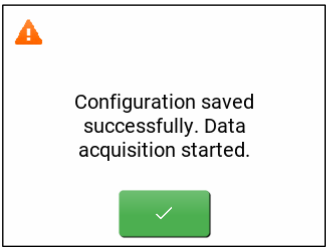


Fig. 22

7. The next screen confirms that the configuration has been successfully changed and that recording has been started.

2.9 Network interface (webserver)

The analyzer is equipped with a built-in www service (web server) allowing for:

- analyzer configuration,
- real-time monitoring of the analyzer status and measured parameters,
- browsing the list of recorded events along with waveforms and $RMS_{1/2}$ graphs,
- managing www service users.

The www service uses the encrypted HTTPS protocol. Webservice default logon data:

- username: **admin**
- password: **pqm**

Detailed instructions for using the www service are described in a separate document.

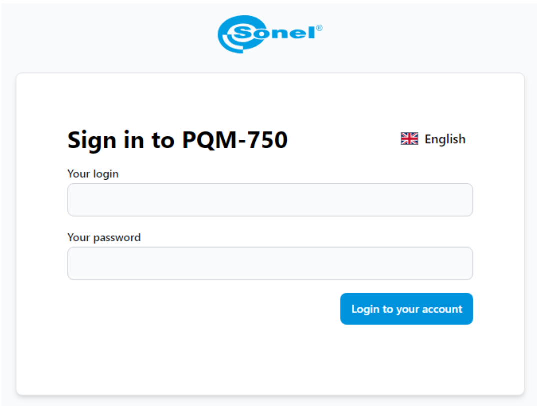


Fig. 23. PQM-750 webserver logon screen.

2.10 Measuring circuits

The analyzer may be connected directly to the following types of networks:
1-phase (Fig. 24)
2-phase (split-phase) with split-winding of the transformer (Fig. 25),
3-phase 4-wire (Fig. 26),
3-phase 3-wire (Fig. 27, Fig. 28),

Indirect measurements in medium voltage networks can be performed:

- in 3-phase 3-wire network (Fig. 29).

In 3-wire systems, currents may be measured with the Aron method, which uses only two current channels that measure currents I_{L1} and I_{L3}. I_{L2} current is then calculated using the following formula:

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

This method can be used in 3-phase 3-wire systems (Fig. 28).

In systems with neutral conductor, the user may additionally activate current measurement in this conductor, after connecting I4 / I_N current channel. This measurement is performed after activating in settings **CURRENT I4**.

In order to correctly calculate total apparent power S_e and total Power Factor (PF) in a 4-wire 3-phase system, it is necessary to measure the current in the neutral conductor. Then it is necessary to activate measurement of I_N current and connect 4th current channel. More information on total apparent power S_e - see Power Quality Guide.

Pay attention to the direction of current channels. The S1 current terminal strips should be connected to the source side, and S2 strips to the load side. It may be verified by conducting an active power measurement – in most types of passive loads active power is positive. When direction is incorrect, it is possible to change their polarity using software.

In all mains systems, measurement of current in channel I5 can be enabled. This measurement is performed after enabling option **Current I5** in the settings. This channel can be used, for example, to measure leakage current.

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

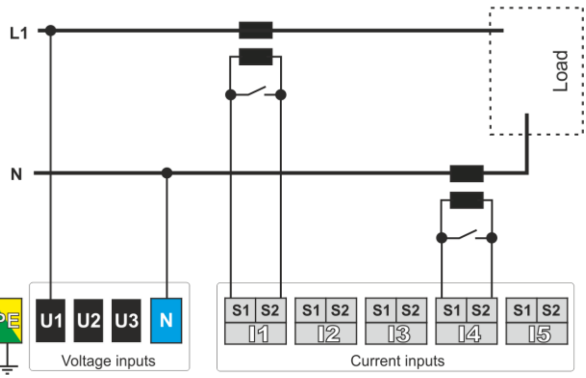


Fig. 24. Wiring diagram – single phase, direct voltage connection.

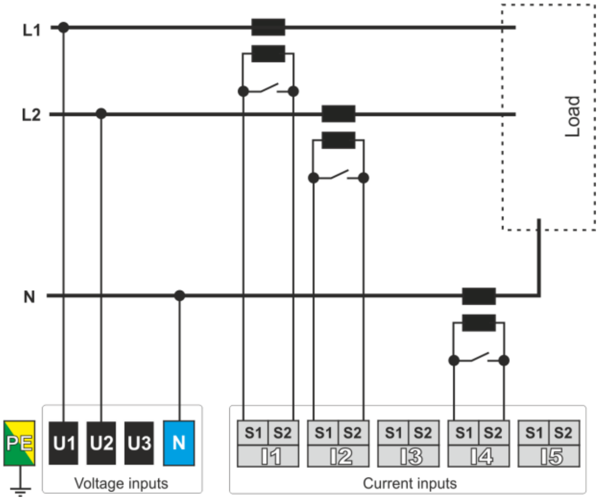


Fig. 25. Wiring diagram – split-phase, direct voltage connection.

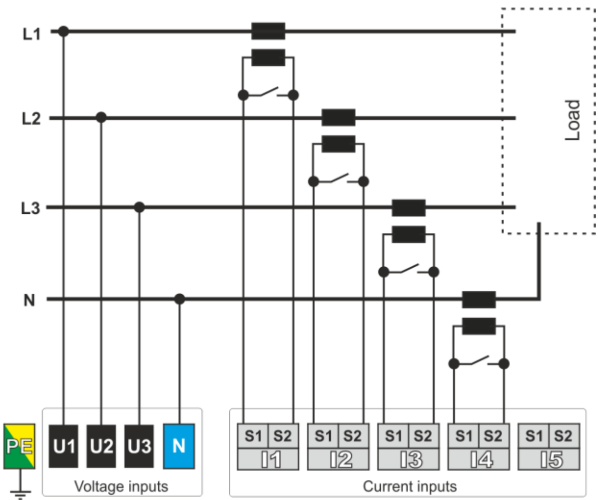


Fig. 26. Wiring diagram – 3-phase 4-wire system, direct voltage connection.

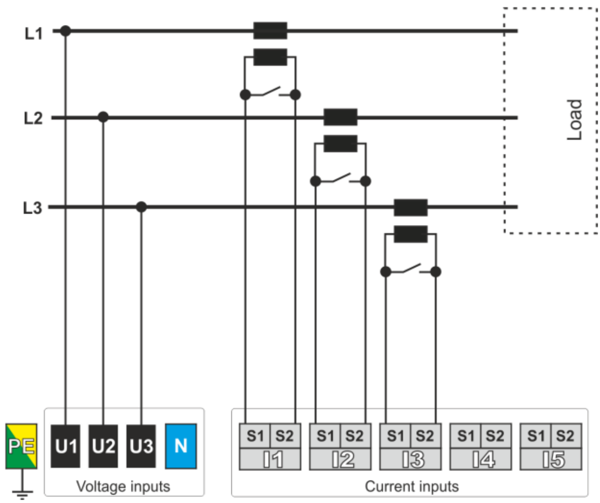


Fig. 27. Wiring diagram – 3-phase 3-wire, direct voltage connection.

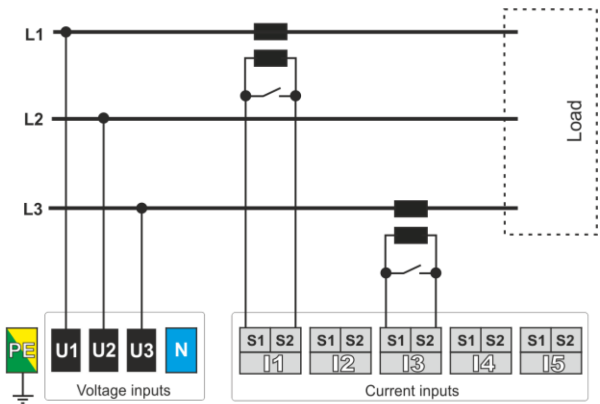


Fig. 28. Wiring diagram – 3-phase 3-wire with current measurement using Aron method.

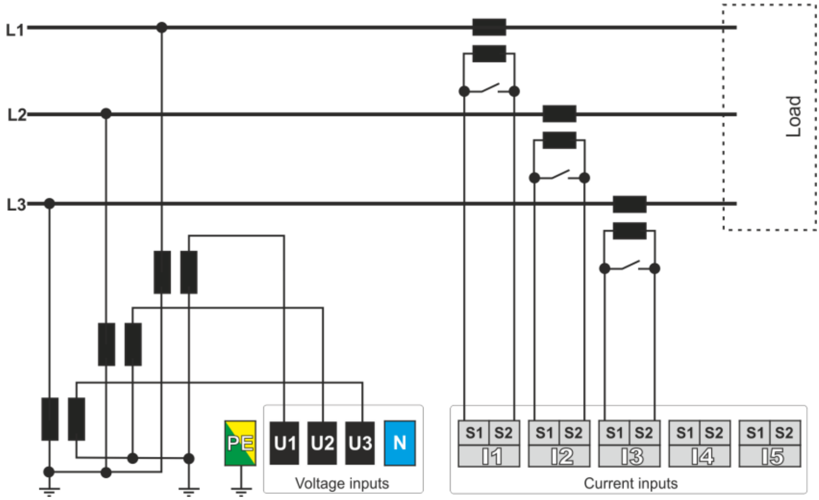


Fig. 29. Wiring diagram – 3-phase 3-wire indirect system with voltage transducers.

Frequency response of transformers is usually very narrow, so the network disturbances at high frequencies (e.g. lightning surges) are largely suppressed and distorted on the secondary side of the transformer. This should be taken into account when making transient measurements in configuration with transformers.

2.11 Data recording

The analyzer saves measurement data on a memory card (in the current firmware version – on an external card), of which the entire available space has been divided into three areas:

- normative data area,
- user data area,
- energy meter area.

The allocation of space to individual areas is configured via the www service. Additionally, each of these spaces can be set to one of two types of recording:

- circular recording, in which case the oldest data is deleted if there is no space,
- linear recording, in which the recording of a given type of data is stopped if the space is exhausted.

Regardless of the selected recording mode, the analyzer can store data from a maximum of 200 days, if this number is exceeded, data from the oldest days is deleted.

Waveforms, $RMS_{1/2}$, transient and other graphs are saved in the user data area, even if the related events come from normative data.

2.12 Normative recording

The analyzer automatically saves the power quality parameters required by selected power quality variant of EN 50150 standard. These parameters with corresponding time intervals are listed in the Table 3.

Table 3. Parameters recorded in the normative data area.

Parameter	Time interval			
	10 s	**10 min**	**15 min**	**2 h**
Frequency	✓			
RMS voltage		✓		
RMS current		✓		
Voltage harmonics		✓		
Current harmonics		✓		
Voltage interharmonics		✓		
Current interharmonics		✓		
Voltage THD-F		✓		
Current THD-F		✓		
Voltage unbalance		✓		
Current unbalance		✓		
Flicker Pst		✓		
Active power			✓	
Reactive power Q1			✓	
Apparent power			✓	
Nonfundamental apparent power			✓	
Active energy			✓	
Reactive energy (4-quadrant)			✓	
Apparent energy			✓	
Tangent φ (4-quadrant)			✓	
Flicker Plt				✓

In addition to the parameters listed in Table 3, the analyzer records events defined in the EN 50160 standard: voltage dips, swells, interruptions and RVC (rapid voltage changes).

2.13 Configuration changes and multi-access

The PQM-750 analyzer offers several ways to change its own settings. Settings are understood as all of the analyzer's configuration parameters, including:

- general analyzer settings (e.g. time zone or GUI language), which are stored in EEPROM,
- settings related to the Ethernet network (e.g. IP address, NTP servers or FTP client settings), which are stored in EEPROM,
- measurement settings (e.g. network type, nominal voltage, recorded parameters), stored on the memory card.

The channels through which you can change settings are listed below:

- changing settings using the meter's GUI (to a very limited extent),
- changing settings using the web server (admin account, incomplete scope),
- changing settings using the Modbus RTU protocol (full scope of settings),
- changing settings using the Modbus TCP protocol (full scope of settings),
- changing settings using the SonelFrame protocol (full scope of settings).

In order to ensure the possibility of changing settings by each of the mentioned interfaces, it was necessary to introduce a mechanism for settings transactions as well as protection against accidental or unauthorized change. The transaction of changing settings always consists of the following steps:

1) optional step - entering the admin PIN.
2) unlocking the settings for modification,
3) changing the configuration parameters,
4) locking the settings.

Each channel, when the settings are unlocked, works on its own copy of the settings, which is created at the time of unlocking. After making changes to the configuration, the settings are locked and the settings are copied from the copy to the global settings of the meter. The time required to complete the transaction is set at 3 minutes. If the settings have not been locked again by that time, the transaction is automatically closed and the changes introduced are discarded. In the case of entering the settings wizard from the meter GUI (**SETTINGS→MEASUREMENTS**), the transaction is also opened. If the user does not go through the entire wizard within 3 minutes, the changes are discarded and the GUI returns to the main screen.

To protect the settings from accidental or unauthorized change, it is necessary to enter a PIN (the same as the admin user PIN in the GUI) before unlocking the settings. This applies only to the protocols: Modbus RTU, Modbus TCP and SonelFrame.

Since in the current version of the meter's firmware, measurement data is saved on an external memory card, changing the settings is not possible if the memory card is removed from the slot. It does not matter whether the changes concern measurement settings or others.

2.14 FTP Client

The analyzer has a built-in FTP/FTPS client, which allows you to upload files listed below to an external server supporting listed protocols. Unencrypted (FTP), encrypted (FTPS) connections, active and passive modes are supported. The FTP client is configured using the web server service.

The analyzer allows you to generate and send the following files via FTP:

- daily PQDIF files with 10-minute normative data,
- daily PQDIF files with 10-second normative data (frequency),
- daily PQDIF files with 15-minute normative data,
- daily PQDIF files with 2-hour normative data (PLT flicker),
- PQDIF files with normative events (voltage dips, swells, interruptions),
- daily PQDIF files with user recording data (limited to 100 MB of source data per day),
- PQDIF files with user recording events (voltage dips, swells, interruptions, phase jumps, waveshape variation, U_{N-E} max., current min. and max.)

Example file name for a PQDIF file with 10-minute data (composed of serial number, date and time of first data record, averaging time, recording type and data type):
CE0026_2024-09-11_T_00-10-00_10min_std_trends.pqd

Example file name for a PQDIF file with a voltage surge event (composed of serial number, date and time of start of event, event type, recording type and data type):
CE0026_2024-09-12_T_23-47-53-542_VoltageSwell_std_event.pqd

Example file name for a PQDIF file with user recording 3-minute data:
CE0026_2025-01-29_T_00-03-00_3min_user_trends.pqd

Since the analyzer records data by day synchronized with UTC, complete daily data is available after midnight UTC. From that point on, the data can be converted to PQDIF format and sent to a remote FTP server. In the FTP service configuration, the user can specify the hour after midnight UTC at which the file upload to the server should begin – you can select a time from 1 to 12 hours after midnight UTC, with a one-hour step.

The FTP configuration panel allows you to perform a connection test, which involves trying to connect the analyzer to the FTP server and uploading a small test file. This allows the user to make sure that the configuration has been performed correctly. This also indicates that any network firewalls between the analyzer and the remote FTP server are configured correctly and do not block FTP traffic.

2.15 Modbus RTU and Modbus TCP

The analyzer supports the Modbus RTU protocol (RS-485 physical interface) and Modbus TCP (Ethernet interface). They provide access to a wide range of measured and configuration parameters of the meter. The following parameters are provided:

- measured instantaneous values 10/12-period (200 milliseconds),
- measured average values 150/180-period (3 seconds),
- measured average values 10 minutes,
- configuration parameters with the option of changing them.

Detailed information on these protocols, together with a full list of shared registers, is available in the dedicated user manual.

2.16 IEC 61850 protocol

The IEC 61850 standard based on the Ethernet physical interface defines the method of exchanging information between power automation devices within power stations. IEC 61850 defines a standard data model and naming convention for intelligent electrical devices (abbreviated as IEDs - Intelligent

Electrical Devices) and a common language for their configuration, ensuring interoperability between devices and engineering tools.

PQM-750 supports edition 2.1 of this standard.

Detailed information about this protocol along with a description of the data model is available in the dedicated user manual.

2.17 Time Synchronization

2.17.1 Requirements of IEC 61000-4-30

Time synchronization of the analyzer with UTC is required by IEC 61000-4-30 standard for class A for marking the measurement data. Maximum error cannot exceed 20 ms for 50 Hz and 16.7 ms for 60 Hz. Such action is necessary to ensure that different analyzers connected to the same signal provide identical read-outs. Synchronization with UTC is also needed when the network of analyzers is dispersed. When the source of the time signal becomes unavailable, an internal real-time clock has to ensure the accuracy of time measurement with accuracy better than ±1 second to 24 hours, but even in these conditions, to ensure the compliance with class A, the accuracy of measurement must be the same as previously specified (i.e., max. 1 period of mains).

There are two options for PQM-750 to fulfil these timing requirements:

- GPS synchronization by adding additional external GPS-1 module to the main analyzer module,
- IRIG-B clock synchronization using external IRIG-B signal source in the RS-485 standard. The IRIG-B signal should be connected to RS-485-2 analyzer input.

As for the NTP time synchronization the clock accuracy can differ significantly depending on the servers selected and network load and configuration. Therefore it cannot be guaranteed for NTP that it will fulfill class A clock accuracy requirements.

2.17.2 Time source prioritization

There are four possible time sources for the analyzer:

- GPS
- IRIG-B
- NTP
- RTC

The GPS has the highest priority, and the next listed sources have the priority in the order on this list. It means that if analyzer has also other time sources connected or active, the GPS source takes precedence as it is the most accurate source among them.
If the GPS source is unavailable, the analyzer switches to the next source with the highest priority: IRIG-B, then NTP, and as a last resort – RTC which is the least accurate.

Please note, that setting the date and time manually, for example via the analyzer GUI, is possible only when the current time source is RTC. If any other time source is active, than the time and date cannot be changed. The only setting than can be always changed is the time zone.

There is also a possibility to set the analyzer in “RTC only” mode, in which the GPS/IRIG-B/NTP sources are ignored.

2.17.3 GPS-1 module

A GPS-1 module receiver and external antenna can be connected to the main analyzer module to enable accurate time synchronization.

GPS synchronization time depends on weather conditions (clouds, precipitation) and on location of receiving antenna. The antenna should be provided with high "visibility" of the sky in order to obtain the best results. To read the time with the required accuracy, the GPS receiver must first determine its own current geographical location (it must "see" at least 4 satellites - position and altitude). After determining the position and synchronizing time to UTC, the receiver enters the tracking mode. To ensure time synchronization in this mode, the visibility of only one GPS satellite is required. However, to determine the analyzer position (when it is moved), still four satellites must be available [seen] (3 satellites if GPS does not update the altitude data).

An additional important reason for extending the synchronization time with UTC is the need to read information about leap seconds. A packet with this information is broadcast by GPS satellites every 12.5 minutes, which can be a decisive factor in increasing the time required to achieve synchronization.

The GPS-1 module has a built-in output that generates an unmodulated IRIG-B time synchronization signal in the RS-485 electrical standard. This output can be used to synchronize the time of other PQM-750 analyzers using their IRIG-B inputs.

NOTE!

Additional modules should only be connected to the analyzer after the power has been turned off and the main module has been powered off. Failure to follow the above recommendation may result in damage to the analyzer.

2.17.4 IRIG-B input

The analyzer is equipped with a time synchronization input compliant with the IRIG-B standard. This uses the RS-485-2 input (default), so sources electrically compatible with the RS-485 differential transmission standard and transmitting an unmodulated signal are accepted. Multiple PQM-750 analyzers can be synchronized simultaneously from a single IRIG-B signal source.

The IRIG-B generator transmits time information encoded on 100 bits with a single bit duration of 10 ms. Full time and date information is transmitted every second. The accuracy of IRIG-B time servers is usually better than ±1 ms, which is fully sufficient to provide analyzer time synchronization that complies with the requirements for Class A.

An add-on module for the PQM-750 - GPS-1 has a built-in IRIG-B signal generator with RS-485 output, which can be used to synchronize other PQM-750 analyzers. The low bit rate of the IRIG-B protocol, together with the electrical and differential RS-485 standard, makes it possible to build a synchronization bus as long as 1200 m.

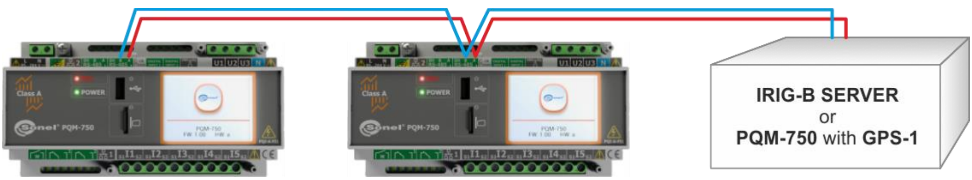


Fig. 30. Example of IRIG-B synchronization bus.

2.17.5 Data flagging concept

The analyzer saves measurement records along with the flag indicating the lack of time synchronization. If for the whole averaging period the analyzer was synchronized to UTC, then the flag is not turned on.

When the analyzer was initially synchronized to UTC reference time and later the signal was lost, this does not mean that the analyzer immediately lost the synchronization of its clock. In fact, for some time (even a few minutes or more) internal timing accuracy is sufficient to meet the requirements of IEC 61000-4-30 in part relating to the accuracy of determining time data. This is because the internal clock of the analyzer is very slow in de-synchronizing from UTC time (due to reference signal unavailability), and the error does not exceed a few milliseconds for an extended period of time. Thus, despite the "No signal" status, data will continue to be saved without the flag signalling the lack of synchronization to UTC. Only when the error exceeds the limit value the flag will be turned on.

2.17.6 Time resynchronization

As the availability of the reference timing signal cannot be guaranteed on a permanent basis, it is necessary to ensure proper management of internal time when the reference source signal becomes available and when it differs from the internal time of the analyzer.

When no recording is on - the situation is simple - after receiving the reference time, the analyzer clock automatically synchronizes with it without any additional conditions.

When the recording process is on, a sudden change of the internal time may lead to a loss of measurement data when time is reset, or it may create a time gap in gathered data, when UTC time is ahead of the analyzer time. To prevent this, a slow synchronizing mechanism is activated to synchronize the internal analyzer time with UTC time. The implementation of this concept is based on the deceleration or acceleration of the internal analyzer clock in such a manner that after a time the two clocks - internal and reference - are equalled and achieve synchronization. The advantage of this solution is the fact that there is no data loss or discontinuity.

To avoid the problems with time measurement during recording, please remember the following:

- The analyzer must have properly set its time zone and the time displayed on its screen must be precisely compatible with local time (if there is no reference signal before starting the recording).
- If possible, before starting the process of recording, receive the reference timing signal to synchronize the analyzer time to UTC. This will ensure the least possible timing errors during the recording and a fast tuning time in case of a temporary loss of reference signal.
- In order to ensure the compliance of the whole measurement with requirements of IEC 61000-4-30 in terms of time marking for devices of Class A, the internal analyzer clock must be synchronized to UTC, and GPS or IRIG-B signal must be available for the whole process of recording.

2.18 Configuration of 1-Wire temperature sensors

Up to four external 1-Wire temperature sensors can be connected to the analyzer. The sensors are connected in parallel to the DQ and GND terminals of the analyzer. Each sensor has an internal unique serial number stored in non-volatile ROM memory, which is used to identify the sensor on the bus. The way of connecting 1-Wire sensors to the PQM-750 analyzer is shown on

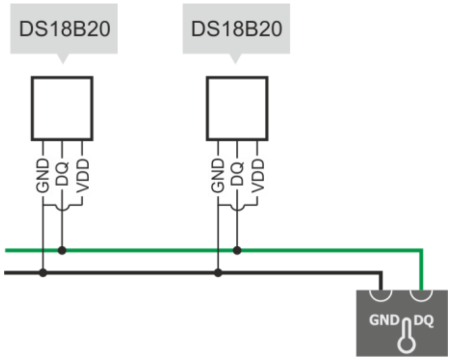


Fig. 31. Connection of 1-Wire sensors to PQM-750 analyzer.

The temperature values measured by the sensors are assigned in the meter to parameters named T1, T2, T3, T4. The user assigns unique sensor numbers, marked ROM1, ROM2, ROM3, ROM4, to the temperature parameters T1-T4. This assignment is performed using the meter's GUI and is described below.

To proceed to the configuration of temperature sensors, select from the main menu: **SETTINGS→1-WIRE**. After connecting the sensors (from 1 to a maximum of 4), press the **SEARCH** button. The analyzer will search for correctly connected sensors and read their unique ROM1-ROM4 numbers, which will be displayed on the screen.

By default, the ROM1 sensor is assigned to the parameter T1, ROM2→T2, ROM3→T3, ROM4→T4. However, the user can change this assignment. To do this, on the 1-wire configuration screen, press the **CHANGE** button and use the up-down arrows to change the number of the T1-T4 parameter assigned to a given ROM1-ROM4 sensor.

The **DELETE** button removes all found sensors from the list.

To view the temperatures measured by the sensors in real time on the screen, you can select **MEASUREMENT→1-WIRE** from the main menu. This screen displays the temperatures (in degrees Celsius) of the configured sensors.

2.19 Digital outputs

The analyzer has two independent digital outputs (relays), the operation of which can be configured by the user. It is possible to link the operation of relay outputs with the events listed in Table 4. Configuration is performed via the web service.

Table 4. List of events for which digital outputs action can be set.

Event (User configuration)	Channels [1)] (any combination)
Voltage dip	U1, U2, U3
Voltage swell	U1, U2, U3
Voltage interruption	U1, U2, U3
Voltage waveshape variation	U1, U2, U3
Phase jumps	U1, U2, U3
Max. current threshold exceeded	I1, I2, I3
Max. active imported power P+ exceeded	L1, L2, L3, TOT (total power)
Max. active exported power P- exceeded	L1, L2, L3, TOT (total power)
Max. reactive power Q1 exceeded	L1, L2, L3, TOT (total power)
Max. apparent power S exceeded	L1, L2, L3, TOT (total power)
Max. voltage THD-F exceeded	U1, U2, U3
Max. current THD-F exceeded	I1, I2, I3
Max. power factor PF exceeded	L1, L2, L3, TOT (total PF)
Max. cosφ exceeded	L1, L2, L3, TOT (total cosφ)

[1)] I the case of voltage parameters 'U1,U2,U3' means U_{1N}, U_{2N}, U_{3N} or U_{12}, U_{23}, U_{31} depending on mains system type.

For each of the events listed in Table 4, you can select the relays to be activated. You can select one or two relays. You can also activate multiple events for each relay.

In the web service you can configure the relay actions (independently for each relay). Only pulse operation of the relays is possible. The following options are available:

- Pulse duration after event detection: from 10 ms to 1000 ms, step 10 ms, default 100 ms.
- Hold time (inactivity) after pulse generation: from 0 to 10 seconds, step 1 second, default 2 seconds.
- Pulse generation mode: O→C→O (open contacts, closed contacts, open contacts) or C→O→C (closed contacts, open contacts, closed contacts).

In the case of changeover relays (SPDT), such as those used in the PQM-750, the O state (open contacts) means the relay is off (contacts in the position as on the sticker on the housing), and the C state (closed contacts) means the relay is on (energized).

2.20 Digital inputs

The analyzer is equipped with two galvanically isolated digital inputs (binary). The status of the digital inputs is monitored by the analyzer - the current status of the inputs is presented, among others, on the analyzer screen. It is possible to activate the function of detecting changes in the status of both inputs. The user can also specify the active triggering status (low or high) independently for both inputs.

2.21 Auto-off

The analyzer turns off automatically also when the battery is fully discharged. Such emergency shutdown is performed regardless of the mode of the device. In case of active recording, it will be interrupted. When the power supply returns, the recording process is resumed. Emergency shutdown is signalled by message **Low battery. Turning off...**, after which the analyzer will shut down. When power returns, recording will resume.

2.22 Firmware update

If the new firmware is released the analyzer can be updated by two methods:

- Remote update via web browser using the embedded webpages,
- Update with the use of a USB flash drive (pen drive).

When the second method is used the procedure is as follows:

- First step is to write the update file (this is a file with the name like "pqm750-update-v1.01.0.pqf") on a USB flash drive formatted to FAT32 filesystem. Other filesystems are not supported. To speed-up the process delete other files on the USB flash drive.
- Insert the flash drive to the USB port of the analyzer. The led next the port should turn on indicating that there is a read operation. Allow at least 10 seconds to decode the file by the analyzer for checking the validity and integrity of the file.
- Next step is to select **SETTINGS**→**>**→**FW UPDATE** from the main menu. If the new file is found the message will display with the detected version number. If you want to update the analyzer confirm by clicking the appropriate button. If there is a message that the update file is missing then try again selecting **FW UPDATE** screen a few seconds later.
- After confirming the update will begin. This can take about few minutes. The analyzer will then restart. You can check if the update was successful by checking **INFO**→**VERSION** screen.

2.23 Downloading of system logs

In some situations, it may be necessary to download system logs from the analyzer. For this purpose, prepare a USB Flash memory formatted in FAT32 system with an empty 'log' directory in the root directory. The prepared memory should be inserted into the USB port of the analyzer. If the above conditions are met, a system log file will be recorded in the 'log' directory, which can be used for further analysis.

2.24 RTC coin cell battery

The RTC clock in the analyzer is also maintained when the analyzer is switched off and no external power supply is connected. In such a situation, the RTC clock is first powered by the built-in Li-Ion battery. Only after it is completely discharged, the RTC power is drawn from the CR1025 coin cell battery placed in the holder at the top of the analyzer next to the LAN2 socket.

The voltage of this battery is monitored by the analyzer – its status can be checked from the meter menu by selecting **SETTINGS** → **POWER SUPPLY**. The **RTC BATTERY** line displays the information: **YES** / **DISCHARGED** / **MISSING** depending on the battery status. A warning screen is displayed on the screen if the battery is discharged or removed. The user can check the **DON'T SHOW AGAIN** toggle so that the message is not repeated multiple times.

To replace a discharged battery use a tool (e.g. a screwdriver) to pull out the holder – a flat screwdriver with a tip width of approx. 3 mm should be inserted into the holder slot from the LAN2 port side and the holder should be pulled out while holding it on the other side with your finger. After inserting a new battery into the holder, insert it into the socket in the meter, remembering the correct orientation of the holder.

2.25 Emergency reset

The analyzer is equipped with a hardware reset button, which is located under the memory card slot. In emergency cases, when the analyzer does not respond and is frozen, it is possible to restart the meter processor using a thin pin and pressing the button located under the sticker. This option should only be used as a last resort. First use will require piercing the sticker. Insert the pin into the hole (no deeper than 5 mm) and press the button for at least 4 seconds (you should feel a slight button click). After this time, the meter will restart or turn off depending on whether it has an external power supply connected or not.

NOTE!

Resetting the meter during normal operation may result in the loss of all or part of the recorded data. The file system on memory cards may become corrupted.

A short press of the reset button reinitializes the LCD display and will not reset the processor.

3 Cybersecurity

3.1 Recommendations

Constantly growing number of measuring devices connected to various types of infrastructure networks, wired and wireless, their increasing capabilities, extensive functions for controlling external devices, the possibility of remote access and configuration, are inextricably linked to their greater susceptibility to attacks. Hardening measures can be achieved by:

- reducing potential vulnerabilities,
- reducing possible attack methods,
- reducing functionality and privileges that can be used in the event of a successful attack,
- increasing the probability of detecting the attacker.

The following are recommendations to increase the analyzer's resistance to attacks:

- The product should operate in a protected area without access by unauthorized persons.
- The product should operate in an isolated Ethernet segment with an active firewall.
- Limit remote access to the device only to secure local connections or via encrypted VPN connections.
- Disable unsecured and unencrypted communication protocols: Modbus RTU, Modbus TCP, IEC 61850, SonelFrame.
- You must secure access to the local GUI by enabling a PIN for the 'administrator' and 'user' users.
- You should secure access to the website by setting a strong password for the 'admin' user. The recommended password should consist of at least 8 characters, including at least:
    - one numeric character
    - one capital letter
    - one lowercase letter
    - one special character

3.2 Password management

The ‘Admin’ user PIN code protects the meter’s GUI from unauthorized persons making changes to the analyzer’s configuration. If this code is forgotten, the only way to regain access to the GUI is to use the special 8-digit individual PUK unlocking code supplied with the analyzer, instead of the PIN code. After the PUK code is entered correctly, the ‘Admin’ and ‘User’ PINs will deactivate and reset, the GUI interface will unlock, and then the user can enter the ‘Admin’ user PIN code setting screen and set a new PIN code.

In the case of a forgotten password for the www service administrator (user ‘admin’), the only way to unlock access to the service is to use the meter’s GUI, enter the **SETTINGS→PASSWORD RESET** screen and confirm the desire to reset the password. After this operation, the www service administrator password is reset to ‘pqm’. After logging back into the service, set a new, strong password using the guidelines from sec. 3.1.

3.3 Used TCP/UDP ports

Table 5. Used TCP/UDP ports

Protocol	Server/ Client	TCP/ UDP	Port	Activated by default	Description
HTTPS	server	TCP	443	yes	Encrypted connection with web service for configuration and viewing
FTP/FTPS	client	TCP	>1024	yes	File upload to remote FTP/FTPS server
NTP	client	TCP	123	yes	Time synchronization
Modbus TCP	server	TCP	502 [1)]	no	Communication with system controller via Modbus TCP protocol
IEC 61850	server	TCP	102	no	Communication with system controller via IEC 61850 protocol
DHCP	client	UDP	68	no	Dynamic Host Configuration Protocol
DNS	client	UDP	53	yes	Communication with DNS server to translate domain names into IP addresses
SonelFrame	server	TCP	4005	yes	Communication with system controller via SonelFrame protocol by Sonel S.A.

[1)] Possibility to change port number

4 Design and measurement methods

4.1 Voltage inputs

The voltage input block has three main paths. The main one consist of four measurement channels (U1, U2, U3 and neutral conductor N) which are referenced to ground (earth, PE) terminal, and they are used for majority of voltage measurements. Sampling frequency of this path is 81.92 kHz and the ADC is 24-bit type.
This path has one voltage range, with peak measurable voltage ±1500 V.

The second path is used for 8-150 kHz voltage emission measurement. This path has three channels (U1, U2, U3) that have selectable reference conductor: N or PE. This path is processed by 16-bit ADC and 1 MHz sampling frequency. The measurement path includes a bandpass filter which cuts off lower frequencies (below few kHz).

The third path is used for fast transient measurement (available when fast transient module is installed). This path allows for ±6 kV peak voltage measurement on 4 channels with maximum sampling frequency of 10 MHz.

4.2 Current inputs

The analyzer has five independent isolated current inputs with identical parameters. Each input may be used for connecting to current transformer with current output of nominal range 5 A (other analyzer variants with different current ranges are possible). The measurement paths are connected to the same ADC as the main voltage measurement path: 81.92 kHz sampling and 24-bit.

4.3 Signal sampling

The signal on the main path is sampled simultaneously in all 9 channels with a frequency synchronized with the frequency of power supply voltage in the reference channel. This frequency is 81.92 kHz for 50 Hz and 60 Hz. Thus, the single cycle contains 1638.4 samples for 50 Hz and 1365.3 for 60 Hz.

24-bit analog-to-digital converter with 64-times oversampling is used.

3-decibel analog attenuation has been specified for frequency approx. 170 kHz, and the amplitude error for the maximum usable frequency 15 kHz (i.e. the frequency of the 256th harmonic for 60 Hz network) is approximately 0.1 dB.

It should be noted that for the correct measurement of phase shift between the voltage harmonics in relation to current harmonics and power of these harmonics, the important factor is not absolute phase shift in relation to the basic frequency, but the phase coincidence of voltage and current circuits. For PQM-750 analyzer the phase error between voltage and current harmonics of the order of 256^{th} is less than 4°.

When estimating measurement errors in power harmonics, also take into account additional error introduced by the probes and transformers.

4.4 PLL synchronization

The synchronization of sampling frequency is implemented with mixed hardware/software solution. After passing through the input circuits, the voltage signal is sent to a band-pass filter which is to reduce the harmonics level and pass only the voltage fundamental component. Then, the signal is routed to the Phase Locked Loop circuit as a reference signal. PLL circuit generates a frequency which is a multiple of the reference frequency required to clock the ADC.

Another issue is the input voltage range for which PLL will work properly. For this issue, IEC 61000-4-7 standard does not provide any specific guidance or requirements. However, 61000-4-30 standard defines the input voltage range in which the metrological parameters cannot be compromised and for class A the range is: 10%...150% U_{din}. The analyzer meets the requirements listed above relating to the operation of PLL, for the rated voltage U_{din} ≥ 100 V, i.e. approx. 10 V.

4.5 Frequency measurement

The signal for measuring frequency of the network, is taken from the reference voltage channel (U_{1N}, U_{2N}, U_{3N}, U_{12}, U_{23}, U_{31} depending on availability and mains type). This is the same signal that is used to synchronize the PLL. The reference signal is sent to a 2nd order band-pass filter, for which the passband was set at range of 40...70 Hz. This filter is designed for reducing the level of harmonics. Then, a square signal is formed from the filtered waveform. For the 10-second frequency value, the signal cycles number and their duration are counted during the 10-second measuring cycle. 10-second time intervals are determined by the real time clock (every full multiple of 10-second time). The frequency is calculated as the ratio of the number of cycles counted and their duration.
A faster, 10/12-cycle frequency (~200 ms) is also available.

4.6 Measurement of ripple control signals (mains signalling)

The analyzer allows user to monitor two user-defined frequencies in the range up to 30000 Hz.
The IEC 61000-4-30 standard lists two methods for measuring the level of a signal:

- one interharmonic bin if the user defined frequency of the control signal falls in the centre of the bin,
- 4 nearest interharmonic bins (root of the sum of the squares) if the frequency is not in the centre of the bin.

The PQM-750 uses both methods, and selects it dynamically and automatically depending on the actual mains frequency and the ripple signal frequency.

After exceeding the threshold limit defined by the user, the analyzer records the signal level for a specified period of time (up to 120 seconds). As a standard, the analyzer measures the average values of signals for the time interval selected in settings (the main averaging period). When recording acc. to EN 50160 is selected, then additionally all 3-second average values are recorded for both frequencies - they are compared with limits specified in the standard.

4.7 Measurement of emissions in the 2 kHz to 9 kHz band

Analyzer enables measurement of emissions in the frequency band from 2 kHz to 9 kHz in accordance with the guidelines of the IEC 61000-4-30 and IEC 61000-4-7 standards. This entire frequency range has been divided into 35 bands, each 200 Hz wide. The input data to the algorithm comes from the FFT results for the main circuits (voltages). Harmonic and interharmonic values are calculated from the same FFTs.

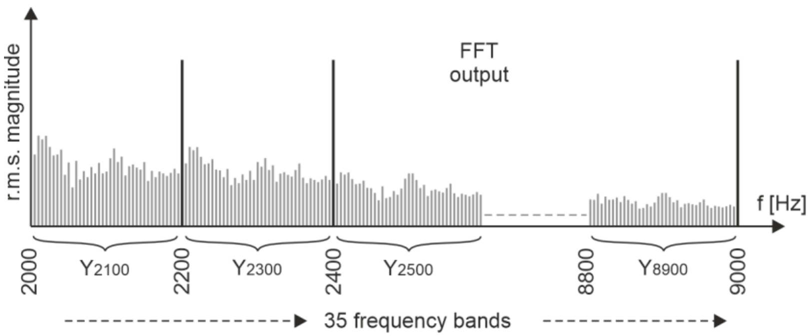


Fig. 32. Measurement in 2-9 kHz frequency band.

For example, for the first 200 Hz subband marked Y2100, the lines (approx. 5 Hz wide each) from 2005 Hz to 2200 Hz are grouped and a single rms value is calculated. This is shown in Figure 27.

35 rms values are calculated for each of the measured channels every 10/12 mains cycles (approx. 200 ms). These values are subject to the same rules of aggregation and searching for minimum and maximum values as other mains parameters.

Additionally, for each measurement window (~200 ms) the following are determined:

- The band with the highest amplitude is determined for each channel,
- Among all channels, the channel with the highest amplitude band and the frequency of this band are found.

Both of these data are displayed on the "2-150 kHz" LCD screen and are available via communication channels.

The analyzer provides calculated 2-9 kHz emission values: 10/12-cycle values, minimum, average and maximum values in the averaging period.

4.8 Measurement of emissions in the 8 kHz to 150 kHz band

The analyzer can measure voltage emissions in the band from 9 kHz to 150 kHz. The measurement method is based on the guidelines given in the IEC 61000-4-30 Ed.3 standard.
Three dedicated measurement channels are equipped with a band filter that attenuates the fundamental voltage component so that it does not reduce the dynamics in the measured band, i.e. between 8 and 150 kHz. After passing through a bandpass filter, the signals are directed to dedicated A/D converters with a sampling frequency of 1.024 MHz and a resolution of 16 bits.
The following voltages are measured:

- U1-E
- U2-E
- U3-E

or

- U1-N
- U2-N
- U3-N

depending on the selected network type.

The signals are sampled in 500 μs time windows. This length of windows translates into a frequency resolution of 2 kHz. Before the Fourier transform, a Blackman window is applied to the samples to minimize the effect of spectral leakage. As a result of the FFT operation, the meter calculates the rms values of 72 frequency bands – from 8 kHz to 150 kHz. In one measurement window of the main path lasting approximately 200 ms, there are tens such 500 microsecond measurements for each of the three measured channels.

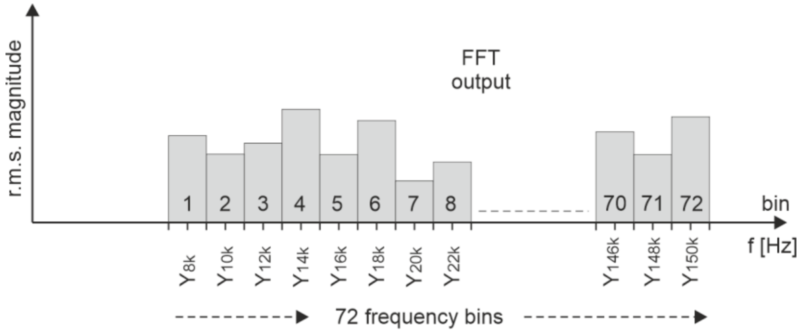


Fig. 33. Frequency bins at 8-150 kHz band measurement.

For each of the 72 bands in a 10/12-cycle window (~200 ms), the following are calculated:

- RMS signal value (average rms),
- minimum value (smallest among 500 μs measurements),
- maximum value (highest among 500 μs measurements),

The calculated average values for the 10/12-cycle window are further averaged according to the averaging time selected by the user.

Since the frequency resolution in this measurement is 2 kHz, the bands are marked with an even number of the central frequency of the band, e.g. the 8 kHz band contains components from 7 to 9 kHz, the 10 kHz band - from 9 to 11 kHz, and so on, up to the 150 kHz band containing spectral components from 149 to 151 kHz.

Similarly to the measurement in the 2-9 kHz band, for each measurement window (~200 ms) the following are determined:

- The band with the highest amplitude is determined for each channel,
- Among all channels, the channel with the highest amplitude band and the frequency of this band are found.

Both of these data are displayed on the “2-150 kHz” LCD screen of the analyzer and are available via communication channels.

The analyzer provides calculated 8-150 kHz emission values: 10/12-cycle values, minimum, average and maximum values in the averaging period.

4.9 Events detection

The analyzer offers wide range of events detection options for measured networks. "Event" is a situation where the parameter value exceeds the threshold defined by the user.
Detected events are recorded on a memory card as an entry containing:

- parameter type,
- channel, in which the event occurred,
- start and end time of the event,
- the threshold value set by the user,
- parameter extreme value measured during the event,
- parameter average value measured during the event.

Depending on the parameter type, you can set one, two or three thresholds which will be checked by the analyzer. Table 6 lists all parameters for which the events can be detected, including specification of threshold types. The “*Waveform and* $RMS_{1/2}$” column indicates those events which has the option to enable recording of waveforms and $RMS_{1/2}$ charts (this list may be expanded in future firmware releases).

Table 6. Types of event thresholds for each parameter.

Parameter		Interruption	Dip	Swell	Min.	Max.	Waveform and $RMS_{1/2}$
U	RMS voltage	✓	✓	✓		✓[1]	✓
$U_{waveshape}$	Waveshape variation					✓	✓
U_{phase_jump}	Phase jump					✓	✓
RVC	Rapid Voltage Changes					✓	✓
U_{DC}	DC voltage						
f	Frequency				✓	✓	
CF U	Voltage crest factor					✓	
u_2	Voltage negative sequence unbalance					✓	
P_{st}	Flicker P_{st}					✓	
P_{lt}	Flicker P_{lt}					✓	
I	RMS current					✓	✓
CF I	Current crest factor						
i_2	Current negative sequence unbalance						
P/P+/P-	Active power					✓	
Q_1, Q_B	Reactive power					✓	
S	Apparent power					✓	
D, S_N	Distortion power						
PF	Power Factor					✓	
$\cos\varphi$	Displacement power factor					✓	
$\tan\varphi$	Tangentφ factor (4-quadrant)						
E_{P+}, E_{P-}	Active energy (imported and exported)					✓	
E_Q	Reactive energy (4-quadrant)					✓	
E_S	Apparent energy					✓	
THD_F U	voltage THD_F					✓	
$U_{h0}..U_{h256}$	Voltage harmonic amplitudes						
THD_F I	current THD_F					✓	
$I_{h0}..I_{h256}$	Current harmonic amplitudes						
TID_F U	voltage TID_F						
$U_{ih0}..U_{ih256}$	Voltage interharmonics amplitudes						
TID_F I	current TID_F						
$I_{ih0}..I_{ih256}$	Current interharmonics amplitudes						
K-Factor	K-Factor						
Factor K	Factor K						
U_{R1}, U_{R2}	Mains signalling						
U_t	Voltage transients (optional)					✓	✓[3]

(1) applies to U_{NE} voltage.
(3) recording of transient chart and waveform, no $RMS_{1/2}$ chart.

Some of the parameters may have values that are positive or negative (+/-). For example: active power, reactive power and power factor. Since the event detection threshold may only be a positive value and to ensure proper detection for these parameters, the analyzer compares absolute values of these parameters with the set threshold.

Example | *Threshold for detecting active power events was set at 10 kW. If the load has a generator nature, the active power with correct connection of probes will be a negative value. If the measured absolute value exceeds the threshold, i.e. 10 kW (e.g. -11 kW) an event will be recorded for exceeded maximum active power.*

In the case of some selected types of events the user may also activate recording of waveforms and $RMS_{1/2}$ plots.

The analyzer records the waveforms of active channels (voltage and current) at the event start and end. The user may set recording time for waveforms and $RMS_{1/2}$ (from 100 ms up to 60 s for waveforms and from 1 s up to 60 s for $RMS_{1/2}$) and the pretrigger time (from 40 ms up to 960 ms for waveforms and from 0.1 s up to 4.9 s for $RMS_{1/2}$). Waveforms are saved in selected formats.

Information about the event is recorded when the event ends. In some cases, it may happen that event is active when the recording is stopped. Information about such event is also recorded, but with the following changes:

- there is no end-time of the event,
- extreme value is calculated only for the period until the recording is stopped,
- the average value is not reported,
- only the beginning waveform and $RMS_{1/2}$ is available.

To eliminate repeated event detection, when the value of the parameter oscillates around the threshold value, the analyzer has a function of user-defined event detection hysteresis. It is defined as a percentage value in the following manner:

- for RMS voltage events, it is the percent of the nominal voltage range (e.g. 2% of 230 V, which is 4.6 V),
- for RMS current events, it is the percent of the nominal current range (e.g. for 5 A nominal current range and in absence of additional current transducers, 2% hysteresis is 0.02×5 A = 0.1 A),
- for events related to DC voltage and U_{N-E} voltage, the hysteresis is calculated as a percentage of the threshold value, but not less than 50 mV (referred to input).
- for remaining parameters, the hysteresis is specified as a percent of maximum threshold (e.g. when maximum threshold for current crest factor has been set to 4.0 the hysteresis is 0.02×4.0 = 0.08).

4.9.1 Waveshape variation events

The PQM-750 provides a method for detecting abnormalities in the shape of the voltage waveform: waveshape variation events.

This method compares two adjacent periods of the voltage waveform and the difference between them is calculated and their maximum amplitude is checked - these values are then compared with the threshold set by the user. The percentage value of the threshold refers to the nominal voltage. If the calculated change in the amplitude exceeds the threshold, the waveshape event is triggered. This event is considered completed when for at least three consecutive waveform periods no detected exceedance of the tolerance threshold is detected.

Keep in mind that at low detection threshold, the analyzer may detect a very large number of events in a short period of time. Therefore, **HOLD-OFF TIME** parameter (expressed in seconds) is provided. After detecting an event, the analyzer blocks the detection of next events (in a given channel) for the time specified by this parameter. It may be set in the range of 1 s to 600 s.

4.9.2 Phase jump events

The analyzer can detect changes in the voltage fundamental phase angle. The detection algorithm compares the angles of the fundamental voltage component of two or three adjacent periods. If the angle difference is greater than the threshold set by the user (expressed in angle degrees), then the information is recorded on detecting the event, along with the measured value of the phase jump.

Information about the detected event includes the time of its occurrence and designated phase jump value, expressed in angle degrees (angle φ shown in the figure). It is also possible to save waveform and graph of $RMS_{1/2}$ values. The lowest value of the detected phase jump is 1 angle degree.

4.9.3 Rapid Voltage Changes (RVC) events

Rapid Voltage Changes (RVC) are described in more detail in Power Quality Guide. The analyzer can detect and record such events, only when you turn on the appropriate option in the measurement configuration. The user sets the following parameters:

- **THRESHOLD** - expressed as a percentage of the nominal voltage, setting the detection sensitivity; the smaller the threshold value, the greater sensitivity and more events of this type will be detected. A typical threshold value is 5% of U_{NOM}. Entered threshold value refers to the value ΔU_{MAX} of RVC events.
- **HYSTERESIS** is also expressed as a percentage of the nominal voltage. It must be lower than the threshold. When the hysteresis is closer to the threshold, then the range of voltage changes is narrower, which is required to state that the voltage value is stable again. Typically, the hysteresis value is set as half of the threshold.
- If the user wants to record oscillographic waveforms and $RMS_{1/2}$ graphs of voltage and currents together with RVC events, then it may be done after selecting appropriate option in configuration. Saved waveforms relate only to the beginning of the RVC event.

In polyphase systems, the device detects both single-phase events and polyphase events (in accordance with IEC 61000-4-30). It should be noted that according to the algorithm specified in IEC 61000-4-30, a polyphase event is also an event which occurred only in one phase ("polyphase" is viewed here as a "systemic" phenomenon and not as a requirement to occur in many phases simultaneously).

In the case of recording for compliance with the selected standard, which also includes the RVC measurement, RVC parameters are taken from the default settings of the selected standard.

4.10 Methods of parameter‘s averaging

Method of parameter averaging	
Parameter	**Averaging method**
RMS voltage, RMS current	RMS
DC voltage, DC current	arithmetic average
Frequency	arithmetic average
Crest factor U, I	arithmetic average
Symmetrical components U, I	RMS
Unbalance factor U, I	calculated from average values of symmetrical components
Active, Reactive, Apparent and Distortion Power	arithmetic average
Power Factor PF	calculated from the averaged power values
cosφ	arithmetic average
tanφ	calculated as the ratio of the average reactive power (in the related quadrant) to the average active power.
THD U, I	calculated as the ratio of the RMS value of the higher order harmonics to the RMS value of the fundamental component (for THD-F), or the ratio of the RMS value of higher order harmonics to the total RMS voltage (for THD-R)
TID U, I	calculated as the ratio of the RMS value of interharmonics to the RMS value of the fundamental component (for TID-F), or the ratio of the RMS value of interharmonics to the total RMS voltage (for TID-R)
Harmonic amplitudes U, I	RMS
Interharmonic amplitudes U, I	RMS
K-factor, Factor K	RMS
The angles between voltage and current harmonics	arithmetic average (Cartesian method)
Active and reactive power of harmonics	arithmetic average

Note:
RMS average value is calculated according to the formula:

$$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N},_i^2}$$

The arithmetic average (AVG) is calculated according to the formula:

$$AVG = \frac{1}{N}\sum_{i=1}^{N},and$$

where:

- X_i is subsequent parameter value to be averaged,
- N is the number of values to be averaged.

5 Calculation formulas

5.1 Single-phase network

Single-phase network			
Parameter			Method of calculation
Name	Designation	Unit	
Voltage (True RMS)	U_A	V	$U_A = \sqrt{\frac{1}{M}\sum_{i=1}^{M} U_i^2}$ where U_i is a subsequent sample of voltage U_{A-N} M = 16384 for 50 Hz and 60 Hz
DC Voltage	U_{ADC}	V	$U_{ADC} = \frac{1}{M}\sum_{i=1}^{M} U_i$ where U_i is a subsequent sample of voltage U_{A-N} M = 16384 for 50 Hz and 60 Hz
Frequency	F	Hz	number of all voltage periods U_{A-N} counted during 10-sec period (clock time) divided by the total duration of full periods
Current (True RMS)	I_A	A	$I_A = \sqrt{\frac{1}{M}\sum_{i=1}^{M} I_i^2}$ where I_i is a subsequent sample of current I_A M = 16384 for 50 Hz and 60 Hz
Active power	P	W	$P = \frac{1}{M}\sum_{i=1}^{M} U_i I_i$ where U_i is a subsequent sample of voltage U_{A-N} I_i is a subsequent sample of current I_A M = 16384 for 50 Hz and 60 Hz
Budeanu reactive power	Q_B	var	$Q_B = \sum_{h=1}^{50} U_h I_h \sin\varphi_h$ where U_h is the h-th harmonic of voltage U_{A-N} I_h is the h-th harmonic of current I_A φ_h is the h-th angle between harmonic U_h and I_h
Reactive power of fundamental component	Q_1	var	$Q_1 = U_1 I_1 \sin\varphi_1$ where U_1 is fundamental component of voltage U_{A-N} I_1 is fundamental component of current I_A φ_1 is angle between fundamental components U_1 and I_1
Apparent power	S	VA	$S = U_{ARMS} I_{ARMS}$
Apparent distortion power	S_N	VA	$S_N = \sqrt{S^2 - (U_1 I_1)^2}$ where U_1 is fundamental component of voltage U_{A-N} I_1 is fundamental component of current I_A
Budeanu distortion power	D_B	var	$D_B = \sqrt{S^2 - P^2 - Q_B^2}$
Power Factor	PF	-	$PF = \frac{P}{S}$ If PF < 0, then the load is of a generator type If PF > 0, then the load is of a receiver type
Displacement power factor	$\cos\varphi$ DPF	-	$\cos\varphi = DPF = \cos(\varphi_{U_1} - \varphi_{I_1})$ where φ_{U1} is an absolute angle of the fundamental component of voltage U_{A-N} φ_{I1} is an absolute angle of the fundamental component of current I_A

Tangent φ (4-quadrant)	$tan\varphi_{(L+)}$	-	$$tan\varphi_{(L+)} = \frac{\Delta E_{Q(L+)}}{\Delta E_{P+}}$$ where: $\Delta E_{Q(L+)}$ is the increase in reactive energy $E_{Q(L+)}$ (Budeanu/IEEE-1459) in a given averaging period, ΔE_{P+} is the increase in active power taken E_{P+} in a given averaging period
	$tan\varphi_{(C-)}$	-	$$tan\varphi_{(C-)} = -\frac{\Delta E_{Q(C-)}}{\Delta E_{P+}}$$ where: $\Delta E_{Q(C-)}$ is the increase in reactive energy $E_{QC-)}$ (Budeanu/IEEE-1459) in a given averaging period, ΔE_{P+} is the increase in active power taken E_{P+} in a given averaging period
	$tan\varphi_{(L-)}$	-	$$tan\varphi_{(L-)} = \frac{\Delta E_{Q(L-)}}{\Delta E_{P+}}$$ where: $\Delta E_{Q(L-)}$ is the increase in reactive energy $E_{Q(L-)}$ (Budeanu/IEEE-1459) in a given averaging period, ΔE_{P+} is the increase in active power taken E_{P+} in a given averaging period
	$tan\varphi_{(C+)}$	-	$$tan\varphi_{(C+)} = -\frac{\Delta E_{Q(C+)}}{\Delta E_{P+}}$$ where: $\Delta E_{Q(C+)}$ is the increase in reactive energy $E_{Q(C+)}$ (Budeanu/IEEE-1459) in a given averaging period, ΔE_{P+} is the increase in active power taken E_{P+} in a given averaging period
Harmonic components of voltage and current	U_{hx} I_{hx}	V A	method of harmonic subgroups according to IEC 61000-4-7 x (harmonic order) = 1..256
Total Harmonic Distortion for voltage, referred to the fundamental component	*THD-F U*	-	$$THDF\ U = \frac{\sqrt{\sum_{h=2}^{k} U_h^2}}{U_1} \times 100\%$$ where U_h is the h-th harmonic of voltage U_{A-N} U_1 is fundamental component of voltage U_{A-N} k = 40, 50, 256
Total Harmonic Distortion for voltage, referred to RMS	*THD-R U*	-	$$THDR\ U = \frac{\sqrt{\sum_{h=2}^{k} U_h^2}}{U_{ARMS}} \times 100\%$$ where U_h is the h-th harmonic of voltage U_{A-N} k = 40, 50, 256
Total Harmonic Distortion for current, referred to the fundamental component	*THD-F I*	-	$$THDF\ I = \frac{\sqrt{\sum_{h=2}^{k} I_h^2}}{I_1} \times 100\%$$ where I_h is the h-th harmonic of current I_A I_1 is fundamental component of current I_A k = 40, 50, 256
Total Harmonic Distortion for current, referred to RMS	*THD-R I*	-	$$THDR\ I = \frac{\sqrt{\sum_{h=2}^{k} I_h^2}}{I_{ARMS}} \times 100\%$$ where I_h is the h-th harmonic of current I_A k = 40, 50, 256
Total Demand Distortion	*TDD*	%	$$TDD = \frac{\sqrt{\sum_{h=2}^{50} I_h^2}}{I_L} \times 100\%$$ where I_h is the h-th harmonic of current I_A I_L is the demand current (in auto-mode I_L maximum average fundamental current from all measured current channels and whole recording period)
Interharmonic components of voltage and current	U_{ihx} I_{ihx}	V A	method of interharmonic subgroups acc. to IEC 61000-4-7 x (interharmonic order) = 0..256 (sub-harmonic also includes the 5 Hz bin)

Total Interharmonic Distortion for voltage, referred to the fundamental component	*TID-F U*	-	$$TIDF\ U = \frac{\sqrt{\sum_{ih=0}^{k} U_{ih}^2}}{U_1} \times 100\%$$ where U_{ih} is the *ih*-th interharmonic of voltage U_{A-N} U_1 is fundamental component of voltage U_{A-N} *k* = 40, 50, 256
Total Interharmonic Distortion for voltage, referred to RMS	*TID-R U*	-	$$TIDR\ U = \frac{\sqrt{\sum_{ih=0}^{k} U_{ih}^2}}{U_{ARMS}} \times 100\%$$ where U_{ih} is the *ih*-th interharmonic of voltage U_{A-N} *k* = 40, 50, 256
Total Interharmonic Distortion for current, referred to the fundamental component	*TID-F I*	-	$$TIDF\ I = \frac{\sqrt{\sum_{ih=0}^{k} I_{ih}^2}}{I_1} \times 100\%$$ where I_{ih} is *ih*-th interharmonic of current I_A I_1 is fundamental component of current I_A *k* = 40, 50, 256
Total Interharmonic Distortion for current, referred to RMS	*TID-R I*	-	$$TIDR\ I = \frac{\sqrt{\sum_{ih=0}^{k} I_{ih}^2}}{I_{ARMS}} \times 100\%$$ where I_{ih} is *ih*-th interharmonic of current I_A *k* = 40, 50, 256
Voltage crest factor	*CFU*	-	$$CFU\ = \frac{max\|U_i\|}{U_{ARMS}}$$ where the operator $max\|U_i\|$ expresses the highest absolute value of voltage U_{A-N} *samples* *i* = 16384 for 50 Hz and 60 Hz
Current crest factor	*CFI*	-	$$CFI\ = \frac{max\|I_i\|}{I_{ARMS}}$$ where the operator $max\|I_{and}\|$ expresses the highest absolute value of current I_A samples *i* = 16384 for 50 Hz and 60 Hz
K-Factor	*K-Factor*	-	$$KFactor = \frac{\sum_{h=1}^{k} I_h^2 h^2}{I_1^2}$$ where I_h is the *h*-th harmonic of current I_A I_1 is fundamental component of current I_A *k* = 40, 50, 256
Factor K	*Factor K*	-	$$FactorK = \sqrt{1 + \frac{e}{1+e}\left(\frac{I_1}{I}\right)^2 \sum_{h=2}^{n}\left(h^q\left(\frac{I_h}{I_1}\right)^2\right)}$$ *n* = 40, 50, 256 For explanations see the Power Quality Guide in a separate document.
Harmonic active power	P_h *h=1..256*	W	$$P_h = U_h I_h \cos\varphi_h$$ where U_h is the *h*-th harmonic of voltage U_{A-N} I_h is the *h*-th harmonic of current I_A φ_h is the angle between harmonics U_h and I_h
Harmonic reactive power	Q_h *h=1..256*	var	$$Q_h = U_h I_h \sin\varphi_h$$ where U_h is the *h*-th harmonic of voltage U_{A-N} I_h is the *h*-th harmonic of current I_A φ_h is the angle between harmonics U_h and I_h
Short-term flicker	P_{st}	-	calculated according to IEC 61000-4-15
Long-term flicker	P_{lt}	-	$$P_{LT} = \sqrt[3]{\frac{\sum_{i=1}^{N} P_{STi}^3}{N}}$$ where P_{STi} is subsequent i-th indicator of short-term flicker

Active energy (imported and exported)	E_{P+} E_{P-}	Wh	$E_{P+} = \sum_{i=1}^{M} P_+(i)T(i)$ $P_+(i) = \begin{cases} P(i) \ for \ P(and) > 0 \\ 0 \ for \ P(i) \leq 0 \end{cases}$ $E_{P-} = \sum_{i=1}^{M} P_-(i)T(i)$ $P_-(i) = \begin{cases} \lvert P(i) \rvert \ for \ P(and) < 0 \\ 0 \ for \ P(i) \geq 0 \end{cases}$ where: *i* is subsequent number of the 10/12-period measurement window *P(i)* represents active power *P* calculated in *i*-th measuring window *T(i)* represents duration of *i*-th measuring window (in hours)
Reactive energy (4-quadrant)	$E_{Q(L+)}$ $E_{Q(C-)}$ $E_{Q(L-)}$ $E_{Q(C+)-}$	varh	$E_{Q(L+)} = \sum_{i=1}^{M} Q_{L+}(i)T(i)$ $Q_{L+}(i) = Q(i)$ if $Q(i)>0$ i $P(i)>0$ $Q_{L+}(i) = 0$ in other cases $E_{Q(C-)} = \sum_{i=1}^{M} Q_{C-}(i)T(i)$ $Q_{C-}(i) = Q(i)$ if $Q(i)>0$ i $P(i)<0$ $Q_{C-}(i) = 0$ in other cases $E_{Q(L-)} = \sum_{i=1}^{M} Q_{L-}(i)T(i)$ $Q_{L-}(i) = \lvert Q(i) \rvert$ if $Q(i)<0$ i $P(i)<0$ $Q_{L-}(i) = 0$ in other cases $E_{Q(C+)} = \sum_{i=1}^{M} Q_{C+}(i)T(i)$ $Q_{C+}(i) = \lvert Q(i) \rvert$ if $Q(i)<0$ i $P(i)>0$ $Q_{C+}(i) = 0$ in other cases where: *i* is subsequent number of the 10/12-period measurement window *Q(i)* represents active power (Budeanu or IEEE1459) calculated in *i*-th measuring window P(i) represents calculated active power in the *i*-th measuring window *T(i)* represents duration of *i*-th measuring window (in hours)
Apparent energy	E_S	VAh	$E_S = \sum_{i=1}^{M} S(and)T(i)$ where: *i* is subsequent number of the 10/12-period measurement window, *S(i)* represents apparent power *S* calculated in *i*-th measuring window *T(i)* represents duration of *i*-th measuring window (in hours)

5.2 Split-phase network

Split-phase network
(parameters not mentioned are calculated as for single-phase)

Parameter			Method of calculation
Name	**Designa-tion**	**Unit**	
Total active power	P_{tot}	W	$P_{tot} = P_A + P_B$
Total Budeanu reactive power	Q_{Btot}	var	$Q_{Btot} = Q_{BA} + Q_{BB}$
Total reactive power of fundamental component	Q_{1tot}	var	$Q_{1tot} = Q_{1\,A} + Q_{1B}$
Total apparent power	S_{tot}	VA	$S_{tot} = S_A + S_B$
Total apparent distortion power	S_{Ntot}	VA	$S_{Ntot} = S_{NA} + S_{NB}$
Total Budeanu distortion power	D_{Btot}	var	$D_{Btot} = D_{BA} + D_{BB}$
Total Power Factor	PF_{tot}	-	$PF_{tot} = \frac{P_{tot}}{S_{tot}}$
Total displacement power factor	$\cos\varphi_{tot}$ DPF_{tot}	-	$\cos\varphi_{tot} = DPF_{tot} = \frac{1}{2}(\cos\varphi_A + \cos\varphi_B)$
Total tangent φ (4-quadrant)	$\tan\varphi_{tot(L+)}$	-	$tan\varphi_{tot(L+)} = \frac{\Delta E_{Qtot(L+)}}{\Delta E_{Ptot+}}$ where: $\Delta E_{Qtot(L+)}$ is the increase in total reactive energy $E_{Qtot(L+)}$ (Budeanu/IEEE-1459) in a given averaging period, ΔE_{Ptot+} is the increase in total active energy E_{Ptot+} in a given averaging period
	$\tan\varphi_{tot(C-)}$	-	$tan\varphi_{tot(C-)} = -\frac{\Delta E_{Qtot(C-)}}{\Delta E_{Ptot+}}$ where: $\Delta E_{Qtot(C-)}$ is the increase in total reactive energy $E_{Qtot(C-)}$ (Budeanu/IEEE-1459) in a given averaging period, ΔE_{Ptot+} is the increase in total active energy taken E_{Ptot+} in a given averaging period
	$\tan\varphi_{tot(L-)}$	-	$tan\varphi_{tot(L-)} = \frac{\Delta E_{Qtot(L-)}}{\Delta E_{Ptot+}}$ where: $\Delta E_{Qtot(L-)}$ is the increase in total reactive energy $E_{Qtot(L-)}$ (Budeanu/IEEE-1459) in a given averaging period, ΔE_{Ptot+} is the increase in total active energy taken E_{Ptot+} in a given averaging period
	$\tan\varphi_{tot(C+)}$	-	$tan\varphi_{tot(C+)} = -\frac{\Delta E_{Qtot(C+)}}{\Delta E_{Ptot+}}$ where: $\Delta E_{Qtot(C+)}$ is the increase in total reactive energy $E_{Qtot(C+)}$ (Budeanu/IEEE-1459) in a given averaging period, ΔE_{Ptot+} is the increase in total active energy taken E_{Ptot+} in a given averaging period

Total active energy (imported and exported)	E_{Ptot+} E_{Ptot-}	Wh	$$E_{Ptot+}=\sum_{i=1}^{M}P_{tot+}(i)T(i)$$ $$P_{tot+}(i)=\begin{cases}P_{tot}(i)\ for\ P_{tot}(and)>0\\ 0\ for\ P_{tot}(i)\le 0\end{cases}$$ $$E_{Ptot-}=\sum_{i=1}^{M}P_{tot-}(i)T(i)$$ where: *i* is subsequent number of the 10/12-period measurement window, $P_{tot}(i)$ represents total active power P_{tot} calculated in *i*-th measuring window *T(i)* represents duration of *i*-th measuring window (in hours)
Total Budeanu reactive energy (4-quadrant)	$E_{Qtot(L+)}$ $E_{Qtot(C-)}$ $E_{Qtot(L-)}$ $E_{Qtot(C+)}$	varh	$$E_{Qtot(L+)}=\sum_{i=1}^{M}Q_{L+}(i)T(i)$$ $Q_{L+}(i) = Q(i)$ if $Q(i)>0$ i $P(i)>0$ $Q_{L+}(i) = 0$ in other cases $$E_{Qtot(C-)}=\sum_{i=1}^{M}Q_{C-}(i)T(i)$$ $Q_{C-}(i) = Q(i)$ if $Q(i)>0$ i $P(i)<0$ $Q_{C-}(i) = 0$ in other cases $$E_{Qtot(L-)}=\sum_{i=1}^{M}Q_{L-}(i)T(i)$$ $Q_{L-}(i) = \|Q(i)\|$ if $Q(i)<0$ i $P(i)<0$ $Q_{L-}(i) = 0$ in other cases $$E_{Qtot(C+)}=\sum_{i=1}^{M}Q_{C+}(i)T(i)$$ $Q_{C+}(i) = \|Q(i)\|$ if $Q(i)<0$ i $P(i)>0$ $Q_{C+}(i) = 0$ in other cases where: *i* is subsequent number of the 10/12-period measurement window, *Q(i)* represents total reactive power (Budeanu or IEEE1459) calculated in *i*-th measuring window, *P(i)* represents total active power calculated in *i*-th measuring window, *T(i)* represents duration of *i*-th measuring window (in hours)
Total apparent energy	E_{Stot}	VAh	$$E_{Stot}=\sum_{i=1}^{M}S_{tot}(i)T(i)$$ where: *i* is subsequent number of the 10/12-period measurement window $S_{tot}(i)$ represents the total apparent power S_{tot} calculated in *i*-th measuring window *T(i)* represents duration of *i*-th measuring window (in hours)

5.3 3-phase 4-wire network

3-phase 4-wire network (parameters not mentioned are calculated as for single-phase)			
Parameter			**Method of calculation**
Name	**Designa-tion**	**Unit**	
Total active power	P_{tot}	W	$P_{tot} = P_A + P_B + P_C$
Total Budeanu reactive power	Q_{Btot}	var	$Q_{Btot} = Q_{BA} + Q_{BB} + Q_{BC}$
Total reactive power acc. to IEEE 1459	Q_1^+	var	$Q_1^+ = 3U_1^+ I_1^+ \sin\varphi_1^+$ where: $U1^+$ is the voltage positive sequence component (of the fundamental component $I1^+$ his the current positive sequence component (of the fundamental component) φ_1^+ is the angle between components U_1^+ and I_1^+
Effective apparent power	S_e	VA	$S_e = 3U_e I_e$ where: $U_e = \sqrt{\frac{3(U_A^2 + U_B^2 + U_C^2) + U_{AB}^2 + U_{BC}^2 + U_{CA}^2}{18}}$ $I_e = \sqrt{\frac{I_A^2 + I_B^2 + I_C^2 + I_N^2}{3}}$
Effective apparent distortion power	S_{eN}	VA	$S_{eN} = \sqrt{S_e^2 + S_{e1}^2}$ where: $S_{e1} = 3U_{e1} I_{e1}$ $U_{e1} = \sqrt{\frac{3(U_{A1}^2 + U_{B1}^2 + U_{C1}^2) + U_{AB1}^2 + U_{BC1}^2 + U_{CA1}^2}{18}}$ $I_{e1} = \sqrt{\frac{I_{A1}^2 + I_{B1}^2 + I_{C1}^2 + I_{N1}^2}{3}}$
Total Budeanu distortion power	D_{Btot}	var	$D_{Btot} = D_{BA} + D_{BB} + D_{BC}$
Total Power Factor	PF_{tot}	-	$PF_{tot} = \frac{P_{tot}}{S_e}$
Total displacement power factor	$\cos\varphi_{tot}$ DPF_{tot}	-	$\cos\varphi_{tot} = DPF_{tot} = \frac{1}{3}(\cos\varphi_A + \cos\varphi_B + \cos\varphi_C)$
Total tangent φ (4-quadrant)	$\tan\varphi_{tot(L+)}$ $\tan\varphi_{tot(C-)}$ $\tan\varphi_{tot(L-)}$ $\tan\varphi_{tot(C+)}$	-	calculated as for the split-phase network
Total active energy (imported and exported)	E_{P+tot} E_{P-tot}	Wh	calculated as for the split-phase network
Total Budeanu reactive energy (4-quadrant)	$E_{Qtot(L+)}$ $E_{Qtot(C-)}$ $E_{Qtot(L-)}$ $E_{Qtot(C+)}$	varh	calculated as for the split-phase network

Total apparent energy	E_{Stot}	VAh	$$E_{Stot}=\sum_{i=1}^{M}S_e(i)T(i)$$ where: i is subsequent number of the 10/12-period measurement window $S_e(i)$ represents the effective apparent power S_e, calculated in i-th measuring window $T(i)$ represents duration of i-th measuring window (in hours)
RMS value of zero voltage sequence	U_0	V	$$\underline{U_0}=\frac{1}{3}(\underline{U_{A1}}+\underline{U_{B1}}+\underline{U_{C1}})$$ $$U_0=mag(\underline{U_0})$$ where $\underline{U_{A1}}$, $\underline{U_{B1}}$, $\underline{U_{C1}}$ are vectors of fundamental components of phase voltages U_A, U_B, U_C Operator *mag()* indicates vector module
Voltage positive sequence component	U_1	V	$$\underline{U_1}=\frac{1}{3}(\underline{U_{A1}}+a\underline{U_{B1}}+a^2\underline{U_{C1}})$$ $$U_1=mag(\underline{U_1})$$ where $\underline{U_{A1}}$, $\underline{U_{B1}}$, $\underline{U_{C1}}$ are vectors of fundamental components of phase voltages U_A, U_B, U_C Operator *mag()* indicates vector module $$a=1e^{j120°}=-\frac{1}{2}+\frac{\sqrt{3}}{2}j$$ $$a^2=1e^{j240°}=-\frac{1}{2}-\frac{\sqrt{3}}{2}j$$
Voltage negative sequence component	U_2	V	$$\underline{U_2}=\frac{1}{3}(\underline{U_{A1}}+a^2\underline{U_{B1}}+a\underline{U_{C1}})$$ $$U_2=mag(\underline{U_2})$$ where $\underline{U_{A1}}$, $\underline{U_{B1}}$, $\underline{U_{C1}}$ are vectors of fundamental components of phase voltages U_A, U_B, U_C Operator *mag()* indicates vector module $$a=1e^{j120°}=-\frac{1}{2}+\frac{\sqrt{3}}{2}j$$ $$a^2=1e^{j240°}=-\frac{1}{2}-\frac{\sqrt{3}}{2}j$$
Voltage zero sequence unbalance ratio	u_0	%	$$u_0=\frac{U_0}{U_1}\cdot 100\%$$
Voltage negative sequence unbalance ratio	u_2	%	$$u_2=\frac{U_2}{U_1}\cdot 100\%$$
Current zero sequence component	I_0	A	$$\underline{I_0}=\frac{1}{3}(\underline{I_{A1}}+\underline{I_{B1}}+\underline{I_{C1}})$$ $$I_0=mag(\underline{I_0})$$ where $\underline{I_{A1}}$, $\underline{I_{B1}}$, $\underline{I_{C1}}$ are vectors of fundamental components for phase currents I_A, I_B, I_C Operator *mag()* indicates vector module
Current positive sequence component	I_1	A	$$\underline{I_1}=\frac{1}{3}(\underline{I_{A1}}+a\underline{I_{B1}}+a^2\underline{I_{C1}})$$ $$I_1=mag(\underline{I_1})$$ where $\underline{I_{A1}}$, $\underline{I_{B1}}$, $\underline{I_{C1}}$ are vectors of fundamental current components I_A, I_B, I_C Operator *mag()* indicates vector module

Current negative sequence component	I_2	A	$\underline{I_2} = \frac{1}{3}(\underline{I}_{A1} + a^2\underline{I}_{B1} + a\underline{I}_{C1})$ $I_2 = mag(\underline{I_2})$ where $\underline{I}_{A1}$, $\underline{I}_{B1}$, $\underline{I}_{C1}$ are vectors of fundamental components for phase voltages I_A, I_B, I_C Operator *mag()* indicates vector module
Current zero sequence unbalance ratio	i_0	%	$i_0 = \frac{I_0}{I_1} \cdot 100\%$
Current negative sequence unbalance ratio	i_2	%	$i_2 = \frac{I_2}{I_1} \cdot 100\%$

5.4 3-phase 3-wire networks

3-phase 3-wire networks (parameters: voltage and current, DC voltage and DC current, THD and K factors, symmetrical components and unbalance factors, flicker are calculated as for signle-phase circuits; instead of the phase voltages, phase-to-phase voltages are used)			
Parameter			**Method of calculation**
Name	**Designation**	**Unit**	
Phase-to-phase voltage U_{CA}	U_{CA}	V	$U_{CA} = -(U_{AB} + U_{BC})$
Current I_2 (Aron measuring circuits)	I_2	A	$I_2 = -(I_1 + I_3)$
Total active power	P_{tot}	W	$P_{tot} = \frac{1}{M}\left(\sum_{i=1}^{M} U_{iAC}I_{iA} + \sum_{i=1}^{M} U_{iBC}I_{iB}\right)$ where: U_{iAC} is a subsequent sample of voltage U_{A-C} U_{iBC} is a subsequent sample of voltage U_{B-C} I_{iA} is a subsequent sample of current I_A I_{iB} is a subsequent sample of current I_B M = 16384 for 50 Hz and 60 Hz
Total apparent power	S_e	VA	$S_e = 3U_eI_e$ where: $U_e = \sqrt{\frac{{U_{AB}}^2 + {U_{BC}}^2 + {U_{CA}}^2}{9}}$ $I_e = \sqrt{\frac{{I_A}^2 + {I_B}^2 + {I_{\circ C}}^2}{3}}$
Total reactive power (Budeanu and IEEE 1459)	Q_{tot}	var	$Q = N = sign\sqrt{S_e^2 - P^2}$ where *sign* is equal to 1 or -1. The sign is determined basing on the angle of phase shift between standardized symmetrical components of voltages and currents
Total Budeanu distortion power	D_{Btot}	var	$D_{Btot} = 0$

Effective apparent distortion power	S_{eN}	VA	$S_{eN} = \sqrt{{S_e}^2 + {S_{e1}}^2}$ where: $S_{e1} = 3U_{e1}I_{e1}$ $U_{e1} = \sqrt{\frac{{U_{AB1}}^2 + {U_{BC1}}^2 + {U_{CA1}}^2}{9}}$ $I_{e1} = \sqrt{\frac{{I_{A1}}^2 + {I_{B1}}^2 + {I_{C1}}^2}{3}}$
Total Power Factor	PF_{tot}	-	$PF_{tot} = \frac{P_{tot}}{S_e}$
Active energy (imported and exported)	E_{Ptot+} E_{Ptot-}	Wh	calculated as for the split-phase network
Total apparent energy	E_{Stot}	VAh	$E_{Stot} = \sum_{i=1}^{M} S_e(i)T(i)$ where: *i* is subsequent number of the 10/12-period measurement window *$S_e(i)$* represents the total apparent power S_e calculated in *i*-th measuring window *T(i)* represents duration of *i*-th measuring window (in hours)

6 Technical data

- Specifications are subject to change without prior notice. Recent revisions of technical documentation are available at the manufacturer's website.
- Basic uncertainty is the uncertainty of a measurement instrument at reference conditions specified in Table 7.
- Provided uncertainties apply to the analyzer without additional transformers and probes.
- The required warm-up time for the analyzer is minimum 30 minutes.
- Abbreviations:
  - m.v. - reference measured value,
  - U_{din} (declared input voltage) – value obtained by dividing nominal voltage U_{nom} by the voltage transducers ratio.
  - I_{rin} (rated input current) – value obtained by dividing nominal current I_{nom} by the current transducers ratio. For PQM-750 equipped with 5 A current transformers the I_{rin} equals 5 A.
  - I_{max} – maximum continuous input current. For PQM-750 I_{max} = 4 x I_{rin}.
  - U_{nom} – nominal voltage (includes transducers),
  - I_{nom} – nominal current range (includes transducers),
  - RMS – root mean square value,
  - n – harmonic order,
  - s.d. – significant digits (or significant figures) – in reference to resolution of measurement result, the value is recorded with the given number of significant digits, e.g. resolution for 230 V with 4 s.d. will be 0,1 V (notation 230,0 V); resolution for 5 A with 4 s.d. will be 0,001 A (notation 5,000 A).
  - δ_{ph} – additional uncertainty caused by the error of phase measurement between the voltage and current harmonics.

6.1 Voltage inputs

Voltage inputs	
Number of inputs	5 – U1, U2, U3, N, E (earth / ground), 4 measuring channels
Maximum input voltage (referred to ground) Measurement category	1000 $V_{RMS,}$ 40…70 Hz or DC CAT IV 300 V / CAT III 600 V / CAT II 1000 V (up to 2000 m) CAT III 300 V / CAT II 600 V (2000 m up to 4000 m)
Peak input voltage (no ADC clamping)	±1500 V
Analog pass band (-3 dB)	170 kHz
Transducers ratio	defined by user
Impedance of measurement inputs (to ground)	6 MΩ || 15 pF
CMRR	>70 dB (50 Hz)

6.2 Current inputs

Current inputs	
Number of inputs	5 (I1…I5)
Input type	Isolated, differential (current transformer)
Measurement category	CAT IV 150V / CAT III 300V
Rated input current I_{rin}	5 A_{RMS}
Maximum continuous input current I_{max}	20 A_{RMS}
Peak current (ADC range)	±70 A
Overload capability	continuous: 20 A_{RMS} < 10 s: 50 A_{RMS} < 1 s: 200 A_{RMS}
Analog pass band (-3dB)	170 kHz
Input Impedance (S1-S2)	≤ 4 mΩ
Transducers ratio	defined by user

6.3 Sampling and RTC

Sampling and RTC	
A/D converter	24-bit , 9 channels
Sampling rate	81.92 kHz for 50 Hz and 60 Hz Simultaneous sampling in all channels
Samples per period	1638.4 for 50 Hz; 1365.3 for 60 Hz
PLL synchronization	40..70 Hz
Reference channel for PLL	U1 (default; possibility to switch to other channels)
Real-time clock	±3.5 ppm max (approx. ±9 sec./month) in the temperature range of -20°C…+55°C

6.4 Transient module (optional)

Transient detection module	
Number of input channels	4 (U1, U2, U3, N)
Peak input voltage	± 6000 V
Analog pass band (-3dB)	2.5 MHz
A/D converter	4-channel, 12-bit, simultaneous sampling in all channels
Sampling frequency	10 MHz, 5 MHz, 1 MHz, 500 kHz, 100 kHz (user selectable)
Waveform recording time	from 2000 to 20000 samples (from 200 µs to 200 ms, depending on settings)
Pretrigger time	from 10% to 90% of the recording time
Detection method	- transient amplitude (50 V…5000 V) - slew rate (dV/dt; from 100 V/500 µs to 100 V/5 µs) - absolute voltage threshold (from 1.5 U_{nom} to 5000 V or from U_{nom} to 5000 V, depending on system type)
Inactivity time after detection (hold-off)	3 s

6.5 Measured parameters - accuracy, resolution and ranges

6.5.1 Reference conditions

Table 7. Reference conditions for testing acc. to IEC 62586-1

Reference conditions	
Ambient temperature	23°C ±2°C
Relative Humidity	40…60%
Auxiliary supply voltage	Rated power supply voltage ±1%
Voltage unbalance	100% ±0.5% U_{din} on all channels
Continuous, external mag-netic field	≤ 40 A/m (d.c.) ≤ 3A / m (a.c.) for 50/60 Hz frequency
DC voltage and DC current	none
Waveforms	sinusoidal
Frequency	50 Hz ±0.5 Hz or 60 Hz ±0.5 Hz
Harmonics	0% to 3% U_{din}
Interharmonics	0% to 0.5% U_{din}

6.5.2 The measurement uncertainty due to ambient temperature

Basic uncertainty given in technical specifications is guaranteed for the reference temperature given in Table 7. Outside this range, the maximum variation caused by change of air temperature from reference conditions shall not exceed the measurement uncertainty multiplied by M, where M is given in Fig. 34. The multiplier has a value of 1.0 in the ambient temperature range of 0°C…+45°C. Above +45°C and up to +55°C, the multiplier rises in linear manner up to 2.0. Below 0°C (down to -20°C), the multiplier rises in linear manner up to 1.8.

Example: Basic uncertainty for RMS voltage measurement is ±0.1% U_{din}. The reference measurement taken in the reference condition shall be within ±0.1% U_{din}. Then, as the temperature varies, the measurement may only vary by the amount given below:
at -20°C, may vary from reference measurement by ±0.18% U_{din} (multiplier 1.8)
at -10°C, may vary from reference measurement by ±0.14% U_{din} (multiplier 1.4)
at 0°C, may vary from reference measurement by ±0.1% U_{din} (multiplier 1.0)
at +45°C, may vary from reference measurement by ±0.1% U_{din} (multiplier 1.0)
at +55°C, may vary from reference measurement by ±0.2% U_{din} (multiplier 2.0)

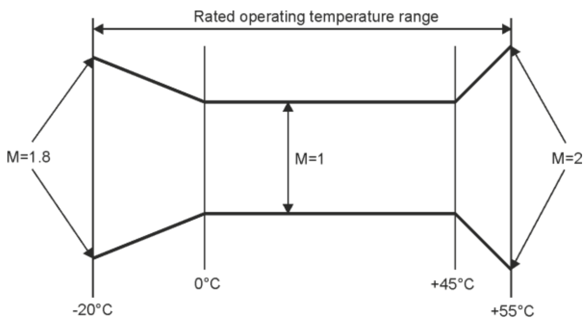


Fig. 34. Measurement variation multiplier M as a function of ambient temperature.

6.5.3 RMS Voltage

Parameter	Range and conditions	Resolution	Basic uncertainty
U_{RMS} (AC+DC)	10% $U_{din} \le U_{RMS} \le$ 150% U_{din} for 64 V $\le U_{din} \le$ 690 V	4 s.d.	±0.1% U_{din}

6.5.4 Voltage Crest Factor

Parameter	Range and conditions	Resolution	Basic uncertainty
CF U	1…6,5 for 64 V $\le U_{din} \le$ 230 V 1...1.65 for 64 V $\le U_{din} \le$ 690 V	0.01	±5%

6.5.5 RMS Current

Parameter	Range and conditions	Resolution	Basic uncertainty
I_{RMS} (AC)	$I_{RMS} \le$ 1% I_{rin}	4 s.d.	±0.01% I_{rin}
	1% $I_{rin} \le I_{RMS} \le$ 5% I_{rin}		±0.4%
	10% $I_{rin} \le I_{RMS} \le$ 400% I_{rin}		±0.2%

6.5.6 Current Crest Factor

Parameter	Range and conditions	Resolution	Basic uncertainty
CF I	1…10 for 1% $I_{rin} \le I_{RMS} \le$ 100% I_{rin}	0.01	±5%

6.5.7 Frequency

Parameter	Range and conditions	Resolution	Basic uncertainty
f_{10s} 10-second measure-ment	40…70 Hz 10% $U_{din} \le U_{RMS} \le$ 150% U_{din} 64 V $\le U_{din} \le$ 690 V	0.001 Hz	±0.01 Hz

6.5.8 Voltage harmonics, THD U

Parameter	Range and conditions	Resolution	Basic uncertainty
U_{hRMS} amplitude Harmonic order 0…256	$U_{RMS} \le$ 120 % U_{din} for 64 V $\le U_{din} \le$ 690 V	4 s.d.	±0.05% U_{din} if m.v. < 1% U_{din} ±5% if m.v. ≥ 1% U_{din} Harmonic subgroups acc. to IEC 61000-4-7, class I
THD-F U_{50} THD-R U_{50} (harmonics 1…50) THD-F U_{256} THD-R U_{256} (harmonics 1…256)	0 %...20% 80% $U_{din} \le U_{RMS} \le$ 120% U_{din} for 64 V $\le U_{din} \le$ 690 V	0.01%	±0.3% (absolute uncertainty)

6.5.9 Current harmonics, THD I, TDD, K-Factor, Factor K

Parameter	Range and conditions	Resolution	Basic uncertainty
I_{hRMS} amplitude Harmonic order 0…256	$I_{RMS} \leq 120\%\ I_{rin}$	4 s.d.	±0.15% I_{rin} if m.v.<3% I_{rin} ±5% if m.v. ≥3% I_{rin} Harmonic subgroups acc. to IEC 61000-4-7, class I
THD-F I_{50} THD-R I_{50} (harmonics 1…50)	0 %...100% 10% $I_{rin} \leq I_{RMS} < I_{rin}$	0.01%	±0.3% (absolute uncertainty)
THD-F I_{256} THD-R I_{256} (harmonics 1…256)	100 %...200% 10% $I_{rin} \leq I_{RMS} < I_{rin}$	0.01%	±0.3% × THD/100 (absolute uncertainty)
TDD (n = 2..256)	0 %...100% 10% $I_{rin} \leq I_L < I_{rin}$	0.01%	±0.3% (absolute uncertainty)
K-Factor (harmonics 1…50)	1.0…50.0 for $I_{RMS} \geq 1\%\ I_{rin}$	0.01	±10%
Factor K (harmonics 1…50) Configurable e and q parameters	1.0…50.0 for $I_{RMS} \geq 1\%\ I_{rin}$	0.01	±10%

6.5.10 Angles between voltage and current harmonics

Parameter	Range and conditions	Resolution	Nominal frequency	Basic uncertainty
φ_{hUI}	-180°…+180° 80% $U_{din} \leq U_{RMS} < 150\%\ U_{din}$ 10% $I_{rin} \leq I_{RMS} \leq I_{rin}$ 64 V ≤ U_{din} ≤ 690 V order n ≤ 256	0.1 °	50 Hz	≤0.05° for n = 1 ≤1° for 2 ≤ n ≤ 60 ≤4° for 61 ≤ n ≤ 256
			60 Hz	≤0.05° for n = 1 ≤1° for 2 ≤ n ≤ 50 ≤4° for 51 ≤ n ≤ 256

6.5.11 Voltage interharmonics, TID U

Parameter	Range and conditions	Resolution	Basic uncertainty
U_{ihRMS} amplitude Interharmonic order 0…256 0-order interharmonic includes also 5 Hz bin	$U_{RMS} \leq 120\ \%\ U_{din}$ for 64 V ≤ U_{din} ≤ 690 V	4 s.d.	±0.05% U_{din} if m.v. < 1% U_{din} ±5% if m.v. ≥ 1% U_{din} Interharmonic subgroups acc. to IEC 61000-4-7, class I
TID-F U_{50} TID-R U_{50} (interharmonics 0…50) TID-F U_{256} TID-R U_{256} (interharmonics 0…256)	0 %...20% 80% $U_{din} \leq U_{RMS} \leq 120\%\ U_{din}$ for 64 V ≤ U_{din} ≤ 690 V	0.01%	±0.3% (absolute uncertainty)

6.5.12 Current interharmonics, TID I

Parameter	Range and conditions	Resolution	Basic uncertainty
I_{ihRMS} amplitude Interharmonic order 0…256 0-order interharmonic includes also 5 Hz bin	$I_{RMS} \leq 120\% I_{rin}$	4 s.d.	$\pm 0.15\% I_{rin}$ if m.v.<3% I_{rin} ±5% if m.v. ≥3% I_{rin} Interharmonic subgroups acc. to IEC 61000-4-7, class I
TID-F I_{50} TID-R I_{50} (interharmonics 0…50) TID-F I_{256} TID-R I_{256} (interharmonics 0…256)	0 %...20% $10\% I_{rin} \leq I_{RMS} < I_{rin}$	0.01%	±0.3% (absolute uncertainty)

6.5.13 Active power and energy

Parameter	Conditions (64 V ≤ U_{din} ≤ 690 V)	Power Factor / cos φ	Basic uncertainty
Active power P Active energy E_P IEC 62053-22 class 0.2S I_{min} = 0.05 A I_{rin} = 5 A I_{max} = 20 A	$I_{min} \leq I_{RMS} < 5\% I_{rin}$	1	±0.4 %
	$5\% I_{rin} \leq I_{RMS} \leq I_{max}$	1	±0.2 %
	$2\% I_{rin} \leq I_{RMS} < 10\% I_{rin}$	0.5 inductive 0.8 capacitive	±0.5 %
	$10\% I_{rin} \leq I_{RMS} \leq I_{max}$	0.5 inductive 0.8 capacitive	±0.3 %
	$10\% I_{rin} \leq I_{RMS} \leq I_{max}$	0.25 inductive 0.5 capacitive	±0.5 %

6.5.14 Reactive power and energy

Parameter	Conditions (64 V ≤ U_{din} ≤ 690 V)	sin φ (inductive or capacitive)	Basic uncertainty
Reactive power Q1/QB Reactive energy E_Q IEC 62053-24 klasa 0.5S I_{min} = 0.05 A I_{rin} = 5 A I_{max} = 20 A	$I_{min} \leq I_{RMS} < 5\% I_{rin}$	1	±1.0 %
	$5\% I_{rin} \leq I_{RMS} \leq I_{max}$	1	±0.5 %
	$5\% I_{rin} \leq I_{RMS} < 10\% I_{rin}$	0.5	±1.0 %
	$10\% I_{rin} \leq I_{RMS} \leq I_{max}$	0.5	±0.5 %
	$10\% I_{rin} \leq I_{RMS} \leq I_{max}$	0.25	±1.0 %

6.5.15 Apparent power and energy

Parameter	Conditions (64 V ≤ U_{din} ≤ 690 V)	Basic uncertainty
Apparent power S Apparent energy E_S I_{rin} = 5 A I_{max} = 20 A	$2\% I_{rin} \leq I_{RMS} < 5\% I_{rin}$	±0.4 %
	$5\% I_{rin} \leq I_{RMS} \leq I_{max}$	±0.2 %

6.5.16 Displacement power factor (cosφ/DPF) and Power Factor

Parameter	Conditions	Basic uncertainty
cosφ / DPF PF Accuracy class 0.5 I_{rin} = 5 A I_{max} = 20 A	64 V ≤ U_{din} ≤ 690 V 50% U_{din} ≤ U_{RMS} < 150% U_{din} 10% I_{rin} ≤ I_{RMS} ≤ I_{max} |cosφ| ≥ 0,5 |PF| ≥ 0,5	±0.05

6.5.17 Harmonics active and reactive powers

Parameter	Conditions	Reso-lution	Basic uncertainty (1)
Active and reactive power of har-monics	80% U_{din} ≤ U_{RMS} < 150% U_{din} 5% I_{rin} ≤ I_{RMS} ≤ I_{rin} 64 V ≤ U_{din} ≤ 690 V order h ≤ 256	4 s.d.	$\pm\sqrt{\delta_{P1}^2 + \delta_{ph}^2}$ % for active harmonics power $\pm\sqrt{\delta_{Q1}^2 + \delta_{ph}^2}$ % for reactive harmonics power where: δ_{P1} – basic measurement uncertainty for active power (sinusoidal conditions), δ_{Q1} – basic measurement uncertainty for reactive power (sinusoidal conditions), δ_{ph} – uncertainty resulting from phase shift between voltage and current har-monics.

(1) See section 6.5.18. Estimating measurement uncertainty values for power and energy.

6.5.18 Estimating measurement uncertainty values for power and energy

The total measurement uncertainty for power, active and reactive energy and harmonics 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):

$$\Delta_{P,Q} \cong \sqrt{\Delta_{Uh}^2 + \Delta_{Ih}^2 + \Delta_{ph}^2}$$

where: $\delta_{P,Q}$ – measurement uncertainty for active or reactive power,
δ_{Uh} – total measurement uncertainty of voltage harmonic amplitude (analyzer, transducers),
δ_{Ih} – total measurement uncertainty of current harmonic amplitude (analyzer, transducers),
δ_{ph} – additional uncertainty of the measurement of the phase between voltage and current har-monics.

δ_{ph} uncertainty may be calculated when the phase angle is known for the considered frequency band. Table 8 shows the phase error between voltage and current harmonics (without external trans-ducers).

Table 8. Phase error of PQM-750 analyzer depending on frequency.

Frequency range	50/60 Hz	100…3000 Hz	3001..15360 Hz
Error	≤0.05°	≤1°	≤4°

Phase error introduced by transducers and probes 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, probes, and the analyzer.

The uncertainty of the 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 Δφ means the total phase error for a given frequency. The conclusion which can be drawn from these relationships is that power measurement uncertainty for the same phase error very clearly depends on the displacement power factor between current and voltage. It is shown in Fig. 35.

Example

Calculation of measurement uncertainty of 15th harmonic active power.
Conditions: $\varphi = 60°$ *(cosφ=0.5),* $U_{RMS} \cong U_{din}$ *,* $I_{RMS} = 5\%\ I_{rin}$.

Basic uncertainty is $\pm\sqrt{\mathbf{0.5^2 + \delta_{ph}^2}}\ \%$.

For the frequency of 15th harmonic (750 Hz @ f_{nom}*= 50 Hz) phase error of the analyzer is 1.0° maximum. After substituting equation:*

$$\boldsymbol{\delta_{ph} = 100\left(1 - \frac{cos(\varphi+\Delta\varphi)}{cos\varphi}\right) = 100\left(1 - \frac{cos(61°)}{cos(60°)}\right) = 3.04\%}$$

therefore, the measurement uncertainty is:

$$\boldsymbol{\delta = \pm\sqrt{0.5^2 + 3.04^2} = \pm 3.08\ \%}$$

These calculations do not take into account additional errors introduced by external transducers.

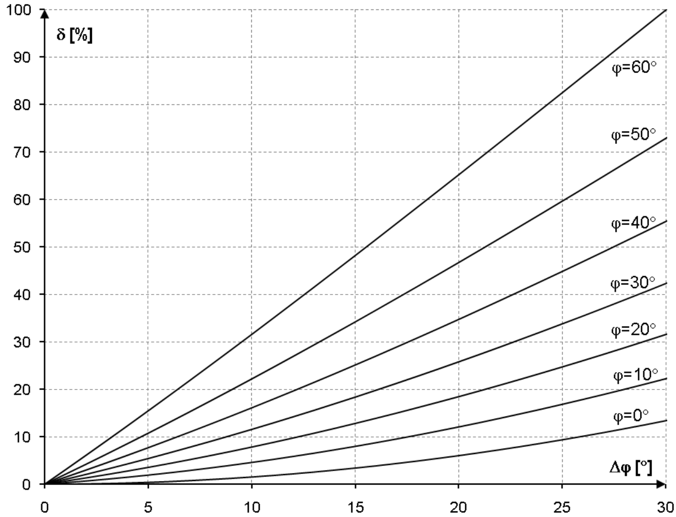


Fig. 35. Additional uncertainty due to the phase error, depending on the phase angle.

6.5.19 Flicker

Parameter	Range and conditions	Resolution	Basic uncertainty
P_{st} (10 min.) P_{lt} (2 h) Class F1 according to IEC 61000-4-15	0.2…10 80% U_{din} ≤ U_{RMS} < 150% U_{din} 64 V ≤ U_{din} ≤ 690 V	0.01	±5% within the values presented in tables of IEC 61000-4-15 standard

6.5.20 Unbalance

Parameter	Range and conditions	Resolution	Basic uncertainty
Negative sequence unbalance u_2 Zero sequence unbalance u_0	0.0%...20.0% for 80% U_{din} ≤ U_{RMS} < 150% U_{din} 64 V ≤ U_{din} ≤ 690 V	0.1%	±0.15% (absolute uncertainty)

6.5.21 Mains signalling

Parameter	Range and conditions	Resolution	Basic uncertainty
Amplitude of ripple control signal U_{R1}, U_{R2}	5 Hz ≤ f_R ≤ 30000 Hz	4 s.d.	±0.15% U_{din} if 1% U_{din} ≤ U_R < 3% U_{din} ±5% if 3% U_{din} ≤ U_R ≤ 15% U_{din}

6.5.22 Transients

Parameter	Range and conditions	Resolution	Basic uncertainty
Voltage transients	±6000 V	4 s.d.	±(5% + 25 V)

6.5.23 Emissions in 2 kHz do 9 kHz band

Parameter	Range and conditions	Basic uncertainty
Amplitude U_{xHz} x=2100 to 8900 step 200 35 bins	Single frequency in the 2-9 kHz range, 200 Hz step 64 V ≤ U_{din} ≤ 690 V	±0,1% U_{din} if m.v. < 2% U_{din} ±5% if m.v. ≥ 2% U_{din}

6.5.24 Emissions in 8 kHz do 150 kHz band

Parameter	Range and conditions	Basic uncertainty
Amplitude U_{xkHz} x=8 to 150 step 2 72 bins	Single frequency in the 8-150 kHz range, 2 kHz step Max. 100 V_{rms} 64 V ≤ U_{din} ≤ 690 V	±(5% + 0,1V)

6.6 Event detection

6.6.1 Dips, swells, interruptions

Parameter	Range and conditions	Resolution	Basic uncertainty
Residual voltage Swell voltage	0.0%...150.0% U_{din}	4 s.d.	±0.2% U_{din}
Event duration	hh:mm:ss.ms	Half cycle	One cycle
Detection threshold	Set by the user in percentage of U_{din} or absolute values. Event detection based on the measurement of $U_{RMS(1/2)}$ (1-cycle RMS refreshed every ½ cycle).		

6.6.2 Rapid voltage changes (RVC)

Parameter	Range and conditions	Resolution	Basic uncertainty
ΔU_{SS} ΔU_{MAX}	0.0%...150.0% U_{din}	4 c.z.	±0.2% U_{din}
Event duration	hh:mm:ss.ms	Half cycle	One cycle
Detection threshold	Set by the user in percentage of U_{din} or absolute values. Event detection based on the measurement of $U_{RMS(1/2)}$ (1-cycle RMS refreshed every ½ cycle).		

6.6.3 RMS current (min., max.)

Parameter	Range and conditions	Resolution	Basic uncertainty
I_{MIN} I_{MAX}	0.0%...100.0% I_{max}	4 c.z.	±0.2% I_{rin}
Event duration	hh:mm:ss.ms	Half cycle	One cycle
Detection threshold	Set by the user in percentage of U_{din} or absolute values. Event detection based on the measurement of $U_{RMS(1/2)}$ (1-cycle RMS refreshed every ½ cycle).		

6.6.4 Other parameters

Parameter	Range	Detection method
Frequency	40 ... 70 Hz	Basing on 10/12-cycle value
Voltage crest factor	1.0 ... 10.0	Basing on 10/12-cycle value
Current crest factor	1.0 ... 10.0	Basing on 10/12-cycle value
Voltage unbalance factor for negative sequence	0.0 ... 20.0%	Basing on 10/12-cycle value
Current unbalance factor for negative sequence	0.0 ... 20.0%	Basing on 10/12-cycle value
Short-term flicker P_{st}	0...20	Basing on 10-minute value
Long-term flicker P_{lt}	0...20	Basing on 2-hour value
Active power P	Depending on the configuration	Basing on 10/12-cycle value
Reactive power Q	Depending on the configuration	Basing on 10/12-cycle value
Apparent power S	Depending on the configuration	Basing on 10/12-cycle value
Distortion power D / Apparent distortion power S_N	Depending on the configuration	Basing on 10/12-cycle value
Power Factor PF	0…1	Basing on 10/12-cycle value
Displacement power factor cosφ/ DPF	0…1	Basing on 10/12-cycle value
4-quadrant tanφ	0…10	Basing on 10/12-cycle value
Active energy E_P	Depending on the configuration	Checked every 10/12 cycles
4-quadrant reactive energy E_Q	Depending on the configuration	Checked every 10/12 cycles
Apparent energy E_S	Depending on the configuration	Checked every 10/12 cycles
Total harmonic distortion of voltage THD-F	0…100%	Basing on 10/12-cycle value
Total harmonic distortion of current THD-F	0…200%	Basing on 10/12-cycle value
Voltage harmonic amplitudes	0 ... 100% or absolute values	Basing on 10/12-cycle value; Independent thresholds for selected harmonics in the range of 2...256
Current harmonic amplitudes	0…200% or absolute values	Basing on 10/12-cycle value; Independent thresholds for selected harmonics in the range of 2...256
Total interharmonics distortion of voltage TID-F	0…100%	Basing on 10/12-cycle value
Total interharmonics distortion of current TID-F	0…100%	Basing on 10/12-cycle value
Voltage interharmonics amplitudes	0 ... 100% or absolute values	Basing on 10/12-cycle value; Independent thresholds for selected interharmonics in the range of 0...256
Current interharmonics amplitudes	0 ... 100% or absolute values	Basing on 10/12-cycle value; Independent thresholds for selected interharmonics in the range of 0...256
K-Factor	1...50	Basing on 10/12-cycle value
Mains signalling	0…U_{nom}	Basing on 10/12-cycle value
Voltage transients (option “TR”)	50…5000 V or dV/dt	Independent transient detection module, Amplitude or slew rate method
Waveshape variation (voltage only)	1.0…100% U_{nom}	Comparison of two subsequent periods of voltage waveform. See sec. 4.9.1.
Phase jumps (voltage only)	1…359° (angle degrees)	Comparison of two or three fundamental voltage phase angles calculated from subsequent periods of voltage waveform

6.6.5 Event detection hysteresis

Parameter	Range	Calculation method
Event hysteresis	0..10%	For each of the parameters calculated as a percentage of maximum threshold value (for exceptions see section 4.9)

6.7 Recording

Recorder	
Averaging time [(1)]	200 ms, 1 s, 3 s, 5 s, 10 s, 15 s, 30 s, 1 min, 3 min, 5 min, 10 min, 15 min, 30 min
Waveforms snapshot	Option to record three periods of waveforms of active channels, after each averaging period
Recording time	Depending on the configuration (see 2.8.2)
Memory	8 GB internal memory, 8 GB user removable microSD card, option of extending up to 32 GB
Memory write model	Linear, circular

(1) Averaging times shorter than 10 sec. are in fact equal to a multiple of the mains cycle: 200 ms – 10/12 cycles, 1 s – 50/60 cycles, 3 s – 150/180 cycles, 5 s – 250/300 cycles.

Recorded parameters (User data set)	Mean value	Minimum value	Maximum value	Instantaneous value
RMS phase/phase-to-phase voltage (depending on the type of system) U_{RMS}	✓	✓	✓	
RMS phase-to-phase voltage (only 3-phase 4-wire and split-phase systems) U_{RMS}	✓	✓	✓	
Voltage DC component	✓	✓	✓	
RMS current I_{RMS}	✓	✓	✓	
Frequency f	✓	✓	✓	
Voltage crest factor CF U	✓	✓	✓	
Current crest factor CF I	✓	✓	✓	
Unbalance factors for negative and positive sequence, symmetrical components: negative, positive, zero (voltage) U_0, U_1, U_2, u_0, u_2	✓	✓	✓	
Unbalance factors for negative and positive sequence, symmetrical components: negative, positive, zero (current) I_0, I_1, I_2, i_0, i_2	✓	✓	✓	
Flicker severity P_{st} and P_{lt}	✓	✓	✓	
Active power (imported and exported) P_+, P_-	✓	✓	✓	
Reactive power (4-quadrant) Q_1/Q_B	✓	✓	✓	
Apparent power S	✓	✓	✓	
Distortion power D / Apparent distortion power S_N	✓	✓	✓	
Power Factor PF	✓	✓	✓	
Displacement power factor cosφ/DPF	✓	✓	✓	
tanφ factor (4-quadrant): tanφ	✓	✓	✓	
Active energy (consumed and supplied) E_{P+}, E_{P-}				✓
Reactive energy (4-quadrant) E_Q				✓
Apparent energy E_S				✓
Voltage total harmonic distortion THD-F U, THD-R U	✓	✓	✓	
Current total harmonic distortion THD-F I, THD-R I	✓	✓	✓	
Total Demand Current (TDD)	✓			
Voltage harmonic amplitudes $U_{h0}…U_{h256}$	✓	✓	✓	

Current harmonic amplitudes $I_{h0} \ldots I_{h256}$	✓	✓	✓	
Voltage total interharmonic distortion TID-F U, TID-R U	✓	✓	✓	
Current total interharmonic distortion TID-F I, TID-R I	✓	✓	✓	
Voltage interharmonics amplitudes $U_{ih0} \ldots U_{ih256}$	✓	✓	✓	
Current interharmonics amplitudes $I_{ih0} \ldots I_{ih256}$	✓	✓	✓	
K-Factor	✓	✓	✓	
Factor K	✓	✓	✓	
Harmonics active power $P_{h1} \ldots P_{h256}$	✓	✓	✓	
Harmonics reactive power $Q_{h1} \ldots Q_{h256}$	✓	✓	✓	
Angles between voltage and current harmonics $\varphi_1 \ldots \varphi_{256}$	✓	✓	✓	
Ripple control signals U_{R1}, U_{R2}	✓	✓	✓	
Emissions in the 2-9 kHz band (35 bands)	✓	✓	✓	
Emissions in the 8-150 kHz band (72 bands)	✓	✓	✓	

6.8 Power supply

Power supply	
Input voltage range (nominal) Option “AC”	85…264 V AC, 40…70 Hz 120…300 V DC
Input voltage range (nominal) Option “DC”	18…60 V DC Protected against reverse polarity
Overvoltage category of the power supply (option “AC”)	CAT III 300 V
Power supply isolation rating (option “AC”, option “DC”)	1000 V_{RMS}
Analyzer power consumption (max)	10 W (without external modules)

6.9 Battery

Rechargeable battery	
Type	Li-Ion 3.67 V, 5.5 Ah
Operating time on battery	approx. 1 h
Battery charging time (fully discharged battery)	< 12 h
Charging temperature range	0°C …+60°C
Current consumption from battery in analyzer off mode (mains power disconnected)	< 1 mA
Transportation standard	UN 38.8 certified

6.10 Supported mains types

Types of supported mains (directly and indirectly)	
1-phase	1-phase with a neutral conductor (voltage terminals: U1, N, E) I_1, I_4/I_N, I_5/I_E
2-phase (split-phase)	Split phase with a neutral conductor (voltage terminals: U1, U2, N, E) I_1, I_2, I_4/I_N, I_5/I_E
3-phase 4-wire	3-phase 4-wire with a neutral conductor (voltage terminals: U1, U2, U3, N, E) I_1, I_2, I_3, I_4/I_N, I_5/I_E
3-phase 3-wire	3-phase 3-wire (voltage terminals: U1, U2, U3, E) I_1, I_2, I_3
3-phase 3-wire (Aron)	3-phase 3-wire (voltage terminals: U1, U2, U3, E) I_1, I_2, I_3 (I_2 calculated)

6.11 Communication protocols

Communication protocols	
HTTPS	TCP port 443, embedded webserver service for configuration and viewing
MODBUS RTU (RS-485-1)	Galvanic isolated (1000 V_{RMS}) Max. transmission speed 921.6 kbit/s Supported baudrates: 57600, 115200 (default), 128000, 230400, 256000, 460800, 921600 Default setting: 8 data bits, 1 stop bit, even parity
MODBUS TCP/IP	TCP port 502 (default), max. 5 clients
IEC 61850	TCP port 102
SonelFrame	TCP port 4005, proprietary Sonel S.A. protocol for managing the analyzer

6.12 Ethernet

Ethernet	
Connector	2x RJ45 10/100 Base-T acc. to IEEE 802.3 LED green: flashing: data transfer on: link is up off: no connection LED yellow: on: 10 Base-T connection off: 100 Base-T connection
Isolation voltage	1000 V rms
Transmission rate	10 / 100 Mbit/s
Cable type	CAT 5/6 STP/FTP (shielded)
Max. cable length for 10/100 Base-T	100 m
PoE PD	Port LAN1, compliant with IEEE 802.3 at (25.5 W) and IEEE 802.3 af (15.4 W)

6.13 RS-485 ports

RS-485 ports	
Number of interfaces	2 (RS-485-1, RS-485-2)
Isolation type	Digital isolator (separate for both interfaces)
Isolation rating	1000 V rms
Max. transmission speed	921.6 kbit/s
Max. number of nodes	256
Max. cable length	1200 m (up to 100 m @ 921.6 kbit/s)
Termination resistors	Switchable on both interfaces – "ON" (top) means resistor enabled (120 Ω between A and B)
Default function	RS-485-1: MODBUS RTU RS-485-2: IRIG-B input

6.14 Digital inputs

Digital inputs	
Number of inputs	2
Voltage range	0…250 V AC rms or DC
Voltage polarity	Don't care
H level L level	20…250 V AC rms or DC 0…10 V AC rms or DC
Isolation type	Optocoupler
Isolation rating	1000 V rms
Input impedance	200 kΩ
Signal frequency	DC … 70 Hz

6.15 Digital outputs

Digital outputs	
Number of outputs	2
Output type	Mechanical relay
Contact configuration	SPDT
Nominal voltage	250 V AC
Nominal current	6 A
Rated load AC1	1500 VA
Rated load AC15	300 VA
Breaking capacity DC1: 30/110/220 V	6 A / 0.2 A / 0.12 A
Isolation rating	1000 V rms

6.16 Watchdog output relay

Watchdog output relay		
Operation mode	The relay is energized and the contacts are closed if the analyzer is operating (powered on)	
Output type	Mechanical relay	
Contact configuration	SPST-NO	
Nominal voltage	250 V AC	
Nominal current	5 A	
Rated load	Resistive load: 5A at 250 V AC 5A at 30 V DC	Inductive load (cosφ = 0.4): 2A at 250 V AC 2A at 30 V DC
Isolation rating	1000 V rms	

6.17 1-wire temperature sensor input

1-wire temperature sensor input	
Operation mode	Isolated parasitic power 1-wire bus
Max. number of sensors	4
Max. bus length	100 m
Compatible sensors	DS18B20, DS18B20-PAR
Isolation type	Digital isolator
Isolation rating	1000 V rms

6.18 Replaceable coin cell

Replaceable coin cell	
Battery type	Lithium 3V CR1025
Lifetime	5 years

6.19 Environmental conditions and other technical data

Environmental conditions	
Operating temperature range:	-20°C…+55°C
Storage temperature range	-30°C…+60°C
Humidity	10…90% RH
Ingress protection (according to IEC 60529)	IP30 Indoor use only
Solar radiation	Do not use in direct sunlight conditions, use sunshade cover.
Reference conditions	Ambient temperature: 0°C…+40°C Humidity: 40…60%
Operating altitude	up to 2000 m (up to 4000 m with derated measurement category, see section 6.1)
Dimensions	157 x 87 x 59 mm
Weight	0.55 kg
Display	color LCD TFT, 320x240 pixels, diagonal 2.4", resistive touchpanel
Data Memory	built-in memory card 8 GB (internal) + 8 GB (user removable micro SD card), option of extending up to 32 GB

6.20 Electrical safety

Electrical safety	
Compliance with	IEC 61010-1:2010/AMD1:2016 (Ed. 3.0) IEC 61010-2-030:2017 (Ed. 2.0)
Measurement category	CAT IV 300 V / CAT III 600 V / CAT II 1000 V (voltage inputs) CAT IV 150 V / CAT III 300 V (current inputs) pollution class 2
Overvoltage category (internal AC/DC power supply, “AC” option)	III 300 V pollution class 2
Insulation	single + protective earth terminal (Protective Class I)

6.21 Electromagnetic compatibility

EMC	
Compliance with	IEC 61010-1:2010/AMD1:2016 (Ed. 3.0) IEC 61010-2-030:2017 (Ed. 2.0)
Measurement category	CAT IV 300 V / CAT III 600 V / CAT II 1000 V (voltage inputs) pollution class 2
Overvoltage category (internal AC/DC power supply, “AC” option)	III 300 V pollution class 2
Insulation	single + protective earth terminal (Protective Class I)
Electromagnetic compatibility	IEC 61000-6-5:2015 EN 55032 (CISPR 32)
Immunity to electrostatic discharge	IEC 61000-4-2 Air discharge: 8 kV Contact discharge: 6 kV
Immunity to radio frequency interferences	IEC 61000-4-3 sinusoidal modulation 80% AM, 1 kHz 80…1000 MHz, 10 V/m 1.4…2.0 GHz, 3 V/m 2.0…2.7 GHz, 1 V/m

Immunity to series of fast transients/bursts	IEC 61000-4-4 Amplitude 2 kV, 100 kHz (voltage and current inputs, power supply inputs) Amplitude 2 kV, 100 kHz (RS-485 ports, digital inputs, 1-wire input, relay outputs)
Immunity to surges	IEC 61000-4-5 Amplitude 6 kV (voltage inputs L-L), Amplitude 6 kV (voltage inputs L-E) Amplitude 1 kV (line-earth; RS-485 ports, digital inputs and outputs, 1-wire input)) Amplitude 2 kV (line-earth; current inputs)
Immunity to conducted disturbances, induced by radio-frequency fields	IEC 61000-4-6 sinusoidal modulation 80% AM, 1 kHz 0.15…80 MHz, 10 V (voltage inputs, power supply, RS-485 ports, digital inputs and outputs, 1-wire input)
Immunity to voltage dips and short interruptions	IEC 61000-4-11 AC power supply port 70% U_T, 1 cycle 40% U_T, 50 cycles test for U_T=85 V and U_T=264 V
	IEC 61000-4-29 DC power supply port 70% U_T, 0.1 s 40% U_T, 0.1 s 0% U_T, 0.05 s test for U_T=18 V and U_T=60 V
Immunity to conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz	IEC 61000-4-16 RS-485 ports, voltage inputs, digital inputs, LAN ports, DC power supply (DC power supply only signalling voltages) Signalling voltages: 10 V continuous 100 V for 1 s Conducted, common mode disturbances: Level 3: 15-150 Hz: 10 V to 1 V 150 Hz-1.5 kHz: 1 V 1.5-15 kHz: 1 V to 10 V 15-150 kHz: 10 V
Emission of radiated RF disturbances	CISPR 32, class A: 30…230 MHz, 40 dB(μV/m) at 10 m 230…1000 MHz, 47 dB(μV/m) at 10 m 1…3 GHz: 56 dB(μV/m), avg, 76 dB(μV/m), peak, at 3 m 3…6 GHz: 60 dB(μV/m), avg, 80 dB(μV/m), peak, at 3 m
Emission of conducted disturbances	CISPR 32, class A: AC power supply Levels for a quasi-peak detector: 0.15 kHz…0.5 MHz: 66 dBμV avg 0.5 MHz…30 MHz: 60 dBμV avg

EN 55032 (CISPR 32) Compliance statement:

PQM-750 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 distance between affected devices).

6.22 Mechanical tests

Mechanical tests, De-energized state	**Standard and test level**	**Test requirement**
Behaviour to vibrations	IEC 60068-2-6 Test Fc	Frequency range: 10 Hz do 150 Hz Sweeping frequency range: 58 Hz to 60 Hz 0,075 mm, 2 Hz to 9 Hz, 20 cycles 0,5 g_n, 9 Hz to 150 Hz, 20 cycles
Behaviour to earthquakes	IEC 60068-2-57	1-35 Hz, Zero period acceleration = 1 g_n horizontal, 0,5 g_n vertical
Mechanical tests, De-energized state **(during transport)**	**Standard and test level**	**Test requirement**
Endurance to vibrations	IEC 60068-2-6 Test Fc	Frequency range: 5 Hz to 150 Hz Sweeping frequency range: 8 Hz to 9 Hz 7,5 mm, 2 Hz to 9 Hz, 20 cycles 2 g_n, 9 Hz to 150 Hz, 20 cycles
Resistance to shocks	IEC 60068-2-27 Test Ea	15 g_n / 11 ms, 3 pulses
Free fall tests	IEC 60068-2-31 Test Ec, procedure 1	Test conducted with equipment in the transport packaging Free fall 500 mm Number of stresses: 2 each side

6.23 Standards

Conformity Note
SONEL S.A. hereby declares that the device type PQM-750 complies with Directives 2014/35/UE and 2014/30/UE. The full text of the EU Declaration of Conformity is available at the following website address:
https://sonel.pl/en/download/declaration-of-conformity/

Standards	
Product standard	IEC 62586-1:2017 (Ed. 2.0) IEC 62586-2:2017/COR1:2018 (Ed. 2.0) Product classification: PQI-A-FI1 (measurement class **A** acc. to IEC 61000-4-30, **F**ixed, **I**ndoor, EMC environment G)
Measurement methods	IEC 61000-4-30:2015/COR1:2016 (Ed. 3.0) class A
Measurement accuracy	IEC 61000-4-30:2015/COR1:2016 (Ed. 3.0) class A
Power quality	EN 50160:2010
Flicker	IEC 61000-4-15:2010/COR1:2012 (Ed. 2.0)
Harmonics	IEC 61000-4-7:2002/AMD1:2008 (Ed. 2.0)
Safety	IEC 61010-1:2010/AMD1:2016 (Ed. 3.0) IEC 61010-2-030:2017 (Ed. 2.0)
EMC	EN 55032 (CISPR 32):2015 IEC 61000-6-5:2015
Quality standard	design, construction and manufacturing are ISO 9001 compliant

6.23.1 Compliance with standards

The analyzer is designed to meet the requirements of the following standards.

Product standards:

- IEC 62586-1:2017 – Power quality measurement in power supply systems - Part 1: Power quality instruments (PQI).
- IEC 62586-2:2017 – Power quality measurement in power supply systems - Part 2: Functional tests and uncertainty requirements.

Standards for measuring network parameters:

- IEC 61000-4-30:2015/COR1:2016 (Ed. 3.0) – Electromagnetic compatibility (EMC) - Testing and measurement techniques - Power quality measurement methods.
- IEC 61000-4-7:2002/AMD1:2008 (Ed. 2.0) – Electromagnetic compatibility (EMC) – Testing and Measurement Techniques - General Guide on Harmonics and Interharmonics Measurements and Instrumentation for Power Supply Systems and Equipment Connected to them.
- IEC 61000-4-15:2010/COR1:2012 (Ed. 2.0) – Electromagnetic compatibility (EMC) – Testing and Measurement Techniques - Flickermeter - Functional and Design Specifications.
- EN 50160:2010 – Voltage characteristics of electricity supplied by public distribution networks.

Safety standards:

- IEC 61010-1:2010/AMD1:2016 (Ed. 3.0) – Safety requirements for electrical equipment for measurement control and laboratory use. Part 1: General requirements.
- IEC 61010-2-030:2017 (Ed. 2.0) – Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 2-030: Particular requirements for equipment having testing or measuring circuits

Standards for electromagnetic compatibility:

- EN 55032 (CISPR 32):2015 – Electromagnetic compatibility of multimedia equipment - Emission Requirements.
- IEC 61000-6-5:2015 – Electromagnetic compatibility (EMC) - Part 6-5: Generic standards - Immunity for equipment used in power station and substation environment.

The device meets all the requirements of Class A as defined in IEC 61000-4-30. The summary of the requirements is presented in the table below.

Table 9. Summary of selected parameters in terms of their compliance with the standards.

Aggregation of measurements at different intervals	IEC 61000-4-30 Class A: • Basic measurement time for parameters (voltage, current, harmonics, unbalance) is a 10-cycle interval for 50 Hz power supply system and 12-cycle interval for 60 Hz system, • Interval of 3 s (150 cycles for the nominal frequency of 50 Hz and 180 cycles for 60 Hz), • Interval of 10 minutes, • Interval of 2 hours, • Synchronization of aggregation intervals
Real-time clock (RTC) uncertainty	IEC 61000-4-30 Class A: • Clock synchronization to external GPS time using the GPS-1 receiver module with external antenna, • Clock synchronization to external IRIG-B signal (multiple analyzers can be synchronized to IRIG-B signal by using IRIG-B output from GPS-1 receiver module), • Built-in real time clock • RTC accuracy when GPS or IRIG-B signal is not available - better than ±0.3 s/day
Frequency	Compliant with IEC 61000-4-30 Class A of the measurement method and uncertainty
Power supply voltage	Compliant with IEC 61000-4-30 Class A of the measurement method and uncertainty
Voltage fluctuations (flicker)	The measurement method and uncertainty meets the requirements of IEC 61000-4-15 standard, class F1
Dips, interruptions and surges of supply voltage	Compliant with IEC 61000-4-30 Class A of the measurement method and uncertainty
Supply voltage unbalance	Compliant with IEC 61000-4-30 Class A of the measurement method and uncertainty
Voltage and current harmonics	Compliant with IEC 61000-4-30 Class A of the measurement method and uncertainty (IEC 61000-4-7 Class I)
Voltage and current interharmonics	Compliant with IEC 61000-4-30 Class A of the measurement method and uncertainty (IEC 61000-4-7 Class I)
Mains signalling voltage on the supply voltage	Compliant with IEC 61000-4-30 Class A of the measurement method and uncertainty
Rapid Voltage Changes (RVC)	Compliant with IEC 61000-4-30 Class A of the measurement method and uncertainty
Magnitude of current	Compliant with IEC 61000-4-30 Class A of the measurement method and uncertainty

6.23.2 Product specification according to IEC 62586

Product specification	PQI-A-FI1 (measurement class **A** acc. to IEC 61000-4-30, **F**ixed, **I**ndoor, EMC environment G)			
Symbol	**Function**	**Class acc. to IEC 61000-4-30**	**Range**	**Additional information**
f	power frequency	A	40…70 Hz	
U	magnitude of the supply voltage	A	10%...150% U_{din}	6,4…1000 V $U_{din} \leq 665$ V
P_{ST}, P_{LT}	flicker	A	P_{ST} 0.2…10	class F1
U_{dip}, U_{swl}	supply voltage dips and swells	A	–	
U_{int}	supply voltage interruption	A	–	
u_0, u_2	supply voltage unbalance	A	0.0%...20.0%	
U_h	voltage harmonics	A	200% of class 3 compatibility levels from IEC 61000-2-4	
U_{ih}	voltage interharmonics	A	200% of class 3 compatibility levels from IEC 61000-2-4	
MSV	mains signalling voltage	A	0...15% U_{din}	$U_{din} \leq 665$ V
Under/over	under/over deviation	*not applicable*	–	
RVC	rapid voltage change	A	–	
I	magnitude of current	A	0%...150% I_{rin}	
i_0, i_2	current unbalance	A	0,0%...20.0%	
I_h	current harmonics	A	200% of class 3 compatibility levels from IEC 61000-2-4	
I_{ih}	current interharmonics	A	200% of class 3 compatibility levels from IEC 61000-2-4	

Notes:

- U_{din} is declared input voltage of the analyzer i.e. taking into account the transducers. If transducers are not used then $U_{nom} = U_{din}$. If transducers are used then $U_{nom} = k \times U_{din}$, where k is the transducer ratio, eg. for a transducer 15 kV:100 V $\Rightarrow$ k=150, U_{nom}=15 kV, U_{din}=100 V.
- I_{rin} is nominal current range of the analyzer i.e. taking into account the transducers. For PQM-750 with 5 A current inputs I_{rin}=5 A. If no current transducers are used then $I_{nom} = I_{rin}$. If transducers are used then $I_{nom} = k \times I_{rin}$, where k is the transducer ratio, e.g. for a transducer 100 A : 5 A $\Rightarrow$ k=20, I_{nom}=100 A, I_{rin}=5 A.

7 Cleaning and maintenance

NOTE!

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

The casing of the analyzer may be cleaned with a soft, damp cloth using all-purpose detergents. Do not use any solvents or cleaning agents which might scratch the casing (powders, pastes, etc.).

The analyzer electronic system does not require maintenance.

8 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.
- In order to prevent a total discharge of the accumulators in the case of a prolonged storage, charge them from time to time.

9 Dismantling and utilization

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 local regulations concerning disposal of packages, waste batteries and accumulators.

10 Manufacturer

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

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.

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