

# Power Quality Controller

The image shows a FRAKO PQC (Power Quality Controller) unit. The main display area contains the following information:

- $\cos \varphi$ : 0.936 IN
- Utilization: 77%
- Control: auto (Profile 1)

Below the display are five control buttons:

- ESC
- Up Arrow
- Down Arrow
- Left/Right Arrows
- i (Information)

At the bottom of the unit, the FRAKO logo is visible on the left, and "FRAKO Germany" is printed on the right.

# Contents

<b>1</b>	<b>About this manual .....</b>	<b>4</b>
1.1	Objective .....	4
1.2	Safekeeping .....	4
1.3	Symbols used in this manual .....	4
1.4	Reference documents .....	5
<b>2</b>	<b>Safety .....</b>	<b>6</b>
2.1	Intended use .....	6
2.2	Instrument-specific dangers .....	6
2.3	Management information .....	7
2.4	Disclaimer .....	7
2.5	Relevant standards .....	8
2.6	Repair .....	8
<b>3</b>	<b>Technical data .....</b>	<b>9</b>
<b>4</b>	<b>Instrument description .....</b>	<b>15</b>
4.1	Function .....	15
4.2	Instrument versions .....	16
4.3	User interface .....	16
4.4	Password protection .....	17
<b>5</b>	<b>Installation .....</b>	<b>18</b>
5.1	Mounting at the desired location .....	18
5.1.1	Preparing for installation .....	18
5.1.2	Scope of supply .....	18
5.1.3	Suitable location .....	18
5.1.4	Mounting the instrument .....	19
5.2	Electrical installation .....	20
5.2.1	Electrical installation procedure .....	20
5.2.2	Completing the electrical installation .....	21
5.2.3	Specifications for the electrical connections .....	22
5.2.4	Earth connection .....	22
5.2.5	Power supply .....	22
5.2.6	Voltage measurement .....	23
5.2.7	Current measurement .....	24
5.2.8	Output relays (control outputs) .....	25
5.2.9	Alarm function .....	25
5.2.10	Connection diagrams for all PQC types .....	25
5.3	Commissioning (initial start-up) .....	29
5.3.1	Preparations for start-up .....	29
5.3.2	PQC initial start-up .....	30
5.3.3	Automatic connection and stage identification .....	31
5.3.4	Manual connection and stage identification .....	32

<b>6</b>	<b>Description of the menu .....</b>	<b>35</b>
6.1	Main menu .....	35
6.2	Display .....	36
6.2.1	PQC overview .....	37
6.2.2	System & PQ .....	39
6.2.3	Service .....	41
6.2.4	Alarms & notifications .....	42
6.3	Configuration .....	45
6.3.1	System parameters .....	46
6.3.2	PFC Equip. parameter .....	46
6.3.3	Control parameters .....	46
6.3.4	Alarms .....	54
6.3.5	Communication (optional) .....	59
6.3.6	Temperature I/O (optional) .....	62
6.3.7	Service .....	64
6.4	About PQC .....	66
6.5	Factory settings .....	66
6.6	Service interface .....	70
<b>7</b>	<b>General operation .....</b>	<b>71</b>
<b>8</b>	<b>Cleaning and maintenance.....</b>	<b>72</b>
8.1	Safety during cleaning and maintenance .....	72
8.2	Cleaning .....	72
8.3	Maintenance .....	72
<b>9</b>	<b>Troubleshooting.....</b>	<b>73</b>
<b>10</b>	<b>Decommissioning and removal, storage and disposal .....</b>	<b>77</b>
10.1	Decommissioning the PQC .....	77
10.2	PQC removal .....	78
10.3	Storage .....	78
10.4	Disposal .....	78

# 1 About this manual

The PQC Power Quality Controller is an instrument for controlling the power factor and other power quality parameters. Throughout this manual, it will be referred to simply as the PQC.

The current version of this manual can be accessed at our website: [www.frako.com](http://www.frako.com).

## 1.1 Objective

This operating manual has been prepared for persons who install, connect, commission and operate the PQC. The manual must be read through carefully and completely before any work on or with the instrument is carried out. All actions taken must be in accordance with this manual.

## 1.2 Safekeeping

This operating manual contains important instructions for operating the PQC safely, correctly and cost-effectively. It is to be considered part of the instrument itself and must be held in a secure place where it can be referred to at all times.

## 1.3 Symbols used in this manual

Special instructions in this operating manual are marked by symbols and separated from the other text by lines.

### Warning signs

In order to avoid accidents, death or injury and damage to assets, these instructions must always be followed. The warning signs consist of the appropriate key word – DANGER, WARNING, CAUTION or ATTENTION – plus a yellow symbol on the left-hand side, as shown below:



#### **WARNING!**





##### **Type of danger!**

Description of the danger and possible consequences

– Actions to avoid the danger

---

The symbols and key words classify the extent of the danger:

Symbol	Key word	Meaning
	DANGER	This key word indicates a hazard with a high level of risk that if not avoided can result in death or serious injury.
	WARNING	This key word indicates a hazard with an intermediate level of risk that if not avoided can result in death or serious injury.
	CAUTION	This key word indicates a hazard with a low level of risk that if not avoided can result in slight or moderate injury.
	ATTENTION	Damage to property could occur if this sign is not heeded.

## Notes

Notes supplement the general text with additional information on the correct functioning and fault-free operation of the PQC. They are marked with the white-on-blue symbol on the left-hand side, as shown below:



### Note

Example of a note

## 1.4 Reference documents

For further information on the PQC please refer to the following documents:

- “PQC Application Note”
- “Modbus Specification”
- “Application Note”
- “REST Application Note”

## 2 Safety

### 2.1 Intended use

Within the scope of the technical data (see *Section 3 “Technical data”*), the PQC Power Quality Controller is intended for the control of power factor  $\cos \varphi$  by switching reactive power in and out. Any use of the instrument that deviates from its intended use must be expressly approved by the manufacturer.

### 2.2 Instrument-specific dangers

The PQC has been manufactured using state-of-the-art technology. Nevertheless, not all potential dangers can be excluded.

Failure to observe the safety instructions can result in death, serious injury or severe damage to equipment and other assets.

#### **Danger from electricity**

The PQC operates at the supply voltage. Touching live components at the instrument terminals and connecting cables can cause serious injury or may even be life-threatening.

- Installation, commissioning and decommissioning of the PQC may only be carried out by appropriately qualified technicians who are also familiar with and understand the contents of this manual.
- When the PQC is being installed or serviced, the instrument and the electrical system must be isolated from the power supply.
- The isolated electrical system must be locked out and tagged to prevent its being inadvertently switched on again.
- It must be verified that none of the terminals are live!
- All live components in the vicinity must be covered to prevent inadvertent contact.
- Current transformer circuits must be short-circuited before they are interrupted.
- Only approved installation cables must be used.
- The PQC must only be employed on duties up to the specified maximum power. Overloading the instrument can result in its destruction, create a fire hazard or cause an electrical accident. The load ratings for the various connections must not be exceeded.
- Do not open the PQC.
- When the PQC is in operation, the USB port must not be touched.

## **Danger from heat**

The instrument terminals can become hot during operation.

- After the PQC has been operating, sufficient time must be allowed for the PQC and its terminals to cool down before work is carried out on the connections.

## **2.3 Management information**

### **Personnel qualifications**

The following qualifications are required for personnel working with the PQC:

- Installing, commissioning, troubleshooting (installation):  
electrician
- Operation, troubleshooting (faulty configuration):  
persons who have read and understood the operating manual.
- Troubleshooting (instrument faults):  
FRAKO Service + Support

### **User responsibility**

In commercial operations in Germany, it is essential to comply with the regulations of the Social Accident Insurance Institution covering electrical installations. In other countries, the equivalent local regulations must be followed.

The safety of the system in which the PQC is incorporated is the responsibility of the persons installing and operating the system.

For safety reasons and to retain conformity with product approval requirements (CE marking), the user is not permitted to convert or otherwise modify the PQC.

The user must ensure that all operators are familiarized with this operating manual and follow it at all times.

## **2.4 Disclaimer**

No claims under guarantee shall be valid in the event of damages caused by failure to observe the instructions in this operating manual. We shall not be held liable for consequential damages!

Incorrect operation or failure to observe the safety instructions will invalidate all claims under the guarantee, and no liability is accepted for any injuries to persons or damages to assets arising therefrom or occasioned thereby!

## 2.5 Relevant standards

Installation and commissioning of the instrument in industrial plant must be carried out in strict compliance with the following standards:

- EN 61508-1:2011-02; VDE 0803-1:2011-02

Any other laws, standards, regulations and safety rules (IEC, EN, VDE, etc.) relevant to this product and the protection of persons and assets must be observed. In Germany, it is essential to comply with the Equipment Safety Act (GSG) and the regulations of the German Social Accident Insurance Institutions. In other countries, the equivalent local regulations must be followed.

## 2.6 Repair

Should repair work be necessary, the customer or user must contact the manufacturer of the PQC: FRAKO Kondensatoren und Anlagenbau GmbH, Tscheulinstrasse 21A, D-79331 Teningen, Germany, [www.frako.com](http://www.frako.com).



## 3 Technical data

### Power supply:

Type	xxx240x-xx	xxx480x-xx
Supply voltage	85–267 V AC (absolute limits), frequency 45–65 Hz, or 100–377 V DC (absolute limits)	85–530 V AC (absolute limits), frequency 45–65 Hz, or 100–750 V DC (absolute limits)
Power draw	maximum 5 VA	
Overcurrent protection	External, maximum 2 A (time delay) specified	

### Inputs:

Category	Single phase	3-phase
Type	xxxxxx1-xx	xxxxxx3-xx
Voltage path measurement inputs	80 V AC – maximum 760 V AC (phase–phase, absolute limits), suitable for 115–690 V AC networks, electrically interconnected via high resistances, measurement of medium voltages possible using an x/100 V transformer; In areas where UL / CSA standards apply (versions PQC xxx480x-xx): networks with nominal voltages 115–600 V AC; power failure detection after duration of a half-wave	
Current path measurement inputs	x/5 A AC or x/1 A AC (transformer secondary current $\geq 15$ mA), electrically isolated, power draw maximum 1 VA per transformer connection, continuous overload rating up to 6 A AC, transient overload maximum 10 A AC for 10 seconds	
Digital inputs	Up to five digital inputs	
	5-24 VDC inputs, alternatively usable as up to 5 x 24 V DC, 100 mA outputs, electrically interconnected with each other and the temperature input	
Temperature inputs	1 x PT-100 or PT-1000 RTD, 4-wire or 2-wire configuration, automatic probe type identification; 2 x NTC thermistor type TDK/Epcos-B57861S0502F040, FRAKO Article No. 29-20094, measuring range $-50^{\circ}\text{C}$ to $+200^{\circ}\text{C}$ , electrically connected with the digital outputs	

Category	Single phase	3-phase
Type	xxxxxx1-xx	xxxxxx3-xx
Type	xxxxxx-4x	
Profile switching (T)	S0 pulse as per DIN 43864, common earth with FRAKO Starkstrombus (Frakobus)	

## Interfaces:

Type	xxxxxx-2x	xxxxxx-3x	xxxxxx-4x
Modbus RTU interface	120 $\Omega$ terminating resistor required at the end of the bus system		
Ethernet interface (Modbus TCP, web server)		100 Mbit/s Ethernet standard 100 BASE-T	
FRAKO Starkstrombus (Frakobus)			RS-485, surge impedance 120 $\Omega$ , for connection to the FRAKO Energy Management System

## Outputs:

Category	12 output relays	6 output relays	6 output relays
Type	120xxxx-xx	060xxxx-xx	061xxxx-xx
Output relays (outputs for switching stages)	NO contact with common pole P; AC - 14 250 V AC, maximum 3 A or DC - 13 30 V DC, maximum 3 A, mechanical service life $2 \times 10^7$ cycles, electrical service life AC - 14 at 3 A: $1 \times 10^5$ cycles, AC - 14 at 0.5 A: $2 \times 10^6$ cycles		AC-14 440 V AC, max. 3 A or DC-13 125 V DC, max. 3 A, mechanical service life $1 \times 10^7$ cycles, electrical service life AC-14 at 3 A: $1 \times 10^5$ cycles, AC - 14 at 0.5 A: $2 \times 10^6$ cycles
	Common supply conductor P to the output relays maximum 10 A; Note: utilization category AC-14/DC-13 as per IEC 60947-5-1; for all PQC types in areas where UL / CSA standards apply: 3 A 250 V AC $\cos \varphi = 1$ at 85 °C, 3 A 30 V DC L/R=0ms at 85 °C		

Category	12 output relays	6 output relays	6 output relays
Type	120xxx-xx	060xxx-xx	061xxx-xx
Alarm contact	Volt-free NO contact, AC-14 250 V AC, max. 3 A or DC-13 30 V DC, max. 3 A, mechanical service life $2 \times 10^7$ cycles, electrical service life AC-14 at 3 A $1.5 \times 10^5$ cycles, AC-14 at 0.5 A $2 \times 10^6$ cycles. Note: utilization category AC-14/DC-13 as per IEC 60947-5-1, in areas where UL / CSA standards apply: 3 A 250 V AC $\cos \varphi = 1$ at 85 °C, 3 A 30 V DC L/R = 0 ms at 85 °C		
Type	xxxxxxx-x1		
Digital outputs	Up to 5 digital outputs 24 V DC, 100 mA, electrically interconnected with each other and the temperature input. Alternatively usable as up to $5 \times 5$ –24 V DC digital inputs. Note: This internal interconnection gives rise to a minimum current of about 1 µA at the outputs. In the case of a relay with low power LEDs, for example, a weak glow may therefore result.		

### Connections: Via pluggable screw terminals

Type	xxx240x-xx	xxx480x-xx
Instrument power AUX, Insulation rating	Conductor cross section max. 2.5 mm <sup>2</sup> , min. 0.2 mm <sup>2</sup>	
	min. 250 V AC, 70 °C	500 V AC, 70 °C
Protective earth PE	Via 6.3 mm female slide connector; conductor cross section at least equal to the largest conductor cross section of the AUX phases, the voltage measurement connections, the output relays and the alarm connections; insulation colour yellow/green	
Voltage measurement inputs L1, L2, L3, N	Conductor cross section max. 2.5 mm <sup>2</sup> , min. 0.2 mm <sup>2</sup> Insulation rating; Example 1: for 230 V AC, select at least 250 V AC, 70 °C; Example 2: for 690 V AC, select at least 750 V AC, 70 °C	
Current measurement inputs L1, L2, L3, terminals S1 and S2 in each case	Conductor cross section max. 2.5 mm <sup>2</sup> , min. 0.2 mm <sup>2</sup> Insulation rating: min. 250 V AC, 70 °C	
Type	xx0xxxx-xx	xx1xxxx-xx
Output relays (outputs for switching stages)	Conductor cross section max. 2.5 mm <sup>2</sup> , min. 0.2 mm <sup>2</sup>	
	250 V relay Insulation rating: min. 250 V AC, 70 °C	440 V relay Insulation rating: min. 500 V AC, 70 °C
Alarm contact	Conductor cross section max. 2.5 mm <sup>2</sup> , min. 0.2 mm <sup>2</sup> Insulation rating: min. 250 V AC, 70 °C	

USB for updates (service interface)	USB Micro A and Micro B ports
Type	xxxxxxx-x1
Digital inputs and outputs	Conductor cross section max. 1.5 mm <sup>2</sup> , min. 0.14 mm <sup>2</sup> Insulation rating: 50 V DC, 70 °C
Temperature inputs	Conductor cross section max. 1.5 mm <sup>2</sup> , min. 0.14 mm <sup>2</sup> Insulation rating: 50 V DC, 70 °C
Type	xxxxxxx-2x
Modbus RTU interface	Conductor cross section max. 1.5 mm <sup>2</sup> , min. 0.14 mm <sup>2</sup> Insulation rating: 50 V DC, 70 °C
Type	xxxxxxx-3x
Ethernet interface	Ethernet cable Cat 5 as per TIA-568A/B, S/FTP shielding, RJ45 plug
Type	xxxxxxx-4x
FRAKO Starkstrombus (Frakobus)	Conductor cross section max. 1.5 mm <sup>2</sup> , min. 0.14 mm <sup>2</sup> Insulation rating: 50 V DC, 70 °C
Input for profile switching	Conductor cross section max. 1.5 mm <sup>2</sup> , min. 0.14 mm <sup>2</sup> Insulation rating: 50 V DC, 70 °C



#### Note

0.14 mm<sup>2</sup> = AWG 26; 0.2 mm<sup>2</sup> ≈ AWG 25;  
1.4 mm<sup>2</sup> ≈ AWG 16; 2.5 mm<sup>2</sup> = AWG 14

#### Design data:

Dimensions (W x H x D)	144 mm x 144 mm x 70 mm casing 144 mm x 165 mm x 70 mm casing including connectors
Mounting	Front of panel in 138 mm x 138 mm cutout to IEC 61554, held by four retaining lugs at the corners of the casing Maximum screw tightening torque 0.4 Nm
Weight	approx. 770 g without packaging
Ingress protection	Front of instrument when mounted in cabinet IP40, when mounted in cabinet with upgrade kit (Article No. 20-50015) IP54; rear of instrument and terminals IP20; all as per EN 60529 Pollution degree 2 as per EN 61010-1:2011-07.

Electrical design	<p>Casing protection class I as per EN 61140</p> <p>Working voltage up to max. 760 V AC absolute value at voltage measurement inputs.</p> <p>TNVI circuits, some of which interconnected: digital inputs and outputs, optional temperature inputs, optional Modbus interface.</p>
Casing design	<p>Flammability rating UL 94 V-0 according to casing manufacturer</p> <p>Impact resistance IK06 as per EN 61010-1:2011-07, 8.2.2</p>
Service life	At +25 °C ambient temperature 15 years
EMC	<p>EMC as per EN 61326-1</p> <p>EN 61000-4-2, electrostatic discharge: air 8 kV and contact 6 kV with horizontal and vertical coupling plane</p> <p>EN 61000-4-3, radiated immunity (EMS) 80 MHz – 1 GHz, horizontal and vertical, level 10 V/m = industrial environment radiation, Class A</p> <p>Hardware version V1.0:</p> <p>EN 55022A EMI 30 MHz – 1 GHz = industrial environment, Class A</p> <p>Being a Class A device, this version can cause radio interference in residential areas. In this case, users may be called upon to take appropriate remedial measures at their own expense.</p> <p>From hardware version V1.2:</p> <p>EN 55022A EMI 30 MHz – 1 GHz = office and residential area, Class B</p> <p>EN 61000-4-6, immunity to conducted disturbances, level 10 V RMS, 150 kHz – 80 MHz<sup>1</sup></p> <p>PQC xxxxxx-3x:</p> <p>EN 55022A EMI 30 MHz – 1 GHz = office and residential area, Class A</p> <p>EN 61000-4-4, burst immunity, 1 kV capacitive coupling, 2 kV injection into power supply cable and voltage measurement inputs</p> <p>EN 61000-4-5 surge immunity, 6 kV injection into power supply cable and voltage measurement inputs</p>

<sup>1</sup> The standard radio-frequency field test as per EN 61000-4-6 (EMC immunity) calls for amplitude modulation at a modulation frequency of 1 kHz. However, this frequency lies within the measurement range of the instrument in its intended use (20th harmonic of 50 Hz = 1 kHz). It is therefore to be expected that the measuring circuit clearly respond to the standard test. For this reason, the radio-frequency field test can only be carried out without amplitude modulation.

**Ambient conditions:**

Temperature range	-25 °C to +65 °C, noncondensing
Installation altitude	Maximum height above sea level 2000 m

**Measuring system:**

Accuracy	Voltage and current measurement $\pm 1\%$ at 50/60 Hz and 25 °C ambient temperature
Averaging function	Over 1 second, updated every 100 ms
Harmonics	Measured via Lx–N All even and uneven harmonics up to the 19th

## 4 Instrument description

### 4.1 Function

The PQC Power Quality Controller continuously calculates the reactive and active power components in the supply network using the measurement data from the current path (current transformer) and the voltage path (voltage measurement connection). If the reactive power component exceeds certain thresholds, which the PQC has determined during the calibration procedure or which have been set as described, switching commands are given via the instrument outputs. If the inductive reactive power is greater than the value preset during instrument configuration (target  $\cos \varphi$ ), after an adjustable time delay one or more of the PQC control contacts are closed. The PQC thus switches capacitor stages in as required in order to restore the target power factor. If the inductive reactive power component of the loads reduces again, this causes capacitor stages to be switched out. The PQC makes a variety of options possible for customizing the control settings to suit the individual application. The clear overview in the display provides effective monitoring of power factor correction. So-called 'cyclic switching' is a useful feature for prolonging the service life of the installation, since it ensures that all capacitor stages of the same power rating are on average switched in equally frequently.

#### Regeneration

The PQC has a four-quadrant control function. If active power is fed back into the supply network, for example by combined heat and power systems, the PQC continues to correct for the reactive power drawn from the supply network. When this regeneration occurs, the active power  $P$  is displayed with a minus sign before it. Regeneration mode is also indicated by a symbol appearing on the display screen.






## 4.2 Instrument versions

The PQC is available in various versions, identifiable by their type designation:

PQC	xx	x	xxx	x	–	x	x	Type designation
PQC	12	0	240	1	–	2	1	Example
PQC	06	1	480	1	–	3	0	
								↳ Measurement inputs: 1 = Temperature (I/O extension)
								Interface: 2 = Modbus RTU 3 = Ethernet 4 = FRAKO Starkstrombus (Frakobus)
								Measurement inputs: 1 = single-phase 3 = 3-phase
								Max. supply voltage: 240 V 480 V
								Output relays: 0 = 250 V 1 = 440 V
								Number of switching outputs: 12 06

## 4.3 User interface

The instrument is operated with the following keys located below the display:






Key					
Action	PQC overview	Select	Select	Open submenu	Display information



### Note

The keys are assigned different functions according to the particular menu. These specific functions are described in the appropriate section.



Icon	Key	Function
	Escape	Go back one level in the system tree.
	Up	Increase a selected parameter by an increment. Move a selected item upwards.
	Down	Decrease a selected parameter by an increment. Move a selected item downwards.
	Return/Enter	Go one level deeper in the system tree (e.g. Select a chosen parameter). Select and confirm a chosen parameter (e.g. Adopt a value).
	Info	Help text

The PQC can be operated in three languages, which are selected at **Main menu > Parametrization > Service > Initial start-up** (see *Section 5.3.2 “PQC initial start-up”*):

- **German**
- **English**
- **French**




## 4.4 Password protection

The PQC uses a password to prevent sensitive menu items being accessed by unauthorized persons.

Protected menu items:

- **Main menu > Parametrization**  
Security level 1, Password: last four digits of the serial number (see label on PQC or *Section 6.4 “About PQC”*).
- **Main menu > Parametrization > Service > Reset switching cycles**
- **Main menu > Parametrization > Service > Service**  
Security level 2, Password: 3725

The user is prompted to enter the password as soon as a protected menu is selected.

The  and  keys are used to adjust each digit, which is then confirmed with the  key. Once the 4th digit has been confirmed with this key, the menus at the security level concerned become accessible for one hour.



# 5 Installation

The installation of the PQC is carried out in three steps:

- Mounting at the desired location (see *Section 5.1.1 “Preparing for installation”* and *Section 5.1.4 “Mounting the instrument”*)
- Electrical connections (see *Section 5.2.1 “Electrical installation procedure”* and *Section 5.2.2 “Completing the electrical installation”*)
- Commissioning (see *Section 5.3.1 “Preparations for start-up”*)

The steps must always be taken in this order.

## 5.1 Mounting at the desired location

### 5.1.1 Preparing for installation

1. Verify that the set is complete (see *Section 5.1.2 “Scope of supply”*).
2. Inspect the instrument for any external damage.  
If any damage is apparent, for safety reasons it must **not** be put into service.  
In case of doubt, please contact FRAKO Service.
3. Verify that the intended location of the PQC is suitable (see *Section 5.1.3 “Suitable location”*).

### 5.1.2 Scope of supply

The PQC and its accessories consist of:

- 1 PQC instrument
- 4 or more (depending on the instrument version) reverse-polarity-proof male connectors, supplied loose
- 1 operating manual
- 1 DVD

### 5.1.3 Suitable location

The location where the PQC is installed must comply with the following conditions (see also *Section 2.1 “Intended use”* and *Section 3 “Technical data”*):

- Only install the PQC in areas where there is no danger of gas or dust explosions.
- Do not expose the PQC to direct sunlight or high temperatures, and do not install the instrument near to devices that generate heat.
- The PQC must be mounted in an adequately ventilated area. Its rear and sidewalls must not be covered.
- Do not expose the instrument to rain, water, dampness or high levels of humidity.

Avoid direct contact with water at all cost.

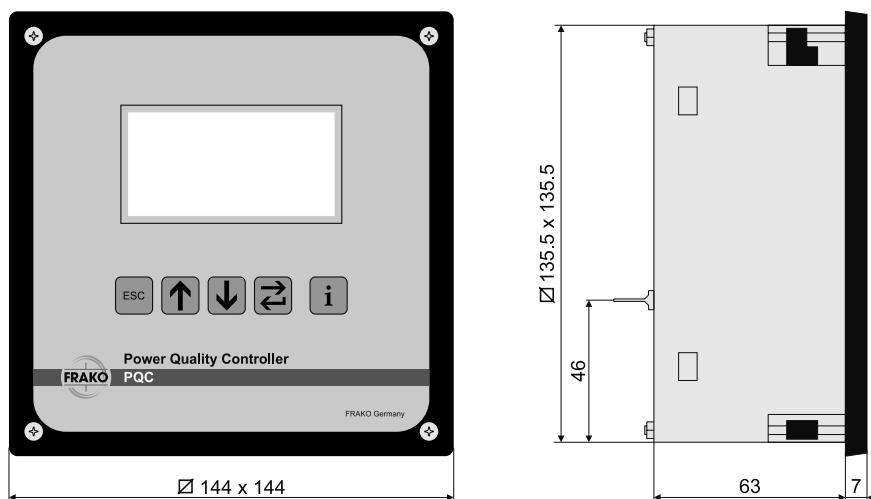
- Protect the PQC against jolting and physical blows.

The instrument is installed vertically on the outside of the control cabinet or enclosure so that the controls and display are accessible to the operator.

Hardware version V1.0: This is a Class A device. In office and residential areas, it can cause interference to radio reception. In this case, it may be necessary to take appropriate precautions with the installation.

When considered from the rear, the PQC is a panel-mounted instrument with IP20 ingress protection. Adequate protection against inadvertently touching live components must be provided, and the ingress of dust and water must be prevented by ensuring that the instrument is installed in a suitable enclosure (e.g. control cabinet or distribution panel).

### 5.1.4 Mounting the instrument



The PQC is designed for mounting in a 138 mm x 138 mm cutout to IEC 61554 in the front of a control cabinet. It is held in place by four retaining lugs in the corners of the instrument.



#### Note

The option is given of mounting the PQC in control cabinets with IP54 ingress protection. For this an additional gasket (Article No. 20-50015) is available that seals the gap between the PQC front panel and the wall of the control cabinet.



## **WARNING!**

### **Danger from electricity!**

Touching live components at the instrument terminals and connecting cables can cause serious injury or may even be life-threatening.

- Installation, commissioning, decommissioning and removal of the PQC may only be carried out by appropriately qualified personnel who have read and understood the content of this manual.
  - When the PQC is being fitted and connected, the instrument and the electrical system must be isolated from the power supply.
  - The isolated electrical system must be locked out to prevent its being inadvertently switched on again.
  - It must be verified that none of the terminals are live.
  - All live components in the vicinity must be covered to prevent inadvertent contact.
- 

1. Turn the four retaining screws at the front of the PQC anticlockwise so that the four retaining lugs in the corners of the instrument are swivelled to lie flat behind its front panel.
2. Option: In the case of a cabinet with IP54 ingress protection, fit the gasket from the accessories set in the rear groove behind the PQC front panel.
3. Insert the sheet-metal rear of the PQC through the cutout provided in the control cabinet until fully home.
4. Press the PQC front panel gently against the control cabinet exterior and tighten the four retaining screws at the corners by turning them clockwise, applying a torque of  $\leq 0.4$  Nm. This causes the retaining lugs to swivel outwards and be drawn towards the inner side of the cabinet wall until they are held tightly up against it.

## **5.2 Electrical installation**

### **5.2.1 Electrical installation procedure**

---



## **WARNING!**

### **Danger from electricity!**

Touching live components at the instrument terminals and connecting cables can cause serious injury or may even be life-threatening.

- Installation, commissioning, modification and retrofitting at the PQC may only be carried out by appropriately qualified personnel who have read and understood the content of this manual.
- When the PQC is being fitted and connected, the instrument and the electrical system must be isolated from the power supply.

- The isolated electrical system must be locked out to prevent its being inadvertently switched on again.
- It must be verified that none of the terminals are live.
- All live components in the vicinity must be covered to prevent inadvertent contact.



### **CAUTION!**

#### **Danger from heat**

The instrument terminals can become hot during operation and could cause burns.

- After the PQC has been operating, sufficient time must be allowed for the instrument and its terminals to cool down before work is carried out on the connections.

---

The PQC is connected as shown in the diagrams in *Section 5.2.10 “Connection diagrams for all PQC types”* and as specified in *Section 5.2.3 “Specifications for the electrical connections”*:

1. Connect the earth (see *Section 5.2.4 “Earth connection”*).
2. An external disconnecting device with a fuse must be fitted in the power supply line to the PQC (see *Section 5.2.5 “Power supply”*).
3. Connect the voltage measurement cabling (see *Section 5.2.6 “Voltage measurement”*).
4. Connect the current measurement cabling (see *Section 5.2.7 “Current measurement”*).
5. Connect the output relays (see *Section 5.2.8 “Output relays (control outputs)”*).
6. If required, connect the alarm relay to transmit an alarm signal (see *Section 5.2.9 “Alarm function”*).

## **5.2.2 Completing the electrical installation**



### **WARNING!**

#### **Danger from electricity!**

If there is a fault in the wiring adjacent to the PQC, there is a danger that its four retaining screws could become live and therefore a safety hazard. Touching live components at the instrument terminals and connecting cables can cause serious injury or may even be life-threatening.

- Securely fasten the cabling at the location where the PQC is mounted (e.g. control panel, cabinet).

---

At the location where PQC is installed (e.g. control cabinet, enclosure), verify that all wires and cables are securely fastened or grouped in harnesses to ensure that any stray wire or strand cannot contact one or more of the instrument’s retaining screws.

### 5.2.3 Specifications for the electrical connections

- Only approved solid core or stranded wire cables having an adequate cross section and sufficiently high voltage withstand ratings must be used for the connecting cabling.
- If flexible stranded cables are used for the PQC connections, short ferrules 6 mm in length must be crimped onto their ends.
- Suitable clips or other fasteners must be fitted to relieve any strain on the wires and cables connected to the PQC.
- No additional connectors must be fitted in the wires and cables connected to the PQC.
- All the connectors supplied with the PQC must be plugged in, even when it is not intended to use them, and be secured to the instrument with their retaining screws, if provided.

### 5.2.4 Earth connection



An earthing tab is provided for the PE connection in the rear wall of the casing. It is marked with the earthing symbol as per EN 60617-2 shown at left

The PE conductor cross section must be at least equal to that of the largest conductor of the AUX phases, the voltage measurement connections, the relay outputs or the alarm connections. Its insulation colour is yellow/green. Earthing connections for network power circuits must have at least the same current-carrying capacity rating as the circuits themselves.

If the earthing tab has broken off, the PQC must not be started up. The instrument must either be repaired or replaced.



#### Note

The PQC may only be put into service if the earthing conductor is connected to it.

### 5.2.5 Power supply

#### External disconnecter

An external disconnecting device, such as an isolator or circuit breaker, must be fitted in the power supply line to the PQC. This must be located in the vicinity of the instrument and must be able to isolate all cables connected to the AUX terminals of the PQC. This device must not disconnect the earthing conductor.

## Fuses

The instrument power supply circuit AUX must be protected externally by one or two fuses, either:

- 2 A time delay, 250 V AC (PQC Type: PQC xxx240x-xx) or
- 2 A time delay, 500 V AC (PQC Type: PQC xxx480x-xx).

One such fuse is required in the phase line when the power is from a **phase–neutral** connection, but two fuses must be installed, one in each phase, if a **phase–phase** connection is used.

Please refer to the diagrams in *Section 5.2.10 “Connection diagrams for all PQC types”*, for further information.

## 5.2.6 Voltage measurement

Depending on the instrument type, the PQC can measure one, two or three AC voltages. The voltage measurement inputs are electrically interconnected via high resistances. See *Section 3 “Technical data”* for the measurement ranges. DC voltages cannot be measured.

The PQC voltage measurement inputs are designed for 100–690 V AC networks.

It is possible to measure medium voltages using an x/100 V transformer.

It is not necessary to provide external overcurrent protection in the voltage measurement circuits since these are safety impedance-protected. In this case, a short-circuit-proof cable (double insulated stranded wire) must be used to connect the voltage measurement inputs.

### Instrument types with single-phase measurement:

For single-phase measurement, the terminals **L** and **N/L** are connected as shown in the diagrams in *Section 5.2.10 “Connection diagrams for all PQC types”*. The voltage can be measured between any two phases or between any phase and neutral.

### Instrument types with 3-phase measurement:

For 3-phase measurement, the terminals **L1**, **L2**, **L3** and **N** are connected as shown in the connection diagrams in *Section 5.2.10 “Connection diagrams for all PQC types”*. Phases **L1**, **L2** and **L3** must be connected in correct phase sequence.

For 3-phase measurement, it is advisable to connect the **N** terminal as well. This enables the high measurement accuracy of the PQC to be achieved when measuring phase–neutral voltages and the parameters derived from these. If no neutral conductor is present, the **N** terminal can be left unconnected. However, this is only advisable when the phases are symmetrically loaded.



### Note

If an instrument type designed for three-phase measuring is used to measure only one phase, the terminals **L1** and **N** must be used. The terminals **L2** and **L3** must then be commoned with the terminal **N** to prevent incorrect measurements being made.

---

## 5.2.7 Current measurement

The PQC is designed for connection to x/1 A and x/5 A external current transformers electrically isolated from the power supply. Depending on the instrument type, the PQC can measure one, two or three AC currents. Attention must be paid to the allowable measurement range. See *Section 3 “Technical data”* for further information.



### **WARNING!**

#### **Danger from electricity!**

If live current transformer circuits are interrupted, there is the danger that arcing may occur, which could cause electric shock, burns or eye injuries. In addition, red-hot metal particles could be spattered, which apart from the health hazard also constitute a fire risk.

- The retaining screws on the connectors must be tightened to prevent the connectors accidentally working loose.
- The secondary-side connections of the current transformers must be short-circuited before the circuits to the PQC are interrupted or the connector removed!



### **Note**

If an earth terminal is provided at the secondary side of the current transformer, this must be connected to an earthing conductor! We recommend in general that every current transformer circuit be earthed.

---

### **Instrument types with single-phase measurement:**

The current can be measured in any desired phase, with the current transformer circuit connected to the **L** terminals **S1** and **S2** as shown in the diagram (see *Section 5.2.10.1 “Connection diagram: Type PQC 1202401-xx”*).

### **Instrument types with 3-phase measurement:**

The current transformer circuits must be connected to the respective S1 and S2 terminals for each of the phases L1, L2 and L3, as shown in the diagram (see *Section 5.2.10.2 “Connection diagram: Type PQC 1202403-xx”*).

Unassigned current measurement inputs can be left unconnected.



### **Note**

In networks with a nominal voltage of 1000 V and more, the regulations call for the current transformer circuits to be earthed.

If networks with a nominal voltage of 1000 V or over are left unearthed, damage may occur to the instrument.

With three-phase measurement, automatic connection identification is not possible.



## 5.2.8 Output relays (control outputs)

Depending on instrument type, the PQC is equipped with 6 or 12 output relays (control outputs). Relays or contactors are usually connected to these to switch the capacitor stages in and out.

The output relays **Q1–Q12** (**Q1–Q6** in the case of PQC versions with 6 output relays) receive their control voltage from a common feed **P**. The load ratings of the output relays and the common feed line **P** can be found in the connection diagrams or the technical data (see *Section 3 “Technical data”*).

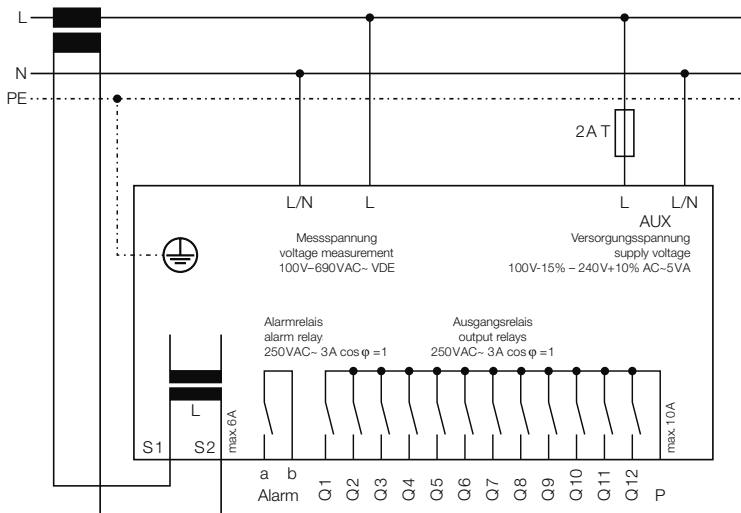
If not all of the available output relays are to be used, it is recommended to connect the output cables starting with output 1 and leaving no gaps.

## 5.2.9 Alarm function

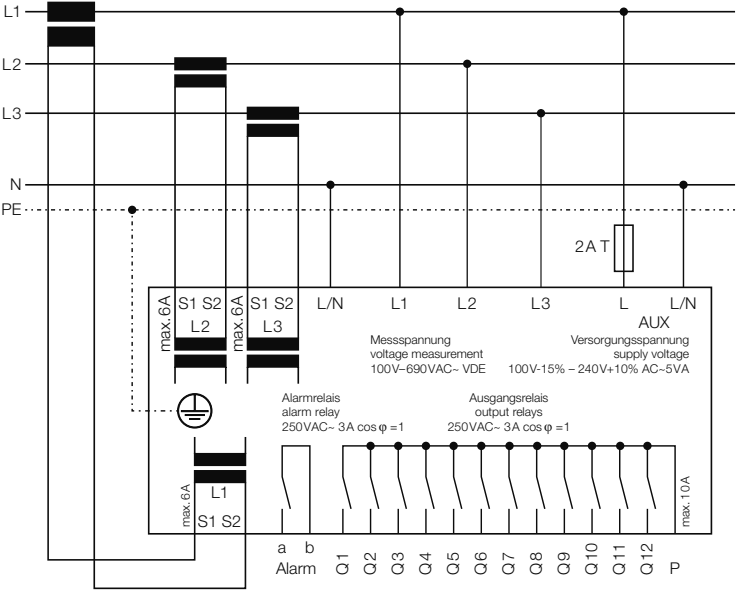
The PQC has a volt-free contact to transmit alarms externally, alarm terminals **a** and **b** being provided for this external connection as shown in the diagrams in *Section 5.2.10 “Connection diagrams for all PQC types”*. Attention must be paid to the load rating of the contact (see *Section 3 “Technical data”*).

## 5.2.10 Connection diagrams for all PQC types

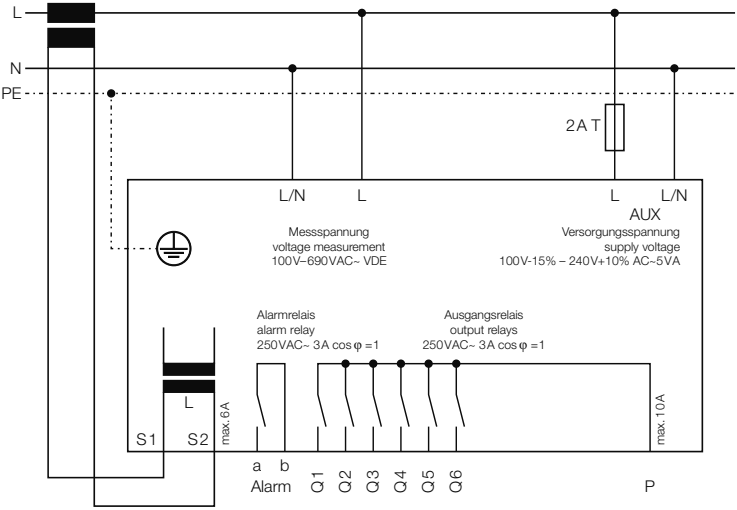
### 5.2.10.1 Connection diagram: Type PQC 1202401-xx



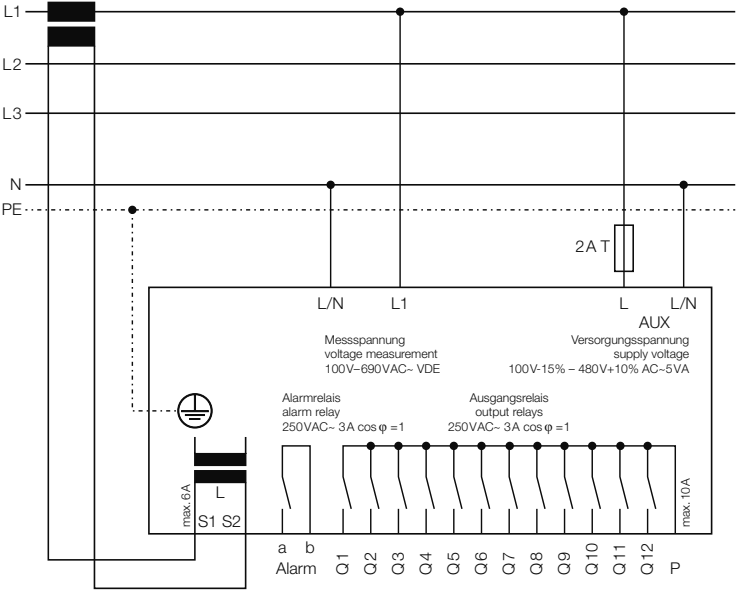
5.2.10.2 Connection diagram: Type PQC 1202403-xx



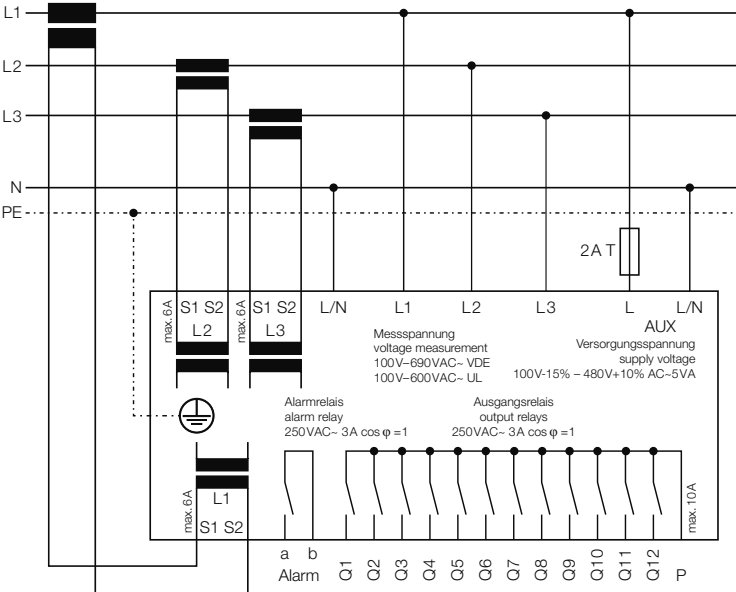
5.2.10.3 Connection diagram: Type PQC 0602401-xx



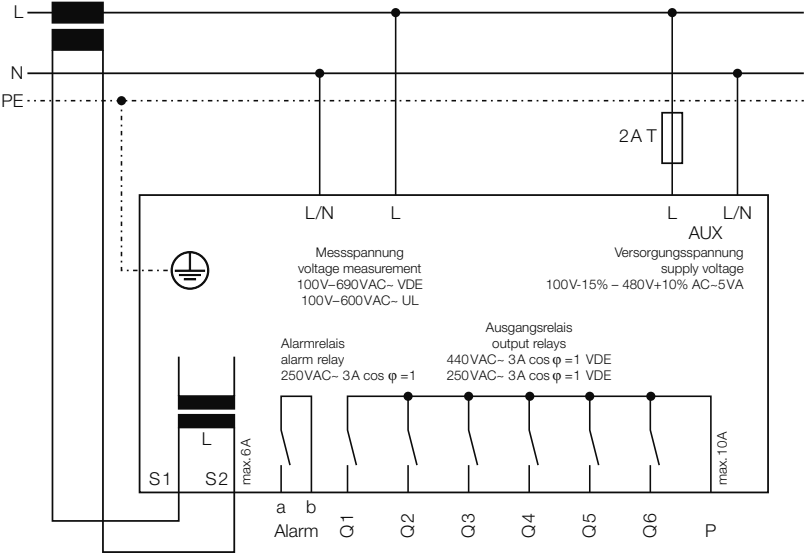
### 5.2.10.4 Connection diagram: Type PQC 1204801-xx



### 5.2.10.5 Connection diagram: Type PQC 1204803-xx



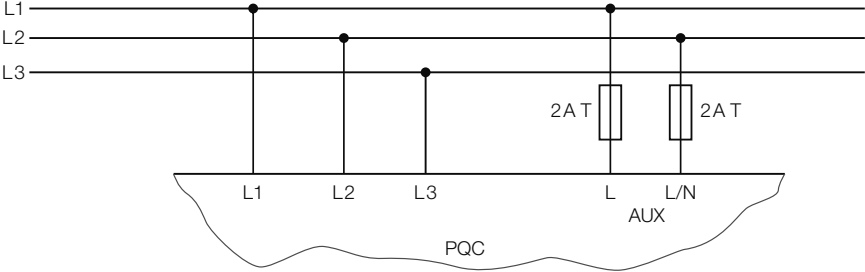
5.2.10.6 Connection diagram: Type PQC 0614801-xx



5.2.10.7 Options for connecting the AUX power supply for PQC xxx480x-xx types

Connecting the AUX terminals to a 100 to 480 V AC power supply

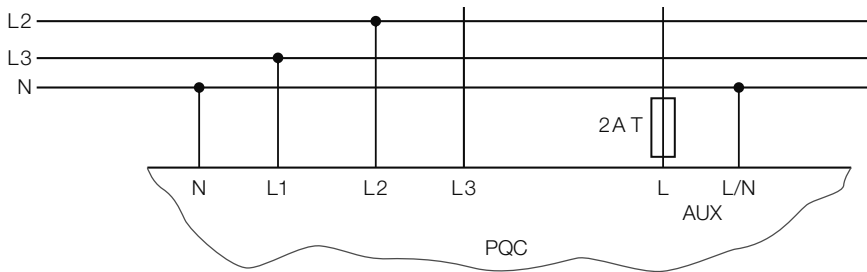
Part of connection diagram for 400/415 V networks with no neutral conductor



Instrument type: PQC xxx480x-xx

400 V AC / 415 V AC – Networks with no neutral N

## Part of connection diagram for 690 V networks with a neutral conductor



Instrument type: PQC xxx480x-xx

690 V AC networks with neutral N (phase–neutral = 400 V AC)

## 5.3 Commissioning (initial start-up)

### 5.3.1 Preparations for start-up



#### **WARNING!**

##### **Danger from electricity!**

Touching live components at the instrument terminals and connecting cables can cause serious injury or may even be life-threatening.

- It must be verified that the PQC is installed and connected in accordance with its intended use before power is switched on.
- Cover the instrument terminals



#### **ATTENTION!**

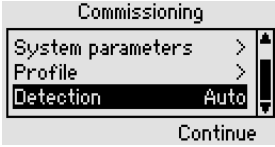
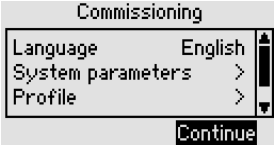
##### **Risk to equipment!**

If the PQC terminals are wrongly connected, or if the wrong voltages or signals are applied to them, this can damage the instrument itself and the installation.

- Verify that all the connections are correct before switching on the power.

1. Verify that the PQC has been correctly installed and connected as described in Section 5.1 “Mounting at the desired location” and Section 5.2 “Electrical installation” and that all the connectors supplied with the instrument have been plugged in.
2. Verify that the earth connection has been made.
3. Ensure, for example by means of a closed door or a suitable cover, that the instrument terminals can no longer be touched.
4. Switch on the instrument power.
5. Carry out the initial start-up (see Section 5.3.2 “PQC initial start-up”)

### 5.3.2 PQC initial start-up



Key					
Action	Main menu	Select language dt – en – fr	Select language dt – en – fr	Confirm language and return to parameter selection	–

When the power is switched on, the PQC Start screen is displayed, showing information about the installed firmware. The initial start-up dialogue then starts automatically, in which the essential parameters for operation can then be set and the start-up mode selected.

**Note**

If the PQC does not start, switch off the power and check the cabling.

The following parameters must be selected or confirmed:

**Language**                      German, English (factory default), French

**Network parameters** **Voltage transformer ratio**

Range 1 to 300, transformer ratio:  $\frac{V_{primary}}{V_{secondary}}$

**Current transformer ratio**

Range 1 to 7000, transformer ratio:  $\frac{I_{primary}}{I_{secondary}}$

Example: current transformer  $\frac{500A}{5A}$


Transformer ratio:  $k = \frac{I_{primary}}{I_{secondary}} = \frac{500A}{5A} = 100$

**Profile**                      Control profile, with which the PQC is to operate after a successful start-up.


The PQC as delivered from the factory is set with the FRAKO specific kinked control characteristic curve and the target  $\cos \varphi_{target} = 0.92$  ind. See Section 6.3.3 “Control parameters”.

**Communication**              Where relevant: settings for communication interface (Modbus RTU / Modbus TCP / Frakobus). See Section 6.3.5 “Communication (optional)”, for further information.

**Identification** Automatic / manual connection and stage identification (see *Section 5.3.3 “Automatic connection and stage identification”* and *Section 5.3.4 “Manual connection and stage identification”*)

 **Note** For the voltage and current readings (and the values of power derived from them) to be displayed correctly, it is essential that the voltage and current transformer ratios be entered.

Regardless of the initial start-up mode, all the configuration data are saved in a non-volatile memory. In the event of power loss (intended or not) these data are not lost. When the power supply returns, the PQC starts up automatically and begins the control process after booting up.

 **Note** Automatic connection and capacitor stage identification is only possible with single-phase measurement.

### 5.3.3 Automatic connection and stage identification


To start the automatic connection and capacitor stage identification procedure, select **Auto** in the **Detection** menu and confirm this with **Continue**.

The PQC switches the individual output relays one after the other and identifies not only the phase angle of the current and voltage measurement paths but also to which output each capacitor stage is assigned. Each output is switched several times until the PQC can verify the measured values.

This is shown in the following screenshots:

Stage capacitive power identification is being carried out; connection identification is complete, with the result connection type 4.

```
Commissioning
Analyse stage      7
Connection Typ     6
c/k Value[mA]     ---
Switch Seq.       ---
Status            Detection...
```

When the PQC has successfully completed the connection and stage identification procedure, the operator must confirm the result with the  key. The PQC then switches to operating mode and displays the **PQC overview** screen. If at this moment there is a concrete need for reactive power control, the PQC commences to switch stages in or out as necessary.

```
Commissioning
Analyse stage      4
Connection Typ     6
c/k Value[mA]     67
Switch Seq. 120122020021
Status            Press enter
```

If the PQC was not able to complete the connection and stage identification procedure successfully, or if the user presses the ESC key to cancel it, this is indicated by a message on the screen. The initial start-up procedure can then be restarted.

5.3.4 Manual connection and stage identification

To initiate the manual start-up procedure, select **Man** in the **Detection** menu and confirm this with **Continue**.

In the manual start-up, the following parameters must be determined manually and entered:

- Connection type** see Section 5.3.4.1 “Connection type”
- c/k value** see Section 5.3.4.2 “Calculation of c/k”


Commissioning	
Connection Typ	0
c/k Value[mA]	15
Switch Seq.	1:1:1:1..
No. of Stages	12
Continue	

**Switching sequence** The switching sequence must be set in terms of the relative values of the individual stages to each other:

1:1:1:1:1...	1:1:2:4:4...	1:2:3:4:4...
1:1:2:2:2...	1:1:2:4:8...	1:2:3:6:6...
1:1:2:2:4...	1:2:2:2:2...	1:2:4:4:4...
1:1:2:3:3...	1:2:3:3:3...	1:2:4:8:8...

**Number of C stages** Indicates the number of control outputs used.

When all the necessary information has been entered, confirm this with **Continue**. The PQC then switches to operating mode and displays the **PQC overview** screen. If at this moment there is a concrete need for reactive power control, the PQC commences to switch stages in or out as necessary



**Note**

Manual start-up mode deactivates the capacitive power identification function when the PQC is operating.



### 5.3.4.1 Connection type

With the connection type, the phase angle of the current and voltage measurement paths is indicated. It can be found from the table below:

Connection type	Connection to voltage path		
	L/N – L	L/N – L	L/N – L
0	L1 – N	L2 – N	L3 – N
1	L1 – L3	L2 – L1	L3 – L2
2	N – L3	N – L1	N – L2
3	L2 – L3	L3 – L1	L1 – L2
4	L2 – N	L3 – N	L1 – N
5	L2 – L1	L3 – L2	L1 – L3
6	N – L1	N – L2	N – L3
7	L3 – L1	L1 – L2	L2 – L3
8	L3 – N	L1 – N	L2 – N
9	L3 – L2	L1 – L3	L2 – L1
10	N – L2	N – L3	N – L1
11	L1 – L2	L2 – L3	L3 – L1
Current transformer in:	↑ L1	↑ L2	↑ L3

#### Example:

The current transformer is installed in phase **L2**, while the voltage is measured between the phase **L3** and **N**. It is therefore connection type 4.

If the current transformer is installed or connected the wrong way round, this can be corrected for by the choice of connection type, i.e. by adding 6 to the connection type number given by the table. In the above example, this gives the connection type 10. If the result of this addition were to be greater than 11, the rule is to subtract 6 from the connection type number instead.

### 5.3.4.2 Calculation of c/k

To operate the system, the value of c/k (response current) must be determined. This equals 65 % of the nominal current of the smallest capacitor stage and is to be detected in the PQC current measurement path.

The c/k value can be calculated from the following formula:

$$I_A = 0.65 \cdot \frac{Q_{\text{smallest stage}}}{V \cdot \sqrt{3} \cdot k} \cdot 1000 \approx 0.375 \cdot \frac{Q_{\text{smallest stage}}}{V \cdot k} \cdot 1000 [\text{mA}]$$

$I_A$  = response current in mA to be set

$Q_{\text{smallest stage}}$  = capacitive power of smallest stage in var (not the total capacitive power of the system)

V = network voltage in V at the primary side of the voltage transformer

k = transformer ratio (primary side / secondary side)

Alternatively, for a 400 / 50 Hz network the c/k setting can also be read off from the table below:

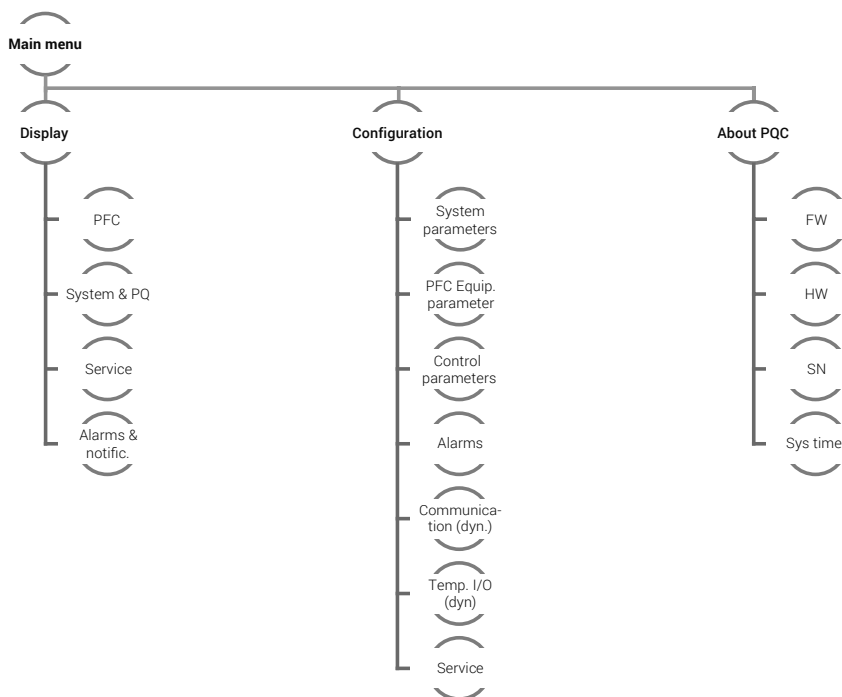
c/k setting for 400 V 50 Hz AC network ~															
Current		Stage power (not total power) of the PF correction system in kvar													
	k	2.5	5	6.25	7.5	10	12.5	15	20	25	30	40	50	60	100
30/5	6	400	800	980	1200	1600									
40/5	8	300	600	740	900	1200	1500								
50/5	10	240	480	590	720	960	1200	1440							
60/5	12	200	400	490	600	800	1000	1200	1600						
75/5	15	160	320	390	480	640	800	960	1280	1600	1920				
100/5	20	120	240	300	360	480	600	720	960	1200	1440	1920			
150/5	30	80	160	200	240	320	400	480	640	800	960	1280	1600	1920	
200/5	40	60	120	150	180	240	300	360	480	600	720	960	1200	1440	
250/5	50	50	100	120	140	190	240	290	380	480	580	770	960	1150	1920
300/5	60	40	80	100	120	160	200	240	320	400	480	640	800	960	1600
400/5	80	30	60	80	90	120	150	180	240	300	360	480	600	720	1200
500/5	100	20	50	60	70	100	120	140	190	240	290	380	480	580	960
600/5	120		40	50	60	80	100	120	160	200	240	320	400	480	800
750/5	150		30	40	50	60	80	100	130	160	190	260	320	380	640
1000/5	200		20	30	40	50	60	70	100	120	140	190	240	290	480
1500/5	300			20	20	30	40	50	60	80	100	130	160	190	320
2000/5	400					20	30	40	50	60	70	100	120	140	240
2500/5	500						20	30	40	50	60	80	100	120	190
3000/5	600							20	30	40	50	60	80	100	160
4000/5	800								20	30	40	50	60	70	120
5000/5	1000									20	30	40	50	60	100
6000/5	1200										20	30	40	50	80
7000/5	1400											20	30	40	70

## 6 Description of the menu

### 6.1 Main menu

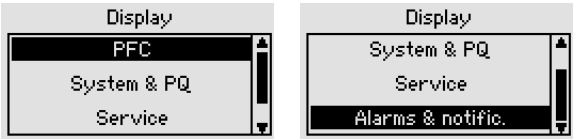
From the main menu, all the measurement readings and settings that the PQC makes available can be displayed and where possible changed.

The main menu is divided into three main groups: **Display**, **Parametrization** and **About PQC**



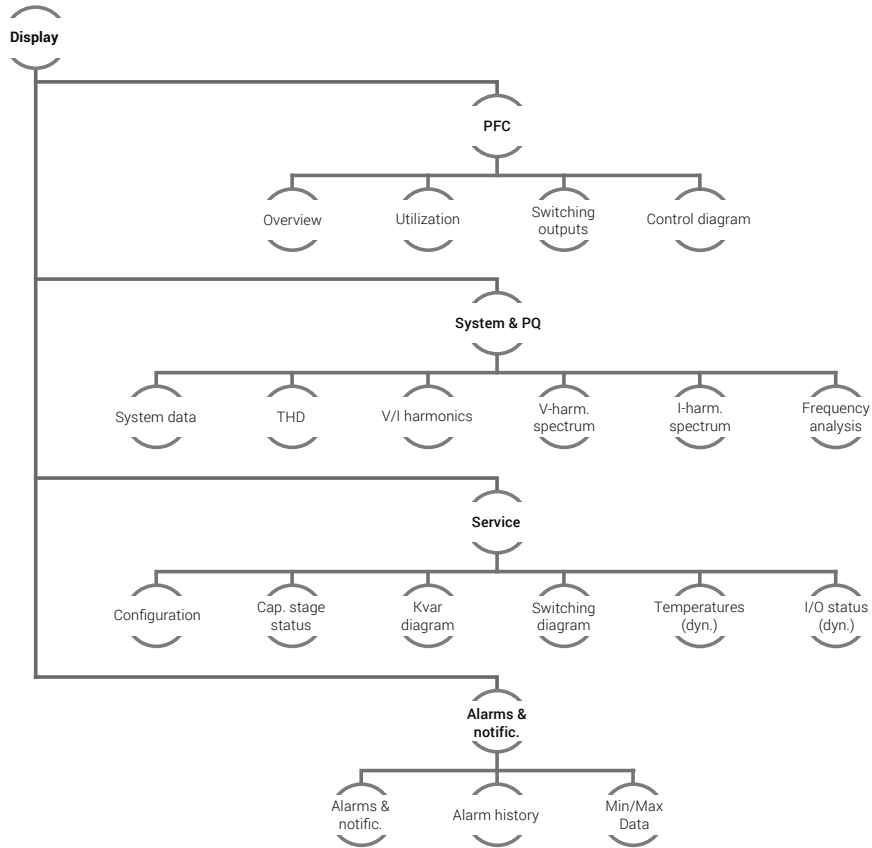
# 6.2 Display

Main menu > Display



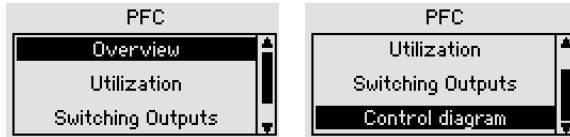
In the Display menu, all measurement readings and parameters relevant to power factor correction are shown. The main Display menu items are:

- PQC overview** Measurement readings relevant to power factor correction
- Netw. and PQ** Network and power quality parameters
- Service** Status display
- Alarms & Messages** Display of momentary alarms and the alarm history



## 6.2.1 PQC overview

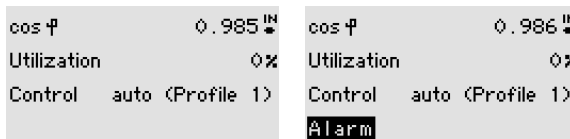
Main menu > Display > PQC overview



All measurement readings and parameters relevant to power factor correction are shown here.

### 6.2.1.1 Overview

Main menu > Display > PQC overview > Overview



**cos  $\phi$**  Display of the momentary value of cos  $\phi$

**Capacity utilization** The ratio of the momentary switched-in capacitance to the total available capacitance, expressed as a percentage (0 % = no capacitors switched in, 100 % = all capacitors switched in).

**Control** Auto / Man and active control profile

**Alarm** Flashes if an alarm is present.

**Regeneration** Flashes if power is being fed in to the supply network

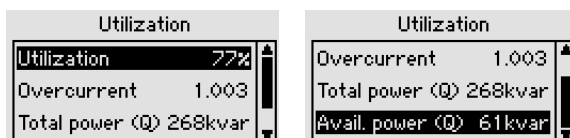


#### Note

If Alarm flashes, pressing the **[i]** key will display the list of active alarms and messages.

### 6.2.1.2 Capacity utilization

Main menu > Display > PQC overview > Cap. utilization



**Capacity utilization** The ratio of the momentary switched-in capacitance to the total available capacitance, expressed as a percentage.

- Overcurrent

This parameter is the ratio  $I_{rms} / I_{50Hz,60Hz}$  i.e. the theoretically determined ratio of the momentary RMS current to the fundamental current in the capacitor. The choke factor  $p$  of the power factor correction system is also taken into account in this calculation.
- Total Q power

This parameter is the sum of all the connected 3-phase capacitor stage corrective powers.
- Available Q power

This parameter is the 3-phase capacitor corrective power still available for switching in.

6.2.1.3 Control outputs

Main menu > Display > PQC overview > Control outputs

The overview display shows the momentary statuses of all the capacitor stages.

Stages 1,4,5,7,10,11: switched-out active stages

Stages 8 and 12 switched-in active stages

A permanently switched-in fixed capacitor stage is shown as a switched-in active stage with an F.

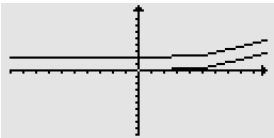
Switching Outputs						
Stage	1	2	3	4	5	6
	1	F	x	1	F	1
	2	8	9	10	11	12
	x	F	x	x	1	F

6.2.1.4 Control diagram

Main menu > Display > Correction > Control diagram

The control diagram shows the currently selected control characteristic curve (active control profile) and provides visualization of the momentary operating point.

Scale: One scale division on the y-axis represents 2/3 x smallest capacitor stage



Key	ESC	↑	↓	↔	i
Action	Back to main menu	Zoom +	Zoom -	-	Additional info

- Zoom +

Zoom in on control diagram
- Zoom -

Zoom out of control diagram
- Additional info

The following information is presented in a separate dialogue:  $\cos \varphi_{target}$ , limitation L, parallel shift SP and the zoom factor.

## 6.2.2 System & PQ

Main menu > Display > System & PQ

System & PQ	
System data	▲
THD	▼
W/I harmonics	▼

System & PQ	
THD	▲
W/I harmonics	▼
V-harm. spectrum	▼

System & PQ	
V-harm. spectrum	▲
I-harm. spectrum	▼
Frequency analysis	▼

### 6.2.2.1 Network variables

Main menu > Display > System & PQ > Network variables

<b>cos <math>\varphi</math></b>	Display of the momentary power factor cos $\varphi$	<div>System data</div> <div>cos <math>\varphi</math> 0.986</div> <div>V 391.4V I 486.4A</div> <div>P 325.2kW S 329.8kVA</div> <div>Q 54.6kvar</div> <div><div><math>\Sigma</math></div> L</div>
<b>V<math>\Delta</math> /V</b>	V $\Delta$ phase-phase voltage / V phase-neutral voltage	
<b>P</b>	Display of the momentary active power	
<b>Q</b>	Display of the momentary reactive power (if capacitive reactive power with a minus sign)	
<b>I</b>	Display of the momentary current	
<b>S</b>	Display of the momentary apparent power	
<b><math>\Sigma</math></b>	Sum of all the phases (L1 to L3); if a single-phase PQC, theoretical calculation of the sum assuming a balanced load	

### 6.2.2.2 THD

Main menu > Display > System & PQ > THD

Display of THDv and THDi and their magnitudes as percentages of the fundamental H1


Single phase PQC: display of Lx and Ix

3-phase PQC: display of all three THDv and THDi values

THD			
	THD	H1	
L V	0.4%	226.6V	
L I	23.8%	280.9A	

### 6.2.2.3 V/I Harmonics

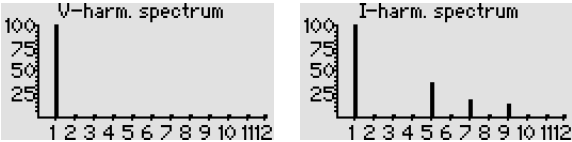
Main menu > Display > System & PQ > V/I Harmonics

Display of percentage values of the voltage and current harmonics together with the fundamental values for voltage and current. With a 3-phase PQC, pressing the  key toggles the display through the phases L1 to L3.

W/I harmonics Lx			
	V(227V)	I(281A)	
H4	0.2%	0.8%	
H5	0.3%	24.7%	
H6	0.2%	0.7%	

6.2.2.4 V Harm. spectrum, I Harm. spectrum

Main menu > Display > System & PQ > V Harm. spectrum, I Harm. spectrum



Graphical display of the harmonics spectrum up to the 19th

Key					
Action	Back to Display menu	Zoom +	Zoom -	Toggle between H1-12 and H13-19	Additional info

The fundamental at 50/60 Hz is shown as 100 %. One scale division on the y-axis represents 5 %.

6.2.2.5 Frequency analysis

Main menu > Display > System & PQ > Frequency analysis

**Phase** Measurement on Lx [ $1 \leq X \leq 3$ ]

**Frequency** 10 Hz to 2,500 Hz in steps of 10 Hz

**V(f)** Magnitude of voltage at the selected frequency as a percentage of the fundamental voltage  $V_1$  ( $f = 50/60$  Hz)

**I(f)** Magnitude of current at the selected frequency as a percentage of the fundamental  $I_1$  ( $f = 50/60$  Hz)

**Angle  $\varphi$**  Angle between  $V_{(f)}$  and  $I_{(f)}$  in degrees

**Angle  $\gamma$**  Angle between  $V_1$  (fundamental) and  $I_{(f)}$  in degrees

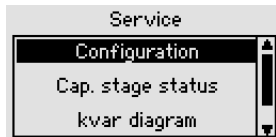
Frequency analysis	
Phase:	L1
frequency:	50 Hz
V(f)=	100% (Vg)
I(f)=	100% (Ig)
$\varphi / \gamma$	190 / 0

Key					
Action	Info status	Frequency +10 Hz	Frequency -10 Hz	Select phase	-



## 6.2.3 Service

Main menu > Display > Service



### 6.2.3.1 Configuration

Main menu > Display > Service > Configuration

**Control status** Automatic or manual control mode

**Switching sequence** Display of the capacitor stages detected. The relative values (switching sequence) can be distributed over the available stages as desired. The largest permitted relative value is 16, the smallest 0.

**Available stages** Number of capacitor stages detected

**c/k setting [mA]** The response current is determined from the smallest capacitor stage detected

**Connection type** Type of connection for L1, L2 and L3 current transformers. See Table in Section 5.3.4 "Manual connection and stage identification"

Configuration	
Controlstatus	auto
Switch Seq. 120122020021	
No. of Stages	8
c/k Value[mA]	66
Connection Typ	6

### 6.2.3.2 Stage status

Main menu > Display > Service > Stage status

**No.** No. of the stage [1–12]

**Stat. (status)** ON / OFF / [x seconds]  
ON: Switches stage in manually  
OFF: Switches stage out manually [x seconds]: Time remaining until the capacitor stage can be switched in again (discharge time)

**Q[var]** This is the stage corrective power in var (3-phase stage corrective power).

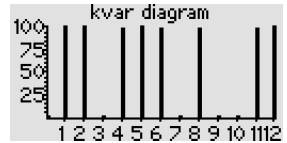
**Switching cycles** Number of stage switching cycles

Cap. stage status			
No	Stat.	Q [var]	Swit.cyc.
1	ON	20.2k	14
2	ON	40.5k	9
3	OFF	0.0	8

### 6.2.3.3 Kvar diagram

Main menu > Display > Service > Kvar diagram

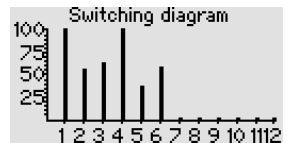
The **capacitor stages rating diagram** shows the momentary corrective power of the capacitor stages as a percentage. After the instrument has been started up, this graphic shows every detected stage as 100 %. With time, however, capacitor wear causes this corrective power to fall.



### 6.2.3.4 Switching diagram

Main menu > Display > Service > Switching diagram

This diagram shows the switching cycle counters for all the stages as a column chart. 100 % on the y-axis represents the set limit for the number of switching cycles counted.



### 6.2.3.5 Temperatures (optional temperature I/O extension)

Main menu > Display > Service > Temperatures

Displays the temperature from the activated PT 100/1000, NTC1 and NTC2 probes.

Temperatures	
PT- 100	25.0°C
NTC1	23.4°C
NTC2	23.6°C

### 6.2.3.6 Temperatures (optional temperature I/O extension)

Main menu > Display > Service > I/O Status

Shows the available inputs and outputs of the temperature I/O extension and indicates the status of each.

I/O status	
I/O 1 outp.	OFF
I/O 2 input	ON
I/O 3 outp.	OFF

## 6.2.4 Alarms & notifications


Main menu > Display > Alarms & notific.

Status of the momentary alarms Display of Alarms and Min/Max histories.

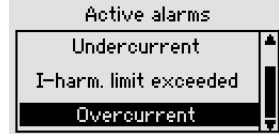
Alarms & notific.	
Alarms & notific.	
Alarm history	
Min/Max Data	

### 6.2.4.1 Alarms & notifications


Main menu > Display > Alarms & messages > Alarms & notific.

All currently active alarms are shown in a list. If one of these is selected and the  key is pressed, details such as the momentary reading are displayed.

The limits for several alarm can be set in the Parametrization menu (see Section 6.3.4 “Alarms”). All alarms are listed in Section 9 “Troubleshooting” gelistet.

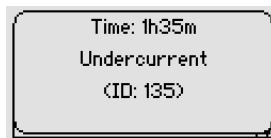
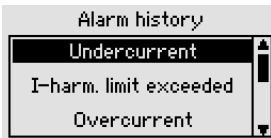



#### Note

The **Alarms & messages** menu can also be displayed from the menu item **Display > PQC overview > Overview** if the  key is pressed.

### 6.2.4.2 Alarm history

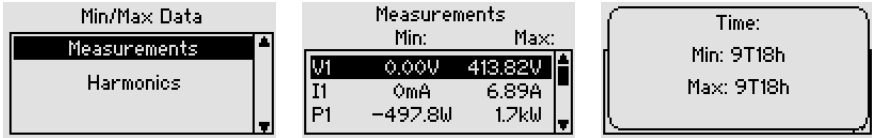
Main menu > Display > Alarms & messages > Alarm history



The alarm storage function displays the 10 most recently occurring alarms, with the latest alarm at the top and the oldest one at the bottom of the list (sorted by time). Selecting one of the lines shown and pressing the  key causes the alarm condition to be displayed in plain language.

### 6.2.4.3 Min/Max data

Main menu > Display > Alarms & messages > Min/Max data



The Min/Max storage holds the minimum and maximum values of the following measurement readings:

- Measurement data per phase:
  - Voltage
  - Current
  - Power (active, reactive and apparent)
  - Network frequency
  - Overcurrent
- Harmonics:
  - Voltage harmonics
  - Current harmonics
- Temperatures: (only available with the optional temperature and I/O extension)
  - PT
  - NTC1
  - NTC2



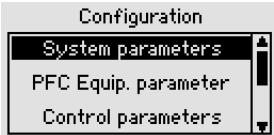
#### Note

Pressing the **i** key shows the times elapsed since the minimum and maximum values displayed on the screen occurred.

# 6.3 Configuration

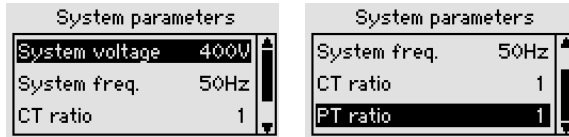
From the Parametrization menu, all the parameters relevant to the operation of the power factor correction system can be changed and configured to give customer-specific control characteristics.

## Main menu > Configuration



### 6.3.1 System parameters

Main menu > Parametrization > System parameters



Setting the specific parameters for the network to be controlled:

**System nominal voltage** Setting range: 60 V – 60 kV

**System nominal frequency** 50 Hz, 60 Hz, Auto

Automatic mode: The PQC determines the network frequency automatically. In the case of networks with heavy voltage harmonics or commutation notches, it can be necessary to set the network nominal frequency manually to the appropriate value.

**Voltage transformer** range 1 to 300, transformer ratio =  $\frac{V_{primary}}{V_{secondary}}$

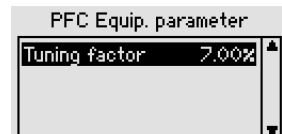
**Current transformer** range 1 to 7000, transformer ratio =  $\frac{I_{primary}}{I_{secondary}}$   
e.g. for a current transformer 500 A / 5 A  
transformer ratio  $K = \frac{I_{primary}}{I_{secondary}} = \frac{500 A}{5 A} = 100$

### 6.3.2 PFC Equip. parameter

Main menu > Parametrization > PFC Equip. parameter

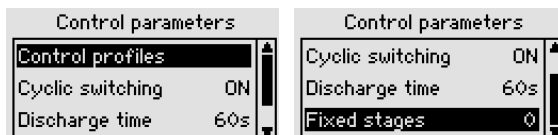
Setting the specific parameters for the power factor correction system:

**Choke factor** Detuning of the power factor correction system (A value must be set for correct computation of overcurrent. If the system is not detuned, 0 % must be entered.)



### 6.3.3 Control parameters

Main menu > Parametrization > Control parameters



Setting the specific parameters for the PQC control function:

<b>Control profiles</b>	<p>Profile, profile switching</p> <p><b>Profile:</b> 5 control profiles, see Section 6.3.3.1 “Control profiles”</p> <p><b>Profile switching:</b> Automatic switching of profiles to Q(V) or Q(P), digital input, see Section 6.3.3.3 “Automatic switching over of the control profiles (profile switching)”</p>
<b>Cyclic switching</b>	ON / OFF (ON is recommended). The purpose of cyclic switching is to ensure that all capacitor stages of the same power rating are switched in equally frequently.
<b>Discharge time</b>	5 – 900 s (1 s increments) capacitor stage discharge time. The discharge time must be at least as long as the longest discharge time of the capacitors in use
<b>Fixed stages</b>	Capacitor stages permanently switched in, not under PQC control

### 6.3.3.1 Control profiles

Main menu > Parametrization > Control parameters > Control profiles

<b>Profile</b>	see Section 6.3.3.2 “Settable control profiles”
<b>Profile switching</b>	see Section 6.3.3.3 “Automatic switching over of the control profiles (profile switching)”



### 6.3.3.2 Settable control profiles

Main menu > Parametrization > Control parameters > Control profiles > Profile

Profile

Profile 1 (Active)

cos  $\varphi$

0.920<sup>EN</sup>

Parallel shift

-1.0

Limitation

1.0

Profile

Profile 2

cos  $\varphi$

1.000<sup>EN</sup>

Parallel shift

0.0

Limitation

OFF

Profile

Profile 3

cos  $\varphi$

1.000<sup>EN</sup>

Parallel shift

1.0

Limitation

OFF

Profile

Profile 4

cos  $\varphi$

0.920<sup>EN</sup>

Parallel shift

-1.0

Limitation

OFF

Profile

Profile 5

cos  $\varphi$

0.960<sup>EN</sup>

Parallel shift

-1.0

Limitation

OFF

Five control profiles can be individually selected and edited. The instrument is supplied with the following factory settings:

Profile	1	2	3	4	5
COS $\varphi_{\text{target}}$	0.92 ind	1.0	1.0	0.92 ind	0.96 cap
Parallel shift	-1.0	0.0	+1.0	-1.0	-1.0
Limitation	+1,0	off	off	off	off
Switching delay	45 s	45 s	45 s	45 s	45 s
Phase	L1	L1	L1	L1	L1

Typical control profile applications

- Profile 1 Describes the ideal control characteristic curve for all **consumer networks** where an **inductive** cos  $\varphi$  is called for.
- Profile 2 Suitable for **consumer networks** where an average cos  $\varphi$  =1 is to be achieved.
- Profile 3 Suitable for **consumer networks** where cos  $\varphi$  is close to 1 but overcorrection is to be avoided.
- Profile 4 Suitable for **consumer networks**, as described in Profile 1, but which have their own generating facilities (e.g. CHP units) with permanent or frequent **feed-in** (regeneration) to the power supply network.
- Profile 5 Suitable for **generating networks**, such as hydropower or wind turbines, where a capacitive cos  $\varphi$  is called for.








**Note**

Further information is given in the “PQC Application Note“

Control profile parameters (Edit profile)







Key					
Action	Profile selection (Save Yes/No)	Select parameter	Select parameter	Parameter selection Back to parameter selection	–



Parametrizing control profile

Profile	
Profile 1 (Active)	
Limitation	1.0
switch delay	45s
Phase	L1

Key	ESC				
Action	Profile selection (Save Yes/No)	Increase value +	Decrease value -	Back to parameter selection	-

cos $\varphi_{\text{target}}$	0.90 capacitive to 0.80 inductive (in increments of 0.01)
Parallel shift	-2.0 to +4.0 (in increments of 0.5)
Limitation	-2.0 to +2.0 (in increments of 0.5), OFF or with the SP (parallel shift) option (mirror image of the characteristic curve across the y-axis into the regeneration quadrants). Additional information is given in the “PQC Application Note”.
Switching delay	5 to 500 seconds (in 1 s increments)
Phase	L1, L2 or L3: select control phase
Active	Activate control profile (only one profile can be active)

Setting cos  $\varphi_{\text{target}}$

The desired value of cos  $\varphi_{\text{target}}$  can be set from 0.80 inductive to 0.90 capacitive in increments of 0.01. The mode of operation of this adjustment can be seen in the following diagrams:

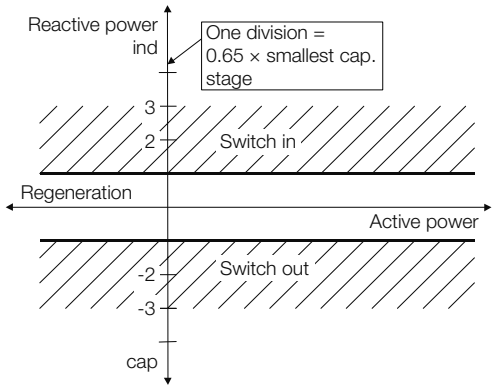
Control characteristic at

cos  $\varphi_{\text{target}} = 1$

Limitation = 0

Parallel shift = 0

If the system operates within the band range shown, no switching operations will be activated.



Control characteristic at

$\cos \varphi_{\text{target}} = 0.92 \text{ ind}$

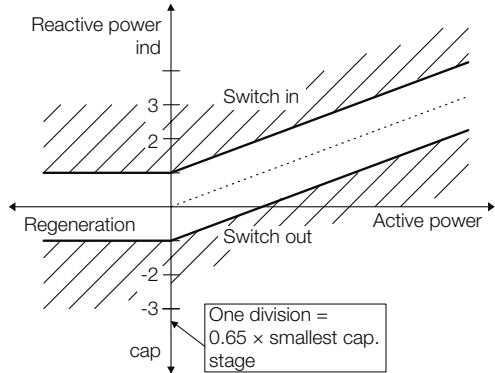
ind Limitation = 0

Parallel shift = 0

If the system operates outside the band range, the PQC will try to return to within the band range with the minimum number of switching cycles.

In this diagram, the action of the PQC during regeneration (feed-in to the supply network) can be seen. The 'kink' in the band (characteristic line) is not reflected in the regeneration quadrants. Instead, the band extends laterally from the point where it crosses the reactive power axis (y axis).

By shifting the band into the capacitive range (see Parallel shift below), inductive reactive power during regeneration can be avoided almost completely. When a capacitive  $\cos \varphi_{\text{target}}$  is set, the control band is a mirror image from the power draw side to the regeneration side (see 3rd diagram in the subsection „Limitation“ auf Seite 5152).



### Parallel shift

This setting causes a parallel shift of the band range shown above through the set value. It will shift in the inductive direction if a plus sign is used, and in the capacitive direction if a minus sign is used.

The values -2 to +4 can be set in increments of 0.5. The effects are illustrated by the two examples in the following diagrams:

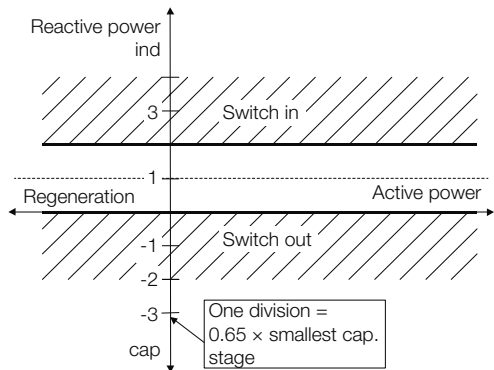
Control characteristic at

$\cos \varphi_{\text{target}} = 1$

Limitation = 0

Parallel shift = +1.0 (inductive)

The set  $\cos \varphi_{\text{target}}$  is therefore the upper limit of the control band. Overcompensation is avoided.



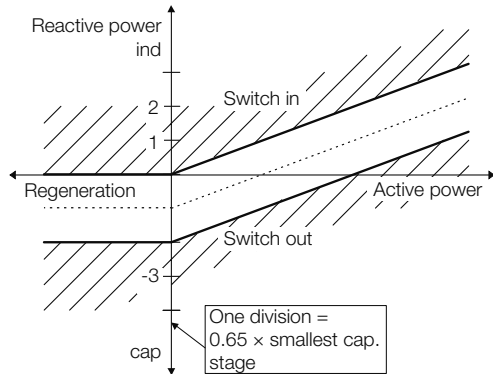
Control characteristic at

$\cos \varphi_{\text{target}} = 0.92 \text{ ind}$

Limitation = OFF

Parallel shift =  $-1.0$  (capacitive)

Here the set  $\cos \varphi_{\text{target}}$  constitutes the lower (more inductive) limit of the control band. When regeneration occurs, the lower (more inductive) limit constitutes a  $\cos \varphi_{\text{target}}$  of 1. This means that no inductive reactive power can result during feed-in operation.



### Limitation

This setting gives new possibilities that could not be attained previously due to conflicting requirements.

The range of values for limitation are  $-2$  to  $+2$  in increments of  $0.5$ , plus the setting OFF. Setting the limitation at  $1$  and  $\cos \varphi_{\text{target}}$  at  $1.00$  has exactly the same effect as the parallel shift described above. If  $\cos \varphi_{\text{target}}$  is not set at  $1$ , a kink results in the control curve, as shown in the following example. The limitation forms an absolute boundary beyond which the reactive power may not go.

Control characteristic at

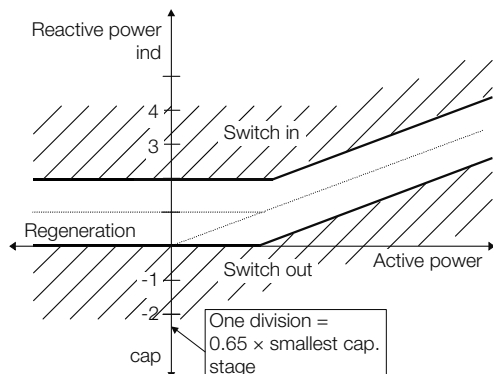
$\cos \varphi_{\text{sol}} = 0.92 \text{ ind}$

Limitation =  $+1.0$

Parallel shift =  $0.0$

This setting has the following effects:

- The set  $\cos \varphi_{\text{target}}$  is attained, on average, in the upper power range.
- Overcorrection (capacitive, usually disruptive) is avoided in the low load range.



An effective combination of “parallel shift” and “limitation” is illustrated in the following diagram:

Control characteristic at

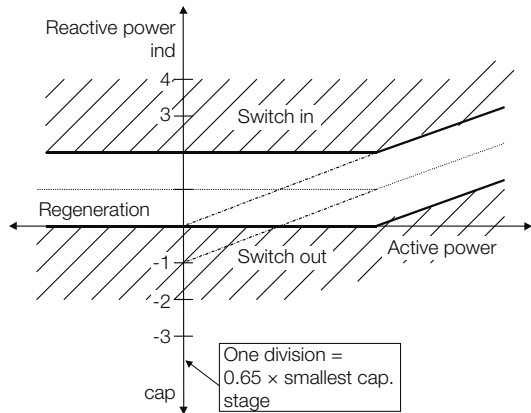
$\cos \varphi_{\text{target}} = 0.92 \text{ ind}$

Limitation = +1.0

Parallel shift = -1.0 (capacitive)

This example illustrates:

- In the “upper” power range, the set  $\cos \varphi_{\text{target}}$  is specified as the lower (more inductive) limit value.
- Overcorrection is avoided in the low load range.



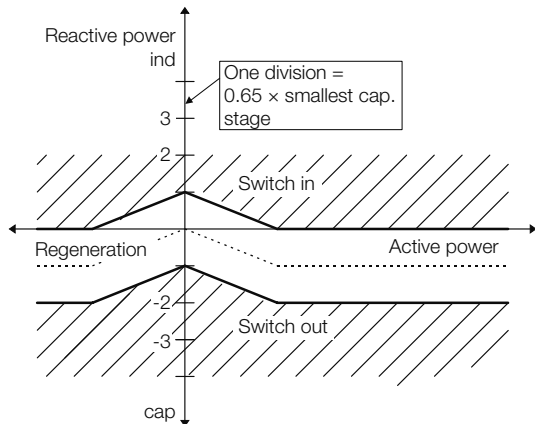
For the sake of completeness, the following diagram shows the characteristics of the control band when set for a capacitive  $\cos \varphi_{\text{target}}$ . In this case, the control range does not extend laterally at the reactive power axis into the regeneration quadrants, but is mirrored from the power draw side into the regeneration side.

Control characteristic at

$\cos \varphi_{\text{target}} = 0.95 \text{ cap}$

Limitation = -1.0

Parallel shift = 0



## Switching delay

The switching delay, i.e. the time between one switching action and the next for the same capacitor stage, can be set between the values of 5 and 500 seconds in 5-second increments. When a stage is to be switched in or out, the PQC waits for this switching delay to elapse before switching takes place. If more stages are required, the switching time delay is shortened in accordance with the number of stages concerned (e.g. 2 stages required = switching delay time ÷ 2, or 3 stages required = switching delay time ÷ 3).


In order to keep the wear of the contacts to a minimum, the switching delay time should be set to less than 45 seconds only in exceptional cases. The discharge time, which ensures that the capacitors are fully discharged before they are switched on again, takes precedence over, i.e. overrides, the switching delay.

Selecting the controlled phase

The **Control profiles** menu also includes the **Phase** setting. This is used to select the phase used by the PQC for control purposes (can only be edited on 3-phase PQC).

Any one of the three phases **L1**, **L2** and **L3** may be selected.

Profile	
Profile 1 (Active)	
switch delay	45s
Phase	L1
Active	ON



**Note**

With single-phase PQCs, it is always the connected phase that is controlled.

6.3.3.3 Automatic switching over of the control profiles (profile switching)






Main menu > Parametrization > Control parameters > Control profiles > Profile switching

Profil switch		
Profile	Type	OFF

Automatic profile switching off

Profil switch		
Profile	Type	Q(U1)
P 1	U1 <	200.0V
P 2	U1 <	225.0V
P 3	U1 <	250.0V

Automatic profile switching Q(V)

Key					
Action	Control setting	-	Profile switching settings	Switching type (Q(V1) etc.)	-

The automatic profile switching function enables the PQC control profiles to be changed automatically. With this, a Q(V) or Q(P) control curve with 5 points on it can be set up (see PQC Application Note).

The following parameters can be used to prompt switching:

- Voltage (L-N) and (L-L)
- Active power (phase power, total power)
- Digital inputs of the Temp. I/O option
- Frakobus tariff input (optional); only Profiles 1 and 2 can be switched over

### 6.3.4 Alarms

Main menu > Parametrization > Alarms

**Alarms** see Section 6.3.4.1 “Alarms”

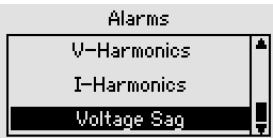
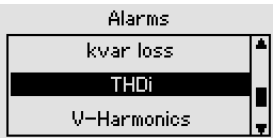
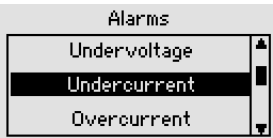
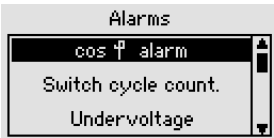
**Relay function** With this option, the action of the alarm relay can be inverted:

**NO** mode: contact closes when an active alarm occurs.

**NC** mode: contact opens when an active alarm occurs.



#### 6.3.4.1 Alarms



Key					
Action	PQC setting	Select alarm limit	Select alarm limit	Edit alarm limit	-

#### Alarm management

When an alarm condition occurs, the PQC offers various actions for signalling or processing the alarm. These can be parametrized individually for each alarm type.

– Transmission via **alarm relay**

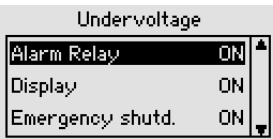
If the alarm relay function is assigned to an alarm, the alarm relay incorporated in the PQC switches when the alarm occurs (connections: Alarm a, b) and remains in that state as long as the alarm is active.

– Alarm **warning** in the display

If the alarm display function is assigned to an alarm, an information window pops up in the PQC display. This message can be acknowledged by pressing the key, regardless of whether the alarm condition is still present or not.

– **Emergency trip** of the power factor correction system

Under critical alarm conditions, such as overcurrent, the PQC can initiate an emer-



gency trip in response to the alarm in order to protect the power factor correction system. This interrupts the automatic control function and deactivates (switches off) all the control outputs. Automatic control remains deactivated for the duration of the alarm plus a further 240 seconds. After this time, the PQC automatically begins to control the system to achieve  $\cos \varphi_{\text{target}}$  again.

– Alarm signal via **Temperature I/O output**

If the PQC has the Temperature I/O option, the alarms can also be connected to separate outputs. The assigned output remains switched on for the duration of the alarm concerned (NO mode only).

– Alarm signal via **Modbus**

If the PQC has the Modbus communications interface (RTU or TCP), the alarm register can be read for all existing alarms. Please refer to the Modbus Specification for further information



**Note**

The alarm setting options are describe in detail in the following sections. All Alarm messages are listed in *Section 9 “Troubleshooting”*.

### 6.3.4.2 Cos $\varphi$ Alarm

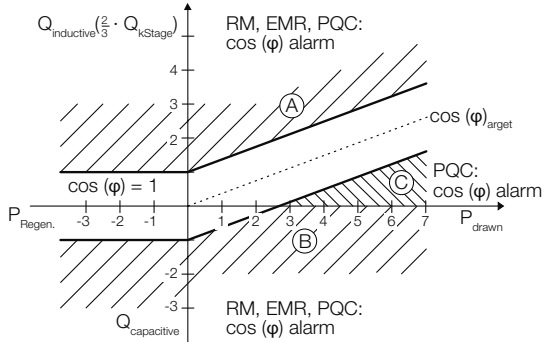
cos $\varphi$ alarm	
Controlband Alarm	OFF
Alarm Relay	ON
Display	ON

cos ( $\varphi$ ) alarm	
Emergency shutd.	OFF
Q = 0.29kvar	

Control band alarm: the PQC gives a  $\cos \varphi$  alarm under the following conditions:

- The measured  $\cos \varphi$  is more inductive than the control band and all the capacitors are switched in. The PQC can therefore not switch in any more capacitance to make  $\cos \varphi$  more capacitive (see A).
- The measured  $\cos \varphi$  is more capacitive than the control band and all the capacitors are switched out. The PQC can therefore not switch out any more capacitance to make  $\cos \varphi$  more inductive (see B and C).

With the control band alarm option OFF, the alarm for  $\cos \varphi$  in the C range can be suppressed. This range is not critical in most applications, since here  $\cos \varphi$  is less than  $\cos \varphi_{\text{target}}$ .



### 6.3.4.3 Switching cycle counter

Switch cycle count.

Limit	80k
Alarm Relay	ON
Display	ON

Warning  
Switching counter

↩

**Alarm limit** 10 k to 500 k (increments of: 1k), default value = 80 k

### 6.3.4.4 Undervoltage

Undervoltage

Emergency shutd.: OFF
V= 141V < 173V

Error detected  
Undervoltage

↩

**Alarm limit** Cannot be adjusted. Triggered when the measured voltage drops to less than 10 % of the set nominal network voltage.

### 6.3.4.5 Undercurrent

Undercurrent

Alarm Relay	OFF
Display	ON
Emergency shutd.	ON

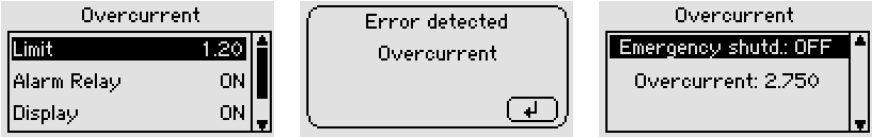
Error detected  
Undercurrent

↩

**Alarm limit** Cannot be adjusted. Triggered when the measured secondary current drops below 10 mA.



### 6.3.4.6 Overcurrent



Overcurrent is the theoretically determined ratio of the momentary RMS current to the fundamental current in the capacitor ( $I_{rms} / I_{50Hz,60Hz}$ ). It therefore indicates how great the proportion of harmonic currents is compared to the fundamental current.

The choke factor p of the power factor correction system is also taken into account in this theoretical calculation.

The overcurrent in the capacitor can only be computed correctly when the exact system choke factor is entered. If the system is not detuned, 0 % must be entered.


**Alarm limit**                      1 to 2.00 (increments of 0.01)

### 6.3.4.7 Zero (dud) stage detection

Alarm for detecting the fall in corrective power of a capacitor stage from its calibrated value. If the measured corrective power drops below the set limit, the stage is excluded from the power factor control process.

Setting range: OFF to 95 % (OFF: In the power factor correction process, there is no monitoring of stage corrective power.)





**Note**

If the PQC is calibrated manually, this alarm is automatically deactivated and the alarm limit set at OFF.

### 6.3.4.8 THDi

**Alarm limit**                      5 % to 500 % (increments of 1 %)



### 6.3.4.9 V Harmonics

V-Harmonics	
Limit	----
Alarm Relay	OFF
Display	ON

V-Harmonics	
UH2	2.00%
UH3	100.00%
UH4	1.00%

**Alarm limit**                      0 % to 100 % (increments of 0.01 %)

### 6.3.4.10 I Harmonics

**Alarm limit**                      0 % to 100 %  
(increments of 0.01 %)

I-Harmonics	
Limit	----
Alarm Relay	OFF
Display	OFF

### 6.3.4.11 Short-term voltage blackout (voltage sag)

The voltage sag alarm is designed to protect the capacitors and their contactors against power cuts that are short enough to make the capacitor contactors open and immediately close again.

**Alarm limit**                      50 % to 93 % (increments of 1 %)

Voltage Sag	
Limit	85%
Alarm Relay	ON
Display	ON

Voltage blackout (sag) in % (100 % being the nominal supply voltage): This is the root-mean-square voltage setting at which the voltage sag detection function is to react.

Presettings: Alarm given if voltage drops below 85 % of the nominal voltage.

– Voltage blackout (sag) 85 %

For this very important function to operate effectively, it is vitally important that the phase selected for the instrument power supply to the switching outputs is the same one selected for the voltage measurement.

#### 6.3.4.12 Temperature PT-100 / 1000 / NTC1 / NTC2 (optional temperature I/O extension)

Temp. PT100/1000	
Limit	50°C
Alarm Relay	OFF
Display	ON

Warning	
Temp. exceeded (PT)	
⏏	

**Alarm limit**                      -50 to 200 °C (increments of 1 %)

#### 6.3.4.13 Inputs I/O 1–I/O 5 (optional temperature I/O extension)

Input 2	
Alarm Relay	OFF
Display	OFF
Emergency shutd.	OFF

Warning	
Input 2 active	
⏏	

An activated input of the temperature and I/O extension can allow the PQC to process logical signals.

Example: Interruption of the control function when a logical 1 is received. The possibilities here are extremely diverse.

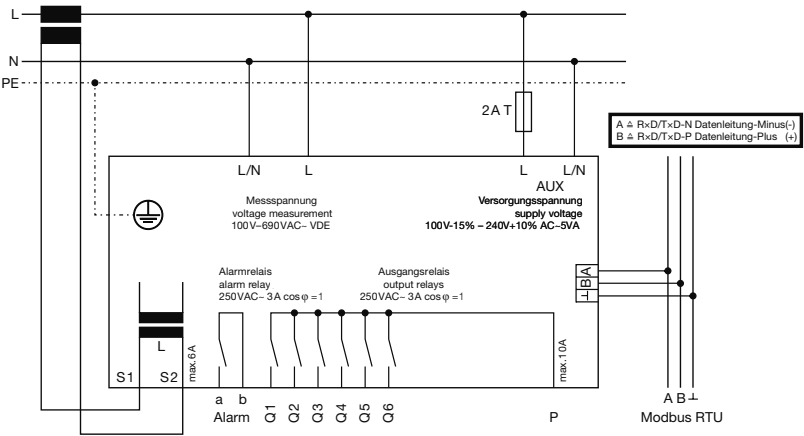
### 6.3.5 Communication (optional)

**Main menu > Parametrization > Communication (dyn.)**

The PQC has several optional means of communication. The existence of this menu depends on whether the PQC is equipped with a communication option, and if so, what type.

# 6.3.5.1 Modbus RTU

## Modbus RTU connection



The following parameters can be set in the Modbus configuration menu:

<b>Bus address</b>	The PQC is accessed at the set bus address
<b>Baud rate</b>	1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200
<b>Data bits</b>	5 to 8
<b>Stop bits</b>	1 or 2
<b>Parity</b>	even, odd or none

Modbus RTU	
Mode:	RTU
Slave address:	89
Baudrate:	19200
Data bits:	8



### Note

Further details are described in the Modbus Specification.

### 6.3.5.2 Modbus TCP (IoT)

#### DHCP ON

Network
DHCP ON
IP :0.0.0.0
Mask:0.0.0.0

Network
IP :10.192.255.172
Mask:255.255.255.0
Gateway:0.0.0.0

To operate the PQC in DHCP mode, DHCP ON must be selected. The data displayed in this menu (IP, Mask, Gateway) indicate the network settings assigned by the server, meaning that the available services (Modbus TCP, web server) are accessible in the network.

#### DHCP OFF

Network
DHCP OFF
IP :10.192.255.172
Mask:255.255.255.0

Network
IP :10.192.255.172
Mask:255.255.255.0
Gateway:0.0.0.0

To use the Ethernet interface with manual network configuration, the following settings must be made in the PQC:

- IP address
- Subnet mask
- Gateway (optional)

When these settings have been made, the available services (Modbus TCP, web server) can be accessed in the network.

The PQC is accessible via the Modbus TCP/IP protocol and port 502 at the set IP address. The data that can be retrieved are listed in the FRAKO Modbus Specification.



#### Note

The web server is only fully functional with the following browsers:

- Mozilla Firefox version 60.0.1 or later
- Google Chrome version 66.0.3359.181 or later.

The PQC allows a maximum of 2 simultaneous connections.

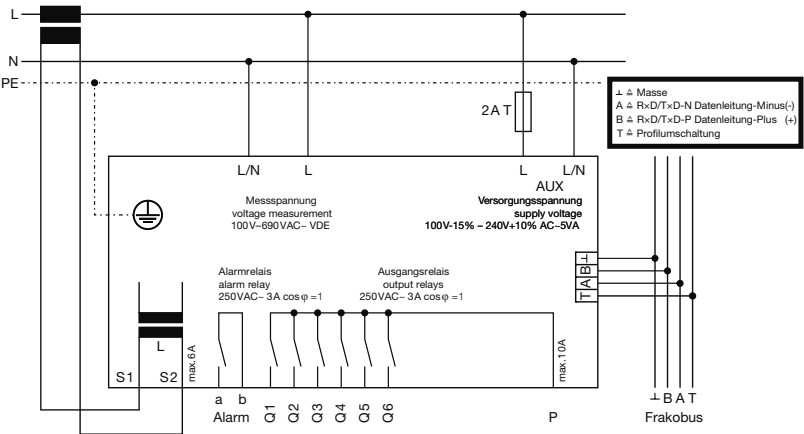


#### Note

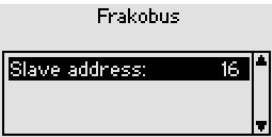
For additional information on the optional Ethernet interface please refer to the “PQC Application Note”.

### 6.3.5.3 FRAKO Starkstrombus (Frakobus)

#### Frakobus connections



The PQC address can only be changed at the instrument itself.



### 6.3.6 Temperature I/O (optional)

Typical circuits for the passive digital inputs and outputs, plus the temperature measurement inputs, are shown in the following diagram:

#### Temperature measurement inputs

The configuration of the temperature measurement inputs can be carried out at the PQC: **Main menu > Parametrization > Temp. I/O (dyn.)**.

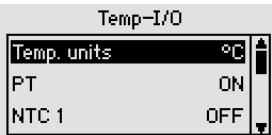
The possible temperature units are:

- C (degrees Celsius)
- K (Kelvin)
- F (degrees Fahrenheit)

Here the temperature probes actually used are configured as active/inactive.

The temperatures measured by active probes connected to the inputs are displayed in the PQC Temperatures menu.

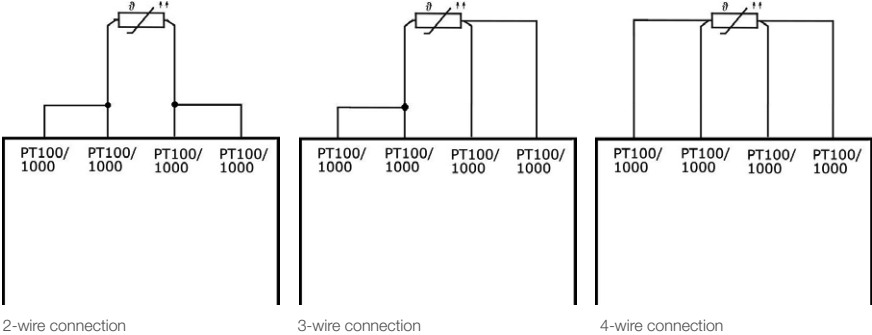
See Section 6.2.3.5 "Temperatures (optional temperature I/O extension)".



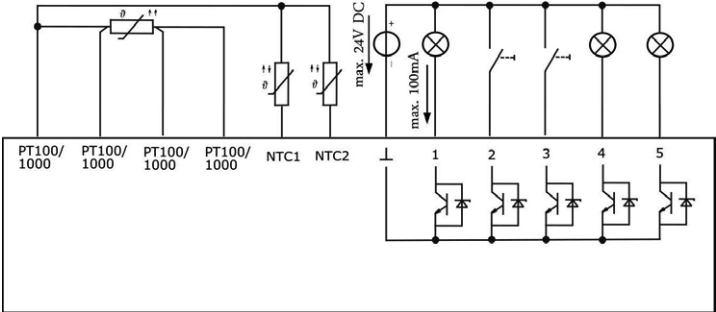
If a defined alarm limit is to be monitored with each temperature measurement input, these can be set in the PQC Alarms menu (see *Section 6.3.4 “Alarms”*). A fixed hysteresis of 1.5 K is programmed.

Connections for a PT-100/1000 temperature measurement input are provided:

Temp. PT100/1000	
Limit	50°C
Alarm Relay	OFF
Display	ON



In addition, one or two 2-wire NTC probes (Article No. 29-20094, 7-metre cable) can be connected as shown below:



### Passive digital inputs and outputs

The terminals 1 to 5 can be configured for the particular application as inputs or outputs in the PQC: **Main menu > Parametrization > Temp. I/O (dyn.)**. If the configured inputs or outputs as used as alarms, the alarm routes can be set in the **Alarms** menu (see *Section 6.3.4 “Alarms”*).

The momentary statuses of the inputs and outputs are shown in the **I/O Status** menu (see *Section 6.2.3.6 “Temperatures (optional temperature I/O extension)”*).

I/O status	
I/O 1 input	ON
I/O 2 outp.	OFF
I/O 3 input	ON

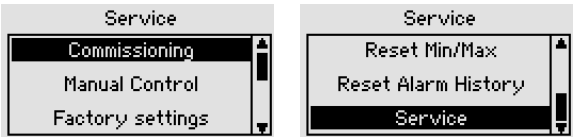
One input can be used to switch between control profiles 1 and 2. This is configured in the PQC by navigating as follows: **Main menu > Parametrization > Temp. I/O (dyn.)**. When this option is active, profile switching takes place exclusively via this input (no profile switching is then possible from the PQC menu or optional Modbus RTU interface) and only between the stored control profiles 1 (input 1: low level) and 2 (input 1: high level).

The digital inputs are suitable for electrical signals from 5 V DC up to a maximum of 24 V DC.

The digital outputs (open collector type) are suitable for an externally applied voltage up to a maximum of 24V DC and a maximum current of 100 mA.

### 6.3.7 Service

**Main menu > Parametrization > Service (password protected)**



#### 6.3.7.1 Start-up

**Main menu > Parametrization > Service > Start-up**

See Section 5.3.2 “PQC initial start-up”.

#### 6.3.7.2 Manual control

**Main menu > Parametrization > Service > Manual control**



**ATTENTION!**  
**Risk to equipment!**

Switching in capacitor stages manually can result in overcorrection of the system. This can cause other problems, such as resonance-induced over-voltage in the supply network and/or damage to the capacitor stages or other loads connected to the network.

- The supply network must be monitored for resonant conditions and over-voltage whenever stages are switched in manually.

This menu shows the numbers of the stages (1 to 12), the status of each stage (ON/OFF), its corrective power (determined automatically or set manually) and its switching cycles.

Manual Control			
No	Stat.	Q [var]	Swit.cyc.
1	ON	20.2k	14
2	ON	40.5k	9
3	OFF	0.0	8



<b>No.</b>	No. of the stage [1–12]
<b>Stat. (status)</b>	ON / OFF / [x seconds] ON: switches stage in manually OFF: switches stage out manually [x seconds]: Time remaining until the capacitor stage can be switched in again (discharge time)
<b>Q(var)</b>	Momentary stage corrective power in var (This is the 3 phase stage corrective power.)
<b>Switching cycles</b>	Number of stage switching cycles

When a stage is switched out again, this is done immediately. Before this stage can be switched in again, it is necessary to wait until the capacitor's set discharge time has elapsed. A countdown of the remaining discharge time is displayed in the Status column. Not until this time has elapsed can the stage be switched in again. If it is attempted to switch in the stage before the countdown is finished, the message 'Not possible' is displayed. (The stage is then not switched in automatically after the discharge time has elapsed.)

Pressing the  key displays the momentary values of  $\cos \varphi$ , P and Q.

$\cos \varphi = 0.626^{IN}$
P = 72kW
Q = 90kvar

### 6.3.7.3 Factory default settings

**Main menu > Parametrization > Service > Factory settings**

Resets the PQC at its factory default settings (without affecting the switching cycle counter).

### 6.3.7.4 Clear switching cycles counters

**Main menu > Parametrization > Service > Clear switching cycles**

Reset switching cycle counters for all stages to zero (singly or individually, service password necessary); see *Section 4.4 "Password protection"*.



**Note**

A switching cycle counter may only be reset after the corresponding contactor has been replaced.

### 6.3.7.5 Reset Min/Max

**Main menu > Parametrization > Service > Reset Min/Max**

Reset all Min/Max values.

### 6.3.7.6 Reset Alarm history

Main menu > Parametrization > Service > Reset Alarm history

Reset all alarms saved until now.

### 6.3.7.7 Service

Main menu > Parametrization > Service > Service

Optional service functions

Temp. I/O update	Software update mode for Temp.
I/O Temp. I/O CLI	for FRAKO Service
IoT update	Software update mode for IoT
IoT CLI	for FRAKO Service
Frakobus update	Software update mode for Frakobus

## 6.4 About PQC

Main menu > About PQC

This item gives information about the instrument:

<b>FW</b>	Firmware version number
<b>HW</b>	Hardware version number
<b>SN</b>	Serial number
<b>Sys Time</b>	Operating hours

About PQC	
FW:	3.0.eba62a
HW:	1.0
SN:	1000

## 6.5 Factory settings

Menu	Parameter	Setting
Network parameters (Section 6.3.1 "System parameters")		
Network parameters	Nominal voltage	400 V
	Nominal frequency	Auto
	Transformer ratio (I)	1
	Transformer ratio (V)	1
System parameters (Section 6.3.2 "PFC Equip. parameter")		
System parameters	Choke factor	7 %
Control parameters (Section 6.3.3 "Control parameters")		
Control parameters	Cyclic switching	ON
	Discharge time	60 s
	Fixed stages	0

Menu	Parameter	Setting
Settings for control profile 1	cos $\varphi$	0.92 ind
	Parallel shift	-1
	Limitation	1
	Switching delay	45 s
	Phase	L1
	Active	ON
Settings for control profile 2	cos $\varphi$	1.0
	Parallel shift	0
	Limitation	OFF
	Switching delay	45 s
	Phase	L1
	Active	OFF
Settings for control profile 3	cos $\varphi$	1
	Parallel shift	+1
	Limitation	OFF
	Switching delay	45 s
	Phase	L1
	Active	OFF
Settings for control profile 4	cos $\varphi$	0.92 ind
	Parallel shift	-1
	Limitation	OFF
	Switching delay	45 s
	Phase	L1
	Active	OFF
Settings for control profile 5	cos $\varphi$	0.96 cap
	Parallel shift	-1
	Limitation	OFF
	Switching delay	45 s
	Phase	L1
	Active	OFF
Alarms (Section 6.3.4 "Alarms")		
Alarms	Relay function	NO (normally open)
cos $\varphi$ alarm	Control band alarm	OFF
	Alarm relay	ON
	Display	ON
	Emergency trip	OFF

Menu	Parameter	Setting
Switching cycle counters	Alarm limit	80 k
	Alarm relay	ON
	Display	ON
	Emergency trip	OFF
Undervoltage	Alarm relay	ON
	Display	ON
	Emergency trip	ON
Undercurrent	Alarm relay	OFF
	Display	ON
	Emergency trip	ON
Overcurrent	Alarm limit	1.20
	Alarm relay	ON
	Display	ON
	Emergency trip	ON
Zero stage detection	Alarm limit	80 %
	Alarm relay	ON
	Display	ON
	Emergency trip	OFF
THDi	Alarm limit	50 %
	Alarm relay	OFF
	Display	OFF
	Emergency trip	OFF

Menu	Parameter	Setting	
V Harmonics	Alarm limit	Harmonic	Alarm limit %
		2	2
		3	100
		4	1
		5	6
		6	100
		7	5
		8	0.5
		9	100
		10	0.5
		11	3.5
		12	100
		13	3
		14	0.43
		15	100
		16	0.41
		17	2
		18	100
		19	1.76
	Alarm relay	OFF	
	Display	ON	
	Emergency trip	OFF	
I Harmonics	Alarm limit	100 % all (IH2 – IH19)	
	Alarm relay	OFF	
	Display	OFF	
	Emergency trip	OFF	
Voltage blackout	Alarm limit	85%	
	Alarm relay	ON	
	Display	ON	
	Emergency trip	ON	
Communication (Section 6.3.5 “Communication (optional)”)			
Modbus RTU	Slave address	0	
	Baud rate	19200	
	Data bits	8	
	Parity	None	
	Stop bits	1	
Modbus TCP	DHCP	OFF	
	IP	0.0.0.0	
	Subnet	0.0.0.0	
	Gateway	0.0.0.0	

Menu	Parameter	Setting
Frakobus	Frakobus address	0
Temp. I/O (Section 6.3.6 "Temperature I/O (optional)")		
Temp. I/O	Temperature units	°C
	PT	OFF
	NTC1	OFF
	NTC2	OFF
	I/O 1	Input
	I/O 2	Input
	I/O 3	Input
	I/O 4	Input
	I/O 5	Input

## 6.6 Service interface

The PQC has a service interface in the form of a Micro USB port. This is used for servicing tasks such as firmware updates.



### Note

Use of this interface is solely for the use of trained FRAKO Service personnel.

For further information concerning firmware updates please contact FRAKO Service by telephone at +49 7641 453 544 or by e-mail at [service@frako.de](mailto:service@frako.de).

## 7 General operation

The following points must be observed when the PQC is operated:

- The instrument must always be operated in a closed control cabinet.
- All voltages applied to the instrument must never exceed the limits specified in the technical data.
- The ambient temperatures must always be within the range specified in the technical data.

## 8 Cleaning and maintenance

### 8.1 Safety during cleaning and maintenance

---



#### **WARNING!**

#### **Danger from electricity!**

There are dangerous voltages present inside the PQC. Touching live components in the PQC or at the instrument terminals and connecting cables can cause serious injury or may even be life-threatening.

- Do not open the PQC casing.
  - During cleaning and maintenance, the PQC and the connecting cables must be isolated from the power supply.
  - The isolated electrical system must be locked out to prevent its being inadvertently switched on again.
  - All connections must be checked to verify that they are no longer live.
  - All live components in the immediate vicinity must be covered.
- 

### 8.2 Cleaning

The PQC may only be cleaned with a dry cloth. Do not use aggressive or abrasive cleaning agents or solvents.

### 8.3 Maintenance

The PQC does not contain any components that need maintenance.



## 9 Troubleshooting

If alarms occur during operation of the PQC, the following table provides assistance in identifying and remedying the faults.

Alarm message	Fault	Possible cause	Remedial action
	PQC not working; no display at front of instrument	No power – or the wrong voltage – connected	Check that the correct instrument power supply is connected and that the fuse in the circuit has not blown.
cos $\varphi$ cannot be achieved	PQC gives a cos $\varphi$ alarm although the momentary cos $\varphi$ is better (nearer to 1) than the target value. More capacitive than the control band but still inductive	See <i>Section 6.3.4.2 “Cos <math>\varphi</math> Alarm”</i> for control band alarm settings.	See <i>Section 6.3.4.2 “Cos <math>\varphi</math> Alarm”</i> for control band alarm settings.
Voltage < set limit	PQC indicates or states that voltage is less than set alarm limit, although a voltage is shown on the screen.	The alarm limit has not been adjusted for the network nominal voltage. Default setting is for 400 V networks. Triggered when the network voltage is less than 85 % of the nominal voltage.	Set the correct alarm limit for the network nominal voltage (see <i>Section 6.3.1 “System parameters”</i> )
Current < set limit	No value for current shown in the display (0 A)	Break or short-circuit in the current transformer cable	Use an ammeter to check current in current path ( $I_{\min} * 0.015$ A). Danger: see <i>Section 5.2.7 “Current measurement”</i>
		The current in the current path is too low.	( $I_{\min} * 0.015$ A) Install a smaller current transformer.
		Defective current transformer	Check the current transformer.
Voltage < set limit + Current < set limit	PQC shows no measured voltage and no current, although it has been verified that power is connected and a current is flowing.	Multiple zero-voltage crossings in measured voltage.	Settings for the Network nominal parameters → Change setting from Auto to the appropriate network frequency (50 Hz or 60 Hz).

Alarm message	Fault	Possible cause	Remedial action
Overcurrent > set limit	Voltage harmonics in network too high	Triggered when ratio $I_{rms}/I_{50Hz,60Hz}$ exceeds alarm limit.	
Switching cycles > set limit	Number of switching cycles of one or more contactors exceeds set maximum		Replace the contactors concerned and clear their switching cycle counters.
V Harm. > set limit	Voltage harmonics in network too high		
Zero stage detected	The PQC has detected one of more stages whose nominal power has fallen.	Capacitor stage(s) has/ have lost capacitance.	Replace capacitor(s)
		Because of an unstable network, the PQC has mistakenly detected a loss of capacitance.	Deactivate the zero stage detection function.
Voltage blackout (sag)	The PQC has detected one of more stages whose nominal power has fallen.	Capacitor stage(s) has/ have lost capacitance.	Replace capacitor(s)
		Because of an unstable network, the PQC has mistakenly detected a loss of capacitance.	Deactivate the zero stage detection function.
Connection not detected Stages not detected		Short-time voltage blackout (voltage sag)	
		Triggered if a voltage sag causes the RMS voltage to fall below the set limit within the duration of a half-wave	

Alarm message	Fault	Possible cause	Remedial action
Connection not detected Stages not detected	During automatic calibration this message appears: Alarm detected No cap. stage	Fault in control circuit (contactors not switching).	Check the control circuit against the connection diagram and check the fuse.
		Fuses for the capacitor stages missing or defective	Check whether capacitors are energized after switching.
		Current transformer installed in the wrong location	Check whether the current transformer has been installed as per the connection diagram.
		Severe reactive power fluctuations	Wait for power supply to stabilize; set c/k factor and connection type manually.
	Despite inductive load, no stages are switched in when PQC is in automatic mode.	When the PQC was programmed, c/k, switching time delay or discharge time have been set too high.	Check the PQC programming and change if necessary.
		In automatic operation, the response current c/k was not correctly identified.	Check the control circuit against the connection diagram and repeat the calibration procedure.
		Another current measuring instrument (e.g. an ammeter) has been connected in parallel with the current path.	All measuring instruments in the current path must always be connected in series.
	In automatic mode, one stage is continually being switched in and out (hunting).	The value of c/k was set too low when the PQC was programmed.	Set c/k value correctly according to the table.
		Severe load fluctuations; the delay time was set too low.	Set higher delay time.

Alarm message	Fault	Possible cause	Remedial action
	The displayed $\cos \varphi$ is less than $\cos \varphi_{\text{target}}$ although the PQC has switched in all stages.	Type of connection incorrectly entered.	Select type of connection again.
		Fault in control circuit.	Check whether the capacitor contactors have been activated.
		Fault in capacitor circuit	Check the fuses and contacts of the capacitor contactors and possibly also measure the currents of each capacitor stage with a tong tester.
		Severe reactive power fluctuations	Read off the corrective power still lacking from the menus.
		Faulty calibration	Repeat the calibration procedure.
	PQC does not switch out all stages under low load conditions or during plant shutdown.	c/k set too high	Set c/k according to table.
		PQC is in manual mode.	Deactivate manual control.
		Wrong control profile selected	Adjust the control profile to suit system requirements.
	The LCD backlighting comes on briefly then goes off again, while the LCDs display nothing or only the starting logo – the instrument restarts repeatedly.	Instrument power supply voltage is too low.	Check whether the correct voltage is reaching the PQC. Is there is a high contact resistance in the power supply circuit?
	Capacitor stage statuses display appears on screen but capacitor contactors are not activated.	Control circuit is not connected properly or there is no control voltage.	Check the control circuit against the connection diagram and check the fuse.
		Neutral not connected to contactors.	



### Note

Additional error messages are described in the “PQC Application Note”.

# 10 Decommissioning and removal, storage and disposal

## 10.1 Decommissioning the PQC

---



### **WARNING!**

#### **Danger from electricity!**

Touching live components at the instrument terminals and connecting cables can cause serious injury or may even be life-threatening.

- Installation, commissioning and decommissioning of the PQC may only be carried out by appropriately qualified personnel who have read and understood the content of this manual.
  - Isolate the PQC and the system from the power supply before decommissioning it.
  - The isolated electrical system must be locked out to prevent its being inadvertently switched on again.
  - It must be verified that none of the terminals are live.
  - All live components in the vicinity must be covered to prevent inadvertent contact
- 



### **CAUTION!**

#### **Danger from heat**

The instrument terminals can become hot during operation and could cause burns.

- After the PQC has been operating, sufficient time must be allowed for the instrument and its terminals to cool down before work is carried out on the connections.
- 



### **ATTENTION!**

#### **Risk to equipment!**

If the exposed ends of disconnected cables come into contact with each other, this can result in short-circuits and overloading of the installation conductors, resulting in damage to equipment.

- All disconnected cables must be individually isolated and insulated, and measures must be taken to prevent their inadvertent contact with live components or electrically conducting parts.
- 

1. Current transformers must be short-circuited.
2. Remove all cables from the PQC.
3. Individually isolate and insulate all disconnected cables and take measures to prevent their inadvertent contact with live components or electrically conducting parts.

## 10.2 PQC removal

The PQC is held in place against the rear of the cabinet front wall by four retaining lugs in the corners of the instrument. These can be released by undoing the retaining screws.

1. Turn all four screws anticlockwise with a screwdriver. This slackens the four retaining lugs and swivels them to lie flush behind the PQC front panel.
2. Withdraw the PQC from the front of the cabinet.

## 10.3 Storage

- The PQC must be stored in a clean, dry and dust-free location.
- The storage temperature must be within the range -20 °C to +80 °C.

## 10.4 Disposal

Any electronic instrument that is no longer required must be disposed of in an environmentally sound manner.



### **ATTENTION!**

#### **Risk to equipment!**

Incorrect disposal can cause environmental pollution.

- Dispose of the instrument in compliance with the regulations of the country concerned.



In the European Union, electrical scrap and electronic components are subject to the WEEE (Waste Electrical and Electronic Equipment) Directive. These components must not be disposed of as normal domestic or commercial waste. In other countries, the equivalent local regulations must be followed when electronic instruments are disposed of. They must be handed in at special recycling centres.

One way of ensuring environmentally sound disposal is to return the instruments to FRAKO Kondensatoren- und Anlagenbau GmbH in Teningen, Germany, or the company's local representatives. Alternatively, the instruments can be given to a firm specializing in the recycling of electronic equipment.

## Notes

[illegible]

Power capacitors

**Reactive power controllers**

Power factor correction systems

Modules

EMS components

Measuring instruments and network analysers

Power quality

EMS ISO 50001



FRAKO Kondensatoren- und Anlagenbau GmbH

Tscheulinstraße 21a

D-79331 Teningen

Phone: +49 7641 453-0

Fax: +49 7641 453-535

[sales@frako.de](mailto:sales@frako.de)

[www.frako.com](http://www.frako.com)