PEM735

Power quality analyser
Software version 2.00.xx

PEM735_D00084_03_M_XXEN/04.2022

Manual **EN**

BENDER
The Power in Electrical Safety©

Bender GmbH & Co. KG
PO Box 1161 • 35301 Grünberg • Germany
Londorfer Str. 65 • 35305 Grünberg • Germany

Tel.: +49 6401 807-0
Fax: +49 6401 807-259

E-Mail: info@bender.de
www.bender.de

Photos: Bender Archive

Table of Contents

1. Important information

1.1 How to use this manual

*This manual is intended for **qualified personnel** working in electrical engineering and electronics!*

Always keep this manual within easy reach for future reference.
To make it easier for you to understand and revisit certain sections in this manual, we have used symbols to identify important instructions and information.
The meaning of these symbols is explained below:

DANGER

The signal word indicates that there is a high risk of danger,, that will result in death or serious injury if not avoided.

WARNING

*This signal word indicates a **medium risk of danger** that can lead to **death** or **serious injury** if not avoided.*

CAUTION

*This signal word indicates a **low level risk** that can result in **minor or moderate injury** or **damage to property** if not avoided.*

*This symbol denotes information intended to assist the user in making **optimum use** of the product.*

Although great care has been taken in the drafting of this operating manual, it may nevertheless contain errors and mistakes. Bender cannot accept any liability for injury to persons or damage to property resulting from errors or mistakes in this manual.

1.2 Technical support: Service and support

For commissioning and troubleshooting Bender offers you:

1.2.1 First level support

Technical support by phone or e-mail for all Bender products:

- Question about specific customer applications
- Commissioning
- Troubleshooting

Telephone	+49 6401 807-760*
Fax:	+49 6401 807-259
In Germany only:	0700BenderHelp (Tel. and Fax)
E-mail:	support@bender-service.de

1.2.2 Repair service

Repair, calibration, update and replacement service for Bender products

- Repair, calibration, testing and analysing Bender products
- Hardware and software update for Bender devices.
- Delivery of replacement devices for faulty or incorrectly delivered Bender devices.
- Extended warranty for Bender devices with in-house repair service resp. replacement devices at no extra cost.

Telephone	+49 6401 807-780** (technical issues) +49 6401 807-784**, -785** (commercial matters)
Fax:	+49 6401 807-789
E-mail:	repair@bender-service.de

Please send the devices for **repair** to the following address:

Bender GmbH, Repair-Service,
Londorfer Straße 65,
35305 Grünberg

1.2.3 Field service

On-site service for all Bender products:

- Commissioning, parameter setting, maintenance, troubleshooting for Bender products
- Analysis of the electrical installation in the building (power quality test, EMC test, thermography).
- Practical training courses for customers.

Telephone	+49 6401 807-752**, -762 **(technical issues)
	+49 6401 807-753** (commercial issues)
Fax:	+49 6401 807-759
E-mail:	fieldservice@bender-service.de
Internet:	www.bender.de

*Available from 7.00 a.m. to 8.00 p.m. on 365 days of the year (CET/UTC+1)
**Mo-Thu 7.00 a.m. - 8.00 p.m., Fr 7.00 a.m. - 13.00 p.m

1.3 Seminars

Bender is happy to provide training regarding the use of test equipment.
The dates of training courses and workshops can be found on the Internet at www.bender.de -> Know-how -> Seminars.

1.4 Delivery conditions

The conditions of sale and delivery set out by Bender apply.
For software products the "Softwareklausel zur Überlassung von Standard-Software als Teil von Lieferungen, Ergänzung und Änderung der Allgemeinen Lieferbedingungen für Erzeugnisse und Leistungen der Elektroindustrie" (software clause in respect of the licensing of standard software as part of deliveries, modifications and changes to general delivery conditions for products and services in the electrical industry) set out by the ZVEI (Zentralverband Elektrotechnik- und Elektronikindustrie e. V.) (German Electrical and Electronic Manufacturer's Association) also applies.
Conditions of sale and delivery can be obtained from Bender in printed or electronic format.

1.5 Inspection, transport and storage

Inspect the dispatch and equipment packaging for damage, and compare the contents of the package with the delivery documents. In the event of damage in transit, please contact Bender immediately.
The devices must only be stored in areas where they are protected from dust, damp, and spray and dripping water, and in which the specified storage temperatures can be ensured.

1.6 Warranty and liability

Warranty and liability claims in the event of injury to persons or damage to property are excluded if they can be attributed to one or more of the following causes:

- Improper use of the device.

- Incorrect mounting, commissioning, operation and maintenance of the device.
- Failure to observe the instructions in this operating manual regarding transport, commissioning, operation and maintenance of the device.
- Unauthorised changes to the device made by parties other than the manufacturer.
- Non-observance of technical data.
- Repairs carried out incorrectly and the use of replacement parts or accessories not approved by the manufacturer.
- Catastrophes caused by external influences and force majeure.
- Mounting and installation with device combinations not recommended by the manufacturer.

This operating manual, especially the safety instructions, must be observed by all personnel working on the device. Furthermore, the rules and regulations that apply for accident prevention at the place of use must be observed.

1.7 Disposal

Abide by the national regulations and laws governing the disposal of this device. Ask your supplier if you are not sure how to dispose of the old equipment.
The directive on waste electrical and electronic equipment (WEEE directive) and the directive on the restriction of certain hazardous substances in electrical and electronic equipment (RoHS directive) apply in the European Community. In Germany, these policies are implemented through the "Electrical and Electronic Equipment Act" (ElektroG). According to this, the following applies:

- Electrical and electronic equipment are not part of household waste.
- Batteries and accumulators are not part of household waste and must be disposed of in accordance with the regulations.
- Old electrical and electronic equipment from users other than private households which was introduced to the market after 13 August 2005 must be taken back by the manufacturer and disposed of properly.

For more information on the disposal of Bender devices, refer to our homepage at www.bender.de -> Service & support.

2. Safety instructions

2.1 General safety instructions

Part of the device documentation in addition to this manual is the enclosed " Safety instructions for Bender products".

2.2 Work activities on electrical installations

*Only **qualified personnel** are permitted to carry out the work necessary to install, commission and run a device or system.*

DANGER

Danger of electrocution due to electric shock!

Touching live parts of the system carries the risk of:

- *An electric shock*
- *Damage to the electrical installation*
- *Destruction of the device*

***Before installing and connecting the device, make sure** that the **installation** has been **de-energised**. Observe the rules for working on electrical installations.*

***Refer to the rated and supply voltage values** as specified in the technical data!*

If the device is being used in a location outside the Federal Republic of Germany, the applicable local standards and regulations must be complied with. European standard EN 50110 can be used as a guide.

2.3 Intended use

The PEM735 power quality analyser is intended for

- analysing energy and power (Power Analyser)
- monitoring the power supply quality (Power Quality)
- recording relevant data for energy management (Energy Management).

As a compact device for front panel mounting it is suitable for replacing analogue indicating instruments. The PEM735 can be used in three-phase 4-wire systems, three-phase 3-wire systems and in TN, TT and IT systems (see "Connection diagram voltage inputs" on page 24 ff). The current measurement inputs of the PEM are connected via external …/1 A or …/5 A measuring current transformers. In principle, measurements in medium and high-voltage systems are carried out via measuring current and voltage transformers.
Use for the intended purpose includes:

- Device-specific settings according to the installation and operating conditions on site.
- The observation of all information in the operating manual.

Any other use than that described in this manual is regarded as improper.
Although great care has been taken in the drafting of this operating manual, it may nevertheless contain errors and mistakes. Bender cannot accept any liability for injury to persons or damage to property resulting from errors or mistakes in this operating manual.

3. Device description

3.1 Area of application

For humans, electric current is not immediately visible. Power quality analysers for monitoring electrical parameters are used wherever energy consumption, power demand measurements or the quality of the supply voltage are to be made visible.
The PEM735 is suitable for monitoring

- Power generation systems (PV systems, CHPs, hydro power and wind power plants)
- Energy-intensive equipment and parts of installation
- Sensitive equipment

3.2 Device features

The PEM735 power quality analyser for power quality and energy management is characterised by the following features:

- Class A power analyser, certified according to DIN EN 61000-4-30:2008
- Monitoring of the power quality in accordance with EN 50160
- Accuracy class according to IEC 62053-22: 0.2 S
- TFT colour display (640 x 480) 5.7“
- Modbus RTU and Modbus TCP
- Memory: 2 GB (1 GB for data recording)
- Panel mounting 138x138
- Integrated web server
- Flicker measurement
- Detection and recording of transient events (40 µs)
- Sampling rate: 512 samples/cycle
- Freely configurable recorders for waveform, consumption and long-term recording
- Sampling rate of the measuring channels: 25.6 kHz
- Calculation of the total harmonic distortion THDU/THDI:
  harmonics up to the order 63
- Individual current/voltage harmonics
- Password protection

- History memory for minimum and maximum values of current, voltage, energy, power etc. for each month.
- Inputs and outputs:
  - 2 digital outputs,
  - 4 relay outputs,
  - 8 digital inputs (sampling: 1 kHz)
  - 2 LED pulse outputs for active and reactive energy
- Setpoints: 32 configurable setpoints (24 standard, 8 highspeed)
- System protocol:
  - 1024 entries
  - Setup changes
  - Setpoints
  - DI status changes
  - DO switching operations
- Communication:
  - Galvanically separated RS-485 interface (1,200 to 38,400 bit/s)
  - Modbus RTU protocol
  - Modbus TCP (100 Mbit/s)

Measurements at a glance

- Measured quantities

– Phase voltages	U_{L1}, U_{L2}, U_{L3} in V
– Line-to-line voltage	U_{L1L2}, U_{L2L3}, U_{L3L1} in V
– U4	in V
– Phase currents	I_1, I_2, I_3 in A
– Neutral current (calculated)	I_0 in A
– Neutral current (calculated) I_4 in A	
– Frequency	f in Hz
– Phase angle	for U and I in °
– Power per phase conductor	P in kW, Q in kvar, S in kVA
– Total power	P in kW, Q in kvar, S in kVA
– Displacement factor	cos φ
– Power factor	λ
– Active and reactive energy import	in kWh, kvarh
– Active and reactive energy export	in kWh, kvarh
– Voltage unbalance	in %
– Current unbalance	in %

  - Harmonic distortion (THD, TOHD, TEHD) for *U* and *I*
  - k-factor for *I*
  - Minimum and maximum values for *U*, *I*, r.m.s., fundamental component
- Measured quantities PQ
  - k-factor for *I*
  - THD, TOHD and TEHD for *U* and *I*
  - Harmonic analysis for P, Q and S for harmonics of the order 2…63
  - Fundamental component for *U, I, P, Q, S* and λ
  - Fundamental component for active and reactive energy (import and export)
  - Total harmonics for active energy
  - Individual harmonics 2…31 for active energy import
- Report in accordance with EN 50160
  - Power frequency
  - Supply voltage variations
  - Rapid voltage changes
  - Flicker severity
  - Voltage unbalance
  - Harmonic voltage up to the order 25 in % or RMS value
  - Interharmonic voltage for harmonics up to the order 25 in % or RMS value
  - THDU up to the order 40
  - Mains signalling
  - Voltage swells
  - Voltage sags
  - Interruptions
  - Transient overvoltages

3.3 Versions

PEM735 100/690 V, **50 Hz**; Current input 5 A
PEM735 100/690 V, **60 Hz**; Current input 5 A

3.4 Application example

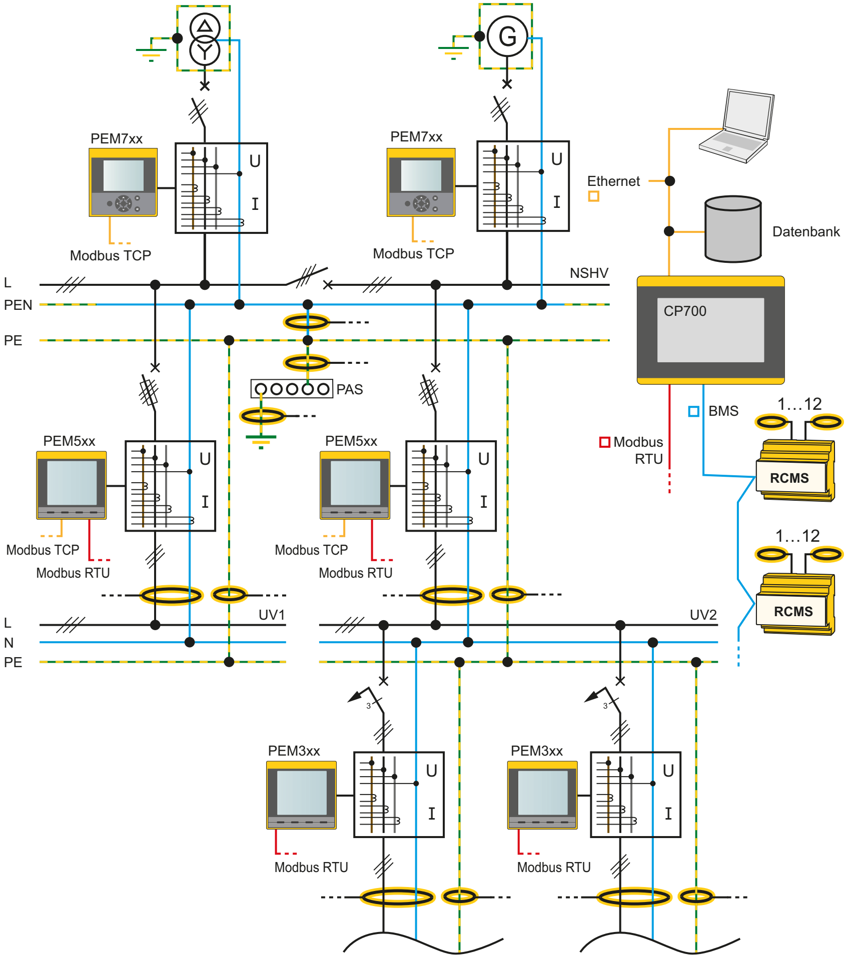


Fig. 3.1: Application example

3.5 Functional description

The PEM735 power quality analyser is suited for measuring and displaying electrical quantities of electricity networks. The PEM735 can measure currents, voltages, energy consumption and power as well as represent individual harmonic components of current and voltage for the assessment of voltage and current quality according to EN 50160.

The accuracy of the active energy metering corresponds to class 0.2 S, which is in compliance with the DIN EN 62053-22 (VDE 0418 Part 3-22):2003-11.
The current inputs are connected via external …/1 A or …/5 A measuring current transformers.

The large display of the panel mounting device makes the relevant measured quantities easily legible and enables fast configuration. In addition, the interfaces (RS-485 and Ethernet) allow central evaluation and processing of data. Switching operations can be monitored or initiated via the digital inputs and outputs (Example: switching off uncritical loads if the peak load threshold value is exceeded).

The PEM735 provides the following functions:

- Provision of energy consumption data for a well thought-out energy management
- Power quality monitoring for cost reduction and increased plant availability
- High resolution waveform recording allows analysis of power quality phenomena

4. Mounting and connection

4.1 Project planning

For any questions associated with project planning, please contact Bender:
Internet: www.bender.de
Telephone: +49-6401-807-0

4.2 Safety instructions

*Only **qualified personnel** are permitted to carry out the work necessary to install, commission and run a device or system.*

DANGER

Danger of electrocution due to electric shock!
Touching live parts of the system carries the risk of:

- *An electric shock*
- *Damage to the electrical installation*
- *Destruction of the device*

***Before installing and connecting the device, make sure** that the **installation** has been **de-energised**. Observe the rules for working on electrical installations.*
***Refer to the rated and supply voltage values** as specified in the technical data!*

4.3 Mounting the device

4.3.1 Dimension diagrams

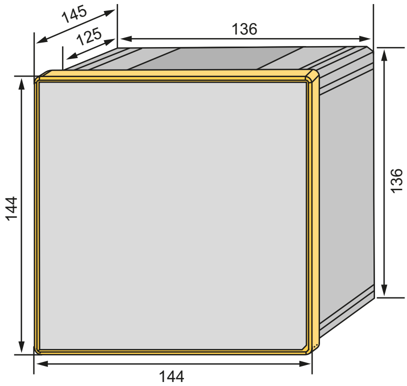


Fig. 4.1: Dimension diagram PEM735 (front view)

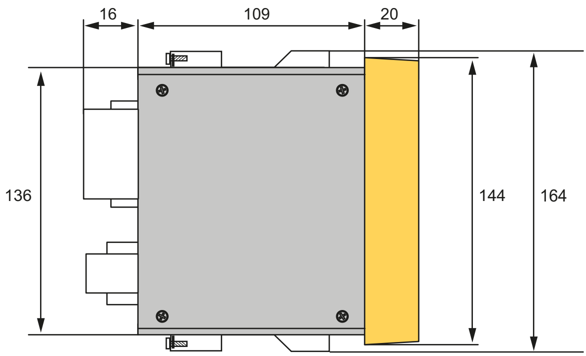


Fig. 4.2: Dimension diagram PEM735 (side view)

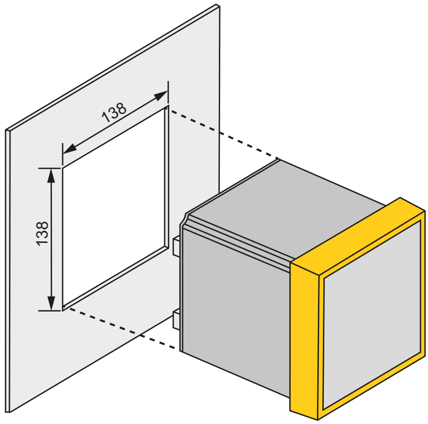


Fig. 4.3: Dimension diagram PEM735 (panel cutout)

4.3.2 Front panel mounting

A front-panel cutout of 138 mm x 138 mm is required for the device.

1. Unscrew the screws of the fixing brackets.
2. Slide the fixing brackets along the grooves provided in the enclosure and remove them.
3. Insert the device into the installation opening of the front panel.
4. Refit the brackets in the reverse order.
5. Tighten the screws of the brackets.
6. Check the device to ensure that it is firmly installed in the front panel.

The device is installed.

4.4 Connection of the device

4.4.1 Safety instructions

DANGER

Danger of electric shock!
Follow the basic safety rules when working with electricity.
***Refer to the rated and supply voltage values** as specified in the technical data!*

4.4.2 Back-up fuses

Back-up fuse supply voltage: 6 A
Back-up fuse measuring inputs:
Voltage 6 A
Current inputs without fuse

"The breaking capacity of the overcurrent protection device should be compatible with the current rating of the installation". (DIN EN 61010-1(VDE 0411-1):2011-07 9.6.1 Overcurrent protection).
A suitable separator must be provided. For more details, refer to the operating manuals of the measuring current transformers currently used.

*If the supply voltage U_S is supplied by an **IT system** , **both line conductors** are to be protected.*

4.4.3 Connection of measuring current transformers

When connecting the measuring current transformers it is important to consider the requirements of DIN VDE 0100-557 (VDE 0100-557) – Low voltage installations - Part 5: Selection and erection of electrical equipment - Chapter 557: Auxiliary circuits.

4.5 Connection details

- Connect the PEM735 to the supply voltage (terminals A1 and A2 or +/-). Connect terminal " ⏚ " to the protective conductor.
- Power protection by a 6 A fuse. If being supplied from an IT system, both lines have to be protected by a fuse.
- Connection to the RS-485 bus is carried out via the terminals D+, D- and SH. Up to 32 devices can be connected to the bus. The maximum cable length for the bus connection of all devices is 1200 m.

4.6 Wiring diagram

Connect the device according to the wiring diagram. The connections are located on the back of the device.

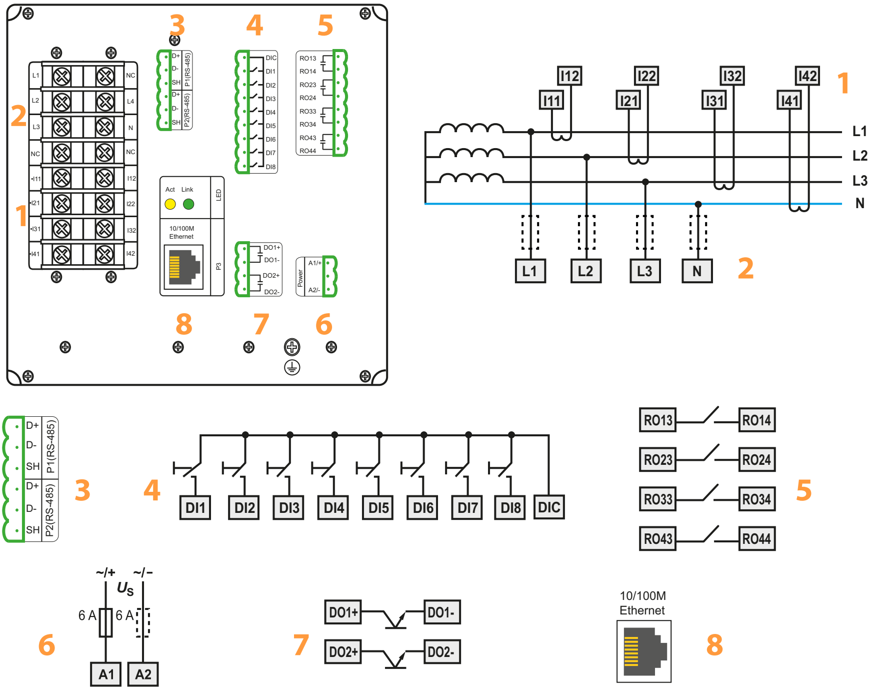


Fig. 4.4: Wiring diagram

Legend to wiring diagram

1	Connection to the system to be monitored
2	Measuring voltage inputs: The measuring leads should be protected with appropriate back-up fuses.
3	RS-485 bus connection
4	Digital inputs
5	Relay outputs
6	Supply voltage. Power protection by a 6 A fuse, quick response. If being supplied from an **IT system** both lines have to be protected by a fuse.
7	Digital outputs (N/O contacts "solid state")
8	Modbus TCP connection

4.7 Connection diagram voltage inputs

4.7.1 Three-phase 4-wire system (TN, TT, IT system)

The PEM735 can be used in three-phase 4-wire systems, independent of the type of distribution system (TN, TT, IT system).

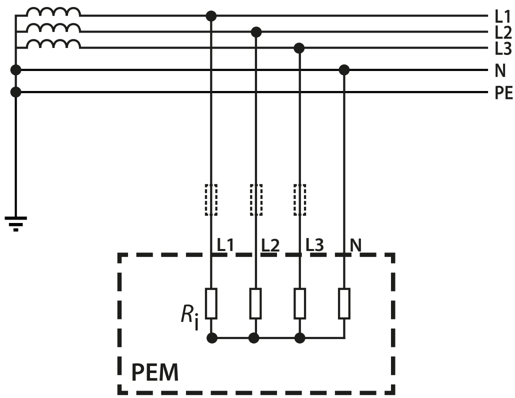


Fig. 4.5: Connection diagram three-phase 4-wire system (e.g. TN-S system)

4.7.2 Three-phase 3-wire system

The PEM735 can be used in three-phase 3-wire systems.

> *When used in a three-wire system the **wiring mode DELTA** is required.*

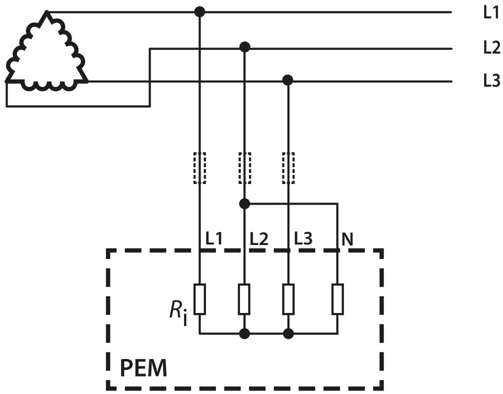


Fig. 4.6: Connection diagram three-phase-3-wire system (U_{LL} = 400 V)

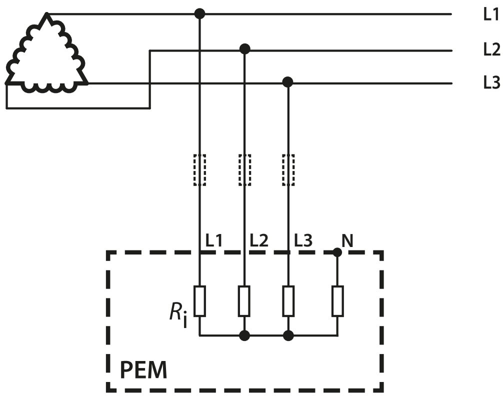


Fig. 4.7: Connection diagram three-phase-3-wire system (U_{LL} = 690 V)

4.7.3 Connection via voltage transformers

The coupling of the voltage transformers allows the use of the measuring device in medium and high-voltage systems.
The transformation ratio can be adjusted in the PEM735 (1…1,000,000).

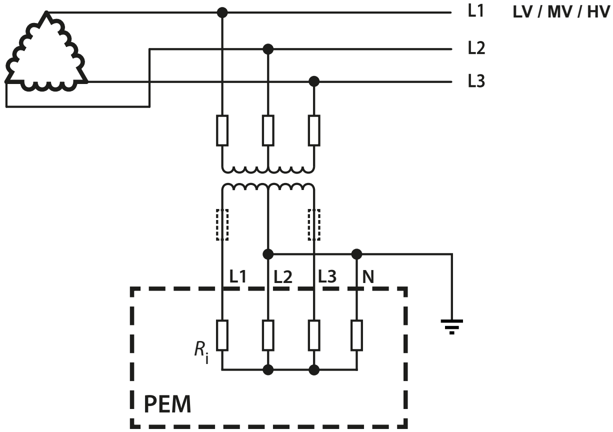


Fig. 4.8: Connection diagram 3-wire system via voltage transformers

4.8 Digital inputs

The PEM735 features 8 digital inputs. The inputs are supplied by a galvanically separated DC 24 V voltage. An external circuit providing at least a current of I_{min} > 2.4 mA is required for triggering the inputs.

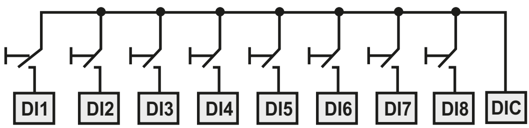


Fig. 4.9: Digital inputs

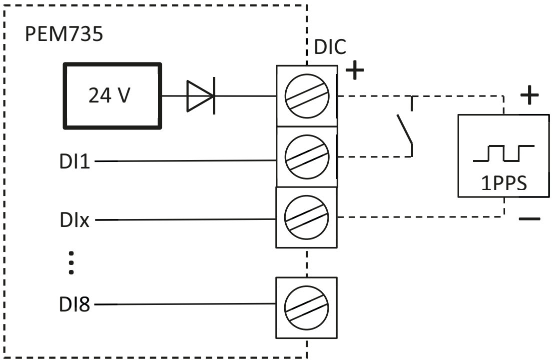
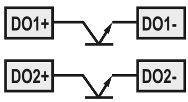


Fig. 4.10: Digital inputs (internal connection diagram)

Note: PPS = pulse per second, pulse/s

4.9 Digital outputs DO1…2

The PEM735 features two configurable outputs (N/O contacts "solid state relay").

	**Rated operational voltage**	max. 30 V
	Rated operational current	50 mA

Tab. 4.1: Digital outputs

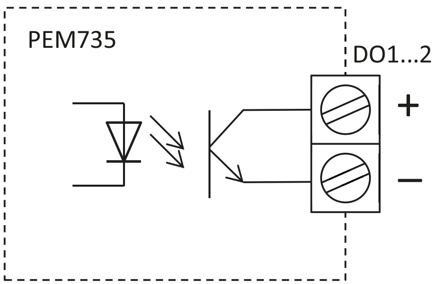
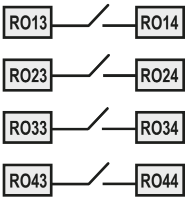


Fig. 4.11: Digital outputs (internal connection diagram)

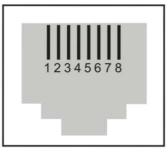
4.10 Relay outputs RO1…4

The PEM735 features four relay outputs.

	**Rated operational voltage**	AC 250 V or DC 30 V
	Rated operational current	3 A

Tab. 4.2: Relay outputs

4.11 Modbus TCP (connector pin assignment)

RJ45	**Pin**	**assignment**
	1	Transmit Data +
	2	Transmit Data –
	3	Receive Data +
	4, 5, 7, 8	not used
	6	Receive Data –

Tab. 4.3: Modbus TCP (connector pin assignment)

5. Commissioning and operation

5.1 Getting to know the operating elements

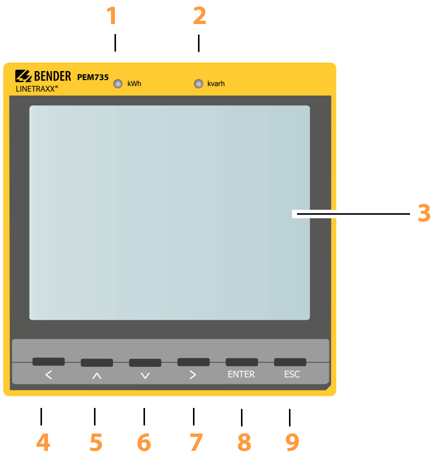


Fig. 5.1: Operating elements

Legend to operating elements

No.	Element	Description
1	kWh LED	Pulse output, see "LED display (Energy pulsing)" on page 30
2	kvarh LED	
3	LC display	
4	<	back; submenu: scroll; move left on display
5	Λ	main menu: move upwards in the menu; increase number/selection
6	V	main menu: move down in the menu; decrease number/selection
7	>	select menu item; submenu: scroll; move right on display

8	"ENTER" button	ok; switch to the submenu "freeze" waveform recorder depending on the submenu, other function (information on the display)
9	"ESC" button	exit submenu; "unfreeze" waveform recorder depending on the submenu, other function (information on the display)

Tab. 5.1: Legend operating elements

5.2 LED display (Energy pulsing)

The PEM735 features two red LEDs on the front side to display active and reactive energy measurements: kWh and kvarh. The LEDs flash each time a certain energy value is reached (1 kWh or 1 kvarh).
The amount of energy displayed corresponds to the amount of energy measured by the measuring device. In order to relate the flashing frequency to the amount of energy, the transformation ratios and the pulse constant have to be considered.

$$\text{Pulses per kWh} = \frac{\text{Pulse constant}}{\text{ratio VT x ratio CT}}$$

$$\text{Amount of energy per pulse} = \frac{\text{ratio VT x ratio CT}}{\text{Pulse constant}}$$

Note:
VT = voltage transformer
CT = measuring current transformer

5.3 Check proper connection

Observe the relevant standards and regulations for installation and connection as well as the operating manual of the respective device.

5.4 Before switching on

Consider the following questions before switching on:

1. Does the connected supply voltage correspond to the information on the nameplate?
2. Has the nominal insulation voltage of the measuring current transformers been exceeded?

3. Does the measuring current transformer's maximum current correspond to the nameplate information of the connected device?

5.5 Switching on

To switch the device on, follow the steps below:

1. Connect the supply voltage.
2. Set the language
   The following figure illustrates the language setting schematically so that you can easily set the language when you start working with the PEM735.

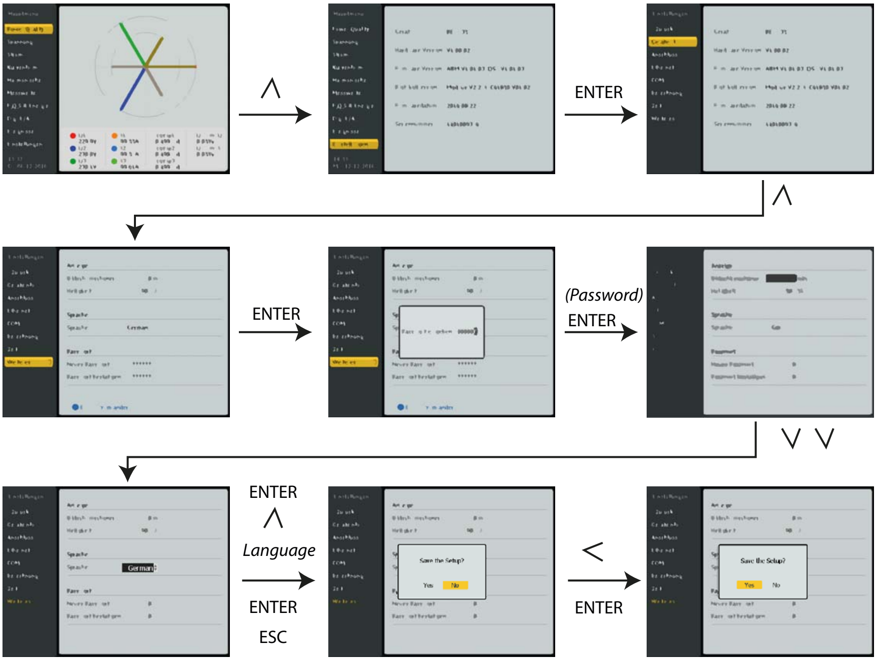


Fig. 5.2: Schematic language setting

   The confirmation dialogue box is always in English.

3. Set the bus address/IP address (Settings > Ethernet).
4. Set the measuring current transformer ratio (Settings > Basic > CT Primary/Secondary or I4 Primary/Secondary).
5. Change the measuring current transformer's counting direction, if

required.(Settings > Basic > I… Polarity).

6. Set voltage potential ratio (Settings > Basic > PT Primary/Secondary or U4 Primary/Secondary).
7. Set nominal voltage U_{LL} (Settings > Basic > Nominal VLL).
8. Set nominal frequency (Settings > Basic > Nominal Freq).

Please observe the device variant!
The nominal frequency can be changed to the value deviating from the device type. However, in this case, the accuracy class 0.2 S is no longer fulfilled.

9. Select wye connection or delta connection (Settings > Basic > Wiring Mode).

5.6 System

The PEM735 can be programmed and queried via Modbus RTU/Modbus TCP. For more details, refer to annex "PEM735-Modbus".
In addition, it is possible to integrate the device into Bender's own bus protocol BMS bus (**B**ender **M**essgeräte **S**chnittstelle) via additional communication modules. In this way, communication with (already existing) Bender devices for device parameterisation and visualisation of measured values and alarms can be achieved.

Help and examples of system integration can be found on the Bender homepage www.bender.de or you can contact our Bender Service for personal advice (see "chapter 1.2 Technical support: Service and support“).

5.7 Overview diagram

The following diagram will help you navigate through the menus.

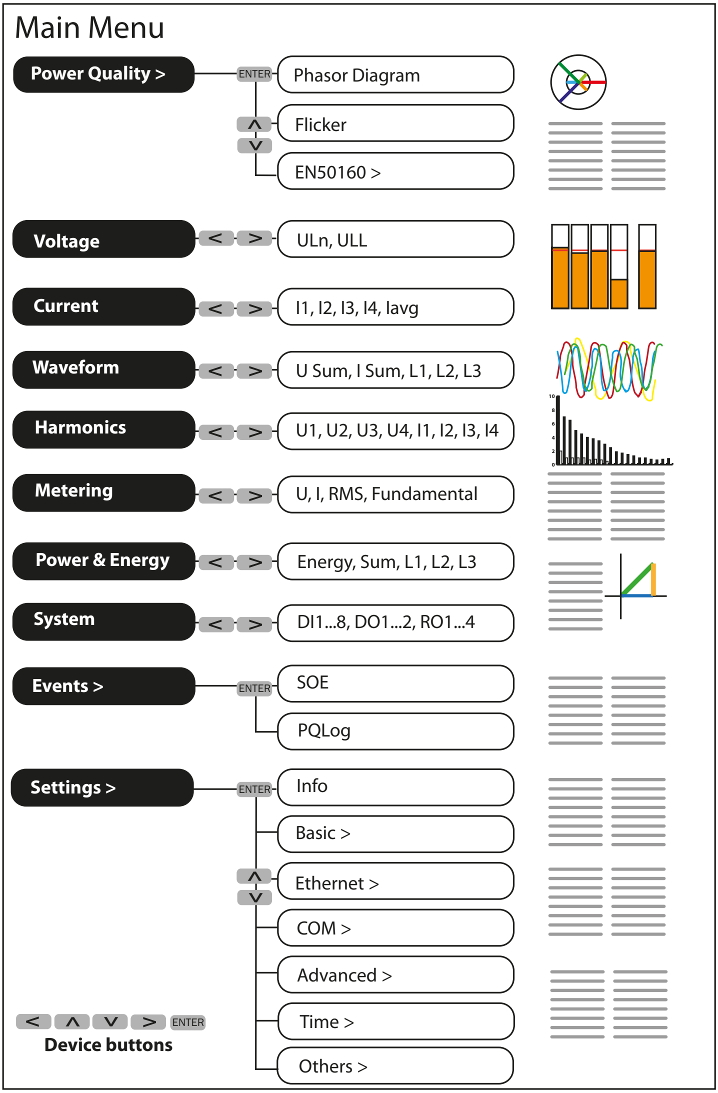


Fig. 5.3: Menu overview

6. Power Quality

The PEM735 offers the possibility of evaluating different power quality measurement results directly at the device. Here, both the actual measured values and graphic illustrations can be displayed.

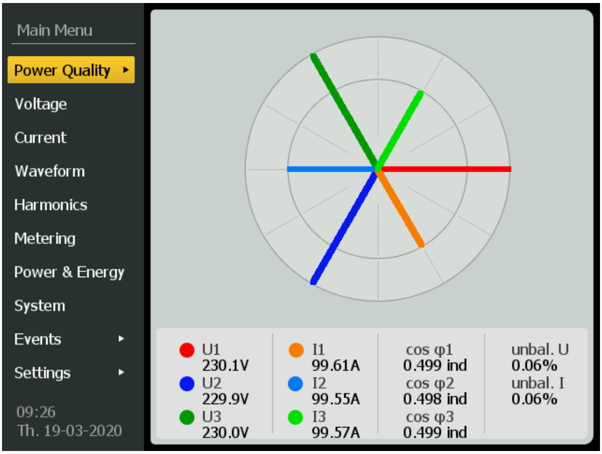


Fig. 6.1: "Power Quality" display (default display screen)

In addition to the phasor diagram, an overview of the flicker events and the starting point for the report according to DIN EN 50160 are displayed at the "Power Quality" menu item.

Press "ENTER" to go back one menu level.
You can navigate between the individual views of a menu level using the ⋀ and ⋁ buttons.
Press the "ESC" button to exit the submenu.

6.1 Phasor diagram

The phasor diagram shows the fundamental components of the voltages and currents in relation to each other. The voltages and currents that belong together are depicted in similar colours (light blue and dark blue, light green and dark green, red and orange). In this way, the phase angles between the sinusoidal curves can easily be assigned. The currents are depicted within the inner circle while the voltages are shown in the outer circle.

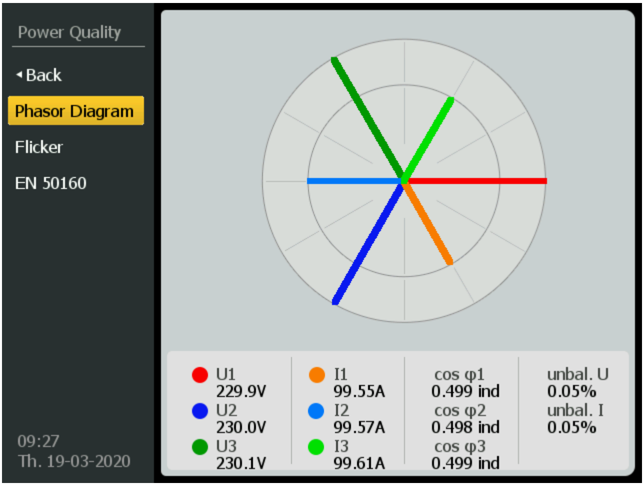


Fig. 6.2: Display "Phasor diagram"

The display shows:

Display text	Description
U1…U3	Fundamental components of the voltages U_{L1}, U_{L2}, U_{L3}
I1…I3	Fundamental components of the currents I_1, I_2, I_3
cos φ 1…3	Phase angle cosφ between current and voltage
Unbal. U	Voltage unbalance
Unbal. I	Current unbalance

6.2 Flicker

Flicker can be caused by short-term operating voltage fluctuations. Every occurrence of flicker is recorded for each phase and represented in tabular form on the display.
For more detailed description, refer to the standard DIN EN 61000-4-15.

Fig. 6.3: Display "Flicker"

The display shows:

Display text	Description	Note
Present	Present measured value	
Max	Maximum measured value in the observation period	
Pst	**P s**hort **t**erm, short-term flicker P_{st}	10-minute value
Plt	**P l**ong **t**erm, long-term flicker P_{lt}	2-hour value, cubic average value from 12 P_{st}
Time stamp	Time stamp of the maximum value	

*To **reset the maximum values**, press and hold the "ESC" button for at least two seconds.*

6.3 Report EN 50160

The evaluation according to EN 50160 (Voltage characteristics of electricity supplied by public distribution systems) contains the following items:

- Power Frequency
- Supply voltage variations
- Rapid voltage changes [1)]
- Flicker severity
- Voltage unbalance
- Harmonic voltages
- Interharmonic voltage [1)]
- Mains signalling (ripple control signals)
- Voltage swells [1)]
- Voltage sags [1)]
- Voltage interruptions [1)]
- Transient overvoltages [1)]

Note:
[1)] *These values are recorded and, if applicable, subdivided into classes. But the EN 50160 does not specify threshold values.*

The EN 50160 report clearly represents the measured values of frequencies, voltages, waveforms and the symmetry of the line voltages directly at the device. Since there is a large number of measured values, switch between the different display representations using the arrow buttons.

The start page of the EN 50160 report provides an overview of the measurements and the errors occurred. This makes it possible to see at a glance whether the conditions of DIN EN 50160 were met during the measurement period or not. If errors occur, the parameters are marked with ✖ and can be further analysed on the subpages.

Fig. 6.4: Display "EN 50160" (start page report)

The display shows:

Display text	**Description**	**Note**
Time stamp	Observation period for the report	
	Measured values comply with specified threshold values	
	Measured values do not comply with specified threshold values	
Detail	Results are shown in detail on several sub-pages;	Scroll with arrow buttons; return to start page by pressing "ESC"

When several reports are stored, navigate through the reports using the < and > buttons. Activate fast automatic scrolling by pressing and holding the arrow button.
To navigate through individual parameters in the report, use the ⋀ and ⋁ buttons. Press "ENTER" to go to the respective subpage.
Exit subpage by pressing the "ESC" button.

6.3.1 Power frequency

The nominal frequency f_n is 50 Hz or 60 Hz.

For systems with a synchronous connection to an interconnected system, regarding the power frequency f_n the EN 50160 requires an interval (f_n ±1 %) during 99.5 % of the time (narrow limits).

All measured values of a year must be in the interval (f_n -6 /+ 4 %).

Measurement overview

f_n	50 Hz	60 Hz
f_n ± 1 % (during min. 99.5 % of a year)	49.5…50.5 Hz	59.4…60.6 Hz
f_n –6/+4 % (for all measured values of a year)	47…52 Hz	56.4…62.4 Hz
Basic value	Mean value	
Integration interval	10 s	
Observation period	1 week	
Number of intervals	60480	

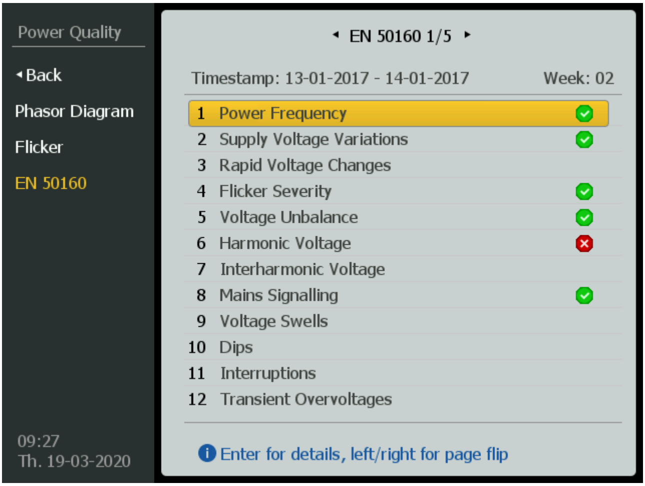


Fig. 6.5: "Power frequency" (selection of the parameters)

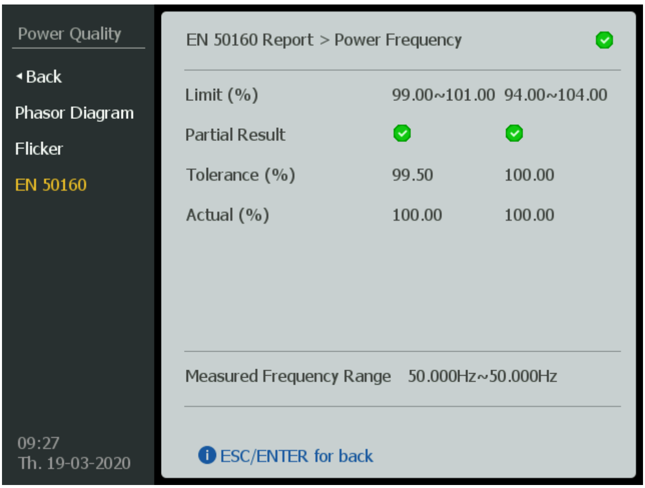


Fig. 6.6: "Power frequency" (detailed view)

The display shows:

Display text	Description	Note
Limit (%)	Permissible deviations from the nominal frequency (tolerance band)	**Left column**: max. ±1 % permissible deviation for 99.5 % of the measured values (narrow limits) **Right column**: max. -6 %/ +4 % for all measured values (wide limits)
Partial result	Limits complied with?	Specifications complied with Specifications not complied with
Tolerance (%)	Number [%] of measured values, which must be within the tolerance band during a measurement period	
Actual (%)	Number of measured values [%] within the tolerance band during a measurement period	The average value derived from 10-second observation periods

Applies to a system in an interconnected system.

6.3.2 Supply voltage variations

The voltage must not differ from the nominal voltage U_n by more than ±10 % during 95 % of the observation time (= one week) (**narrow limits**).
All measured values of a week must be in the interval of -15 %/ +10 % (**wide limits**).
To consider the voltage level, 10 minute mean r.m.s. values of the voltage are applied.

Measurement overview

U_n	Nominal voltage
Basic value	r.m.s. value
Integration interval	10 minutes
Observation period	1 week
Number of measurement intervals	1008

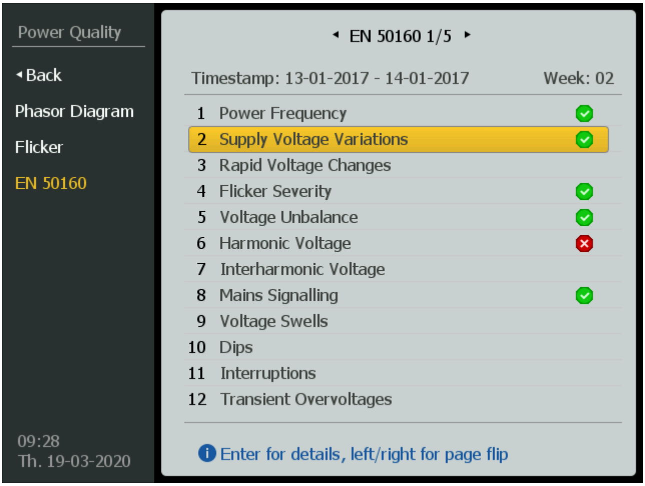


Fig. 6.7: "Supply voltage variations" (selection of the parameters)

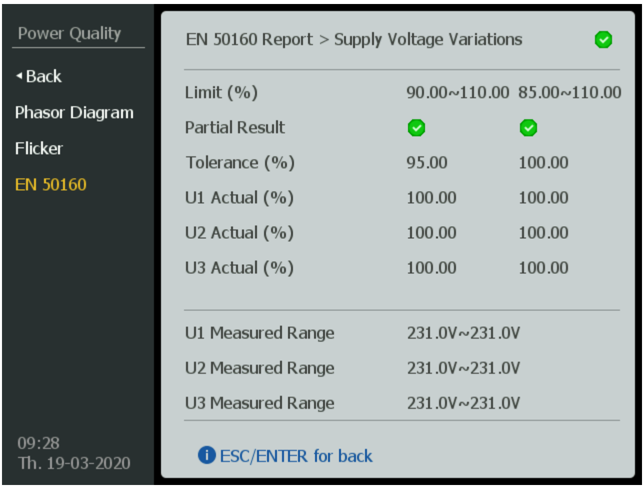


Fig. 6.8: "Supply voltage variations" (detailed view)

The display shows:

Display text	Description	Note
Limit (%)	Permissible deviations from the nominal voltage U_n (tolerance band)	**Left column**: max. ±10 % permissible deviation for 95 % of the measured values (narrow limits) **Right column**: -15/+10 % for all measured values (wide limits)
Partial result	Limits complied with?	✓ Specifications complied with ✗ Specifications not complied with
Tolerance (%)	Number [%] of measured values, which must be within the tolerance band during a measurement period	
U1…3 Actual (%)	Number of measured values [%] within the tolerance band during a measurement period	
U1…3 Measured Range	Range of measured values for $U_{L1...3}$	Absolute values in V

6.3.3 Rapid voltage changes

Rapid voltage changes are rapid variations of the r.m.s. value between two consecutive voltage values. These changes are characterised by a definable but unspecified duration.

Rapid voltage changes can be due to load variations or switching operations in the user's system, or faults in the supply system.

If, in the case of rapid voltage changes, the conditions for voltage sags or swells are also fulfilled, the occurring events are often regarded as voltage sags or swells rather than rapid voltage changes.

Measurement overview

U_n	Nominal system voltage
Rapid voltage changes	5…10 %
Basic value	r.m.s. value
Integration interval	10 ms
Observation period	1 week

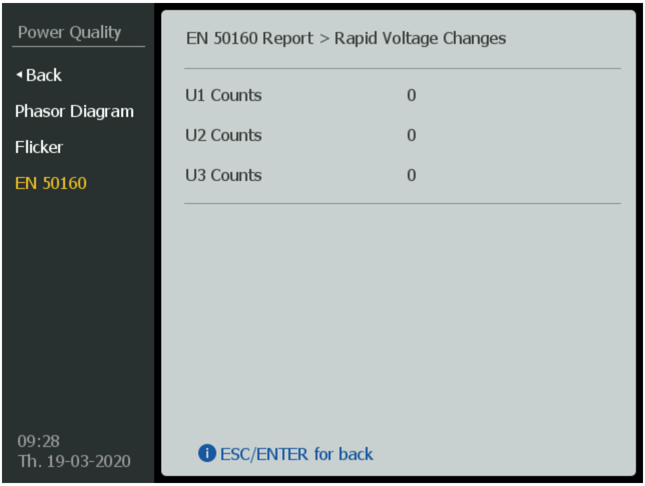


Fig. 6.9: "Rapid voltage changes" (detailed view)

The display shows:

Display text	Description
U1…3 Counts	Counts the number of rapid voltage changes for $U_{L1…3}$

EN 50160 does not specify limits for these measured values.

6.3.4 Flicker severity

Supply voltage variations cause changes in the luminance of lamps which can create the visual phenomenon called flicker. Above a certain threshold flicker becomes annoying. The annoyance grows very rapidly with the amplitude of the fluctuation. At certain repetition rates even very small amplitudes can be annoying.
The intensity of flicker annoyance can be evaluated by the following quantities:

- Short-term flicker severity (perceptibility unit short term $\boldsymbol{P_{st}}$), measured over a period of 10 minutes;
- Long-term flicker severity (perceptibility unit long term $\boldsymbol{P_{lt}}$), calculated from a sequence of 12 P_{st} values (= two-hour interval) according to the following equation

$$P_{lt} = \sqrt[3]{\sum_{i=1}^{12} \frac{P_{sti}^{\ 3}}{12}}$$

P_{lt} must be ≤ 1 during each period of one week for 95 % of the time.

The reaction to flicker is subjective and can vary depending on the perceived cause of the flicker and the period during which it persists. In some cases $P_{lt} = 1$ gives rise to annoyance, whereas in other cases higher levels of P_{lt} are noticed without annoyance.

Measurement overview

U_n	Nominal system voltage
Flicker	≤ 1 for 95 % of the time
Basic value	Flicker algorithm
Integration interval	2 h
Observation period	1 week
Number of measurement intervals	84

Fig. 6.10: "Flicker severity" (selection of the parameters)

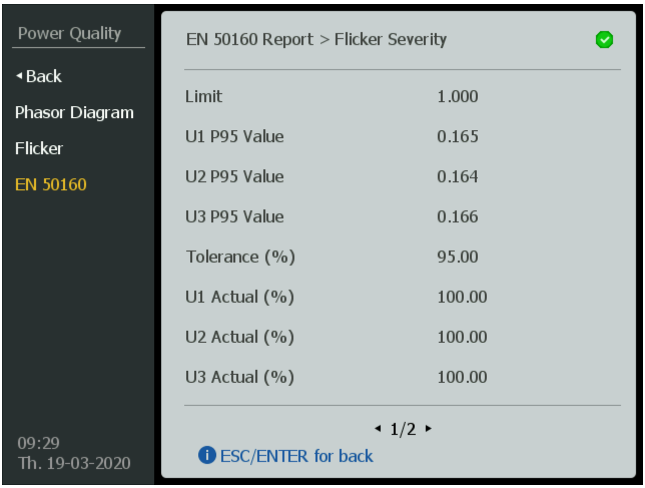


Fig. 6.11: "Flicker severity" (detailed view page 1)

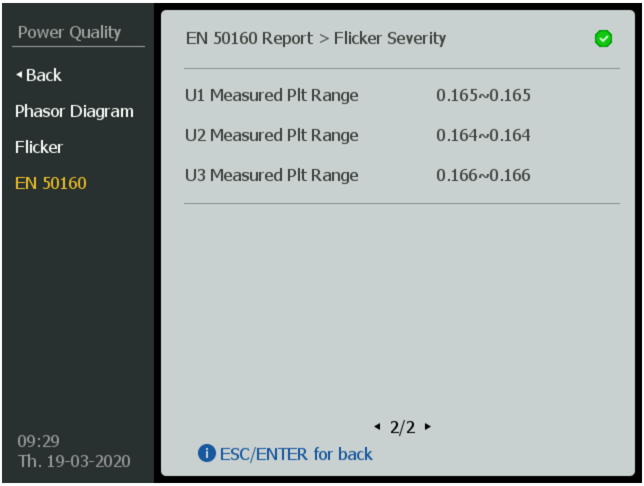


Fig. 6.12: "Flicker severity" (detailed view page 2)

The display shows:

Display text	Description
Specifications complied with?	Specifications complied with Specifications not complied with
Limit	Permissible limit
Tolerance (%)	Number [%] of the measured values, which must be within the tolerance band during a measurement period (≤ 1)
U1…3 P95 Value	Flicker measured value of the 95th percentile (P95) during an observation period
U1…3 Actual (%)	Number of measured values [%] within the tolerance band during a measurement period
U1…3 Measured Plt Range	Range of measured values for long-term flicker $U_{L1...3}$

6.3.5 Voltage unbalance

Under normal operating conditions, during each period of one week, 95 % of the 10 min mean r.m.s. values of the negative phase sequence component (fundamental) of the supply voltage must be within the range of 0…2 % of the positive phase sequence component (fundamental).

In some areas with partly single-phase or two-phase connected systems of grid users, unbalances up to about 3 % at the three-phase supply terminals occur. In this European standard only values for the negative phase sequence component are given because this component is the relevant one for the possible interference of appliances connected to the system.

Measurement overview

Voltage unbalance (ratios of the negative to the positive phase sequence component)	2 % , in special cases 3 %
Percentage	95 % of the measured values in the measurement period
Basic value	r.m.s. value
Integration interval	10 minutes
Observation period	1 week
Number of measurement intervals	1008

Fig. 6.13: Voltage unbalance

The display shows:

Display text	**Description**
Specifications complied with?	Specifications complied with Specifications not complied with
Limit (%)	Permissible deviations from the nominal supply voltage (unbalance tolerance band)
Tolerance (%)	Number [%] of the measured values, which must be within the tolerance band during a measurement period.
Unbalance u2 P95 Value (%)	Measured value of the 95th percentile (P95) during an observation period
Actual (%)	Number of measured values [%] within the tolerance during a measurement period.
Measured unbalance u2 Range (%)	Range of measured values for voltage unbalance

Measurement interval: 10 min mean values

Unbalance u_2 = (negative sequence/positive sequence component) x 100 %

6.3.6 Harmonic voltages

Under normal operating conditions, during each period of one week, 95 % of the 10 min mean r.m.s. values of each individual harmonic voltage must be less than or equal to the values given in table 6.1. Resonances may cause higher voltages for an individual harmonic.
Moreover, the THD of the supply voltage (including all harmonics up to the order 40) must be ≤ 8 %.

Overview of the limits for individual harmonics

Harmonics order	Percentage [%]	Harmonics order	Percentage [%]
2	2.0	**3**	5.0
4	1.0	**5**	6.0
6	0.5	**7**	5.0
8	0.5	**9**	1.5
10	0.5	**11**	3.5
12	0.5	**13**	3.0
14	0.5	**15**	0.5
16	0.5	**17**	2.0
18	0.5	**19**	1.5
20	0.5	**21**	0.5
22	0.5	**23**	1.5
24	0.5	**25**	1.5
No values are given for harmonics of order higher than 25, as they are usually low, but largely unpredictable due to resonance effects.			

Tab. 6.1: Limits for individual harmonics

Note table 6.1: The **3n harmonics** are highlighted. They contribute significantly to the unwanted heating of the neutral conductor.

Measurement overview

Total harmonic distortion THD (including harmonics up to the order 40)	max. 8 %
Percentage	95 % of the measured values must be ≤ limit value
Basic value	r.m.s. value
Integration interval	10 minutes
Observation period	1 week
Number of measurement intervals	1008

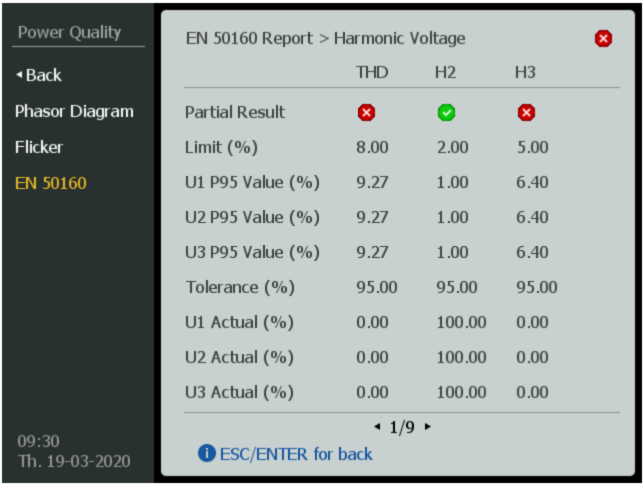


Fig. 6.14: "Harmonic voltages" (detailed view page 1)

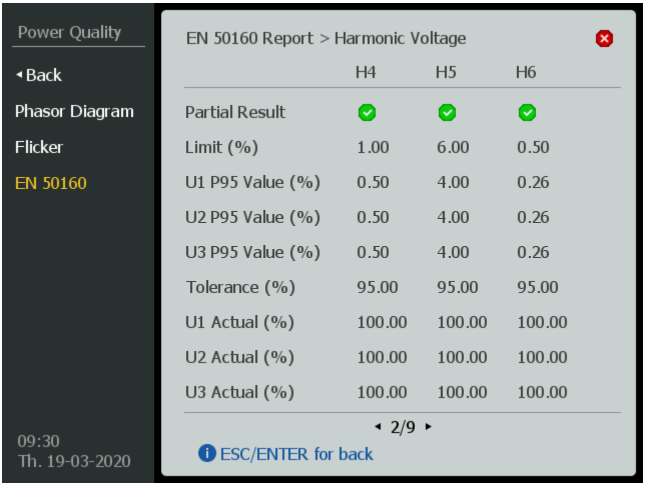


Fig. 6.15: "Harmonic voltages" (detailed view page 2)

The display shows:

Display text	Description
Partial Result	✓ Specifications complied with ✗ Specifications not complied with
THD	Total harmonic distortion
H2…25	Harmonics 2…25
Limit (%)	Permissible limit
U1…3 P95 Value (%)	Measured value of the 95th percentile (P95) during an observation period
Tolerance (%)	95 % of the measured values H… must be smaller than the permissible limit
U1…3 Actual (%)	Number of measured values [%] within the tolerance band during a measurement period

Use the ⋀ and ⋁ buttons to navigate between the individual pages of the interharmonics. Activate fast automatic scrolling by pressing and holding the arrow button.
Press the "ENTER" or the "ESC" button to return to the report overview.

6.3.7 Interharmonic voltages

An interharmonic voltage is a sinusoidal voltage with a frequency not equal to an integer multiple of the fundamental frequency (e.g. f_n = 50 Hz)

Interharmonic voltages at closely adjacent frequencies can appear at the same time forming a wide band spectrum. The level of interharmonics is increasing due to the development of frequency converters and similar control equipment. Levels are under consideration, pending more experience.
In certain cases, interharmonics, even at low levels, give rise to flicker or cause interference in ripple control systems.

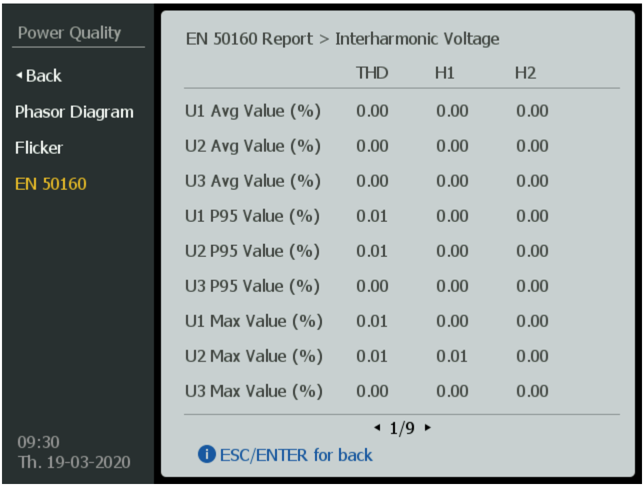


Fig. 6.16: Interharmonic voltages (detailed view page 1)

The display shows:

Display text	Description	Note
U1…3 Avg Value (%)	Ø measured value per phase	Percentage

Display text	Description	Note
U1…3 P95 Value (%)	Measured value of the 95th percentile (P95) during an observation period	Percentage
U1…3 Max Value (%)	Maximum measured value per phase	Percentage
THD	Total harmonic distortion (interharmonics)	Percentage
H1…H25	Interharmonics H1…25	Percentage

Use the ⋀ and ⋁ buttons to navigate between the individual pages of the interharmonics. Activate fast automatic scrolling by pressing and holding the arrow button.
Press the "ENTER" or the "ESC" button to return to the report overview.

EN 50160 does not specify limits for these measured values.

6.3.8 Mains signalling (ripple control signals)

Mains signalling voltages

Ripple control signals are signals superimposed on the supply voltage for the purpose of transmitting information in the public supply network and to the premises of network users.

Signals in the public supply network can be classified as follows:

- Ripple control signals: Superimposed sinusoidal voltage signals in the frequency range 110…3 000 Hz;
- Mains marking signals: Superimposed short-term supply voltage variations (transients) at selected points of the voltage waveform.

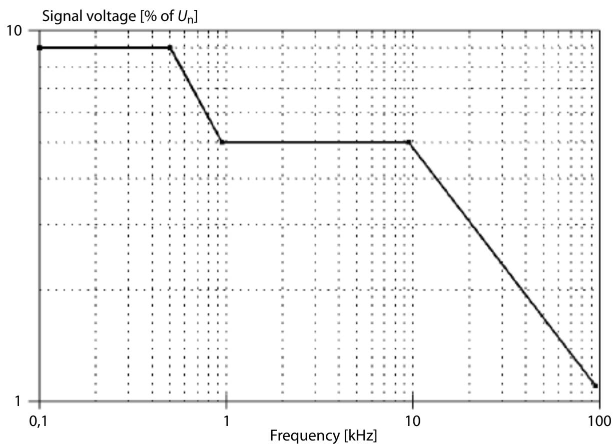


Fig. 6.17: Voltage levels of signal frequencies in percent U_n used in public LV networks (according to EN 50160)

In some countries the public networks may be used by the network operators for the transmission of signals. For 99 % of a day the 3 s mean value of the signal voltages must be less or equal to the values given in Fig. 6.17.

PEM735 can detect the voltage of the signals for three different frequency ranges. The limits of the voltages for these frequencies are stored in the device according to Fig. 6.17. The frequency range is limited to 3 kHz.

Fig. 6.18: "Mains signalling" (detailed view page 1)

The display shows:

Display text	Description	Note
Frequency (Hz)	Frequency of the ripple control signals	The three frequencies used can be adjusted via Modbus or the web interface.
Partial Result	Specifications complied with Specifications not complied with	
Limit (%)	Permissible deviations (tolerance band)	Percentage
Tolerance (%)	Number [%] of measured values, which must be within the tolerance band during a measurement period	Percentage

Display text	Description	Note
U1…3 P95 Value (V)	Measured value of the 95th percentile (P95) during an observation period	Percentage
U1…3 Actual (%)	Latest measured value $U_{L1...3}$	Percentage

6.3.9 Voltage swells

Voltage swells are typically caused by switching operations and load disconnections. The nominal supply voltage U_n is used as reference. The swell start threshold is equal to 110 % of U_n , the hysteresis is 2 %.
In addition to the threshold, the duration of the voltage swell is also determined.

These settings can only be made via the communication interface.
For more detailed information, refer to the annexes "Modbus" and "Web server".

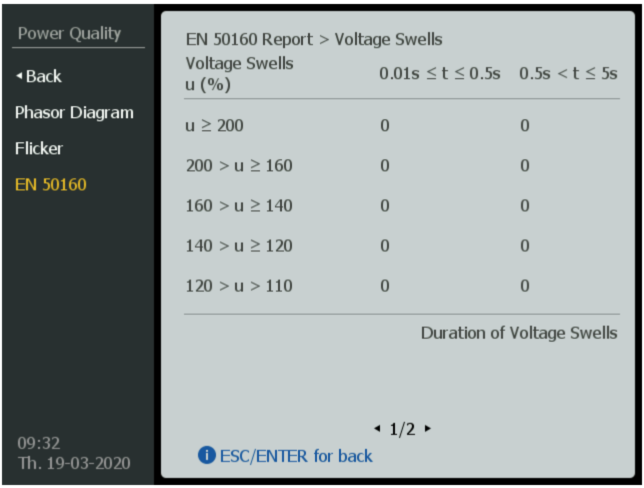


Fig. 6.19: "Voltage swells" (detailed view 1)

The display shows:

Display text	Description
t	Duration of the swells (ms)
Voltage swells u (%)	Voltage swell level in %

For voltage swell classification, the percentages of the voltage levels u are summarised as follows:

u ≥ 200
200 > u ≥ 160
160 > u ≥ 140
140 > u ≥ 120
120 > u >110

Use the < and > buttons to navigate through the individual pages of the voltage swells.
Press the "ENTER" or the "ESC" button to return to the report overview.

EN 50160 does not specify limits for these measured values.

6.3.10 Voltage sags

Voltage sags are typically originated by faults occurring in the public network or in the systems of network users. The nominal supply voltage U_n is used as reference. The voltage sag start threshold is equal to 90 % of the U_n , the hysteresis is 2 %.
The ratio between the residual voltage U_{res} and the nominal supply voltage U_n is displayed as a percentage value.

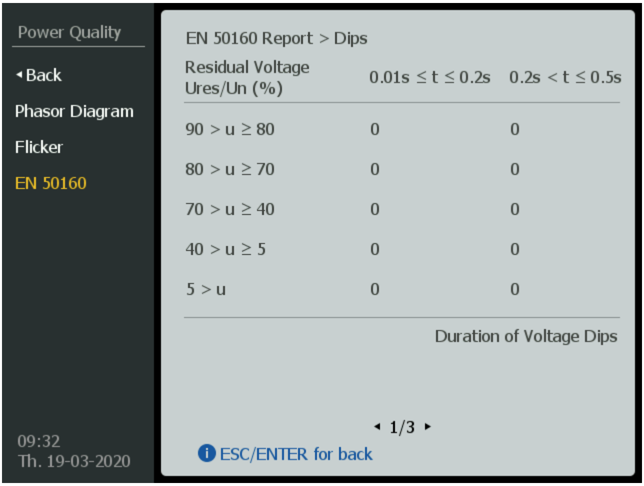


Fig. 6.20: Voltage sags (detailed view on page 1 of 3)

For voltage sag classification, the percentages of the voltage levels u are summarised as follows:

$90 \geq u \geq 80$
$80 > u \geq 70$
$70 > u \geq 40$
$40 > u \geq 5$
$5 > u$

The display shows:

Display text	**Description**
Residual Voltage	Residual voltage level U_{res}
t	Duration of the voltage sag (ms)
90>u>=80	Classification of the voltage sag (% of the residual voltage)
10<t<=200	Classification of the voltage sag (duration *t* in ms)

Note: If the "Sliding Reference Voltage U_{sr}" detection method is used, the calculation should be made using a first order and a constant set to one minute.

$$U_{sr(n)} = 0.9967 \text{ x } U_{sr(n-1)} + 0.0033 \text{ x } U_{(10/12)rms}$$

Use the < and > buttons to navigate through the individual pages of the voltage sags.
Press the "ENTER" or the "ESC" button to return to the report overview.

EN 50160 does not specify limits for these measured values.

6.3.11 Voltage interruptions

Interruptions are, by their nature, very unpredictable and variable depending on place and time. For the time being, it is not possible to give fully representative statistical results of measurements of interruption frequency covering the whole of European networks. The voltage interruptions measured are counted and classified according to their duration.

Fig. 6.21: Interruptions (detailed view)

The time periods *t* are differentiated as follows:

$t < 1$ s
$1 \text{ s} \leq t < 180$ s (3 minutes)
$180 \text{ s} \leq t$

The display shows:

Display text	Description
Counts	Number of counts during the observation period
1s ≤ t < 180 s	Classification of the voltage interruption according to duration (in this case, it varies between 1 second and 3 minutes)

Voltage interruption evaluation

On polyphase systems, a voltage interruption begins when the r.m.s. value $U_{L1/2\,(rms)}$ of all channels falls below the voltage interruption threshold. A voltage interruption ends as soon as at least one channel reaches or exceeds the interruption threshold plus hysteresis again.

The voltage interruption threshold and the hysteresis are both set by the user according to the application. The voltage interruption threshold should not be set below the measurement uncertainty of the residual voltage U_{res} plus hysteresis. Typically, the hysteresis is 2 % of U_s (U_{din}). The voltage interruption threshold could thus be set, for example, to 5 % or 10 % of U_s (U_{din}).

These settings can only be carried out via the communication interface (see annexes "Modbus" and "Web server").

EN 50160 does not specify limits for these measured values.

6.3.12 Transient overvoltages

Transient overvoltages at the supply terminals are generally caused by lightning (induced overvoltage) or by switching in the system.

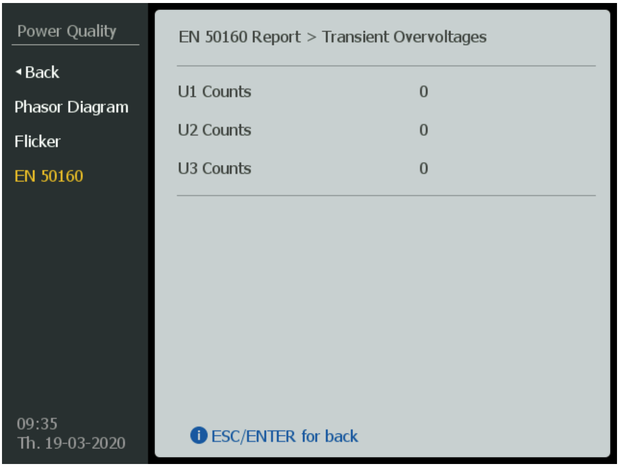


Fig. 6.22: Transient overvoltages

The display shows:

Display text	Description
Counts	Number of counts during the observation period

These settings can only be carried out via the communication interface (see annexes "Modbus" and "Web server"). This also applies for the setting of limits for the transient measurement.

EN 50160 does not specify limits for these measured values.

***Note 1**: The rise time can cover a wide range from milliseconds down to much less than a microsecond. However, for physical reasons, transients of longer durations usually have much lower amplitudes. Therefore, the coincidence of a high amplitude and a long rise time is extremely unlikely.*

***Note 2**: The energy content of a transient overvoltage varies considerably according to the origin. An induced overvoltage due to lightning generally has a higher amplitude but lower energy content than an overvoltage caused by switching, because of the generally longer duration of such switching overvoltages.*

***Note 3:** For withstanding transient overvoltages in the vast majority of cases, LV installations and end user appliances are designed according to EN 60664-1. Where necessary (see IEC 60364-4-44), surge protection devices should be selected according to IEC 60364-5-53, to take account of the actual situations. This is assumed to cover also induced overvoltages due to both lightning and switching.*

7. Voltage

Overview of the measured voltages U_{LL} or U_{Ln} as well as the average voltage (U_{avg}) from U1…U3 as a bar graph.

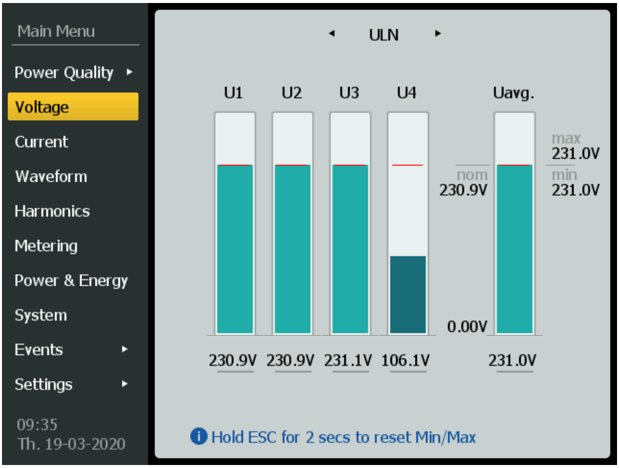


Fig. 7.1: "Voltage" display

Use the < and > buttons to switch between the individual displays.

*The displayed minimum and maximum values refer to the current month. To reset the **minimum and maximum values**, press and hold the "ESC" button for at least two seconds.*

8. Current

Overview of measured and calculated currents $I_{0...4}$ as well as the average current (I_{avg}) as a bar graph.

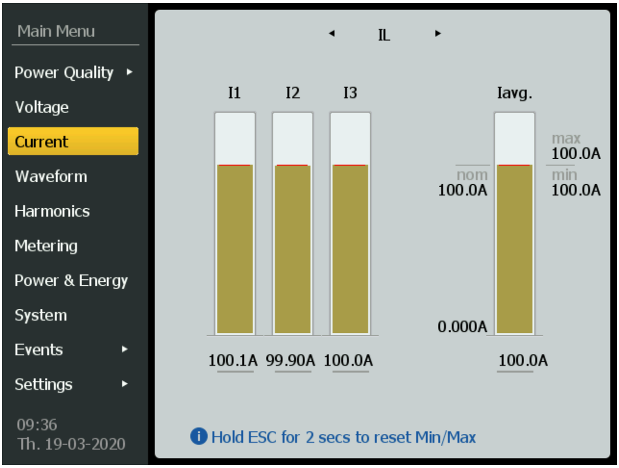


Fig. 8.1: "Current" display

Use the < and > buttons navigate between the displays IL and I0/I4.

The displayed minimum and maximum values refer to the current month. To reset the ***minimum and maximum values****, keep the "ESC" button pressed for at least two seconds.*

9. Waveform

In addition to the numeric values, the waveform recorder represents the waves of the measured voltages and currents on the display. Here, a comprehensive view of all voltages $U_{L1...3}$ and currents $I_{1...3}$ and the consideration of individual waves is possible.

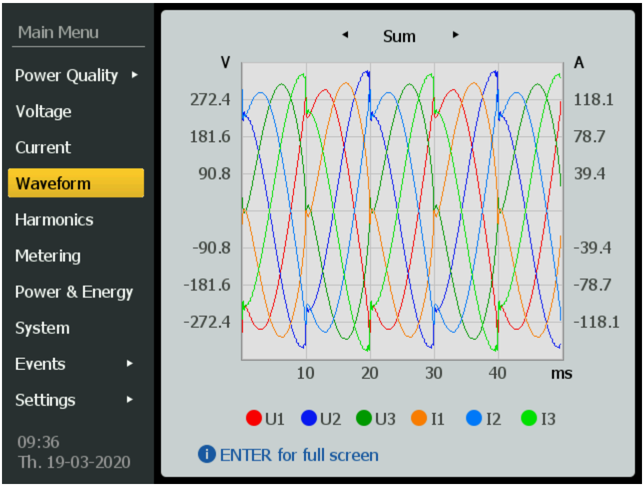


Fig. 9.1: "Waveform" display (overall view)

Press the "ENTER" button to enable full screen display mode:

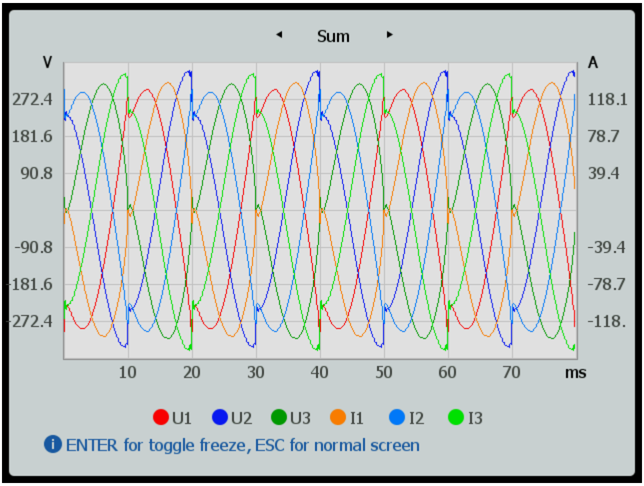


Fig. 9.2: "Waveform" display (full screen display)

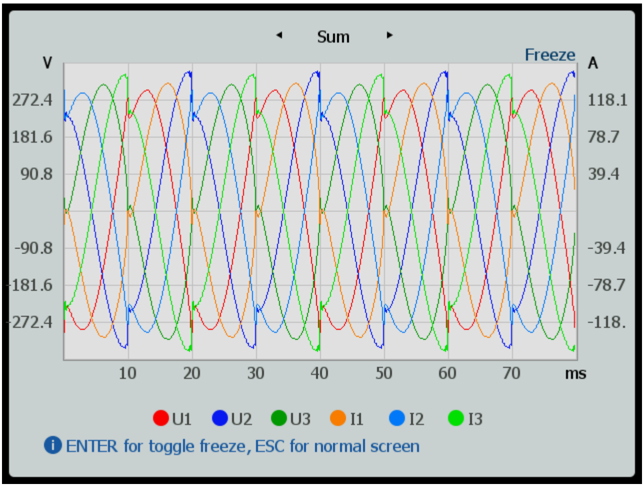


Fig. 9.3: "Waveform" display (freeze image)

In full screen mode, a freeze image of the latest waves can be generated by pressing the "ENTER" button (stop) to be able to analyse the graph in more detail. Pressing the "ENTER" button again cancels the freeze image and you return to the full screen display mode.
Return directly from the freeze image to the normal screen by pressing the "ESC" button.

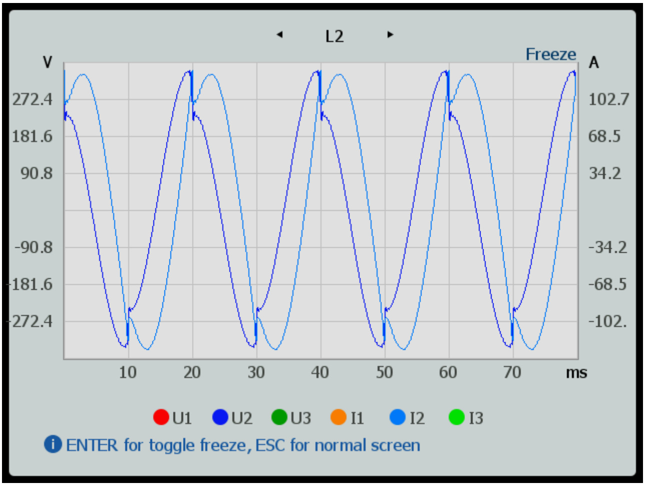


Fig. 9.4: "Waveform" display (display of current and voltage of a phase)

10. Harmonics

Overview of the measured harmonics as bar graphs. Use the < and > buttons to switch between the individual displays.

There are two possibilities to calculate the individual harmonic distortion (RMS and distortion). This setting can be made directly on the device:
Settings > Calculation

Distortion

% U_k/ U_{FUND}
"Fundamental"

THD calculation of an individual harmonic (related to the fundamental
U_1 or I_1)

$$THD_{U(k)} = \frac{U_k}{U_1} \times 100\ \%$$

$$THD_{I(k)} = \frac{I_k}{I_1} \times 100\ \%$$

RMS

% of RMS
"Root Mean Square", r.m.s. value:

Harmonic distortion calculation of an individu
harmonic (THF, related to the
total value U_{tot} or I_{tot})

$$THF_{U(k)} = \frac{U_k}{\sqrt{\sum_{k=1}^{\infty} U_k^2}} \times 100\ \%$$

$$THF_{I(k)} = \frac{I_k}{\sqrt{\sum_{k=1}^{\infty} I_k^2}} \times 100\ \%$$

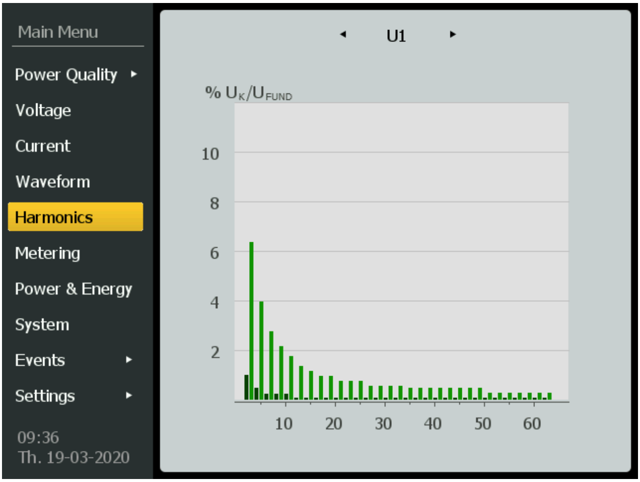


Fig. 10.1: "Harmonics" display (voltages of a phase)

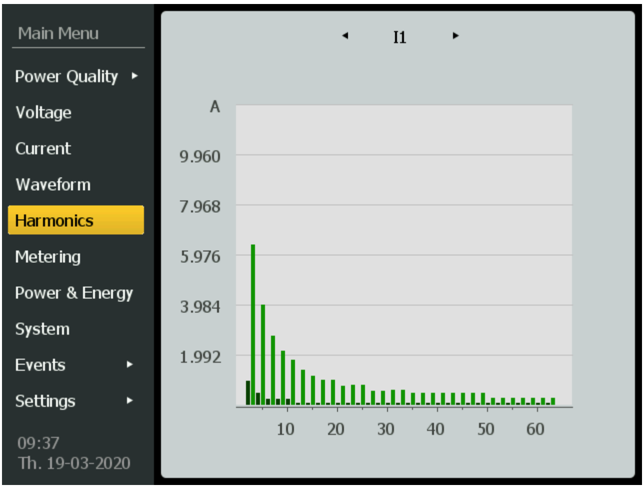


Fig. 10.2: "Harmonics" display (currents of a phase)

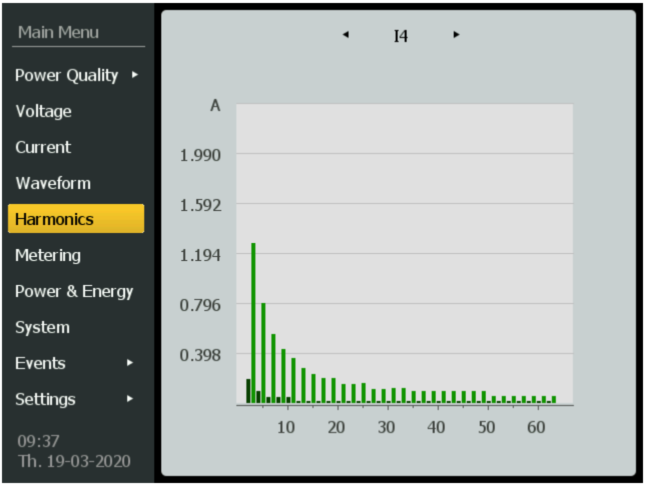


Fig. 10.3: "Harmonics" display (currents I4)

When "RMS" is selected, the harmonics are displayed as r.m.s. values (V or A).
When "Distortion" is selected, the harmonics are displayed as a percentage value.

11. Metering

Measured values for voltages, currents, r.m.s. values and fundamentals in tabular form. Use the < and > buttons to switch between the individual displays.

Display	Parameter	Measured values	Note
U	$U_{L1...3}$	Act, Min, Max	Shows only RMS voltages.
	$U_{L1L2...L3L1}$	Act, Min, Max	
	f	Act	
	U4	Act	
I	$I_{1...3}$	Act, Min, Max	Shows only RMS current.
	I_4	Act, Min, Max	
	I_0	Act, Min, Max	
RMS	$U_{L1...3}$	Act	Shows a combination of RMS voltage, RMS current and power incl. all harmonics.
	$U_{L1L2...L3L1}$	Act	
	$I_{1...3}$	Act	
	P	For L1, L2, L3 and total value	
	Q		
	S		
	P. F. (λ)		
Fundamental	$U_{L1...3}$	Act	Shows a combination of RMS voltage, RMS current and power for fundamental only.
	$U_{L1L2...L3L1}$	Act	
	$I_{1...3}$	Act	
	P	For L1, L2, L3 and total value	
	Q		
	S		
	λ		

Tab. 11.1: Overview of measured values in the"Metering" menu

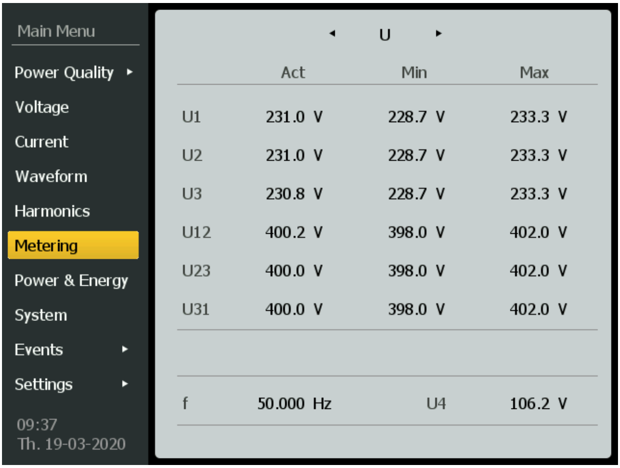


Fig. 11.1: "Metering" display (voltages)

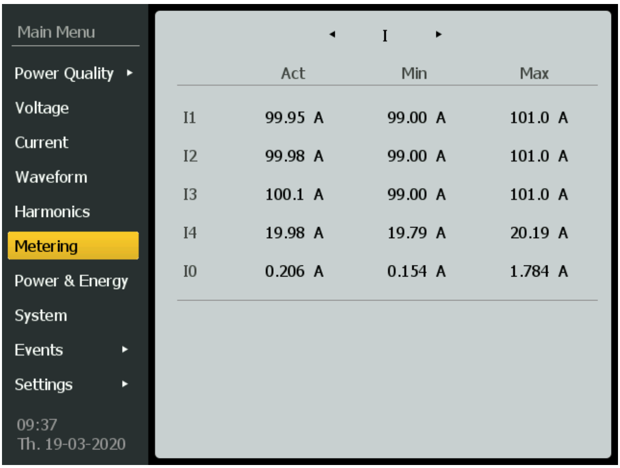


Fig. 11.2: "Metering" display (currents)

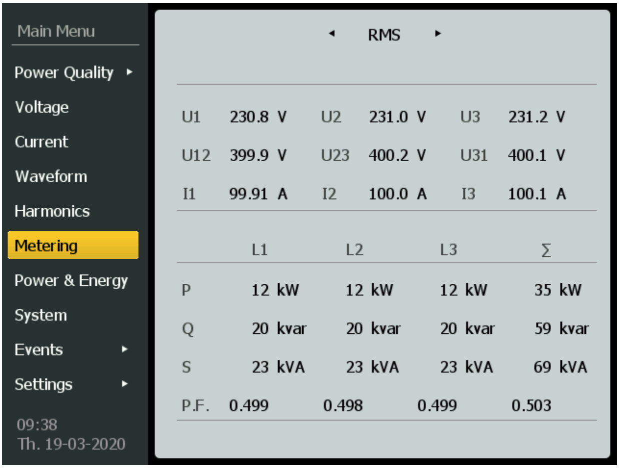


Fig. 11.3: "Metering" display (r.m.s. values)

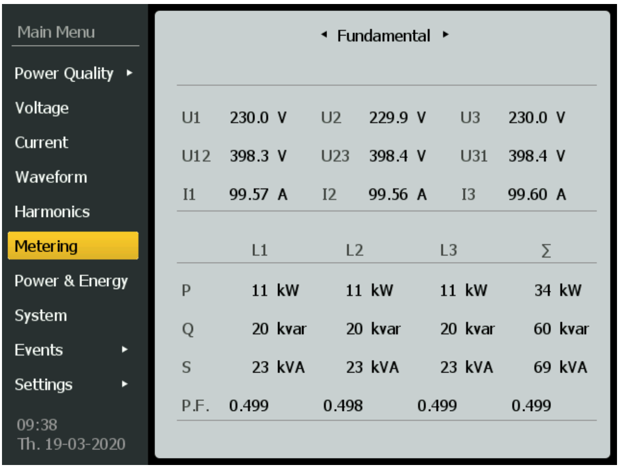


Fig. 11.4: "Metering" display (fundamentals)

12. Power & Energy

Display of the fundamental values of the active and reactive power as numerical values and as vectors in the quadrants Q1…4. The power values are displayed either as total measurement (total) or for each individual conductor L1…3.

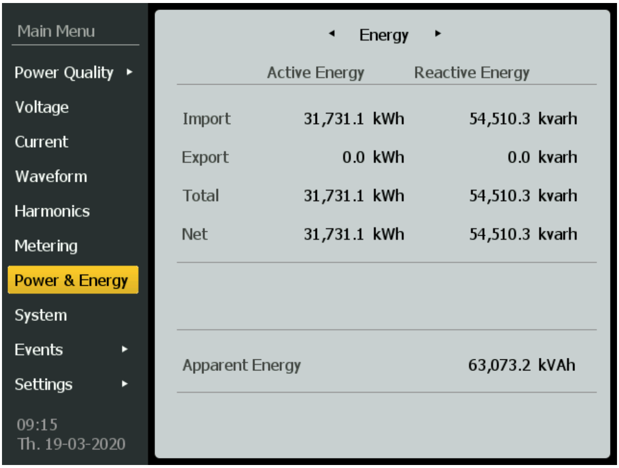


Fig. 12.1: "Power & Energy" display

Import	= Energy import
Export	= Energy export
Net	= Import – Export
Total	= Import + Export

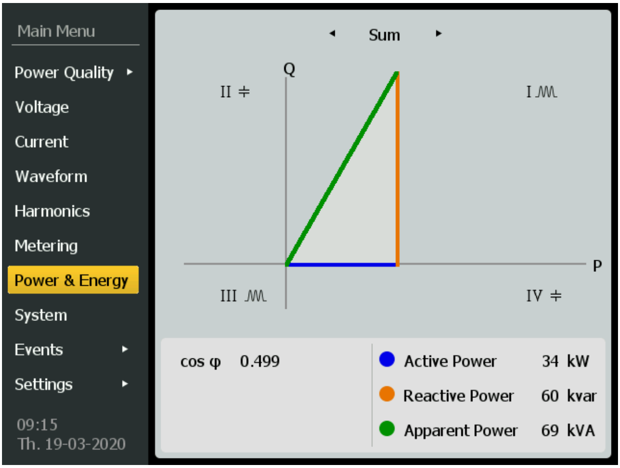


Fig. 12.2: "Power & Energy" display (phasor diagram)

Set calculation power factor λ convention on the device:
Settings > Advanced > PF Convention

Set calculation apparent power on the device:
Settings > Advanced >S Calculation

For explanations on the calculation of the power factor and the apparent power, refer to page 94.

13. System

The PEM735 features 8 digital inputs, 2 digital outputs and 4 relay outputs. These are displayed directly on the device.

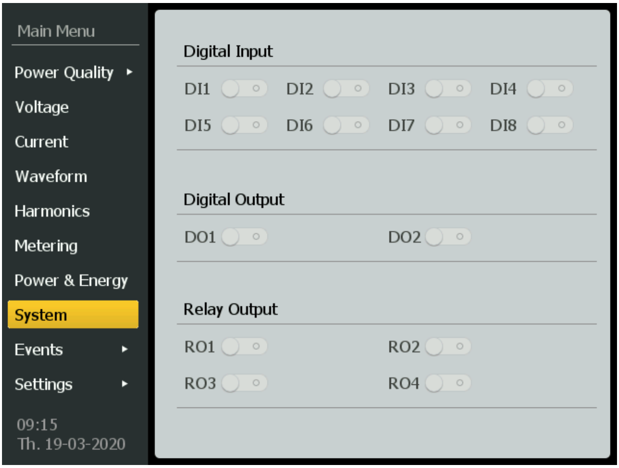


Fig. 13.1: "System" display

Inputs (DI)

The device features eight digital inputs which are internally operated with DC 24 V. Digital inputs are normally used for **monitoring external states**. The switching states of the digital inputs can be read from the LC display or the connected system components. External state changes are stored as events in the event log with a resolution of 1 ms.
One of the digital inputs can be programmed as a **pulse receiver for the synchronisation of the demand measurement**. The setting can be carried out via the registers.

Outputs (DO, RO)

The device features 2 digital outputs and 4 relay outputs which are accessible from the back.
The required functionality can only be set via the Modbus register (see annex "Modbus").
At the device itself the connected inputs and outputs can only be displayed.

14. Events

Access to stored events of the recorders (SOE and PQLog).
In addition to the time stamp, the event description in clear text format and the associated values are displayed.

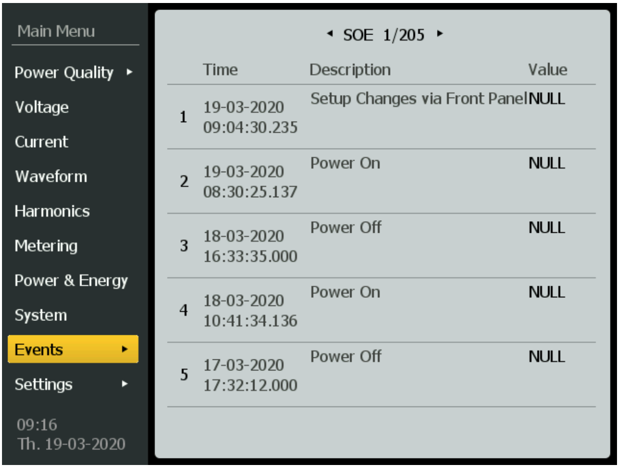


Fig. 14.1: "Events" display (start page SOE)

Press "ENTER" to go back one menu level.
Use the ∧ and ∨ buttons to switch between the event and the PQ recorder.
Use the < and > buttons to navigate between the individual subpages. Activate fast automatic scrolling by pressing and holding the arrow button.
Press the "ESC" button to return to the main menu.

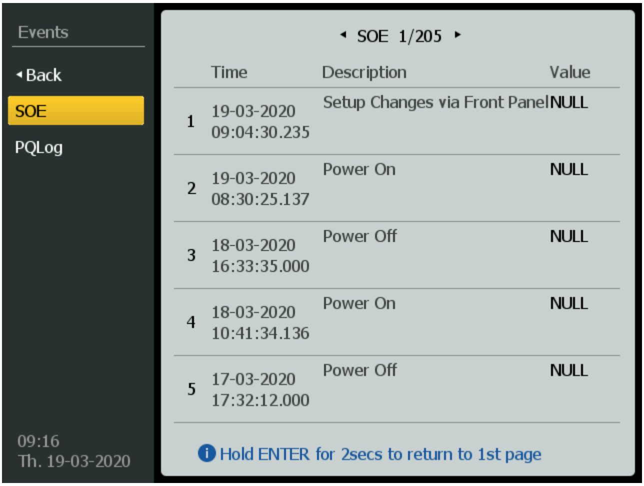


Fig. 14.2: "Events" display (SOE, page 1 of 205)

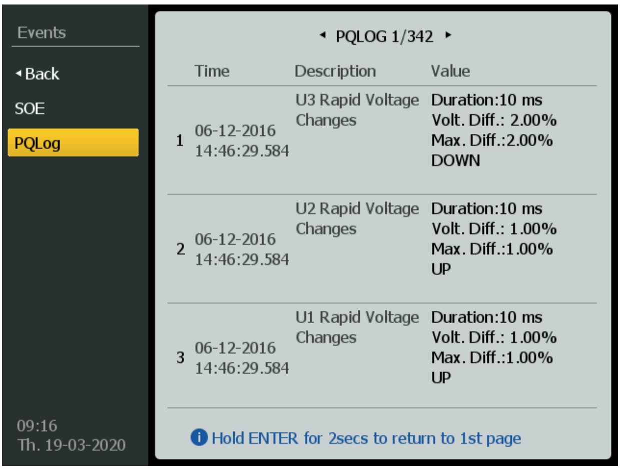


Fig. 14.3: "Events" display (PQLog)

15. Settings

Here, general information about the device is displayed. In addition, parameters for the device can be set (password protected).

Press "ENTER" to go to the"Settings" menu.
Use the ⋀ and ⋁ buttons to navigate between the individual items. To change parameters, press the "ENTER" button for password request.
After entering the correct password, press the "ENTER" button to go to the setting mode.
Press the "ESC" button to exit the submenus.

15.1 Info

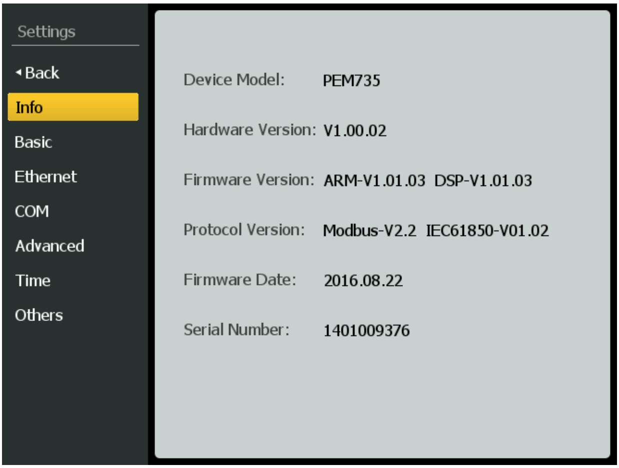


Fig. 15.1: Settings ("Info" view)

No settings can be made in the info view. This page is only for information purposes.

15.2 Basic

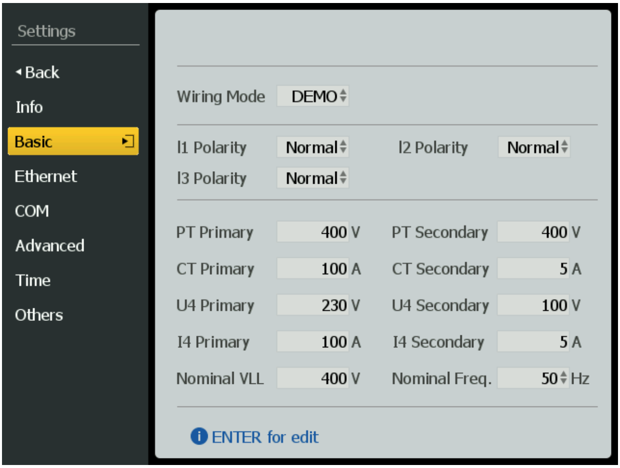


Fig. 15.2: Settings ("Basic" menu item)

Before changing the settings, the correct password must be entered (factory setting: 000000).

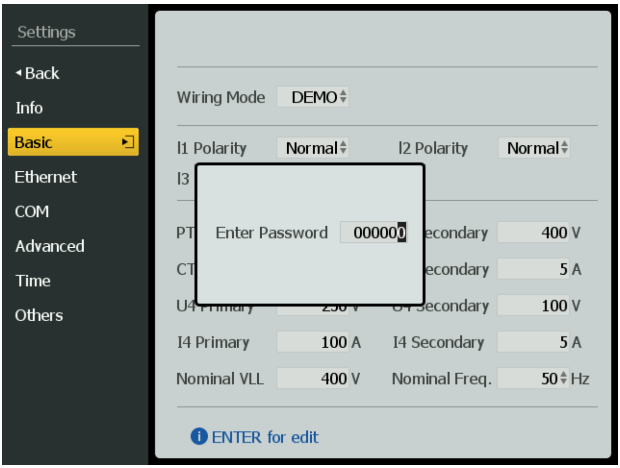


Fig. 15.3: "Settings" display (enter password)

Press the ⋀ and ⋁ buttons to change a number.
Use the < and > buttons to navigate between the individual digits of the password.
Confirm the password with the "ENTER" button.

You can set the password yourself (**Settings > Others > Password**).

After the password has been entered successfully, changes can be made to the settings. The currently selected parameter is highlighted in black.

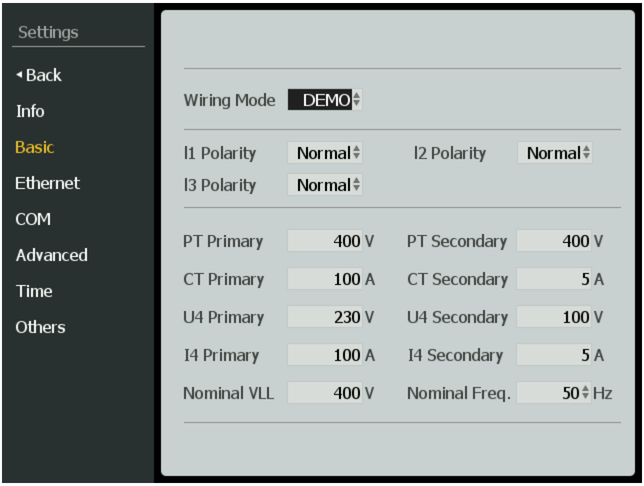


Fig. 15.4: "Settings" display (Basic, selected parameter)

Use the arrow buttons to jump from one field to another.
To change settings, enter the currently selected field (highlighted in black) using the "ENTER" button and then use the arrow buttons to adjust the values or selections.

15.2.1 Ethernet

The settings for the Ethernet interface can be defined in this menu. The following parameters have to be set:

- IP address
- Subnet mask
- Gateway

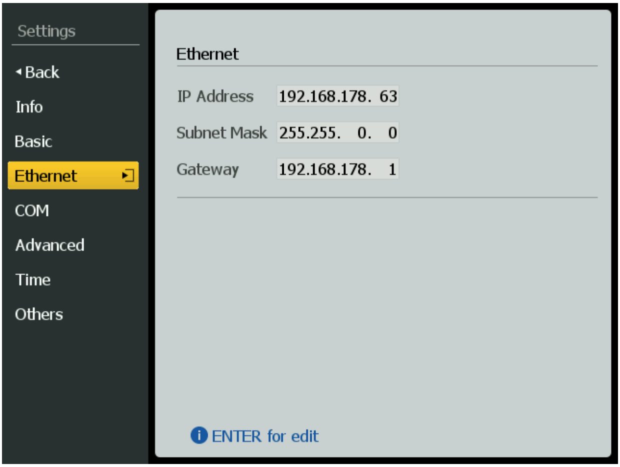


Fig. 15.5: "Settings" display (Ethernet)

Press "ENTER" to enter the setting mode (after successful password entry).
Select the field to be edited (highlighted in black) using the arrow buttons.
Activate the field with the "ENTER" button. The field that can be edited is marked and can be set using the arrow buttons.

Press the ∧ and ∨ buttons to change a number.
Use the < and > buttons to navigate between the individual digits of an address.
Complete the input with the "ENTER" button. To exit the menu and save the settings, confirm the final query with "ENTER". To discard the changes, press "ESC".

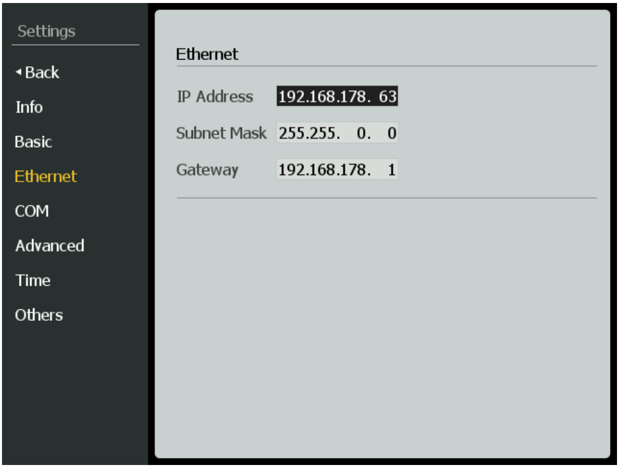


Fig. 15.6: "Settings" display Ethernet, change settings)

15.2.2 COM (communication interface)

PEM735 features two communication interfaces the settings of which can be made directly on the device.

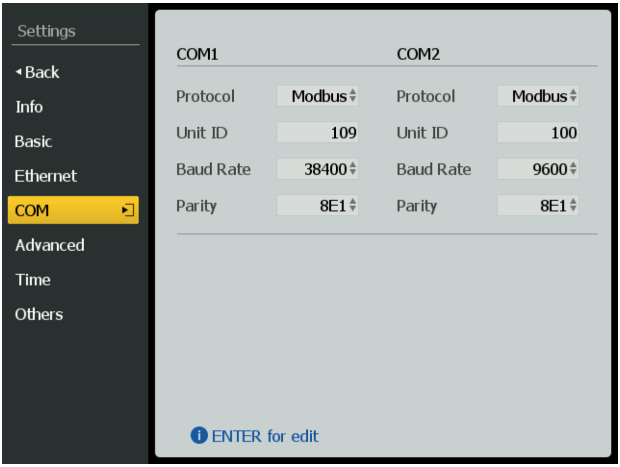


Fig. 15.7: "Settings" display (COM)

The display shows:

Display text	Description
Protocol	COM1: time source or Modbus COM2: gateway or Modbus
Unit ID	
Baud Rate	38400, 19200, 9600, 4800, 2400, 1200
Parity	Parity bit: 8N1, 8E1, 8O1, 8N2, 8E2, 8O2

15.2.3 Advanced

In the advanced settings, the calculation method for the power factor λ and apparent power *S* can be defined. In addition, the calculation settings for the harmonics are made here.

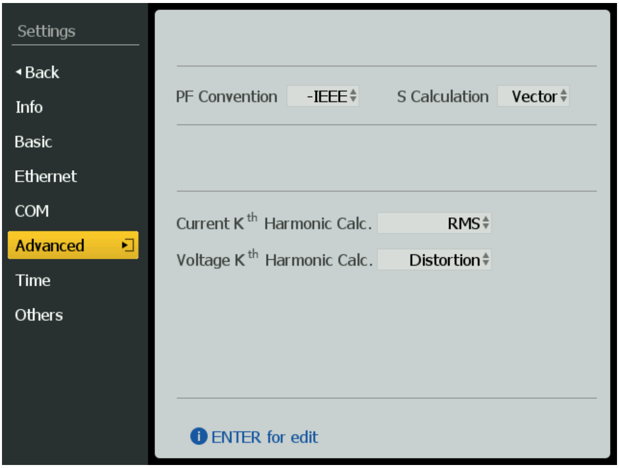
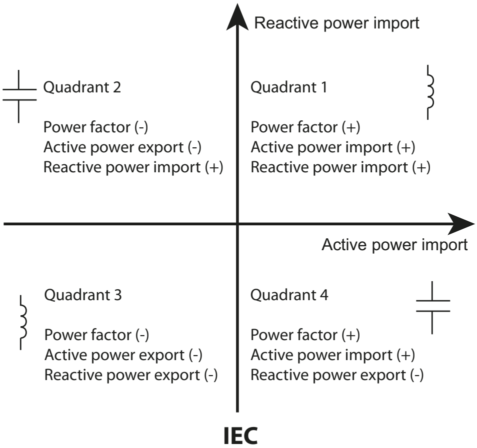


Fig. 15.8: "Settings" display (Advanced)

The display shows:

Display text	Description	Note
PF Convention	Power factor λ	IEC, IEEE, -IEEE; see Fig. 15.9
S Calculation	Calculation method apparent power	Vector or Scalar
Current K^{th} Harmonic Calc.	Display of the harmonic in the diagram as RMS value or percentage (distortion).	RMS, Distortion
Voltage K^{th} Harmonic Calc.		RMS, Distortion

Explanation of power factor λ conventions:



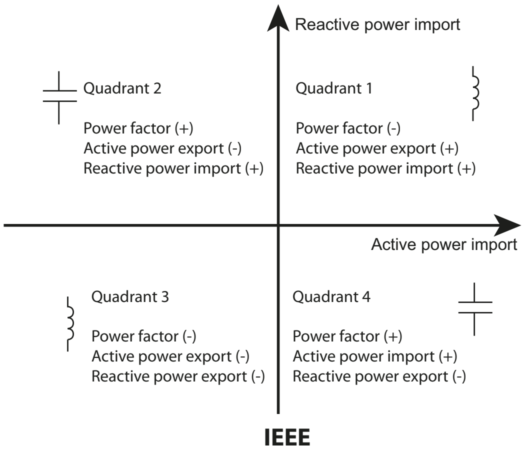


Fig. 15.9: Explanation of power factor λ conventions

"**IEEE**" is the same as "**–IEEE**" but with the opposite sign.

Explanation of apparent power calculation

Vector method V:

$$S_{ges} = \sqrt{P_{ges}^{2} + Q_{ges}^{2}}$$

Scalar method S:

$$S_{ges} = S_{L1} + S_{L2} + S_{L3}$$

15.2.4 Time (setting date and time)

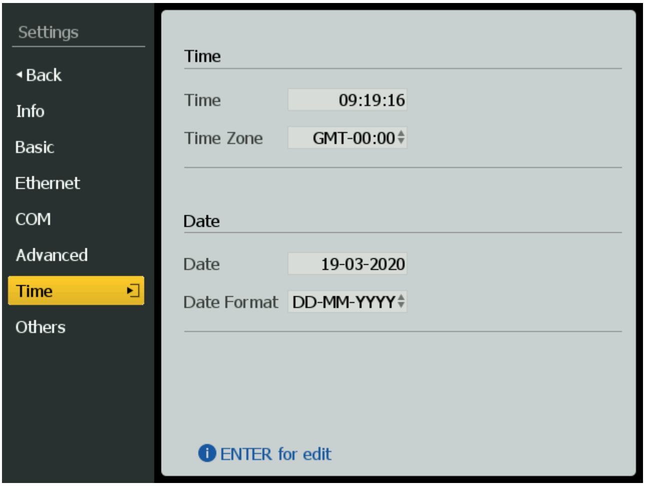


Fig. 15.10: "Settings" display (Time)

The display shows:

Display text	Description	Note
Time	Local time	Indication in hh:mm:ss
Time Zone	Global time zone	Relative to GMT
Date	Current date	
Date Format	Date format	DD-MM-YYYY, MM-DD-YYYY, YYYY-MM-DD

The clock is automatically set by a connected CP700.

15.2.5 Others

The display properties and the device language as well as a new password can be set in this menu.

Setting a password:
Press the ∧ and ∨ buttons to change a number.
Use the < and > buttons to navigate between the individual digits of the password. Complete the input with the "ENTER" button.
Confirm entered password by pressing "ENTER" again.

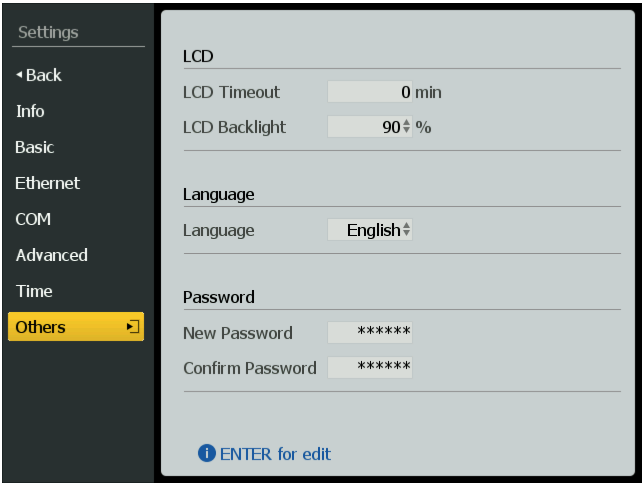


Fig. 15.11: "Settings" display (Others)

The display shows:

Display text	Description	Note
LCD Timeout	To set the time after which the background lighting automatically turns off	0…60 minutes
LCD Backlight	Brightness of the display	10…100 %

Display text	Description	Note
Language	Display language	German, Russian, English
Password	Set and confirm new password	six-digit, one number 0…9 per digit

When LCD Timeout is set to 0 min , the background lighting remains permanently on (max 24 h).

16. Other

16.1 Resetting to factory settings

If necessary, the device can be reset to the state upon delivery.

Factory settings: *Press and hold the "<" and "ESC" buttons simultaneously for 3 s and then confirm the dialogue box (English).*

Previous successful software updates remain unchanged.

16.2 Creating display screenshots

Screenshots of the present display can be created in order to document the device settings, for example.
They can be exported via FTP.

Screenshot: *Press and hold "<" and ">" simultaneously. After releasing the buttons, a confirmation appears.*

16.3 Data export via FTP

The recordings of the

- waveform recorders
- created screenshots (chapter 16.2)

can be downloaded from the device via FTP. FTP access is read-only; changes or memory deletions are not possible.

FTP access

- ***Server***: *IP address of the PEM735*
- ***User name***: *anonymous (cannot be changed)*
- ***Password***: *random, but not empty (cannot be changed)*

The searched data can be found in the folders

- data > ScreenShot (data as *.bmp)
- data > Wave > waveRec (data in COMTRADE format *.cfg and *.dat).

17. Technical data

Insulation coordination

Measuring circuit

Rated insulation voltage .... 600 V
Overvoltage category III
Pollution degree 2

Supply circuit

Rated insulation voltage .... 300 V
Overvoltage category II
Pollution degree 2

Supply voltage

Rated supply voltage U_S .... AC/DC 95 . . . 250 V
Frequency range of U_S .... DC, 47 . . . 440 Hz
Power consumption .... ≤ 14 VA

Measuring circuit

Measuring voltage inputs

$U_{L1-N,L2-N,L3-N}$ .... 400 V
$U_{L1-L2,L2-L3,L3-L1}$ .... 690 V
Measuring range .... 10 . . . 120 % U_N
CT transformation ratio
Primary .... 1 . . . 1,000,000 V
Secondary .... 1 . . . 690 V ($U_{L1...3}$)
Secondary .... 1 . . . 400 V (U4)
Internal resistance (L-N) .... > 6 MΩ

Measuring current inputs

External measuring current transformers should at least comply with accuracy 0.2 S
Burden .... –, due to internal current transformers
Measuring range .... 1 . . . 200 % I_n
Overload range, current
2x I_n .... permanently
10x I_n .... max. 1 s
Measured values < 0.1 % of I_n are indicated as 0 A.

Transformation ratio of the measuring current transformer, secondary .... 1 . . . 5 A
Transformation ratio of the measuring current transformer, primary .... 1 . . . 30,000 A

Accuracies

Phase voltage U_{L1-N}, U_{L2-N}, U_{L3-N} .... ±0.1 %
Current .... ±0.1 %
Neutral current I_4 .... ±0.1 %
Frequency .... ±0.005 Hz
Phasing .... ± 1 °
Reactive power .... ±0.2 %
Power factor λ .... ±0.5 %
cos φ .... ±0.2 %
Voltage underdeviation and overdeviation .... ±0.1 %
Voltage unbalance .... ±0.1 %
Current unbalance .... ±0.5 %
Time accuracy of the internal RTC .... < 6 ppm (< 0.5 s per day)
Measurement of the active energy 0.2 S .... acc. to DIN EN 62053-22 (VDE 0418 Part 3-22)
Measurement of the voltage r.m.s. values .... acc. to DIN EN 61557-12 (VDE 0413-12), chapter 4.7.6
Measurement of the phase current r.m.s. values .... according to DIN EN 61557-12 (VDE 0413-12), chapter 4.7.5
Frequency measurement .... according to DIN EN 61557-12 (VDE 0413-12), chapter 4.7.4
Measurement of the harmonics acc. to DIN EN 61000-4-7 Class A
Harmonic voltages and currents .... IEC 61000-4-7 Class I
Flicker P_{st} .... IEC 61000-4-15:2010 Class A
Flicker P_{lt} .... IEC 61000-4-15:2010 Class A

Interface

Interface .... 2 x **RS-485**
Protocol Modbus RTU
Baud rate .... 1.2 . . . 38.4 kbit/s
Cable length .... 0 . . . 1200 m
Shielded cable (shield connected to SH terminal on one side) .... recommended: J-Y(St)Y min. 2 x 0.8
Interface .... **Ethernet**
Protocol .... Modbus TCP
FTP
Baud rate .... 100 Mbit/s

Switching elements

2 electronic outputs (DO) ..... max. 30 V

I_{max} ..... 50 mA

4 relay outputs (RO) ..... 4 x N/O contacts

Operating principle ..... N/O operation

Rated operational voltage ..... AC 250 V, DC 30 V

Rated operational current ..... 3 A

Minimum contact rating ..... 1 mA at AC/DC ≥ 10 V

Inputs ..... 8 galv. separated digital inputs

I_{min} ..... 2.4 mA

U_{DI} ..... DC 24 V

Environment/EMC

EMC ..... IEC 61326-1

Operating temperature ..... −25 . . . +55 °C

Classification of climatic conditions acc. to IEC 60721 (stationary use) 3K23

Classification of mechanical conditions acc. to IEC 60721 (stationary use) 3M11

Connection

Connection ..... screw-type terminals

Other

Degree of protection, installation IP20

Degree of protection, front IP52

Weight ..... ≤ 2000 g

17.1 Standards and certifications

PEM735 was designed in accordance with the following standards:

EN 50160
Voltage characteristics of electricity supplied by public distribution networks

DIN EN 61000-4-30:2008 (VDE 0847-4-30)
Electromagnetic compatibility (EMC)
Part 4-30: Testing and measurement techniques – Power quality measurement methods (IEC 61000-4-30)

DIN EN 61557-12 (VDE 0413-12)
Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 12: Performance measuring and monitoring devices (PMD) (IEC 61557-12:2007)

DIN EN 62053-22 (VDE 0418 Part 3-22)
Electricity metering equipment (a.c.) – Particular requirements – Part 22: Static meters for active energy (classes 0.2 S and 0.5 S) (IEC 62053);

17.2 Ordering information

17.2.1 PEM

Type	Nominal frequency	Current input	Article number
PEM735 100…690 V	50 Hz	5 A	B93100735
PEM735 100…690 V	60 Hz *	5 A	B93100740

To comply with the accuracy class, the nominal frequency must be considered!

** Availability and delivery time on request*

17.2.2 Measuring current transformers

All measuring devices of the PEM series can be operated with standard measuring current transformers (1 A or 5 A).
It must be ensured that the measuring device as well as the used measuring current transformers are of class 0.5 S or higher to comply with an accuracy class (e.g. 0.5 S).

18. Glossary and terms

Abbreviation/ Term	Long form	Description
COM1, COM2	Communication	Communication interface 1 (Modbus or time source) Communication interface 2 (Modbus or gateway)
DI	Digital Input	Digital input (2.4 mA, DC 24 V)
DO	Digital Output	Digital output (max. 50 mA, max. 80 V)
r.m.s. value		Square root of the arithmetic mean of the squares of the instantaneous values of a quantity taken over a specified time interval and a specified bandwidth
GB	Giga Byte	
GMT	Greenwich Mean Time	act. UTC (Coordinated Universal Time)
High-speed data recorder	HS-DR1…4	Trigger: timer or setpoint Recording mode "Stop when full" Recording interval 0.5…60 cycles Number of data points: max. 65535 for each HS-DR 0…16 measured quantities, can be selected from 31 measured quantities No recording delay
High-speed setpoint		Setpoints are tested once every half cycle, suitable for fast reactions, selectable from 18 different measured quantities
MB	Mega Byte	
P		Active power in kW
P95	Measured value of the 95th percentile	95th percentile: 95 % of the values are less than or equal to this measured value
percentile		Percentile rank divides the set of data into 100 equal parts

Abbreviation/ Term	Long form	Description
P_{lt}	perceptibility unit long term	Long-term flicker (2-hour value, cubic average value from 12 P_{st})
PPS	Pulse Per Second	Pulse per second
PQ	Power Quality	
P_{st}	perceptibility unit short term	Short-term flicker; 10-minute value
Q		Reactive power
rms	root mean square	r.m.s. value
RO	Relay output	Relay output (current-carrying capacity 3 A, AC 250 V or 3 A, DC 30 V)
Ripple control signal		Mains signalling voltages on electrical low-voltage systems, called "ripple control signal"; are a burst of signals. Often applied at a non-harmonic frequency that remotely control industrial equipment, revenue meters and other devices. f < 3 kHz;
S		Apparent power
Voltage sag		Temporary reduction of the voltage to an amount below a threshold of 90 % of U_n with a hysteresis of 2 %; voltage interruptions are a special case of voltage sag.
Voltage swell (single-phase system)		Starts when the U_{rms} voltage is above the swell threshold; ends when the U_{rms} voltage is equal to or below the swell threshold minus the hysteresis voltage; Typically, the swell threshold is > 110 % of U_{din}; Typically, the hysteresis is equal to 2 % of U_{din}

Abbreviation/ Term	Long form	Description
Voltage swell (polyphase system)		Starts when the U_{rms} voltage of at least one channel is above the swell threshold; ends when the U_{rms} voltage on all measured channels is equal to or below the swell threshold minus the hysteresis voltage; Typically, the swell threshold is > 110 % of U_{din}; Typically, the hysteresis is equal to 2 % of U_{din}
Voltage interruption (single-phase system)		Starts when the U_{rms} voltage falls below the voltage interruption threshold; ends when the U_{rms} voltage is equal to or greater than the voltage interruption threshold plus the hysteresis Typically, the swell threshold for voltage interruptions is 5 % or 10 % of U_{din}; Typically, the hysteresis is equal to 2 % of U_{din}
Voltage interruption (polyphase system)		Starts when U_{rms} on all measured channels falls below the voltage interruption swell threshold; ends when U_{rms} on any measured channel is equal to or greater than the interruption threshold plus the hysteresis; Typically, the swell threshold for voltage interruptions is 5 % or 10 % of U_{din}; Typically, the hysteresis is equal to 2 % of U_{din}
Standard data recorder	DR 1…16	Trigger: timer or setpoint Recording mode "Stop when full" or "FIFO" Recording interval 1…3,456,000 seconds (40 days) Number of data points: max. 65535 for each DR 0…16 measured quantities, can be selected from 1741 measured quantities Timer for trigger mode: Recording delay 0…43200 s (12 h)
TEHD	Total Even Harmonic Distortion	Total even harmonic distortion
THD	Total Harmonic Distortion	Total harmonic distortion

Abbreviation/ Term	**Long form**	**Description**
TOHD	Total Odd Harmonic Distortion	Total odd harmonic distortion
Transients		Short-term alterations superimposed to the supply voltage, can be recorded up to ±750 V
U_0		Zero sequence component
u_0		Zero sequence component (ratio expressed as a percentage); $u_0 = (U_0/U_1)$ x 100 %
U_0 / I_0		Zero sequence component voltage/current
U_0 / I_0 Unb		Unbalance zero sequence component voltage/ current
U_1		Positive sequence component
U_1 / I_1		Positive sequence component voltage/current
U_2		Negative sequence component
u_2		Negative sequence component ration expressed as a percentage; $u_2 = (U_2/U_1)$ x 100 %
U2 / I2		Negative sequence component voltage/current
U2 / I2 Unb		Negative sequence component unbalance voltage/current
U_{din}	Declared input voltage	Value obtained from the declared supply voltage by the ratio of a measuring current transformer
Supply voltage unbalance		r.m.s. values of the line-to-line voltages (fundamental component) and/or the phase angles between consecutive line conductors, are not all equal; apply only to three-phase systems
U_{res}	Residual voltage	Minimum value of $U_{rms(1/2)}$ {class A} recorded during a voltage sag or interruption; the residual voltage is expressed as a value in V or % or as a per unit value of the declared input voltage
$U_{rms(1)}$		Value of the r.m.s. voltage measured over one cycle and refreshed each cycle

Abbreviation/ Term	Long form	Description
$U_{rms(1/2)}$	Half-cycle r.m.s. voltage	r.m.s. value, refreshed every half-cycle (r.m.s. value measured over one cycle, commencing at a fundamental zero crossing)
Interharmonics		Interharmonic between the (n-1)th and nth harmonic

Document revision history

Date	Document version	State/Changes
04.2022	03	*Editorial revision* chapter 17.2.2 Measuring current transformers

INDEX

BENDER
The Power in Electrical Safety©

BENDER Group

Bender GmbH & Co. KG
Postfach 1161 • 35301 Grünberg • Deutschland
Londorfer Str. 65 • 35305 Grünberg • Deutschland
Tel.: +49 6401 807-0 • Fax: +49 6401 807-259
E-Mail: info@bender.de • www.bender.de

Bender GmbH & Co. KG
PO Box 1161 • 35301 Grünberg • Germany
Londorfer Str. 65 • 35305 Grünberg • Germany
Tel.: +49 6401 807-0 • Fax: +49 6401 807-259
E-Mail: info@bender.de • www.bender.de

Fotos: Bender Archiv

Photos: Bender Archive