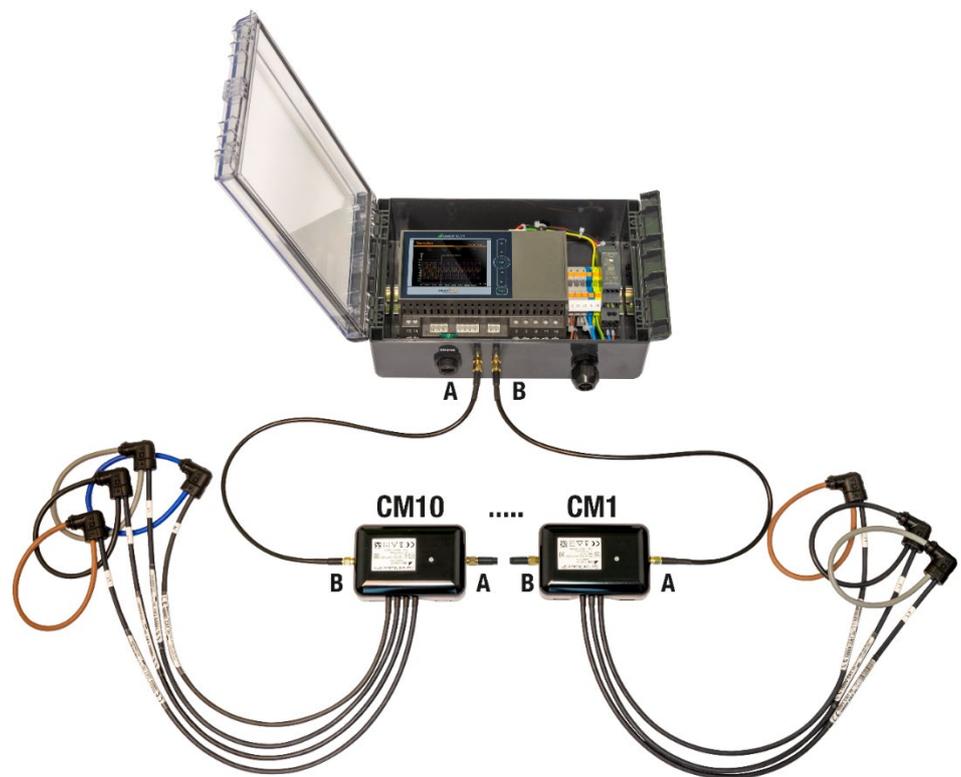System handbook

LINAX PQ5000-CURRENT LINK

Operating instructions LINAX PQ5000-CURRENT LINK (2023-04)

CAMILLE BAUER

Legal information

Warning notices

In this document warning notices are used, which you have to observe to ensure personal safety and to prevent damage to property. Depending on the degree of danger the following symbols are used:

> If the warning notice is not followed death or severe personal injury **will** result.

> If the warning notice is not followed damage to property or severe personal injury **may** result.

> If the warning notice is not followed the device **may** be damaged or **may** not fulfill the expected functionality.

Qualified personnel

The product described in this document may be handled by personnel only, which is qualified for the respective task. Qualified personnel have the training and experience to identify risks and potential hazards when working with the product. Qualified personnel are also able to understand and follow the given safety and warning notices.

Intended use

The product described in this document may be used only for the application specified. The maximum electrical supply data and ambient conditions specified in the technical data section must be adhered. For the perfect and safe operation of the device proper transport and storage as well as professional assembly, installation, handling and maintenance are required.

Disclaimer of liability

The content of this document has been reviewed to ensure correctness. Nevertheless, it may contain errors or inconsistencies and we cannot guarantee completeness and correctness. This is especially true for different language versions of this document. This document is regularly reviewed and updated. Necessary corrections will be included in subsequent version and are available via our webpage http://www.camillebauer.com.

Feedback

If you detect errors in this document or if there is necessary information missing, please inform us via e-mail to:

customer-support@camillebauer.com

Contents

1. Introduction

1.1 Purpose of this document

This document describes the universal power quality analysis device LINAX PQ5000CL (PQ5000 with the Current Link extension) combined with the current modules 3P and 3PN. It is intended to be used by:

- Installation personnel and commissioning engineers
- Service and maintenance personnel
- Planners

Scope

This handbook is valid for all hardware versions of the devices. Some of the functions described in this document are available only, if the necessary optional components are included in the device.

Required knowledge

A general knowledge in the field of electrical engineering is required. For assembly and installation of the device knowledge of applicable national safety regulations and installation standard is required.

1.2 Scope of supply

- Measurement device PQ5000CL (PQ5000 with the Current Link extension)
- Rogowski current sensor modules 3P and / or 3PN, according to order
- Safety instructions (multiple languages)

1.3 Further documents

The following documents are provided electronically via
https://www.camillebauer.com/pq5000cl-en:

- Safety instructions
- Data sheet
- IEC 61850 interface LINAX PQ5000CL
- Camille Bauer certificate for encrypted HTTPS communication
- Modbus interface description

2. Safety notes

⚠ 📖	🗑	Device may only be disposed in a professional manner!

The installation and commissioning should only be carried out by trained personnel.

Check the following points before commissioning:

- that the maximum values for all the connections are not exceeded, see "Technical data" section,

- that the connection wires are not damaged, and that they are not live during wiring,

- that the power flow direction and the phase rotation are correct.

The instrument must be taken out of service if safe operation is no longer possible (e.g. visible damage). In this case, all the connections must be switched off. The instrument must be returned to the factory or to an authorized service dealer.

It is forbidden to open the housing and to make modifications to the instrument. The instrument is not equipped with an integrated circuit breaker. During installation check that a labeled switch is installed and that it can easily be reached by the operators.

Unauthorized repair or alteration of the unit invalidates the warranty.

3. Device overview

3.1 Short description

The LINAX PQ5000 CURRENT LINK system is designed for power quality and load flow analysis in power distribution systems. The voltage is measured centrally in the PQ5000CL base unit and its quality is determined. At the same time, this device can be expanded with up to 32 power channels to form a system that can then also monitor the status and load flow of up to 10 outgoing feeders in a low-voltage distribution system, e.g. in a transformer station. This expansion with current channels is implemented using current modules, which are arranged in a ring, the so-called current link, and supply 3 or 4-channel current information from the outgoing circuits. This current measurement is synchronized with the central voltage measurement to ensure that the power is correctly determined.

The process environment is connected via communication interfaces such as Modbus/RTU, Modbus/TCP, IEC 61850 or MQTT. The functionality of the basic device can be parameterized directly on the device, via a web browser or the remote maintenance tool «CBM Current Link Manager».

The products of the LINAX PQ5000 series are independently certified Class A devices according to IEC 61000-4-30 Ed. 3. They provide reliable and comparable information for regulatory authorities, negotiations with energy suppliers or internal quality control.

By means of continuous monitoring, incidents can be analyzed immediately and their causes permanently eliminated. In addition, long-term acquisition permits the early recognition of changes in order to improve supply security and thus system availability.

The flexible approach without any software excels both in autarchy and flexible software integration options. It is based on standardized interfaces, generates power quality compliance reports directly via the device website and excels with a comprehensive cyber security concept.

3.2 System overview

The base unit LINAX PQ5000CL monitors centrally the power quality of the distribution system and collects, synchronized to the voltage, the current information of the current modules for state monitoring and load flow analysis of the individual feeders. Two version of the basic unit are available:

Version	Image	Description
PQ5000CL-0 / -1		**Hat-rail device** with / without display. The user has to connect the device himself, must assure the device is powered (100-230V AC/DC) and has to provide 24 up to 30 VDC for powering the current link.
PQ5000CL-2 / -3		Hat-rail device with / without display, built-in a **field housing for wall mounting**. All connections of the device are pre-wired. The user only has to connect the voltages L1, L2, L3, (N) and PE to the terminals inside the housing.

Using the current modules 3P and 3PN three or four currents of the feeders in a TNC or TNS low-voltage system are measured and transferred to the base unit via Current Link. The modules can measure normal operating currents and short-circuit currents up to a few kA.
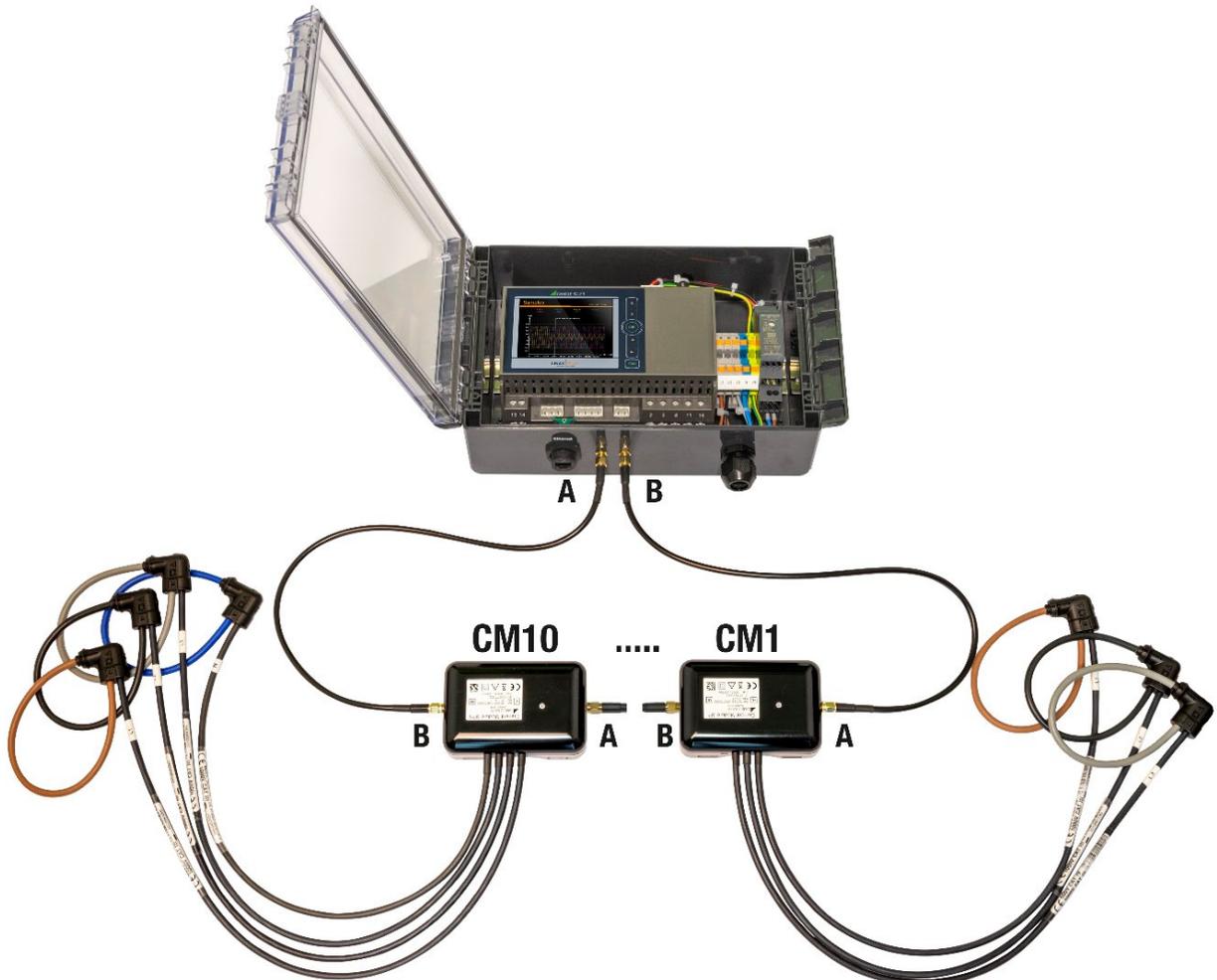
PQ5000CL-3 in a field housing with connected 3PN and 3P current modules

3.3 Available measurement data

Power quality

The device provides all necessary data for power quality assessment according to the standards EN 50160 or IEC 61000-2-2 / 2-4 / 2-12. User-defined limit-values may be defined and monitored as well. A compliance report (PQEasy Report) can be generated directly via the website of the device.

The events frequency deviation, voltage dip / swell / interruption and rapid voltage change (RVC) can be monitored and recorded as sequences of RMS 1/2 values.

Stata and load flow information

For all feeders monitored by current modules the following Measurements are available:

- All voltages and currents

- Frequency

- Active, reactive and apparent power for each phase and totally

- Load factor, for each phase and totally

- Active and reactive energy incoming / outgoing

- Phasing of all voltages and currents

Measurement data is provided via the following menus of the web-interface and, if available, the local display:

a) **Instantaneous values**: Present TRMS values with phasor diagram, phase sequence and energy direction information for each current module

b) **Energy**: Energy meters for each current module

c) **Harmonics**: Total harmonic distortion THD/TDD, individual harmonics and their maximum values, phase angle of the harmonics. For currents this information is available for the configured current reference channel only.

d) **Waveform**: Display of voltages and the currents of the selected reference channel

e) **Events**: Chronological lists of PQ events and ripple control events

f) **PQ statistic**: Data of the statistical power quality analysis including a facility for PQ report creation

4. Mechanical mounting

> ℹ️ Please ensure that the operating temperature limits are not exceeded when determining the place of mounting (place of measurement).

> ⚠️ By installing, the device becomes part of an electrical power installation that must be designed, operated and maintained in accordance with country-specific regulations so that the installation is safe and provides prevention against fire and explosion as far as possible.
>
> ⚡ It is the task of this installation to ensure that dangerous connections of the device cannot be touched during operation and that the spread of flames, heat and smoke from the interior is prevented. This may be done by providing an enclosure (e.g. case, cabinet) or using a room accessible to qualified personal only and compliant with local fire safety standards.

4.1 Hat rail mounting PQ5000CL-0 /- 1

The device can be clipped onto a top-hat rail according to EN 60715, orientation as shown below.
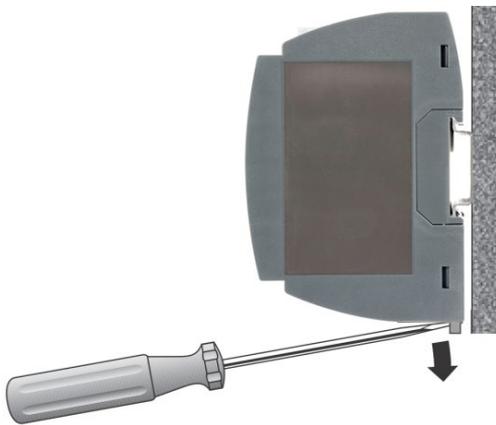
Dimensional drawing PQ5000: See section 10
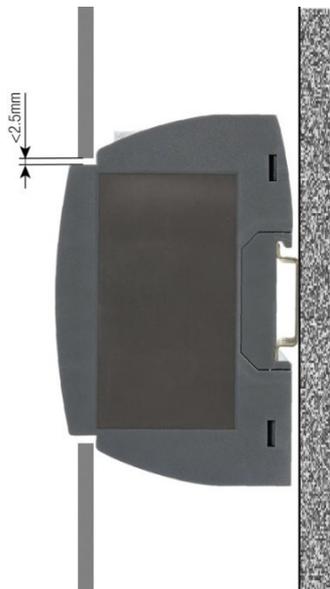
The **PQ5000CL-1 / -2 with display** can also be mounted that the front of the device protrudes through a cut-out in the enclosure. So, the operating buttons and the display become accessible. With centric mounting using the below maximum cut-out a gap between enclosure and device results, which does not exceed 2.5mm on each side.

165^{-1}

85^{-1}

<2.5mm
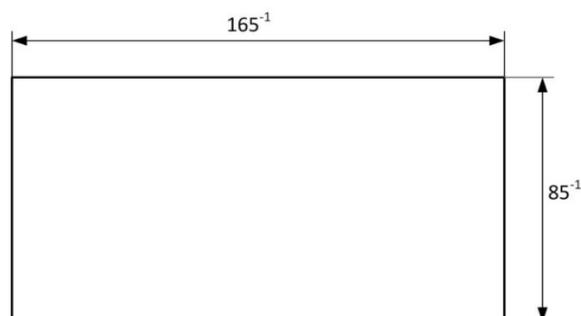
4.2 Wall mounting PQ5000CL-2 /- 3

The field housing can be mounted on a wall with four screws (not included). Installation position as shown below.
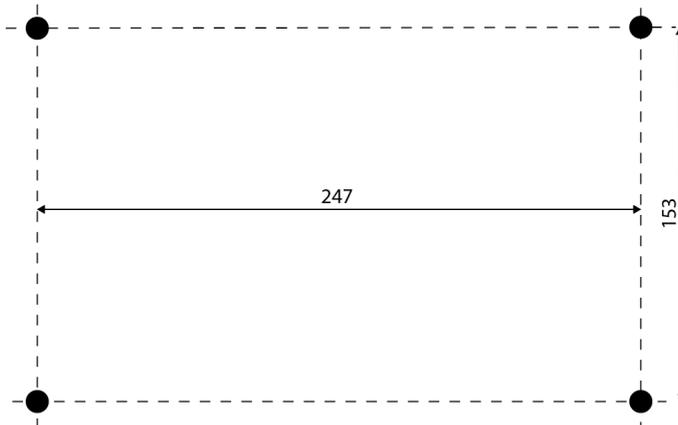
Drilling plan for field housing

5. Electrical connections

⚠ **Ensure under all circumstances that the leads are free of potential when connecting them!**

5.1 General safety notes

ℹ **Please observe that the data on the type plate must be adhered to!**

The national provisions have to be observed in the installation and material selection of electric lines, e.g. in Germany VDE 0100 "Erection of power installations with nominal voltages up to 1000 V"!

Name plate of PQ5000CL-2 / -3

- Version in field housing
- Internal power supply via L1-N
- IEC 61850 protocol
- MQTT protocol
- Disturbance recorder

Name plate of PQ5000CL-0 / -1

- Version for hat-rail mounting
- Power supply 100-230V AC/DC
- Without IEC 61850 protocol
- Without MQTT protocol
- Without disturbance recorder

Symbol	Meaning
	Device may only be disposed of in a professional manner!
	Double insulation, device of protection class 2
CE	CE conformity mark. The device fulfills the requirements of the applicable EU directives.
⚠	Caution! General hazard point. Read the operating instructions.
→○	General symbol: Power supply
→►	General symbol: Input
○→►	General symbol: Output
CAT III	Measurement category CAT III

5.2 Possible cross sections and tightening torques PQ5000CL-0 / -1

Inputs L1(2), L2(5), L3(8), N(11), PE(16), power supply (13-14)	
Single wire	• 1 x 0,5...6.0mm^2 or 2 x 0,5...2.5mm^2 • 1 x 20 AWG…9 AWG or 2 x 20 AWG…14 AWG
Multiwire with end splices	• 1 x 0,5...4.0mm^2 or 2 x 0,5...2.5mm^2 • 1 x 20 AWG…11 AWG or 2 x 20 AWG…14 AWG
Tightening torque	• 0.5…0.6Nm • 4.42…5.31 lbf in
I/O's, relays, RS485 connector (A, B, C/X)	
Single wire	• 1 x 0.5 ... 2.5mm^2 or 2 x 0.5 ... 1.0mm^2 • 1 x 20 AWG…14 AWG or 2 x 20 AWG…17 AWG
Multiwire with end splices	• 1 x 0.5 ... 2.5mm^2 or 2 x 0.5 ... 1.5mm^2 • 1 x 20 AWG…14 AWG or 2 x 20 AWG…16 AWG
Tightening torque	• 0.5…0.6Nm • 4.42…5.31 lbf in

5.3 Possible cross sections PQ5000CL-2 / -3

Grommet

The diameter of the feeder cable to the input terminals through the cable gland can be 8 to 13 mm.

Input terminals L1, L2, L3, N, PE

- Push-in terminals

- Cross section 0,2…6,0mm^2 (AWG 24...10)

⚠ If there is only a PEN conductor present in the installation, i.e. PE and N are not routed separately, the PEN conductor must be connected to PE and N.

5.4 Voltage connection base unit

> ⚠️ The **voltage measurement inputs** L1, L2 and L3 must originate at circuit breakers or fuses rated 5 Amps or less. This does not apply to the neutral connector.
> You have to provide a method for manually removing power from the device, such as a clearly labeled circuit breaker or a fused disconnect switch in accordance with IEC 60947-2 or IEC 60947-3.

Voltage connection PQ5000CL-0 / -1

Connection is done via the terminals 2, 5, 8, 11 and 16 of the hat-rail device

> ⚡ Maximum permissible rated voltage 400 VAC to ground (693V Ph-Ph)!

Voltage connection PQ5000CL-2 / -3

Connection is done via the terminals L1, L2, L3, N and PE of the terminal block.
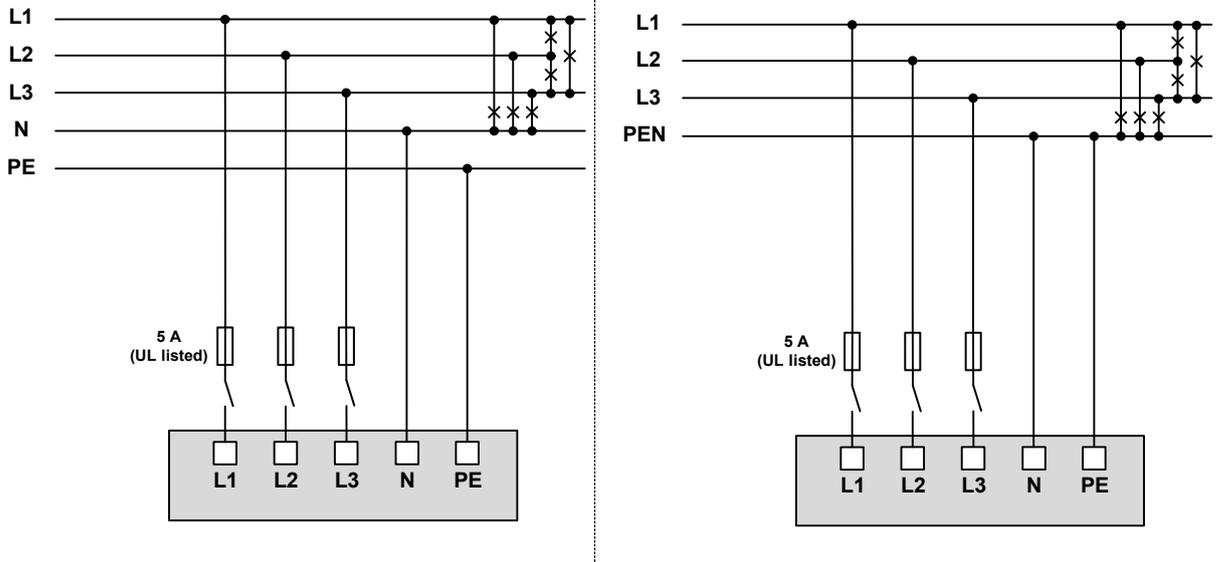
> ⚠️ If there is only a PEN conductor present in the installation, i.e. PE and N are not routed separately, the PEN conductor must be connected to PE and N.

> ⚡ Maximum permissible rated voltage 230 VAC to ground or 400V Ph-Ph.

5.5 Current Link

Current Modules 3P and / or 3PN have to be arranged in a ring structure. The connection of the individual elements of the ring is done using SMA connection cables.

> ⚠ The SMA connection cables must not be kinked during assembly, as the conductors could be damaged. The bending radius should be not smaller than 50mm.
>
> The fastening of the SMA cables to the corresponding connectors should be done with a torque wrench with a maximum torque of 1 Nm.
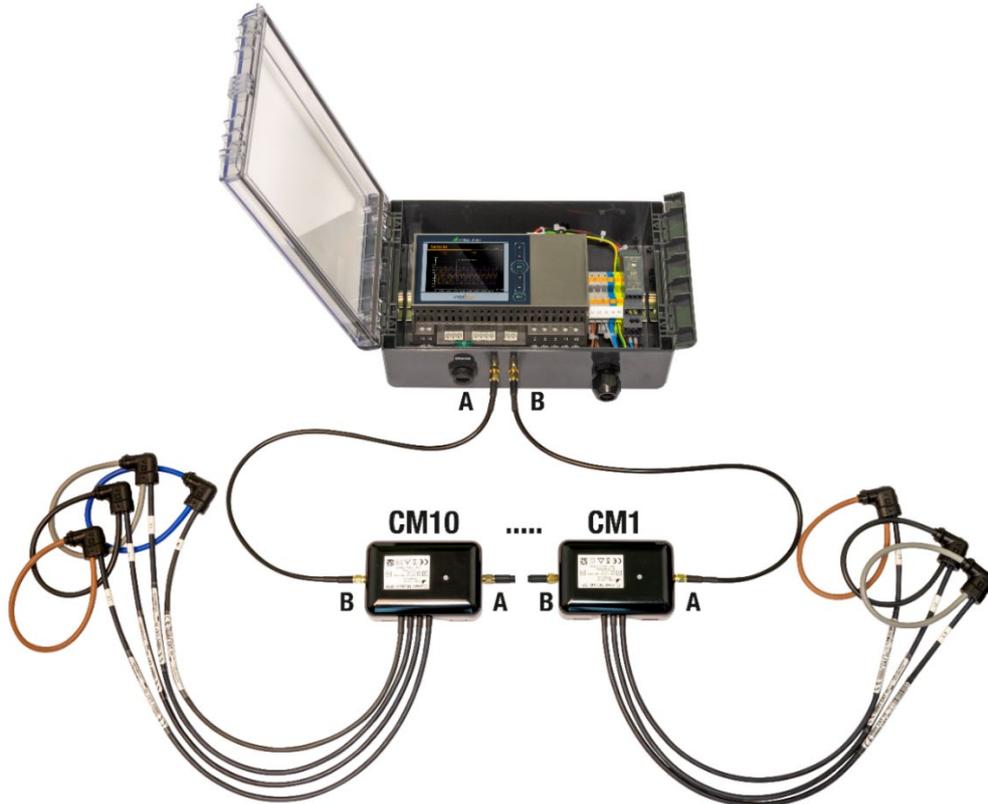
PQ5000CL-2/3

PQ5000CL-0/1

Powering the current link (PQ5000CL-0/-1)

A power supply of 24 up to 30 VDC is required for the connected Current Modules 3P and / or 3PN. The following requirements must be met:

- Minimum voltage X3 (+/-)
  - When used with a maximum of 9 current modules: U ≥ 22 VDC
  - When used with 10 current modules: U ≥ 24 VDC
- Maximum voltage X3 (+/-): U ≤ 30 VDC
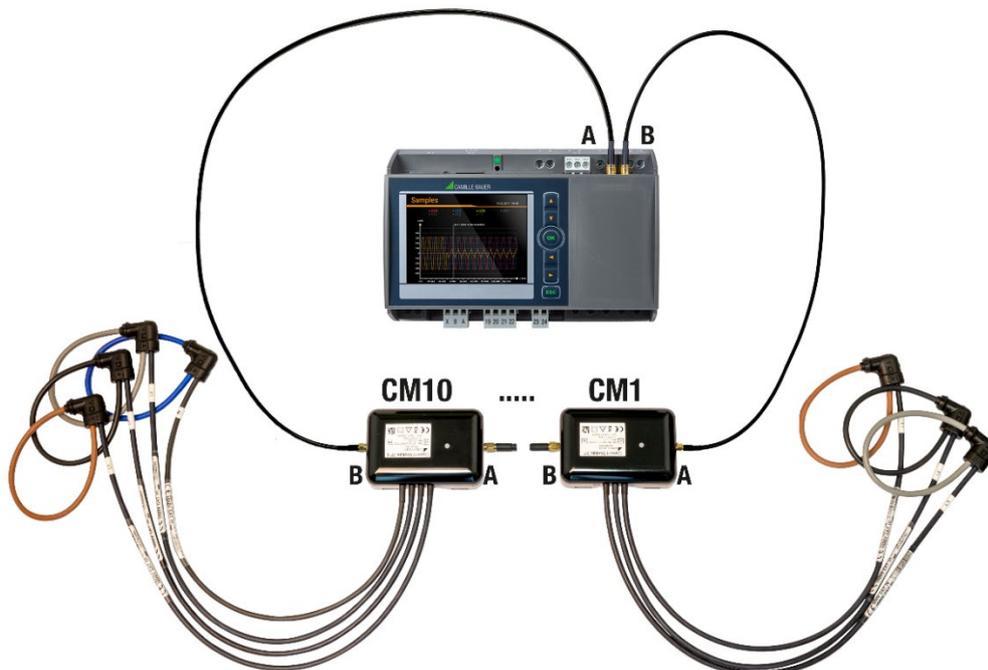- Consumption per current module: typ. 1W
- Maximum ripple: <150 mVpp

Rogowski coils

The Rogowski coils of the current modules are different in color and also marked:

- Brown – L1
- Black – L2
- Gray – L3
- Blue – N

The Rogowski coils are placed directly around the respective conductors. The current direction, which is indicated by an arrow on the measuring head, must be observed.

Connection of the modules to each other and to the base unit

Connector B is always connected to connector A. Starting from connector B of the base unit, connector A of the 1st module (CM1) is connected, then connector B of the 1st module is connected to connector A of the 2nd module (CM2) and so on, until finally connector B of the last module is connected back to connector A of the base unit.

Mounting of the junction box
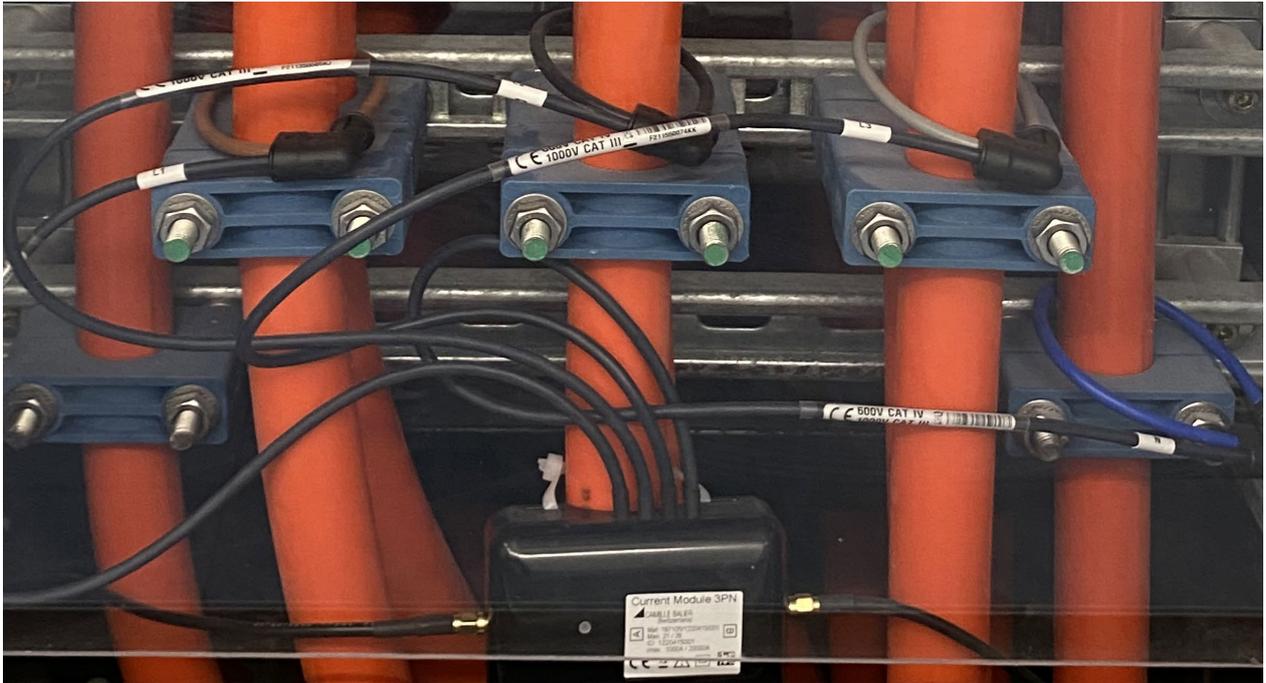
The connection housing of a current module can be fixed directly to a cable using cable ties.

	The junction box of a current module must not be mounted on bare conductors, nor must connecting cables be routed over bare live conductors. If there are bare connections or busbars in the immediate vicinity, the junction box and connecting cables must be secured in such a way that their metal parts cannot touch live, bare parts in the event that the fixing of the junction box or a connecting cable becomes detached unexpectedly.

	The cable shielding of the current link must be grounded to ensure transmission is as free of interference as possible. With the PQ5000CL-2/-3 this is done via the PE terminal of the connection block, if there is only one PEN conductor, PE must therefore be connected to N. With the PQ5000CL-0/-1, connection 1 of the current module must be connected to PE or PEN.

5.6 GPS time synchronization

The optional GPS connection module serves for connecting a GPS receiver as a very accurate time synchronization source for the measurement device. The GPS receiver, available as an accessory, is used as outdoor antenna to process data from multiple GPS satellites simultaneously.

GPS receiver

Only use the receiver **Garmin GPS 16x-LVS** (article no. 181'131), offered as an accessory. This device is preconfigured by us and provides the required time information (sentences) without further configuration effort.

- Protection: IPx7 (waterproof)
- Operating temperature: -30...80°C
- Storage temperature: -40...80°C
- 1Hz pulse accuracy: 1µs
- Connector: RJ45

Choosing a mounting location

For a correct operation the GPS receiver requires data from at least 3 satellites at the same time. Therefore, position the receiver so that the clearest possible view of the sky and horizon in all direction is obtained. This can be on the roof of a building, at best without reception being restricted by other buildings or obstacles. Avoid mounting the receiver next to large areas of conductible material, as this may cause poor signal reception. It should be also not closer than 1 meter away from any other antenna.

> ⚠ If lightning protection is required, this must be provided by the user.

Mounting the GPS receiver

- The GPS receiver **Garmin GPS 16x-LVS** can be flush mounted by means of 3 M4 screws.

- 120° distribution over a circle of ø71.6mm

- Thread length max. 8mm. Using longer screws may damage the GPS receiver.
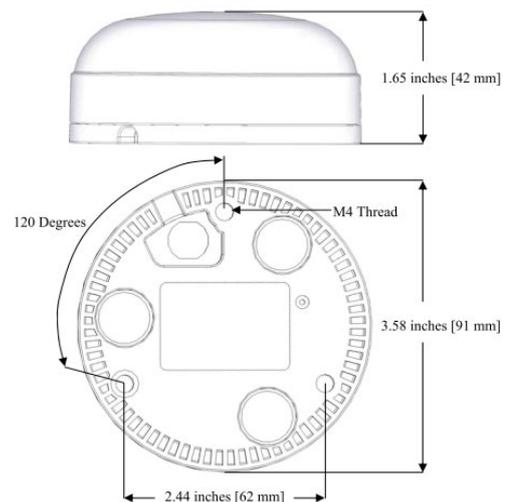
Connecting the GPS receiver

> ⚠ Never connect the RJ45 socket of the connecting cable directly to a network device such as a router or switch. These devices could be damaged.

The GPS receiver is plugged directly into the GPS connection module. The connection cable has a length of 5m. It may be extended to up to 50m using an RJ45 coupling and an Ethernet cable. The connection cable should not be laid in parallel to live conductors. Twisting or sharp kinking of the cable should be avoided.

Commissioning

- In the settings menu change time synchronization to „NTP server / GPS"
- Check the time synchronization status

- The time synchronization can be restarted by switching the time synchronization off and on again.
- Time synchronization via GPS and NTP server may work in parallel. If both synchronization sources are available, the system uses the more accurate time source, which is normally GPS.

> ⓘ When connecting a GPS receiver for the first time or when it has been out of operation for a long time, it may take up to 1 hour for finding enough satellites for GPS receiver operation and thus for a reliable time synchronization.

## 5.7 Power supply PQ5000CL-0 / -1

> ⚠ **For PQ5000CL-0 / -1 only**
>
> A marked and easily accessible current limiting switch in accordance with IEC 60947-2 has to be arranged in the vicinity of the device for turning off the power supply. Fusing should be 10 Amps or less and must be rated for the available voltage and fault current.

5.8 Modbus interface RS485

Using a PQ5000CL-0/-1 measurement data may be provided to a superior system via the Modbus interface.

Hint: A device parameterization via Modbus interface is not supported.
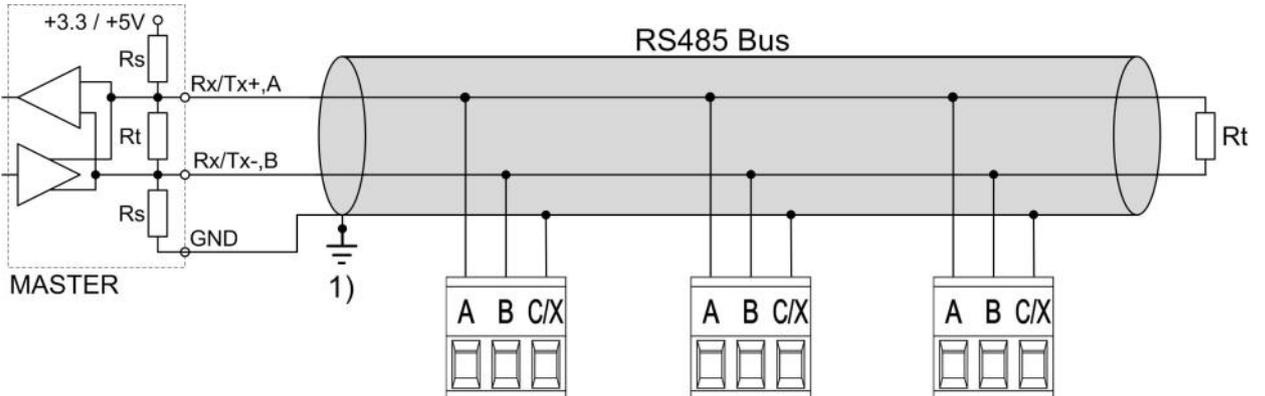
1) One ground connection only. This is possibly made within the master (PC).

Rt: Termination resistors: 120 Ω each for long cables (> approx. 10 m)

Rs: Bus supply resistors, 390 Ω each

The signal wires (A, B) have to be twisted. GND (X) can be connected via a wire or via the cable shield. In disturbed environments shielded cables must be used. Supply resistors (Rs) have to be present in bus master (PC) interface. Stubs should be avoided when connecting the devices. A pure line network is ideal. You may connect up to 32 Modbus devices to the bus.

A proper operation requires that all devices connected to the bus have equal communication settings (baud rate, transmission format) and unique device addresses. Use the appropriate menu in the settings of communication.

If a Modbus/RTU interface is present but not required, communication may be disabled for security reasons.
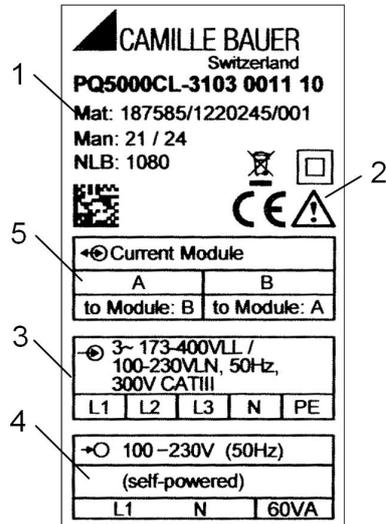
The bus system is operated half duplex and may be extended to a maximum length of 1200 m without repeater.

6. Commissioning

> ⚠ Before commissioning you have to check if the connection data of the device match the data of the plant (see nameplate).
>
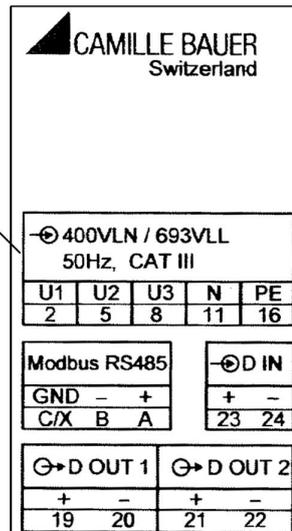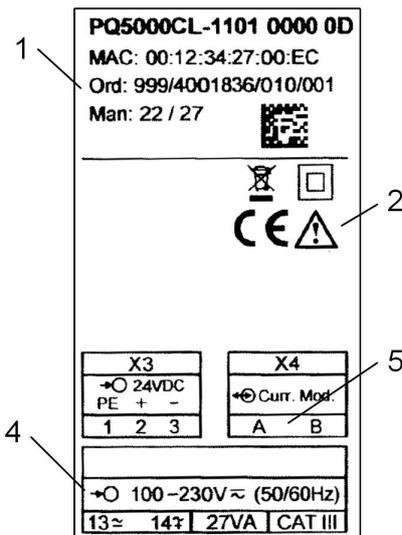> If so, you can start to put the device into operation by switching on the power supply and the measurement inputs.

LINAX PQ5000CL-2 / -3

- ➤ Measurement input
  - Input voltage
  - System frequency
  - Overvoltage category
- 1 Serial number
- 2 Test and conformity marks
- 3 Assignment voltage inputs
- 4 Assignment power supply (internally)
- 5 Connectors Current Link

LINAX PQ5000CL-0 / -1

- ➤ Measurement input
  - Input voltage
  - System frequency
  - Overvoltage category
- 1 Serial number
- 2 Test and conformity marks
- 3 Assignment voltage inputs
- 4 Assignment power supply (internally)
- 5 Connectors Current Link

6.1 Parametrization of the device functionality

A full parameterization of all functions of the device is possible directly at the device or via web browser. This assumes that the user has the required access rights.

For security reasons, the security features "Users and Permissions" (RBAC) and "Web security" (HTTPS) may be activated. In this case, before the device webpage can be displayed using https, you have to install a root certificate, which is provided via our homepage. Once the certificate is downloaded to the local computer the certificate can be installed manually. Just double-click on the file, and install the certificate as a trusted root certification authority.

See: Configuration (7.5)

6.2 Operating LED of the base unit

The operating LED shows the present device state

Procedure	LED display
Booting of device	• Flashes green (1 Hz) • If successful: Change to static green display
Firmware update	• Change to update mode: Static red • During update: Flashes red (1 Hz) • If successful or cancelled: Booting of device
Factory reset or reset of communication settings	• During reset: Flashes red (1 Hz) • Then (for a factory reset): Booting of device

6.3 Operating LED of the Current Module 3P / 3PN
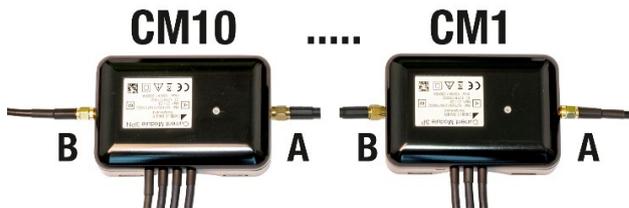
Each Current Module shows its state by means of a color status LED.

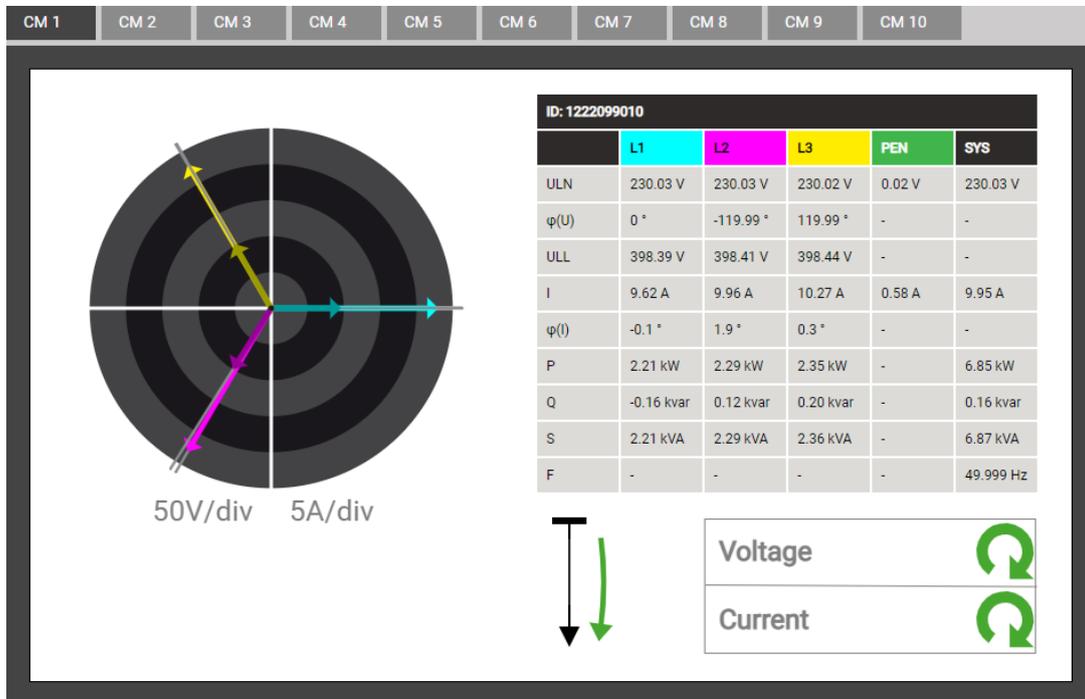| LED	Color	State
ON	Red	Error: FIFO overflow / underrun
	Yellow	Link not active, no error
	Green	Link active, no error
	Blue	Firmware update is running
OFF	-	Current Link not closed, missing supply

As long as the current module is not initialized, the LED is sequentially driven in a way that first the brightness is slowly increased and then abruptly switched dark. As soon as the module is initialized, the brightness is slowly increased and then slowly decreased.

6.4 Installation check

The correct connection of the current and voltage inputs can be checked in two ways.

a) **Sense of rotation check**: Using the sequence of the current and voltage phasors the sense of rotation is determined and compared to the configured one. The phase rotation indicator is arranged in the menu "Phasor diagram".

Test requirement: Magnitude of all connected voltages at least 5% of nominal, magnitude of all connected currents at least 1% of nominal.

| CM 1 | CM 2 | CM 3 | CM 4 | CM 5 | CM 6 | CM 7 | CM 8 | CM 9 | CM 10 |

ID: 1222099010

	L1	L2	L3	PEN	SYS
ULN	230.03 V	230.03 V	230.02 V	0.02 V	230.03 V
φ(U)	0 °	-119.99 °	119.99 °	-	-
ULL	398.39 V	398.41 V	398.44 V	-	-
I	9.62 A	9.96 A	10.27 A	0.58 A	9.95 A
φ(I)	-0.1 °	1.9 °	0.3 °	-	-
P	2.21 kW	2.29 kW	2.35 kW	-	6.85 kW
Q	-0.16 kvar	0.12 kvar	0.20 kvar	-	0.16 kvar
S	2.21 kVA	2.29 kVA	2.36 kVA	-	6.87 kVA
F	-	-	-	-	49.999 Hz

50V/div   5A/div

| Voltage | ↻ |
| Current | ↻ |

Possible results

↻ Correct sense of rotation

↺ Wrong sense of rotation

⚠ Missing phase or magnitude too small

b) **Phasor verification**: The phasor diagram shows a technical visualization of the current and voltage phasors, using a counter-clockwise rotation, independent of the real sense of rotation.

> ℹ️ **The diagram is always built basing on the voltage of the reference channel (direction 3 o'clock)**
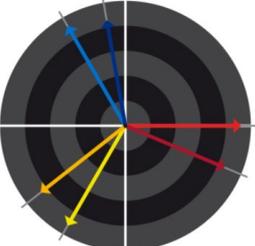
<table>
<tr><td>

50V/div 20A/div
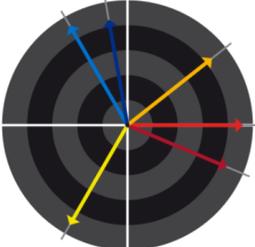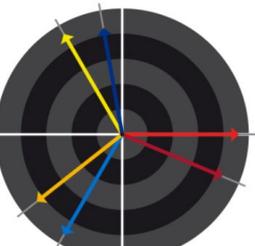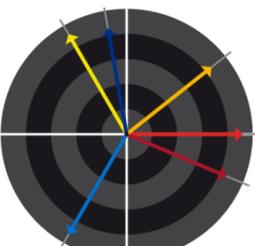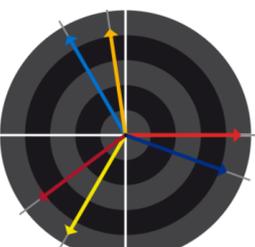
<table>
<tr><td>L1</td><td>L2</td><td>L3</td><td></td></tr>
<tr><td>230.60</td><td>230.64</td><td>230.54</td><td>V</td></tr>
<tr><td>0.00</td><td>-119.97</td><td>120.03</td><td>°</td></tr>
<tr><td>85.97</td><td>86.03</td><td>85.86</td><td>A</td></tr>
<tr><td>-22.9</td><td>-21.7</td><td>-20.0</td><td>°</td></tr>
<tr><td>0.921</td><td>0.929</td><td>0.940</td><td>PF</td></tr>
</table>

</td><td>

Correct installation (expectation)
- Voltage sequence in clock-wise order
  L1 → L2 → L3 (0° → -120° → 120°)
- Current sequence in clock-wise order
  L1 → L2 → L3
- Similar angle between voltage and current phasors in all phases (approx. -20°)

</td></tr>

<tr><td>

50V/div 20A/div

<table>
<tr><td>L1</td><td>L2</td><td>L3</td><td></td></tr>
<tr><td>230.58</td><td>230.63</td><td>230.53</td><td>V</td></tr>
<tr><td>0.00</td><td>-119.97</td><td>120.03</td><td>°</td></tr>
<tr><td>85.96</td><td>86.04</td><td>85.87</td><td>A</td></tr>
<tr><td>-22.9</td><td>158.4</td><td>-20.0</td><td>°</td></tr>
<tr><td>0.921</td><td>-0.930</td><td>0.940</td><td>PF</td></tr>
</table>

</td><td>

What's wrong?
- Voltage sequence: L1 → L2 → L3
- Current sequence: L1 → L3 → L2; Current L2 is out of the expected sequence
- Angle U-I: Angle between U_{L2} and I_{L2} is approx. 180° wrong

Required correction
Reversing the polarity of current I_2

</td></tr>

<tr><td>

50V/div 20A/div

<table>
<tr><td>L1</td><td>L2</td><td>L3</td><td></td></tr>
<tr><td>230.59</td><td>230.49</td><td>230.70</td><td>V</td></tr>
<tr><td>0.00</td><td>120.04</td><td>-119.99</td><td>°</td></tr>
<tr><td>85.97</td><td>86.02</td><td>85.86</td><td>A</td></tr>
<tr><td>-22.9</td><td>98.3</td><td>-140.0</td><td>°</td></tr>
<tr><td>0.921</td><td>-0.145</td><td>-0.766</td><td>PF</td></tr>
</table>

</td><td>

What's wrong?
- Voltage sequence: L1 → L3 → L2; L3 and L2 seems to be interchanged
- Current sequence: L1 → L2 → L3
- Angle U-I: Angles between U_{L2} / I_{L2} and U_{L3} / I_{L3} do not correspond to the expectations

Required correction
Exchanging the connections of the voltages L2 and L3

</td></tr>

<tr><td>

50V/div 20A/div

<table>
<tr><td>L1</td><td>L2</td><td>L3</td><td></td></tr>
<tr><td>230.58</td><td>230.49</td><td>230.68</td><td>V</td></tr>
<tr><td>0.00</td><td>120.04</td><td>-119.99</td><td>°</td></tr>
<tr><td>85.97</td><td>86.04</td><td>85.86</td><td>A</td></tr>
<tr><td>-22.9</td><td>-81.6</td><td>-140.0</td><td>°</td></tr>
<tr><td>0.921</td><td>0.145</td><td>-0.766</td><td>PF</td></tr>
</table>

</td><td>

What's wrong?
- Voltage sequence: L1 → L3 → L2; L3 and L2 seems to be exchanged
- Current sequence: L1 → L3 → L2; Current L2 is out of the expected sequence
- Angle U-I: Angles between U_{L2} / I_{L2} and U_{L3} / I_{L3} do not correspond to the expectations

Required correction
Exchanging the connections of the voltages L2 and L3 and reversing the polarity of the current input I_2

</td></tr>

<tr><td>

50V/div 20A/div

<table>
<tr><td>L1</td><td>L2</td><td>L3</td><td></td></tr>
<tr><td>230.45</td><td>230.48</td><td>230.58</td><td>V</td></tr>
<tr><td>0.00</td><td>-120.02</td><td>119.98</td><td>°</td></tr>
<tr><td>85.96</td><td>86.00</td><td>85.86</td><td>A</td></tr>
<tr><td>-143.0</td><td>-141.6</td><td>-140.0</td><td>°</td></tr>
<tr><td>-0.798</td><td>-0.784</td><td>-0.766</td><td>PF</td></tr>
</table>

</td><td>

What's wrong?
- Voltage sequence: L1 → L2 → L3
- Current sequence: L3 → L1 → L2
- Angle U-I: The U-I angles do not correspond to the expectation, but are similar

Required correction
Cyclical exchange of the voltage connections: L1→L3, L2→L1, L3→L2. As an alternative the sequence of all currents may be changed as well (more effort required).

</td></tr>
</table>

6.5 Ethernet installation

6.5.1 Settings

> Before devices can be connected to an existing Ethernet network, you have to ensure that they will not disturb the normal network service. The rule is:
>
> ⚠️ **None of the devices to connect is allowed to have the same IPv4/v6 address than another device already installed**

The device supports both IPv4 and IPv6 communication. IPv4 communication is activated by default; IPv6 can be activated additionally via configuration.

IPv4 communication

Application	Default IPv4	Settings via menu
Configuration / Modbus TCP / IEC61850	192.168.1.101	Settings | Communication | Ethernet

IPv6 Communication

Application	Default IPv6	Settings via menu
Configuration / Modbus TCP / IEC61850	fd2d:bb44:97f1:3976::1	Settings | Communication | Ethernet

Network settings (Communication | Ethernet)

The following settings have to be arranged with the network administrator:

• **IPv4/6: Mode**	Defines how the IP address of the device is assigned. The assignment can be statically, via DHCP or SLAAC (IPv6 only).
• **IPv4/6: IP address**	Must be **unique**, i.e. may be assigned in the network only once
• **IPv4: Subnet mask**	Defines how many devices are directly addressable in the IPv4 network. This setting is equal for all the devices. Examples
• **IPv4/6: Gateway address**	Is used to resolve addresses during communication between different networks. It should contain a valid address within the directly addressable network
• **IPv4/6: DNS-Server x**	Is used to resolve a domain name into an address, if e.g. a name (pool.ntp.org) is used for the NTP server. Further information
• **IPv6: Prefix length**	Is comparable to the subnet mask in IPv4 networks; it is the number of the leftmost bits of the site prefix which need to be identical for direct communication.
• **Hostname**	Individual designation for each device. Via the hostname the device can be uniquely identified in the network. Therefore, for each device a unique name should be assigned.
• **NTP-Server x**	NTP servers are used as base for time synchronization
• **Modbus TCP enabled**	If Modbus/TCP communication is not required it may be disabled for security reasons.
• **Modbus/TCP port**	Selection of the TCP port to be used for Modbus/TCP communication. Standard setting is 502. See also TCP ports.

Network settings Ethernet interface

IPv4: Mode	Static
IPv4: IP address	192.168.63.64
IPv4: Subnet mask	255.255.248.0
IPv4: Gateway address	192.168.56.4
IPv4: DNS server 1	192.168.56.44
IPv4: DNS server 2	192.168.56.144
IPv6: Mode	Static
IPv6: IP address	fd2d:bb44:97f1:3976::1
IPv6: Prefix length	64
IPv6: Gateway address	fd2d:bb44:97f1:3976::5:1
IPv6: DNS server 1	
IPv6: DNS server 2	
Host name	PQ5000-G1-UG-UVE
Clock synchronization	NTP server / GPS
NTP server 1	pool.ntp.org
NTP server 2	

IPv4: Subnet mask

For a direct communication between device and PC both devices need to be in the same network when the subnet mask is applied:

Example 1	decimal	binary
IP address	192.168. 1.101	11000000 10101000 00000001 01100101
Subnet mask	255.255.255.224	11111111 11111111 11111111 11100000
	variable range	xxxxx
First address	192.168. 1. 96	11000000 10101000 00000001 01100000
Last address	192.168. 1.127	11000000 10101000 00000001 01111111

► *The device 192.168.1.101 can access directly the devices 192.168.1.96 … 192.168.1.127*

Example 2	decimal	binary
IP address	192.168. 57. 64	11000000 10101000 00111001 01000000
Subnet mask	255.255.252. 0	11111111 11111111 11111100 00000000
	variable range	xx xxxxxxxx
First address	192.168. 56. 0	11000000 10101000 00111000 00000000
Last address	192.168. 59.255	11000000 10101000 00111011 11111111

► *The device 192.168.57.64 can access directly the devices 192.168.56.0 ... 192.168.59.255*

IPv4: Mode >> DHCP

If a DHCP server is available, alternatively the mode „**DHCP**" or „**DHCP, addresses only**" can be selected for the Standard interface. The device then gets all necessary information from the DHCP server. The difference between the two modes is that for "DHCP" also the DNS server address is obtained.

The settings obtained from the DHCP server can be retrieved locally via the service menu.

> Depending on the settings of the DHCP server the provided IP address can change on each reboot of the device. Thus, it's recommended to use the DHCP mode during commissioning only.
>
> The option DHCP is not available for devices without display.

Time synchronization via NTP protocol

For the *time synchronization* of devices via Ethernet *NTP* (Network Time Protocol) is the standard. Corresponding time servers are used in computer networks, but are also available for free via Internet. Using NTP it's possible to hold all devices on a common time base.

Two different NTP servers may be defined. If the first server is not available the second server is used for trying to synchronize the time.

If a public NTP server is used, e.g. "pool.ntp.org", a name resolution is required. This normally happens via a **DNS server**. So, the IP address of the DNS server must be set in the communication settings of the Ethernet interface to make a communication with the NTP server, and thus time synchronization, possible. Your network administrator can provide you the necessary information.

The time synchronization of the Standard interface can be performed via a GPS receiver as well.

TCP ports

The TCP communication is done via so-called ports. The number of the used port allows determining the type of communication. As a standard Modbus/TCP communication is performed via TCP port 502, NTP uses port 123. However, the port for the Modbus/TCP communication may be modified. You may provide a unique port to each of the devices, e.g. 503, 504, 505 etc., for an easier analysis of the communication traffic. Independent of these setting a communication via port 502 is always supported. The device allows at least 5 connections to different clients at the same time.

Firewall

Due to security reasons nowadays, each network is protected by means of a firewall. When configuring the firewall, you have to decide which communication is desired and which have to be blocked. The TCP port 502 for the Modbus/TCP communication normally is considered to be unsafe and is often disabled. This may lead to a situation where no communication between networks (e.g. via Internet) is possible.

6.5.2 Connection of the standard interface

The RJ45 connector serves for direct connecting an Ethernet cable.

- Interface: RJ45 socket, Ethernet 100BaseTX
- Mode: 10/100 MBit/s, full / half duplex, Auto-negotiation
- Protocols: http, https, Modbus/TCP, NTP

6.5.3 MAC addresses

For uniquely identifying Ethernet connections in a network, a unique MAC address is assigned to each connection. Compared to the IP address, which may be modified by the user at any time, the MAC address is static.

MAC: **00:12.34:27**:xx:xx   (x=sequential number)

6.5.4 Resetting the communication settings

If the communication settings of the Standard interface are no longer known, on devices with a display these settings may be locally displayed and modified. For devices without display this is not possible. The communication settings can then be reset to default settings via the reset button.

Press the sunk-in reset button (located below the operating LED) for at least 3s. During the reset the operating LED flashes red.

6.6 Communication tests

Via the service menu on the device website you may check if the selected network structure is valid. The device must be able to reach the DNS server via gateway. The DNS server then allows resolving the URL of the NTP server to an IP address. The Standard Ethernet interface serves as interface for the communication tests.

- Ping: Connection test to any network device (initial: gateway address)
- DNS: Test, if the name resolution via DNS works (initial: URL of NTP server)
- NTP: Test, if the selected NTP-Server is in fact a time server (stratum x)
- SFTP: Test, if access to SFTP server works. A test file will be copied to the base directory of the server.

NTP server test

6.7 IEC 61850 interface (Option)

The features of the IEC61850 interface are described in a separate document:

>> IEC61850 interface PQ5000CL

This document is available via https://www.camillebauer.com/

6.8 Security system

There are several security mechanisms implemented in the device which can be activated to provide a comprehensive access protection to all device data.

➢ The **role-based access control** (**RBAC**) system allows restricting the access to measured data, configuration settings and service functions to the rights granted to the present user. For access via website or local display this is done by reducing the available menus and / or providing only read access rights to specific services. For accessing data via external applications an API (Application Programming Interface) key is required, which needs to be implemented as a special user.

➢ **HTTPS** provides encrypted communication using TLS (Transport Layer Security)

➢ Via **client whitelist** access to the device can be restricted to specific clients with definable IP addresses

➢ **Communication blocking:** Communication services, such as Modbus/RTU, Modbus/TCP or SYSLOG are blocked by default and must be actively enabled via configuration. This way unauthorized access may be prevented and possible intruding points eliminated.

➢ **Security log**: The device stores all security related messages in a separate list accessible via the service menu. The content of this list can also be transferred to a central log-server using the **SYSLOG** protocol for security auditing.

If the device is equipped with a display, restrictions defined in the security system also take effect when operating the device via the local display. It is also possible to restrict users to local access only.

6.9.1 RBAC management

Each access to device data via website, local display or external software applications can be comprehensively protected using the role-based access control (RBAC) system. This way, access to measured value information, the change of configuration parameters or the resetting / deletion of measurement data can be individually adapted to the role of the active user.

Note: All settings of the security system are stored in the device in encrypted form only; login credentials are never transmitted in plain text.

A maximum of 8 users is supported

➢ **3 pre-defined standard users**

- *admin*: A user with administrator rights (Default setting password: „CBM_1234")
- *localgui*: The standard user for the local display. Its permissions determine what can be displayed or changed via the built-in display without a user having to log in.
- *anonymous*: The standard user for access via device website. Its permissions determine what can be displayed or changed via the website without a user having to log in.

➢ **Up to 5 definable users or API keys**

Users or API keys may be created by each user with write access to the settings of the security system. In any case, each user with a web login can change the password of its own account.

Application programming interface (API) keys are used to allow applications to access device data via REST interface (communication via http/https protocol). Such keys are timely unlimited and have either read-only permissions, all permissions or all permissions except security.

The pre-defined administrator or any other user with full access rights to the settings of the security system can:

- Change its own credentials (user name and/or password)
- Change the credentials (user name and/or password) of any other user
- Freely define the permissions of the standard users *localgui* and *anonymous*; both users are standard users without login credentials
- Create new users up to a maximum of 5
- Restrict users to local operation only (no login via website)

Adding users / API keys

In addition to the 3 predefined users a maximum of 5 users or API keys may be created. To do so, use "Add user / API key" and select the type of user to be created.
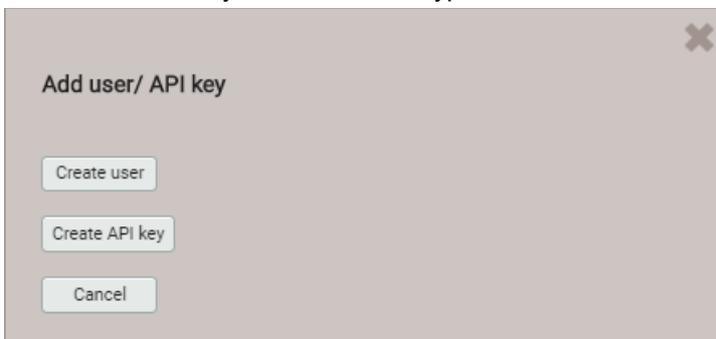
Users: During password definition the requirements for a secure password are checked and the result is displayed. Each new user can be created based on the permission template of an already existing user, but all of these permissions may be changed later.
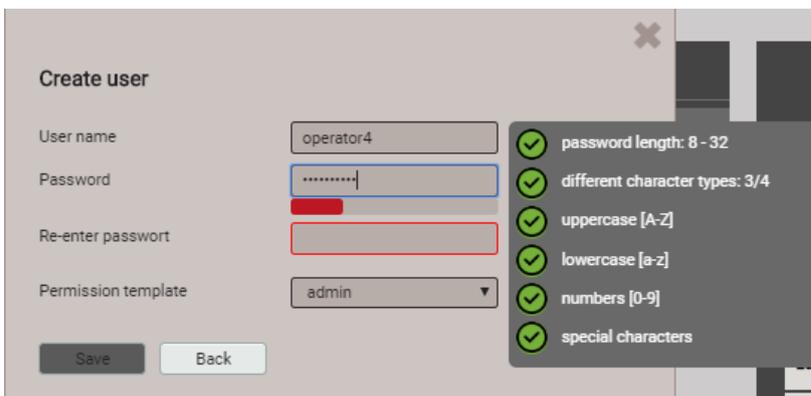
	When defining / changing passwords the following restrictions must be considered: - Password length 8 up to 32 characters - At least three different types of characters must be used (uppercase, lowercase, numbers, special characters)

	CAUTION: If login credentials (user name and / or password) of users with write access to the security system are changed, this information must be kept safe. For security reasons resetting the RBAC system can only be done at the factory, no backdoor is implemented.

API key: Along with the key name you have to define the permissions to be granted to the application using the key via REST interface. The resulting access rights cannot be changed afterwards.

Once the API key is created it can be displayed using "Show API key"

When the application wants to communicate via REST interface with the device, it has to provide the API key and the session token via the cookie field in the request header, e.g.:

```
Cookie:
AccessToken=eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJhdWQiOiIxYjg4IiwiaWF0IjoxNTc5MTU4OTc4LCJzdWIiOi
Jhbm9ueW1vdXMiLCJ0eG4iOiIxOTIuMTY4LjU4LjExNCJ9.LiLjuJcs2bZAmYHlvdMXTAlr87gxUX-3kZ4cfz6jdMc;
sessionToken={5d1ca47c-8d38-4a08-85d5-fefbd941fa20}
```

Further information is provided in the document "http interface SINEAX PQx000"

Assignment of user rights

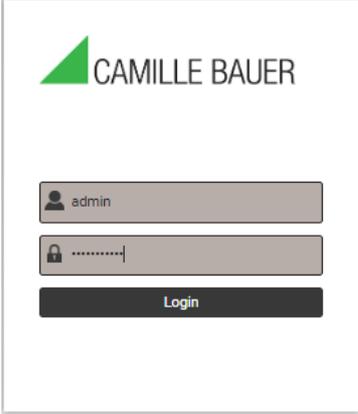The assignment of the user rights granted for operation is done via the menu Settings | Security system | Users and permissions:

Overview of the access rights of each possible user

6.8.2 User log in / out via website

a) If "anonymous" has no granted permissions

Via website	Remarks
	1) Enter user name and password 2) Press \<ENTER\> or select "Login" If successful, depending on the permissions of the user logged in, the appropriate website is displayed

b) If "anonymous" has granted permissions

Via website	Remarks
	1) Click on the symbol 2) Enter user name and password. On first login use the default settings admin / CBM_1234. 3) Press \<ENTER\> or select "Login" If successful, depending on the permissions of the user logged in, the appropriate website is displayed

c) If another user is already logged in

Via website	Remarks
	Log out the current user by selecting "Logout"
	1) Click on the symbol 2) Enter user name and password 3) Press \<ENTER\> or select "Login" If successful, depending on the permissions of the user logged in, the appropriate website is displayed

6.8.3 User log in / out via local display

a) If "localgui" has no granted permissions

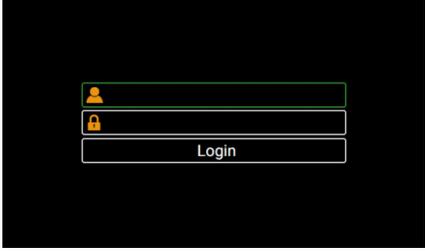| Locally	Remarks
	No information is displayed on the screen. Press <ESC> to enter the login screen.
	1) Press <OK> to enter the user name 2) Proceed to password using ▼ 3) Press <OK> to enter the password 4) Proceed to Login and press <OK> If successful, depending on the permissions of the user logged in, the appropriate menu is displayed.

b) If localgui has granted permissions

Locally	Remarks
	Repeatedly press <ESC> until the login screen is displayed. 1) Press <OK> to enter the user name 2) Proceed to password using ▼ 3) Press <OK> to enter the password 4) Proceed to Login and press <OK> If successful, depending on the permissions of the user logged in, the appropriate menu is displayed

c) If another user is already logged in
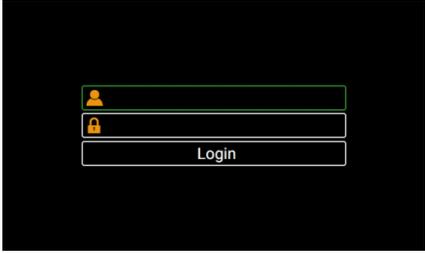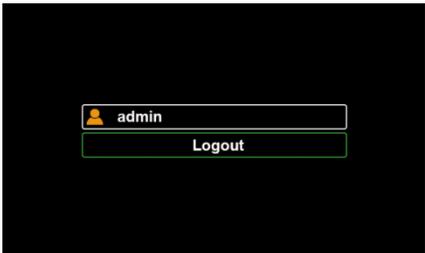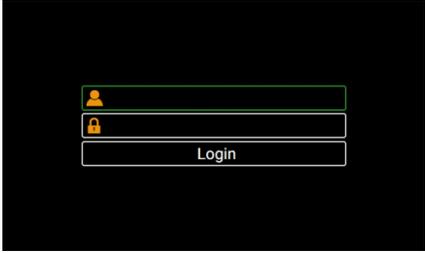
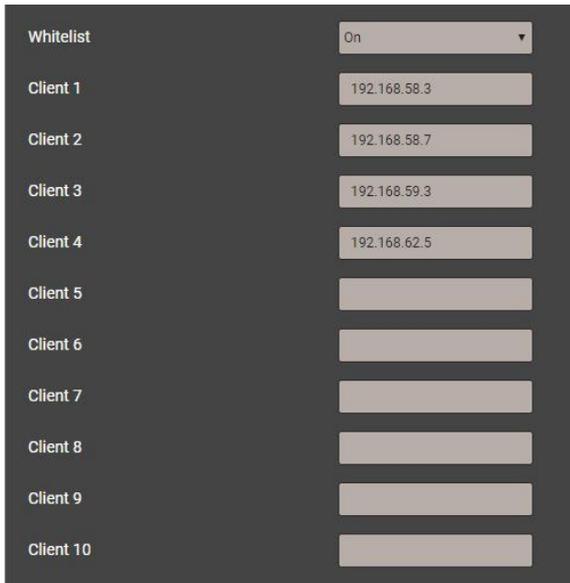| Locally	Remarks
	Repeatedly press <ESC> until the login screen is displayed. Log out the current user by selecting "Logout" Depending on the permissions of localgui either a menu or the lock symbol is displayed Repeatedly press <ESC> until the login screen is displayed. 1) Press <OK> to enter the user name 2) Proceed to password using ▼ 3) Press <OK> to enter the password 4) Proceed to Login and press <OK> If successful, depending on the permissions of the user logged in, the appropriate menu is displayed.

6.8.4 Whitelisting clients

It is possible to define a list of IPv4 and/or IPv6 addresses of up to 10 clients allowed to have access to the device. All other clients will be blocked. Enable the whitelist via the *Settings* of the *Security system* in the item *Whitelist*.

> *If a DHCP server is used in the system, clients may get different IP addresses on each startup, losing this way access to the device.*
>
> *If a device is no longer accessible you can reset its IP address (LAN), deactivating the whitelist at the same time.*

6.8.5 Secure communication using https

According to Enel specifications https communication is activated by default. This protocol provides encrypted communication using TLS (Transport Layer Security). Such as bidirectional encryption of communications between a client and server protects against eavesdropping and tampering of the communication, by creating a secure channel over an insecure network.

Before HTTPS communication can be used a root certificate needs to be installed. The user can either use a Camille Bauer certificate (default setting) or its own customer certificate. This may be changed when defining the Settings of the Security system.
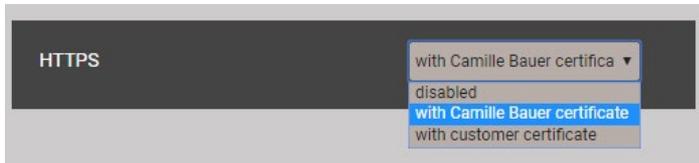
Camille Bauer certificate

Source: https://www.camillebauer.com/pq1000cl-en. Install the certificate before starting the browser.

Once the certificate is downloaded to the local computer the certificate can be installed manually. Just double-click on the file. **Install certificate**, then select **Place all certificates in the following store**, **Browse** and select **Trusted Root Certification Authorities**. **Finish** the Import Wizard.
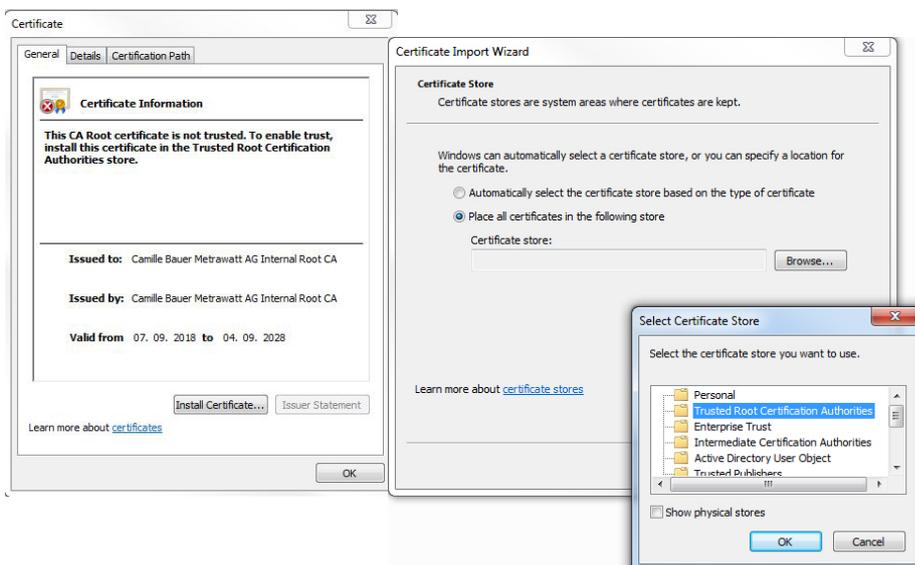
The imported certificate is valid for all devices of the PQ, AM, DM and CU series.

Agree to install the certificate if the below security warning appears:

Customer certificate

You may also use a customer server certificate with a private key, but for that you first need to change the *Settings* of the *Security system* in the item *Web Security*.

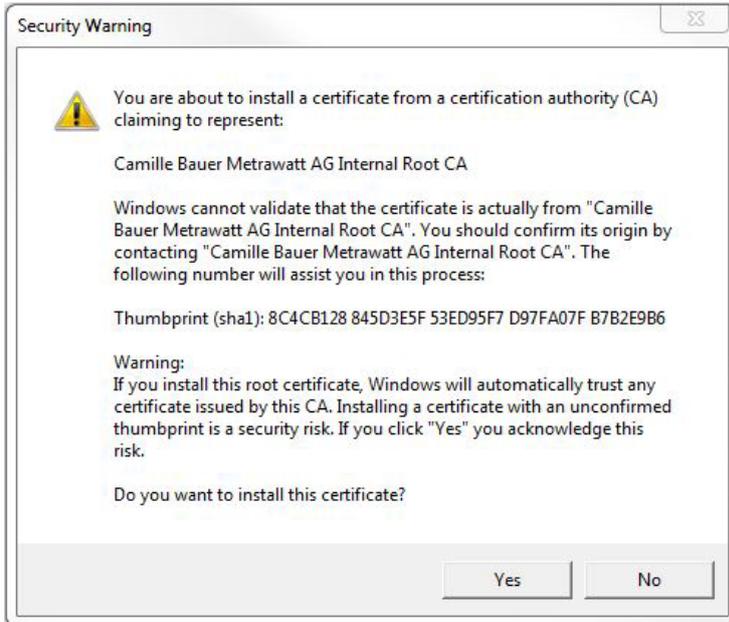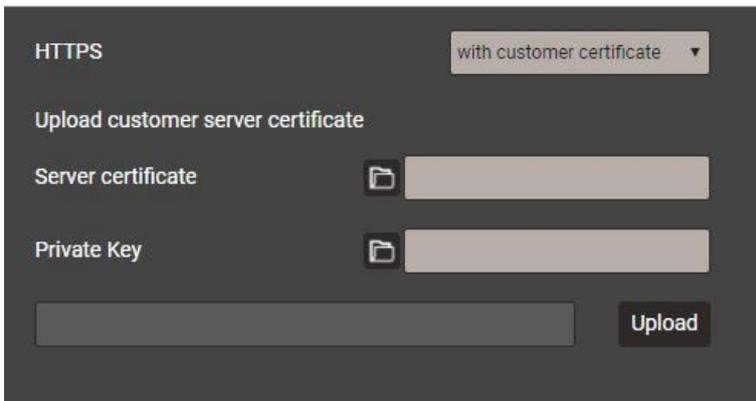> ℹ️ You may use https communication also by ignoring any browser warning and establishing an **unsecure** connection to the device. However, for security reasons you should not work like that in the intended network environment.

6.8.6 Audit log (SYSLOG)

Security related events, such as …

- a computer establishing a connection to the device
- a user logged in /out
- a failed login attempt
- each changing of the device configuration
- the view of the security log by a user
- etc.

are logged in a security log accessible via the service menu.

Example of a security log: The severity of each message is shown in a color code, which may also serve as filter criteria.

Each entry into this list may, if activated, also be transferred to a central log-server using the **SYSLOG** protocol for security auditing. This transfer may be performed based on UDP, TCP or TLS. The settings of the Syslog server are available via Settings | Communication | Syslog server:

7. Operating the device

7.1 Operating elements
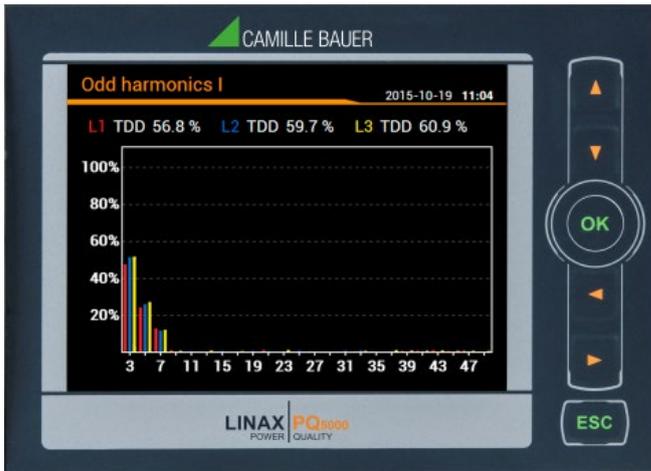
The operation of devices with display is performed by means of 6 keys:

- 4 keys for **navigation** (◄, ▲, ▼, ►) and for the selection of values
- OK for **selection** or confirmation
- ESC for **menu display**, terminate or cancel

The **function** of the operating keys changes in some measurement displays, during parameterization and in service functions. For the PQ3000 the valid functionality of the keys is then shown in a help bar.

7.2 Selecting the information to display

Information selection is performed via menu. Menu items may contain further sub-menus.

Displaying the menu
Press **ESC**. Each time the key is pressed a change to a higher menu level is performed, if present.

Displaying information
The menu item chosen using ▲,▼ can be selected using **OK**. Repeat the procedure in possible submenus until the required information is displayed.

Return to measurement display
After 2 min. without interaction the menu is automatically closed and the last active measurement display is shown.

7.3 Measurement displays and used symbols

For displaying measurement information, the device uses both numerical and numerical-graphical measurement displays.

Examples	Measurement information
	Phasor diagram
	Instantaneous values of voltages and currents (here for Current Module CM1) with the associated phase angles.
	Phase sequence of voltages and currents and direction of energy flow.
	Data of harmonics analysis
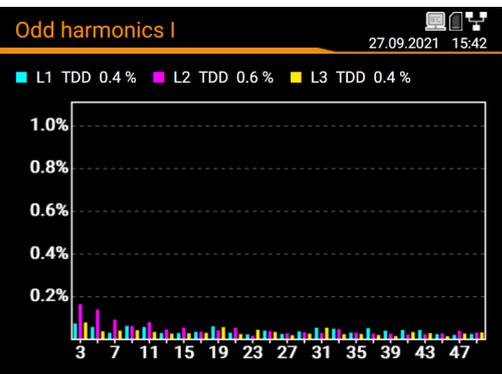
Incoming / outgoing / inductive / capacitive

The device provides information for all four quadrants. Quadrants are normally identified using the roman numbers I, II, III and IV, as shown in the adjacent graphic. Depending on whether the system is viewed from the producer or consumer side, the interpretation of the quadrants is changing: The energy built from the active power in the quadrants I+IV can either been seen as delivered or consumed active energy.

By avoiding terms like incoming / outgoing energy and inductive or capacitive load when displaying data, an independent interpretation of the 4-quadrant information becomes possible. Instead the quadrant numbers I, II, III or IV, a combination of them or an appropriate graphical representation is used. You can select your own point of view by selecting the reference arrow system (load or generator) in the settings of the measurement.
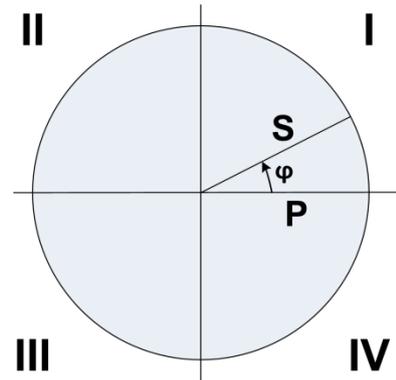
Used symbols

For defining a measurement uniquely, a short description (e.g. U_{1N}) and a unit (e.g. V) are often not sufficient. Some measurements need further information, which is given by one of the following symbols or a combination of these symbols:

Symbol	Description	Symbol	Description
(mean-value icon)	Mean-value	ΣHT	Meter (high tariff)
(mean-value trend icon)	Mean-value trend	ΣLT	Meter (low tariff)
(bimetal icon)	Bimetal function (current)	▲	Maximum value
(energy quadrant icon)	Energy quadrants I+IV	▼	Minimum value
(energy quadrant icon)	Energy quadrants II+III	TRMS	True root-mean-square value
(energy quadrant icon)	Energy quadrants I+II	RMS	Root-mean square value (e.g. fundamental or harmonic content only)
(energy quadrant icon)	Energy quadrants III+IV	(H1)	Fundamental component only
I,II,III,IV	Quadrants	Ø	Average (of RMS values)

Example
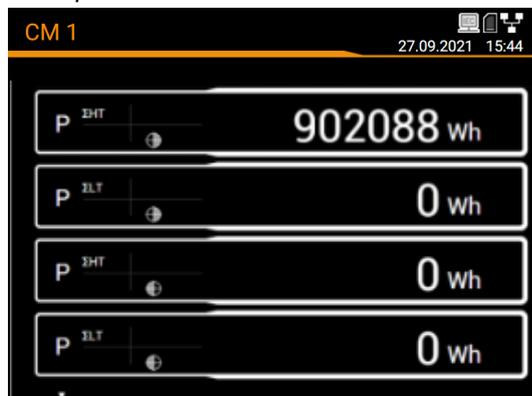
Meters for CM1 with tariff and quadrant information

7.4 Resetting measurement data

- **Meter contents** may be individually set or reset during operation using the service menu

- **Recorded logger data** can be individually reset via the service menu. This makes sense whenever the configuration of the quantities to record has been changed.

7.5 Configuration

> ⚠️ The configuration options of the device can be reduced on a customer-specific basis, so that certain parameters are predefined and cannot be changed

7.5.1 Local configuration at the device

With the exception of the security system a full parameterization of the device can be performed via the menu "Settings".

Modifications will not take effect before the user accepts the query "Store configuration changes" when leaving the settings menu. Changings in the "Country and clock" menu have immediate effect (e.g. a different operating language is used), but nevertheless must be stored.

- **Country and clock**: display language, date format, time zone, clock synchronization, time/date

- **Display**: Refresh rate, brightness, screen saver

- **Communication**: Settings of the Ethernet interface and Modbus communication. In addition, a SFTP server may be defined, to push user definable data files to.

- **Measurement**: System type, sense of rotation, nominal values of U / I / f, sampling, reference arrow system etc.

    Hints

    - *U transformer: The primary to secondary ratio is used only for converting the measured secondary to primary values, so e.g. 16000 / 100 is equivalent to 160 / 1. The values do not have any influence on the display format of the measurements.*

    - *Nominal voltage: Is used as the 100% reference for monitoring power quality events and corresponds to the declared input voltage U_{din} in accordance with IEC 61000-4-30*

    - *Maximum primary values U: This value is used only for fixing the display format of the measurements.*

    - *Synchronous sampling: yes=sampling is adjusted to the measured system frequency to have a constant number of samplings per cycle; no=constant sampling based on the selected system frequency*

    - *Reference channel: The measurement of the system frequency is done via the selected voltage input*

- **Power quality**: Definition of parameters for monitoring PQ. User-specific limits for the evaluation of the PQ statistic can also be set.

- **Security system**: Definition of the security system (RBAC, https, whitelist). Locally RBAC can only be enabled or disabled, credentials and access rights must be setup via website.

- **Device tag**: Definition of different texts [1] mainly used for report generation, such as device tag, document title, device location and others.

- **Data export scheduler**: Via website you can setup tasks to be performed regularly. Each time such a task is running, it creates a data file to be transferred to a SFTP server and/or to be stored locally on the device. Via local configuration tasks can be enabled or disabled only.

7.5.2 Configuration via web browser

	It's recommended to use either Google Chrome or Firefox as browser.
	Internet Explorer works with limitations only (partly missing texts, firmware update not possible)

For configuring via Webbrowser you have to display the device website using:

- IPv4 communication: http://IPv4_addr,   e.g. http://192.168.1.101
- IPv6 communication: http://[IPv6_addr],   e.g. http://[fd2d:bb44:97f1:3976::1]

This request works only if device and PC are in the same network segment. If the secure communication via https is activated and the root certificate installed, you have to use https instead of http for displaying the website.
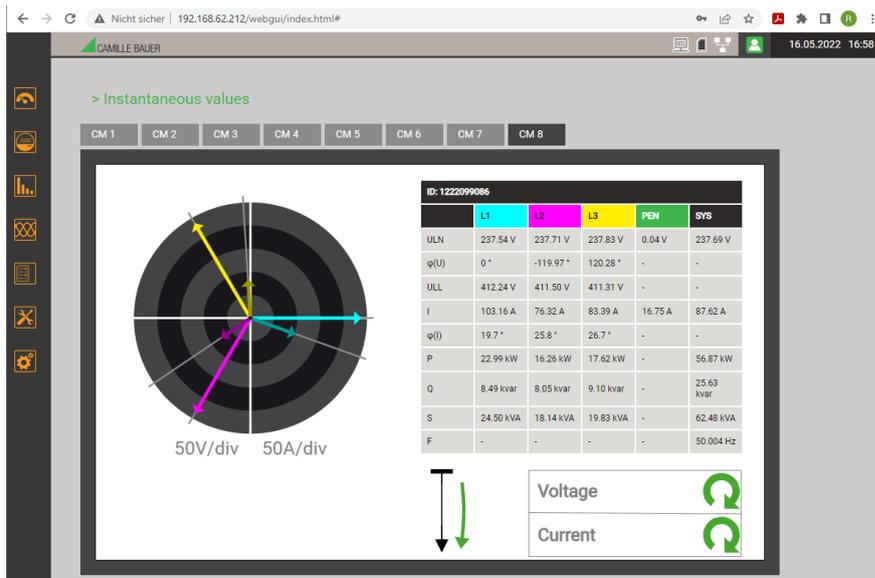
Device website using Google Chrome

	The locker symbol shows that a secure connection is established (if https is used)
	There are three information here: • The SD-card is present and stores data • A network connection is established • No user with credentials has logged in so far. Information granted to the default user 'anonymous' is displayed.

 Via WEB-GUI you can make the same settings as via the local GUI using the Settings menu.

In addition, it is possible to setup the security system and the Data export scheduler. Possibly modifications need to be saved in the device, before all parameters have been set. In such a case the following message appears:
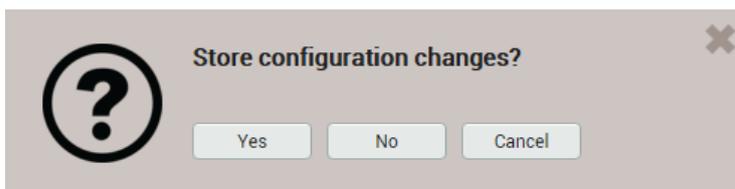
If this request is not confirmed, unsaved modifications of the present device configuration may get lost.

Loading / saving configuration files

The user can save the present device configuration on a storage media and reload it from there. The storage or load procedure varies depending on the browser used.

(i)	**The settings of the security system are not part of the configuration file. There is no way to transfer security settings from one device to another.**

📂	**Loading a configuration file from a storage media** The configuration data of the selected file will be directly loaded into the device. The values in the WEB-GUI will be updated accordingly. Normally devices differ in the settings of network and Modbus parameters and device name. Thus, when loading the file, you can choose, whether the appropriate settings of the device should be retained or overwritten by the values in the file to be uploaded. You are going to overwrite the device configuration! ✖ Do you really want to upload a new configuration? Device tag ☐ overwrite Ethernet ☐ overwrite RS-485 Modbus/RTU ☐ overwrite Upload Cancel
💾	**Storing the current parameter settings of the WEB-GUI into the device**
⤓	**Saving the device configuration to a storage media** Attention: Modifications in the WEB-GUI, which haven't been stored in the device, will not be written to the storage media.
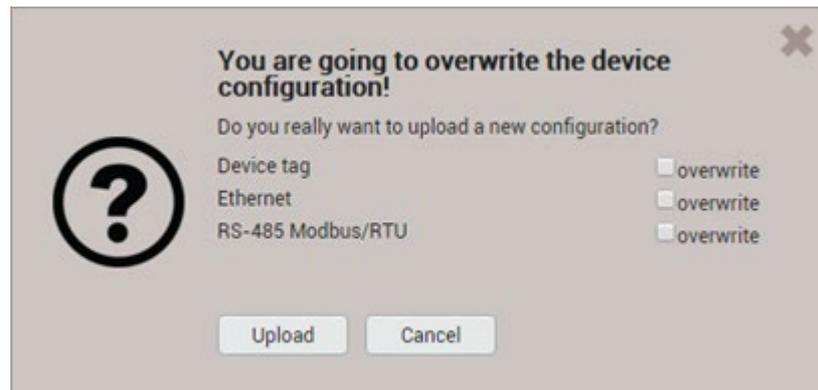
7.6 PQ monitoring

Power quality monitoring provides both a statistical evaluation, allowing an assessment of compliance with standards (e.g. EN 50160) or supply contracts, as well as records of events in the grid (e.g. power voltage dips). This facilitates the analysis of causes and effects. Compliance reports may also be created directly via the website of the device.

7.6.1 PQ events

The device monitors all voltage events in accordance with IEC 61000-4-30. The default values of the trigger thresholds correspond to the common values of the EN 50160 for a public low-voltage distribution system, but can be changed by the user to individual needs.

In addition to the requirements of IEC 61000-4-30 the device can monitor voltage unbalance and frequency anomalies.

Monitored events	Threshold	Hysteresis	Reference value
Voltage dip	90%	2%	Nominal voltage
Voltage interruption	10%	2%	
Voltage swell	110%	2%	
Rapid voltage change	6%	50% [1]	
Homopolar voltage	50%	2%	
Frequency anomaly	lower: 99% upper: 101%	0.5%	Nominal frequency

[1] Related to the respective threshold

> The device does not verify the user-defined event parameters. If these values are not plausible, events may be not recognized correctly or misclassified. In particular, the trigger threshold for RVC events should not be greater than half of the difference of the threshold values of voltage swell and voltage dip.

Recordings

If any of the above events occurs, the device records the half-cycle RMS values and the samples of all voltage channels. In addition, the RMS(1/2) current values of the Current Link reference channel are recorded, if the optional disturbance recorder is implemented.

The event recording times can be configured using the menu *Settings | Power quality | Event recording:*

			Possible recording times
RMS(1/2): Before triggering	s	1.000	*≤1.0s*
RMS(1/2): After triggering (max.)	s	180.000	*≤180.0s*
Samples: Before triggering	s	0.100	*≤1.0s*
Samples: After triggering	s	0.200	*≤5.0s*

Note: The event recording time "RMS(1/2): After triggering" is a maximum recording time. It is reduced to the real event duration + 1s, if the event duration is shorter than the configured time.

Recorded PQ events can be visualized either via the local display or the webpage of the device.

Mains signalling voltage

The device monitors mains signalling voltages, which are transmitted in the supply system for control purposes, and records them as events. Typically, these are ripple control signals. The user can define the frequency of the signalling voltage, the threshold and hysteresis (related to the nominal voltage) as well as the recording duration in multiples of the measurement interval of 10/12 cycles. The recording duration must not exceed 120s. The ripple control frequency is typically below 3 kHz and can be requested from the local energy provider.

Reference channel		U1
Ripple control frequency	Hz	375
Trigger threshold	%	2
Trigger hysteresis	%	1
Rec. duration (10/12 cycles)	#	50

7.6.2 PQ statistic

Power quality (PQ) is assessed by a comparison between the PQ parameters measured by the device and the limits of a contract agreed upon. The assessment period is usually at least one week to consider possible variations between weekdays and weekends.

Via its website the device can perform an assessment of the measured PQ parameters in accordance with the following standards:

- EN 50160 (2010), low voltage, interconnected systems
- EN 50160 (2010), low voltage, island systems
- EN 50160 (2010), medium voltage, interconnected systems
- EN 50160 (2010), medium voltage, island systems
- EN 50160 (2010), high voltage, interconnected systems
- EN 50160 (2010), high voltage, island systems
- IEC 61000-2-2 (2002), public low voltage systems
- IEC 61000-2-4 (2002), industrial and non-public systems up to 35 kV, class 1
- IEC 61000-2-4 (2002), industrial and non-public systems up to 35 kV, class 2
- IEC 61000-2-4 (2002), industrial and non-public systems up to 35 kV, class 3
- IEC 61000-2-12 (2003), public medium voltage systems
- User specific limit sets

The assessment of the PQ statistic is shown in the chapter Data recording | PQ statistic, including the creation of compliance reports.

Recorded PQ parameter groups

Measurement	Averaging time	Applied limits
Power frequency	10 s	*The applied limits and time conditions of the preset standards can be seen via the device website.*
Voltage magnitude	10 min.	*They can be displayed via the following menu:*
Flicker P_{st}	10 min.	`Settings`
Flicker P_{lt}	2 h	`	Power Quality`
Mains signalling voltage	3 s	`	Custom threshold limits`
Supply voltage unbalance	10 min.	`	(Standard)`
THDS of voltages	10 min.	*Within the same menu user data sets with specific limits and evaluation criteria can be defined*
Voltage harmonics	10 min.	*User specific data sets can also be deleted*
Voltage interharmonics	10 min.	*again.*

7.6.3 Provision of PQ data

The device can create PQ related data, such as PQ events or PQ statistic, using the standard format PQDIF (**P**ower **Q**uality **D**ata **I**nterchange **F**ormat) acc. IEEE 1159.3. The automatic or event-driven generation of such files can be defined via the Data export scheduler in the Settings menu. By default, daily PQDIF will be created periodically after midnight for the past day and provided in a hierarchical time structure (year, month, day) for download.

PQDIF files may also be generated manually via web interface. This may be done either for the present day (including data since midnight) or contiguous, selectable time ranges of up to 7 days. The file(s) is added in the time structure of the end day. Days with existing files are marked with a red dot.

If for the selected time range PQDIF files are already stored in the device the below warning will be displayed.
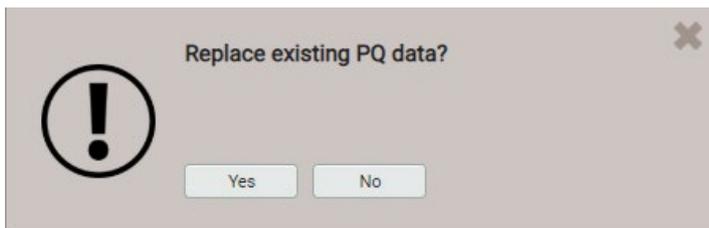
7.7 Data recording

The device stores long-term recordings of measurement progressions, events and PQ statistics. Some of these recordings provide predefined contents; some is based on user-defined contents.

In addition, file-based information may be periodically created using the data export scheduler. This data may be saved internally and / or send securely to a SFTP server.

In general, recordings are done in endless mode. The oldest data will be deleted, as soon as the associated memory is used for more than 80%.

Group	Data type	Request	
PQ events	The occurrence of PQ events will be registered in the PQ event list. By selecting the entries for voltage events, the course of the measurements during the disturbance will be displayed	Events	• PQ events and Mains Signalling
Security events	Security log (SYSLOG)	Service	• Log of the security system
PQ statistic	For a selectable weekly interval, the evaluation of the PQ statistic is displayed, depending on the selected standard. In addition, daily trends of the monitored PQ variables can be displayed. By means of PQ-Easy Report, compliance reports can be created directly via website.		

7.7.1 PQ events

Configuration of the events to record

See 7.6

Display of PQ event recordings (locally)

Recorded events are available in the form of a logbook, mains signalling events are stored in a separated list. Each detected event is present in the PQ event list with the time of its occurrence, the remaining voltage and the duration of the event. By selecting a list entry, the graphical display of the measured values during this event is entered.

> Recordings including the currents of the reference Current Link channel can be displayed only if the optional disturbance recorder is implemented in the device.
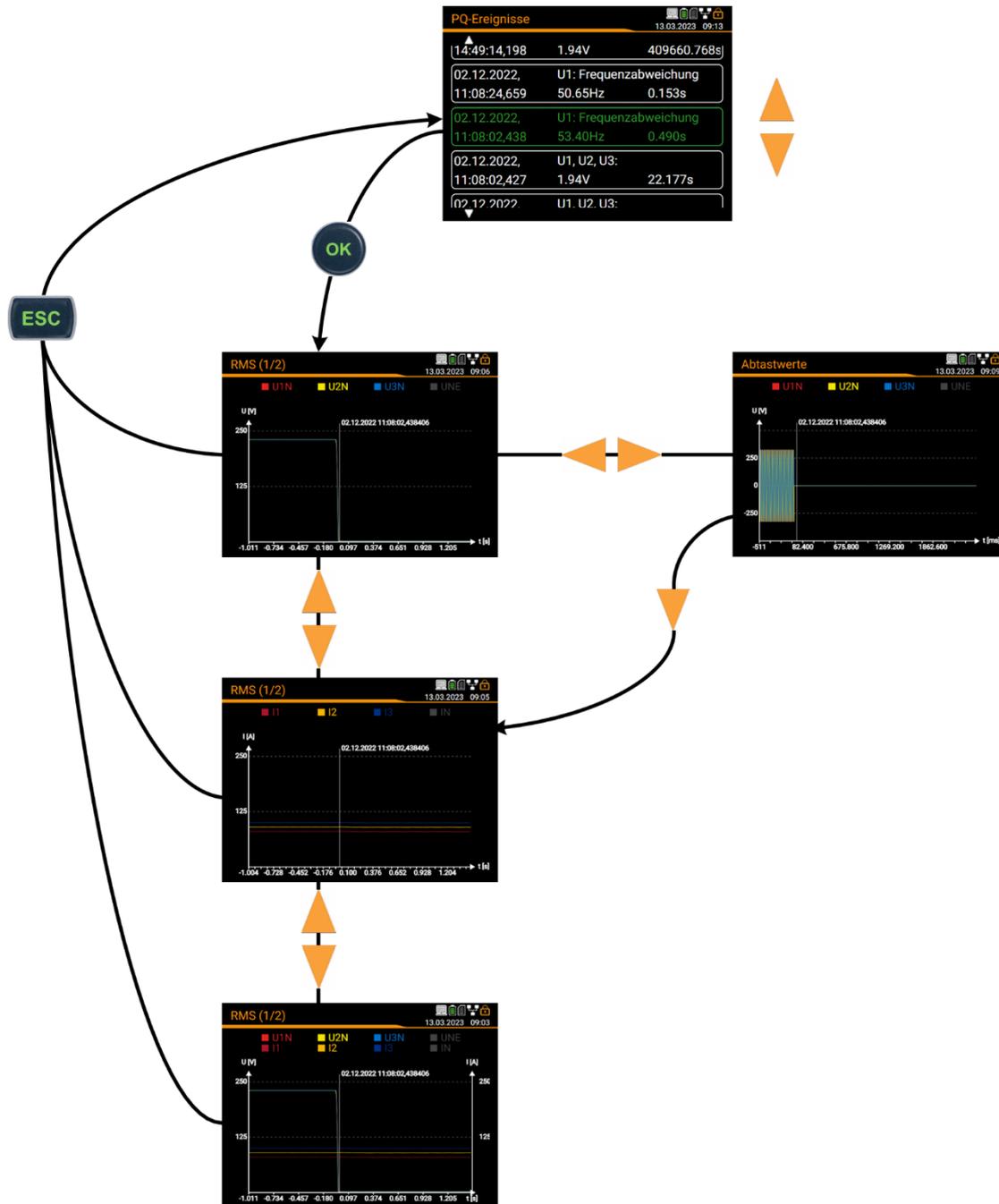
Display matrix on the local

Restriction of the quantities to display on the local display

The user can adapt the displayed information to its needs. Once the graphic is displayed, the setting window for the selection of the quantities to display is entered by pressing <OK>.

Voltage display

U1N	ON
U2N	ON
U3N	ON
UNE	OFF

Current display

I1	ON
I2	ON
I3	ON
IN	OFF

Mixed display

U1N	ON
U2N	ON
U3N	ON
UNE	OFF
I1	ON
I2	ON
I3	ON
IN	OFF

Display of PQ events (WEB-GUI)

As with the local GUI, recorded events are available in the form of a logbook. Events may be filtered by event type and event date. By selecting a list entry, the graphical display of the measured values during this event is entered.

> Recordings including the currents of the reference Current Link channel are displayed only if the optional disturbance recorder is implemented in the device.
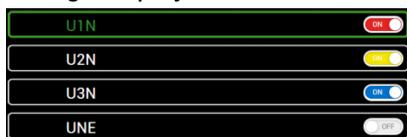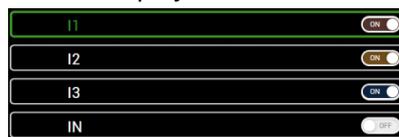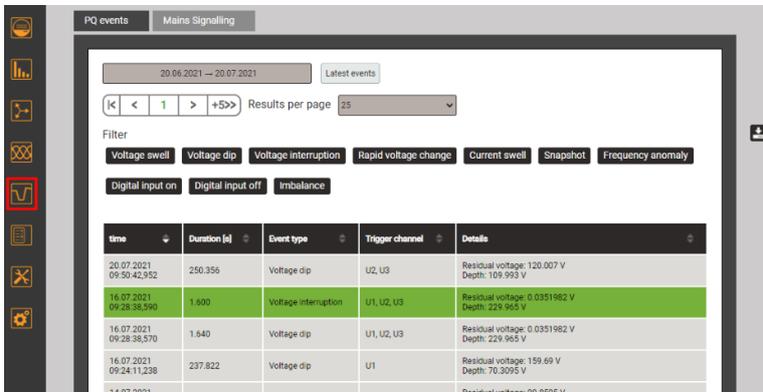

List of PQ events

Graphical display of a PQ event

By selecting a time range via left mouse key, the graphical event display may be zoomed.
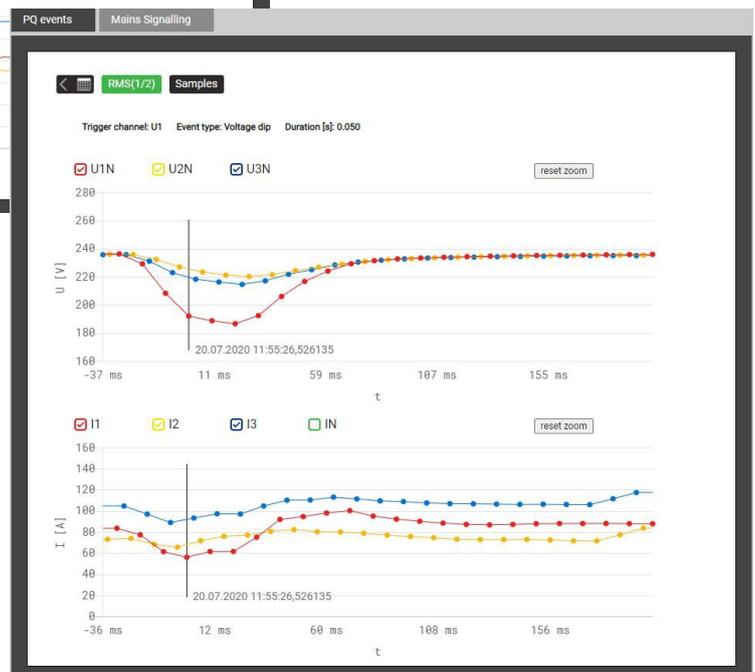
Zoomed PQ event

7.7.2 PQ statistic

From the PQ statistic it is very easy to see whether the limits of the <u>monitored criteria</u> are respected or not. Each criterion is represented by a bar, which itself may be composed of multiple color components:

 Requirement fulfilled

 Missing data

 Requirement not fulfilled

Example for monitoring voltage variations:
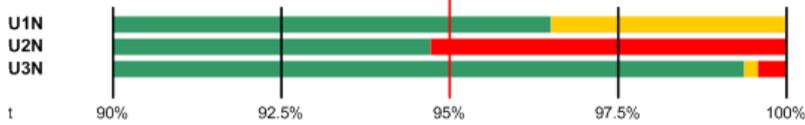
- Limit to be respected is marked with a red line (95% of the time range)

- U1N: Requirement fulfilled, because green bar > 95%

- U2N: Requirement not fulfilled, because green bar < 95%

- U3N: Requirement fulfilled, because green bar > 95%

Display of PQ statistic (WEB-GUI)

Selection via the menu PQ statistic
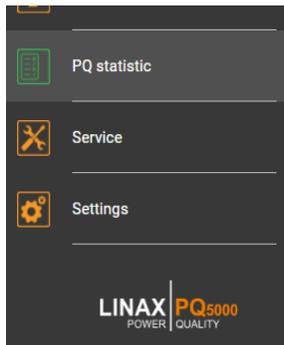
The PQ statistic is shown for a time range of one week. The end of the time range can be selected. The time range always starts and ends at 00:00h.

In the overview you can directly select the standard to be used for assessment.
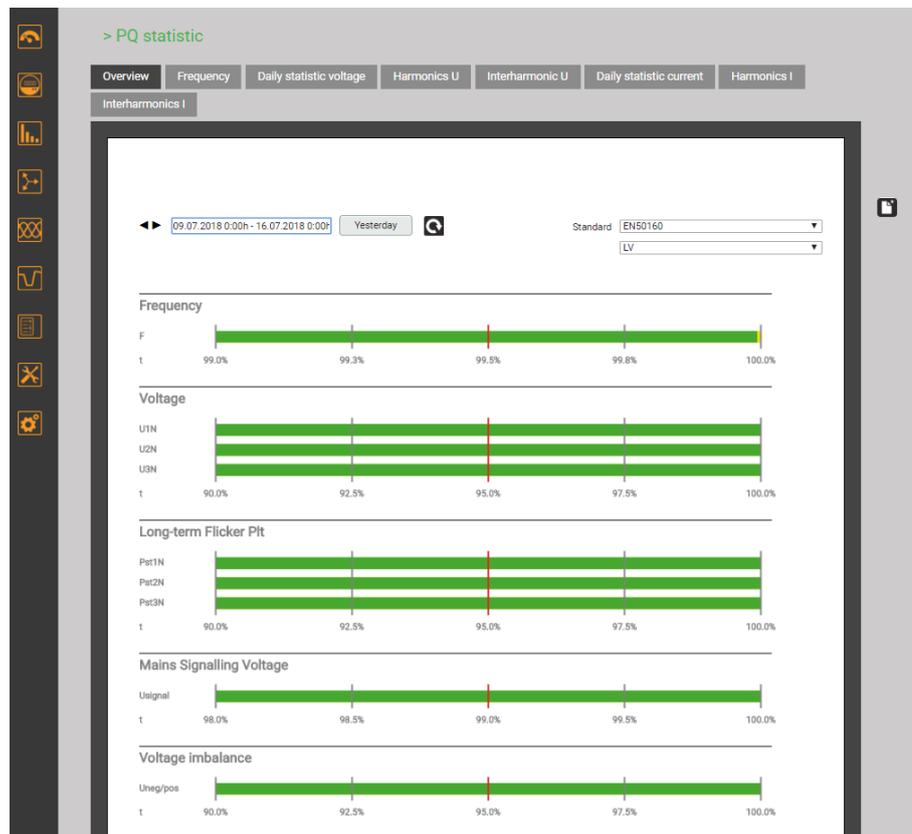
Display of PQ statistic (locally)

Selection via Main menu | PQ statistic
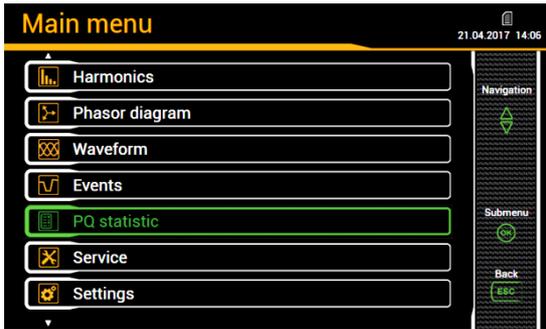
The PQ statistic is always displayed for the past seven days. Another time range cannot be selected.

The standard to be used for the assessment of the statistic can be changed by selecting the entry "Standard".
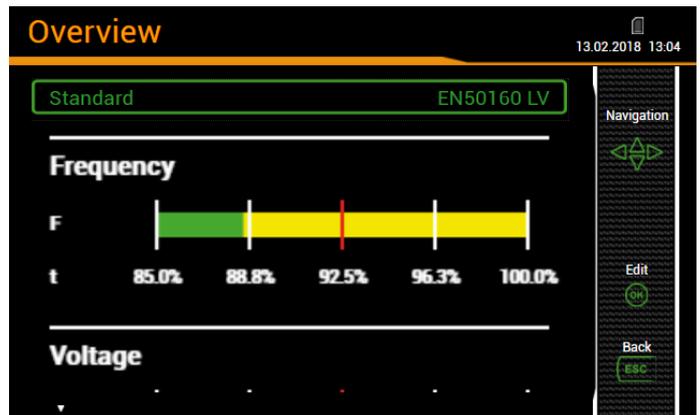
Display of PQ statistic details

For the recorded PQ quantities details can be displayed on a daily basis. On the local display this feature is limited to the past day.

...	Frequency	Daily statistic U	Harmonics U	Interharmonics U
	Distribution	Voltage	Harmonics U1x	Interharmonics U1x
	Daily statistic	Flicker Pst	Harmonics U2x	Interharmonics U2x
		Flicker Plt	Harmonics U3x	Interharmonics U3x
		Imbalance U		
		THD U		

Local display options
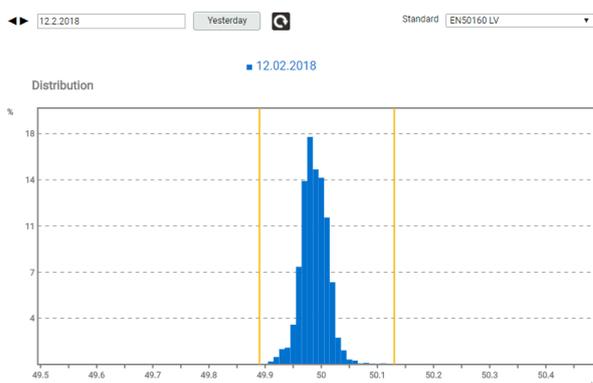
Statistical distribution of 10-s frequency values
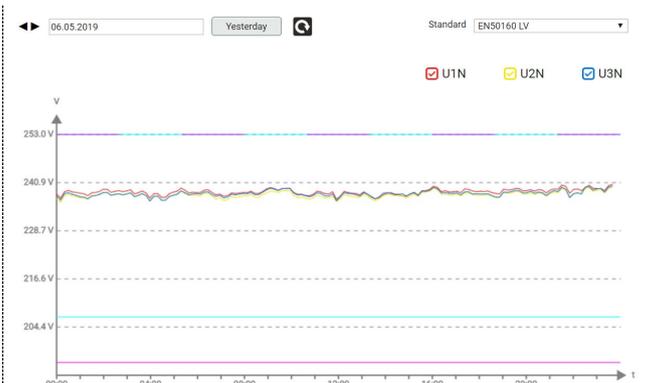
Course of 10-min voltage values

Creating a compliance report via the device website – PQ-Easy Report

Via ⬛ a compliance report in PDF format can be created.
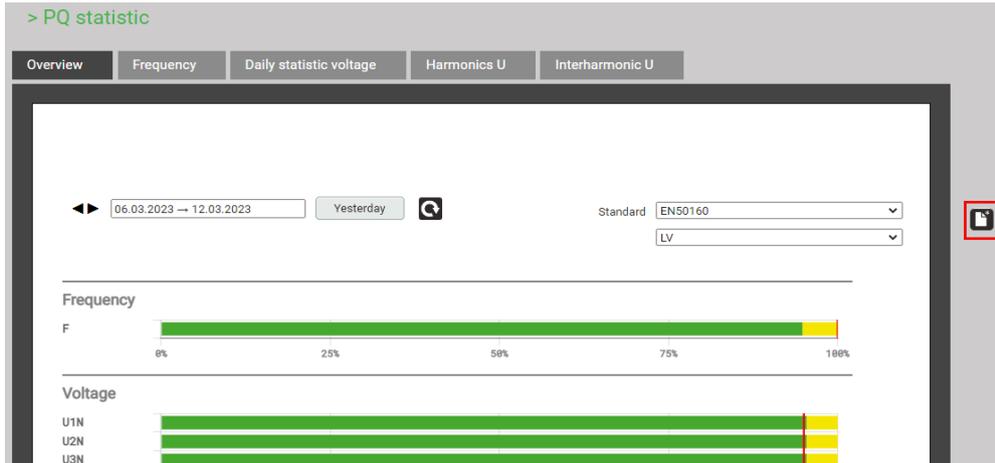
1. Select assessment period: At least 1 week

2. Select standard which compliance needs to be proven

3. Select content of report (3 levels)

4. Enter a comment, which needs to be shown on the first page of the report

5. Start report generation…

During report generation a progress bar is shown at the upper side of the screen. The duration of the report generation depends on the selected content, the assessment period and the number of recorded PQ events.

The generated report can be downloaded.

Depending on the browser and its settings, you can either choose where to save the file or the report will be saved in the default download directory.

Example of a compliance report

a) Overview

b) Details

c) Events
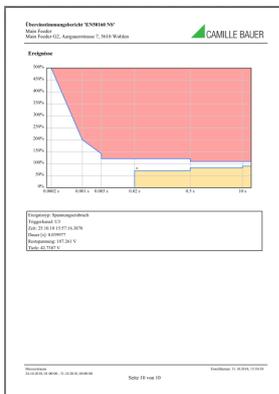
7.8 Measurement information in file format

Using the data export scheduler, measurement information may be provided also in file format. Such files can then:

- periodically or event-driven being sent to a SFTP server
- locally stored in the device and downloaded via webpage

The management and setup of tasks for providing files is done via the item *Data export | Data export scheduler* in the settings menu.

7.8.1 Predefined tasks

The data export scheduler contains two predefined tasks for providing PQDIF files with power quality information:
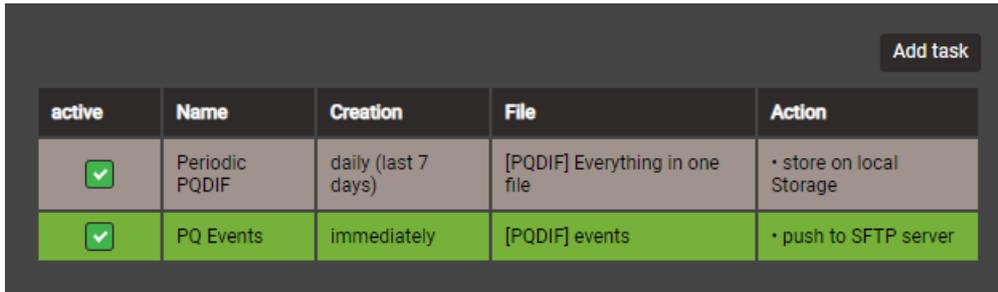
active	Name	Creation	File	Action
☑	Periodic PQDIF	daily (last 7 days)	[PQDIF] Everything in one file	• store on local Storage
☑	PQ Events	immediately	[PQDIF] events	• push to SFTP server

These tasks may be activated, deactivated and changed, but not deleted. Local storage and push to SFTP server are possible actions to be defined.

Periodic PQDIF

This task is executed periodically shortly after midnight and saves the file (s) in a hierarchical time structure (year, month, day). The task can be adjusted by selecting the entry. You can choose whether the information should be contained in one file or in up to three files (statistics, histograms, events). The time period can be either one day or seven days, and generation can be daily or weekly. The factory setting is the daily generation of up to 3 files, each for the previous day.

PQ Events

If this task is activated a PQDIF file with event data is created as soon as a PQ event has ended. Typically, this file is then sent to an SFTP server.

7.8.2 Creating periodic file data

(This function may be missing in customer-specific versions)

In addition to the predefined tasks new tasks can be setup for creating CSV files with mean-values information at regular intervals. These files may then be stored locally and / or pushed to a SFTP server.

By selecting "Add task" new schedules can be set-up. An example is shown below:

The task "24h_PowerMeans" will generate daily CSV files containing standard mean-values for the past 24 hours.

The files will be both stored locally and pushed to the subfolder PowerMeans of a SFTP server. The settings of the SFTP server to be used can be defined via Communication | SFTP in the Settings menu.

The transmission window selected here causes a random transmission of the file to the SFTP server within one hour since creation. The transmission window may last up to 6 hours, but can also be deactivated in order to force an immediate transmission.

The task list then shows three active tasks. Predefined tasks are marked gray to highlight that they can be deactivated but not removed. On the other hand, at any time the newly created task "24h_PowerMeans" can be fully modified, deactivated or deleted.

Via the settings of the local display only the activation / deactivation of the tasks is supported.

CSV settings

CSV files are intended for transmitting statistics of mean values. You may adjust the below parameters to adapt the file format and the content of the created files to your requirements.

- The **Separator** separates the individual entries on a text line for later display in table form.

- The **Decimal separator** defines how numbers or measured values are written to the file. The decimal separator must correspond to the country-specific number format of the operating system so that the CSV file can be opened directly in Excel without an import process. Common separators are periods (123.45) or commas (123.45).

- **Time format** defines the time format to be written. With the "local time + AB" time format, the double entries between 2 and 3 AM are supplemented with the letters A and B when switching back from daylight saving time.

- **Include min/max values** defines whether mean values with / without minimum and maximum values are written to the CSV file.

- **Scaled to** specifies whether the numerical value is based on the base unit (e.g. 1087.65W) or on the units specified according to the nominal values (e.g. 1.0876kW), which are also used in the web interface.

- **Digits after decimal point** defines the number of digits after the decimal separator with which the numbers are written to the file.

7.8.3 Accessing file information via webpage

You can access files stored in the device using the service menu **Local data storage | Download data**. Depending on the tasks defined in the data export scheduler the available file structure may be different:

- **csv**: container for all CSV files to be locally stored

- **pqdif**: container for all PQDIF files to be locally stored

The structure is displayed in a new tab.
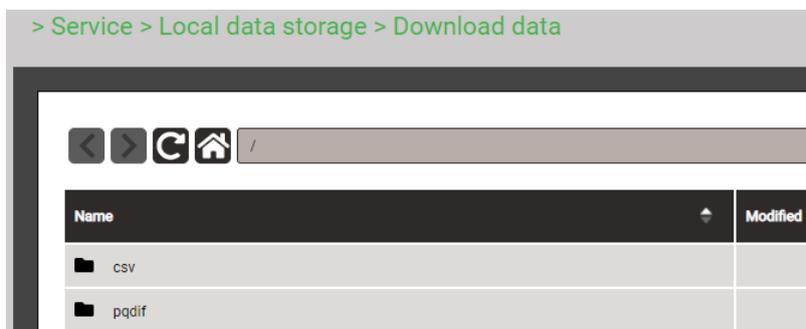
Files in the **pqdif** folder are stored in a hierarchical time structure (year, month, day). By selecting the desired date and double-clicking on the appropriate file, a PQDIF may be easily downloaded.
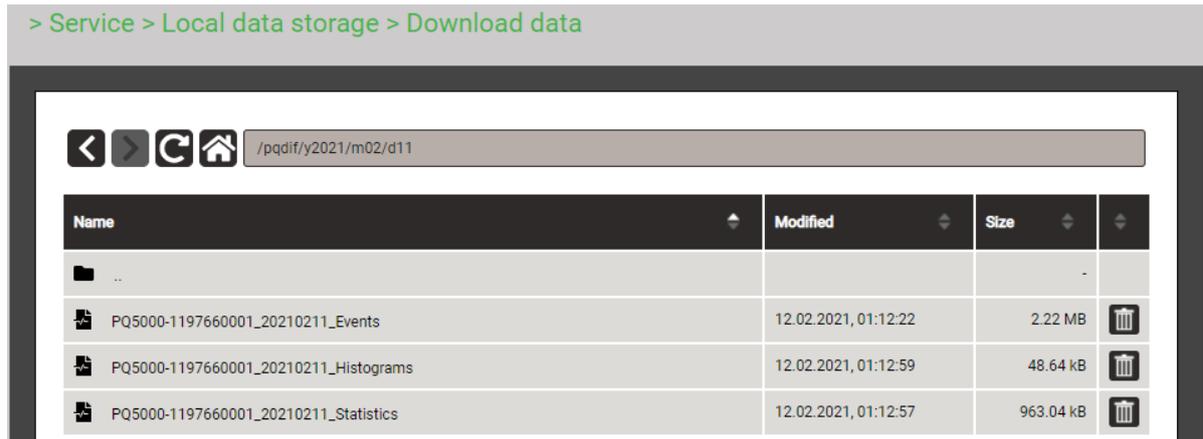
7.8.4 Periodical sending to a SFTP Server

If in the data export scheduler the sending to an SFTP server was selected as action, the appropriate files will be sent periodically to the SFTP server defined in the settings of the communication.

For improving security, you may select that the device connects to trusted hosts only. When activating this setting the host must be present and sends a public key back to the device. If you accept this key the associated host will be added to the list of trusted servers.
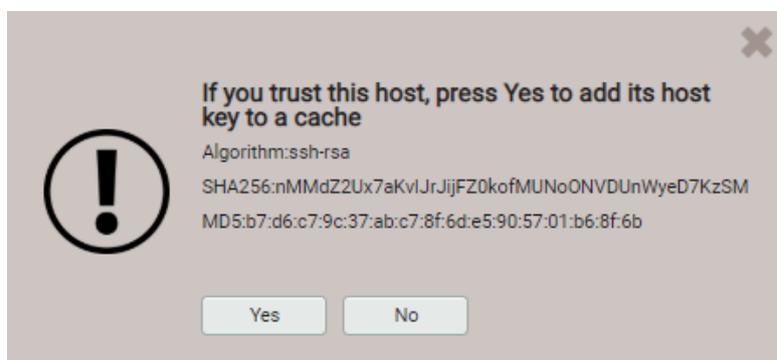
7.8.5 Evaluation of the PQDIF files

For the analysis of the data of the PQDIF files a free tool with limited functionality, such as the PQDiffractor from Electrotek Concepts (http://www.pqview.com/pqdiffractor/; registration required), or any other software (e.g. Dranview-7) supporting the PQDIF format can be used.
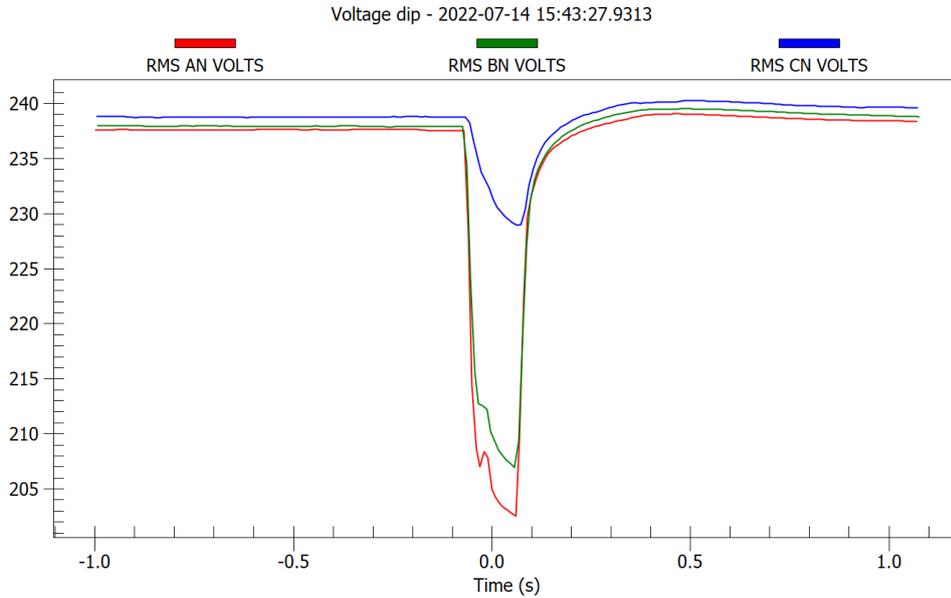
Representation of a voltage dip using PQDiffractor

7.9 Display timeouts

Devices with display are designed for displaying measurements. So, any other procedure will be terminated after a certain time without user interaction and the last active measurement image will be shown again.

Menu timeout

A menu timeout takes effect after 2 min. without changing the present menu selection. It doesn't matter if the currently displayed menu is the main menu or a sub-menu: The menu is closed and the last active measurement image is displayed again.

Configuration timeout

After 5 min. without interaction in a parameter selection or during entering a value in the settings menu, the active configuration step is closed and the associated parameter remains unchanged. The next step depends on what you have done before:

- If the user did not change configuration parameters before the aborted step, the main menu will be displayed and the device starts to monitor a possible menu timeout.

- If the user changed configuration parameters before the aborted step, the query "Store configuration changes?" is shown. If the user does not answer this query within 2 min. this dialogue is closed: The changed configuration will be stored and activated and then the last active measurement image is displayed again.

8. Service, maintenance and disposal

8.1 Calibration and new adjustment

Each device is adjusted and checked before delivery. The condition as supplied to the customer is measured and stored in electronic form.

The uncertainty of measurement devices may be altered during normal operation if, for example, the specified ambient conditions are not met. If desired, in our factory a calibration can be performed, including a new adjustment if necessary, to assure the accuracy of the device.

8.2 Cleaning

The display and the operating keys should be cleaned in regular intervals. Use a dry or slightly moist cloth for this.

> ⚠ **Damage due to detergents**
>
> Detergents may not only affect the clearness of the display but also can damage the device. Therefore, do not use detergents.

8.3 Battery

The device contains a battery for buffering the internal clock. It cannot be changed by the user. The replacement can be done at the factory only.

8.4 Disposal

The product must be disposed in compliance with local regulations. This particularly applies to the built-in battery.

9. Technical data

Measurement inputs

Voltage base unit PQ5000CL-0/-1

Nominal voltage:	57,7…400 V_{LN} (UL: 347 V_{LN}), 100...693 V_{LL} (UL: 600 V_{LL});
Range maximum:	520 V_{LN}, 900 V_{LL} (sinusoidal)
Measurement category:	600V CAT III
Uncertainty:	± 0,1%
Consumption:	≤ U^2 / 1,54 MΩ per phase
Impedance:	1,54 MΩ per phase
Overload capacity:	continuous: 520 V_{LN}, 900 V_{LL}
	10 x 1 s, interval 10s: 800 V_{LN}, 1386 V_{LL}

Voltage base unit PQ5000CL-2/-3

Nominal voltage:	100…230 V_{LN} , 173...400 V_{LL}
Range maximum:	265 V_{LN}, 460 V_{LL} (sinusoidal)
Measurement category:	300V CAT III
Uncertainty:	± 0,1%
Consumption:	≤ U^2 / 1,54 MΩ per phase
Impedance:	1,54 MΩ per phase
Overload capacity:	continuous: 265 V_{LN}, 460 V_{LL}

Currents Current Module 3P / 3PN

Nominal current range 1:	400 A (typ.), 1000 A (max.)
Nominal current range 2:	8 kA (typ.), 20kA (max.)
Measurement category:	600V CAT IV
Uncertainty:	± 0,5% (with centered conductors and no external field)
Angle error:	± 1,0°
Design:	3 or 4 Rogowski coils

Measurement uncertainty

Reference conditions: Acc. IEC/EN 60688, ambient 15…30°C, sinusoidal input signals, Rogowski current measurement with centered conductors and no external field

Quantity	
Voltage	± 0,1 %
Current	± 0,5 %
Power	± 2,0 % (typical)
Power factor	± 1,0°
Frequency	± 0,01 Hz
Active energy	Class 3 (typical)
Reactive energy	Class 3 (typical)

Systems:	4-wire, unbalanced
Nominal frequency:	42...<u>50</u>...58Hz
Sampling rate:	18 kHz (U), 54 kHz (I)
Internal data memory:	16 GB

Power Quality

Type of device: (IEC 62586-1) **PQI-x FI1**: **P**ower **Q**uality **I**nstrument – Class **A**; **F**ixed installation; **I**ndoor environment with uncontrolled temperature variations (**1**)
x=S (PQ1000), **x=A** (PQ3000, PQ5000)

Measurement cycle: 10 cycles at 50Hz, approx. 200ms

Flagging concept: Multiphase approach in accordance with IEC 61000-4-30

Certification: According to IEC62586-2 (standard for verifying compliance with IEC 61000-4-30)

Certification body: Federal Institute of Metrology METAS, an independent and accredited laboratory

Conformity assessment against IEC 62586-2:2017

Clause	PQ parameter	Compliance 120 V- 60 Hz	Compliance 230 V – 50 Hz
6.1	Power frequency	Yes	Yes
6.2	Magnitude of the supply voltage	Yes	Yes
6.3	Flicker	Yes (class F1)	Yes (class F1)
6.4	Supply voltage interruptions, dips and swells	Yes	Yes
6.5	Supply voltage unbalance	Yes	Yes
6.6	Voltage harmonics	Yes	Yes
6.7	Voltage Interharmonics	Yes	Yes
6.8	Mains signalling voltage of the supply voltage	Yes	Yes
6.9	Measurement of underdeviation / overdeviation parameters	Yes	Yes
6.10	Flagging	Yes	Yes
6.11	Clock uncertainty testing	Yes	Yes
6.12	Variations due to external influence quantities	Yes	Yes
6.13	Rapid voltage changes (RVC)	Yes	Yes

Zero suppression, range limitations

The measurement of specific quantities is related to a pre-condition which must be fulfilled, that the corresponding value can be determined and sent via interface or displayed. If this condition is not fulfilled, a default value is used for the measurement.

Quantity	Condition	Default
Voltage	$U_x < 1\%\ U_{x\,nom}$	0.00
Current	$I_x < 0{,}1\%\ I_{x\,nom}$	0.00
PF	$S_x < 1\%\ S_{x\,nom}$	1.00
QF, LF, $\tan\varphi$	$S_x < 1\%\ S_{x\,nom}$	0.00
Frequency	voltage and/or current input too low [1]	Nominal frequency
Voltage unbalance	$U_x < 5\%\ U_{x\,nom}$	0.00
Current unbalance	mean value of phase currents $< 5\%\ I_{x\,nom}$	0.00
Phase angle U	at least one voltage $U_x < 5\%\ U_{x\,nom}$	120°
Harmonics U, THD-U	fundamental $< 5\%\ U_{x\,nom}$	0.00

[1] *Specific levels depend on the device configuration*

Power supply	via terminals 13-14 (PQ5000CL-0/-1), internally (PQ5000CL-2/-3)
Nominal voltage:	100…230V AC 50/60Hz / DC ±15% (PQ5000CL-0/-1)
	100…230V AC 50/60Hz ±15% (PQ5000CL-2/-3)
Overvoltage category:	OVC III
Consumption:	≤ 27VA, ≤ 12W (PQ5000CL-0/-1)
	≤ 60VA (PQ5000CL-2/-3)

Available functional extensions

Extensions	Optional functions
	• IEC 61850 interface
	• MQTT interface
	• Disturbance recorder

Communication

Ethernet	via RJ45 socket
Protocol:	Modbus/TCP, NTP, http, https, IPv4, IPv6, IEC61850 (optional)
Physics:	Ethernet 100BaseTX
Mode:	10/100 Mbit/s, full/half duplex, auto-negotiation
Modbus/RTU	via plug-in terminal (A, B, C/X)
Protocol:	Modbus/RTU
Physics:	RS-485, max. 1200m (4000 ft)
Baud rate:	9'600, 19'200, 38'400, 57'600, 115'200 Baud
Number of participants:	≤ 32
Internal clock (RTC)	
Uncertainty:	± 2 minutes / month (15 up to 30°C)
Synchronization:	none, via Ethernet (NTP protocol) or GPS
Running reserve:	> 10 years

Ambient conditions, general information

Operating temperature:	–10 up to 15 up to 30 up to +55°C
Storage temperature:	-25 up to +70°C;
Temperature influence:	0.5 x measurement uncertainty per 10 K
Long term drift:	0.5 x measurement uncertainty per year
Usage group:	II (acc. EN 60 688)
Relative humidity:	< 95% no condensation
Altitude:	≤ 2000 m max.
Device to be used indoor only!	

Mechanical attributes

Housing material:	Polycarbonate (Makrolon)
Flammability class:	V-0 acc. UL94, non-dripping, free of halogen
Weight:	400 g (PQ1000), 800 g (PQ3000), 600g (PQ5000)
Dimensions:	Dimensional drawings

Vibration withstand (test according to DIN EN 60 068-2-6)

Acceleration:	• Device with display: ± 0.25 g (operating); 1.20 g (storage)
	• Device without display: ± 2 g
Frequency range:	10 … 150 … 10 Hz, rate of frequency sweep: 1 octave/minute
Number of cycles:	10 in each of the 3 axes

Safety

The current inputs are galvanically isolated from each other

Protection class:	II (protective insulation, voltage inputs via protective impedance)
Pollution degree:	2
Protection	acc. EN 60529
• PQ5000CL-0/-1:	front IP40; housing IP30; terminals IP20;
• PQ5000CL-2/-3:	IP66 (housing), IP43 (connections)
• Current Module 3P/3PN:	IP43
• Rogowski coils:	IP67
Rated voltage versus earth:	Power supply 100…230V AC / DC
	I/O's: 24 V DC

Test voltages	Test time 60s, acc. IEC/EN 61010-1 (2011)	
	• power supply versus inputs U [1]:	3600V AC
	• power supply versus inputs I:	3000V AC
	• power supply V1, V3 versus bus, I/O's:	3000V AC
	• inputs U versus inputs I:	1800V AC
	• inputs U versus bus, I/O's [1]:	3600V AC
	• inputs I versus bus, I/O's:	3000V AC
	• inputs I versus inputs I:	1500V AC

Test voltages	Test time 60s, acc. IEC/EN 61010-1 (2011)	
PQ5000CL-2/-3	• Power supply / inputs U versus bus [1]:	3000V AC

[1] During type test only, with all protective impedances removed

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> **The device uses the principle of protective impedance for the voltage inputs to ensure protection against electric shock. All circuits of the device are tested during final inspection.**
>
> ⚠ **Prior to performing high voltage or isolation tests involving the voltage inputs, all output connections of the device, especially Modbus and Ethernet interface, must be removed. A possible high-voltage test between input and output circuits must be limited to 500V DC, otherwise electronic components can be damaged.**

Applied regulations, standards and directives

IEC/EN 61010-1	Safety regulations for electrical measuring, control and laboratory equipment
IEC/EN 61000-4-30 Ed.3	Power quality measurement methods
IEC/EN 61000-4-7	General guide on harmonics and interharmonics measurements
IEC/EN 61000-4-15	Flickermeter - Functional and design specifications
IEEE 1159.3	Recommended Practice for the Transfer of Power Quality Data
IEC 62586-1 Ed.2	Power quality measurement in power supply systems – Power quality instruments (PQI)
IEC 62586-2 Ed.2	Power quality measurement in power supply systems – Functional tests and uncertainty requirements
EN50160	Voltage characteristics of electricity supplied by public distribution systems
IEC/EN 60688	Electrical measuring transducers for converting AC electrical variables into analog or digital signals
DIN 40 110	AC quantities
IEC/EN 60068-2-1/	Ambient tests
-2/-3/-6/-27:	-1 Cold, -2 Dry heat, -3 Damp heat, -6 Vibration, -27 Shock
IEC/EN 60529	Protection type by case
IEC/EN 61000-6-4	Electromagnetic compatibility (EMC): Emission standard for industrial environments
IEC/EN 61000-6-5	Electromagnetic compatibility (EMC): Immunity for equipment used in power station and substation environment
IEC/EN 62053-22	Static meters for AC active energy (classes 0,1S, 0,2S and 0,5S)
IEC/EN 62053-24	Static meters for reactive energy at fundamental frequency (classes 0,5S, 1S, 1, 2 and 3)
UL94	Tests for flammability of plastic materials for parts in devices and appliances
2011/65/EU (RoHS)	EU directive on the restriction of the use of certain hazardous substances

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Warning

This 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.


This device complies with part 15 of the FCC:

Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

This Class A digital apparatus complies with Canadian ICES-0003.

10. Dimensional drawings

All dimensions in [mm]

LINAX PQ5000CL-0 / -1
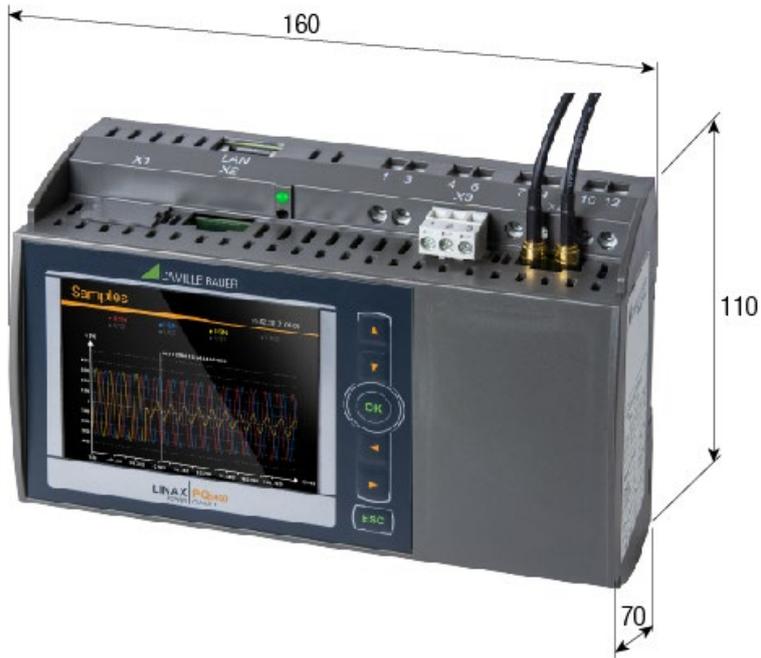
LINAX PQ5000CL-2 / -3

Annex

A Description of measured quantities

A1 Basic measurements

The basic measured quantities are calculated each 200ms by determining an average over 10 cycles at 50Hz. The subsequent listed values are available for each installed Current Module and the base unit (with option «Current measurement in the base unit»).

Measured quantity
Voltage U_{1N}
Voltage U_{2N}
Voltage U_{3N}
Voltage U_{12}
Voltage U_{23}
Voltage U_{31}
Voltage U_{NE} [3]
Current I1
Current I2
Current I3
Neutral current I_N
Earth current I_{PE} (calculated)
Active power P
Active power P1
Active power P2
Active power P3
Total reactive power Q
Total reactive power Q1
Total reactive power Q2
Total reactive power Q3
Apparent power S
Apparent power S1
Apparent power S2
Apparent power S3
Frequency F
Power factor PF
Power factor PF1
Power factor PF2
Power factor PF3
$U_{mean}=(U1N+U2N+U3N)/3$
$I_{mean}=(I1+I2+I3)/3$
Phase angle between U1 and U2
Phase angle between U2 and U3
Phase angle between U3 and U1
Angle between U1 and I1
Angle between U2 and I2
Angle between U3 and I3

Zero displacement voltage U$_{NE}$

Starting from the generating system with star point E (which is normally earthed), the star point (N) on load side is shifted in case of unbalanced load. The zero displacement voltage between E und N may be determined by an addition of the voltage phasors of the three phases:

$$\underline{U}_{NE} = -(\underline{U}_{1N} + \underline{U}_{2N} + \underline{U}_{3N}) / 3$$

A displacement voltage may also occur due to harmonics of order 3, 9, 15, 21 etc., because the dedicated currents add in the neutral wire.
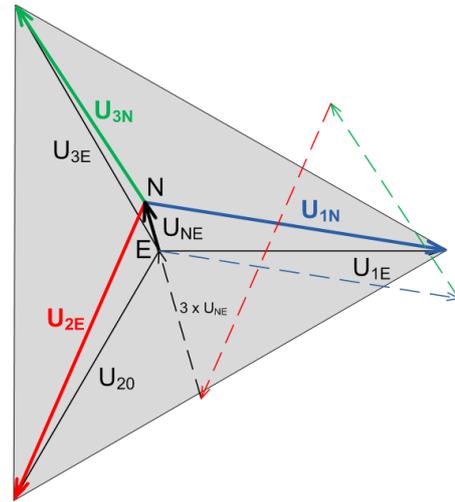
A2 Harmonic analysis

The harmonic analysis is performed according IEC 61000-4-7 over 10 cycles at 50Hz. The voltages of the base unit and the currents of the selectable reference channels are calculated.

Measurement
THD Voltage U1N
THD Voltage U2N
THD Voltage U3N
THD Current I1
THD Current I2
THD Current I3
Harmonic contents 2nd...50th U1N
Harmonic contents 2nd...50th U2N
Harmonic contents 2nd...50th U3N
Harmonic contents 2nd...50th I1
Harmonic contents 2nd...50th I2
Harmonic contents 2nd...50th I3

Harmonics

Harmonics are multiples of the fundamental or system frequency. They arise if non-linear loads, such as RPM regulated drives, rectifiers, thyristor-controlled systems or fluorescent lamps are present in the power system. Thus, undesired side effects occur, such as additional thermal stress to operational resources or electrical mains, which lead to an advanced aging or even damage. Also, the reliability of sensitive loads can be affected and unexplainable disturbances may occur.

TDD (Total Demand Distortion)

The complete harmonic content of the currents is calculated additionally as Total Demand Distortion, briefly TDD. This value is scaled to the rated current or rated power. Only this way it's possible to estimate the influence of the current harmonics on the connected equipment correctly.

> The accuracy of the harmonic analysis strongly depends on the quality of the current and voltage transformers possibly used. In the harmonics range transformers normally change both, the amplitude and the phase of the signals to measure. It's valid: The higher the frequency of the harmonic, the higher its damping or phase shift.

A3 System imbalance

Measured quantity
UR1: Positive sequence [V]
UR2: Negative sequence [V]
U0: Zero sequence [V]
U: Imbalance UR2/UR1
U: Imbalance U0/UR1

Imbalance in three-phase systems may occur due to single-phase loads, but also due to failures, such as e.g. the blowing of a fuse, an earth fault, a phase failure or an isolation defect. Also, harmonics of the 3rd, 9th, 15th, 21st etc. order, which add in the neutral wire, may lead to imbalance. Operating resources dimensioned to rated values, such as three-phase generators, transformers or motors on load side, may be excessively stressed by imbalance. So, a shorter life cycle, a damage or failure due to thermal stress can result. Therefore, monitoring imbalance helps to reduce the costs for maintenance and extends the undisturbed operating time of the used resources.

Symmetrical components (acc. Fortescue)
The imbalance calculation method by means of the symmetrical components is ambitious and intensive to calculate. The results may be used for disturbance analysis and for protection purposes in three-phase systems. The real existing system is divided in symmetrical system parts: A positive sequence, a negative sequence and (for systems with neutral conductor) a zero sequence system. The approach is easiest to understand for rotating machines. The positive sequence represents a positive rotating field, the negative sequence a negative (braking) rotating field with opposite sense of direction. Therefore, the negative sequence prevents that the machine can generate the full turning moment. For e.g. generators the maximum permissible current imbalance is typically limited to a value of 8...12%.

A4 Meters

The subsequent listed meter values are available for each feeder monitored by a Current Module.

Measured quantity
Active energy I+IV
Active energy II+III
Reactive energy I+II
Reactive energy III+IV
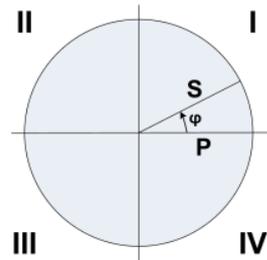
B Display matrices
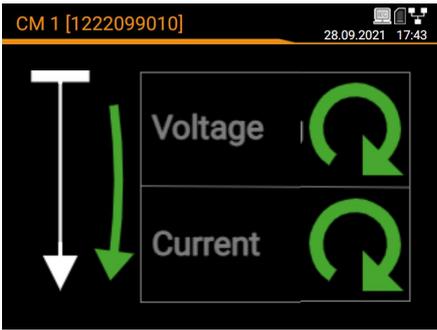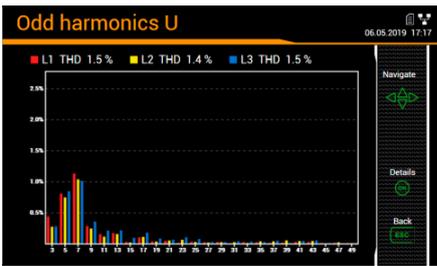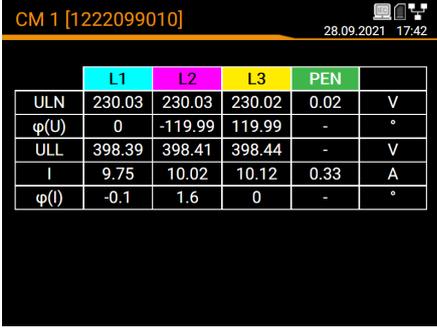
B0 Used abbreviations for the measurements

Instantaneous values

Name	Measurement identification			Unit	Description
U	U		TRMS	V	Voltage system
U1N	U	1N	TRMS	V	Voltage between phase L1 and neutral
U2N	U	2N	TRMS	V	Voltage between phase L2 and neutral
U3N	U	3N	TRMS	V	Voltage between phase L3 and neutral
U12	U	12	TRMS	V	Voltage between phases L1 and L2
U23	U	23	TRMS	V	Voltage between phases L2 and L3
U31	U	31	TRMS	V	Voltage between phases L3 and L1
UNE	U	NE	TRMS	V	Zero displacement voltage 4-wire systems
I	I		TRMS	A	Current system
I1	I	1	TRMS	A	Current phase L1
I2	I	2	TRMS	A	Current phase L2
I3	I	3	TRMS	A	Current phase L3
IN	I	N	TRMS	A	Neutral current
IPE	I	PE	TRMS	A	Earth current
P	P		TRMS	W	Active power system (P=P1+P2+P3)
P1	P	1	TRMS	W	Active power phase L1
P2	P	2	TRMS	W	Active power phase L2
P3	P	3	TRMS	W	Active power phase L3
Q	Q		TRMS	var	Reactive power system (Q=Q1+Q2+Q3)
Q1	Q	1	TRMS	var	Reactive power phase L1
Q2	Q	2	TRMS	var	Reactive power phase L2
Q3	Q	3	TRMS	var	Reactive power phase L3
S	S		TRMS	VA	Apparent power system
S1	S	1	TRMS	VA	Apparent power phase L1
S2	S	2	TRMS	VA	Apparent power phase L2
S3	S	3	TRMS	VA	Apparent power phase L3
F	F		TRMS	Hz	System frequency
PF	PF		TRMS		Active power factor P/S
PF1	PF	1	TRMS		Active power factor P1/S1
PF2	PF	2	TRMS		Active power factor P2/S2
PF3	PF	3	TRMS		Active power factor P3/S3

Meters

Name	Measurement identification			Unit	Description
ΣP_I_IV_HT	P	⊕	ΣHT	Wh	Active energy I+IV
ΣP_II_III_HT	P	⊕	ΣHT	Wh	Active energy II+III
ΣQ_I_II_HT	Q	⊕	ΣHT	varh	Reactive energy I+II
ΣQ_III_IV_HT	Q	⊕	ΣHT	varh	Reactive energy III+IV

Graphical measurement displays

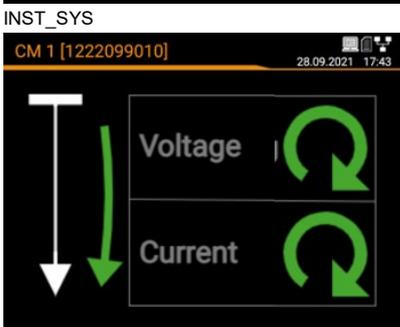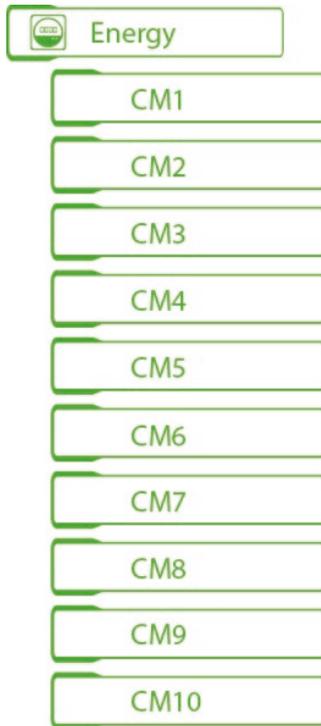| Name	Presentation	Description
PHASOR	 CM 1 [1222099010] 28.09.2021 17:41 50V/div 5A/div	Graphic: All current and voltage phasors
PHASE_SEQ	 CM 1 [1222099010] 28.09.2021 17:43 Voltage Current	Phase sequence display for the voltages and the currents of a Current Module, here CM1
HO_UX	 Odd harmonics U 06.05.2019 17:17 L1 THD 1.5 % L2 THD 1.4 % L3 THD 1.5 %	Graphic: Odd harmonics 3rd up to 49th + Total Harmonic Distortion of all voltages
HO_IX	(as HO_IX)	Graphic: Odd harmonics 3rd up to 49th + Total Harmonic Distortion of all currents
HE_UX	(as HO_IX)	Graphic: Even harmonics 2nd up to 50th + Total Harmonic Distortion of all voltages
HE_IX	(as HO_IX)	Graphic: Even harmonics 2nd up to 50th + Total Harmonic Distortion of all currents
INST_UI	 CM 1 [1222099010] 28.09.2021 17:42 <table><tr><td></td><td>L1</td><td>L2</td><td>L3</td><td>PEN</td><td></td></tr><tr><td>ULN</td><td>230.03</td><td>230.03</td><td>230.02</td><td>0.02</td><td>V</td></tr><tr><td>φ(U)</td><td>0</td><td>-119.99</td><td>119.99</td><td>-</td><td>°</td></tr><tr><td>ULL</td><td>398.39</td><td>398.41</td><td>398.44</td><td>-</td><td>V</td></tr><tr><td>I</td><td>9.75</td><td>10.02</td><td>10.12</td><td>0.33</td><td>A</td></tr><tr><td>φ(I)</td><td>-0.1</td><td>1.6</td><td>0</td><td>-</td><td>°</td></tr></table>	Instantaneous values of voltages and currents with phase angle information

INST_PQS		Instantaneous power values per phase
INST_SYS		Instantaneous values of system quantities

B1 On-site display

Instantaneous values

CM1 ▶ **CM2** ▶ **CM3 . . . .** ▶ **CM10**

PHASOR

	L1	L2	L3	PEN	
ULN	230.03	230.03	230.02	0.02	V
φ(U)	0	-119.99	119.99	-	°
ULL	398.39	398.41	398.44	-	V
I	9.75	10.02	10.12	0.33	A
φ(I)	-0.1	1.6	0	-	°

INST_UI

	L1	L2	L3	PEN	
P	2.24	2.29	2.33	-	kW
Q	-0.05	0.10	-0.15	-	kvar
S	2.24	2.29	2.33	-	kVA

INST_PQS

	SYS	
I	9.97	A
P	6.87	kW
Q	0.17	kvar
S	6.88	kVA
F	49.999	Hz

INST_SYS

PHASE_SEQ

Energy

CM1

CM2

CM3

CM4

CM5

CM6

CM7

CM8

CM9

CM10

ΣP_I_IV_HT
ΣP_II_III_HT
ΣQ_I_II_HT
ΣQ_III_IV_HT

C FCC statement

The following statement applies to the products covered in this manual, unless otherwise specified herein. The statement for other products will appear in the accompanying documentation.

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules and meets all requirements of the Canadian Interference-Causing Equipment Standard ICES-003 for digital apparatus. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/T.V. technician for help.

Camille Bauer AG is not responsible for any radio television interference caused by unauthorized modifications of this equipment or the substitution or attachment of connecting cables and equipment other than those specified by Camille Bauer AG. The correction of interference caused by such unauthorized modification, substitution or attachment will be the responsibility of the user.

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