BRISBANE CITY COUNCIL

Sewerage Pump Station SP178

Oldfield Road
Seventeen Mile Rocks

Contract : **BW 70103-023**

Job Number : **WT400039**

ELECTRICAL INSTALLATION

OPERATIONS and MAINTENANCE MANUAL

INSTALLATION BY:

SJ Electric (Qld) Pty Ltd
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1.1 General Workplace Health and Safety

- The Workplace Health and Safety Act (1995) sets out the laws about Workplace Health and Safety for all workplaces, workplace activities and specified high risk plant. The Electrical Safety Act (2002) sets out the laws covering electrical safety. Nothing in this document is designed, in any way, to undermine the authority of the Acts.
- All reasonable care must always be taken to ensure the plant is without risk to the health and safety of personnel operating and maintaining plant and equipment.
- Employers have an obligation to ensure the workplace health and safety of all personnel at work.
- It is employer responsibility to ensure that all persons entering or working on the premises use appropriate personal protective equipment.
- Personal protective equipment includes gloves, safety glasses, hard hats, ear protection, safe foot ware and, where necessary, specialist protective clothing for hazardous areas.
- Any item of equipment should always be isolated before maintenance or repairs commence to ensure that inadvertent operation of the item does not result in risk to the health and safety of any person.
- Where the item is isolated, any total or partial shutdown should not allow a hazardous situation to be created.
- Where the item cannot be isolated, another person should be stationed at the controls of the item and an effective means of direct communication should exist between the persons carrying out the maintenance and the person at the controls.

General Operating Principles

- All persons working the premises must be qualified Electrical Engineers or electrical trades persons capable of performing the required tasks competently. All personnel must also be familiar with plant and equipment.
- Adequate information, instruction, training and supervision must be provided to enable personnel to perform work without risk to health and safety.
- Work in an orderly way.
- Plan work in advance to avoid hazardous situations.
- Warn others of any hazards.
- Make inquiries before starting work, particularly on any unfamiliar installation or equipment.
- Before any work begins ensure that any instructions received or given are fully understood.
- Concentrate on the task on hand.
- Do not distract others or allow yourself to be distracted by foolish actions.
- Work from a safe and convenient position that provides a maximum working space that you do not have to over reach, you cannot slip, trip or stumble and so endanger yourself and others.
- Keep the working area tidy and free of unwanted materials and equipment.
- Use insulated tools where possible.
- Inspect tools and equipment regularly and ensure that any necessary maintenance is carried out.
- Keep yourself in good health.
- Do not work if ill or over tired, to the extent that your concentration, movement or alertness is affected. Illness or fatigue can endanger yourself and others.

1.2 Project Overview

Contract BW70103-013 was for the manufacture and testing of ten (1) new pump station switchboards for various locations throughout Brisbane.

Equipment provided by SJ Electric ensures safe and efficient operation of the pump stations. Equipment supplied and installed by SJ Electric includes: -

- Switchboards
- Instrumentation
- Civil Works

The switchboard incorporates the latest technology in motor control, power monitoring, and instrumentation. It is important engineers, technicians and operators are familiar with the equipment installed before attempting any adjustments, modifications or maintenance.

The following Sections of this manual contain a comprehensive description of all equipment supplied, by SJ Electric. It is recommended that this manual be referred to before carrying out any work on any equipment.

1.3 Plant Maintenance

To ensure proper operation of the plant the following should be observed: -

- The plant should be kept clean and tidy at all times. Not only is this of aesthetic value, it extends equipment life.
- Check that all plant and equipment is operating correctly. Correctly operating equipment promotes overall plant efficiency.
- All items and areas of equipment should be hosed down and cleaned regularly.

WARNING

- **Avoid directly hosing <u>any</u> drive motor or electrical item.**

- All maintenance, service, modifications and significant deviations from Normal operating conditions should be recorded in the Plant Service Log
- After a month of operation, check the tension of all bolts associated with the plant and thereafter periodically. Bolted connections on painted surfaces can loosen due to thinning of the paint underneath the bolt head-bearing surface. Motor mounting bolts and other bolted connections subjected to vibration should be periodically checked for loosening.

WARNING

- **Before starting work on any item ensure that the power supply is isolated, tagged off, and the item cannot be started.**

- The importance of preventative maintenance cannot be over-emphasized. Regular maintenance and suitable care of the equipment will ensure a long and reliable service life of the equipment.
- Many stoppages can be avoided by following the recommended maintenance procedures. Do not wait until you hear the grinding of equipment that has broken down. If you see any item wearing down, replace it, before it causes damage to other associated items.

Preventive Maintenance

Maintenance procedures recommended to extend switchboard life are outlined as follows: -

- Switchboard exterior should be regularly wiped down with a solvent base cleaner such as “Spray & Wipe”. This will ensure longevity of the powder-coated surface.
- Accessible areas like distribution boards and motor starter panels should be cleaned with a vacuum cleaner to remove dust and foreign matter.
- PLC panels should be maintained as dust free as possible. Dusting with a dry rag is recommended - taking care not allows dust inside the I/O modules or processor.
- When removing or installing PLC modules care should be taken to ensure that power is turned off to the rack before modules are removed or installed.
- Connections and efficient operation of circuit breakers, contactors and isolators should be checked every 12 months - especially where connected to busbars.
- Busbar connections should be checked every 12 months.
- Globes for indicator lights should be checked on a weekly basis with any faulty lamps replaced.
- Cubicle Fans Filter should be inspected and cleaned frequently.

1.4 Electrical Control System

General Description

The switchboards are manufactured from 3mm aluminium and are suitable for location outdoors; the switchboards have been designed by Brisbane Water and contain several separate sections including:

- Incoming Section.
- Metering.
- Motor Starter Section.
- Distribution Section.
- RTU Section.

1.5 Control and Monitoring System.

The control and monitoring of the system is performed by the Brisbane Water telemetry system and was not included in this contract.

2. MANUFACTURER'S TECHNICAL DATA

Power^{IT} LV Active Filter PQFI

Installation, operation and maintenance instructions

Table of contents

List of figures

List of tables

1. Introduction to this manual

1.1. What this chapter contains

This chapter gives basic information on this manual.

1.2. Intended audience

This manual is intended for all people that are involved in integrating, installing, operating and/or maintaining the PQFI active filter range products. People involved in the integration, installation and maintenance of the equipment are expected to know the standard electrical wiring practices, electronic components and electrical schematic symbols. End users should focus on the Operating instructions (Cf. Chapter 11) and Maintenance instructions (Cf. Chapter 12) of this manual.

1.3. Compatibility

The manual is compatible with all filters of the 3-wire PQFI-range with PQF-Manager software version V1.5.r0 or higher. Technical specifications of this product range are given in Chapter 14 of this manual.

This product is not backward compatible with any other PQFx (x: A, B, L, T) filter product.

1.4. Contents

1.5. Related publications

- Power^{IT} LV Active Filters PQFI-PQFM-PQFK-PQFS Catalogue [English]
- Power Quality Filter, Active Filtering Guide [English]
- PQF-Link Installation and user's guide [English]
- PQF Modbus CD [English]

2. Safety Instructions

These safety instructions are intended for all work on the PQFI.
Neglecting these instructions can cause physical injury and death.

All electrical installation and maintenance work on the PQFI should be carried out by qualified electricians.

Do not attempt to work on a powered PQFI.

After switching off the supply to the PQFI, always wait at least 10 minutes before working on the unit in order to allow the discharge of DC capacitors through the discharge resistors. Always verify by measurement that the capacitors have discharged. DC capacitors may be charged to more than 1000 Vdc.

Before manipulating current transformers, make sure that the secondary is short-circuited. Never open the secondary of a loaded current transformer.

You must always wear isolating gloves and eye-protection when working on electrical installations. Also make sure that all local safety regulations are fulfilled.

DANGER:	**To ensure safe access, supplies to each individual cubicle must be isolated before entry / opening.**

WARNING:	**This equipment contains capacitors that are connected between phase and earth. A leakage current will flow during normal operation. Therefore, a good earth connection is essential and must be connected before applying power to the filter.**

WARNING:	**Stored energy in capacitors: this equipment contains capacitors. Check for residual DC voltage before working inside the equipment.**

WARNING:	**Never discharge DC capacitors through short circuit. Always use a current limiting resistor of minimum 10 Ω.**

WARNING:	**If the ground is defeated, certain fault conditions in the unit or in the system to which it is connected can result in full line voltage between chassis and earth. Severe injury or death can result if the chassis and earth are touched simultaneously.**

3. Industrial^{IT} for LV Active Filters

As a key element of its business strategy, ABB has committed to a broad program of product development and positioning under the Industrial^{IT} umbrella. This initiative is geared towards increasing integration of ABB products as the “building blocks” of larger solutions, while incorporating functionality that will allow multiple products to interact seamlessly as components of real-time automation and information systems.

ABB LV Active Filters represent an important add-on to other fundamental building blocks in the Industrial^{IT} Architecture.

This product has been tested and certified by ABB Group as **Industrial IT Enabled™**. All product information is supplied in consistent electronic format, based on ABB Aspect Object™ technology. Plug and Produce™ installation and integration with other Industrial IT certified products is available through the ABB Aspect Integrator™ Platform.

4. Upon reception

4.1. What this chapter contains

This chapter gives basic information on how to inspect, transport, identify and store the PQFI active filter.

4.2. Delivery inspection

Each PQFI is delivered in an enclosure designed to protect adequately the equipment during shipment. Upon reception of the equipment, make sure that the packing is in good condition. Verify the state of the shock and tilting indicators (if mounted on the enclosure).

After removal of the packing, check visually the exterior and interior of your filter for transportation damage.

Your filter equipment comes with an information package that is present in a documentation holder attached at each filter panel. Verify that all documentation is present, i.e.:

- this manual;
- the electrical drawing and connection diagram.

Any loss or damage should be notified immediately to your ABB representative.

4.3. Lifting and transportation guidelines

Please note that filter equipment weighs hundreds of kilograms. Care should be taken to ensure that correct handling facilities are used. For individual cubicles the lifting lugs should be employed.

Figure 4.1. Lifting a single PQF cubicle by using the lifting lugs

For multiple cubicles mounted on a base frame, lifting rods (not provided) should be used.

Figure 4.2. Lifting a PQF cubicle assembly by using lifting rods

PQFI-cubicles must always be transported vertically.

Table 4.1. Maximum allowed ambient conditions during transportation

	Transportation (in the protected package)
Temperature	-25 to 70°C (-13 to 158°F)
Relative humidity	Max. 95%
Contamination levels (IEC 60721-3-3)	Chemical class 3C3[(a)] Mechanical class 3S3[(b)]

Remarks:

(a) Locations with normal levels of contaminants, experienced in urban areas with industrial activities scattered over the whole area, or with heavy traffic. Also applies to locations with immediate neighborhood of industrial sources with chemical emissions.

(b) Locations without special precautions to minimize the presence of sand or dust. Also applies to locations in close proximity to sand or dust sources.

4.4. Identification tag

Each PQFI is fitted with nameplates for identification purposes.
The main filter nameplate is located at the top of the master panel door, at the outside. Other unit identification nameplates may be present at the inside of the cubicle.

The nameplate information should always remain readable to ensure proper identification during the whole life of the filter. The main filter nameplate includes the filter type, the nominal voltage range and frequency as well as a serial number and an ABB internal article code.

4.5. Storage

PQFI packing is made for a storage period of maximum six months (transport time included from delivery date EXW ABB Jumet factory). Packing for a longer storage period can be done on request.

If your PQFI is not installed once unpacked, it should be stored in a clean indoor, dry, dust free and non-corrosive environment. The storage temperature must be between -25°C (-13°F) and 70°C (158°F) with a maximum relative humidity of 95%, non-condensing.

Table 4.2. Maximum allowed ambient conditions for storage

	Storage (in the protected package)
Temperature	-25 to 70°C (-13 to 158°F)
Relative humidity	Max. 95%
Contamination levels (IEC 60721-3-3)	Chemical class 3C3[(a)] Mechanical class 3S3[(b)]

Remarks:
[(a)] Locations with normal levels of contaminants, experienced in urban areas with industrial activities scattered over the whole area, or with heavy traffic
[(b)] Locations without special precautions to minimize the presence of sand or dust. Also applies to locations in close proximity to sand or dust sources.

5. Hardware description

5.1. What this chapter contains

This chapter describes a typical PQFI-filter system and discusses its main components.

5.2. Typical PQFI filter panel layout

The PQFI active filter is basically composed of two parts (Figure 5.1.):

- A filter controller that determines the anti-harmonic current to be injected based on the line current measurements and the user's requirements. The line current measurements are obtained from current transformers (CTs) provided by the customer. The CTs must be connected upstream of the connection point of the filter and the loads. The user enters his requirements by means of the PQF-Manager user interface. This device also acts as the user's connection point for the alarm/warning contacts, the remote control functionality, the other digital input functionality and the interface for external communication/printer functionality.

- A current generator (power unit) that converts the control signals generated by the filter controller into the filter compensation current. The current generator is connected in parallel with the load(s). Up to eight power units may be connected in parallel in one filter unit. The cubicle containing the filter controller is referred to as the master cubicle. The other cubicles are referred to as the slave cubicles.

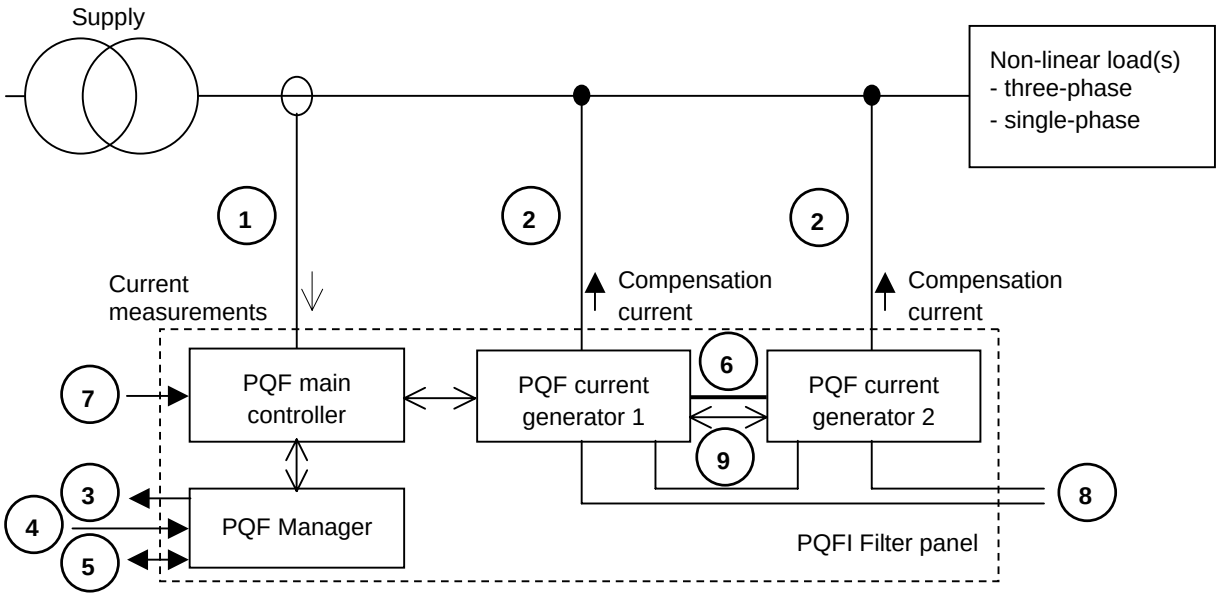


Figure 5.1. PQFI schematic overview with user connections

The user connection description is given in Table 5.1.

Table 5.1. User connections for PQFI

Item	User connections	Connection requirement
1	CT connections	Mandatory
2	Power cable connection to the supply	Mandatory
3	Programmable digital outputs (warnings,…)	Not mandatory
4	Remote control contact connection or/and local on/off buttons or/and main/auxiliary settings control	Not mandatory
5	Modbus communication connection or serial communication/printer connection	Not mandatory
6	PQF current generator power and control interconnections	Mandatory
7	Temperature probe connections (optional)	Not mandatory
8	Earth connections from each unit to installation earth	Mandatory
9	Earth connections between units	Mandatory

Mandatory connections are connections that must be present to make the filter operational. PQF current generator power and control interconnections (6 in Figure 5.1. above) and earth connections between units (9 in Figure 5.1.) have to be cabled by the user only in selected cases. Connections that are not mandatory can be made to enhance the filter's basic functionality. For more information on cabling the user connections, please refer to Chapter 7.

Figure 5.2. shows a typical PQFI master filter panel in CE version.
Figure 5.3. shows a typical PQFI master filter panel in cULus version.

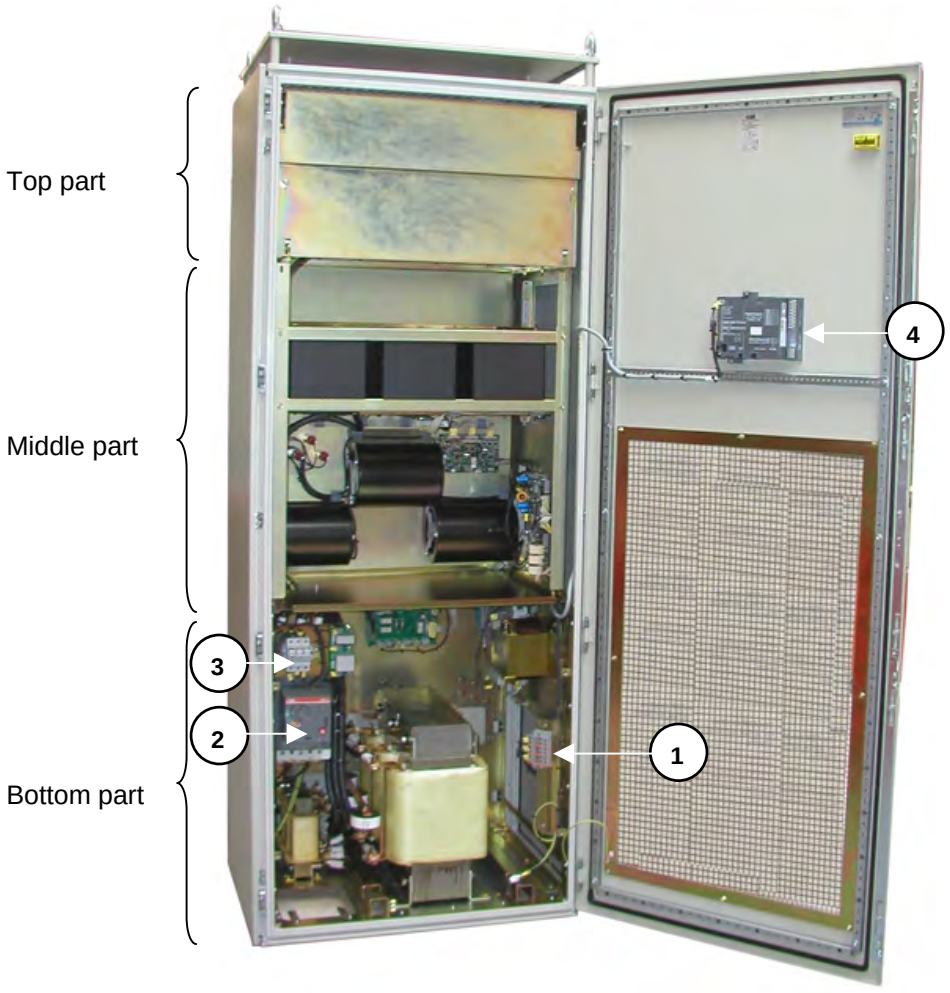


Figure 5.2. Example of a typical PQFI master filter panel (CE version)

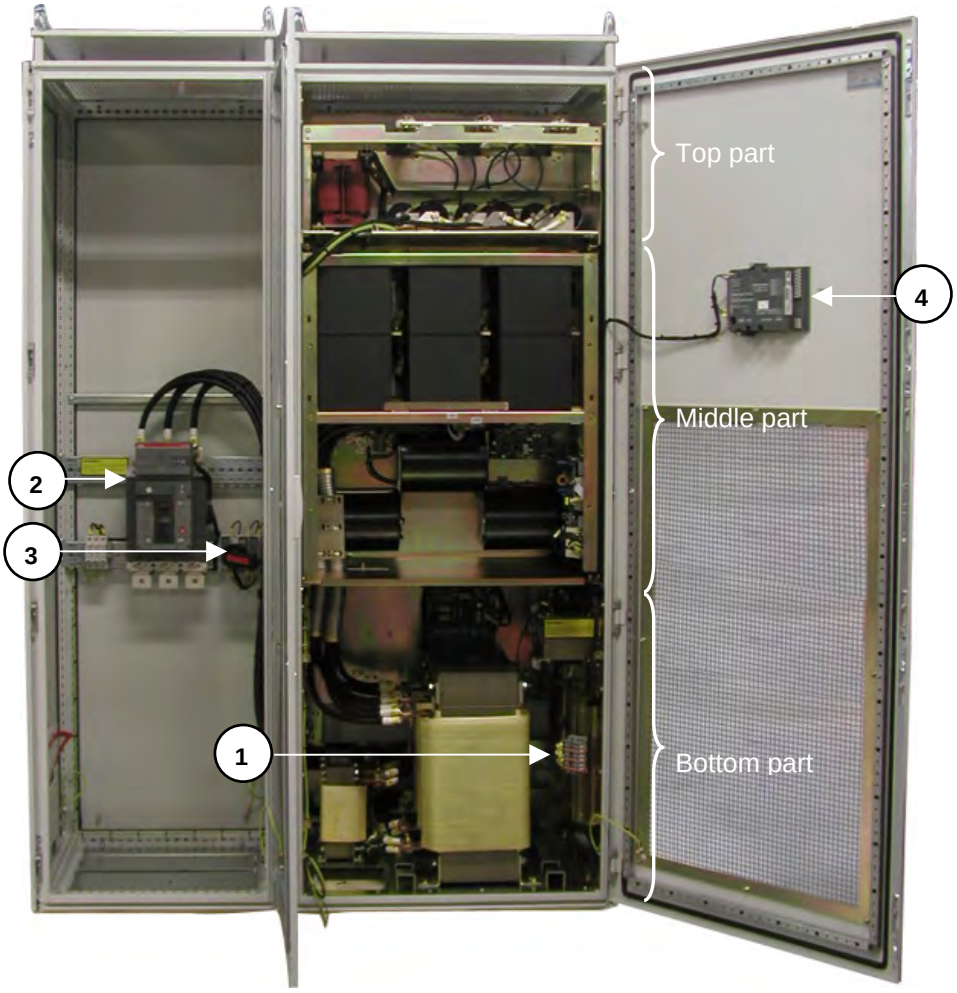


Figure 5.3. Example of a typical PQFI master filter panel (cULus version)

Note that in the cULus version of PQFI, the filter panel breaker is mounted in a separate cubicle. This separate cubicle can be used both as top cable entry cubicle and as bottom cable entry cubicle.

The input/output connections and protection description is given in Table 5.2.

Table 5.2. Input/Output connections

Item	Input/Output connections
1	CT connection terminals
2	Filter panel breaker
3	Auxiliary fuse protection
4	PQF-Manager user interface with connection terminals for user I/O (e.g. alarm contact) and communication interfaces

As can be seen in Figure 5.2. and in Figure 5.3. the PQFI units consist of 3 parts. The components of each part will be discussed later in this chapter.

A PQFI slave panel differs physically from a master panel in that:
- It does not have a main controller board nor voltage measurement board(s).
- It does not have a CT connection terminal block.
- It does not have a preload circuit.
- It has DC link protection fuses.

5.3. The PQF current generator hardware

The power circuit of a 2 unit PQFI is represented hereafter.

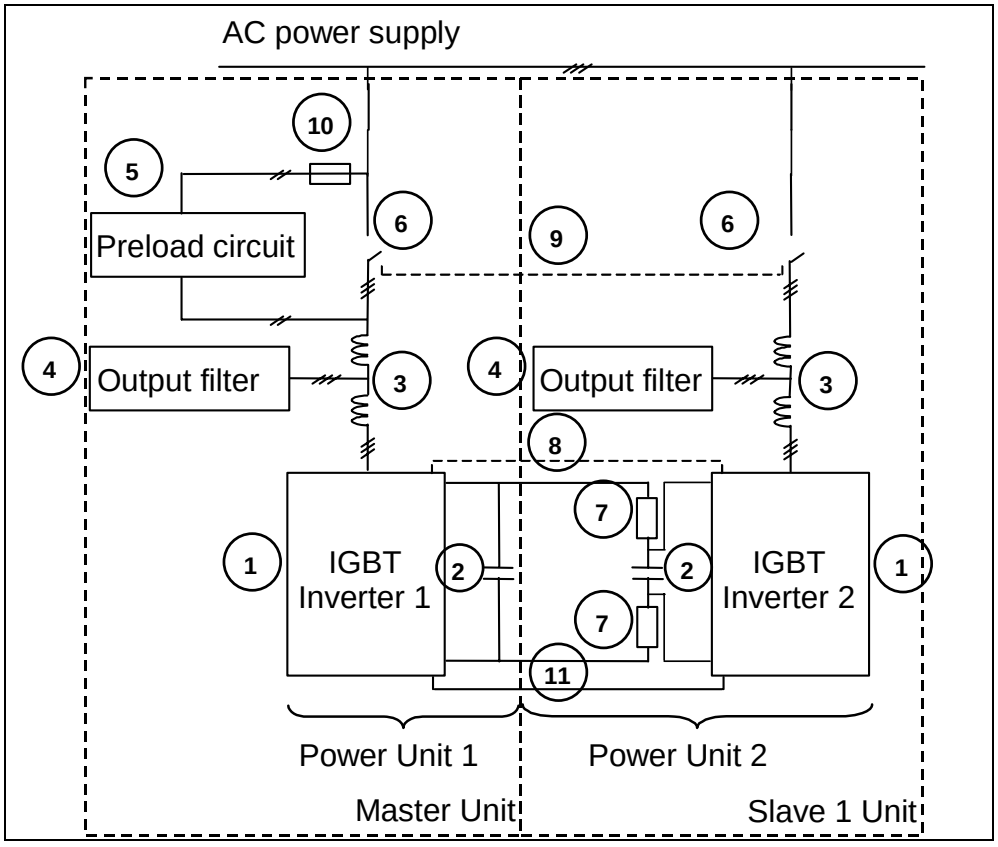


Figure 5.4. Power circuit diagram of a 2 unit PQFI active filter

The description of the main components is given in Table 5.3.

Table 5.3. Main components of a PQFI active filter

Item	Main components
1	IGBT inverter
2	DC bus capacitors
3	PWM reactor
4	Output filter
5	Preload circuit
6	Main circuit breaker
7	DC link with DC bus interlink fuses (fuses incorporated in slave units)
8	Optical link between different IGBT modules
9	Breaker control flat cable
10	Auxiliary fuses
11	Earth cable interconnection

The current generator is physically organized in power units. For CE versions of PQFI, each filter cubicle contains one power unit. For cULus versions of PQFI, a power unit is distributed over two cubicles with the main protection of the unit being mounted in the adjacent panel. A PQFI filter can contain up to 8 power units. The current rating of different units in a filter does not have to be the same. Please refer to Chapter 14 for more information on the possible unit ratings.

In Figure 5.4. it may be seen that each current generator consists of an IGBT-inverter bridge (1) that is controlled using PWM-switching technology. Information from the filter controller is sent to the IGBTs by means of an optical link. At the output of the inverter a voltage waveform is generated which contains the desired spectral components (imposed by the filter controller) as well as high frequency noise (due to the IGBT switching technology). A coupling impedance consisting of a reactor (3) and a high frequency rejection filter (4) ensures that the useful voltage components are converted into a useful current while the high frequency noise is absorbed. The IGBT-inverter is equipped with DC capacitors that act as energy storage reservoirs (2).

In active filters containing more than one power unit the DC capacitors are interconnected. Each slave unit incorporates DC link fuses (7). IGBT control information between different units passes through an optical link (8). Breaker control between breakers of different cubicles is done by means of the flat cable (9).

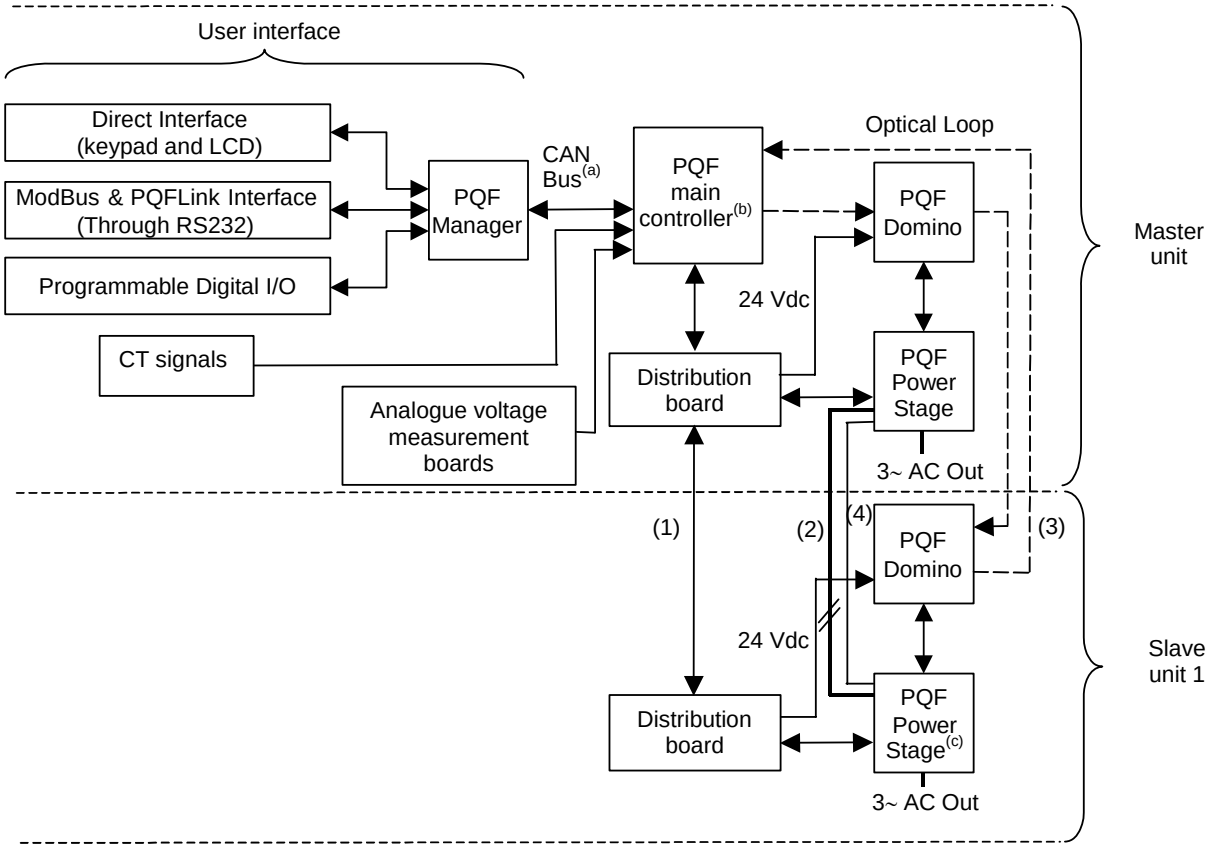
The master cubicle holds the main controller boards and the PQF-Manager display. It also contains a DC capacitors preloading circuit (5) which charges the DC capacitors of the filter unit before closing the main circuit breaker. This approach ensures a smooth filter start-up without excessive inrush currents. The slave cubicles do not have a preload circuit.

5.4. The PQF main controller

The PQF main controller controls the complete active filter system. Its tasks include:

- Accepting and executing customer requests to stop and start the equipment;
- Calculating and generating IGBT-inverter control references based on the line current measurements and the user requirements;
- Interface to the IGBT-inverters;
- Measurement of system voltages and currents for control, protection and presentation purposes.

In order to fulfill these tasks the main controller is connected to other control and measurement boards. Figure 5.5. depicts the controller interface diagram of the PQFI active filter.



(a): The PQF-Manager CAN bus is routed via the distribution board to the main controller.
(b): Temperature probes (optional) must be connected to the PQF main controller.
(c): Slave units incorporate DC link fuses.

Figure 5.5. Controller interface diagram of the PQFI active filter

When the filter consists of a master unit only, the customer has to:
- Wire the CT signals (on a designated terminal),
- Adapt the auxiliary transformer tap settings to the network voltage,
- Connect the AC power lines,
- Set up the installation parameters and user requirements with the PQF-Manager.

He may also want to wire the communication interface (Modbus or serial communication/printer) and the programmable digital I/O (e.g. alarm contact, remote control).

The distribution board channels all the control board power supplies, all internal digital I/O (e.g. preload contactor control, breaker operation control), the CAN bus communication interface and can also be used to connect optional hardware (e.g. lamp indicator set, surge arrester protection set, …). Section 5.6. shows where the main PQF components are physically located in the filter.

When a slave cubicle is added, it is connected to the master cubicle by means of:
- The control connection between the distribution boards (flat cable) (1);
- The DC link connection (power cables) (2);
- The IGBT signal connection (optical loop) (3).
- An earth interconnection between the different units (4).

All slave units have their own AC-connection and breaker protection.

A PQFI active filter system consists of up to 8 units (1 master unit and up to 7 slave units).

5.5. The PQF-Manager user interface

All user interaction with the filter is channeled through the PQF-Manager. Communication between the PQF-Manager and the PQF Main Controller is done by means of the CAN bus.

Figure 5.6. shows the front side of the PQF-Manager.

Figure 5.6. Front side of the PQF-Manager

Four main parts can be distinguished (see Table 5.4.)

Table 5.4. Front side of the PQF-Manager

Item	Description
1	Keypad By navigating through the menus with the arrows and the OK button, the filter can be set-up and controlled (start/stop). On-line help is available by pressing the Help button.
2	Menu display
3	Digital output contact monitor When the PQF-Manager closes one of its output relays, the corresponding symbol lights up. The digital outputs of the PQF-Manager are discussed later in this section.
4	Alarm contact indicator

The PQF-Manager also acts as connection point for external user I/O communication. Connections are made at the rear side of the PQF-Manager. Figure 5.7. depicts the terminals that are present on the PQF-Manager rear side.

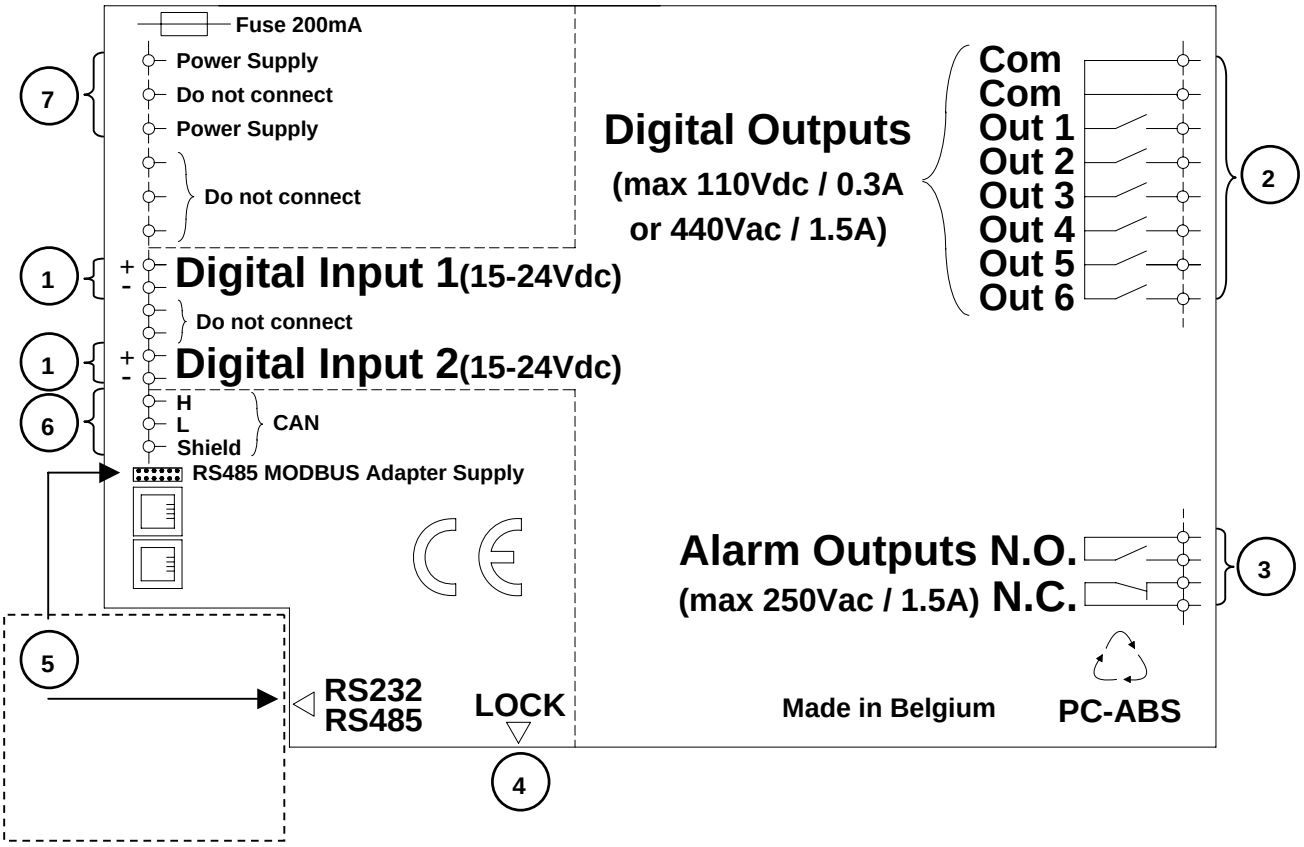


Figure 5.7. PQF-Manager rear side terminal designation

The terminal designation is given in Table 5.5.

Table 5.5. Terminal designation

Item	Customer terminals
1	Digital inputs 1 and 2
2	Digital outputs 1 to 6 with one common point
3	Alarm outputs (2 outputs with complementary signals)
4	Lock switch
5	Modbus adapter interface (optional) connection
Item	**ABB/Panel builders terminals**
6	CAN bus connection interface
7	Power supply terminals

The terminal explanation is given next:

1 Digital input 1 and 2

The digital inputs can be used for three different functions:

- Implementation of remote control functionality;
- Implementation of local on/off buttons (not provided);
- Selection of main filter settings or auxiliary filter settings (e.g. different filter settings for the day and for the night)

The PQF-Manager is used to associate the required functionality with the chosen digital input. The digital inputs can also be disabled.

WARNING: If a function is assigned to a digital input, the same function must never be assigned to the other digital input. Otherwise the filter may behave erratically.

The external voltage source needed to drive the digital inputs has to comply with the following characteristics:

- Vlow: 0 Vdc;
- Vhigh: 15-24 Vdc;
- Driving current: 13 mA @ 24 Vdc (Rint = 1.88 kΩ)

The digital inputs have free of potential contacts (opto-isolated).

When implementing any of the functions described above, please note that according to the setup done with the PQF-Manager for the input considered, the filter may behave differently. Table 5.6. below gives an overview of the possible settings and the resulting filter behavior.

Table 5.6. Overview of possible digital input settings and resulting filter behavior

Function	Vlow applied to digital input	Vhigh applied to digital input
Remote control ***PQF-Manager setup for digital input:*** Remote ON[(a)]	Filter off	Filter on
Selection of main/auxiliary settings ***PQF-Manager setup for digital input:*** Activ. main[(a)]	Auxiliary settings are used	Main settings are used
Selection of main/auxiliary settings ***PQF-Manager setup for digital input:*** Activ. aux.[(a)]	Main settings are used	Auxiliary settings are used
Local ON/OFF buttons ***PQF-Manager setup for digital input:*** Edge ON[(a) (b)]	No effect	Filter starts on rising edge
Local ON/OFF buttons ***PQF-Manager setup for digital input:*** Edge OFF[(a) (b)]	No effect	Filter stops on rising edge
Local ON/OFF buttons ***PQF-Manager setup for digital input:*** Edg ON/OFF[(a) (c)]	No effect	Filter starts on first rising edge, stops on second rising edge etc.

Remarks:

(a) In order for this function to be activated, the PQF-Manager has to be set up accordingly. To do this, navigate to [/Welcome/Settings/Customer set./Digital Inputs]

(b) When using the Edge ON function the filter can only be switched on by applying voltage to the digital input considered. It is therefore recommended in that case to configure and cable the second digital input as Edge OFF.

(c) When using this function, the filter stop and start can be controlled by one digital input leaving the other one available for an additional remote control or switching between main and auxiliary settings.

Information on cabling the digital input contacts is given in Chapter 7.
Information on setting up the digital inputs with the PQF-Manager is given in Chapter 8.
By default, the digital inputs are disabled.

2 Digital Outputs 1 to 6

With each digital output different filter conditions can be associated. The association between the filter condition and the digital outputs is done with the PQF-Manager. Table 5.7. gives an overview of the possible PQF-Manager settings for a digital output and the effect on the corresponding digital output relay.

Table 5.7. Filter conditions that can be related to the digital outputs

PQF-Manager setting for digital output[a]	Output relay closes when…
Auxil. ON	the auxiliary power is present in the main filter cubicle and the main breaker is communicating with the PQF-Manager
PQF runs	the active filter is 'on' (IGBTs switching) or in 'standby' (main breaker closed but IGBTs not switching)
Full load	the active filter is running under full load condition
Armed	the filter is ON or is in the startup procedure, or it is stopped in fault condition but will restart as soon as the fault has disappeared
T limit	the filter temperature limit has been reached and the filter is derating itself to run at a safe temperature
In standby	the filter is in standby[b]
Activ. Main	the main active filter settings are activated
Activ. Aux	the auxiliary active filter settings are activated
Pg. alarm 1	the programmable alarm 1 is activated[c]
Pg. alarm 2	the programmable alarm 2 is activated[c]
Pg. alarm 3	the programmable alarm 3 is activated[c]
Warning 1	the programmable warning 1 is activated[c]
Warning 2	the programmable warning 2 is activated[c]
Warning 3	the programmable warning 3 is activated[c]

Remarks:
[a] In order to set up this function, navigate to [/Welcome/Settings/Customer set./Digital Outputs]
[b] More information on the standby function is given in Section 8.7.3.2.
[c] Different programmable warnings and alarms can be defined. More information on this subject is given in Section 8.7.1.2.

Further it should be noted that:

- Whenever a digital output is activated the corresponding icon on the PQF-Manager display will light up.
- The default set-up for the digital contacts is given in Table 5.8.

Table 5.8. Default set-up for the digital output contacts

Digital output number	Default function
1	Auxil. ON
2	PQF Runs
3	Full Load
4	Armed
5	T limit
6	In standby

- The customer can change the default output settings by means of the PQF-Manager.
- The digital outputs contacts have a common point and are of the NO-type (normal open). The contact ratings are:
  - Maximum continuous ac rating: 440 Vac/1.5 A;
  - Maximum continuous dc rating: 110 Vdc/0.3 A;
  - The common is rated at 9A/terminal, giving a total of 18 A.

Information on cabling the digital output contacts is given in Section 7.10.
Information on setting up the digital outputs with the PQF-Manager is given in Section 8.7.1.2.

3 Alarm outputs
Apart from the digital outputs, two potential free relay contacts are available for alarm information. One is of the NO-type, the other is of the NC-type. These relay contacts are activated if any error condition is present during a preset time. The relay contacts are deactivated if the error condition has disappeared for another preset time. Information on changing the alarm activation/deactivation time is given in Section 8.7.1.2.
The maximum continuous alarm contact ratings are: 250 Vac/1.5 A.

4 Lock switch
Allows to lock the settings of the filter panel. This switch is documented in Section 8.4.

5 Modbus adapter interface (optional) connection
The Modbus adapter interface is connected at this location. The output of the interface is an RS-485 socket. The interface is described in Chapter 9.

6 CAN bus connection interface
The PQF-Manager communicates with the main controller through a CAN bus. This bus consists of three terminals, i.e.:
- Pin H: CAN High signal
- Pin L: CAN Low signal
- Pin Shield: shielding

The CAN bus is connected to the distribution board (Cf. Section 5.6.1.) It is used only for PQF internal communications.

7 Power supply terminals
The PQF-Manager is supplied with 230 Vac (internally derived). The corresponding terminals on the PQF-Manager labeled “Power supply” have to be connected.
The power supply for the PQF-Manager is routed via the distribution board (Cf. Section 5.6.1.)

For information on how to cable external systems (e.g. remote control, Modbus interface) to the PQF-Manager, refer to Chapter 7.
For information on how to use the PQF-Manager, refer to Chapter 8.
For background information on the Modbus communication interface refer to Chapter 9.

5.6. Location of the main PQFI components

5.6.1. Active filter bottom part components

Figure 5.8. shows a picture of the PQFI bottom part in CE version.
Figure 5.9. shows a picture of the equivalent section in the cULus version of PQFI.

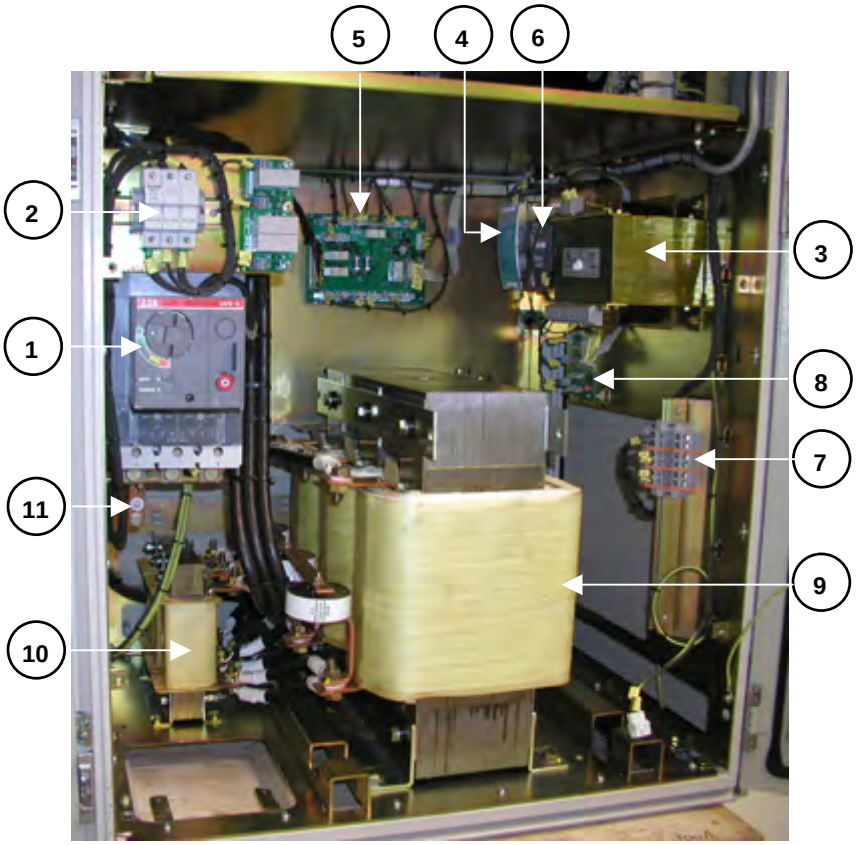


Figure 5.8. PQFI bottom part component identification (CE version)

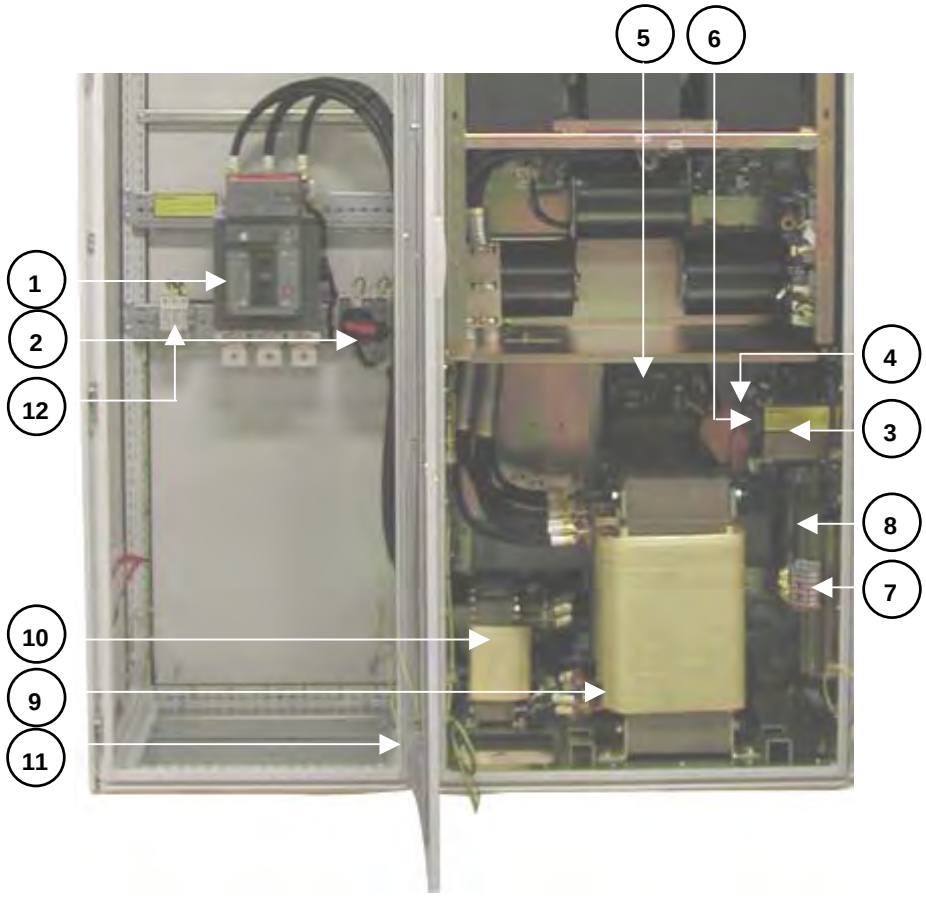


Figure 5.9. PQFI bottom part and cable entry cubicle component identification (cULus version)

The component identification is given in Table 5.9.

Table 5.9. PQFI bottom part description

Item	Description	Circuit diagram designation
1	Motorized circuit breaker (MCB)	Q1
2	Fuse holder auxiliaries circuit (16 Amax)	Q2
3	Auxiliary voltage transformer	T1
4	DC voltage power supply 24V	U2
5	Distribution board	X1… X19
6	Preload contactor (master only)	K1
7	CT connection terminal (master only)	X21
8	AC voltage measurement board (master only)	A1
9	PWM reactor	L12
10	Output reactor	L11
11	Earth bar	-
12	Surge arrester protection (for cULus version only)	F8-F9-F10

Note:
- On CE version of PQFI, EMC compliance circuitry is standard present.
- On cULus version of PQFI, EMC compliance circuitry is optional.

The distribution board (5) acts as a pass through for different information and control channels. It also distributes the auxiliary voltage and the DC control voltage to the different components. The distribution board is shown in Figure 5.10.

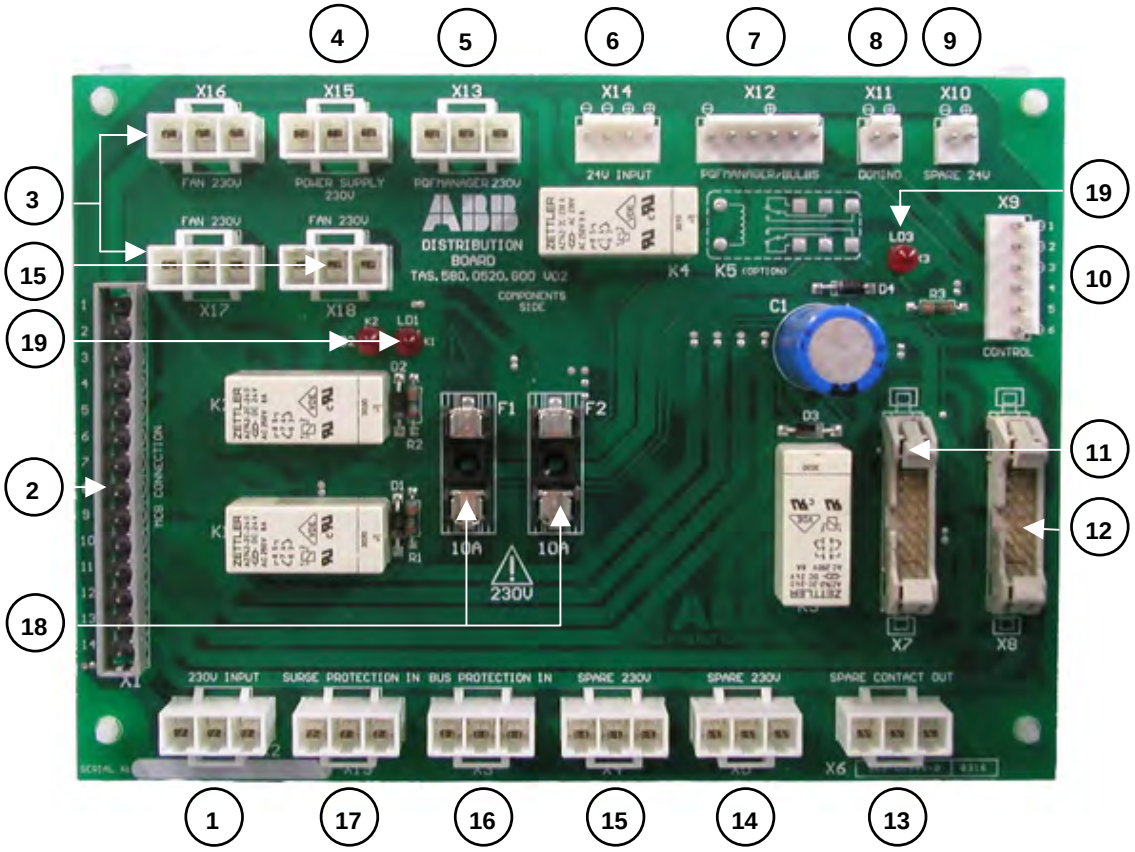


Figure 5.10. Distribution board layout

The distribution board contains the following terminals, LED indicators and fuses (see Table 5.10.)

Table 5.10. Distribution board description

Item	Description	Circuit diagram designation
1	230 Vac input terminal (from auxiliary transformer)	X2
2	MCB control connection terminal	X1
3	Fans supply output (230 Vac). X16 is for IGBT fans. X17 is for door fan	X16, X17
4	230 Vac output to DC power supply	X15
5	230 Vac output to PQF-Manager	X13
6	24 Vdc input from DC power supply	X14
7	CAN connection to PQF-Manager and connection to optional bulb-indicators	X12
8	24 Vdc power supply output to domino board	X11
9	Spare 24 Vdc connector	X10
10	CAN connection and 24 Vdc power supply to main controller board	X9
11	Digital control from main controller board (master unit) or from previous cubicle (slave unit)	X7
12	Digital control connection to next cubicle (if present) If last cubicle in row, a bus end connector has to be plugged into X8	X8
13	230 Vac terminal for cubicle heater (optional)	X6
14	230 Vac preload contactor auxiliary winding control (master unit) 230 Vac spare terminal (slave units)	X5
15	230 Vac spare terminal	X4, X18
16	DC bus protection feedback terminals (from DC bus fuses) If master cubicle, a connector terminator has to be plugged into X3. Else, the DC-link microswitch feedback is connected into X3.	X3
17	Connection terminals for optional surge protection kit If option is not installed, a bus end connector has to be plugged into X19.	X19
18	Fuses protecting auxiliary circuitry (5x20T, 10A/250V) 230 V input (X2) is routed to the fuses, then the rest of the auxiliary circuit follows.	
19	LEDs indicating the status of the control windings of the three relays (if LED on then relay control voltage is present) LED D1 refers to K1 relay (main breaker control: pulse for opening the main breaker) LED D2 refers to K2 relay (main breaker control: pulse for closing the main breaker) LED D3 refers to K3 relay (optional heater control: off when filter is running, on when filter is stopped)	

Remarks:

- Options when present are cabled in the factory. All necessary bus terminators are cabled in the factory. If the filter is upgraded at one stage, bus terminators have to be changed place accordingly.
- Spare terminals and system terminals are reserved for ABB use only!

5.6.2. Active filter middle part components

Figure 5.11. shows a picture of the PQFI middle part.

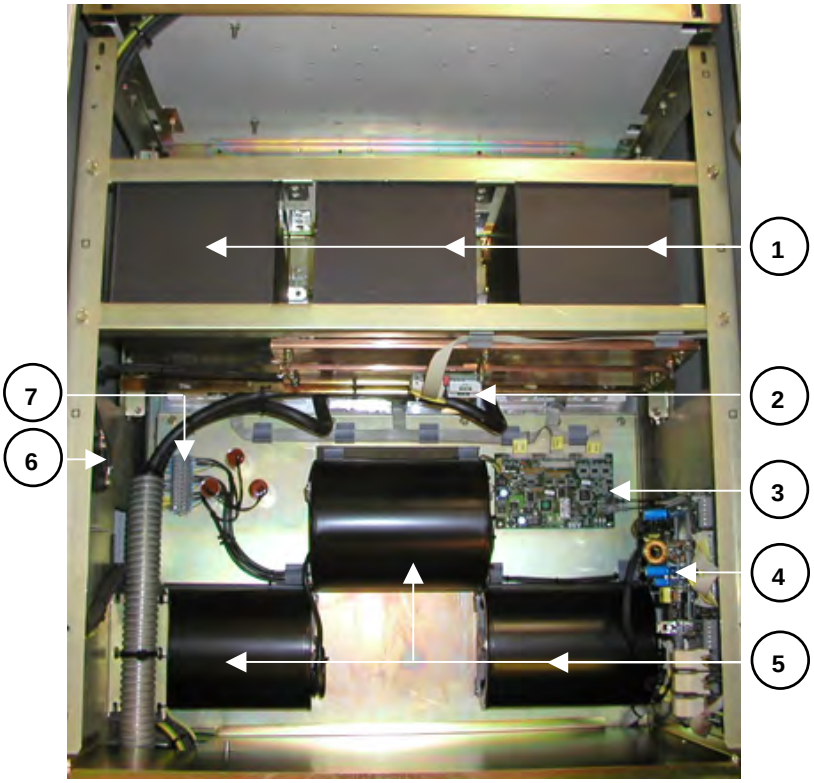


Figure 5.11. PQFI middle part

The component identification is given in Table 5.11.

Table 5.11. PQFI middle part description

Item	Description	Circuit diagram designation
1	IGBT inverter with DC capacitors	U1
2	DC voltage measurement board (master only)	A2
3	IGBT interface board (‘Domino board’)	A3
4	PQF main controller boards (master only)	A5
5	IGBT heat extraction fans	M1, M2, M3
6	DC capacitor discharge resistors	R5, R6
7	Terminals for heat extraction fans	X23, X24, X25

The PQF Main controller board terminals are predominantly system terminals. However, two external temperature probes (optional) can be connected to this board. The main controller board is shown in Figure 5.12.

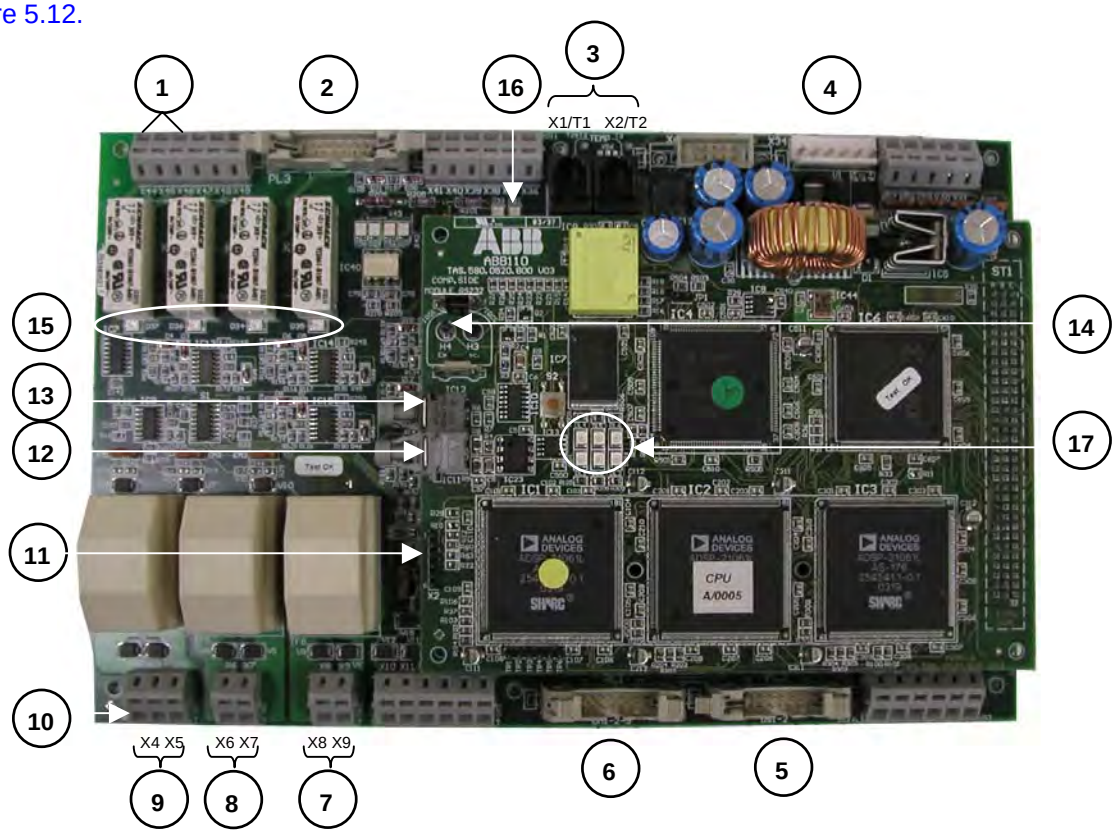


Figure 5.12. PQF main controller board

The designation of the principal terminals is given in Table 5.12.

Table 5.12. PQF main controller board description

Item	Customer terminals	Circuit diagram designation
3	External temperature measurement RJ 11 connectors X1/T1: Temperature probe 1 X2/T2: Temperature probe 2	X1/T1, X2/T2
Item	**ABB/Panel builders terminals**	**Circuit diagram designation**
1	230 Vac preload contactor auxiliary winding control	X44, X46
2	Digital control to distribution board (breaker control and optional heater control)	PL3
4	CAN connection and 24 Vdc power supply from distribution board	X34
5	Flat cable connection to DC voltage measurement board	PL2
6	Flat cable connection to AC voltage measurement board	PL1
7	Internal CT connection for phase L3 (T, Blue) from CT connection terminal in bottom part[(a)] X8: Connection for k-terminal (S1) X9: Connection for l-terminal (S2)	X8, X9
8	Internal CT connection for phase L2 (S, Yellow) from CT connection terminal in bottom part[(a)] X6: Connection for k-terminal (S1) X7: Connection for l-terminal (S2)	X6, X7
9	Internal CT connection for phase L1 (R, Red) from CT connection terminal in bottom part[(a)] X4: Connection for k-terminal (S1) X5: Connection for l-terminal (S2)	X4, X5
10	Earth connection (PE) to filter frame	
11	ABB system connector 1	
12	Optical link transmit diode for connection to domino board(s)	
13	Optical link receive transistor for connection from domino board(s)	
14	ABB system connector 2	
15	Relay monitoring LEDs LEDs are on when corresponding relay is activated D37: Preload relay D36: Optional heater control relay D34: Breaker close command relay D35: Breaker open command relay D37 D36 D34 D35	
16	Main breaker position monitoring LED LED off: Main breaker reports open position LED on: Main breaker reports closed position	
17	LEDs indicating controller and basic filter operation DL1: yellow LED monitoring DSP1-controller operation DL2: yellow LED monitoring DSP2-controller operation DL3: yellow LED monitoring DSP3-controller operation DL4: yellow LED monitoring µcontroller operation In normal operation the above named LEDs are all blinking at the same rate (about 1Hz). DL5: green LED indicating filter operation On: Filter is on or is in startup procedure, or stopped in fault condition but will restart as soon as the fault has disappeared. Off: Filter is off and will not restart. DL6: red LED indicating filter permanent error. On: Filter is stopped due to permanent error that has not yet been cleared. Off: No permanent error condition is present. DL4 DL5 DL6 DL1 DL2 DL3	

Remarks:
[(a)] For physical locations of customer CT connection terminals, please refer to Figure 5.8. item 7.

Terminals not explained above are ABB reserved terminals.

With each IGBT module an IGBT-interface board (“domino board”) is associated. This board receives information from the main controller board to which it is connected through an optical link. The domino board sends IGBT-control commands to the IGBT-drivers and receives measurement and status information from the IGBT-drivers. The information received from the IGBT-drivers is passed on to the main controller via the optical link communication system. Figure 5.13. shows an image of the domino board and identifies its principal I/O.

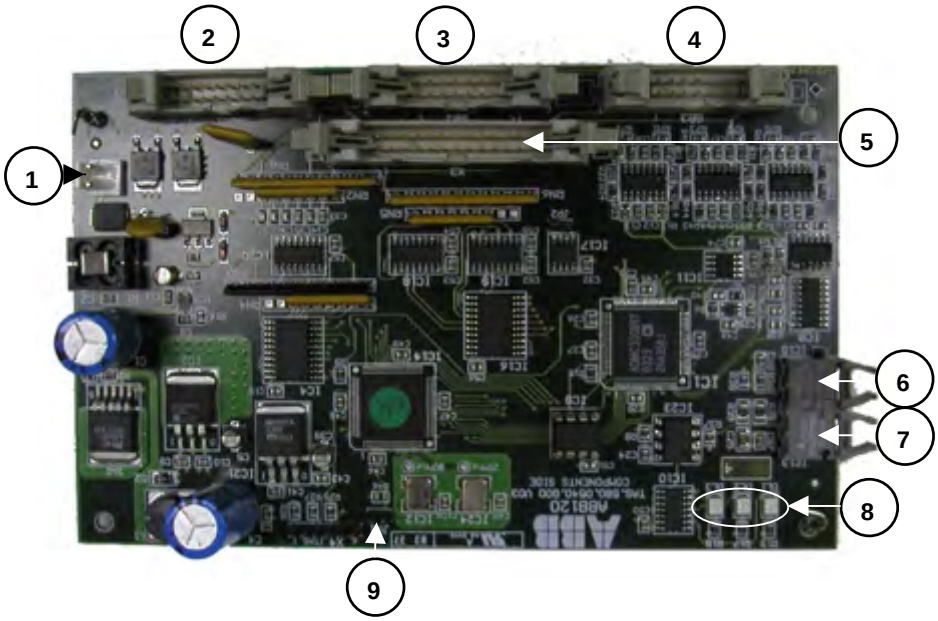


Figure 5.13. Domino board

The designation of the principal terminals and LEDs is given in Table 5.13.

Table 5.13. Domino board designation

Item	Description
1	24 Vdc supply input from domino board terminal X11
2	Flat cable connection to IGBT driver phase L1 (R, Red)
3	Flat cable connection to IGBT driver phase L2 (S, Yellow)
4	Flat cable connection to IGBT driver phase L3 (T, Blue)
5	ABB reserved connector
6	Optical link receive transistor for connection from the main controller board (first unit in chain) or from the previous domino board in the chain (not first unit in chain)
7	Optical link transmit diode for connection to the main control board (one unit filter or last unit in chain) or to the next domino board in the chain (multi-unit filter and not last unit in chain)
8	LEDs indicating the status of the optical link, the main domino board controller and the IGBT-module DL1: Red LED indicating the IGBT status Off: The IGBT module is not reporting a permanent error On: The IGBT-module or domino is reporting an error. This error may be - Overcurrent reported by the IGBT-driver - Overtemperature reported by the IGBT-driver - Power supply failure of the IGBT-driver - Hardware problem domino/optical link not synchronized  DL3 DL2 DL1 DL2: Green LED indicating optical link activity Off or shining bright: optical link is not active Shining dim: optical link is active DL3: Yellow LED indicating activity of the domino's main controller Blinking at the same rate as controller LEDs of main controller board: - Main controller of the domino board is functioning correctly Other conditions (e.g. LED off): main controller of the domino is not functioning correctly.
9	Jumper connection: mounted

5.6.3. Active filter top part components

Figure 5.14. shows a picture of the PQFI top part with the IP protection removed.

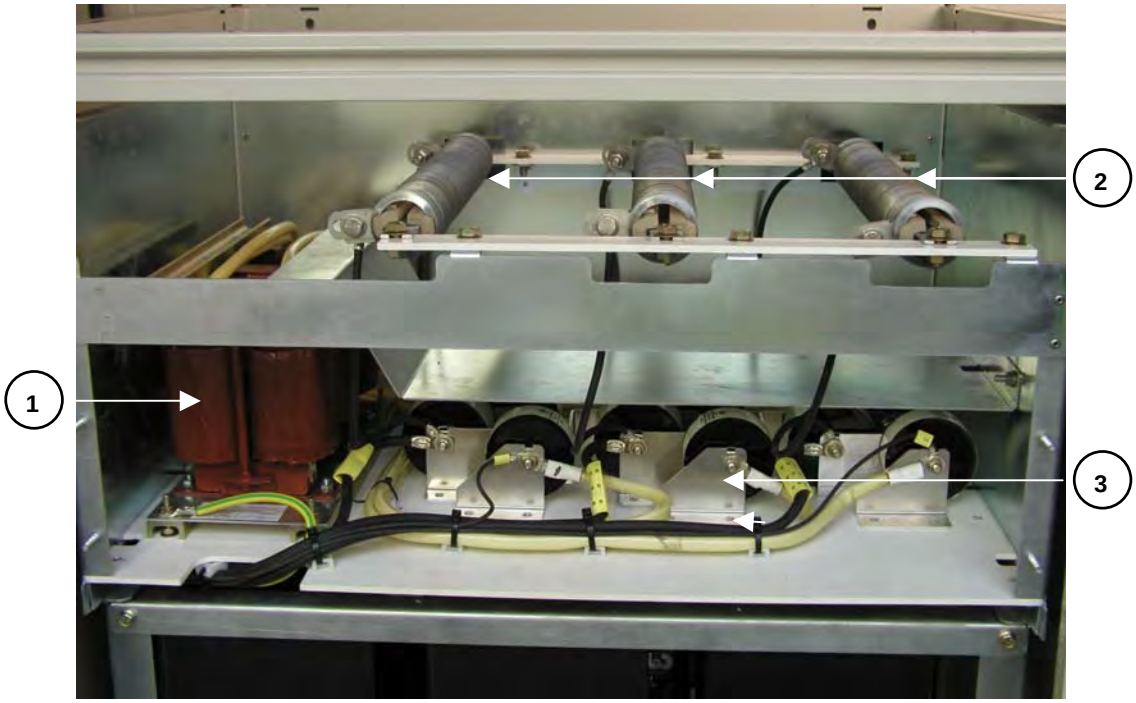


Figure 5.14. PQFI top part

The PQFI top part description is given in Table 5.14.

Table 5.14. PQFI top part description

Item	Description	Circuit diagram designation
1	Output filter reactor	L10
2	Output filter resistors	R2, R3, R4
3	Output filter capacitors	C1, …, C9

The output filter is connected to the main power lines between the reactors L11 and L12 (bottom part).

5.6.4. Active filter door components and protective grid

The active filter master panel door contains the PQF-Manager and possibly bulb indicators (optional). They are routed on to the distribution board. All filters contain a protective grid connected to the filter frame. At the bottom of the protective grid a cooling fan is mounted. The fan is supplied from the distribution board (X17 terminal).

6. Mechanical design and installation

6.1. What this chapter contains

This chapter gives the information required for the mechanical design and installation of the filter system.

6.2. Installation location requirements

The PQFI is suitable for indoor installation, on firm foundations, in a well-ventilated area without dust and excessive aggressive gases where the ambient operating conditions do not exceed the following values:

Table 6.1. Ambient operating conditions for PQFI operation

Altitude	Nominal output at 0 to 1000m (3300ft) above sea level [(a)]
Minimum temperature	-5°C (23°F), non condensing
Maximum temperature	40°C (104°F) [(b)]
Maximum average temperature (over 24 h)	35°C (95°F)
Relative humidity	Max. 95% non condensing
Contamination levels (IEC 60721-3-3)	Chemical class 3C2 [(c)] Mechanical class 3S2 [(d)]

Remarks:

(a) At sites over 1000m (3300ft) above sea level, the maximum output current must be derated by 1% every additional 100m (330ft). The derating factor must be entered at commissioning.

(b) Above 40°C (104°F), the maximum output current must be derated by 3.5% every additional 1°C (1.8°F) up to 50°C (122°F) maximum limit. The derating factor must be entered at commissioning.
If the system voltage is higher than 600V the current rating of the filter unit in this voltage range may be derated automatically depending on the load condition for ambient temperatures higher than 30°C (86°F).

(c) Locations with normal levels of contaminants, experienced in urban areas with industrial activities scattered over the whole area, or with heavy traffic.

(d) Locations without special precautions to minimize the presence of sand or dust, but not situated in proximity to sand or dust sources.

The filter installation must be indoor and it should be taken into account that the standard protection class is IP21 closed door (IP20 open door). Upon request filters with higher protection classes can be provided.

WARNING:	**Conductive dust may cause damage to this equipment. Ensure that the filter is installed in a room where no conductive dust is present.**

The filter foundations have to be leveled and must be able to support the weight of the filter. Table 6.2. gives the weight for one cubicle depending on the unit rating. Please note that one cubicle contains always one unit. For multi-unit filters the total weight can be obtained by multiplying the weight of one cubicle by the number of cubicles (ignoring the base frame weight).

Table 6.2. Weight of a PQFI-cubicle for different unit ratings

Network voltage U (Vrms)	Unit rating (Arms)	Cubicle weight (kg) CE version	Cubicle weight (kg) cULus version
208 ≤ Ue ≤ 480	250	520	630
	450	640	750
480 < Ue ≤ 690[(b)]	180 [(a)]	540	650
	320 [(a)]	640	750

Remark:
[(a)] If the nominal system voltage is higher than 600V (Ue > 600V) the current rating of PQFI units in this voltage range may be derated automatically depending on the load condition for ambient temperatures higher than 30°C (86°F).
[(b)] cULus versions of PQFI are limited to 600 Vrms

Active filters produce a certain level of audible noise when they operate. The audible noise level depends on the operating conditions of the unit. The maximum typical noise level is 70dBA for units up to 250A and 78dBA for units in the range 320A-450A. This value should be taken into account when choosing a location for the filter.

6.3. Airflow and cooling requirements

The PQFI dissipates an amount of heat that has to be evacuated out of the room where the filter is located. Otherwise, excessive temperature rise may be experienced. Please note that life of the electrical equipment decreases drastically if the operating temperature exceeds the allowable limit (divided by 2 every 10°C).
Each PQFI cubicle has its own set of cooling fans. The air intakes are located in the cabinet front doors. From the door intakes, the air flows through the cabinets and is then routed to the top of the cabinets. For proper cooling, a minimum airflow of 2100 m^3/h of cooling air has to be supplied to each cubicle. Please ensure that the air used for cooling is regularly renewed and does not contain conductive particles, significant amounts of dust, or corrosive or otherwise harmful gases. The cooling air intake temperature must not exceed 40°C under any operating condition. The hot exhaust air also has to be properly ducted away. Figure 6.1. shows the cooling air flow diagram for a 3 unit PQFI.

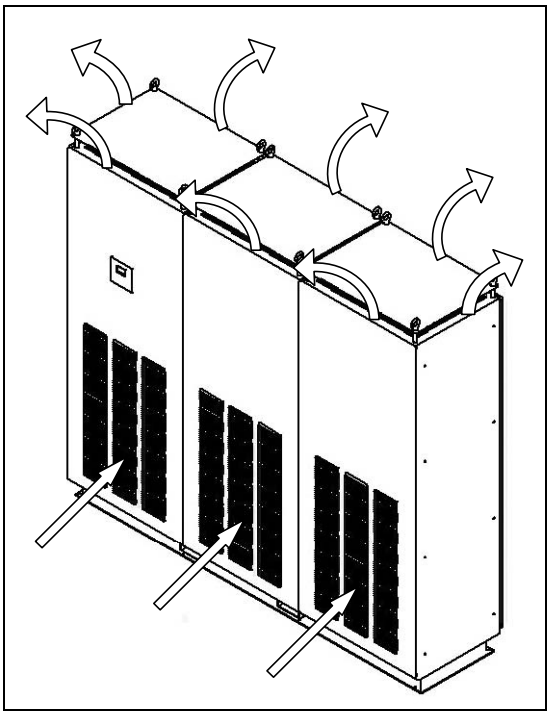


Figure 6.1. Cooling air flow for a 3 unit PQFI

When the natural cooling capacity at the location where the filter is installed is not sufficient, air conditioning systems have to be added to the room. In the design of the air conditioning systems, the filter heat losses have to be taken into account. Table 6.3. gives an overview of the PQFI heat losses for the different power units. For multi-unit filters, the values of Table 6.3. have to be multiplied by the number of filter units. In CE versions of PQFI, one cubicle contains one filter unit. In cULus versions of PQFI, one filter unit is distributed over two cubicles.

Table 6.3. Filter unit heat losses

Network voltage U (Vrms)	Unit rating (Arms)	Heat loss (kW)
208 ≤ Ue ≤ 480	250	≤ 5.2
	450	≤ 11
480 < Ue ≤ 690[(b)]	180 [(a)]	≤ 7.1
	320 [(a)]	-[(c)]

Remark:
[(a)] If the nominal system voltage is higher than 600V (Ue > 600V) the current rating of PQFI units in this voltage range may be derated automatically depending on the load condition for ambient temperatures higher than 30°C (86°F).
[(b)] cULus version of PQFI are limited to 600 Vrms.
[(c)] Not available at time of printing.

6.4. Standard cubicle dimensions, fixing holes and clearances

Standard CE versions of PQFI are mounted in cubicles of the Rittal TS8 type and have dimensions of 800 x 600 x 2150 mm (width x depth x height). The cubicles have an elevated roof with lifting lugs. Each cubicle contains one power unit and is fitted with its own bottom cable entry and breaker. An optional cable entry cubicle (wxdxh 600 x 600 x 2150 mm) may be provided for top cable entry, single cable entry point (multi-unit filters).

Standard cULus versions of PQFI are mounted in cubicles of the Rittal TS8 type. Each cULus filter unit is distributed over two cubicles and is mounted on a base frame. The overall dimensions of a cULus filter unit are 1400 x 600 x 2250 mm (width x depth x height) including the base frame. The cubicles have an elevated roof with lifting lugs. The cable entry cubicle houses a main breaker and can be supplied from the top and the bottom. Slave units also come with their own cable entry cubicle incorporating a protection breaker.

A filter panel (consisting of one or more power units) can be installed against a wall or back to back to other cubicles providing that the heat transfer from the other cubicles to the filter cubicle is negligible. If a high heat transfer is expected, a spacing of 100 mm between the filter panel and the wall or the other cubicles is recommended. Figure 6.2. and Figure 6.3. show a top view of a typical PQFI installation with indication of the cubicle fixation holes. For fixing the cubicle to the floor M12 bolts and washers are recommended.

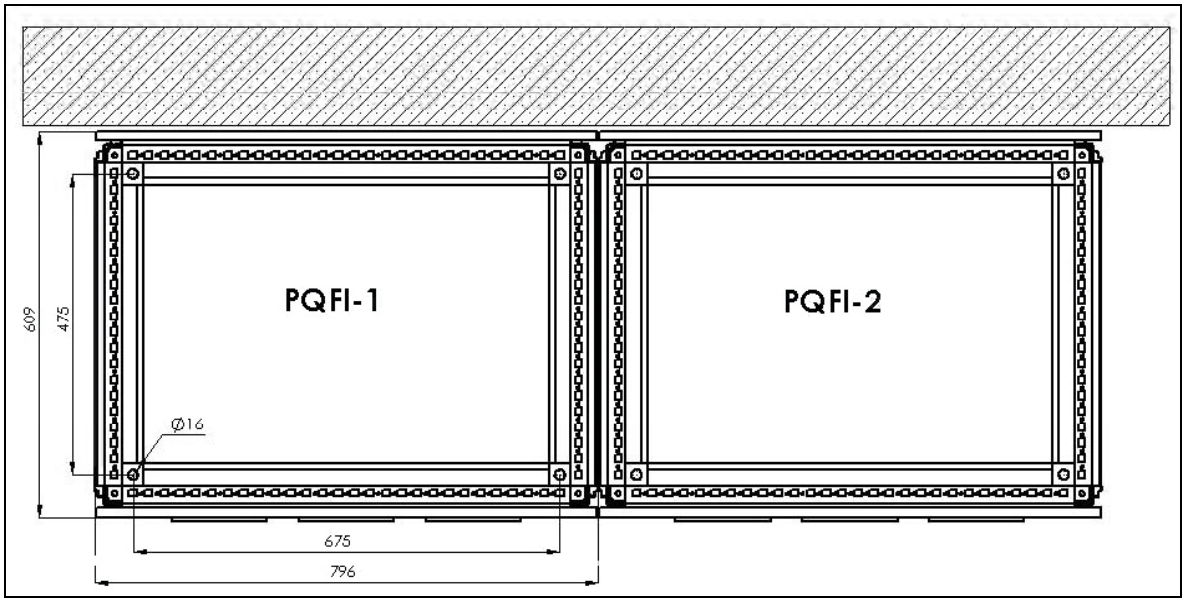


Figure 6.2. Top view of a typical CE version PQFI installation with indication of the fixing holes

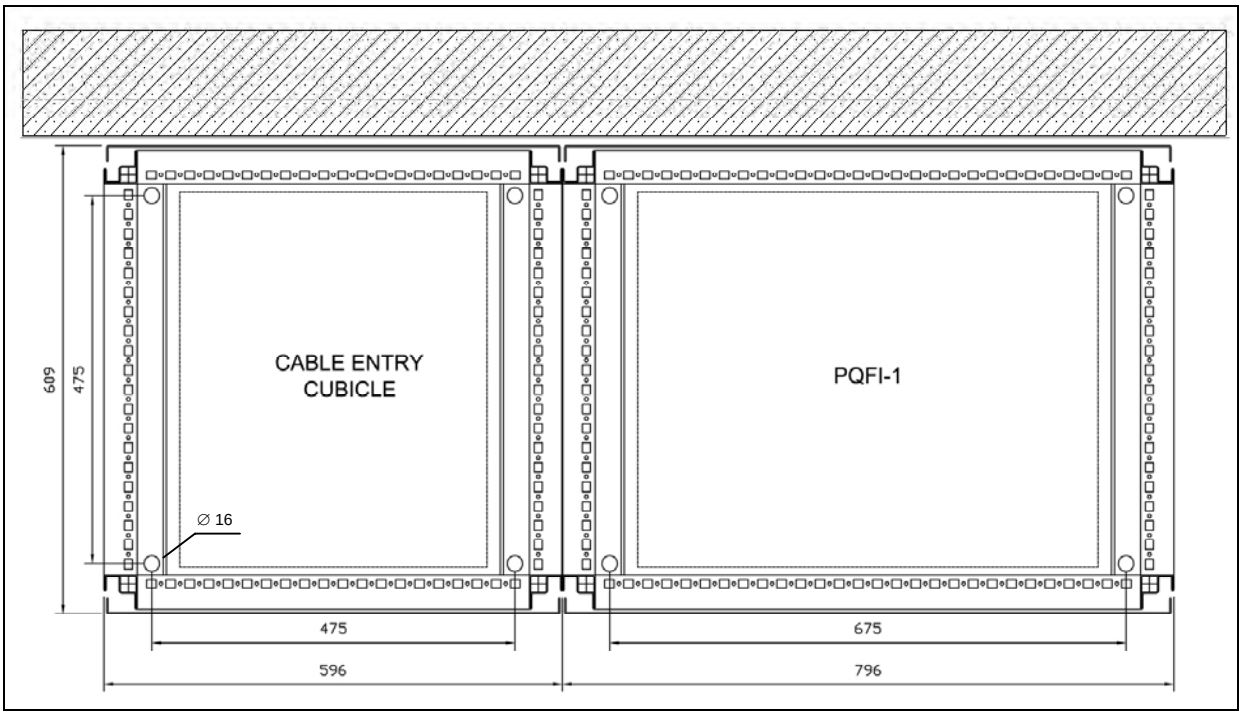


Figure 6.3. Top view of a typical cULus version PQFI installation with indication of the fixing holes

CE versions of PQFI consisting of more than one power unit can optionally be mounted on a common base frame of 100 mm height. Standard dimensions for CE PQFI filters with up to 3 power units are shown in Figure 6.4.

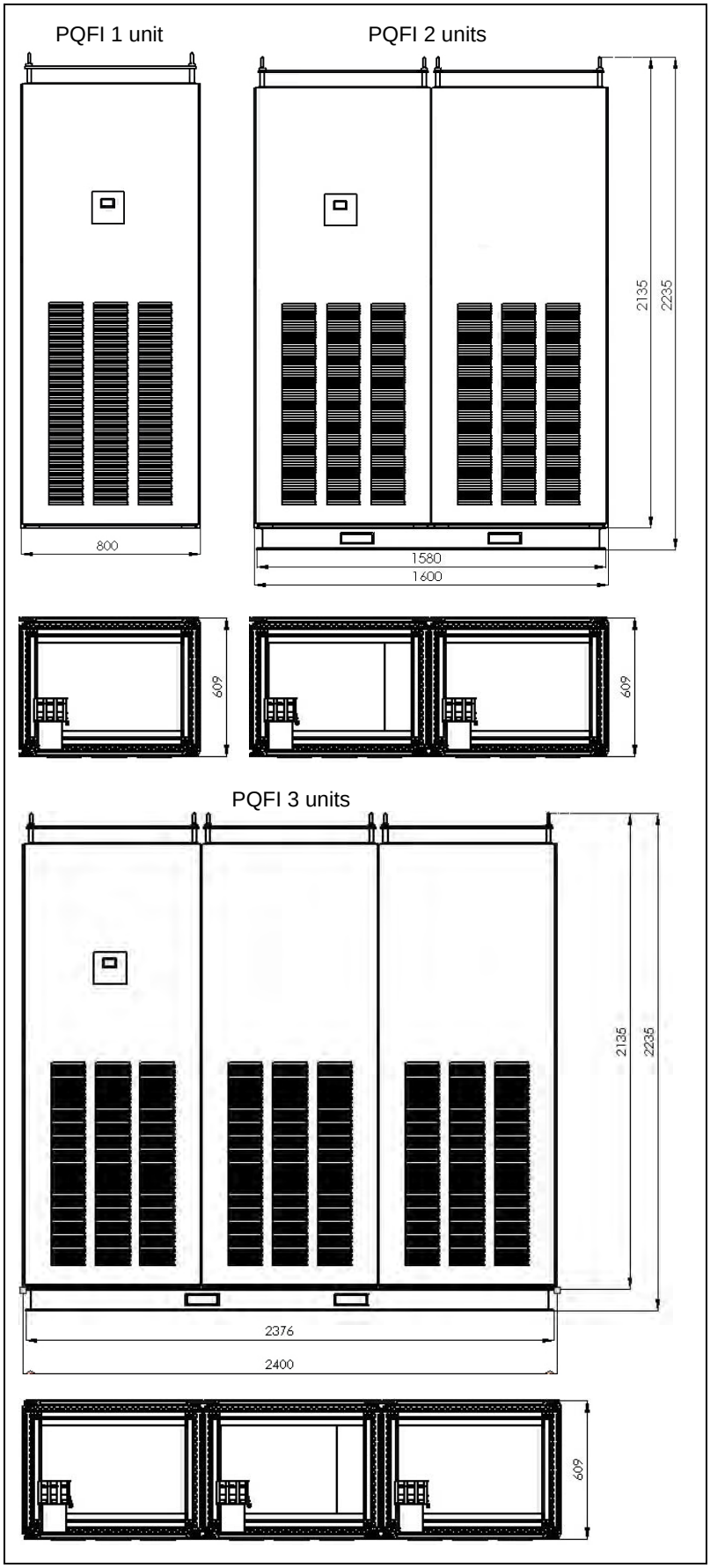


Figure 6.4. *Standard dimensions for CE PQFI filters with up to 3 power units*

cULus versions of PQFI are always mounted on a base frame of 100 mm height. Standard dimensions of cULus PQFI filters with up to 2 power units are shown in Figure 6.5.

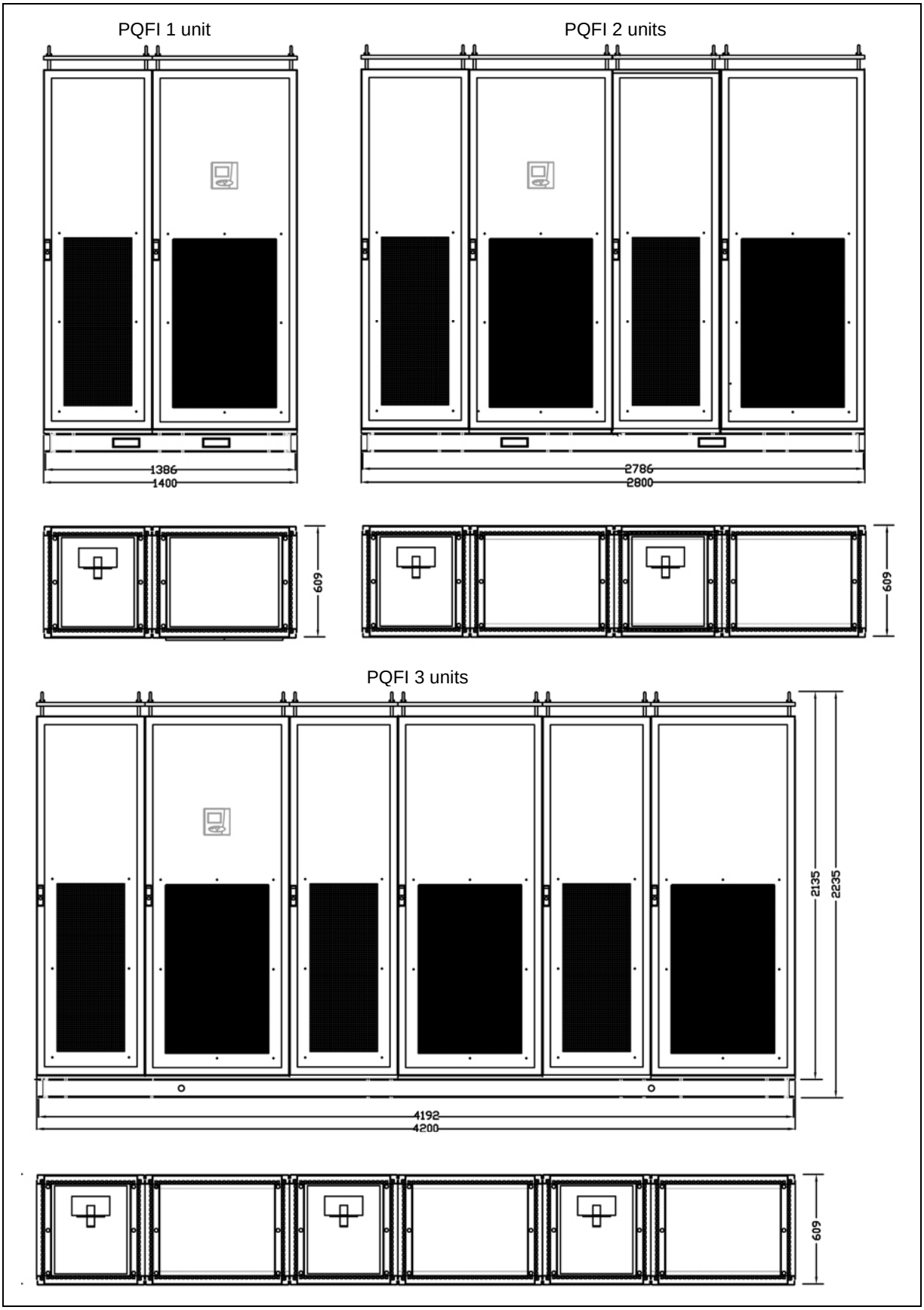


Figure 6.5. Standard dimensions for cULus PQFI filters with up to 3 power units

6.5. Mechanical interconnection of PQFI cubicles

This section explains how to mechanically interconnect PQFI units (master-slave or slave-slave). Figure 6.6. outlines the steps to undertake to mechanically interconnect two PQFI units.

For CE PQFI filters, one unit is housed in one cubicle.
For cULus PQFI filters, one unit is distributed over 2 cubicles which are mounted on a baseframe.

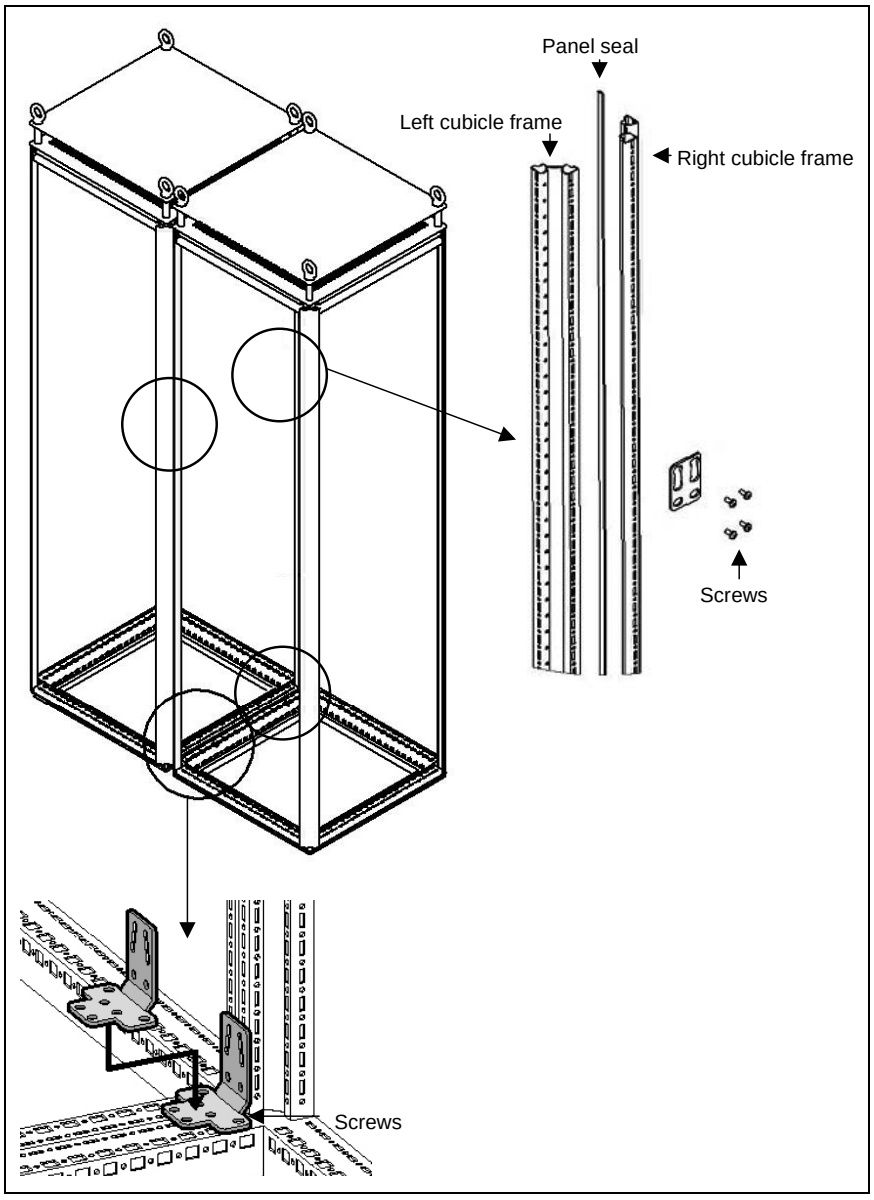


Figure 6.6. Steps required to mechanically interconnect two PQFI-cubicles

The procedure is outlined next:

- Remove the relevant side panels of the cubicles to be interconnected. Pay attention to the earth wire connection that is connected to each panel. This wire has to be removed.
- Fix the divider panel seal on the interior frame between the cubicles.
- Interconnect the cubicles at 4 fixation points as indicated in the above figure.
- Fix the added cubicle to the floor with bolts and washers (M12 recommended)

The interconnection kit is provided with the cubicles to be added.

6.6. Mechanical preparation of a common cable entry cubicle

Some filters are equipped with a common cable entry cubicle. This optional cubicle (wxdxh = 600 x 600 x 2150 mm excluding base frame) may act as a single top or bottom cable entry point for the active filter. This cubicle contains a bus bar system to which the supply cables have to be connected and which distributes the power to the power units in the other cubicles. It may also be equipped with a common disconnector switch for the complete filter system. Figure 6.7. shows an example of a common cable entry cubicle.

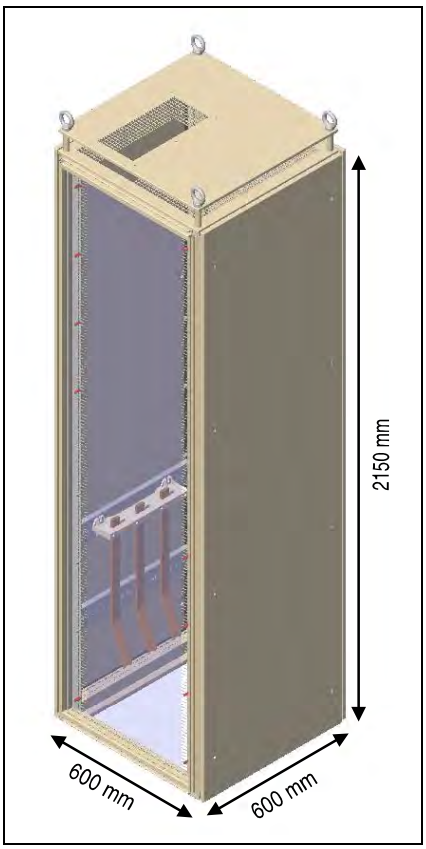


Figure 6.7. Example of a common cable entry cubicle for a PQFI

As can be seen in Figure 6.7. the cubicle has an elevated roof fixed by the lifting lugs and underneath it has a protecting grid. In practice, a cable pass through hole and a gland plate are provided. Some mechanical modifications may have to be done on site to adapt the gland plate to the cable size used.

If the common cable entry cubicle is added to an existing filter panel, the procedure outlined in Section 6.5. may be used to interconnect the different cubicles.

7. Electrical design and installation

7.1. What this chapter contains

This chapter gives the data required for integrating the PQFI active filter successfully in an electrical installation. It also gives electrical connection examples for popular filter options.

WARNING:	**The PQFI is able to operate on networks where the supply voltage is up to 10% higher than the equipment's rated voltage (inclusive of harmonics but not transients). Since operation at the upper limits of voltage and temperature may reduce its life expectancy, the PQFI should not be connected to systems for which it is known that the overvoltage will be sustained indefinitely. Auxiliary circuits are designed to operate in a +/- 10 % range of the equipment nominal auxiliary voltage (230 Vrms, internally derived). Excessive (auxiliary) voltage levels may lead to filter damage.**

The active filter must be connected to the network in parallel with the loads. Basic filter functionality can be obtained after connection of:

- ground (PE) (per unit);
- three power cables (per unit);
- 3 CTs (one per phase, only in the master unit).

More advanced filter features (e.g. external monitoring of the filter status) require some more connections. The connections for these advanced features have to be made on the PQF-Manager.

WARNING:	**Ensure that the filter supply is isolated upstream during filter installation. If the system has been connected to the supply before, wait for 10 mins after disconnecting the mains power in order to discharge the capacitors. Always verify by measurement that the capacitors have discharged. DC capacitors may be charged to more than 1000 Vdc.**

7.2. Checking the insulation of the assembly - earth resistance

WARNING:	**Follow the procedure outlined below to check the insulation of the assembly. Applying other methods may damage the filter.**

Every filter has been tested for insulation between the main circuit and the chassis/frame at the factory. Therefore, do not make any voltage tolerance or insulation resistance tests (e.g. hi-pot or megger) on the inverter units. Check the insulation of the assembly by measuring the insulation resistance of the filter between the Protective Earth (PE) and all 3 phases shorted together, with MCB shorted, and auxiliary circuit open (auxiliary fuses removed).

WARNING:	**Making the test with the auxiliary circuit closed may damage the filter.**

Use a measuring voltage of 500 Vdc. The insulation resistance must be higher than 500 kΩ per cubicle with the flat cables from the AC and DC voltage measurement boards (Figure 5.8. item 8 and Figure 5.11. item 2) removed.

7.3. EMC considerations

The CE version of active filter complies in its standard version with the following EMC guidelines:
EN/IEC 61000-6-2: Immunity standard for industrial environments; Industrial level.
EN/IEC 61000-6-4: Emission standard for industrial environments; Class A.

For the cULus version of active filter an optional EMC compliance kit exists that allows the filter to comply with the aforementioned standards.

The remainder of this section gives background information on the difference between AC drives and active filters regarding EMC issues.

The active filter is using similar IGBT-switching technology as used in AC drives. Therefore in order to comply with EMC guidelines, some actions have to be taken. The active filter has internal EMC circuitry that ensures that the filter is respecting the relevant guidelines providing that the customer has provided proper earth bonding of the cubicles. This is unlike AC drives that may need further special actions to be taken for EMC compliance.

The reason for the different approach to be taken for drives and for filter equipment can be understood when analyzing the power circuit of both devices (Figure 7.1.)

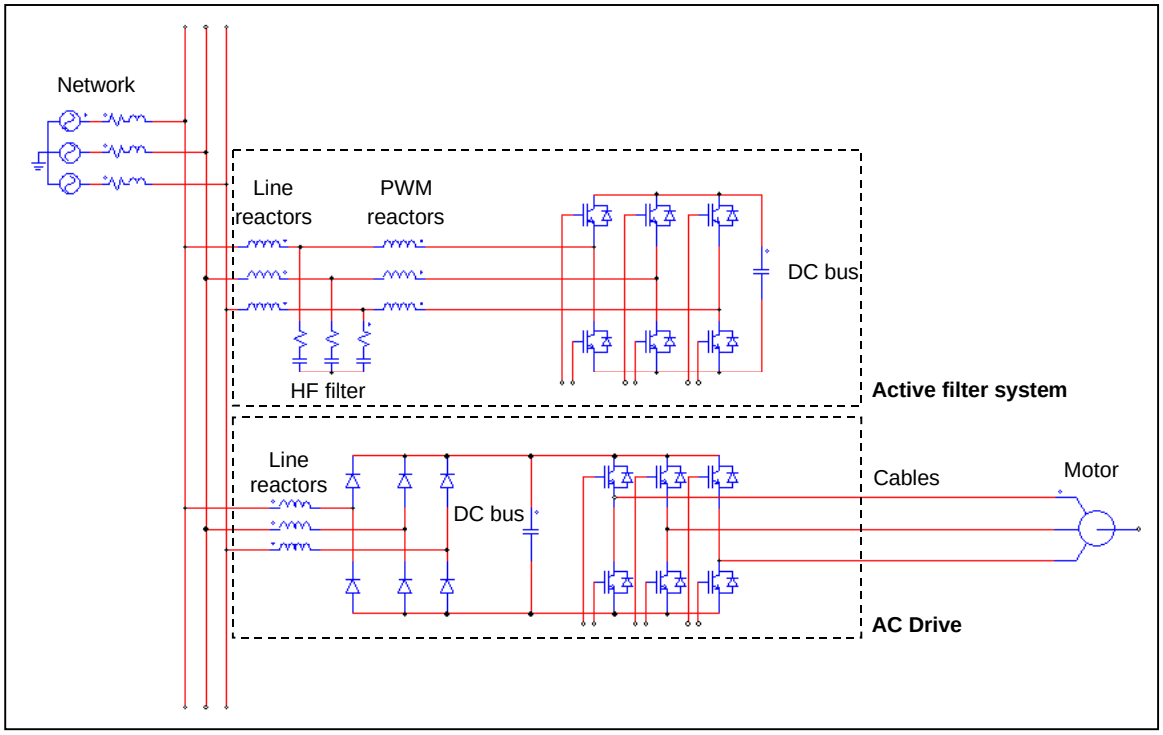


Figure 7.1. Schematic diagram of an active filter and an AC drive power circuit

One of the main differences between the active filter and the AC drive is that while the active filter has three connections to the external world, the drive has six; three on the network side like the active filter and three additional ones, to the motor. Another difference is the presence in the active filter of a HF-filter circuit, symbolically represented in Figure 7.1. by an RC-network.

The consequences of the aforementioned differences are:

- As the cables between the drive and the motor do not exist in an active filter application, all the recommendations that apply for these connections in the 'drives world' **are not applicable** when dealing with active filters. In a drive application, the output cables are connected directly at the IGBTs terminals and are therefore fed with extremely high dV/dT. They are therefore a very significant source of EMC emission. Due to that, strong recommendations apply to the cable type and way of handling the connections of the earth terminal in a drive application.

- The input stage of the active filter is designed in such a way that it shorts the switching frequency ripple current and prevents it flowing into the network. The (customer provided) input cables are therefore just loaded with the harmonic currents and therefore they are not fed with high dV/dt. As a consequence, no special EMC requirements exist for the connection of these cables.

From the above it may be concluded that the connection of an active filter to the network does not require special cables and special earth connection systems for the protective earth conductor. Only the harmonic content of the current may ask for a de-rating current wise, this implying a bigger cross section for a given RMS-current (Cf. Section 7.5.). No special EMC measures are needed. Standard cables types are well suitable for connecting the active filter to the supply.

7.4. Earthing guidelines

Each PQFI-cubicle has a marked earth bar (PE-point).
For CE versions of PQFI, the earth bar is situated just below the filter breaker, in the bottom part of the filter (Figure 7.2.)
For cULus versions of PQFI, the earth bar is situated at the bottom right side of the cable entry cubicle of each unit.

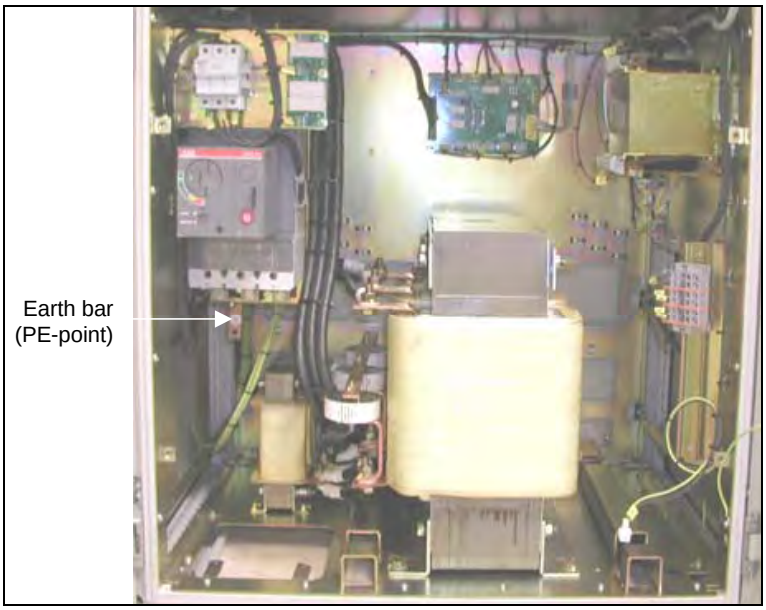


Figure 7.2. Identification of the earth bar in the PQFI-units (CE version)

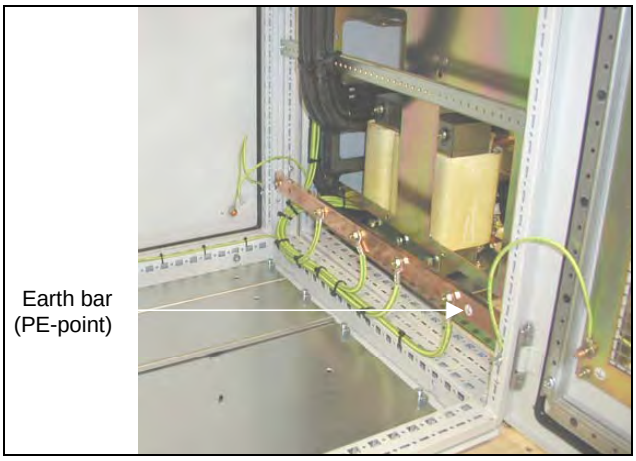


Figure 7.3. Identification of the earth bar in the PQFI-units (cULus version)

For safety reasons and for proper operation of the filter the earth bar of each cubicle must be connected to the installation's earth (PE-point). A copper (Cu) cable of minimum size 16 mm² is recommended but local regulations should also be taken into account.

Further, the following rules should be respected:

- When the PQFI consists of only one cubicle, the cubicle's PE-point must be connected directly to the installation's PE-point.
- When the PQFI consists of more than one cubicle, all cubicle's PE-points must be connected directly to the installation's PE-point and additionally all cubicle's PE-points must be interconnected. This is illustrated in Figure 7.4. The same applies also to the cULus version of PQFI as shown in Figure 7.5. Interconnection cable should be minimum 16 mm².

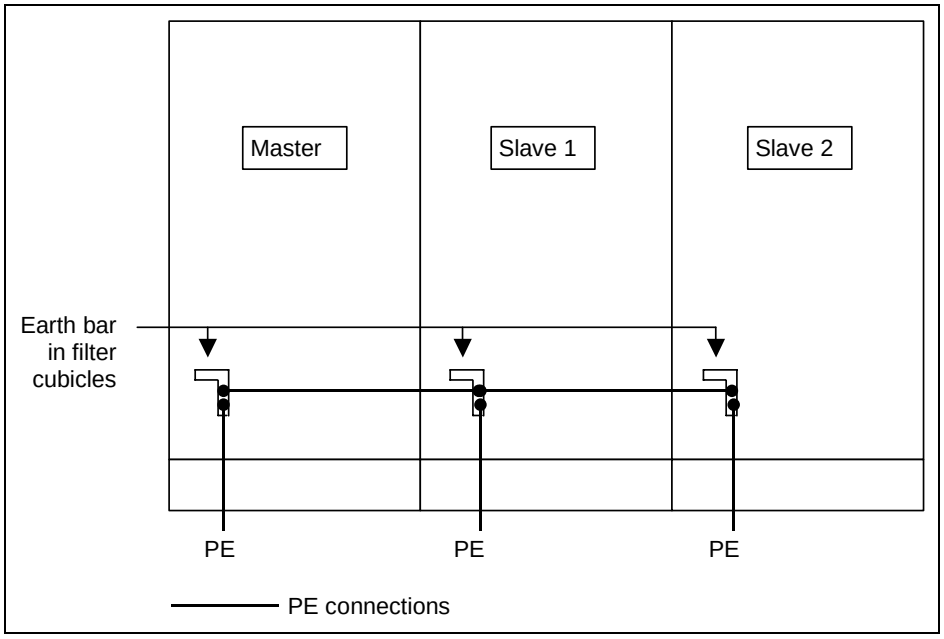


Figure 7.4. Earth connection guidelines for a multi-unit PQFI (CE version)

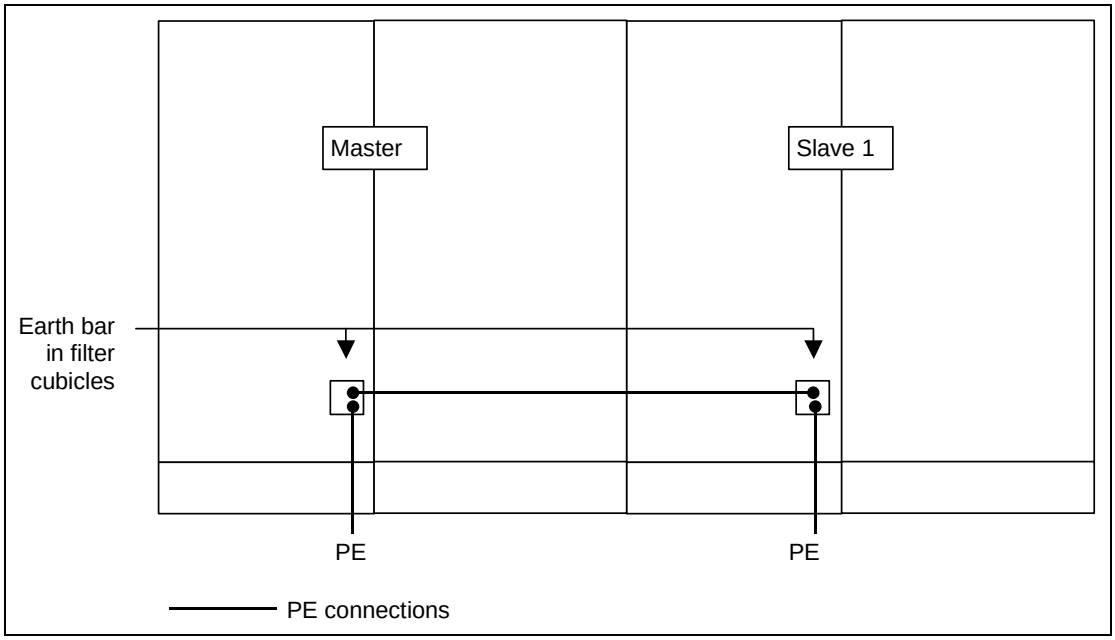


Figure 7.5. Earth connection guidelines for a multi-unit PQFI (cULus version)

When a factory pre-assembled multi-cubicle is installed, the PE-interconnections between the different cubicles are already present and the customer only has to add the connections of each cubicle to the installation's PE-point.

When a cubicle is added on site however, the customer has to ensure the proper interconnection of the different cubicles' PE-point. In this, it must be made sure that the cables are securely fixed and do not run over components.

7.5. Selection of the power cable size

Several types of power cable can be used to connect the filter to the network. Local regulations and habits often determine the user's choice. Note however that due to the high frequency output filter of the PQF, there is no radiated emission through the feeding cables. Consequently, there is no need for special screening of the filter connection cables (Cf. Section 7.3.).

The following steps have to be followed to determine the section of the power cables feeding the filter:

1. Determine the RMS current rating of the cubicle/filter for which the cable has to be rated (Irms).
   The rating is marked on the cubicle label.
   In standard execution each filter cubicle is fitted with its own circuit breaker situated at the bottom of the cubicle. Each cubicle has to be individually connected to the supply and bottom cable entry has to be used. In this case the RMS current for which the cable has to be rated equals the current rating of the unit to be connected to the supply.

   Optionally PQFI filters can be provided with a common cable entry cubicle (wxdxh = 600x600x2150 excluding base frame of 100 mm height). In that case the power cable connections for each power cubicle are centralized on a central bar system in the entry cubicle. When this is the case, the RMS current for which the feeding cables have to be rated, equals the nominal current rating of the complete filter. The filter identification label on the master door contains the nominal filter current rating.

2. Determine the factor X and the cable section required taking into account the skin effect.
   The multiplication factor X is a factor that takes into account that the current that will flow through the filter connection cables is predominantly a harmonic current, i.e. a current of which the frequency of the most important components is higher than the network base frequency. Due to the frequency being higher than the network base frequency a physical phenomenon called 'skin effect' comes into play. This effect implies that for higher frequencies the current will not flow through the complete cross section of the cable but will have the tendency to flow at the cable surface. The result is that although one may use a cable of A mm², the section through which the current flows is only y A mm² (with y < 1). In order to compensate for this "loss of section", the cable has to be oversized such that the total equivalent section through which the current flows taking into account the skin effect is acceptable.

   The multiplication factor X to be used depends on the cable material (e.g. copper [Cu], aluminum [Al]) and on the base frequency of the network on which the filter will be installed. For a given installation its value can be determined using the following process:

   Step 1: Determine in a conventional way (e.g. using cable manufacturer's tables) the cable section A (mm²) for the RMS current Irms obtained in 1 above.
   Step 2: Using the cable section A, the cable material and the network frequency as entry points in Table 7.1., determine the multiplication factor X.

Table 7.1. *Multiplication factors X for different cable sections*

Cable section [mm²]	Network frequency 50Hz		Network frequency 60Hz	
	Al-cable	Cu-cable	Al-cable	Cu-cable
16	1.01	1.01	1.01	1.01
25	1.01	1.02	1.01	1.03
35	1.02	1.03	1.02	1.04
50	1.03	1.06	1.04	1.08
70	1.05	1.1	1.06	1.13
95	1.08	1.16	1.10	1.21
120	1.11	1.23	1.15	1.30
150	1.16	1.30	1.21	1.39
185	1.22	1.41	1.28	1.50
240	1.31	1.55	1.40	1.67
300	1.41	1.70	1.52	1.84

Step 3: Determine in a conventional way the cable section A_2 (mm²) for the current rating found by multiplying Irms by X.
If the new cable section A_2 is equal to the initially found cable section A, the right cable section taking into account the skin effect has been found.
If the new cable section A_2 is bigger than the initially found cable section A, steps 2 and 3 have to be repeated with the new values until the cable section A_2 found is equal to the cable section A.
Remark: during this process it may be found that more than one cable per phase is needed. The process then has to be applied to each cable.

As an illustration of the cable sizing process consider the following example:
PQFM 100 A/60Hz, cable material: Cu (copper)
Step 1: I_N = 100A → cable section = 25 [mm²]
Step 2: multiplication factor for a 25 [mm²] copper cable at 60 Hz = 1.03
Step 3: I = I_N x 1.03 = 100A x 1.03 = 103 A
Step 4: I = 103A → cable section: 25 [mm²]
This section is equal to the section found in the previous step.
Conclusion: one copper cable of 25 [mm²] per phase is sufficient.

Remark: The cable sizing process discussed in point 2 above only takes into account the skin effect. Any further derating due to local standards and/or installation conditions (e.g. distance between cables, number of cables connected in parallel, …) have to be taken into account by the company responsible for the PQF cable connection.

As an example of the cable sizing procedure, consider Table 7.2. and Table 7.3., which show the allowed current for different parameters noting typical cable manufacturer data.

WARNING: Consult your cable manufacturer for the applicable cable manufacturer data.

Table 7.2. Allowed cable current for different cable sections noting the skin effect and typical cable manufacturer data – Network frequency 50Hz

				Copper			Aluminum		
Cross section		Nr of parallel cables	Derating due to paralleling	Rated current [Arms]	Reduction factor	Allowed current [Arms]	Rated current [Arms]	Reduction factor	Allowed current [Arms]
[mm²]	[AWG]								
16	6	1	1	100	0.995	100	75	0.998	75
25	4	1	1	130	0.986	125	100	0.995	100
35	2	1	1	160	0.974	156	120	0.989	119
50	1-1/0	1	1	190	0.951	181	145	0.978	142
70	2/0	1	1	230	0.912	210	180	0.960	173
95	3/0	1	1	285	0.864	246	220	0.932	205
120	4/0	1	1	325	0.818	266	250	0.903	226
150	300MCM	1	1	365	0.770	281	285	0.865	247
185	350MCM	1	1	415	0.712	296	325	0.825	268
240	500MCM	1	1	495	0.646	320	385	0.768	296
300	600MCM	1	1	550	0.590	324	425	0.711	302
16	6	2	0.8	160	0.995	159	120	0.998	120
25	4	2	0.8	208	0.986	205	160	0.995	159
35	2	2	0.8	256	0.974	249	192	0.989	190
50	1-1/0	2	0.8	304	0.951	289	232	0.978	227
70	2/0	2	0.8	368	0.912	335	288	0.960	276
95	3/0	2	0.8	456	0.864	394	352	0.932	328
120	4/0	2	0.8	520	0.818	425	400	0.903	361
150	300MCM	2	0.8	584	0.770	450	456	0.865	394
185	350MCM	2	0.8	664	0.712	473	520	0.825	429
240	500MCM	2	0.8	792	0.646	512	616	0.768	473
300	600MCM	2	0.8	880	0.590	519	680	0.711	483

Remark: The highlighted values in Table 7.2. refer to cable sizes that correspond to typical filter ratings.

Table 7.3. Allowed cable current for different cable sections noting the skin effect and typical cable manufacturer data – Network frequency 60Hz

				Copper			Aluminum		
Cross section		Nr of parallel cables	Derating due to paralleling	Rated current [Arms]	Reduction factor	Allowed current [Arms]	Rated current [Arms]	Reduction factor	Allowed current [Arms]
[mm²]	[AWG]								
16	6	1	1	100	0.992	99	75	0.997	75
25	4	1	1	130	0.980	127	100	0.992	99
35	2	1	1	160	0.962	154	120	0.984	118
50	1-1/0	1	1	190	0.932	177	145	0.969	141
70	2/0	1	1	230	0.885	204	180	0.945	170
95	3/0	1	1	285	0.830	237	220	0.911	200
120	4/0	1	1	325	0.775	252	250	0.872	218
150	300MCM	1	1	365	0.723	264	285	0.831	237
185	350MCM	1	1	415	0.668	277	325	0.784	255
240	500MCM	1	1	495	0.600	297	385	0.718	276
300	600MCM	1	1	550	0.545	300	425	0.661	281
16	6	2	0.8	160	0.992	159	120	0.997	120
25	4	2	0.8	208	0.980	204	160	0.992	159
35	2	2	0.8	256	0.962	246	192	0.984	189
50	1-1/0	2	0.8	304	0.932	283	232	0.969	225
70	2/0	2	0.8	368	0.885	326	288	0.945	272
95	3/0	2	0.8	456	0.830	378	352	0.911	321
120	4/0	2	0.8	520	0.775	403	400	0.872	349
150	300MCM	2	0.8	584	0.723	422	456	0.831	379
185	350MCM	2	0.8	664	0.668	443	520	0.784	408
240	500MCM	2	0.8	792	0.600	475	616	0.718	442
300	600MCM	2	0.8	880	0.545	479	680	0.661	450

Remark: The highlighted values in Table 7.3. refer to cable sizes that correspond to typical filter ratings.

7.6. Connection of the PQFI to the network

WARNING:	**The PQF has to be installed in parallel with the loads, preferably on a free feeder. Local regulations and requirements prevail in determining how the equipment has to be connected to the network. In accordance with good cabling practice, ABB strongly suggests that the feeding cables to the filter are protected by their own cable protection device.**

NOTE:	**When installing ac active filter in installation containing power factor correction capacitor banks, it is recommended to use detuned capacitor banks and to connect the capacitor banks upstream of the filter measurement CTs. More information on this subject is given in Section 7.8.7. and Section 7.8.8.**

Three power cables (L1, L2, L3) have to be connected to each filter circuit breaker (in each cubicle). By default, for CE versions of PQFI a breaker is situated at the bottom left side of each cubicle. For cULus versions of PQFI a breaker is situated in the cable entry cubicle of each unit. Make sure that the phase rotation of the feeding supply is clockwise and that the L1, L2 and L3 terminal in each cubicle is connected to the same phase for all cubicles. Failure to do so may lead to the filter being damaged upon startup.

On the filter side, the power cables are normally connected to the breaker terminals. Figure 7.6. shows the terminal layout and the relevant dimensions for different breaker types for CE versions of PQFI. Figure 7.7. shows the terminal layout and the relevant dimensions for different breaker types for cULus versions of PQFI. Table 7.4. gives an overview of the used breaker types for each power unit size.

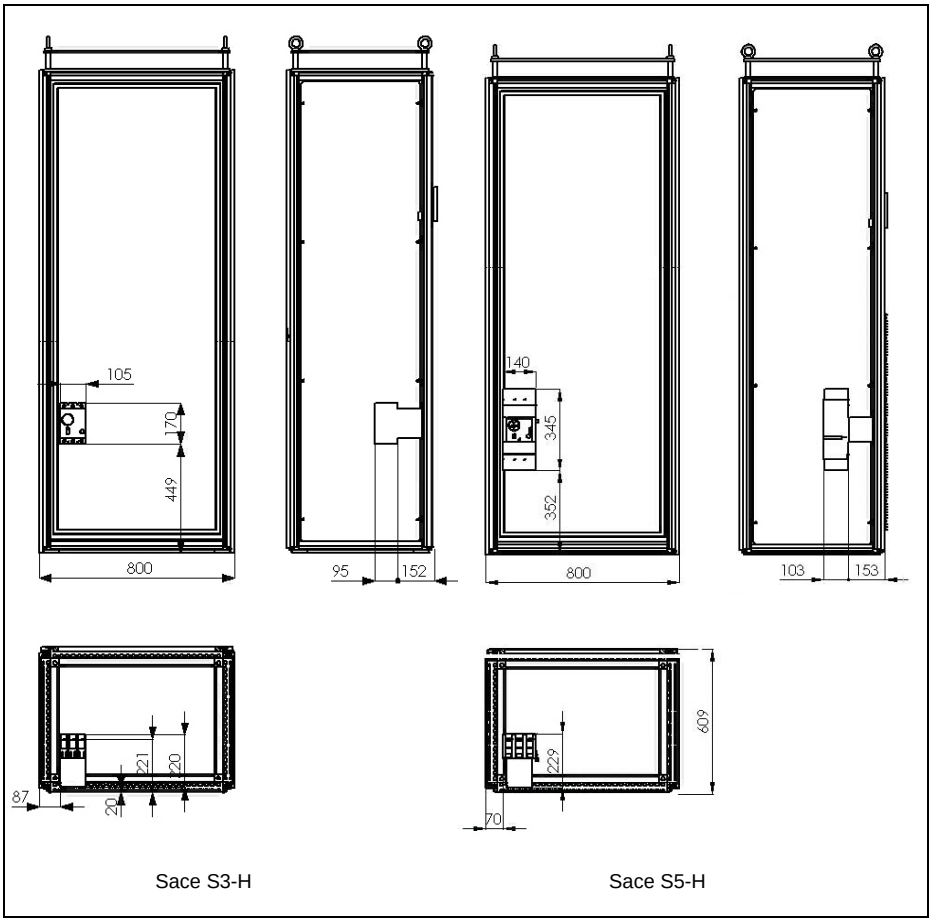


Figure 7.6. Filter connection breaker terminals for the different types of breakers for CE PQFI

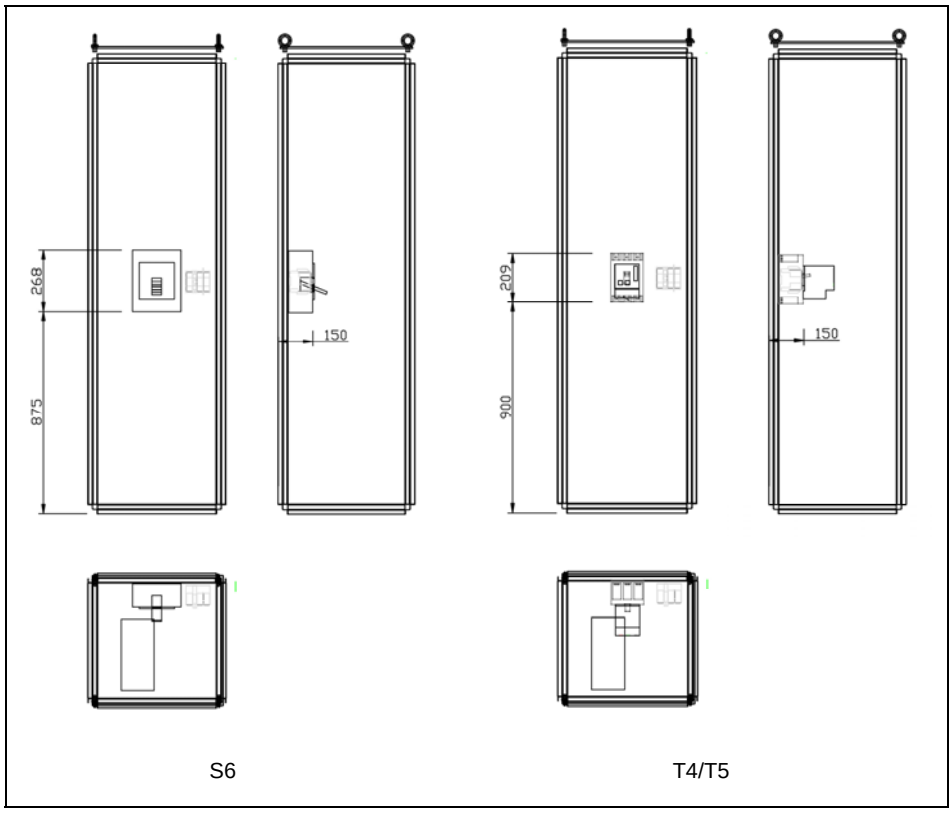


Figure 7.7. Filter connection breaker terminals for the different types of breakers for cULus PQFI

Note for common cable entry PQFI: if the filter is fitted with an additional cubicle for common cable entry, the feeding power cables have to be connected to the busbar installed in the connection cubicle. In that case, the necessary mechanical preparation of the cable entry cubicle has to be done first. Refer to Section 6.6. for more information on this subject.

Remarks:

- In case of regenerative loads (e.g. loads that may inject active energy to the network, usually called 4Q-loads), it is very important to connect the PQF outside the protection of this load. Indeed, consider Figure 7.8. where a common protection is installed for both the regenerative load and for the PQF. When the load re-injects energy to the network and the mains protection trips, the whole energy may be pushed into the PQF, which may become severely damaged. Figure 7.9. shows the correct protection scheme for regenerative loads. In this case, if the breaker of the load trips, the PQF is isolated from the energy fed back by the drive.

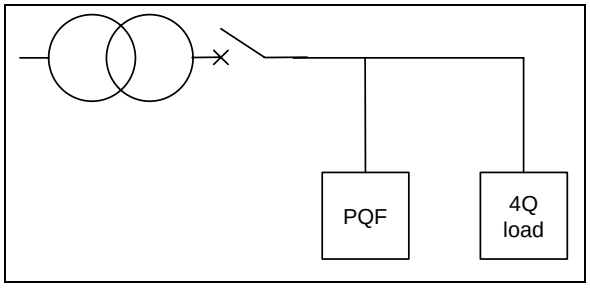


Figure 7.8. Incorrect connection in the case of 4Q-loads

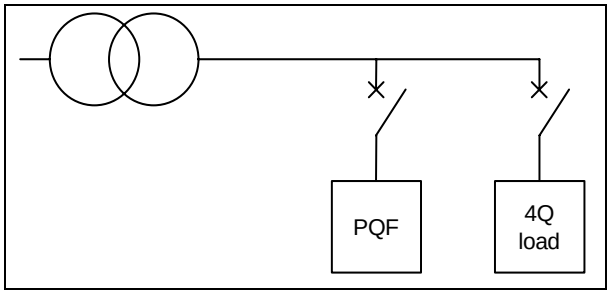


Figure 7.9. Correct connection in the case of 4Q-loads

- When sizing the protection of the power cables, it should be taken into account that the power circuit of the PQFI active filter is protected by its own motorized circuit breaker.
- The control circuit is also protected by fuses. Figure 7.10. shows a symbolic representation of the PQFI input protection for CE versions of PQFI. Figure 7.11. shows a symbolic representation of the PQFI input protection for cULus versions of PQFI.

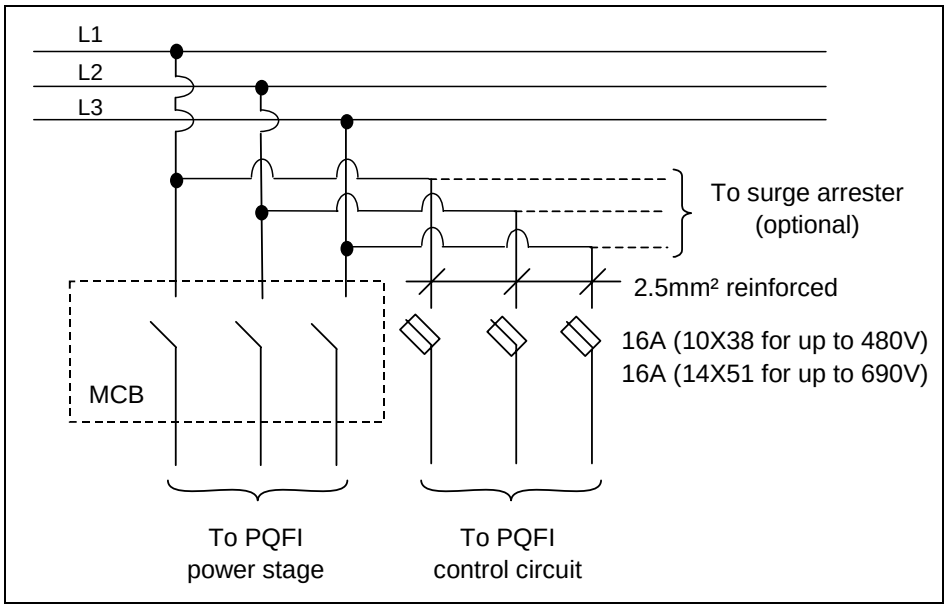


Figure 7.10. Symbolic representation of the PQFI input protection (CE version)

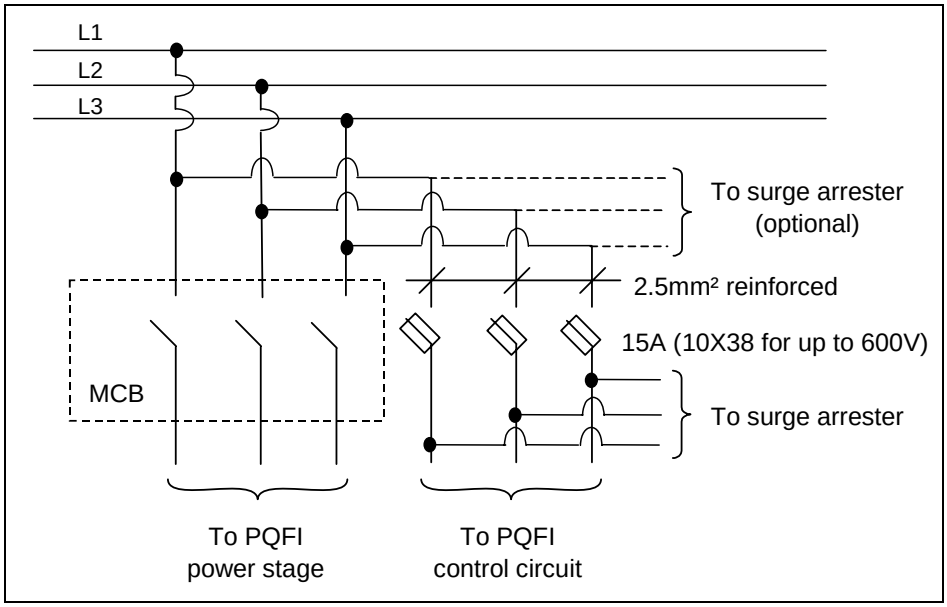


Figure 7.11. Symbolic representation of the PQFI input protection (cULus version)

Depending on the filter type and version different breakers are used. Table 7.4. gives an overview of the breaker type as a function of the cubicle unit rating and filter version.

Table 7.4. Breaker types for different unit ratings

Unit rating (Arms)	Associated power stage breaker
180 (CE version)	ABB Sace S3-H
250 (CE version)	ABB Sace S5-H
320 (CE version)	ABB Sace S5-H
450 (CE version)	ABB Sace S5-H
180 (cULus version)	ABB Sace T4-H250 UL/CSA
250 (cULus version)	ABB Sace T5-H400 UL/CSA
320 (cULus version)	ABB Sace T5-H400 UL/CSA
450 (cULus version)	ABB Sace S6-H600 UL/CSA
Central connection in cable entry cubicle	Breaker in every power stage cubicle according to cubicle rating

Table 7.5. presents the RMS current limit and the short circuit current capability for the most commonly used circuit breakers. Breaker settings must be set to 'MAX' for both the RMS and peak current.

Table 7.5. RMS current limit and short circuit current capability for PQFI circuit breakers

Power stage breaker type	Irms breaker (Arms)	Breaker short circuit current capability [(a)]	
		Uh (Vrms)	Isc (kA)
Sace S3-H	250	220/230	100
		380/415	65
		440	50
		500	40
		690	18
Sace S5-H	500	220/230	100
		380/415	65
		440	50
		500	40
		690	25
T4-H250 UL/CSA	250	220/230	150
		480	65
		600	35
T5-H400 UL/CSA	400	220/230	150
		480	65
		600	35
S6-H600 UL/CSA	600	220/230	150
		480	65
		600	35

Remark:
[(a)] The breaker short circuit current capability depends on the network voltage to which it is connected. For voltages not mentioned in Table 7.5., refer to the voltage which is just higher than the voltage considered.

Table 7.6. and Table 7.7. give an overview of the main control circuit fuse characteristics depending on the nominal network voltage and filter version.

Table 7.6. Control circuit fuse characteristics for PQFI filters (CE version)

Nominal network voltage (Vrms)	Control circuit fuse type	Irms fuse (Arms)	Isc[(a)] fuse (kA) at rated voltage	Rated Voltage (Vrms)
$208 \leq Ue \leq 480$	French Ferrule 10 X 38 gG/gl	16	~ 120	500
$480 < Ue \leq 690$	French Ferrule 14 X 51 gG/gl	16	~ 80	690

Remark:
[(a)] fuse short circuit current capability

Table 7.7. Control circuit fuse characteristics for PQFI filters (cULus version)

Nominal network voltage (Vrms)	Control circuit fuse type	Irms fuse (Arms)	Isc[(a)] fuse (kA) at rated voltage	Rated Voltage (Vrms)
208 ≤ Ue ≤ 600	NAPF 10 X 38 Fast Acting	15	~ 200	600
Remark: [(a)] fuse short circuit current capability				

When a CE version of PQFI filter is equipped with a surge arrester circuit (optional), this circuit has its own fuse protection with following characteristics:

Table 7.8. Surge arresters circuit (optional) protection fuses (CE version)

Nominal network voltage (Vrms)	Surge arresters circuit protection fuse type	Irms fuse (Arms)	Isc[(a)] fuse (kA) at rated voltage	Rated Voltage (Vrms)
208 ≤ Ue ≤ 480	Size 0, gG/gL, with striker	125	120	500
480 < Ue ≤ 690	Size 0, gG/gL, with striker	125	80	690
Remark: [(a)] fuse short circuit current capability				

The surge arrester circuit is connected directly on the feeding supply (in parallel with the power stage protection and the control circuit protection).

The cULus version of PQFI filter is by default equipped with a surge arrester circuit. This circuit has its own fuse protection with following characteristics.

Table 7.9. Surge arresters circuit protection fuses (cULus version)

Nominal network voltage (Vrms)	Surge arresters circuit protection fuse type	Rated Voltage (Vrms)
208 ≤ Ue ≤ 480	OVR 15-660 US	600
480 < Ue ≤ 600	OVR 15-660 US	600

This surge arrester circuit is connected after the auxiliary fuses.

7.7. Selection of the current transformers

The filter has to monitor the line current in order to determine the harmonic load. This is done by three current transformers (CTs). For proper operation of the PQFI standard accuracy CTs with the following minimum specifications have to be used:

- 5 A secondary current rating.
- 15 VA burden for up to 30 meters of 2.5 mm² cable. For longer cables lengths refer to the chart in Figure 7.12. In case the CTs are shared with other loads, the VA burden shall be adapted accordingly.
- Class 1 accuracy.
- Primary side current rating sufficient to monitor the total line current (including transient phenomena such as drive/motor starts …)

It is strongly recommended that the three CTs have the same characteristics.

WARNING:	**The connection of different loads (including the PQFI) on the same CT must be in series.**

In order to determine the suitable CTs for your application, please refer to the chart in Figure 7.12.

Remark: in some applications two or more power source connections exist (e.g. a network transformer connection and a generator connection). When the current in both connections has to filtered, summing CTs have to be used. All summing CTs must have the same ratio. More information on how to install the summing CTs is given in next section.

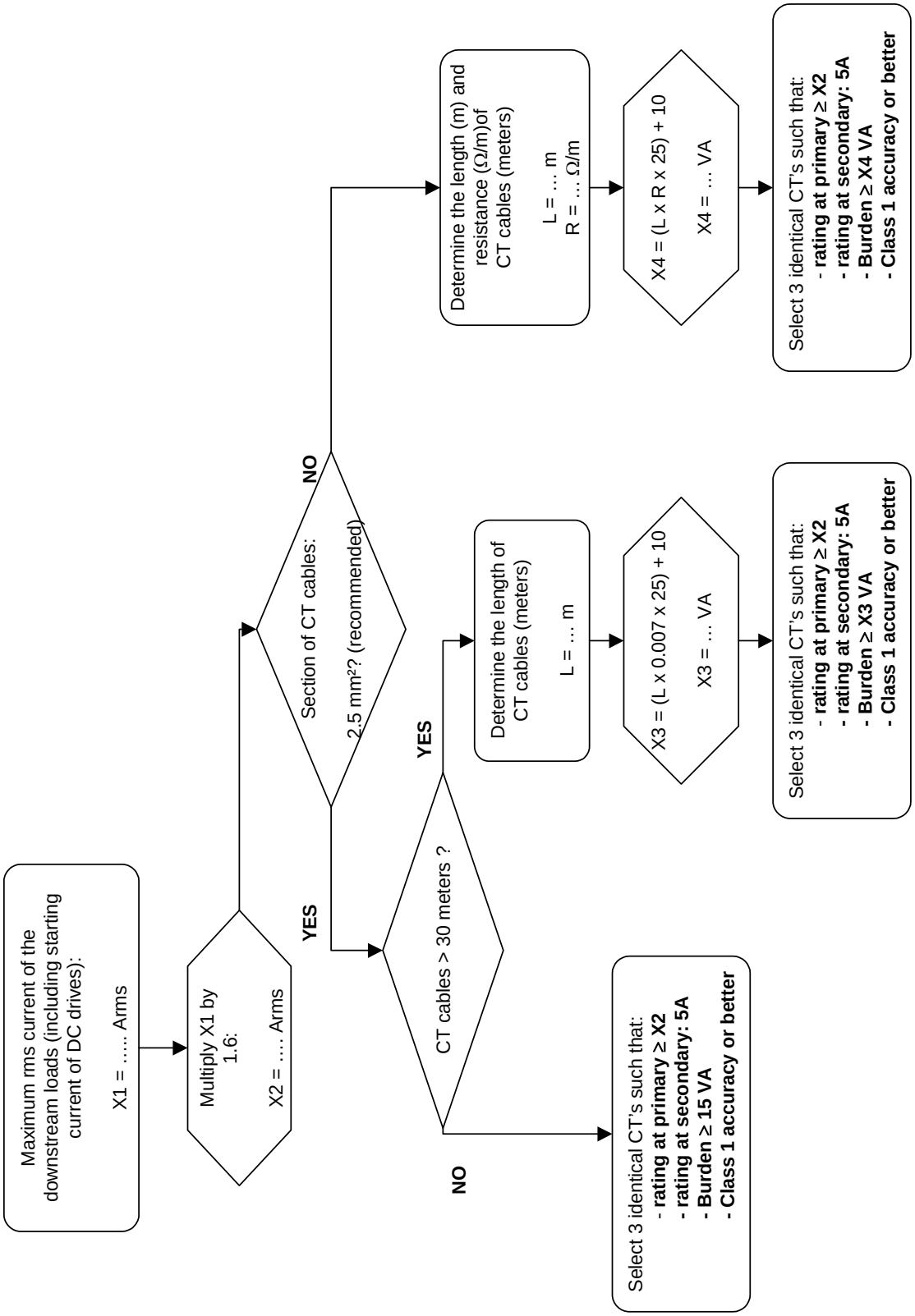


Figure 7.12. Flow chart for CT determination

7.8. Current transformer installation

7.8.1. Basic rules for correct CT installation

The location of the CTs is critical to ensure the proper operation of the active filter. The CTs are the "eyes" of the filter and it will react in accordance with the information supplied by them.

WARNING:	**Special care has to be taken for the connection and location of the CTs: wrong CT installation is the most common source of problems found at the commissioning stage.**

By default, the PQFI active filter is provided with CT terminals that are not shorted. A set of shorting plugs is provided with the filter. They should always be kept with the filter and accessible for service engineers.

WARNING:	**When connecting the CTs to the PQFI, the secondaries of the CTs have to be shorted. Failure to do so may result in CT explosion and consequent damage to the installation.**

The basic rules for successful CT installation are given next (Cf. Figure 7.13.):

- The three filter CTs have to be positioned for closed loop control, i.e. the CT must monitor the load current and the filter current. In some cases, summation CTs may be needed to fulfill the closed loop requirement (Cf. examples further down this section).
- The CTs must be positioned in the correct direction around the power cable: the K (P1) side should be in the direction of the supply and the L (P2) side should be in the direction of the load.
- Each CT must have its own guard circuit, i.e. one terminal of each CTs secondary terminals (k (S1) or l (S2)) should be earthed. Once a terminal is chosen (e.g. k-terminal), the same terminal should be earthed for all the CTs.
- The CT monitoring a phase should be connected to the filter terminal dedicated to the same phase. In practice this means that:
  - The k (S1) terminal of the line 1 CT (L1, Red, U) must be connected to terminal X21-1 of the filter.
  - The l (S2) terminal of the line 1 CT (L1, Red, U) must be connected to terminal X21-2 of the filter.
  - The k (S1) terminal of the line 2 CT (L2, Yellow, V) must be connected to terminal X21-3 of the filter.
  - The l (S2) terminal of the line 2 CT (L2, Yellow, V) must be connected to terminal X21-4 of the filter.
  - The k (S1) terminal of the line 3 CT (L3, Blue, W) must be connected to terminal X21-5 of the filter.
  - The l (S2) terminal of the line 3 CT (L3, Blue, W) must be connected to terminal X21-6 of the filter.
- The CT connection terminal X21 is located at the bottom right part of the filter (Cf. Figure 7.14.)

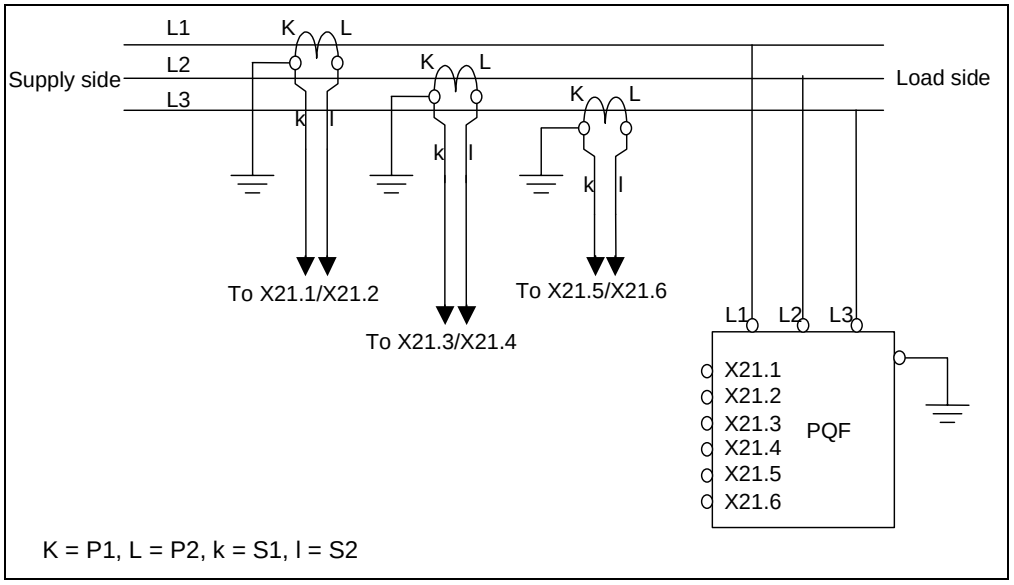


Figure 7.13. Basic CT connection example

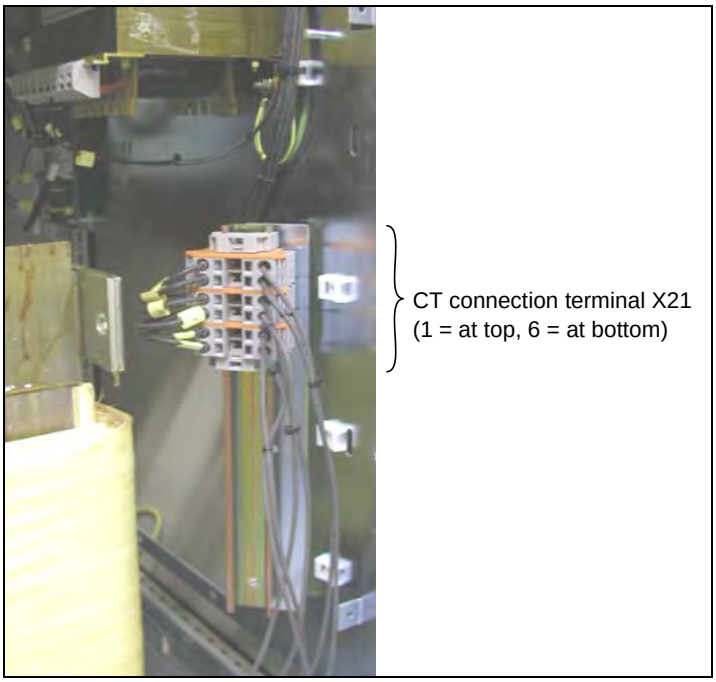


Figure 7.14. Location of the CT connection terminal X21 in the PQFI

The terminal block X21 can handle control cable wiring with sections from 2.5 mm² to 10 mm².

In addition to the 6-wire CT cabling approach shown in Figure 7.13. above, a 4-wire approach may also be used. This approach is illustrated in Figure 7.15. In this case the CT secondary terminal to which the guard circuit is connected is interconnected between the CTs and also on the filter terminal X21. One common cable is used for this terminal. Note that this cable must be able to withstand three times the secondary current rating of the CTs.

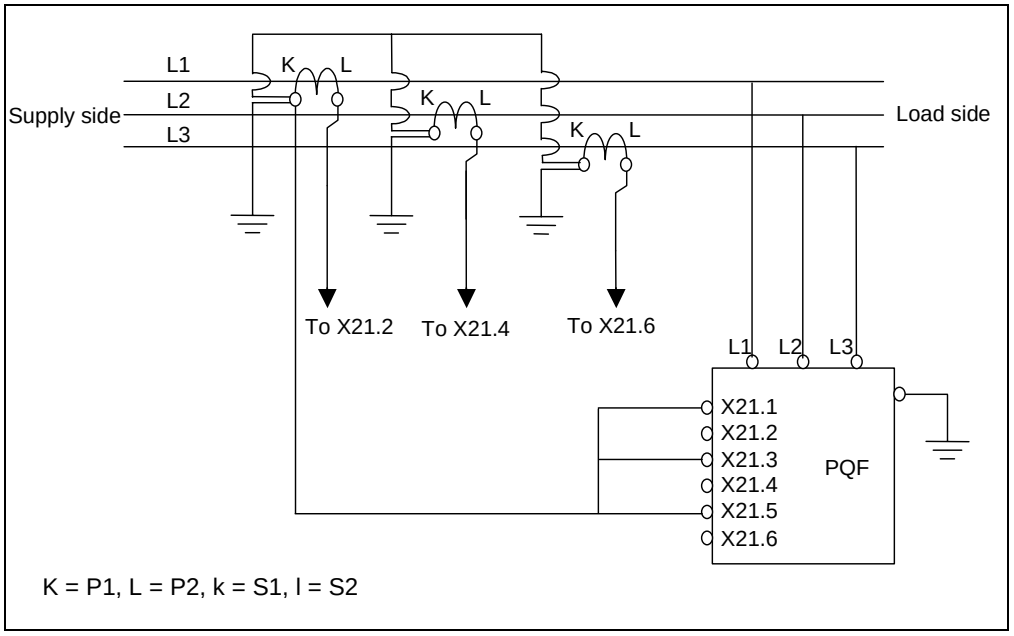


Figure 7.15. *Four wire CT wiring approach that may be used with the PQFI active filter*

In the next sections typical circuit topologies and appropriate corresponding CT locations are described. The cases considered are:

Case 1: Global compensation – one feeding transformer.
Case 2: Individual compensation – one feeding transformer.
Case 3: Global compensation – transformer busbar not accessible.
Case 4: Two independent feeding transformers.
Case 5: Back-up generator.
Case 6: CT connection location when plain capacitors are present in the network.

7.8.2. CT locations for the case of global compensation – one feeding transformer

This case handles the most frequent configuration: one transformer feeds several non-linear loads. The active filter is installed at a central position and filters the harmonic currents of all the loads. This configuration is shown in Figure 7.16.

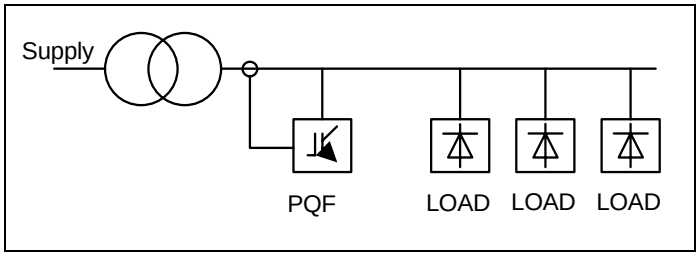


Figure 7.16. CT connections for the case of global compensation – one feeding transformer

The connection method for the three CTs to the filter is described in Section 7.8.1.

7.8.3. CT locations for the case of individual compensation – one feeding transformer

Instead of installing one active filter in a central position, it is also possible to connect the active filter and its CTs so that it compensates one particular load only. In the example hereafter, the active filter PQF is connected to compensate load 1 only. It does not see load 2.

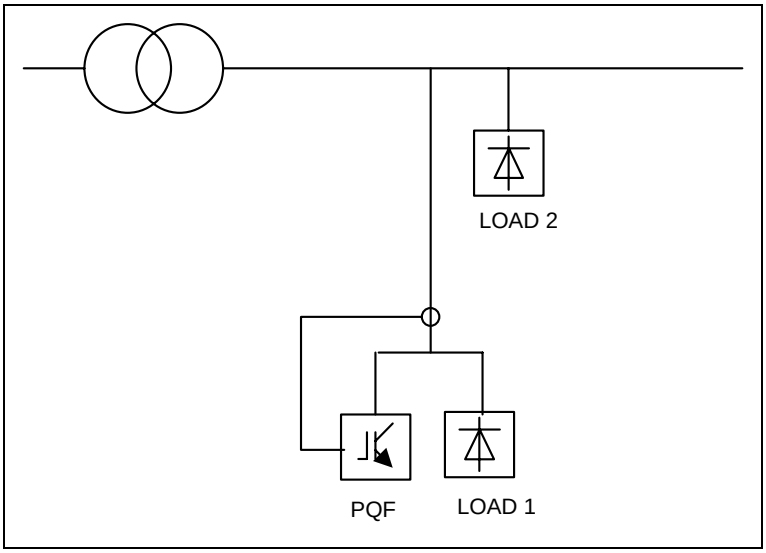


Figure 7.17. CT connections for the case of individual compensation – one feeding transformer

The connection method for the three CTs to the active filter is described in Section 7.8.1.

7.8.4. CT locations for the case of global compensation – transformer busbar not accessible

The active filter is required to filter the loads of side A and side B (Cf. Figure 7.18.) but the transformer busbar is not accessible. As a result, the CTs cannot be installed in a central position.

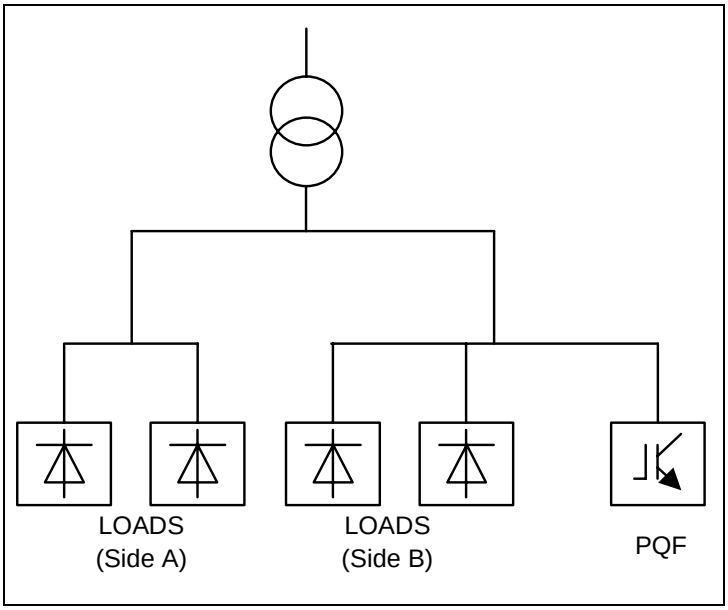


Figure 7.18. Case of multiple loads and transformer busbar not accessible

For this configuration, three CTs (one per phase) have to be installed on side A and on side B (i.e. in total 6 CTs). Those CTs will then feed 3 summation CTs (one per phase) that are connected to the active filter. This CT topology is represented in Figure 7.19.

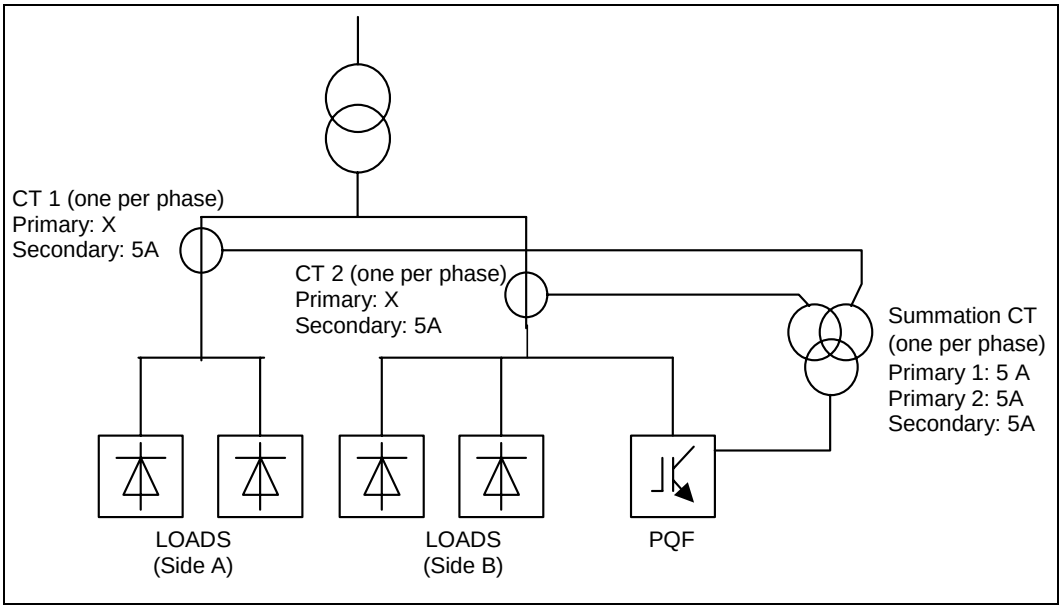


Figure 7.19. CT connections for the case of multiple loads and transformer busbar not accessible (to be done for each phase)

The CTs installed in each phase of side A et B (CT1 and CT2) must be identical (X/5A) and feed a summation CT whose secondary is 5A (5+5/5A). The summation CT is then connected to the active filter in accordance with Section 7.8.1. A total of 3 summation CTs (one per phase) must be used.

The CT ratio to be programmed in the filter is: 2X/5 where X is the primary side current rating of the main measurement CTs (CT1 and CT2 in Figure 7.19. above).

The connection diagram of the main measurement CTs to the summation CTs and from the summation CTs to the filter terminals is represented in Figure 7.20. This diagram has to be implemented for the three phases.

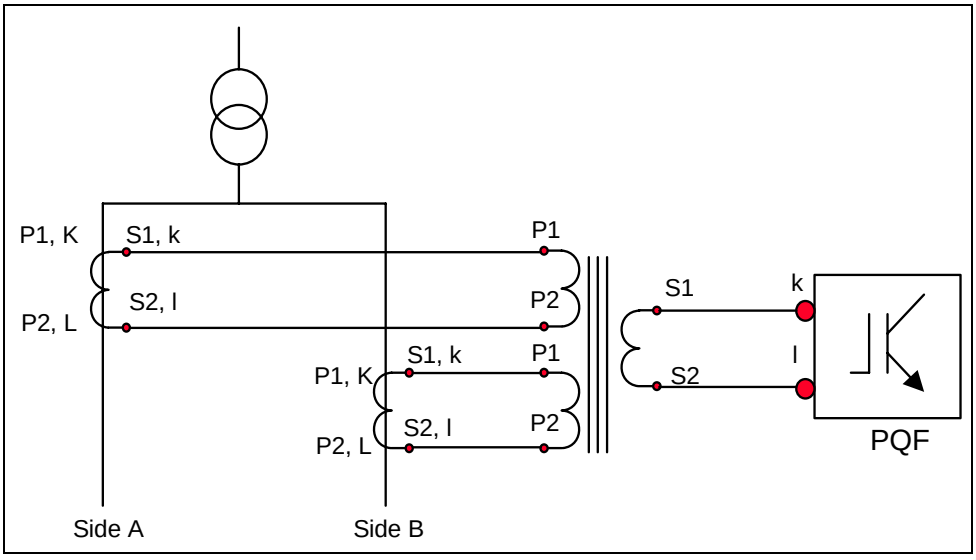


Figure 7.20. Connections between CT1, CT2 , the summation CT and the PQF for one phase

7.8.5. CT locations for the case of two independent feeding transformers

Two independent transformers (the tie is normally open) feed two different sets of loads. One active filter is connected to each LV busbar. The system may also have to work in degraded mode, i.e. the tie is closed and only one transformer feeds the whole LV system. This case is illustrated in Figure 7.21.

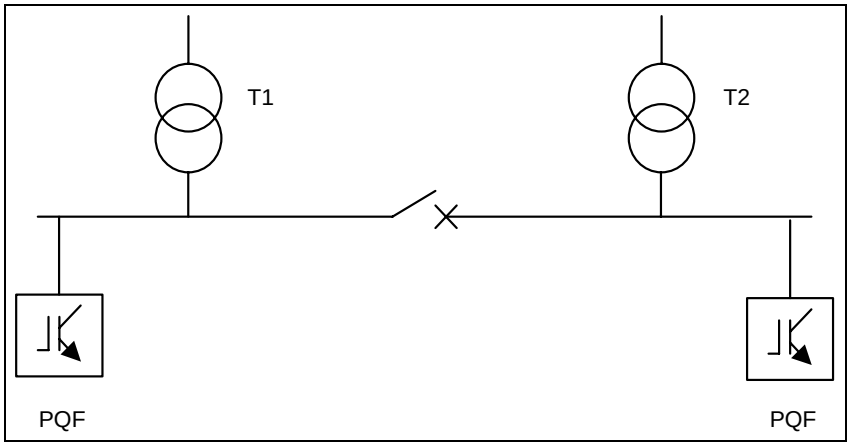


Figure 7.21. Case of two independent feeding transformers

By connecting the CTs as described in Figure 7.22. it is possible to filter the harmonics and to correct the power factor under the aforementioned conditions.

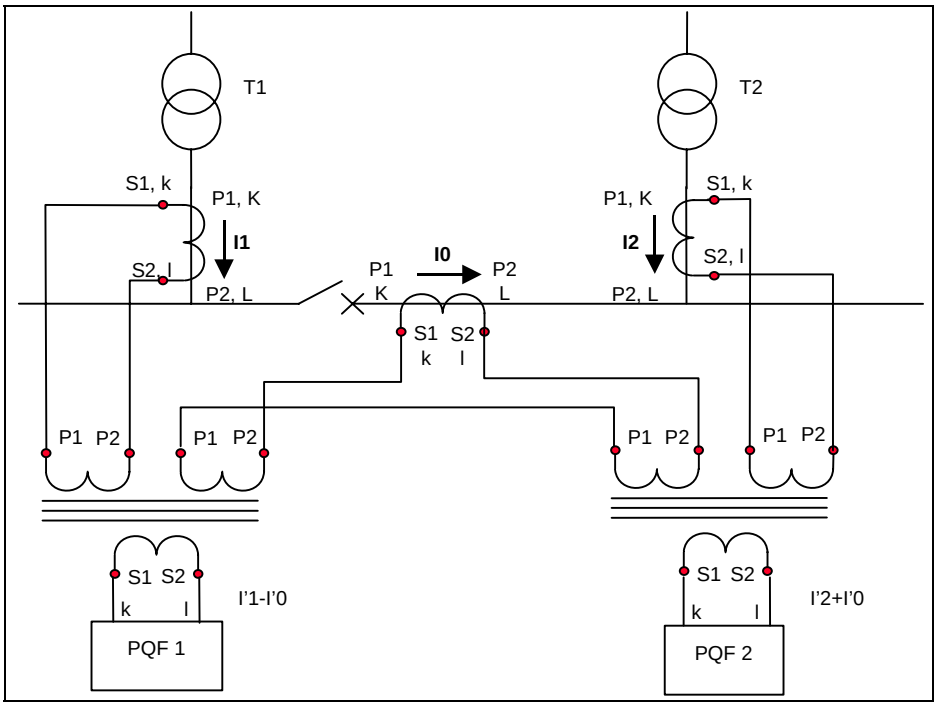


Figure 7.22. CT connections for the case of two independent transformers (to be done for each phase)

For each phase, 3 CTs must be installed:
- one to measure I1
- one to measure I2
- one to measure I0.

The CTs must be identical: X/5 A.
CT I1 and CT I0 feed a summation CT which is connected to PQF1.
CT I2 and CT I0 feed a summation CT which is connected to PQF2.

The summation CTs must be rated 5+5 / 5 A.

Condition 1: the tie is open.
The filter PQF1 sees I1 and the filter PQF2 sees I2 (I0 = 0). The two transformers work independently and the total current to be compensated is I1 + I2.

Condition 2: the tie is closed but both transformers feed the loads.
In this configuration, the filter PQF1 sees (I1-I0) and the filter PQF2 sees (I2+I0). The total current seen by the two filters is I1 + I2.

Condition 3: the tie is closed but only one transformer feeds the loads (degraded mode).
If only T1 feeds the loads with the tie closed, PQF1 sees (I1-I0) and PQF2 sees I0 (I2 is zero). If only T2 feeds the load, I1 will be zero.

Please note that the above described connection must be done for each phase. The CT ratio to be programmed in the filter is: 2·X/5.

7.8.6. CT locations for the case of feeding transformer and backup generator

Many installations are fitted with back up generators to ensure the proper operation of the installation in case of a mains supply outage.

A typical configuration is given in Figure 7.23.

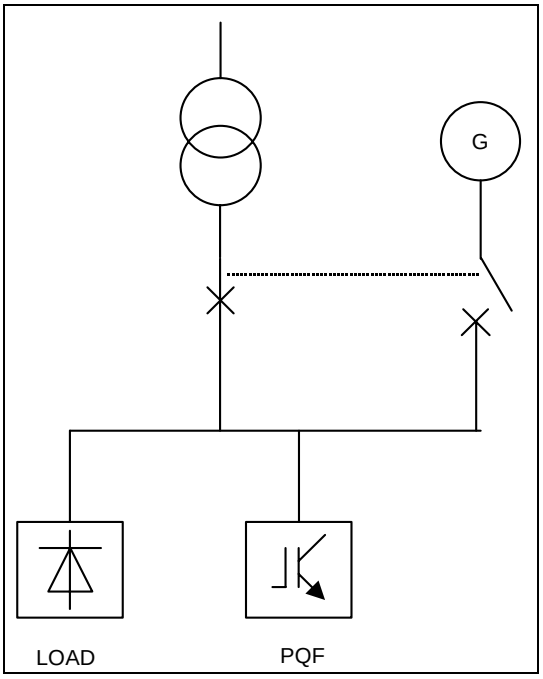


Figure 7.23. Single line diagram of an installation with a backup generator

The CT connection must be such that the active filter works whatever the type of supply: generator or transformer-MV network.

For each phase, one CT is installed in the transformer branch and one in the generator branch. Those two CTs must be identical (X / 5 A) and must be connected to a summation CT rated 5+5 / 5 A.

The CT ratio to be programmed in the filter is: 2·X/5. Figure 7.24. gives the corresponding connection diagram per phase.

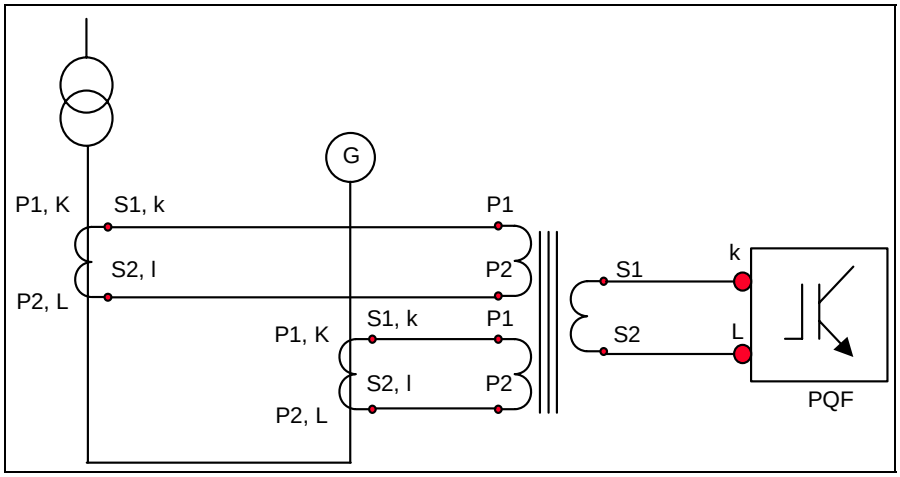


Figure 7.24. CT connections for the case of a feeding transformer with backup generator (to be done for each phase)

7.8.7. CT connections for the case that plain capacitors are present in the network

In some installations plain capacitors (without detuning reactors) coexist with harmonic producing loads. This situation is not advisable given that the harmonics impose a very high stress on the capacitors as a result of which their lifetime is greatly reduced. Moreover, due to the resonance condition created (by the capacitor and the predominantly inductive transformer and line impedance) high voltage distortion may be introduced which can cause other equipment in the plant to malfunction. Also a resonance amplifies the harmonic current created by the loads as a result of which the feeders and transformers may be overloaded. For these reasons ABB suggests to replace the plain capacitor by a detuned capacitor bank when harmonics are present in the network.

In installations where plain capacitors are present and cannot be changed to detuned capacitor banks, the connection diagram of Figure 7.25. is recommended as opposed to the diagram shown in Figure 7.26.

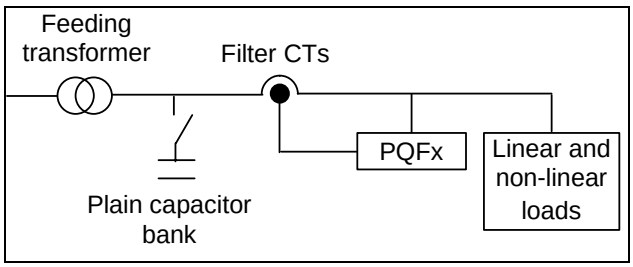


Figure 7.25. Recommended connection diagram for PQFI and plain capacitors

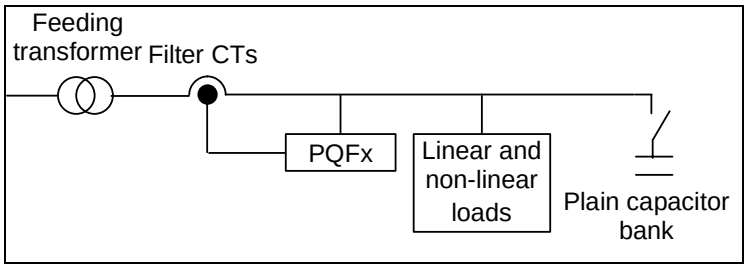


Figure 7.26. Alternative for Figure 7.25. when the connection approach of Figure 7.25. cannot be implemented (solution to be avoided)

When it is not possible to implement the connection diagram shown in Figure 7.25. the alternative diagram given in Figure 7.26. may be used.

NOTE:	**In order to be able to operate in installations where plain capacitors are present, the PQF active filters incorporate a dedicated advanced SDP control algorithm. This algorithm will, if needed, stop filtering harmonics momentarily to optimize the harmonic control parameters for the changing network conditions (e.g. due o capacitor bank switching). As a result, the overall filtering efficiency of the filter may be lower when plain capacitors are present in the network. Therefore ABB advises for best performance to always replace plain capacitor banks by appropriately sized detuned capacitor banks in installations where harmonics are present and where filtering devices are used.**

7.8.8. CT connections for the case that detuned capacitor banks are installed adjacent but downstream to the active filter CTs

In some installations appropriately detuned capacitor banks are installed adjacent to the active filter units, but they are connected downstream of the filter CTs. If this is the case and if background distortion is present on the supply network then it is recommended to connect the detuned capacitor banks physically upstream of the CT connections (Cf. Figure 7.25.) When this is not possible a CT arrangement can be made such that the current flowing into the detuned capacitor bank is subtracted from the total current measured by the filtering CTs. This is illustrated in Figure 7.26.

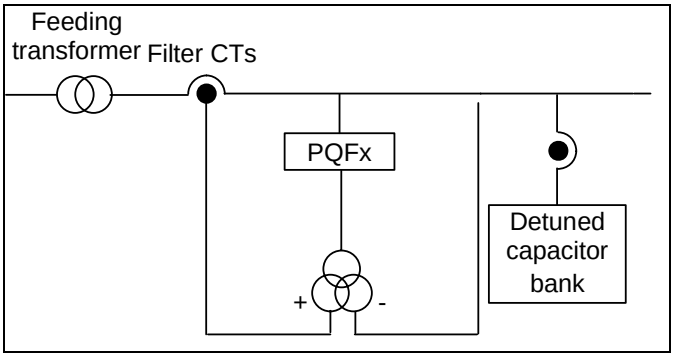


Figure 7.27. Alternative connection approach for installations where detuned capacitor banks are installed adjacent to the active filter but downstream to the active filter CTs

By using the approach shown in Figure 7.27. it is ensured that the filter performance remains optimal without the loss of filter resources when background distortion is present on the supply network.

7.9. Electrical interconnection of PQFI cubicles

This section explains how to electrically interconnect different PQFI units.

Figure 7.28. shows schematically which interconnections have to be made between two filter units.

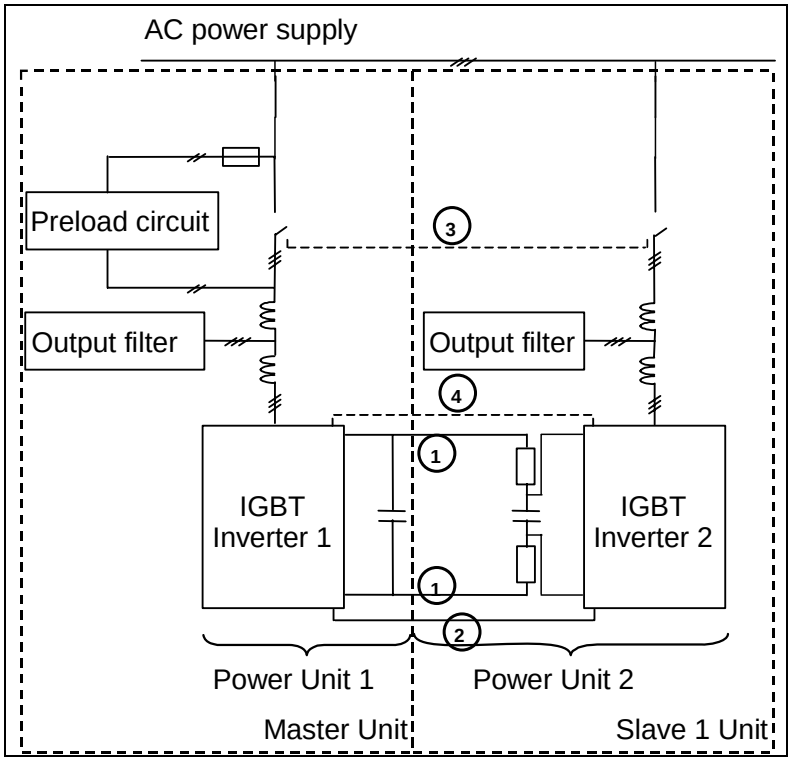


Figure 7.28. *Overview of the connections to be made between two filter units*

The interconnection description is given in Table 7.10.

Table 7.10. Interconnections between two filter units

Item	Description
1	DC link interconnection
2	Earth interconnection
3	Digital control interconnection flat cable
4	Optical link between different IGBT module domino boards

Six steps have to be followed to electrically interconnect a new PQFI unit with an existing filter. They are outlined in the next six paragraphs.

7.9.1. Mechanical interconnection

Ensure that the new unit is mechanically interconnected with the existing filter. For guidelines on how to mechanically interconnect add-on filter units, please refer to Section 6.5.

7.9.2. DC bus interconnection

Interconnect the DC bus link between the units (Figure 7.28. item 1)

WARNING:	**Inversing the polarity of the DC bus interlink cables may destruct the active filter. Be very careful about the polarity when connecting the DC bus.**

Each new slave cubicle comes from the factory with two power cables that are connected through DC bus fuses to the plus and minus poles of its DC bus. The cables coming from the new slave unit must be routed to the power stage of the existing filter and then fixed to this one's DC busbar system.

- Routing to a master unit

  Figure 7.29. shows the DC busbar system of a master unit to which the DC link cables of the next cubicle have to be connected. The positive pole of the DC bus has to be routed to the front bar whereas the negative pole of the DC bus has to be routed to the rear bar. The cabling must be as short as possible and both cables must be tied together.

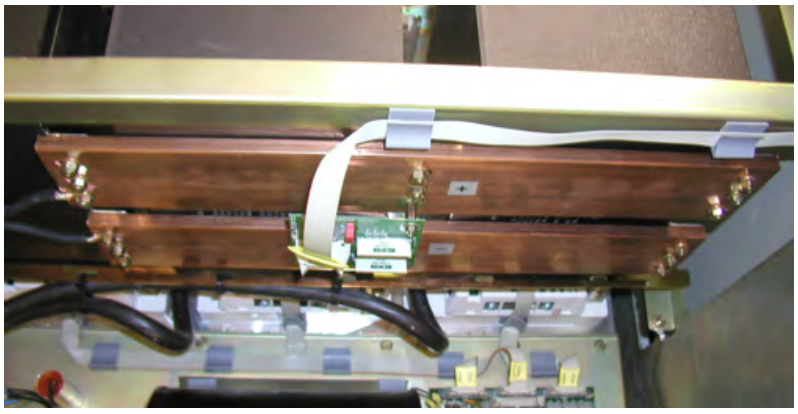


Figure 7.29. *DC busbar system of a PQFI master unit*

The DC interlink fixation holes (Cf. Figure 7.29.) require bolts of type M8 with corresponding washers. The bolts joining the DC link cable lugs and the DC link terminals on the capacitors have to be fixed with a torque equal to 20 Nm.

Figure 7.30. gives an example of how to route the DC link cables in the power stage of the master unit.

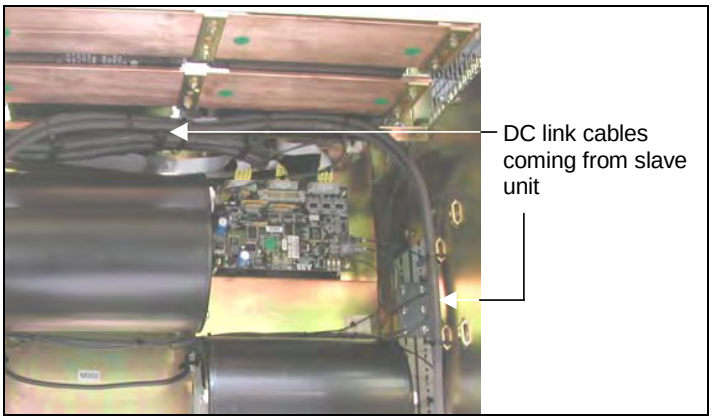


Figure 7.30. DC link connection in the master unit for master-slave arrangements

- Routing to a slave unit

  Figure 7.31. shows the DC bus system of a slave unit to which the DC link cables of the next slave unit have to be connected. The difference between the master and the slave unit is the presence of the DC link fuses that are incorporated in each slave unit cubicle.

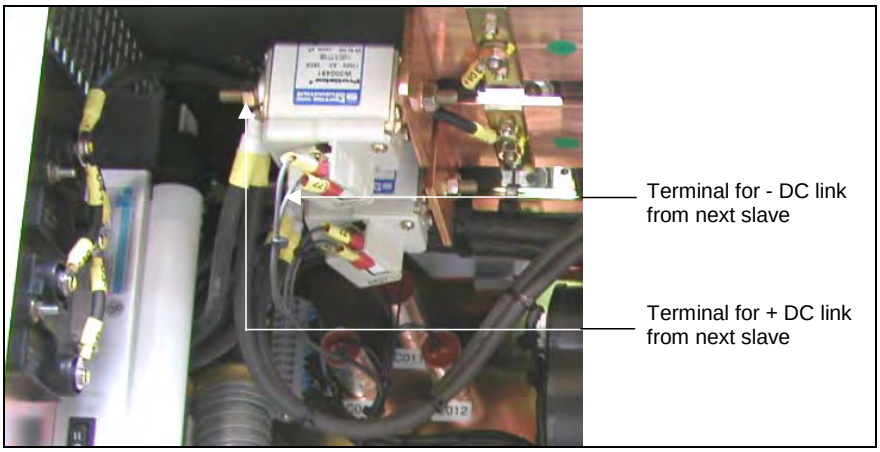


Figure 7.31. DC bus system of a PQFI slave unit

The positive pole of the next slave DC bus has to be routed to the front pole on the DC link fuse terminal. The negative pole of the next slave DC bus has to be routed to the rear pole on to the DC link fuse terminal. The cabling must be as short as possible and both cables must be tied together.

The bolts (Cf. Figure 7.31.) joining the DC link cables and the DC link fuse are of type M8 with corresponding washers and have to be fixed with a torque equal to 13.5 Nm.

Please note the following cable numbering convention for the DC bus interlink:

Table 7.11. *Cable numbering convention for DC bus interlink cables*

DC link cable identification (coming from slave)	Corresponding to the slave's DC bus polarity
01-	Minus
02+	Plus

Make sure not to inverse the DC interlink connections from one cubicle to another!

7.9.3. Earth points interconnection

Interconnect the earth points of the different units (Cf. Figure 7.28. item 2) and earth the new cubicle individually. Refer to Section 7.4. for more information on this topic.

7.9.4. Digital control flat cable interconnection

Interconnect the digital control connection flat cable (Cf. Figure 7.28. item 3)

- The digital control interconnection flat cable is by default connected to the new unt's distribution board (connector X7). Refer to Figure 7.32.

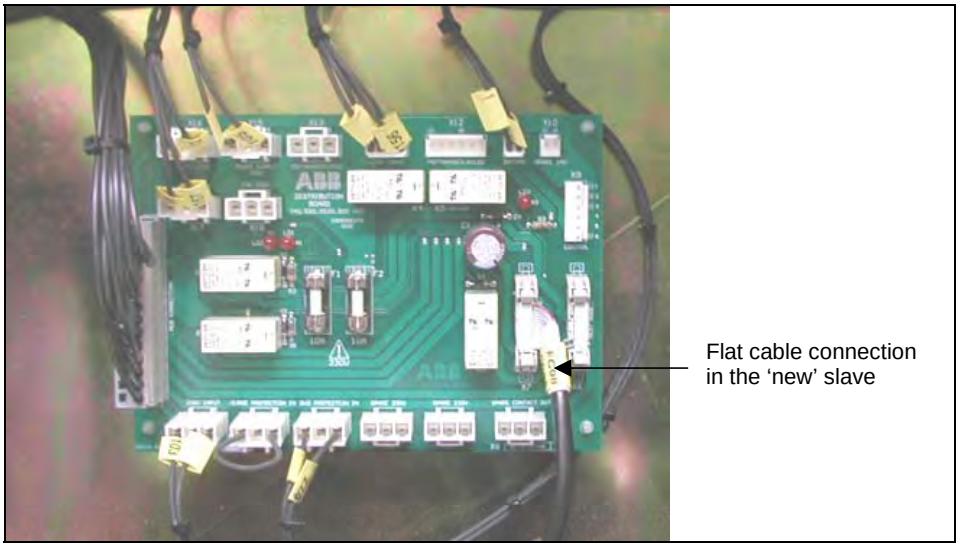


Figure 7.32. Digital control flat cable connection in PQFI slave unit

- Remove the bus end connector from the previous unit's distribution board (connector X8).
- Plug the bus end connector into the new unit's distribution board (connector X8). This is shown in Figure 7.33. below.

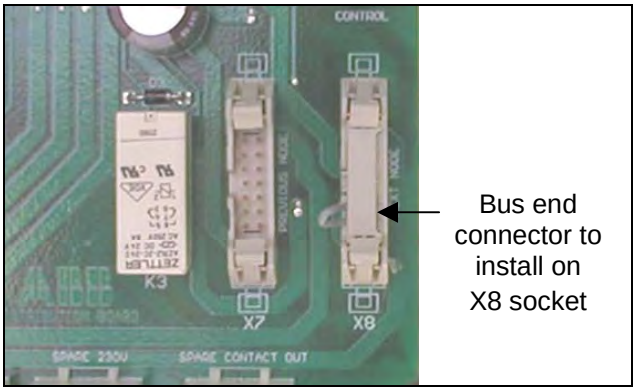


Figure 7.33. Bus end connector illustration

- Secure the interconnection flat cable properly and plug its free end in the previous unit's distribution board (connector X8). The flat cable plugs cannot be inserted wrongly in their sockets. Figure 7.34. shows flat cable routing in the master unit to the slave unit.

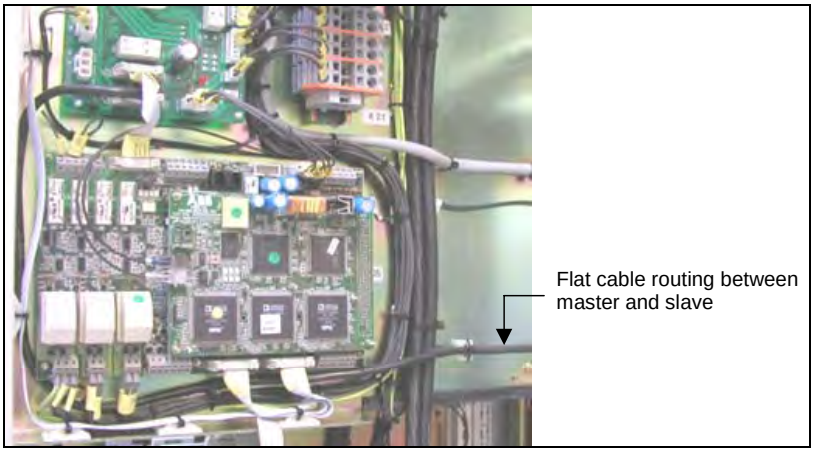


Figure 7.34. Flat cable routing from master to slave unit

The resulting flat cable configuration is shown in Figure 7.35. More information on the distribution board is given in Section 5.6.1.

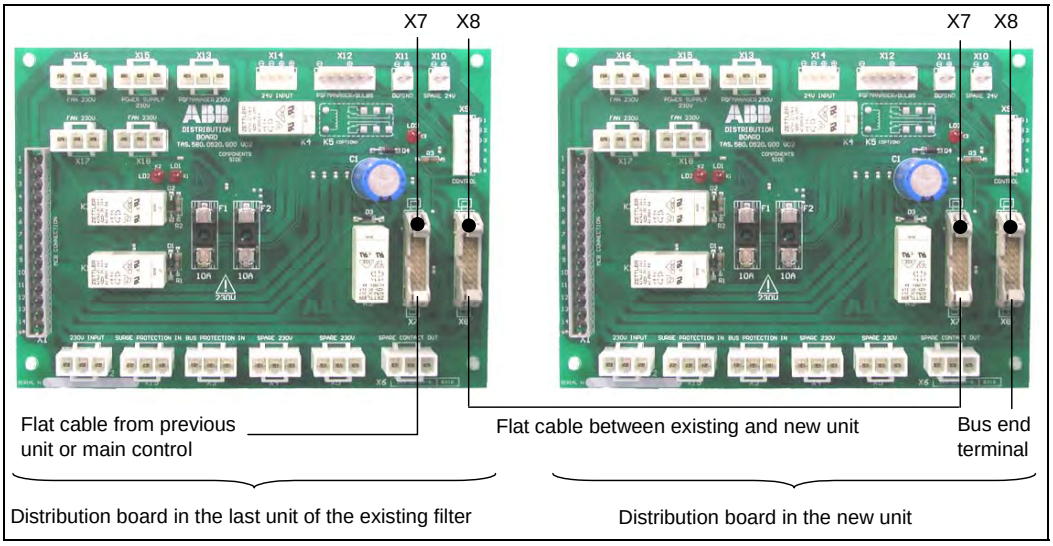


Figure 7.35. *Interconnection of the digital control connection flat cable between two units*

7.9.5. Optical link interconnection

In order for the IGBT control commands to be sent to the new unit, the optical loop of the existing filter has to be extended to include the domino board of the new unit. Figure 7.36. shows the principle of the optical loop communication circuit.

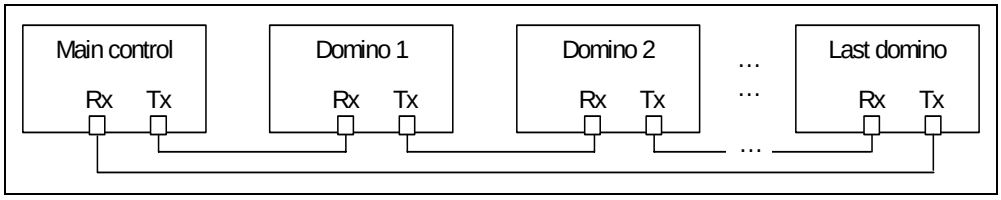


Figure 7.36. Principle of the optical loop communication circuit

An optical fiber must always be connected from a Tx terminal socket (light gray) of the main control or of a domino to the Rx terminal socket (dark gray) of the next domino (or of the master if last domino in the row).

WARNING:	**Optical fibers are very flexible but a minimum bending radius of 35 mm must be respected. They should not be tightened too firmly. Failure to do so may lead to damage to the optical fiber and consequent filter malfunctioning.**

The new unit comes with an adequate length of optical fiber that is already plugged in into the light gray Tx (Transmit) terminal of the new unit's domino board.

In order to extend the optical loop to include the new unit, the optical link configuration given in Figure 7.37. has to be implemented:

- On the existing last unit, ensure that an optical fiber is plugged in into the light gray Tx (Transmit) socket. Route this fiber to the dark gray Rx (Receive) socket of the domino board in the new unit. To do this it may be necessary to unplug the other end of the fiber from the main control board.

- On the last unit, unroll the feedback optical fiber connected to the light gray Tx terminal of the domino board and route it back to the master unit.
- Plug the unrolled feedback optical fiber firmly into the dark gray Rx (Receive) socket of the master unit main controller board.
- Ensure that the optical fibers are properly fixed. Unnecessary long optical fibers can be looped as shown in Figure 7.38.

More information on the domino board is given in Section 5.6.2.

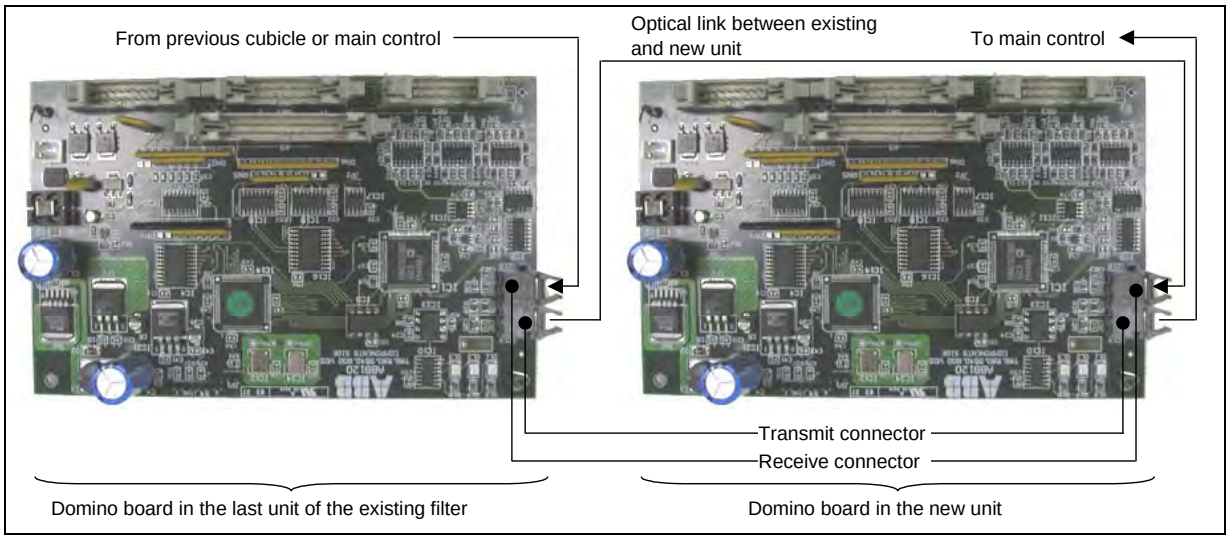


Figure 7.37. Interconnection of the optical link between two units

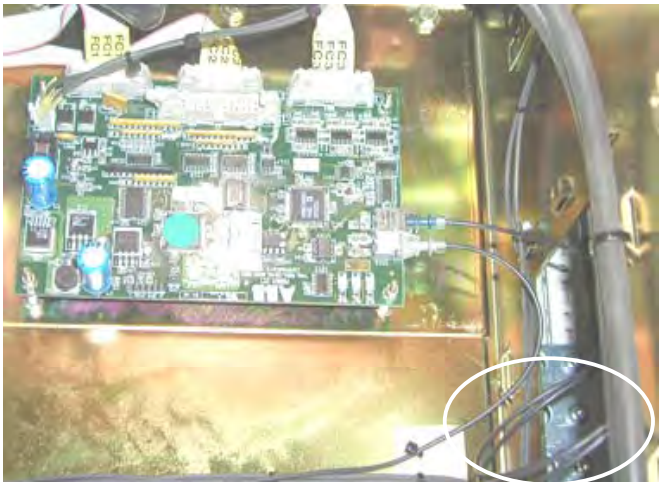


Figure 7.38. Looping of the not needed lengths of optical fiber

7.9.6. Connection of the power stage to the supply

As a final step in the interconnection process, the power stage of the new unit has to be connected to the supply. When the filter has an optional common cable entry cubicle, the power cables have to be routed in the base frame or in a duct under the filter to the common cable entry cubicle where they can be connected on to the central bus bar system. When the filter does not have an optional common cable entry cubicle, the same connection approach as used for the other filter units should be adopted. More information on how to connect a PQFI cubicle to the power supply can be found in Section 7.6.

WARNING:	**Make sure that the phase rotation of the power cable connection is clockwise at the filter terminals and that the L1, L2 and L3 terminal in each cubicle is connected to the same phase for all cubicles. Failure to do so may lead to the filter being damaged upon startup.**

WARNING:	**Once a new cubicle has been added to a filter, the filter controller has to be set up accordingly. More specifically, the commissioning engineer has to specify with the PQF-Manager user interface that a new unit has been added to the system and also the nominal current rating of the new unit.**

If more than one unit is added, it is recommended to first finish the hardware modifications and then set up the controller accordingly. More information on how to change the filter controller unit settings can be found in Section 8.7.2.2. and Section 10.4.

7.10. Electrical connections to the PQF-Manager user interface

The PQF-Manager is the user interface between the outside world and the filter controller. Depending on the user requirements, less or more electrical connections have to be made to it. Figure 7.39. shows the rear side layout of the PQF-Manager.

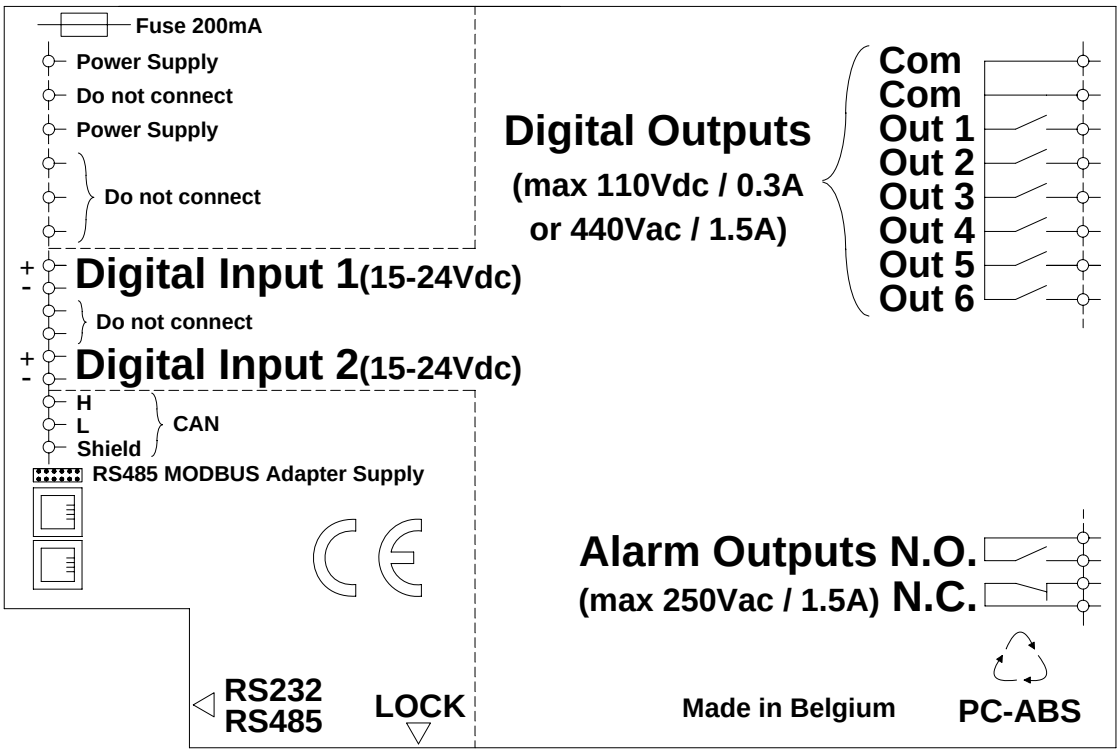


Figure 7.39. Rear side layout of the PQF-Manager user interface

When looking at the PQF-Manager from the rear, on the left side can be found a 15-pole terminal block and on the right side an 8 pole terminal block (top-right) and a 4-pole terminal block (bottom right). In order to make control connections to any of these terminals, the following procedure has to be applied:

1. Push the lever of the connector backwards with a screwdriver.
2. Insert the control wires (from 0.75 mm² to 2.5 mm² single core without cable shoe or max. 1.5 mm² for multi-strand wire) in the corresponding connection hole while keeping the pressure on the lever.
3. Release the screwdriver.
4. The wire is then properly connected.

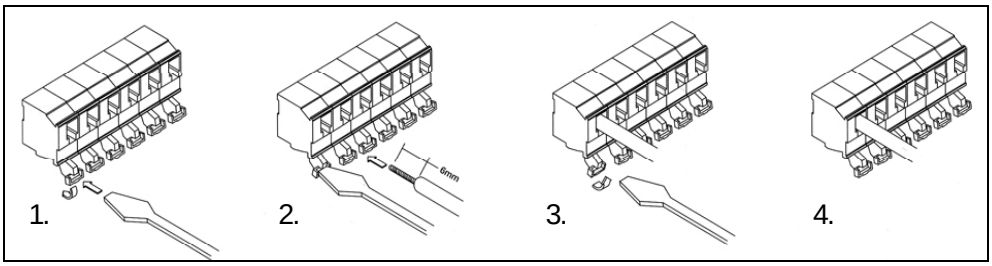


Figure 7.40. PQF-Manager lead connections

The remainder of this section gives examples of how to cable different functions, i.e.
Case 1: Cabling of remote control functionality.
Case 2: Cabling of alarm functionality.
Case 3: Cabling of warning functionality.
Case 4: Cabling of the digital output contacts to monitor other filter operation modes than warnings and alarms.
Case 5: Cabling of main/auxiliary control functionality.
Case 6: Implementation of local start/stop buttons.

WARNING:	**Before cabling any of the circuits discussed below, switch off the power supply to the filter. When the filter has already been installed on site, this is preferably done by opening the protection located just upstream of the filter. Alternatively, the auxiliary circuit fuses may be removed. Refer to Figure 5.8. to locate the fuse holder for the auxiliary fuses.**

7.10.1. Cabling of remote control functionality

The PQFI has the possibility to be controlled by remote control. An example of this approach is a drive that is switched on at a location and which automatically gives a start command to the filter. When the drive is then stopped, the drive sends automatically a stop command to the filter too. This section gives an example of how the cabling has to be done on the filter side.

Any of the two digital inputs on the PQF-Manager (Cf. Figure 7.39.) can be used to cable the remote control functionality. The electrical requirements of the digital inputs are given in Table 14.1. (Filter characteristics section). Figure 7.41. gives an example of how to implement the remote control functionality on Digital Input 1.

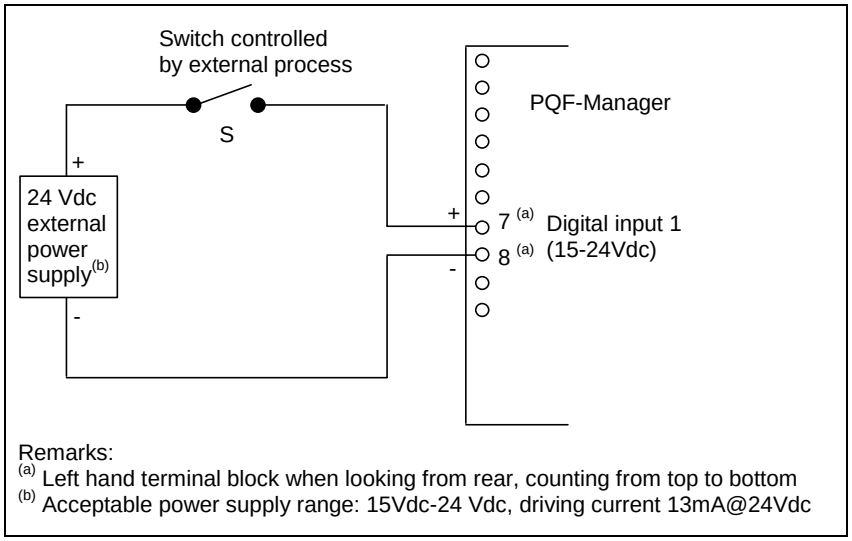


Figure 7.41. Implementation of remote control functionality on Digital Input 1 of the PQF-Manager

WARNING:	**If a function is assigned to a digital input, the same function must never be assigned to the other digital input. Otherwise the filter may behave erratically.**

Once the cabling has been finished, the power to the filter may be restored. Then, the PQF-Manager has to be used to associate the remote control functionality with Digital Input 1. This is done by going to the digital input setup menu and selecting 'Remote ON' for digital input 1. When this is done the filter will switch on when the switch S shown in Figure 7.41. is closed and the filter will switch off when the switch S is opened. Refer to Section 8.7.1.2. for guidelines on how to navigate to the digital input setup menu.

Remarks:

- When the remote control functionality has been activated this function has priority over a local start/stop command. When the local command has to be given, deactivate first the remote control functionality by navigating with the PQF-Manager to the digital input setup menu and setting the digital input considered to 'Disabled'.
- The remote control functionality can also be implemented on the Digital Input 2.

7.10.2. Cabling of alarm functionality

An alarm represents an error condition that makes the filter trip. Two types of error conditions exist:

- External error condition: These are conditions that are imposed on to the filter from the outside world. Consider the example of the network voltage that increases well above the filter safe operation level for a certain time. In that case the filter will disconnect from the network reporting a network overvoltage. When the network voltage returns to a normal level however, the filter will reconnect to the network and continue filtering providing that the same problem does not occur systematically.
- Internal error conditions: These are error conditions that are reported by internal controls of the filter itself. They may indicate an internal filter problem.

Two ways to cable the alarm functionality exist:

- The PQF-Manager alarm outputs located at the bottom right side (when looking at the PQF-Manager from the rear) are triggered (return to default position) whenever:
  - a permanent internal or external error condition is present. In order to avoid transient switching of the contacts, the error has to be present for 3 minutes before the alarm relays are activated.
  - no power is supplied to the filter.

Table 7.14. further down this section gives an overview of all the error conditions that lead to the alarm contact being triggered. Two alarm contacts exist, one being of type 'normally open' (NO) and the other of type 'normally closed' (NC).

The alarm contacts are:
- free of potential,
- rated for a maximum of 250 Vac/1.5 A or 30 Vdc/5 A. When using a 24 Vdc power supply, minimum current of 25 mA should be drawn by the circuit connected to the alarm contact.

Table 7.12. shows the status of the alarm contacts for different operation modes of the filter.

Table 7.12. Status of the alarm contacts for different filter operation modes

Filter state	Normally open alarm contact state	Normally closed alarm contact state
Disconnected from the supply	Open	Closed
Filter (auxiliaries) connected to the supply, no error present	Closed	Open
Filter (auxiliaries) connected to the supply, error appears	Opens when error present for 3 minutes Otherwise, remains closed	Closes when error present for 3 minutes Otherwise, remains open
Filter (auxiliaries) connected to the supply, error disappears	When open before, closes when error disappears When closed before, remains closed	When closed before, opens when error disappears When open before, remains open

Figure 7.42. shows an example of an alarm contact cabling scheme using the NC alarm contact. Using this scheme the bulb B will be on when the power supply to the filter is interrupted or the filter trips due to an error. Otherwise the bulb will be off.

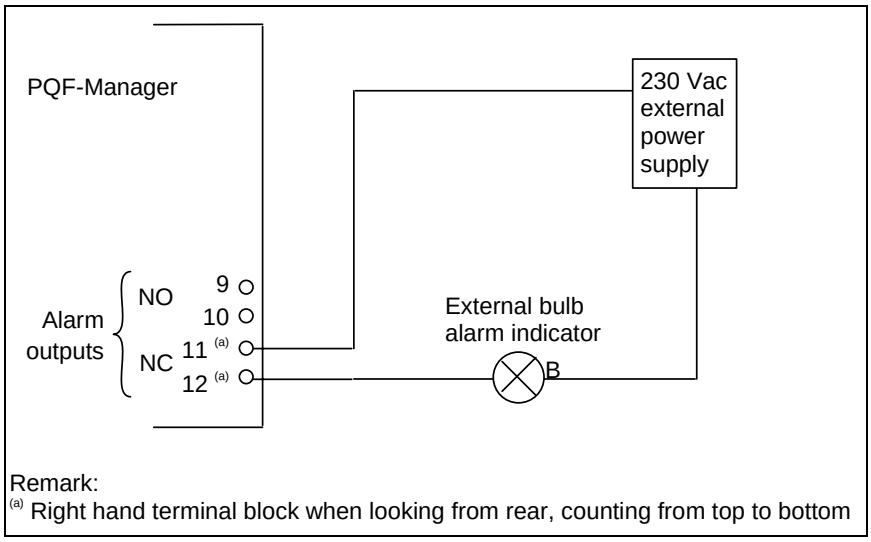


Figure 7.42. Alarm bulb cabling scheme using the NC alarm contact on the PQF-Manager

Figure 7.43. shows a cabling scheme using a 24 Vdc supply in conjunction with the NO alarm contact. The scheme assumes that an external digital input monitors the alarm contact of the filter. In this case the voltage applied to the digital input will be low when:
- the filter is disconnected from the supply OR
- the filter trips due to an error OR
- the external 24 Vdc power supply fails.

The voltage applied to the external digital input is high when:
- the filter is connected to the supply and is not in error AND
- the external 24 Vdc power supply is in working order.

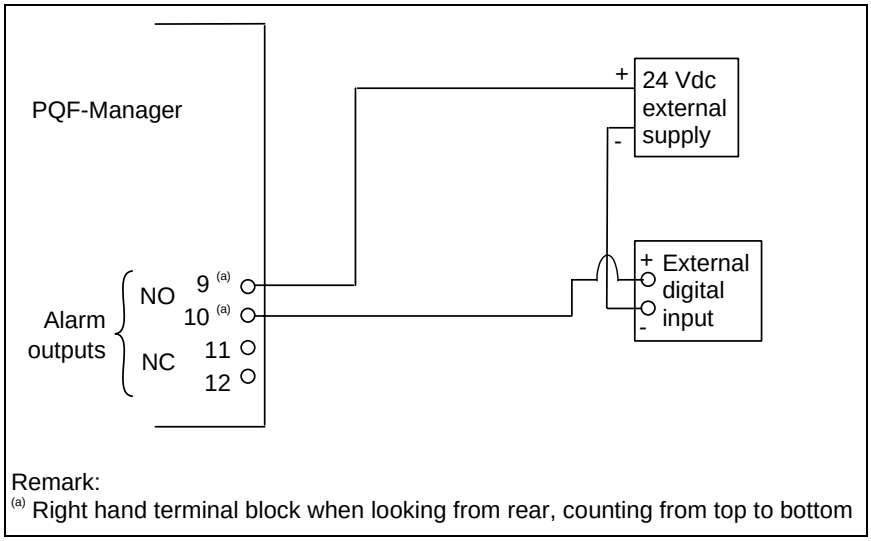


Figure 7.43. Alarm cabling example using NO alarm contact and external digital input

- A second method to implement the alarm functionality is to use the PQF-Manager's programmable digital output contacts. Use this approach when the condition for alarm is uniquely defined, e.g. an alarm has to be given only when the filter trips due to an unacceptably high network voltage or when the filter trips due to a well defined internal error. This type of alarm has to be cabled on the 8 pin terminal block situated at the top right corner when looking at the PQF-Manager from the rear (Cf. Figure 7.39.)

  The digital output contacts have a common point (cabled on contacts 1 and 2) and are of the NO-type (normally open). The contact ratings are:
  - Maximum continuous ac rating: 440 Vac/1.5 A;
  - Maximum continuous dc rating: 110 Vdc/0.3A;
  - The common is rated at 9 A/terminal, giving a total of 18 A;
  - When using a power supply of 24Vdc, a minimum current of 10 mA should be drawn by the circuit connected to the digital output contact.

  Table 7.13. shows the status of a digital output contact configured as alarm contact for different operation modes of the filter.

Table 7.13. Status of a digital output contact configured as alarm contact for different filter operation modes

Filter state	Normally open digital contact state
Disconnected from the supply	Open
Filter (auxiliaries) connected to the supply, no error present	Open
Filter (auxiliaries) connected to the supply, predefined error appears	Closes when error present for 3 minutes. Otherwise, contact remains open.
Filter (auxiliaries) connected to the supply, predefined error disappears	When closed before, opens when error disappears. When opened before, remains open.

The alarm conditions that can be assigned to a digital output are given in Table 7.14. The assignment must be made with the PQF-Manager. Any of the six digital outputs can be used to cable an alarm. A maximum of 3 alarms can be assigned to the digital outputs. Note however that by default the digital outputs have been set up for monitoring other functions than alarms (cf. Table 5.8.) Refer to Section 8.7.1.2. for guidelines on how to navigate to the digital output setup menu.

Table 7.14. List of possible alarm conditions that may trigger the alarm/digital outputs

Alarm condition	Criteria to be fulfilled before contact is activated
Supply voltage (RMS) unacceptably high	Vrms_max > 110% Vnominal
Supply voltage (RMS) unacceptably low	Vrms_min < 90% Vnominal
One of the phases of the supply is missing	Vrms_min < 60% Vnominal
Network imbalance unacceptably high	Vimbalance > 2%
Frequency variation unacceptably high	Frequency variation > 20%/s
PQFI DC bus voltage unacceptably high	Vdc > 105% Vdc_max_allowed
PQFI internal preload error	DC capacitor voltage rise too low in preload phase or the DC capacitors could not be preloaded in an acceptable time.
PQFI overcurrent fault	Internal current higher than allowed
PQFI ground fault	Internal ground current higher than allowed
PQFI IGBT fault	IGBT hardware reports internal permanent error
PQFI IGBT overtemperature	IGBT hardware reports internal overtemperature
Temperature reported by Temp. Probe 1 too high	T1 > T1_max for a minimum duration of T1_max_duration seconds
Temperature reported by Temp. Probe 2 too high	T2 > T2_max for a minimum duration of T2_max_duration seconds
Control board temperature too high	Internal control board temperature probe reports too high temperature
PQFI internal power supply fault	Internal control voltage too low or not present
PQFI control board fault	Internal control board reports an error

Remark: the alarm trigger levels cannot be changed by the user. An exception to this rule is the temperature trip settings of the two (optional) external temperature probes (Temp. Probe 1 and Temp. Probe 2). Refer to Section 8.7.1.2. for guidelines on how to navigate to the external temperature probes setup menu.

For cabling the digital output contacts as alarm contact, the same approach as shown in Figure 7.43. can be adopted. Note however that the following behavior will result:

- The voltage applied to the external monitoring device will be low when:
  - The filter is disconnected from the supply or when there is no error.

- The voltage applied to the external monitoring device will be high when:
  - The predefined error is present for the predefined time (minimum 180s) AND
  - The external 24 Vdc power supply is in working order.

The different electrical characteristics of the digital output contacts compared to the alarm contact characteristics must be respected. Note also that all digital outputs have the same common which is located at the pins 1 and 2 of the right hand terminal of the PQF-Manager (rear view, counting from top to bottom). This is clearly indicated in Figure 7.39. above.

Once the cabling has been finished, the power to the filter may be restored.

7.10.3. Cabling of warning functionality

A warning condition is a condition that can be set up by the user in such a way that if the condition is met, a digital output contact of the PQF-Manager user interface (Cf. Figure 7.39.) is closed. As an example consider a case where the user has set up an upper warning level for the network voltage. If the level measured by the filter becomes higher than the predefined warning level and this conditions remains valid for a preset time, the associated digital output will be closed. By monitoring the digital output, the customer will then know when the network voltage becomes too high and subsequently he can take appropriate action.

Note that the warning functionality is not associated with a filter trip. It only has a monitoring function. Table 7.15. describes the behavior of the digital output contact configured as warning contact for different filter operating modes.

Table 7.15. State of a digital output contact configured as warning contact for different filter operation modes

Filter state	Normally open digital contact state
Disconnected from the supply	Open
Filter (auxiliaries) connected to the supply, no warning present	Open
Filter (auxiliaries) connected to the supply, predefined warning present	Closes when warning present for predefined time Otherwise, contact remains open
Filter (auxiliaries) connected to the supply, predefined warning disappears	When closed before and warning disappears for at least the predefined time, contact opens. When closed before and warning disappears for a time smaller than predefined time, contact remains closed. Otherwise, contact remains open.

Table 7.16. gives a list of the warning conditions that can be assigned to a digital output.

Table 7.16. List of possible warning conditions that can be assigned to a digital output

Warning condition
Supply voltage (RMS) higher than preset value
Supply voltage (RMS) lower than preset value
Supply voltage imbalance higher than preset value
Ground current level higher than preset value
IGBT temperature higher than preset value
Temperature recorded by external probe 1 (optional) higher than preset value
Temperature recorded by external probe 2 (optional) higher than preset value
Control board temperature higher than preset value
Remark: All warning levels can be changed by the user.

Any of the six digital outputs can be used to cable warning functionality. A maximum of 3 warnings can be assigned to the digital outputs. However, by default the digital outputs of the PQF-Manager have been set up for monitoring other functions than warnings (cf. Table 5.8.) Refer to Section 8.7.1.2. for guidelines on how to set up warning conditions and how to associate them with digital output contacts.

For cabling the digital output contacts as warning contact, the same approach as shown in Figure 7.43. can be adopted. The electrical characteristics of the digital output contacts and the points to pay attention to are discussed in Section 7.10.2.

7.10.4. Cabling of the digital output contacts to monitor other filter operation modes than warnings and alarms

Table 5.7. gives an overview of the other functions that can be monitored with the digital outputs in addition to the already discussed warnings and alarms.

For cabling the digital output contacts to monitor other filter operation, the same approach as shown in Figure 7.43. can be adopted. The electrical characteristics of the digital output contacts and the points to pay attention to are discussed in Section 7.10.2.

7.10.5. Cabling of main/auxiliary control functionality

The active filter features main and auxiliary control setup modes. This implies that two different compensation characteristics can be defined, e.g. one for the day and one for the night or one for normal network operation and one for backup generator operation. With the PQF-Manager a set up can be made to either use always the main or the auxiliary settings. In addition, the possibility exists to switch between main and auxiliary settings 'automatically' according to a signal applied to a digital input of the PQF-Manager (Cf. Figure 7.39.) Any digital input can be configured to act as the deciding factor for switching between the main and auxiliary settings. Moreover, both normal and inverse logic can be used to drive the digital inputs.

The electrical requirements of the digital inputs are as discussed in Chapter 14. Figure 7.44. gives an example of how to implement the main/auxiliary control switching functionality on Digital Input 2. It is assumed that normal control logic is used.

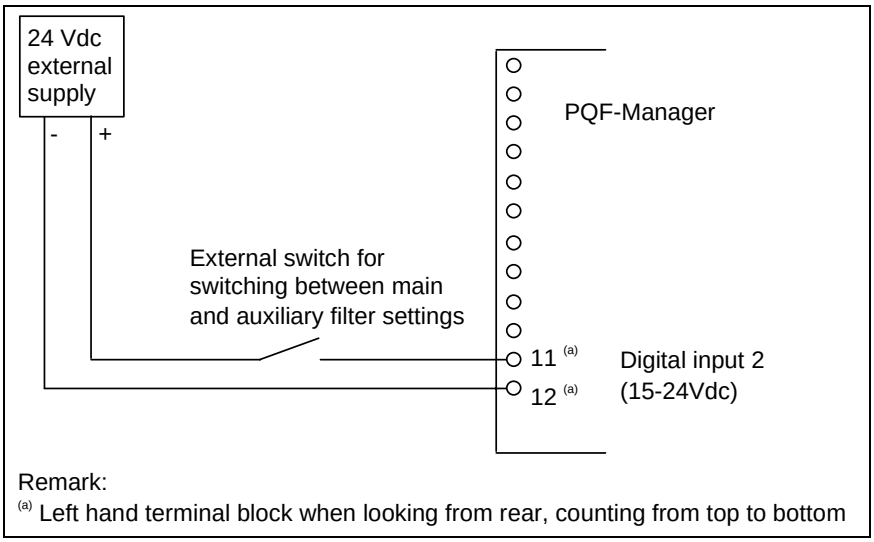


Figure 7.44. Example of how to cable the 2nd digital input of the PQF-Manager for main/auxiliary control switching functionality

When implementing the function described above, please note that according to the setup done with the PQF-Manager for the input considered, the filter may behave differently. Table 7.17. shows the filter behavior as a function of the PQF-Manager settings.

WARNING:	**If a function is assigned to a digital input, the same function must never be assigned to the other digital input. Otherwise the filter may behave erratically.**

Table 7.17. Filter behavior as a function of the PQF-Manager settings for main/auxiliary switching

PQF-Manager setup for digital input	Vlow applied to digital input	Vhigh applied to digital input
Activ. Main	Auxiliary settings are used	Main settings are used
Activ. Aux.	Main settings are used	Auxiliary settings are used
Remark: Vlow = 0 Vdc, Vhigh = 15-24 Vdc		

Once the cabling has been finished, the power to the filter may be restored. Refer to Section 8.7.1.2. for guidelines on how to set up the digital inputs according to the function required.

7.10.6. Implementation of local start/stop buttons

WARNING: If a function is assigned to a digital input, the same function must never be assigned to the other digital input. Otherwise the filter may behave erratically.

The PQFI active filter is equipped with a start/stop function integrated in the PQF-Manager user interface. If the customer desires this however, he can add extra start/stop buttons (not provided) to the filter system. The start and stop button has to be connected to the PQF-Manager's digital inputs and the PQF-Manager has to be set up accordingly.

Two connection approaches exist:

- The first approach is to use one digital input for the start function and the second digital input for the stop function. Table 7.18. shows the PQF-Manager setup for the input considered and the resulting effect when applying voltage to this input.

Table 7.18. Filter behavior as a function of the PQF-Manager settings for local start/stop and using 2 digital inputs

PQF-Manager setup for digital input	Vlow applied to digital input	Vhigh applied to digital input
Edge ON	No effect	Filter starts on rising edge
Edge OFF	No effect	Filter stops on rising edge
Remark: Vlow = 0 Vdc, Vhigh = 15-24 Vdc		

When using the Edge ON function the filter can only be switched on by applying voltage to the digital input considered. It is therefore recommended in that case to configure and cable the second digital input as Edge OFF. Refer to Section 8.7.1.2. for guidelines on how to set up the digital inputs according to the function required.

The electrical requirements of the digital inputs are as discussed in Section 5.5. Figure 7.45. shows a cabling diagram for implementing a start function on the first digital input and a stop function on the second digital input.

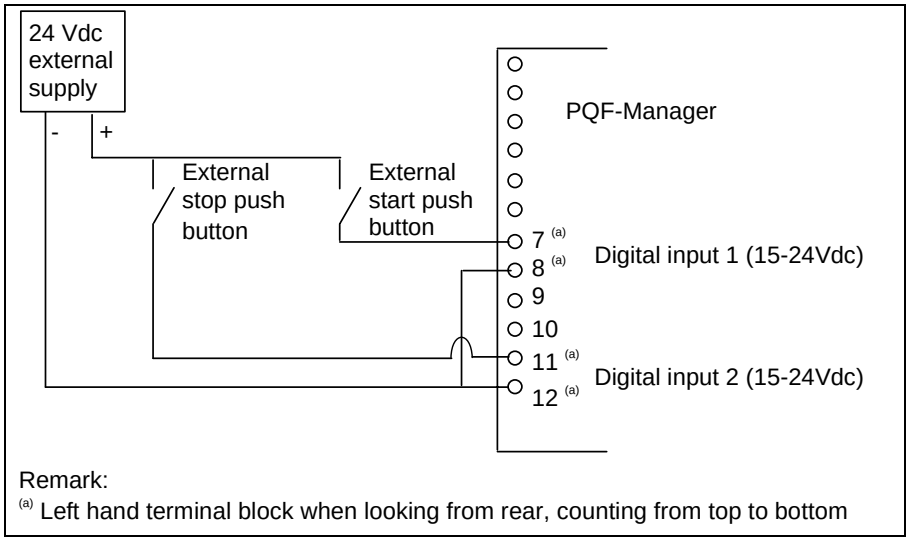


Figure 7.45. Cabling diagram for implementing start on digital input 1 and stop on digital input 2

- The second approach is to use one digital input for both the start function and the stop function. This leaves the other digital input available for the implementation of other functions.

  Table 7.19. shows the PQF-Manager setup for the input considered and the resulting effect when applying voltage to this input.

Table 7.19. Filter behavior as a function of the PQF-Manager settings for local start/stop and using 1 digital input

PQF-Manager setup for digital input	Vlow applied to digital input	Vhigh applied to digital input
Edge ON/OFF	No effect	Filter starts on first rising edge, stops on second rising edge, etc
Remark: Vlow = 0 Vdc, Vhigh = 15-24 Vdc		

Refer to Section 8.7.1.2. for guidelines on how to set up the digital inputs according to the function required.

The electrical requirements of the digital inputs are as discussed in Section 5.5. Figure 7.46. shows a cabling diagram for implementing a start function and a stop function on the first digital input.

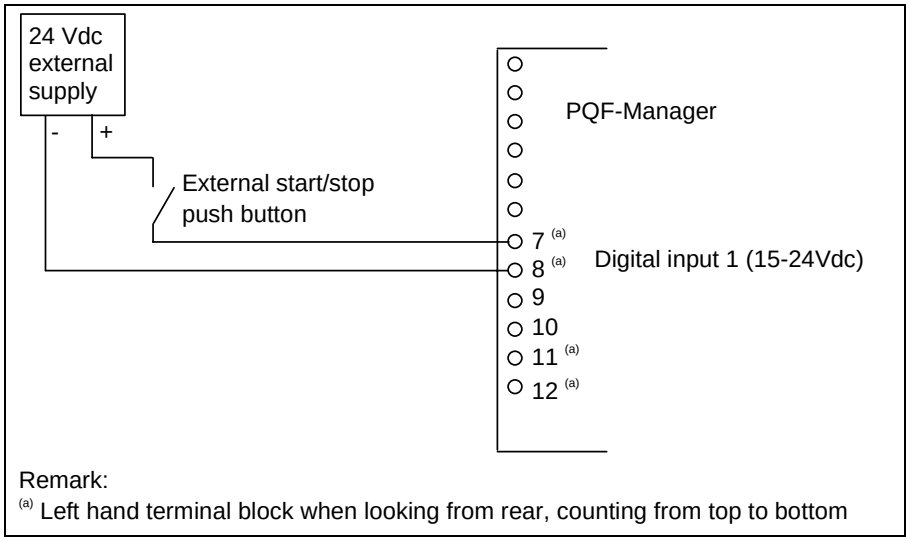


Figure 7.46. Cabling diagram for implementing start and stop on digital input 1

Once the cabling has been finished, the power to the filter may be restored.

Remarks:
- The implementation of local start/stop buttons does not inhibit the usage of the start/stop function on the PQF-Manager.
- When remote control functionality is implemented (cf. Section 7.10.1.) at the same time as local start/stop buttons, the remote control has priority over the local start/stop buttons. When the local start/stop command has to be given, deactivate first the remote control functionality by navigating with the PQF-Manager to the digital input setup menu and setting the digital input associated with the remote control to 'Disabled'.

7.11. Electrical connections of filter options and accessories

Filter options must be ordered in advance and are cabled in the factory. For these options, refer to the wiring diagram provided with your filter to identify the electrical connections if desired. For some accessories however, the customer may have to do the cabling on site. These accessories include:
- The connection of the external temperature probes to the main control board.
- The connection of the RS-232 cable used for PQF-Link software communication (optional).
- The connection of the serial printer to the PQF-Manager.
- The connection of the Modbus adapter.

The connections of the aforementioned accessories are discussed next.

WARNING:	**Before cabling any of the circuits discussed below, switch off the power supply to the filter. When the filter has already been installed on site, this is preferably done by opening the protection system located just upstream of the filter. Alternatively, the auxiliary circuit fuses of the filter may be removed. Refer to Figure 5.8. to locate the fuse holder for the auxiliary fuses.**

7.11.1. Connection of the external temperature probes to the main control board

When external temperature probes (Figure 7.47.) are ordered, they are delivered with the filter but they may not have been installed.

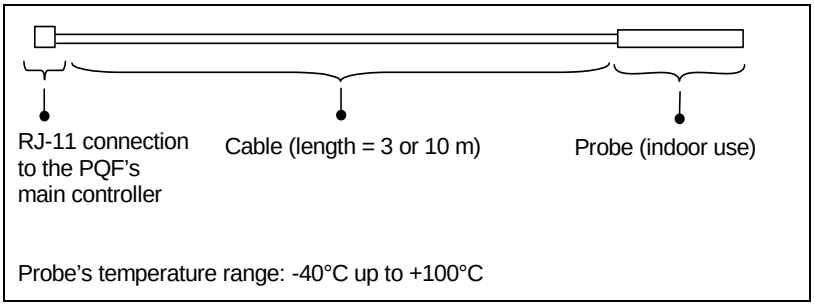


Figure 7.47. Optional temperature probe

The customer can position the probes at a location where he feels the temperature should be monitored. Then, using the PQF-Manager he can associate a maximally allowed temperature for warning and filter trip with each probe. If the temperature reaches the predefined trip level, the filter will trip indicating an overtemperature in the error log. If the digital output contacts have been set up appropriately, the warning and trip level indication can be sent to monitoring equipment outside the filter. For cabling the digital output contacts, refer to Section 7.10.2. For setting up the warning and the trip levels in the PQF-Manager, refer to Section 8.7.1.2.

The installation of the temperature probes requires the following steps:

- Remove the protective grid.
- Connection of the probe to the filter's main controller board (Cf. Figure 5.12. item 3). Two external temperature probes can be connected. This is done by plugging the RJ11 connector of the temperature probe firmly in one of the RJ11 sockets. Figure 7.48. shows a detailed view of the temperature probe sockets on the main controller board. Once the connection is made, the probes will be recognized by the system at the next power-up.

Figure 7.48. Detailed view of the temperature probe sockets on the main controller board

- Route the probe to the location where the temperature has to be monitored ensuring proper cable fixation.
- Using the PQF-Manager and set warning and trip levels if desired (Cf. Section 8.7.1.2.).
- The temperature read by the probe connected to X1/T1 will be displayed by the PQF-Manager as 'T ext 1' and the temperature read by the probe connected to X2/T2 will be displayed by the PQF-Manager as 'T ext 2'.
- After installing the temperature probes, restore the protective grid.

7.11.2. Connection of the RS-232 cable used for PQF-Link software communication

When the PQF-Link software is ordered, it comes with a serial communication cable that is used to connect the PC's serial port to the filter (Figure 7.49.)

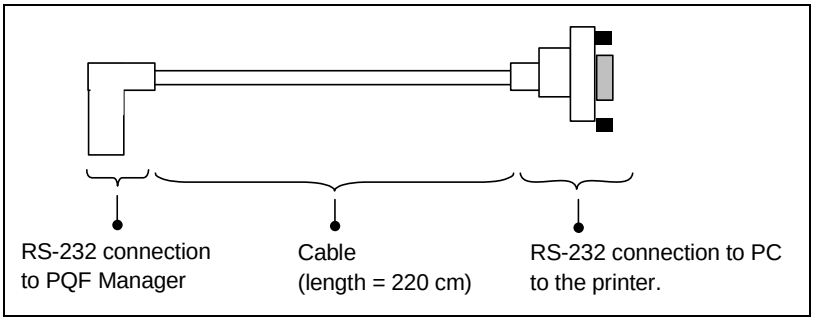


Figure 7.49. RS-232 serial communication cable for PC-filter interconnection

On the filter side the cable has to be connected to the PQF-Manager. This is done by inserting the plug firmly in the dedicated socket. Figure 7.50. shows the location at the rear of the PQF-Manager where the plug has to be inserted.

Figure 7.50. Location at rear of PQF-Manager where the serial communication cable has to be inserted

The other end of the cable has to be connected to the PC's serial port.

More information on the PQF-Link software can be found in the 'PQF-Link installation and user's guide'.

7.11.3. Connection of the serial printer to the PQF Manager and printer setup

When the serial printer accessory is ordered, it comes with a serial communication cable (Figure 7.51.) that allows a connection between the PQF active filter and a Seiko DPU-414 serial printer. Once the PQF is connected to the printer with the appropriate settings, parameter values and/or measurements can be printed.

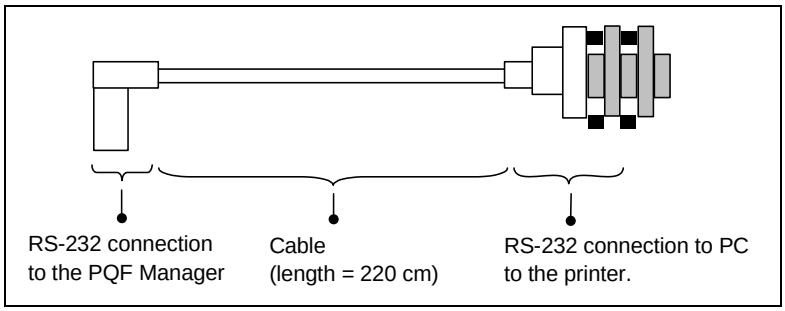


Figure 7.51. PQF-Manager to serial printer connection cable

On the filter side the cable has to be connected to the PQF-Manager. This is done by inserting the plug firmly in the dedicated socket. Figure 7.50. shows the location at the rear of the PQF-Manager where the plug has to be inserted. The other end of the cable has to be connected to the printer's serial port.

In order for the printer to be able to work with the PQF LV Active Filter, its printer settings must be in accordance with Table 7.20.

Table 7.20. Printer settings for operation with the PQF active filter

Dip SW-1			Dip SW-2			Dip SW-3		
1	OFF	Input = Serial	1	ON	Printing columns = 40	1	ON	Data length = 8 bits
2	ON	Printing speed = High	2	ON	User font back-up = 40	2	ON	Parity setting = No
3	ON	Auto loading = On	3	ON	Character select = normal	3	ON	Parity condition = Odd
4	OFF	Auto LF = Off	4	ON	Zero = normal	4	OFF	Busy control = Xon/Xoff
5	ON	Setting command = Enable	5	ON	International	5	OFF	Baud
6	ON	Printing	6	OFF	Character	6	ON	Rate
7	ON	Density	7	ON	Set	7	ON	Select
8	ON	= 72%	8	ON	= France	8	ON	= 9600 bps

In order to get a printout of the printer settings, switch ON the printer supply while pressing simultaneously the 'ON LINE'- button. The printer starts printing its current settings.

If all the printer settings are identical to the settings mentioned in Table 7.20. above, press 'FEED'.
If this is not the case, please follow the procedure below to adjust the settings:

- Step 1: press 'ON LINE' ("Dip SW-A" is printed).
- Step 2: for each setting, press 'ON LINE' to set it to ON or press 'FEED' to set it to OFF.
- Step 3: repeat steps 1 and 2 for "Dip SW-2" and "Dip SW-3".
- When the setup process is finished, "Dip SW setting complete!" is printed.

Once all the printer settings have been set up according to Table 7.20. PQF measurements and/or parameters values can be printed. For additional information on the PQF printing menus, please refer to Chapter 8.

7.11.4. Connection of the Modbus adapter

The connection setup of the Modbus adapter is discussed in Chapter 9.

8. The PQF-Manager user interface

8.1. What this chapter contains

This chapter presents the features and operating instructions for the PQF-Manager user interface (Figure 8.1.). Use the contents of this chapter as background information for the next chapters which explain how to commission, operate and troubleshoot the active filter and how to set up the Modbus communication interface.

Some of the functions discussed in this Chapter require cabling of external I/O to the connection terminals at the rear of the PQF-Manager. Refer to Section 7.10. for guidelines on how to do this.

Figure 8.1. *Front view of the PQF-Manager user interface*

The item description is given in Table 8.1.

Table 8.1. Front side of the PQF-Manager

Item	Description
1	Keypad By navigating through the menus with the arrows and the OK button, the filter can be set-up and controlled (start/stop). On-line help is available by pressing the Help button.
2	Menu display
3	Digital output contact monitor When the PQF-Manager closes one of its output relays, the corresponding symbol lights up. The digital outputs of the PQF-Manager are discussed later in this section.
4	Alarm contact indicator

8.2. PQF-Manager overview and navigation

All user inter-action with the filter is channeled through the PQF-Manager. It provides for the following main functions (Cf. Figure 8.1.):

- **Filter starting, filter stopping and acknowledgement of faults:**
  The PQF-Manager is the default device to be used to start and stop the filter system. Further it is used to acknowledge and reset faults reported by the system.
  Refer to Section 8.5. for detailed information on how to start, stop and reset the filter.
- **Measuring, analyzing, logging and printing of characteristic parameters:**
  The parameters that can be monitored include network voltages, line and filter currents, network power, network power factor and system temperatures.
  Refer to the Section 8.6. for detailed information on the monitoring of variables.
- **Setting up the filter:**
  Setting up the filter consists of various aspects such as defining the customer's requirements for harmonic filtration and reactive power but also the configuration of the external I/O and commissioning the filter at the moment of first use.
  Refer to Section 8.7. for detailed information on setting up the filter.
- **Monitoring the filter load and event logging:**
  The filter load can be monitored to get an idea of its operating point compared to its nominal rating. In addition, logged warnings and faults can be retrieved for troubleshooting the filter operation and any abnormal network conditions.
  Refer to Section 8.8. for detailed information on the monitoring of the filter load and the analysis of warning and error conditions.
- **Providing filter identification information:**
  Filter type information is provided including serial number and firmware versions.
  Refer to Section 8.9. for detailed information on obtaining filter identification information.

All main functions of the PQF-Manager can be accessed through the main 'Welcome' screen.

Figure 8.2. outlines the principle menus that are accessible through the 'Welcome' screen.

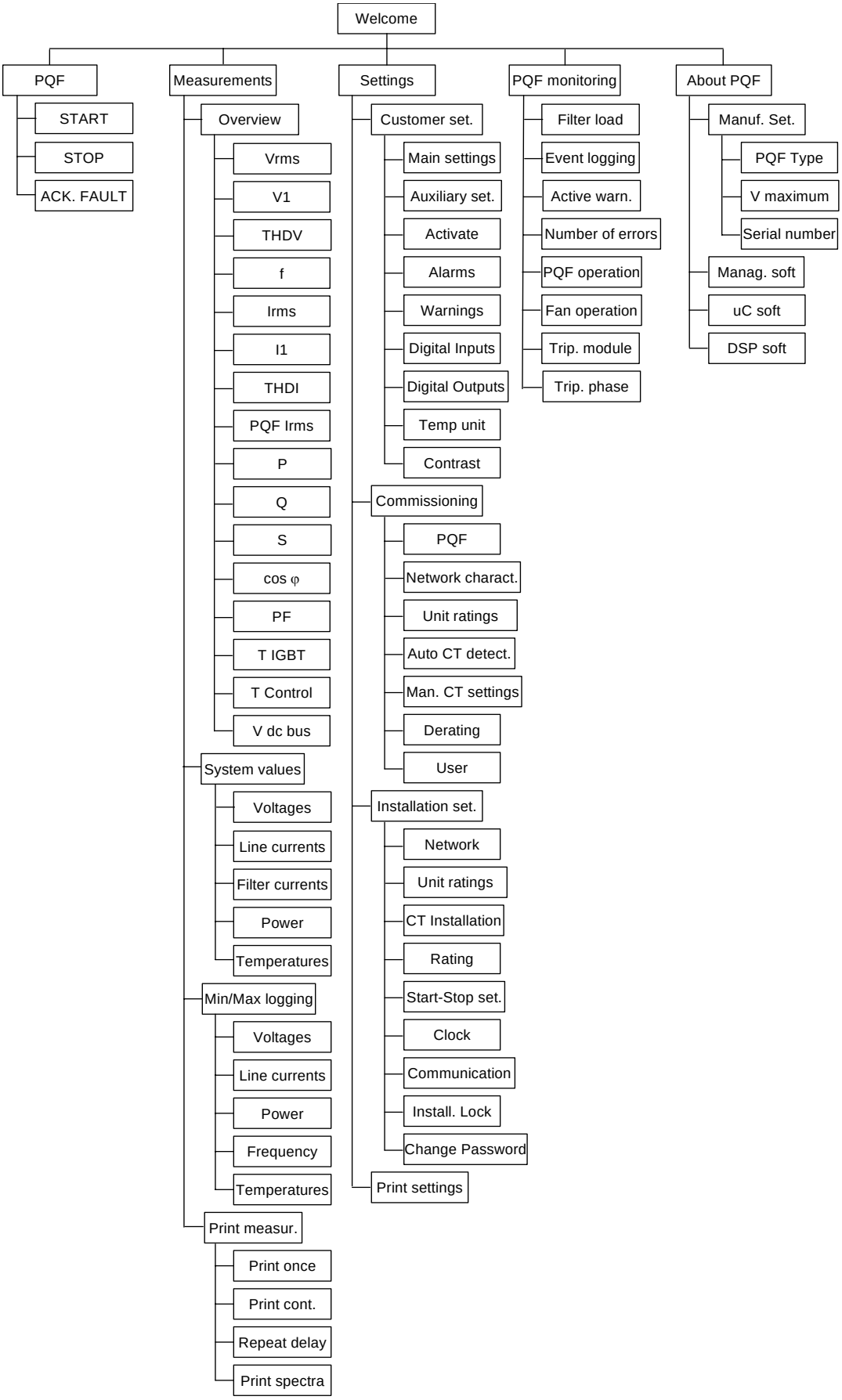


Figure 8.2. Principle menus of the PQF-Manager

In addition to the main functions, the PQF-Manager also incorporates:

- A digital output contact monitor located at the top of the screen (Cf. Figure 8.1. item 3). When the PQF-Manager closes one of its six digital output relays (Cf. Chapter 7) the corresponding symbol lights up. When the relay considered opens again, the symbol disappears.
- An indicator showing when the PQF-Manager's alarm contact has been activated (Cf. Figure 8.1. item 4) For the conditions under which the alarm contact is switched on, refer to Table 7.14. When the alarm condition has disappeared, the indicator switches off.

In order to navigate through the menus of the PQF-Manager, the keypad (Cf. Figure 8.1. item 1) has to be used. The starting point for the navigation after a power up is the 'Welcome' screen. The item selected is highlighted (e.g. the 'Measurements' menu in Figure 8.1.). The keypad and its basic functions are shown in Figure 8.3.

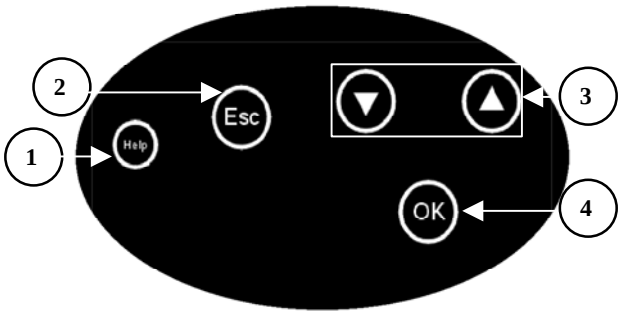


Figure 8.3. Keypad of the PQF-Manager

Refer to Table 8.2. for an explanation on the basic functions of the keypad buttons.

Table 8.2. PQF-Manager keypad button explanation

Item	Description
1	Help key[(a)] Provides on-line help on the highlighted item
2	Escape key[(b)] Esc To go back to the previous window or to leave the current menu or item selection without making changes
3	Up and down arrows[(c)] To go up or down the item list or to go left (▼) or right (▲) in the item list or to increase or decrease a value
4	OK key[(b)] OK To go to the next submenu or to validate a modification or an operation

Remark:
(a) On some items, help is not available. In that case pressing the Help key will have no effect.
(b) Depending on the menu, this key has a different meaning.
(c) Depending on the menu, these keys have a different meaning.

Please note that:

- Walking through a list of items happens in a circular manner. When arriving at the last item in a menu and pressing ▼, the first item of the menu is highlighted. Similarly, when arriving at the first item in a menu and pressing the ▲ key, the last item of the menu is highlighted.
- Sometimes the complete item list in a menu cannot be shown on the display. This is indicated by a small ▲ and/or ▼ symbol that appear(s) at the bottom right and/or the top right corner(s) of the display (Cf. Figure 8.4.)

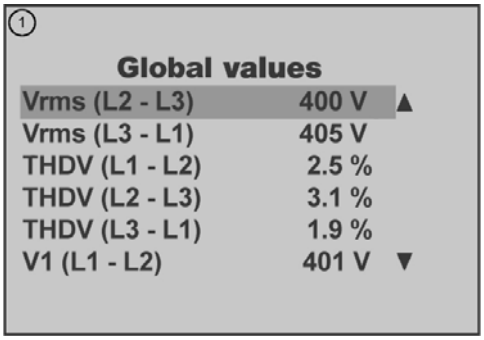


Figure 8.4. *Illustration of ▲ and ▼ symbols on the PQF-Manager display*

When any of these symbols is visible, the user can scroll down/up beyond the limit of the screen. The item list will be adjusted accordingly.

- When a 'right arrow' symbol is visible next to a menu item, a submenu or sub-item will be opened when pressing the OK key after highlighting this item. As an example consider the item 'Main PFC/Bal.' in Figure 8.5.
- When a menu item consists of two fields separated by a space, three possibilities exist:
  1. The first field contains a parameter and the second field contains a parameter value which can be changed by the user. As an example consider the item 'Filter mode' in Figure 8.5. When this item is highlighted and OK is pressed, the parameter value can be changed. Validation of the value is done by pressing OK. Leaving the selected item without modification is done by pressing Esc.
  2. The first field contains a parameter and the second field contains a parameter value which cannot be changed by the user. As an example consider any item of Figure 8.4. Pressing OK will not have any effect. Pressing Esc will bring up the previous menu.
  3. Same case as 2 above but when pressing OK on a selected line the whole line starts to blink. By using the arrow keys, the position of the selected item in the list can then be changed. Press OK when the item is placed at the desired position. The only PQF-Manager menu in which it is possible to change the position of the parameters displayed is the 'Measurements-overview' menu.
- Pressing Esc successively from any menu will bring up the main 'Welcome' screen.

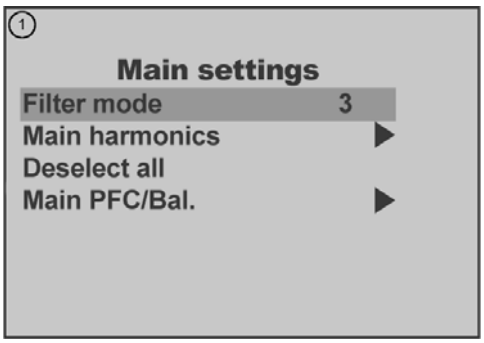


Figure 8.5. *Illustration of different menu item types*

The next sections discuss the five main submenus of the 'Welcome' screen.

Remark:
This manual uses a directory structure convention to indicate a submenu.
The main 'Welcome' screen is referenced as [/Welcome].

Example: **[/Welcome/Measurements/System values]** indicates that the 'System values' menu can be accessed by:

- Press Esc successively until the 'Welcome' screen is reached.
- Highlighting the 'Measurements' menu in the main 'Welcome' screen using the arrows
- Pressing the OK key after which the 'Measurements' menu opens
- Highlighting the 'System values' menu using the arrows
- Pressing the OK key will open the menu.

8.3. The PQF-Manager behavior during filter initialization

After a system reset, the filter is initialized. This includes the PQF-Manager. Depending on the type of reset, the initialization process of the PQF-Manager may consist of the first or the first and the second step discussed below.

- Step 1: The PQF-Manager waits for the communication channel to be initialized. This process can be observed when looking closely at the PQF-Manager. During this period the following message will appear on the display (Figure 8.6.)

Figure 8.6. PQF-Manager display during communication initialization

- Step 2: Once the communication channel has been initialized, the user interface is set up. During this process the PQF-Manager retrieves the data structure to be displayed from the PQF main controller. When the PQF-Manager is setting up the user interface, the following message is displayed (Figure 8.7.)

Figure 8.7. PQF-Manager display when the user interface is set up

Table 8.3. gives an overview of the initialization steps for common reset conditions.

Table 8.3. Overview of common reset conditions and corresponding PQF-Manager initialization steps

Reset condition after…	PQF-Manager initialization steps
Applying power to the filter	Step 1 and Step 2
Setting up commissioning parameters	Step 1
Acknowledging fault successfully	Step 1

8.4. The PQF-Manager locking facilities

In order to prevent unauthorized people to modify any of the active filter settings, switch on the hardware lock (Figure 5.7. item 4).

The hardware lock is switched on by pushing the blue button located at the bottom rear side of the PQF-Manager with a pointed object (e.g. pencil). When the lock is set:

- will appear in the upper left-hand corner of the graphics display.
- will appear next to the menus that are locked. No modification can be made to the settings.
- Most setting values can be consulted.

Once the PQF-Manager is locked, it can be unlocked by pushing the blue button again.

In order to prevent unauthorized people to modify the core installation settings of the active filter but still giving them access to typical user settings (e.g. harmonics selection, programming digital outputs, …), switch on the software lock.

The software lock is switched on in the menu [/Welcome/Settings/Installation set./Install. lock].
In order to unlock the system go to the same menu. After giving the appropriate password, the system will be unlocked. The password is a four digit number which is set by default to 1234. Entering the password is done by choosing the right value with the ▲ and ▼ keys and then validating with OK. The password can be changed in the menu [/Welcome/Settings/Installation set./Change Password]. Entering the new password is done by choosing the desired value with the ▲ and ▼ keys and then validating with OK.

If hardware and software lock are combined, the hardware lock has priority over the software lock.

8.5. The PQF start, stop and fault acknowledgement menu

WARNING: The active filter should only be started when it has been installed and commissioned according to the guidelines of this manual. Failure to adhere to this guideline may damage the filter and void warranty.

Refer to Chapter 10 for more information on commissioning the filter.

'The PQF start, stop and fault acknowledgement' menu is a one-line menu that can be accessed:

- In the main 'Welcome' screen [/Welcome/PQF].
- In the 'Commissioning' screen [/Welcome/Settings/Commissioning/PQF]. For more information on the 'Commissioning' screen refer to the Section 8.7.

'The start, stop and fault acknowledgement' menu is the default menu for starting, stopping and resetting the filter.

As can be seen in Table 8.4. the 'start, stop and fault acknowledgement' menu has another function depending on the filter status.

Table 8.4. 'Start, stop and fault acknowledgement' menu functionality according to the filter status

Filter status	Menu display	Pushing OK results in…
Filter stopped, no critical error present (i.e. 'normal' stop condition)	PQF START	Starting the filter[(a)]
Filter running, no critical error present (i.e. 'normal' running condition)	PQF STOP	Stopping the filter[(a)]
Filter stopped on critical fault	ACK. FAULT	Acknowledging the fault[(a)]
Filter controlled by remote control	PQF START or PQF STOP or ACK. FAULT	No action on filter behavior Display shows message that filter is controlled by digital input

Remark:
[(a)] After pushing OK, there is always a validation phase.

Acknowledging of a fault has two possible consequences:

- If the fault is permanent (e.g. permanent network undervoltage due to phase loss), it cannot be cleared and the message 'ACK. FAULT' will remain on the display. In this case the cause of the problem has to be identified and removed before the filter can be restarted.
- If the fault is not present anymore when the 'ACK. FAULT' command is given, the menu will change into 'PQF START' to indicate that the filter can be restarted.

Fault analysis can be done by consulting the 'PQF Monitoring' menu [/Welcome/PQF Monitoring]. For more information on the 'PQF monitoring' menu, refer to Section 8.8.

If the filter is set up for remote control operation, the local start/stop command has no effect. Disable the digital inputs to override the remote control [/Welcome/Settings/Customer set./Digital inputs].

8.6. The 'Measurements' menu

The 'Measurements' menu can be accessed in the main 'Welcome' screen [/Welcome/Measurements]. This menu allows to monitor a variety of variables (e.g. voltage, current, …) in a variety of formats (e.g. RMS-values, spectra, time domain waveforms). Its submenus are discussed next.

8.6.1. The 'Overview' menu [/Welcome/Measurements/Overview]

The Overview menu summarizes the following characteristic parameters (Table 8.5.). These parameters are expressed as numerical values in a list.

Table 8.5. Summary of parameters displayed in the 'Overview' menu

Parameter name	Unit	Description
Vrms	V	RMS value of all the line-to-line voltages
V1	V	RMS value of the fundamental component of all the line-to-line voltages
THDV	%	Total harmonic distortion of all the line-to-line voltages.
F	Hz	Network frequency
Irms	A	RMS value of all the line currents
I1	A	RMS value of the fundamental component of all the line currents
THDI	%	Total harmonic distortion of all the line currents.
PQF Irms	A	RMS value of all the filter currents
P	W, kW, MW	Active power in the network at the location of the CTs P > 0: Load absorbing active power P < 0: Load generating active power
Q	var, kvar, Mvar	Reactive power in the network at the location of the CTs Q > 0: Inductive reactive power Q < 0: Capacitive reactive power
S	VA, kVA, MVA	Apparent power in the network at the location of the CTs
cos φ	-	Displacement power factor: calculation based on the fundamental values of the measurements.  : System has inductive behavior  : System has capacitive behavior cos φ > 0: load absorbing active power cos φ < 0: load generating active power
PF	-	Power factor: calculation based on the fundamental and the harmonic values of the measurements. Measurement only valid for quasi-balanced loads.
T IGBT	°C/°F	IGBT module temperature (hottest module)
T Control	°C/°F	Main control board temperature
V dc bus	V	Active filter DC capacitor voltage

On the display, the parameters are organized in such a way that a maximum of information is obtained without having to scroll down. The user may customize the display to his particular needs. To do this, follow the steps given below:

- Select the measured parameter that has to be moved.
- Press OK. The selected parameter starts flashing.
- Press ▲ or ▼ to move the selected parameter up or down the list.
- Once the selected parameter is located at the desired position in the list, press OK.

Remark: During the display customization process, the Esc key cannot be used to revert back to the original situation.

8.6.2. The 'System values' menu [/Welcome/Measurements/System values]

The 'System values' menu (Figure 8.2.) gives detailed information on the following parameters:

- **The voltages**: (Refer to Table 8.5. for an explanation of the symbols).
  - Vrms, V1 and THDV in table format.
  - The network voltage waveforms for all phases (Figure 8.8.)
    All waveforms are synchronized with the rising edge zero crossing of the voltage V (L1-L2).

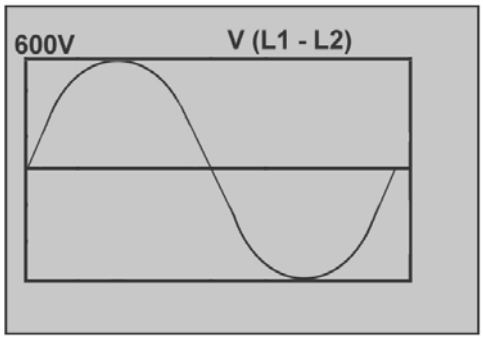


Figure 8.8. Time domain waveform of line voltage displayed by the PQF-Manager

  - The network voltage spectrum for all phases in chart format (Figure 8.9.)
    The spectral components up to the 50th order are expressed as a % of the fundamental component with absolute values also shown in the top right corner.

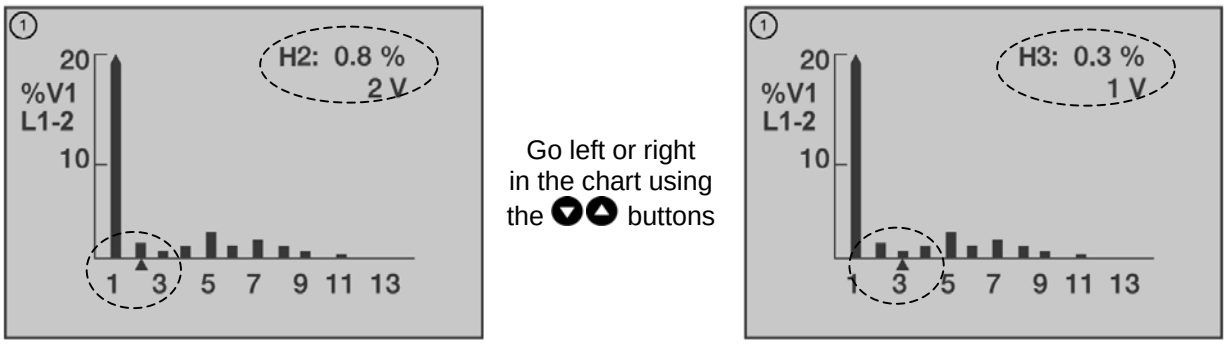


Figure 8.9. Spectrum of the network voltage in chart format displayed by the PQF-Manager

  - The network voltage spectrum for all phases in table format (Figure 8.10.)
    Both the absolute values and the % of the fundamental component values are shown for each spectral component up to the 50th order.

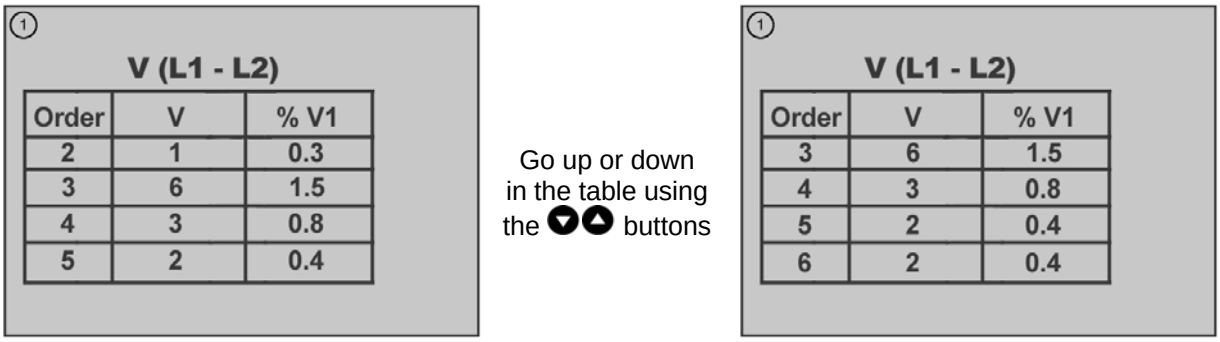


Figure 8.10. Spectrum of the network voltage in table format displayed by the PQF-Manager

  - The network frequency
  - The network imbalance
  - The active filter DC bus voltage

- **The line currents**: (refer to Table 8.5. for an explanation of the symbols)
  - Irms, I1 and THDI in table format.
  - The line current waveforms for all phases. The graph layout is similar to the one of the voltages (Figure 8.8.) All waveforms are synchronized with the rising edge zero crossing of the voltage V (L1-L2).
  - The line current spectrum for all phases in chart format. The chart layout is similar to the one of the voltages (Figure 8.9.)
  - The line current spectrum for all phases in table format. The table layout is similar to the one of the voltages (Figure 8.10.)
- **The filter currents**: (Refer to Table 8.5. for an explanation of the symbols)
  - PQF Irms in table format
  - The filter current waveforms for all phases. The graph layout is similar to the one of the voltages (Figure 8.8.) All waveforms are synchronized with the rising edge zero crossing of the voltage V (L1-L2).
  - The filter current spectrum for all phases in chart format. The chart layout is similar to the one of the voltages (Figure 8.9.) but the values are expressed in absolute terms.
  - The filter current spectrum for all phases in table format. The table layout is similar to the one of the voltages (Figure 8.10.) but only absolute current values are shown.
- **The power in the system at the location of the CTs**: (Refer to Table 8.5. for an explanation of the symbols).
  - Active power P.
  - Reactive power Q.
  - Apparent power S.
  - Displacement power factor cos φ.
  - Power factor PF.
- **Temperatures**: (Refer to Table 8.5. for an explanation of the symbols)
  Temperatures may be expressed in °C and in °F. For changing the temperature unit, go to [/Welcome/Settings/Customer set./Temp unit].
  - Temperature of the hottest IGBT ('T IGBT') with indication of the module number ('Hot module') and the hottest phase ('Hot phase').
  - Temperature of the main control board ('T Control').
  - Temperature 'T ext 1' reported by the external temperature sensor (optional) connected to X1/T1 of the main controller board (Cf. Figure 7.48.)
  - Temperature 'T ext 2' reported by the external temperature sensor (optional) connected to X2/T2 of the main controller board (Cf. Figure 7.48.)

    Remark: If the external temperature probes are not connected, the display will show 'No sensor' for the corresponding probe temperature. For instructions on how to install a temperature probe, refer to Section 7.11.1.

8.6.3. The 'Min-Max logging' menu [/Welcome/Measurements/Min-Max logging]

The 'Min-Max logging' function allows for the user to log for each significant measured item and since the last clearance:
- The maximum (or minimum) value
- The duration above (or below) the threshold

Once a threshold has been set the PQF-Manager starts recording the maximum (or minimum) value automatically as well as the total duration until a reset is performed. Figure 8.11. illustrates this.

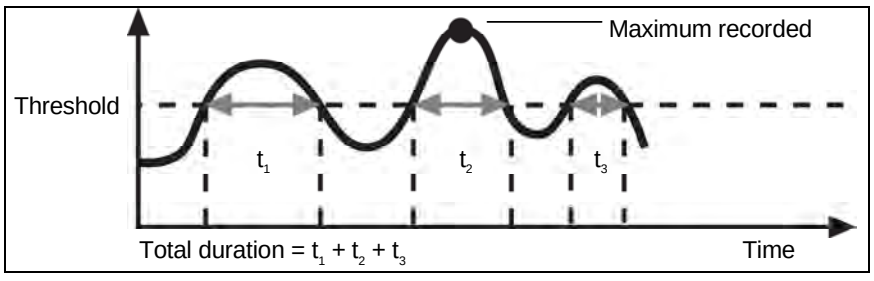
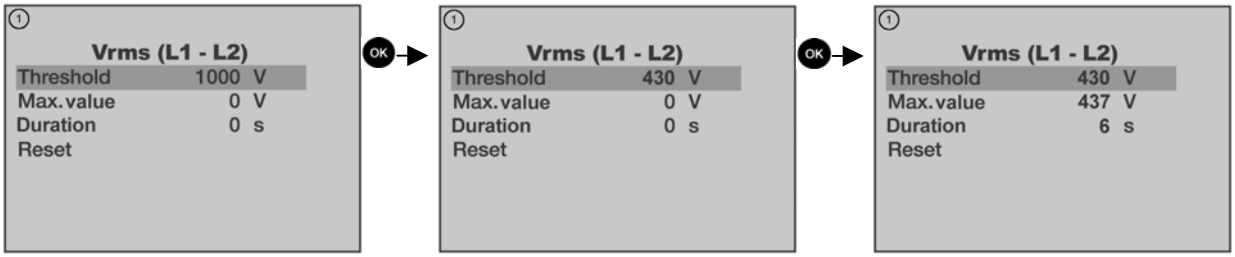


Figure 8.11. Illustration of the threshold and the maximum recorded value used in the Min/Max logging function

The parameters that can be used with the logging function are Vrms, THDV, Irms, P, Q, S, f, T IGBT, T ext 1 and T ext 2. Refer to Table 8.5. for an explanation of the symbols. For the frequency, minimum values and duration below a threshold can also be recorded.

The recorded information may be cleared by selecting and validating the 'Reset' item.
If the hardware lock is engaged, the logging function cannot be started nor reset (Cf. Section 8.4.)

Figure 8.12. shows an example in which the network voltage between L1 and L2 is monitored. The nominal network voltage is assumed to be 400 V. The threshold was initially set at 1000 V and is changed to 430 V.



Highlight value | Change value | Logging starts

Figure 8.12. Example of the Min/Max logging function

8.6.4. The 'Print measurements' menu [/Welcome/Measurements/Print measur.]

Measurements can be printed with the optional printer.

- For guidelines on how to connect and setup the printer, refer to Section 7.11.3.
- The printer communication has to be activated in the PQF-Manager menu [/Welcome/Settings/Installation set./Communication]. Printer setup is discussed in Section 8.7.3.4.

Figure 8.13. gives an overview of the 'Print measurements' menu.

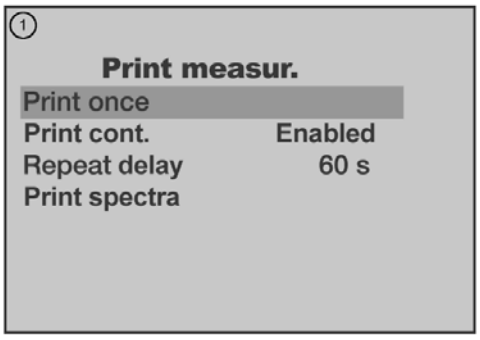


Figure 8.13. The 'Print measurements' menu

A printout can be made once ('Print once' or 'Print spectra') or can be repeated ('Print cont.') with an interval ('Repeat delay').

- When selecting and validating the 'Print once' menu, the measurements discussed in Table 8.5., the measurements recorded from the external temperature probes, the results of the Min-Max logging function, the results obtained from the event logging function and a fault summary are printed once.
- When selecting and validating the 'Print cont.' menu, the measurements discussed in Table 8.5. are printed with an interval defined in the 'Repeat delay' field.
- When activating the menu 'Print spectra', the customer can choose which spectrum to print (voltage or current). The selected spectrum is then printed.

8.7. The ‘Settings’ menu

The ‘Settings’ menu [/Welcome/Settings] has three main levels:

- The **customer level** which allows the user to set up the typical user requirements such as harmonic filtration settings, the reactive power settings, set up the digital inputs and outputs and define the programmable warnings and alarms including trip-points for the optional external temperature probes. At this level, the user can also change the temperature unit used by the system. The customer level is accessed through [/Welcome/Settings/Customer set.]
- The **commissioning level** which allows the commissioning engineer to set up the equipment according to the customer’s installation. Typical parameters that need to be entered are the network voltage and frequency, the rating of the filter unit(s), the CT parameters and a derating factor that needs to be applied when the installation is at great height above sea level or in conditions where excessive ambient temperatures are present. At the commissioning level the possibility also exists to set up the user’s requirements for harmonic filtration and reactive power compensation. The commissioning level is accessed through [/Welcome/Settings/Commissioning].
- The **installation settings level** allows for the commissioning engineer to set up advanced system functions such as the filter autorestart and standby functions, the clock, the communication of Modbus and printer/PQF-Link and the setting of a system lock with password.
  For information purposes the installation settings level also shows the settings for the network voltage and frequency, the rating of the filter unit(s), the CT parameters and the derating factor that has been set-up at the commissioning level. The installation settings level is accessed through [/Welcome/Settings/Installation set.]

From within the ‘Settings’ menu, the ‘Print settings’ function can be activated to obtain a paper copy of the filter settings.

- For guidelines on how to connect and setup the optional printer, refer to Section 7.11.3.
- The printer communication has to be activated in the PQF-Manager menu [/Welcome/Settings/Installation set./Communication/Protocol]. Printer setup is discussed in Section 8.7.3.4.

The three main levels of the ‘Settings’ menu are discussed in more detail in the next sections.

8.7.1. The ‘Customer settings’ menu [/Welcome/Settings/Customer set.]

The customer settings menu is intended to be used by people that are authorized to change the filter operation settings.

Refer to Section 8.4. for determining appropriate locking facilities for this menu.

8.7.1.1. Settings up harmonics, reactive power and filter mode

- Setting up harmonics, reactive power and filter mode can be done in a main window [/Welcome/Settings/Customer set./Main settings] and in an auxiliary window [/Welcome/Settings/Customer set./Auxiliary settings]. By having two windows, the customer can set two sets of different settings, e.g. one set for mains operation and one set for generator operation, or one set for day settings and one set for night settings. Both main and auxiliary settings windows have the same setup possibilities, i.e.
  - Definition of the filter mode
  - Selection of the harmonics with setting of curve levels
  - Selection of reactive power compensation with balancing functionality
  - Deselection of all harmonics

- The filter has to be informed about whether the main window settings or the auxiliary window settings must be used. This is done by the ‘Activate’ flag [/Welcome/Settings/Customer set./Activate]. Possible values for this flag are given in Table 8.6. By default the filter uses the main filter settings.

Table 8.6. Possible settings for the activate field

'Activate' field value	Description
Main	Main window settings are always used
Auxiliary	Auxiliary window settings are always used
Ext. input	The filter switches between the main and the auxiliary settings according to a signal applied to the PQF-Manager's digital input[(a)].

Remark:
[(a)] Refer to Section 7.10.5. for cabling instructions for this feature. Refer to Section 8.7.1.2. configuring the digital input for this feature.

- **Setting up the filter mode**

For setting up the filter's main filter mode go to [/Welcome/Settings/Customer set./Main settings/Filter mode]

For setting up the filter's auxiliary filter mode go to [/Welcome/Settings/Customer set./Auxiliary settings/Filter mode]

The filter can have three types of effect on the network:
- Filter the selected harmonics until their magnitudes are close to zero (Maximum Filtering);
- Filter the selected harmonics until their magnitudes reach the residual level permitted by the user (Filtering to Curve);
- Produce or absorb reactive power including load balancing.

The user can put the emphasis on one of the above effects by selecting the filtering mode. Table 8.7. shows the three available modes:

Table 8.7. Available filter modes

	Highest priority level	◄——►	Lowest priority level
Mode 1	Filtering to curve	Maximum filtering	Reactive compensation
Mode 2	Filtering to curve	Reactive compensation	Maximum filtering
Mode 3	Filtering to curve	Reactive compensation	-

In Mode 1, the filter will first filter to the pre-programmed curve. Once the requirements are fulfilled, the remaining resources will be allocated to reducing the selected harmonics as close as possible to zero. If further resources are then available, reactive power compensation and load balancing will be performed as required.

In Mode 2, the second priority after filtering to the curve is reactive power compensation and load balancing. Maximum filtering comes in third place and will be done if both the curve specification and the reactive power requirements are fulfilled.

In Mode 3, the filter will first ensure that the harmonic curve specification is fulfilled. If then there are still resources available, the filter will do reactive power compensation and load balancing if requested by the user.

Figure 8.14. illustrates the principle of filtering to curve for one particular harmonic order. The flexibility of the PQF control is such that a specific curve level may be defined for each selected harmonic.

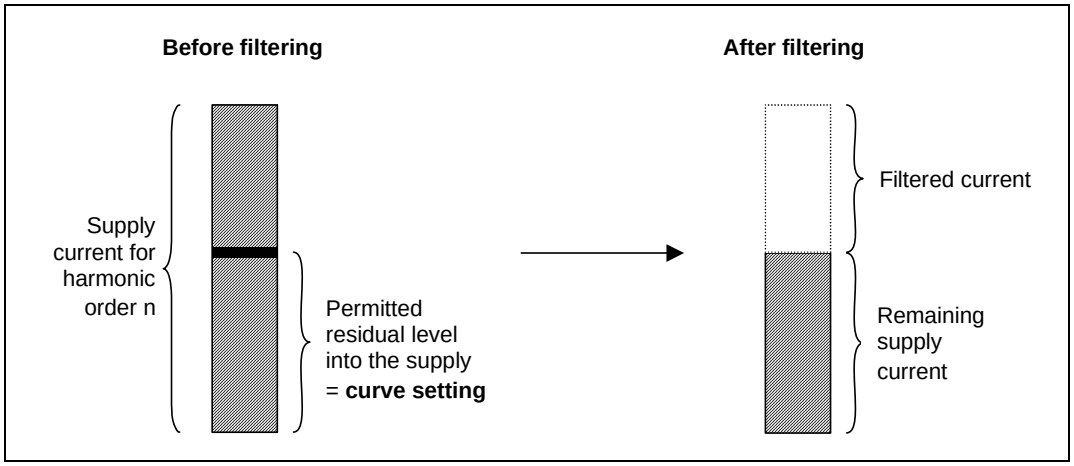


Figure 8.14. Filtering to curve for harmonic order n

The default filter mode is Mode 3.

- **Selecting the harmonics with setting of curve levels**

For setting up the filter's main harmonics selection go to [/Welcome/Settings/Customer set./Main settings/Main harmonics]

For setting up the filter's auxiliary harmonics selection go to [/Welcome/Settings/Customer set./Auxiliary settings/Aux. harmonics]

The harmonics that can be selected are presented in a table such as presented in Table 8.8.

Table 8.8. Example of harmonic settings table displayed by PQF-Manager

Order	Select[(a)]	Curve[(b)]
3	No	0 A
5	No	10 A
7	No	0 A
9	No	0 A

Remarks:
(a) The 'Select' column may have three values:
No: Harmonic not selected by user
Yes: Harmonic selected by user and being filtered
S: Harmonic selected by user but put in 'standby' by the filter. Refer to Section 10.9. for more information on the "harmonic standby" mode.
(b) Curve settings for allowed current into the network are expressed in Amps

In order to select the harmonics and set up a curve level (if desired)

- Open the harmonic table. The first line will be highlighted.
- Use ▲ and ▼ to select the desired order and press OK to activate the corresponding line. The item in the column 'Select' will be highlighted.
- If the harmonic order of the selected line has to be changed, press ▼ to go to the 'Order' field. Press OK and use ▲ or ▼ to change the order. The PQF-Manager will automatically propose the orders that are not yet in the list. If the desired order is displayed, press OK. Then, press ▲ which will highlight the item in the column 'Select'.
- Press OK and then ▲ or ▼ to select (Yes) or deselect (No) the harmonic. Press OK to validate the choice made.
- Use the ▲ to switch to the 'Curve' level column.
- Press OK and then the ▲ or ▼ to set up the desired curve level in Amps. Press OK to validate the choice made.
- Press Esc to highlight the complete line after which the other harmonics can be programmed using the same procedure.
- Once all the harmonics are programmed, the harmonic selection table can be exit by pressing Esc.

- **Deselect all harmonics**

For deselecting all harmonics of the main window at once go to [/Welcome/Settings/Customer set./Main settings/Deselect all]

For deselecting all harmonics of the auxiliary window at once go to [/Welcome/Settings/Customer set./Auxiliary settings/Deselect all]

This function allows for the customer to quickly deselect all harmonics in the main or the auxiliary window. This may be useful e.g. when the commissioning engineer realizes that the CTs have been installed wrong and an intervention is required to correct the problem.

- **Selecting the reactive power compensation options**

For setting up the filter's main reactive power mode go to [/Welcome/Settings/Customer set./Main settings/Main PFC/Bal.]

For setting up the filter's auxiliary filter mode go to [/Welcome/Settings/Customer set./Auxiliary settings/Aux. PFC/Bal.]

The active filter can perform different reactive power tasks, each of which require the appropriate setup. Table 8.9. shows an overview of the possible tasks and shows how the filter set up should be done to implement this task. The parameters (italic print) referred to in Table 8.9. can be accessed in the 'Main PFC/Bal.' and 'Aux. PFC/Bal.' windows of the PQF-Manager.

Table 8.9. Reactive power tasks that the filter can perform

Reactive power task requirement	Description and filter setup to be made
No requirements	***PFC type***: Disabled ***Balance load***: Disabled The filter will not do any reactive power task, regardless of the values set for cos φ or static reactive power
Power factor compensation with inductive power factor setpoint, no load balancing required[(a)]	***PFC type***: Dyn. ind. ***Target cos φ***: Desired power factor between 0.6 and 1.0 The filter will do power factor compensation up to the cos φ setpoint, regardless of the value set for static reactive power[(b)]
Power factor compensation with capacitive power factor setpoint, no load balancing required[(a)]	***PFC type***: Dyn. cap. ***Target cos φ***: Desired power factor between 0.6 and 1.0 The filter will do power factor compensation up to the cos φ setpoint, regardless of the value set for static reactive power[(c)]
Fixed capacitive power step with a rating of x kvar, no load balancing required[(a)]	***PFC type***: Static cap. ***Q static***: x kvar The filter will generate x kvar reactive capacitive power, regardless of the value set for the target cos φ
Fixed inductive power step with a rating of x kvar, no load balancing required[(a)]	***PFC type***: Static ind. ***Q static***: x kvar The filter will absorb x kvar reactive inductive power, regardless of the value set for the target cos φ

Remarks:

(a) When load balancing is required, set '***Balance load***' to 'L-L'. In that case the filter will generate an additional amount of reactive power in order to balance the load which is unbalanced between the three power lines/phases.

(b) If the measured cos φ is higher than the setpoint and is inductive (e.g. measured 0.97 inductive and setpoint 0.92 inductive), then the filter will not make any correction. If the measured cos φ is capacitive, the filter will correct the power factor to 1.0

(c) If the measured cos φ is higher than the setpoint and is capacitive (e.g. measured 0.97 capacitive and setpoint 0.92 capacitive), then the filter will not make any correction. If the measured cos φ is inductive, the filter will correct the power factor to 1.0

8.7.1.2. Setting up alarms, warnings and digital inputs and outputs (D I/O)

The PQF-Manager contains 2 digital inputs, 6 digital outputs and 1 alarm contact (with two complementary outputs). These contacts can be used to provide data to the filter (e.g. remote control signals) and get data out of the filter (e.g. filter status information, alarm information etc). This section discusses the PQF-Manager setup for controlling all the digital I/O and creating warnings and alarms including the setup of trip-points for the optional external temperature probes.

- **Set up of the digital inputs of the PQF-Manager**

For setting up the digital inputs go to [/Welcome/Settings/Customer set./Digital Inputs]

WARNING: If a function is assigned to a digital input, the same function must never be assigned to the other digital input. Otherwise the filter may behave erratically.

Table 5.6. gives an overview of the possible digital input settings and the resulting filter behavior. The settings given in this table can be applied to any of the two digital inputs.

For more information on:
- The remote control functionality, refer to Section 7.10.1.
- The main/auxiliary control functionality, refer to Section 7.10.5.
- The implementation of local start/stop buttons, refer to Section 7.10.6.

The default setting for the digital inputs is 'Disabled'.

- **Set up of the digital outputs of the PQF-Manager**

For setting up the digital outputs go to [/Welcome/Settings/Customer set./Digital Outputs]

Table 5.7. gives an overview of the possible filter conditions that can be associated with any of the six digital outputs. When interpreting this table it should be noted that:
- The 'In standby' function refers to a state of the filter in which it is connected to the power supply (i.e. breaker closed) but the IGBTs are not switching. As a result the filter will have virtually no losses. This mode can be activated when the load requirement is lower than a preset value (e.g. all loads switched off for a long time). For more information on the 'In standby' function, refer to Section 8.7.3.2.
- The three programmable alarms and warnings have to be set up before they can be used. This is explained in the next sections. If a programmable alarm has been disabled, the digital output associated with it will never be activated.

The default settings for the digital outputs are given in Table 5.8. In order to disable the digital outputs, choose the option 'Disabled'.

For more information on cabling the digital output contacts refer to the Sections 7.10.2. - 7.10.4.

- **Set up of the programmable alarms and external temperature probes trip points**

For setting up the programmable alarms go to [/Welcome/Settings/Customer set./Alarms/Prog. alarms]

In addition to the alarm contact which is triggered by any filter fault, three programmable alarms can be defined. They can be associated with a digital output (see preceding paragraph). Table 8.10. shows the possible alarm conditions that can be associated with each programmable alarm.

Table 8.10. Overview of possible programmable alarm settings that can be associated with each digital output

Alarm condition	Setting for programmable alarm
Supply voltage (RMS) unacceptably high	Vrms_max
Supply voltage (RMS) unacceptably low	Vrms_min
One of the phases of the supply is missing	Phase loss
Network imbalance unacceptably high	Imbalance
Frequency variation unacceptably high	Fq change
Temperature reported by Temp. Probe 1 too high	T1 max
Temperature reported by Temp. Probe 2 too high	T2 max
PQFI DC bus voltage unacceptably high	Vdc_max
PQFI internal preload error	Prel. err.
PQFI overcurrent fault	Overcur.
PQFI ground fault	Gnd fault
PQFI IGBT fault	IGBT fault
PQFI overtemperature fault	IGBT temp.
PQFI main control board overtemperature fault	T ctrl max
PQFI control board supply fault PS fault	PS fault
PQFI control board fault	Ctrl board
Any fault (of the ones listed above)	Any fault

If the alarm condition is met, the programmable alarm will be set and the associated digital output will be activated when the alarm is present for a preset time.

The time during which the alarm condition has to be present has a minimal value of 180 s and can be increased if desired. In order to increase the time during which the alarm has to be present before the digital output is triggered, go to [/Welcome/Settings/Customer set./Alarms/Prog. alarms/Alarm delay].

Note that the delay programmed here is also applied to the filter alarm contact.

The digital output will be deactivated if the alarm has disappeared for a preset time which is by default 1 s. In order to change the alarm reset delay, go to [/Welcome/Settings/Customer set./Alarms/Prog. alarms/Alarm rst. del.].

When configuring the programmable alarm as ‘Any’ it will trigger the digital output if any of the fault conditions presented in Table 8.10. is met.

The programmable alarms can be deactivated by setting them to ‘Disabled’.

Remarks:

- Difference between the alarm contact and the digital output used as alarm contact
  The alarm contact is triggered by any fault that makes the system trip. These faults include the conditions mentioned in Table 8.10. but includes also all other internal filter faults that may occur. An exhaustive list of faults that may make the filter trip and thus trigger the alarm contact is given in Table 8.17. and Table 8.18. Use the digital outputs as alarm contact if the aim is to find the exact cause of the filter trip without having to analyze the event logging window.

- Setting up of the trip points for the external temperature probes (optional)
  When external temperature probes are connected to the system they have to be set up. This is done in the menu [/Welcome/Settings/Customer set./Alarms/Protection levels]. With each temperature probe a trip level is associated ('T1 prot.' and 'T2 prot.') and a duration during which the trip point has to be exceeded before a filter trip is generated ('T1 prot. del.' and 'T2 prot. del.'). Note that T1 relates to the probe connected to the terminal X1/T1 of the main controller board and T2 relates to the terminal X2/T2. More information on the hardware set up of the temperature probes is given in Section 7.11.1.

- **Set up of the programmable warnings**

For setting up the programmable warnings go to [/Welcome/Settings/Customer set./Warnings/Prog. warnings]

Three programmable warnings can be defined. Similar to the programmable alarms, they can be associated with a digital output. Table 8.11. shows the possible warning conditions that can be associated with each programmable warning.

Unlike alarms that cause a filter trip, warnings only activate the digital output contact.

Table 8.11. Overview of possible programmable warning settings that can be associated with each digital output

Warning condition	Setting for programmable warning
Supply voltage (RMS) higher than preset value	Vrms_max
Supply voltage (RMS) lower than preset value	Vrms_min
Supply voltage imbalance higher than preset value	Imbalance
Temperature recorded by external probe 1 (optional) higher than preset value	T1 Max
Temperature recorded by external probe 2 (optional) higher than preset value	T2 Max
PQFI ground current level higher than preset value	Gnd Fault
PQFI IGBT Temperature higher than preset value	IGBT temp.
PQFI control board temperature higher than preset value	T ctrl max

If the warning condition is met, the programmable warning will be set and the associated digital output will be activated when the warning is present for a preset time. This time has a minimal value of 1 s and can be increased if desired. In order to increase the time during which the warning has to be present before the digital output is triggered, go to [/Welcome/Settings/Customer set./Warnings/Prog. warnings/Warning delay].

The digital output will be deactivated if the warning has disappeared for a preset time which is by default 1 s. In order to change the warning reset delay, go to [/Welcome/Settings/Customer set./Warnings/Prog. warnings/Warn. rst del.]

The warning levels can be changed by the user. In order to do this, go to [/Welcome/Settings/Customer set./Warnings/Warning levels].

8.7.1.3. Setting up the unit for temperature measurements

For changing the default unit for the temperature measurements, go to [/Welcome/Settings/Customer set./Temp unit]

The temperature unit can either be °C or °F.

8.7.2. The 'Commissioning' menu [/Welcome/Settings/Commissioning]

WARNING:	**The commissioning menu is intended to be used by qualified commissioning engineers that are authorized to change the filter's core installation settings and to set up the user's requirements.**

Refer to Section 8.4. for determining appropriate locking facilities for this menu.

For an overview of the main items of the commissioning window, refer to Figure 8.2. These items are discussed next.

For commissioning the active filter follow the commissioning procedure presented in Chapter 10.

Remarks:
- The commissioning window incorporates the start, stop and fault acknowledgement menu (Cf. Section 8.5.)
- For advanced filter setup (autorestart function, standby function, system clock setup, external communication setup, system lock activation and password setup) refer to Section 8.7.3.

8.7.2.1. Setting up the network characteristics

For modifying the network characteristics, go to [/Welcome/Settings/Commissioning/Network charact.]

The network characteristics include:
- The nominal supply voltage: This value has to be set up according to the nominal value of the grid voltage.

WARNING:	**The auxiliary transformer primary winding tap setting is set at the highest position at the active filter production stage. The tap setting has to be changed first to match the network voltage to which the filter is connected (cf. Figure 5.8. item 3). Failure to do so may result in the auxiliary voltage being too high/low as a result of which the filter may be damaged. Isolate the filter supply upstream before changing the transformer tap setting.**

- The nominal value of the network frequency: This value has to be set up according to the nominal value of the network frequency.

WARNING:	**If the filter nominal frequency is changed to the wrong value, the filter will refuse to start indicating a frequency error in the event logging window.**

Remarks:
- After going through the network characteristics menu, the filter system will be automatically reset after which the new values will be taken into account.
- The filter needs to be stopped before the network characteristics menu can be accessed. Attempting to access the menu while the filter is running will result in a fault message being displayed.
- Pressing Esc in the network characteristics setup menu will result into jumping to the next step in the menu without the values entered being taken into account. When involuntarily entering the menu, walk through the menu by pressing OK or Esc repeatedly. This way the menu can be quit without modifying any values.

8.7.2.2. Setting up the number of filter units and the unit ratings

For modifying the number of filter units and the unit ratings, go to [/Welcome/Settings/Commissioning/Unit ratings]

The number of filter units and the unit ratings must be adapted to the on-site configuration. In addition, when the filter configuration is changed on site (e.g. adding an extra unit), the filter setup has to be adapted accordingly.

WARNING: Setting up a wrong filter configuration may lead to filter malfunction. This should only be done by experienced commissioning engineers.

In order to enter the number of filter units and the unit ratings, follow the procedure given below:
- Identify the nominal current rating of each power unit. This information is present on the identification label present at the inside and outside of each cubicle door.
- Open the unit ratings setup window. The PQF-Manager will display the current rating for the first power unit. If the value is correct, press OK to go to the next unit. Otherwise, modify the value with the ▲ and ▼ keys to match the actual cubicle rating. Then press OK to go to the next cubicle.
- The rating for the second cubicle will be displayed. If the filter was initially set up for one unit, the value displayed will be '0'.
- If a second cubicle is physically present, enter the current rating for the second cubicle and press OK to go to the next unit.
- Repeat the previous two steps until all the cubicles physically present have been programmed.
- To terminate the set up process, set the current rating of the next (not physically existing) cubicle to '0' and press OK. This will reset the filter system. Alternatively, if eight units are programmed, the system will automatically reset after programming the eight units. After the reset, the new unit ratings will be taken into account.

Remarks:
- After the system reset, the filter controller will compare the number of units physically present with the number of units reported by the commissioning engineer. If there is a mismatch between the two values, the filter will refuse to start and generate an error in the event logging window.
- The filter needs to be stopped before the unit ratings menu can be accessed. Attempting to access the menu while the filter is running will result in a fault message being displayed.
- Pressing Esc in the unit ratings setup menu will result into jumping to the next step in the menu without the values entered being taken into account. When involuntarily entering the menu, walk through the menu by pressing OK or Esc repeatedly. This way the menu can be quit without modifying any values.

8.7.2.3. Setting up the current transformer ratios and position

The current transformers connected to the filter have to be entered into the filter system. Two methods can be used to do this.
- Using the automatic CT detection feature;
- Entering the CT ratios and positions manually.

These approaches are discussed next.

- **Detection of the CT positions and ratio's using the automatic CT detection feature:**

For detecting the CT-settings automatically, go to [/Welcome/Settings/Commissioning/Auto CT detection]

WARNING: When launching the automatic CT detection procedure, the filter will connect to the network automatically. This may take several minutes in the case of large multi-unit filter. During this operation (high) operating voltages will be present in the cubicle. For personal safety reasons, close the filter cubicle door before launching the CT detection procedure. Also ensure that the filter CT terminals (X21) are not shorted.

When engaging the automatic CT detection procedure the filter will execute the following steps:
- Deselect harmonics and reactive power/balancing settings previously entered by the customer
- Display a warning message to wait for the identification procedure to end
- Preload the DC capacitors, close the main breaker and start the IGBTs
- Inject a small current into the supply
- Record the current measured by the CTs and calculate the filter CT ratios and positions
- Display a message indicating whether the CT identification ended successfully or not.

NOTE: After the CT detection procedure has finished, the user has to reprogram the filter settings that were automatically deselected.

If the CT identification ended successfully, the filter carries on by:
- Showing the CT positions found. This is done in a table format as given in Table 8.12.

Table 8.12. Automatic CT detection position-results presentation

Filter connection CT terminal[(a)]	Physical CT location and orientation[(b)]
Input 1	Line 1
Input 2	Line 2
Input 3	Line 3

Remarks:
[(a)] This column refers to the filter terminal X21 located in the filter cubicle.
Input 1: filter input X21/1-2 (L1, R, U)
Input 2: filter input X21/3-4 (L2, S, V)
Input 3: filter input X21/5-6 (L3, T, W)
[(b)] This column refers to the physical location of the CT connected to the input shown in the first column.
Line 1: CT connected in phase 1 (L1, R, U) with correct orientation
-Line1: CT connected in phase 1 (L1, R, U) with inversed orientation
Line 2: CT connected in phase 2 (L2, S, V) with correct orientation
-Line 2: CT connected in phase 2 (L2, S, V) with inversed orientation
Line 3: CT connected in phase 3 (L3, T, W) with correct orientation
-Line 3: CT connected in phase 3 (L3, T, W) with inversed orientation

When all CTs have been correctly installed, the PQF Manager should display the results as in Table 8.12. If the CTs have been connected wrongly, the corresponding line will read e.g.

Input 1 -Line 3

…

In the example above, the CT connected physically in phase 3 (L3, T, W) has been routed to the filter terminal for phase 1 (L1, R, U). Further the CT orientation or the cabling has been inversed (k terminal of CT connected to l terminal of filter and vice versa).

- After showing the CT positions found, the customer is asked to either acknowledge the results found (by pressing OK) or either not to accept them by pressing any other key. If any other key than OK is pressed, the automatic CT detection program will be quit. The CT parameters existing before the automatic CT detection program was started will be restored.

If the CTs have been wrongly connected and the results are acknowledged by the commissioning engineer, the filter controller will automatically take into account the wrong positions and correct them internally. Hence, there is no need to correct the CT connections manually. However, in line with proper installation guidelines, it may be recommended to correct physically the CT installation. In that case, the CT setup of the filter has to be adapted accordingly.

- When the CT positions have been acknowledged the filter will carry on by showing the CT ratio found phase per phase. The values shown are indicative only and always have to be verified by the commissioning engineer. He can change the values with the ▲ and ▼ if desired. In order to approve the value entered, OK has to be pressed. Table 8.13. explains the meaning of the text that appears on the display:

Table 8.13. Automatic CT detection ratio-results presentation

Text on PQF Manager display	Meaning
Ratio found	Ratio found for the CT in the considered phase E.g. 200 means a CT of 1000/5
CT Ratio L1[(a)]	Ratio that will be used by the filter for the CT physically connected in phase 1 (L1, R, U) of the installation
CT Ratio L2[(a)]	Ratio that will be used by the filter for the CT physically connected in phase 2 (L2, S, V) of the installation
CT Ratio L3[(a)]	Ratio that will be used by the filter for the CT physically connected in phase 3 (L3, T, W) of the installation
Remark: [(a)] The first phase has to be acknowledged before the second phase is displayed etc.	

After acknowledging the last phase with OK, the filter will automatically reset and the new values will be taken into account. Pressing Esc at any time will interrupt the automatic CT detection process and restore the CT-values and positions existing prior to the start of the procedure.

At the end of the automatic CT identification process, the user has to reselect the harmonics and reactive power/balancing settings that were possibly present before the automatic CT identification process was started. Otherwise the filter will not execute its compensation tasks.

If the CT identification ended unsuccessfully:

- The filter displays an error message indicating the reason for the problem. Table 8.14. gives a list of the possible error messages.

Table 8.14. Possible error messages during automatic CT identification

PQF-Manager error messages during automatic CT identification
The CT identification found inconsistent CT positions.
The CT identification did not end within an appropriate time frame.
The CT identification required an abnormally high DC voltage.

The most common causes for these messages are:
- CTs not connected or shorted
- CTs connected in open loop configuration
- Usage of an excessive CT ratio (including summation CTs). The CT ratio limit is set at 20000/5.

- After acknowledging the error message, the CT values existing before the start of the process will be restored and the automatic CT detection procedure will be ended. The unsuccessful CT detection attempt is recorded in the filter event logging window.

Conditions under which the automatic CT identification process may give unsatisfactory results include:
- The use of CTs with extremely high ratio's (> 20000/5). This will result in an error message indicating inconsistent CT positions. In this, the ratio of the summation CTs that may be present should be included.
- The presence of a low impedance directly downstream of the filter connection although the CTs have been correctly installed upstream of the filter connection. This will result in wrong CT ratio's being found. In that case the commissioning engineer can easily correct the CT ratio's found.
- The use of complex CT arrangements including summing CTs.

It is recommended that the results obtained with the automatic CT detection procedure be crosschecked with a visual inspection of the installation.

- **Setting up the CT positions and ratio's using the manual setup procedure:**

For entering the CT-settings manually, go to [/Welcome/Settings/Commissioning/Man. CT settings]

When entering the manual CT setup menu the user is subsequently prompted to define:
- ***for the CT connected to the filter CT terminals X21/1-2 (Input 1):***
  - in which line (phase) is it installed (Line 1, Line 2, Line 3)
  - does the CT (cabling) have the good orientation (Line x) or not (-Line x)

  Remark: If the CT installation is correct, enter 'Line 1'.
  If the CT is installed in the right phase but inversed, enter '-Line 1'.
- ***for the CT connected to the filter CT terminals X21/3-4 (Input 2):***
  - in which line (phase) is it installed (Line 1, Line 2, Line 3)
  - does the CT (cabling) have the good orientation (Line x) or not (-Line x)

  Remark: If the CT installation is correct, enter 'Line 2'.
  If the CT is installed in the right phase but inversed, enter '-Line 2'.
- ***for the CT connected to the filter CT terminals X21/5-6 (Input 3):***
  - in which line (phase) is it installed (Line 1, Line 2, Line 3)
  - does the CT (cabling) have the good orientation (Line x) or not (-Line x)

  Remark: If the CT installation is correct, enter 'Line 3'.
  If the CT is installed in the right phase but inversed, enter '-Line 3'.
- ***for the CT physically installed in Line 1 (L1, R, U):***
  - the CT ratio, which is always positive; e.g. a CT of 5000/5 has a ratio 1000
- ***for the CT physically installed in Line 2 (L2, S, V):***
  - the CT ratio, which is always positive; e.g. a CT of 5000/5 has a ratio 1000
- ***for the CT physically installed in Line 3 (L3, T, W):***
  - the CT ratio, which is always positive; e.g. a CT of 5000/5 has a ratio 1000

After entering all the abovementioned values, the filter resets and the settings are taken into account.

Remarks:
- Pressing Esc during the manual CT setup procedure will result in the old CT values being restored and the procedure being quit.
- Section 10.5. gives guidelines on how to identify the position of the CTs in case the automatic CT detection procedure cannot be used or is unsuccessful.
- Refer to Section 7.7. and Section 7.8. for more information on the selection and the installation of the current transformers.

8.7.2.4. Setting up the filter derating parameter

For entering the derating parameter, go to [/Welcome/Settings/Commissioning/Derating]

The permissible ambient conditions for PQFI operation are laid out in Table 6.1.

- If the filter is installed at locations higher than 1000 m (3300 ft) above sea level, the maximum filter output current must be derated by 1% every additional 100m (330ft).
- Above 40°C (104°F), the maximum output current must be derated by 3.5% every additional 1°C (1.8°F) up to 50°C (122°F) maximum limit.

The total required derating is the sum of all the deratings taking into account the installation height and the ambient temperature.

The PQF-Manager derating menu shows the filter nominal rating which is by default 100%. The new value to be set when derating is required is 100% - (total required derating %).

After approving the new derating value (OK), the filter will reset and the new value will be taken into account. In practice, this implies that the output current of the unit will be limited to the filter nominal current times the entered rating factor. E.g. a rating factor of 50% implies that the maximum RMS filter current is half the nominal filter current.

Pressing Esc will result in the original value being restored and the derating menu being quit.

8.7.2.5. Setting up the user's requirements

For entering the user's requirements at the commissioning level, go to [/Welcome/Settings/Commissioning/User]

At the commissioning level, a shortcut exists to the principal user set up menus. These consist of:

- Setting up the filter mode for the main settings. After selecting the desired value, press OK to go to the next step.
- Setting up the harmonic selection table for the main settings. After entering the desired values (cf. Section 8.7.1.1.), press Esc repeatedly until the next step is displayed.
- Setting up the reactive power requirements including balancing for the main settings. After selecting the desired values, press OK to go to the next step.
- After entering the data, the main settings can be copied on to the auxiliary settings (if desired) by pressing OK. Pressing any other key will omit this step.
- The set-up ends by displaying the main commissioning menu.

Remarks:

- Refer to Section 8.7.1.1. for more explanation on the main and auxiliary filter settings, the filter mode, the harmonics selection table and reactive power setup possibilities.
- A more complete user set up process can be done at he customer settings level (cf. Section 8.7.1.)
- In order to interrupt the set up process, press Esc repeatedly until the stop message appears. It should be noted that any parameters entered before the procedure is stopped, will have been recorded in the filter's memory. Re-enter the user set up to change the values again if desired.

8.7.3. The 'Installation settings' menu [/Welcome/Settings/Installation set.]

WARNING:	**The installation settings menu is intended to be used by qualified commissioning engineers that are authorized to change the filter's advanced settings.**

The filter's advanced settings include:
- the autorestart function
- the standby function
- the system clock setup
- the external communication setup
- the software lock activation and password setup

The aforementioned functions are discussed more in detail later in this section.

For convenience, the installation settings menu also gives an overview of the installation settings. More specifically, the following settings can be read:
- Settings for the nominal voltage and frequency ([/Welcome/Settings/Installation set./Network]);
- Unit rating settings ([/Welcome/Settings/Installation set./Unit ratings]);
- CT installation settings ([/Welcome/Settings/Installation set./CT Installation]);
- % Rating setting ([/Welcome/Settings/Installation set./Rating]).

Note that the settings of the above-mentioned parameters can only be changed at the commissioning level (Cf. Section 8.7.2.)

8.7.3.1. Setting up the 'autorestart' function

For setting up the 'autorestart' function, go to [/Welcome/Settings/Installation set./Start-Stop set.]

The 'autorestart' function when enabled ensures that the filter restarts automatically after a power outage if the filter was on before the power outage occurs. A time delay can be programmed to define how long after the power returns, the filter will restart. When the 'autorestart' function is disabled, the filter will not restart automatically after a power outage.

- To enable/disable the 'autorestart' function, go to [/Welcome/Settings/Installation set./Start-Stop set./Auto start].

- To program the delay after which the filter has restart once the power returns, go to [/Welcome/Settings/Installation set./Start-Stop set./Auto st. del].

Remark: By default the 'autorestart' function is enabled and the delay time is set at 5 s.

8.7.3.2. Setting up the 'standby' function

For setting up the 'standby' function, go to [/Welcome/Settings/Installation set./Start-Stop set.]

The 'standby' function when enabled puts the filter in standby, a preset time after the load requirement disappears. In this condition, the IGBTs stop switching while the main breaker remains closed (filter remains connected to the network). This way the filter losses become virtually zero. The filter will resume normal operation a preset time after the load requirement comes back. The standby function is particularly interesting for applications where the load is present for a long time and subsequently switches off for another long time.

In order to set-up the standby function, five parameters have to be defined:
- 'Stdby status':
  When enabled, the 'standby' function is activated.
  When disabled, the 'standby' function is deactivated.
- 'Standby level' and 'Standby hyst':
  Define the filter load level in % on which the filter goes in standby and comes out of standby.
- 'Stdby del off':
  Defines the time during which the filter load level has to be smaller than the lower threshold level before the filter is put in standby.
- 'Stdby del on':
  Defines the time during which the filter load level has to be higher than the upper threshold level before the filter comes out of standby.

The filter standby parameters are illustrated in Figure 8.15.

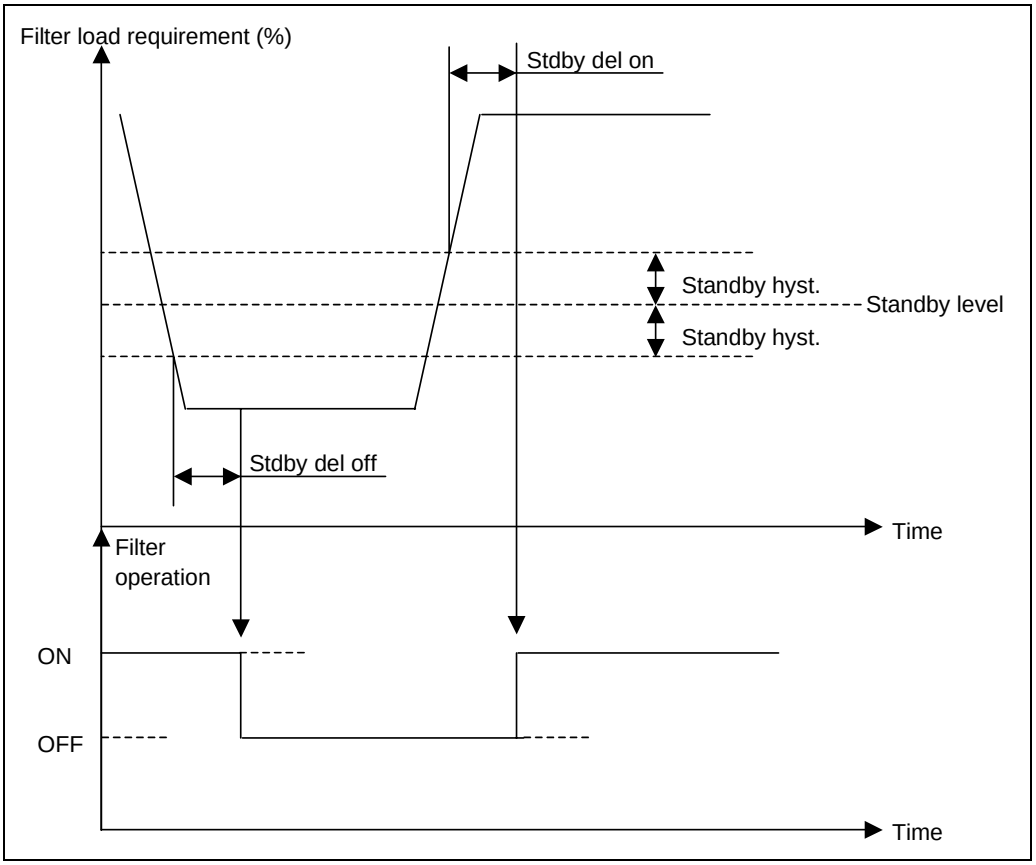


Figure 8.15. Illustration of the filter standby parameters

Remarks:

- The filter load requirement is determined from the user settings for harmonic filtration and reactive power compensation.
- It is recommended to put the lower threshold (i.e. [Standby level – Standby hyst.] %) of the standby function at least to 15%.

8.7.3.3. Setting up the system clock

For setting up the system clock, go to [/Welcome/Settings/Installation set./Clock]

The PQF is equipped with a system clock which can be modified by the user. Both the date and the hour can be changed. The hour is presented in 24 hour format and is set up for the time zone GMT +1.

8.7.3.4. Setting up the external communication parameters

For setting up the external communication parameters, go to [/Welcome/Settings/Installation set./Communication]

Two communication protocols can be selected for the external communication:

- Printer-PC:
  Choose this setting if a serial printer or a PC running the PQF-Link software (optional) will be connected to the PQF-Manager. When choosing this protocol, no other communication parameters have to be set-up on the filter side. For more information on how to connect and set up the serial printer, refer to Section 7.11.3. For more information on how to connect and set up the PQF-Link software, refer to the PQF-Link manual.

- Modbus protocol:
  Choose this setting if the filter will be connected to a Modbus network.

  When the Modbus protocol is used, some more parameters have to be configured. To do this, go to [/Welcome/Settings/Installation set./Communication/Modbus]. The parameters to be set include:
  - Baud rate, parity and number of stop bits for the communication
  - The PQF address in the Modbus network
  - The Modbus lock which when activated ensures that the PQF parameters can only be changed from the Modbus network.

  For more information on the Modbus communication system, refer to Chapter 9.

8.7.3.5. Setting up the software lock and password

The settings section of the PQF-Manager can be protected by a software and a hardware lock. More information on these locks is given in Section 8.4.

8.8. The 'PQF monitoring' menu

The 'PQF monitoring' menu can be accessed in the main Welcome screen [/Welcome/PQF monitoring].

This menu allows to monitor the filter load and to get an idea of its operating point compared to the nominal rating of the filter. In addition, logged warnings and faults can be retrieved for troubleshooting the filter operation and any abnormal network conditions.

The items of the 'PQF Monitoring' menu are discussed next.

8.8.1. The 'Filter load' menu [/Welcome/PQF monitoring/Filter load]

The filter load menu shows bar graphs expressed in % indicating the filter load with respect to the nominal rating of the following parameters:

- Inverter DC bus voltage: 'Udc' graph
- Peak current of the IGBT-modules: 'Ipeak' graph
- RMS current of the IGBT-modules: 'Irms' graph
- IGBT-temperature: 'Temp' graph

8.8.2. The 'Event logging' menu [/Welcome/PQF monitoring/Event logging]

The 'event logging' window stores the events that are recorded by the filter controllers. The event buffer store the 200 most recent events. Figure 8.16. gives an example of the event window.

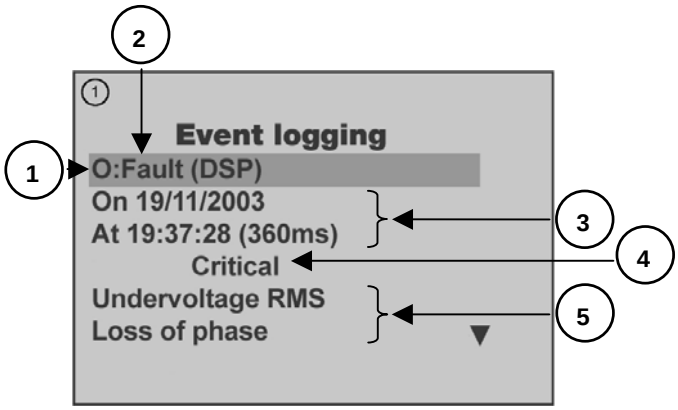


Figure 8.16. Example of an event window

The explanation of the different items is given in Table 8.15.

Table 8.15. Item explanation of the event window

Item	Explanation
1	Event number (0-199) The smaller the number, the more recent the event
2	Event type Table 8.16. gives an overview of the possible event types
3	Date and time at which the event occurred
4	If the event reported is a fault which is considered critical by the system, a 'Critical' indication will appear on the screen.
5	Fault description list if the event was a fault. Table 8.17. and Table 8.18. give an overview of the possible faults that can be reported.

When entering the 'Event logging' window, the most recent event is always displayed. Use the arrow keys to scroll through the event list. Use any other key to quit the menu.

Table 8.16. Overview of the events that can be recorded

Event	Description
No event	No storable event has occurred yet
Energization	The power has been switched on
System reset	The filter controller has been reset
Start request	A filter start has been requested
Stop request	A filter stop has been requested
Fault (DSP)	The DSP controllers have reported a fault
Fault (uC)	The µcontroller has reported a fault
Fault cleared	A user attempt to clear a fault has been recorded (by validating the 'ACK. FAULT' option on the PQF-Manager
No more fault	The system detects no more faults
Power outage	The system has detected a power outage
Download DSP	A DSP controller firmware upgrade (attempt) has been recorded
DSP stop	An internal stop command coming from the DSP controllers has been recorded

From Table 8.16. it can be seen that both the DSP controllers and the µcontroller can record faults. Where the faults reported by the µcontroller are predominantly relating to a control board failure, the faults reported by the DSPs relate predominantly to the filter interacting with the installation. Table 8.17. gives an overview of the faults that can be reported by the DSP controllers. The list is in alphabetical order.

Table 8.17. Overview of the faults that can be reported by the DSP controllers

DSP fault message	Description
Bad parameters	The filter parameters entered by the commissioning engineer are not consistent with the filter configuration reported by the controllers.
Bad message sequence	Internal system error.
Bad CT connection	The automatic CT detection procedure has encountered a problem during the identification process.
CT input overload	The CT inputs on the main controller card are overloaded.
DC overvoltage (SW)	The DC software overvoltage protection has been triggered (Cf. Table 7.14. for limit values).
DC undervoltage (SW)	The DC software undervoltage protection has been triggered (Cf. Table 7.14. for limit values).
DC overvoltage (HW)	The DC hardware overvoltage protection has been triggered.
DC undervoltage (SW)	The DC software undervoltage protection has been triggered.
Ground fault	A ground fault has been detected.
IGBT check cooling	The software IGBT temperature protection has been triggered.
IGBT over temp (HW)	The hardware IGBT temperature protection has been triggered.
IGBT permanent	The IGBT modules report an error that cannot be cleared by the system. This error can be due to peak overcurrent or too low control voltage for the IGBT drivers.
IGBT temporary	The IGBT modules report a transient error that could be cleared by the system. This error can be due to peak overcurrent or too low control voltage for the IGBT drivers.
Loss of phase	The system has detected a loss of supply on at least one phase.
No synchronization	The system cannot synchronize on to the network.
Optical clock lost	The system has detected a problem with the optical link.
Optical link no synchro	The system has detected a problem with the optical link.
Optic Lnk Rx frame mis.	The system has detected a problem with the optical link.
Out of mains freq. Limit	The system has detected that the network frequency is out of range.
Overvoltage RMS	The RMS value of the supply voltage is higher than the acceptable maximum value.
Overvolt. Transient (HW)	The hardware transient overvoltage protection has been triggered.
Overvolt. Transient (SW)	The software transient overvoltage protection has been triggered.
Overcurrent RMS	The system has detected RMS overcurrent.
Overcurrent peak (HW)	The hardware peak current protection has been triggered.
Overcurrent peak (SW)	The software peak current protection has been triggered.
Preload problem	The DC capacitors could not be preloaded. The voltage increase on the DC capacitors during the preload phase is not high enough.
Unbalanced supply	The supply imbalance is out of range.
Undervoltage RMS	The RMS value of the supply voltage is lower than the acceptable minimum value.
Unstable mains frequ.	The network frequency is varying too fast.
Wrong phase rotation	The filter is fed by a supply system which has the wrong phase rotation.
Remark: Maximum limits for certain parameters are given in Table 7.14.	

Table 8.18. gives an overview of the faults that can be reported by the µcontroller.

Table 8.18. Overview of the faults that can be reported by the µcontroller

µcontroller fault message	Description
Breaker/Cont trip	The system has detected a main breaker trip
Class B fault	Internal system error
Com. Problem (CAN bus)	Communication problem between the PQF-Manager and the main controller board.
Com. Problem (RS-232)	Serial communication problem between the main controller board and an external PC
Corrupted DSP code	Internal system error
Corrupted uC code	Internal system error
Ctrl overtemperature	The system detected an overtemperature of the main controller board
DSP 1 watchdog	Internal system error
DSP 2 watchdog	Internal system error
DSP 3 watchdog	Internal system error
DSP not responding	Internal system error
Ext. overtemperature 1	The system detected an overtemperature on the probe connected to X1/T1 of the main controller board
Ext. overtemperature 2	The system detected an overtemperature on the probe connected to X2/T2 of the main controller board
Flash memory corrupted	Internal system error
NMI fault	Internal system error
Parameters corrupted	Internal system error
Power supply fault	Internal system error
Preload time-out	The DC capacitors could not be preloaded in an acceptable time
Real time clock problem	Internal system error
Stack overflow fault	Internal system error
Stack underflow fault	Internal system error
Uncategorized fault	Internal system error
Watchdog fault	Internal system error

For guidelines on how to troubleshoot and solve the reported problems, refer to Chapter 13.

Remarks:

- Internal system errors are most likely due to faulty hardware and thus the only solution may be to exchange the controller cards.

- If the message ‘IGBT check cooling’ or ‘’IGBT over temp (HW) appear, this implies that the system is stopped due to an overtemperature problem.

In that case, check the cooling of the system (fans, filters) and of the switchgear room (air conditioning system etc.)

After the problem is solved the system has to be manually reset (fault acknowledgement) before normal operation can be resumed.

- In case the filter trips on overtemperature (the message 'IGBT check cooling' appears in the event logging window), the IGBT module and the phase that have caused the problem are reported in the menu variables 'Trip module' and 'Trip phase' (Cf. Section 8.8.6.) An external intervention is required to solve the problem and to reset the filter. Resetting is done by acknowledging the fault ([/Welcome/PQF/ACK. FAULT]).

- In general the occurrence of transient faults is no problem for the proper operation of the active filter. Only when an error becomes 'critical', a problem may exist.

A fault is considered critical if after occurrence, it cannot be successfully automatically cleared by the system within a reasonable time. The time frame considered depends on the error type.

In practice the word 'Critical' will appear in the 'Event logging' window if the system has detected a critical error. The user can then backtrack in the logging window to see which errors were already present in the previous events, to know which is/are the critical error(s).

8.8.3. The 'Active warnings' menu [/Welcome/PQF monitoring/Active warn.]

The 'Active warnings' menu is constantly updated by the system. It shows at any time the warning conditions set up by the customer that are met. For more information on setting up the programmable warnings, refer to Section 8.7.1.2. and Table 7.16.

Table 8.19. shows an overview of the warning messages that will be displayed and the corresponding warning condition.

Table 8.19. Warning messages that can be displayed by the PQF-Manager and corresponding warning conditions

Warning condition	Warning message displayed
Supply voltage (RMS) higher than preset value	Overvoltage RMS
Supply voltage (RMS) lower than preset value	Undervoltage RMS
Supply voltage imbalance higher than preset value	Unbalanced supply
Temperature recorded by external probe 1 (optional) higher than preset value	Ext. overtemperature 1
Temperature recorded by external probe 2 (optional) higher than preset value	Ext. overtemperature 2
PQFI ground current level higher than preset value	Ground fault
PQFI IGBT temperature higher than preset value	IGBT temperature
PQFI control board temperature higher than preset value	Ctrl overtemperature

8.8.4. The 'Total number of errors' menu [/Welcome/PQF monitoring/Number of errors]

The 'Total number of errors' menu keeps track of all the errors that have been recorded since the controller system has been initialized at the production stage. The errors that have occurred the most are listed first. Errors that have not occurred are not listed. For an explanation on the errors listed, refer to the Table 8.17. and Table 8.18.

8.8.5. The 'PQF operation' and 'Fan operation' parameters

The 'PQF operation' ([/Welcome/PQF monitoring/PQF Operation]) parameter indicates the total operating time of the filter (filter 'on').

The 'Fan operation' ([/Welcome/PQF monitoring/Fan Operation]) parameter indicates the total operating time of the fans cooling the filter.

8.8.6. The 'Trip. module' and 'Trip. Phase' parameters

If the filter trips due to an overtemperature problem, the 'Trip. module' and 'Trip. phase' parameters can be used to identify the unit and phase causing the problem.

The 'Trip. module' parameter ([/Welcome/PQF monitoring/Trip. module]) gives the number of the hottest module (1 – 8). The count starts from the master cubicle.

The 'Trip. phase' parameter ([/Welcome/PQF monitoring/Trip. phase]) gives the number of the hottest phase (1 – 3). The count goes from left to right, i.e. 1 = L1 (R, U), 2 = L2 (Y, V) and 3 = L3 (B, W).

If no temperature problem exists, the parameter values are 0. If a problem exists, an external intervention is required to solve the problem after which the unit has to be reset by acknowledging the fault ([/Welcome/PQF/ACK. FAULT]). After doing this, the parameters are reset to 0.

8.9. The 'About PQF' menu

The 'About PQF' menu can be accessed in the main Welcome screen [/Welcome/About PQF].

This menu gives basic data on the filter. This data includes:

- Basic manufacturer settings such as filter type, maximum voltage rating and filter serial number. These settings can be accessed in [/Welcome/About PQF/Manufacturer set.]
- Firmware version numbers for the PQF-Manager, the μcontroller and the DSP controllers.

WARNING:	**When communicating with your ABB representative on a specific filter, please provide always the data shown in the 'About PQF' menu.**

9. The Modbus communication interface

9.1. What this chapter contains

This chapter contains the information needed to install the RS-485 Modbus adapter (optional) on to the PQF-Manager and the data required to integrate the PQF filter in a Modbus network. At the end of this chapter, background information on Modbus communication is given.

9.2. Introduction to Modbus

Modbus is a serial, asynchronous protocol. The Modbus protocol does not specify the physical interface. The PQF has an RS-485 Modbus adapter interface. Modbus is designed to allow communication between components of an installation including one or several supervision systems. Amongst the countless advantages and benefits of the communication capability, Modbus is a well spread protocol in the industrial world and allows, for example, interconnection between components for linked actions and information centralization. Gateways between Modbus and other fieldbusses can be found on the market giving access to several other fieldbus systems.

9.3. The RS-485 Modbus adapter

The Modbus adapter is an optional device for the PQF filter which enables the connection of the PQF to a Modbus system. The PQF filter is considered as a slave unit in the Modbus network. Through the RS-485 Modbus adapter, it is possible to:

- Read measurements and logged values
- Read and write parameters settings of the PQF
- Read status information
- Read device identification

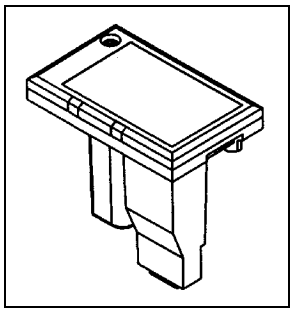


Figure 9.1. RS-485 Modbus adapter

9.3.1. Main features

The adapter is self powered through the power supply of the controller
- → an external power supply is not needed
- → low power consumption

The adapter is fixed directly on the rear side of the PQF-Manager
- → the RS-485 Modbus adapter does not need any DIN rail or other fixation methods.

The adapter is electrically isolated from the PQF-Manager power supply
- → the PQF-Manager is protected against common mode voltage levels applied on the RS-485 network
- → no ground loop

The adapter has an integrated termination resistor which may be connected with a switch
- → no external device to be added

The adapter contains transient voltage suppressors
- → the device and the network are protected against voltage surges

The adapter is fitted with transmission and reception indication LED's
- → it allows visualizing of Modbus queries and Modbus answers.

The controller allows a software adjustment of communication parameters
- → no multiple hardware dipswitches to handle
- → permits self-tuning of communication parameters with a higher level software application

9.3.2. Physical dimensions

The Modbus adapter physical dimensions are given next.

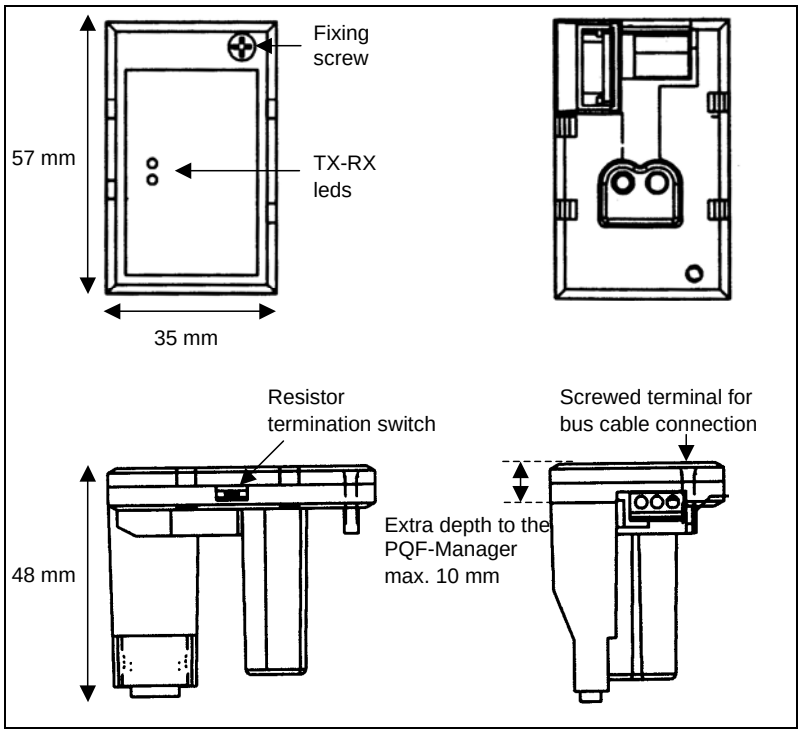


Figure 9.2. Physical dimensions of the RS-485 Modbus adapter

9.3.3. Technical data

- Operating ambient temperature: -20 to +70 °C
- Number of nodes (Tx drive): 32 max
- Rx loading: receiver impedance is 1 unit load per RS-485 Modbus adapter
- Size of the Link: 247 stations including repeaters (31 stations and 1 repeater per segment)
- Medium: Shielded, twisted pair RS-485 cable (Belden 9841 typical)
- Maximum Bus Length: 1200 m
- Topology: Multi-drop
- Serial Communication Type: Asynchronous, 2 wires half Duplex
- Baud rate: 110, 300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600 bauds selectable by the user (can be adjusted through the PQF-Manager menus)
- Termination resistor: built in, selectable by a switch. A 120 ohm resistor is needed at both ends of the line and must be switched on or not depending on the location in the Modbus network topology.
- Transient voltage suppressors
- Screw-type terminals on the RS-485 side
- TX – RX Led indication for easy debugging and troubleshooting
- Slew-Rate Limited for Error-Free Data Transmission (minimizing EMI and reducing reflections caused by improperly terminated cables)
- Drivers are short-circuit current limited
- The receiver input has a fail-safe feature in case of broken connection
- Compatible Devices: Any Modbus device capable of Modbus communication as a master.
- Speed reply time: better than 10 ms at 57600 bauds
- Max data packet: Any complete table provided in the Modbus data table

9.3.4. RS-485 Modbus adapter terminal switch

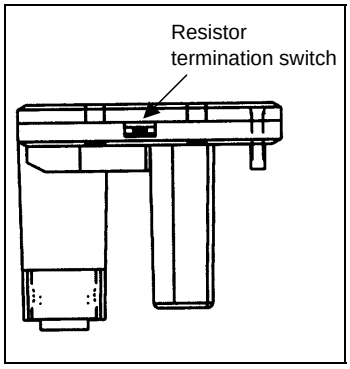


Figure 9.3. Resistor termination switch

Depending on the position of the PQF-Manager in the Modbus line topology, the resistor termination switch must be switched ON or OFF.
If the RS-485 Modbus adapter is one of the two ending stations on the communication line, the resistor termination switch must be switched in the ON position. If not, it must be switched in the OFF position.
Make sure all other Modbus stations (master and slaves) are properly connected.

9.4. RS-485 Modbus adapter mounting

In case the Modbus adapter has not been mounted yet, follow the instructions given next.
The Modbus adapter has a customized design to fit the PQF-Manager case:
- plug the RS-485 Modbus adapter in the PQF-Manager dedicated connectors,
- fix the RS-485 Modbus adapter with the fixing screw (included with the delivery),
- ensure that all connections are tight.

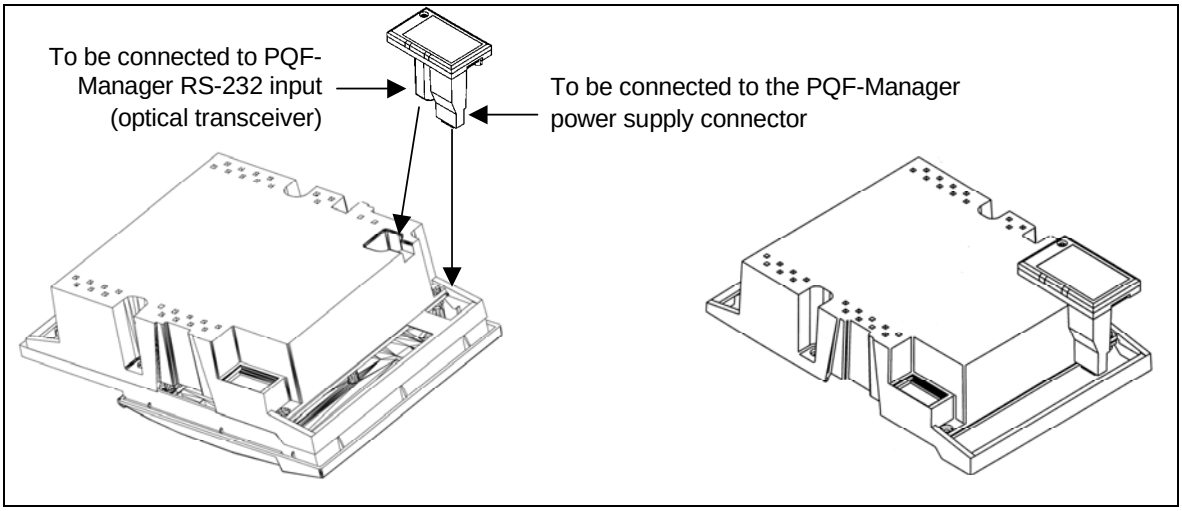


Figure 9.4. RS-485 Modbus adapter mounting

Please note that if the PQF-Manager is already installed and connected, the PQF-Manager power supply has to be switched OFF during the RS-485 Modbus adapter connection.

9.5. RS-485 Modbus adapter wiring

To wire the RS-485 Modbus adapter, follow the following steps:
- Disconnect the filter from the supply
- Connect the signal ground (if present) to GND of the RS-485 Modbus adapter
- Connect the twisted pair to the A and B connections of the RS-485 Modbus adapter

This is illustrated in Figure 9.5.

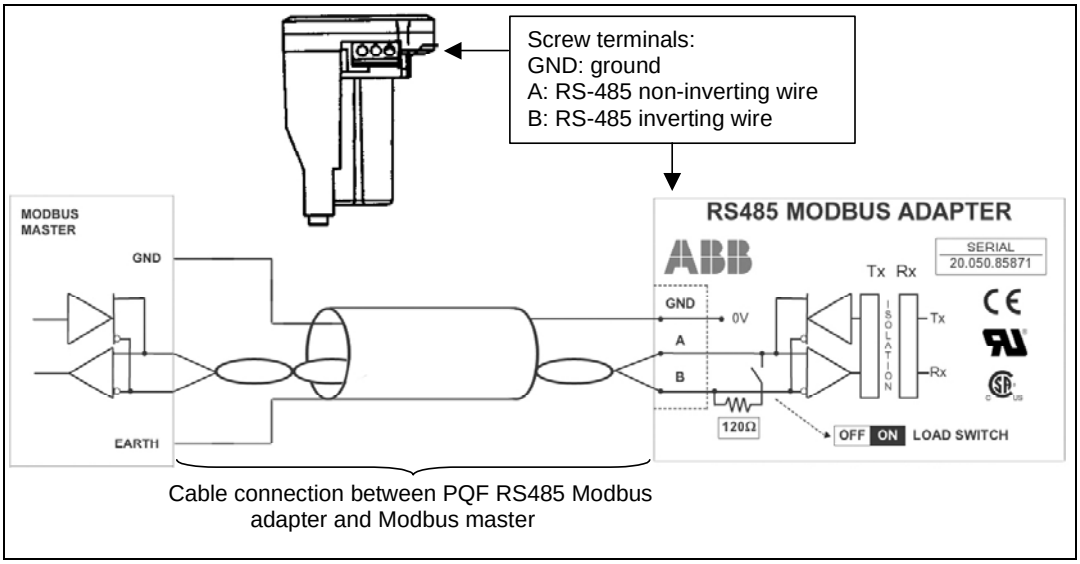


Figure 9.5. RS-485 Modbus adapter wiring

A proper cable must be used for the connection between the RS-485 Modbus adapter and the Modbus master. For an RS-485 connection and up to 1200 m (4000 ft), a 24 AWG twisted pair with foil shield and drain wire on each pair is usually required (Belden 9841 for 2-wire and 9729 for 4-wire or equiv.)
Please note that if the PQF is already installed and connected, the PQF power supply has to be switched OFF during the Modbus adapter connection.

9.6. RS-485 Modbus adapter commissioning

- Connect the adapter mechanically and electrically (cf. Section 9.4. and Section 9.5.)
- If the RS-485 Modbus adapter is one of the two ending station on the communication line put the load termination switch in the ‘ ON ‘ position. If not, put it in the ‘ OFF ‘ position.
- Make sure all other Modbus stations (master and slaves) are properly connected
- Apply power to the filter auxiliaries.
- Enter the protocol selection menu [/Welcome/Settings/Installation set./Communication/Protocol]
- Enter the MODBUS menu [/Welcome/Settings/Installation set./Communication/Modbus]
  → Select the right communication speed (baud rate)
  → Select the right parity checking
  → Select the right number of stop bits
  → Choose a slave address (the address must be unused in the Modbus network it is inserted in)

The Modbus slave is now ready to receive Modbus queries from the Modbus master and to send Modbus response accordingly. If something goes wrong, see Section 9.8.

If the PQF filter’s parameters should only be changed from the Modbus network, set the Modbus lock item as locked. It can be found under the menu [/Welcome/Settings/Installation set./Communication/Modbus]
→ Set the Modbus lock parameter to ‘Locked’

Depending on the way the PQF filter is connected to the Modbus network, different ways of testing the communication may be chosen.
A small PC interface is provided with the documentation in order to check the communication with the RS-485 Modbus adapter: see CheckModbusComm.exe (on CD).
In case of problems, please refer to Section 9.8.

9.7. Data access

9.7.1. PQF access levels

The appropriate access levels must be set to allow filter parameters to be changed. Both hard- and software locks of the PQF-Manager must be released. For more information on the PQF-Manager hard- and software lock, refer to Section 8.4.
Another parameter (MODBUS LOCK) is used to add access rights to Modbus users.
The access levels of the Modbus writings are coded in the Modbus data table.

9.7.2. Minimum and maximum values

Variables have a limited range. If a write operation to a variable exceeds the minimum and maximum allowable values, the variable will be overridden with its minimum or maximum value.
An ILLEGAL DATA VALUE exception error is sent back.
See the Modbus data table for more details.

9.7.3. Modbus data table

The Modbus data is arranged in several tables for convenience. Individual tables contain similar information. Table data may be read only or may have read/write access.
Data in each table is pointed to in a Modbus command by two consecutive data address bytes. The first byte defines the table number, and the second byte the offset of the data in the table. These two bytes are what is called the 'Modbus address' or the 'Modbus register'.
A specific Modbus data table is dedicated to a specific product type.
Access (read or write) to a non-referenced Modbus address result in an ILLEGAL DATA ADDRESS exception error. The Modbus data table gives all information on the various data and how to access them.
To handle PQF-Manager data, please refer to the PQF Modbus data table provided on the CD.

9.8. Troubleshooting

9.8.1. Preferred method of testing

In most cases the Modbus master (usually a PC software package) will be running on a personal computer or on hardware which has RS-232 communications ports. In this case a converter will be needed to convert the RS-232 signals to the RS-485 standard used by the PQF-Manager. Only when the Modbus master is running on hardware fitted with RS-485 ports is a converter unnecessary.
The preferred method of testing communications configuration is to operate with a single PQF-Manager located close to the Master (PC, PLC etc) and minimum cable length.
Once cable connections, PQF-Manager configuration and Modbus Master configuration have been successfully tested the system may be connected to the final installation (multiple slaves and extended cabling systems as needed to meet user requirements). Full system configuration and testing can then take place.
The software used to provide the Modbus Master functionality is not supplied. The commissioning engineer should be familiar with the use of the software both while testing the connection to the PQF-Manager and during the full system configuration. In general, software used during testing can be classed as either application software or Modbus test software, the principal differences between these two types are as follows:

- Application software (such as Data Loggers or SCADA systems) is intended to use Modbus devices to perform a measurement, control or logging function. It often provides tools for quick configuration of known types of instrument. Such packages make it easy for a user to start a system without needing to know Modbus commands, but may not provide the tools for a commissioning engineer to diagnose problems when a system does not respond as anticipated.
- A Modbus test software normally allows Modbus commands to be generated as required and the responses analyzed. Some knowledge of the Modbus protocol and the instrument register addresses will be required before using such a package. Test packages will assist a commissioning engineer in diagnosing communication problems.

9.8.2. Check of identical Slave – Master configuration

The master must have the same communication parameters as the PQF-Manager:
- Enter the protocol selection menu [/Welcome/Settings/Installation set./Communication/Protocol]
- Enter the MODBUS menu [/Welcome/Settings/Installation set./Communication/Modbus]
  → Select the right communication speed (baud rate)
  → Select the right parity checking
  → Select the right number of stop bits
  → Choose a slave address

9.8.3. Check the cabling of the RS-485

- The non-inverting and the inverting output wires should be cabled respectively on the non-inverting and inverting input respectively. No communication will take place if non-inverting wires are mixed with inverting wires.
- Load termination resistors are important at both end of the network to avoid distortion due to reflections in the communication line. Check that the 'Load switch' is at the right position (ON or OFF) according to the network configuration.
- Connection of a ground wire and presence of a shielding will improve the reliability of the communication.

9.8.4. Check the Transmit – Receive LEDs

This is a convenient way to check the presence of TX - RX signals:
- The Receive Led (yellow Led) indicates that a Modbus query is being received by the RS-485 Modbus adapter.
- The Transmit Led (green Led) indicates that a Modbus response is being transmitted from the RS-485 Modbus adapter.

If the Rx Led and the Tx Led are never lit, the problem may come from:
- The wires of the RS-485 cable are not properly fixed or cabled
- The query is not sent (see the application software)
- The PQF and the RS-485 are not powered on

Remark: To check if the RS-485 Modbus adapter is powered on, set the printer protocol and select to print the filter settings. This will activate the Tx Led repeatedly without any query coming from the Modbus system.

- Enter the protocol selection menu [/Welcome/Settings/Installation set./Communication/Protocol]
  → Select: PRINTER
- Enter the print settings functionality [/Welcome/Settings/Print settings]

If only the Tx Led never lights up, the problem may come from:
- The PQF-Manager settings are not correct (check communication parameters settings).
- The Modbus master or the RS-232/RS-485 converter cannot manage efficiently the flow control (Cf. Section 9.9.11.)
- The PQF-Manager entered the 'listen only' mode (reset the filter or send the required command to disable the 'listen only' mode.)
- The master send Broadcast messages (address 0) which are to be acted on by all connected devices and do not require a reply.

If the Tx Led is flashing without any query from the master:
- The Modbus protocol is not selected and printing functionality is activated.

- Enter the protocol selection menu [/Welcome/Settings/Installation set./Communication/Protocol]
  → Select: MODBUS

9.8.5. Check the function called and the register addresses

To ensure that a read or write message to a Modbus address will produce a normal response, check that the register address corresponds exactly to the desired data requested.
In Modbus register addressing there are several categories of register, including holding registers (numbered from 40001 upwards) and input registers (numbered from 30001 upwards). The category of register addressed is implicit in the Modbus function used, e.g. function 03 addresses holding registers and function 04 addresses input registers.
Irrespective of the function used, the register address 30001 or 40001 would be addressed in the transmitted message as register 0, 30002 or 40002 as register 1, 30010 or 40010 as register 9 and so on.
In the Modbus communications all these register addresses are not active and doesn't contain valid information. A read or write command to an unused register address will produce an exception error.

9.8.6. Check the data access level and the limited range of data

To ensure that a write message to a Modbus address will produce a normal response, check that the data value and access level is valid.
Editing parameters in the filter controller memory through Modbus may be restricted by the setting of some access levels. Verify the hard- and software lock settings of the PQF-Manager (Cf. Section 8.4.)
Memory-writes in the filter controller through Modbus are restricted to a limited range applied to that data. An exception error is sent in case of a writing exceeding the allowed limited range of a data to.

9.8.7. Counters and Loopback diagnostics

Modbus offers some interesting functions to help the user to locate errors:
Fetch comm event counter (function 11) to catch successful messages.
Fetch comm event log (function 12) to look at the history of errors.
Diagnostics function and subfunctions (function 8).
Loopback diagnostics (subfunction 0) returns a response identical to the query.
Restart communication (subfunction 1).
Force Listen only mode (subfunction 4).
Read various diagnostic counters.

9.8.8. Debugging tool and documents

A small software interface is provided with the documentation to help the user to test the hardware and the wirings: see CheckModbusComm.exe on the CD. This application sends a query, analyzes the response and displays an OK or not OK status.
Look in the documentation of the corresponding Modbus data table for appropriate information.
Refer to Section 9.10. for more information on the Modbus protocol.

9.9. Serial interface considerations

The Modbus protocol communicates with the instrumentation by means of an industry standard serial interface. This interface may be RS-232, RS-422 or RS-485. Some systems may also support the protocol over other busses or networks, such as Ethernet.
An RS-232 interface allows only two devices to be connected together.
RS-422 supports 1 driver and up to 10 receivers on a single network.
For bi-directional communications, special tri-state circuitry is provided. RS-485 supports up to 32 driver/receiver pairs. With special hardware, the RS-422 and RS-485 limits can be expanded to allow as many as 248 devices on a single network. Each device on a network must have a unique address, which may be soft configured. Address zero is reserved for broadcast messages from the host to all slaves.
All devices on a network must also be configured with the same parameters, such as baud rate and parity. In designing the communication architecture, one should consider communications performance when deciding how many devices to connect to a host port. Generally, nearly twice the performance can be achieved by splitting the devices from one port, onto two ports.

9.9.1. Communication mode

MODBUS protocol uses half-duplex communications, regardless of the hardware.
Half-duplex hardware shares the same lines for transmit and receive, whereas, full-duplex hardware has dedicated transmit and receive lines.

9.9.2. SINGLE ENDED versus DIFFERENTIAL data transmission

- Single-ended transmission is performed on one signal line, and the logical state is interpreted with respect to ground. The main disadvantage of the single-ended solution is its poor noise immunity.
- For differential transmission, a pair of signal lines is necessary for each channel. On one line, a true signal is transmitted, while on the second one, the inverted signal is transmitted. The receiver detects voltage difference between the inputs and switches the output depending on which input line is more positive. Differential data transmission schemes are less susceptible to common-mode noise than single-ended schemes.

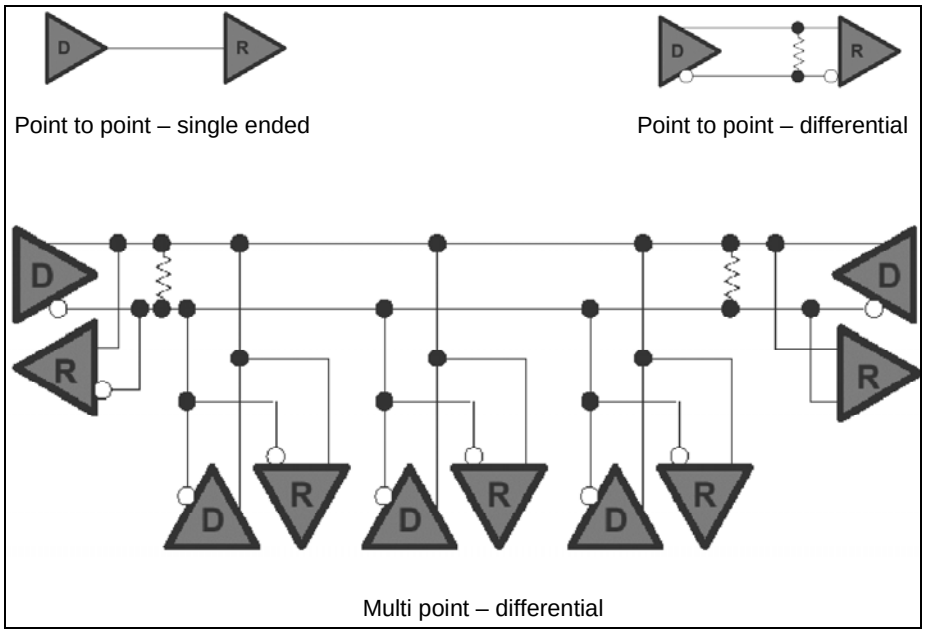


Figure 9.6. Single ended versus differential data transmission

9.9.3. RS-232 interface

An RS-232 interface is rated for distances up to 15 meters (50 feet). At least three wires are required for an RS-232 interface. Wires are required for Transmit, Receive and Signal Ground. Some devices support additional wires for communication handshaking. RS-232 hardware is a full-duplex configuration, having separate Transmit and Receive lines.
Each signal that transmits in an RS-232 data transmission system appears on the interface connector as a voltage with reference to a signal ground. The RS-232 receiver typically operates within the voltage range of +3 to +12 and -3 to -12 volts.

9.9.4. RS-422 interface

An RS-422 interface requires at least four wires. Two wires each are used for Transmit and Receive. A fifth wire is usually required for Signal Ground, when connecting non-isolated devices together. Handshaking lines may also be supported by some hardware. This interface is full duplex, allowing use of the same software drivers as for RS-232. The differential drivers allow for distances up to 1200 meters (4000 feet). The receivers of an RS-422 device are always enabled.

9.9.5. RS-485 interface

For multi-drop operation, drivers must be capable of tri-state operation.
An RS-485 interface requires at least two wires. In a two-wire configuration, the same pair of wires is used for Transmit and Receive. The two-wire configuration utilizes half-duplex communications. Transmit driver circuits are always taken off-line or tri-stated, when not in use. This tri-state feature reduces the load on the network, allowing more devices, without the need of special hardware. This interface also uses differential drivers, supporting distances up to 1200 meters (4000 feet).
In a differential system the voltage produced by the driver appears across a pair of signal lines that transmit only one signal. A differential line driver will produce a voltage from 2 to 6 volts across its A and B output terminals and will have a signal ground (C) connection. Although proper connection to the signal ground is important, it isn't used by a differential line receiver in determining the logic state of the data line.
A differential line receiver senses the voltage state of the transmission line across two signal input lines, A and B. It will also have a signal ground (C) that is necessary in making the proper interface connection. If the differential input voltage Vab is greater than +200 mV the receiver will have a specific logic state on its output terminal. If the input voltage is reversed to less than -200 mV the receiver will create the opposite logic state on its output terminal.

9.9.6. Bias resistors

RS-422 and RS-485 networks often require bias, or pull-up and pull-down resistors. These resistors are used to stabilize the network. By definition, in a MODBUS RTU network, it is the responsibility of the Master to provide this function.
Some systems may function without these stabilizing resistors, but may be more susceptible to communication errors. Though the pull-up and pull-down resistors are the same, the value of these resistors varies from device to device. The actual recommended resistance may be calculated, and varies with the number of devices on the bus.

9.9.7. Termination resistors

Termination resistors are often used to reduce reflections on the network. This problem occurs most with long wires and high baud rates. Due to variations in wire and equipment, whether or not to use these terminators is usually determined by system testing. The general rule is to add them only if needed. The resistors are typically 120 ohms, and installed across the Transmit and Receive wire pairs. Normally, one resistor is installed at each end of each pair of wires.

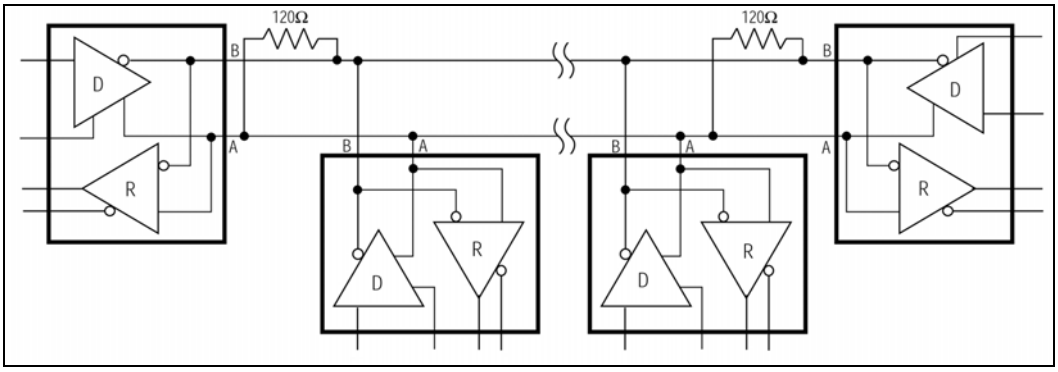


Figure 9.7. Termination resistors

9.9.8. Shielding and grounding considerations

The signal ground conductor is often overlooked when ordering cable. An extra twisted pair must be specified to have enough conductors to run a signal ground. A two-wire system then requires two twisted pairs.
It is often hard to quantify if shielded cable is required in an application or not. Since the added cost of shielded cable is usually minimal it is worth installing the first time.

9.9.9. Cable requirements

The type of wire to use will vary with required length. Wire with twisted pairs and an overall shield is used most often. The shield is tied to earth ground or chassis, and typically at one end only (generally at the Modbus Master side). The shield is not to be used as a signal common or ground. Below are listed the typical cable recommendations:

- RS-232: up to 15m (50ft) virtually any standard shielded twisted pair with drain (Belden 9502 or equivalent)
- RS-422 and RS-485: up to 1200m (4000ft) 24 AWG twisted pair with foil shield and drain wire on each pair (Belden 9841 for 2-wire and 9729 for 4-wire or equiv.)

9.9.10. Network topology

Various kind of network topologies may be done on the basis of an RS-485 Modbus network.
The Modbus network may be managed by a computer collecting data. Typically this computer runs an OPC server connected to a plant intranet. OPC client applications may present these information to any supervision program who will perform the Human machine interface, data logging, data setting, …

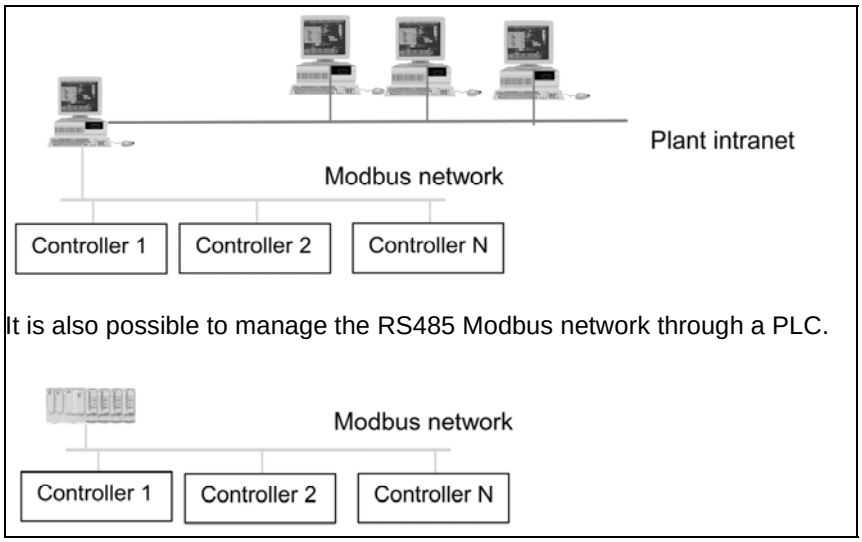


Figure 9.8. Network topology

Various kind of RS-485 to RS-232 converters exists.
To bridge the Modbus network to another kind of software protocol, various kind of protocol converters may be used. They are often called 'protocol gateway: Modbus to Profibus, Ethernet, CAN, …

9.9.11. Choice of a RS-232/RS-485 converter

In an RS-485 network, a control of the direction is needed to alternate between transmission and reception:

- No flow control:
  The direction control is done in the RS-232 to RS-485 converter. The converter senses the data direction and release automatically the line to tristate when no activity is found. The release time is typically one character length (11 bits/baud rate).
- RTS flow control:
  The direction control is done by setting RTS signal (Request To Send) and releasing RTS after transmission. This is done by software. The drawback is that if the software is busy by another task or if the PC is too slow, the direction control may be inverted too late, loosing received data.

In Modbus RTU framing, messages start with a silent interval of at least 3.5 character times.
is related to the RS-485 Modbus adapter. It shows the timings of the minimum silent length between the reception of a query and the transmission of an answer at different baud rate.

Table 9.1. Minimum silent length between the reception of a query and the transmission of an answer

Baud rate (bits/sec)	Minimum silent length (ms)
110	350
300	160
600	80
1200	40
2400	18.8
4800	9.8
9600	5.5
19200	3.4
38400	1.6
57600	1.6

The choice of the RS-232/RS-485 is then particularly important as a bad management of the direction of transmission may lead to communication errors or no communication at all.
If RTS is released too early, the query will not arrive to the Modbus slave and no answer will be initiated.
If RTS is released too late, the answer will not be received completely by the Modbus master.

As a consequence, to ensure higher throughput and reliable communication, the recommendation is done to choose an RS-232/RS-485 to sense and manage the data direction, and to avoid any computer dependent flow control. Missing to do so may lead to force the user to work with a slower transmission speed.

9.10. Modbus protocol overview

MODBUS RTU is a non-proprietary serial communications protocol that is widely used in the process control industry. The protocol was developed by Modicon for PLC communications and later released for public use.
This protocol is available in all major Human Machine Interface (HMI) software packages and terminals. Many of the major controller and PLC
manufacturers also offer MODBUS protocol as a standard or optional protocol in their instrumentation.
The hardware over which MODBUS RTU communications are performed is not defined by the protocol. MODBUS RTU is supported on RS-232, RS-422, RS-485, Ethernet and other electrical standards. It should be noted that MODBUS RTU, MODBUS ASCII and MODBUS Plus are unique communication formats, and are not compatible with each other. This document will discuss MODBUS RTU only.

9.10.1. Transactions on Modbus Networks

Modbus protocol uses a master-slave technique, in which only one device (the master) can initiate transactions (called 'queries'). The other devices (the slaves) respond by supplying the requested data to the master, or by taking the action requested in the query. Typical master devices include host processors and programming panels. Typical slaves include programmable controllers.
The master can address individual slaves, or can initiate a broadcast message to all slaves.
Slaves return a message (called a 'response') to queries that are addressed to them individually. Responses are not returned to broadcast queries from the master.
The Modbus protocol establishes the format for the master's query by placing into it the device (or broadcast) address, a function code defining the requested action, any data to be sent, and an error–checking field. The slave's response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to be returned, and an error–checking field. If an error occurred in receipt of the message, or if the slave is unable to perform the requested action, the slave will construct an error message and send it as its response.

9.10.2. Serial Transmission Mode

The transmission mode defines the bit contents of message fields transmitted serially on the networks. It determines how information will be packed into the message fields and decoded.
Modbus defines two transmission modes: ASCII or RTU.
Only RTU mode will be used here. The mode and serial parameters must be the same for all devices on a Modbus network.

9.10.3. Data Addresses in Modbus Messages

Modbus defines 4 address spaces: 2 address spaces for bit addressable data and 2 address spaces for 16 bits addressable data.

Table 9.2. Data addresses

Address space	Data	Readable/writable	Modbus name
0XXXX	Output bit	Read & write	Coil status
1XXXX	Input bit	Read	Input status
3XXXX	Input word	Read	Input register
4XXXX	Output word	Read & write	Holding register

9.10.4. Supported function codes

Table 9.3. gives the Modbus functions, which are implemented and supported.
The code is the one used in function field of the Modbus message.
The address space concerned and the purpose of the function are given below.

Table 9.3. Supported function codes

Code	Function	Address range / remark
1	Read Coil Status	0XXXX Reads the on/off status of discrete outputs
2	Read Input Status	1XXXX Reads the on/off status of discrete inputs
3	Read Holding Registers	4XXXX Reads contents of output registers
4	Read Input Registers	3XXXX Reads contents of input registers
5	Force Single Coil	0XXXX Sets the status of a discrete output
6	Preset Single Register	4XXXX Sets the value of a holding register
7	Read Exception Status	device specific (see Modbus data table of the device)
8	Diagnostics	Checks the communication system between the master and the slave
11	Fetch Comm. Event Ctr.	Returns amount of successful read/write operations on data points
12	Fetch Comm. Event Log	Returns log registers of communication events
15	Force Multiple Coils	0XXXX Sets the status of multiple discrete outputs
16	Preset Multiple Registers	4XXXX Sets the value of multiple holding registers
17	Report Slave ID	device specific (see Modbus data table of the device)
22	Mask Write 4X registers	4XXXX And / Or write of a holding register
23	Read/Write 4X registers	4XXXX Reads a set of holding registers and writes a set of holding registers in one query

10. Commissioning instructions

10.1. What this chapter contains

This chapter presents the steps to follow to commission the active filter. The commissioning of your PQF should be conducted in strict accordance with this procedure.

Before applying the commissioning procedure, make sure that you are familiar with:
- The filter hardware (discussed in Chapter 5);
- The mechanical installation requirements (discussed in Chapter 6).
- The electrical installation requirements (discussed in Chapter 7).
- The PQF programming interface PQF-Manager (discussed in Chapter 8).
- The Modbus communication interface (discussed in Chapter 9) if Modbus communication has to be set up.

The commissioning procedure consists of 7 steps that should be strictly followed.

Table 10.1. Steps to follow to commission the active filter

Steps	Actions
Step 1	Visual and installation check
Step 2	Voltage rating and phase rotation check
Step 3	Basic commissioning parameters setup (including CT setup)
Step 4	Before starting the filter
Step 5	Start the filter
Step 6	Generate filter load
Step 7	Set up the user requirements

Section 10.10. presents the commissioning report to be filled in when commissioning the filter.

10.2. Step 1: Visual and installation check

WARNING: Make sure that the filter supply is isolated during the visual and installation check. For safety reasons, this should be done upstream of the active filter and before removing the protective internal grid. Open the auxiliary power fuse holder. Verify that the filter DC capacitors are discharged before touching them. Failure to adhere to these guidelines may result in lethal electric shock and/or filter damage.

WARNING:	**Make sure that the filter is installed at a location where no conductive dust is present. Conductive dust when distributed in the filter panel may lead to equipment failure.**

- Check that the mechanical and electrical installation fulfills the requirements described in Chapter 6 and Chapter 7 of this manual.
- Pay attention to the ambient temperature noting the filter cooling requirements.
- Check visually the condition of the filter (e.g. for transportation damage).
- Check the tightness of all connections including power cable connections, CT connections, digital I/O connections on the PQF-Manager and the control board connections inside the filter.
- Ensure that the feeding cable protection devices are rated appropriately.
- Check that the filter cooling fans are free running.

10.3. Step 2: Voltage rating and phase rotation check

- The active filter nominal voltage rating must be adapted to the actual network voltage by adjusting the tap setting of the auxiliary transformer. If the tap setting for your network voltage is not available, then choose a tap just above the network voltage present (e.g. for 390V network choose 400V tap setting). The auxiliary transformer is situated at the bottom of the filter (Cf. Figure 5.8. item 3 for CE filters, Figure 5.9. item 3 for cULus filters). Ensure that the filter panel is isolated (preferably upstream) before changing the transformer tap setting.

By default the tap setting of the auxiliary transformer is set at the highest position at the filter production stage.

WARNING:	**The PQFI is able to operate on networks where the supply voltage is up to 10% higher (inclusive of harmonics but not transients) or lower than the equipment rated voltage. Since operation at the upper limits of voltage and temperature may reduce its life expectancy, the PQFI should not be connected to systems for which it is known that the overvoltage will be sustained indefinitely. Auxiliary circuits are designed to operate in a +/- 10% range of the equipment nominal auxiliary voltage (230 Vrms, internally derived). Excessive (auxiliary) voltage levels may lead to filter damage.**

WARNING:	**The tap setting of the auxiliary transformer's primary should be adapted according to the network voltage to avoid a too high or too low auxiliary voltage. If the tap setting for your network voltage is not available, then choose a tap just above the network voltage present (e.g. for 390V network choose 400V tap setting). Excessive (auxiliary) voltage levels will lead to filter damage.**

- The voltage phase rotation at the active filter incoming power supply terminals must be clockwise (L1 (R,U) -> L2 (Y,V) -> L3 (B,W) -> L1 (R,U)).

WARNING:	**Applying voltage to the filter to check the phase rotation may only be done after ensuring that the network voltage level is acceptable for the filter operation.**

When checking the phase rotation with a phase rotation meter on the filter power supply terminals, ensure that the auxiliary fuse box is open during the measurement process.

WARNING:	**In a multi-cubicle filter arrangement, care must be taken to connect all slaves to the power supply in an identical way as the master cubicle (individual phases and phase rotation). Otherwise, filter damage may result.**

If in normal operation the voltage phase rotation of a master cubicle is not clockwise, the filter when started will refuse to start indicating a fault in the filter event log (Cf. Section 8.8.2.). 'ACK. FAULT' will be shown on the PQF-Manager 'Welcome' screen.

If the voltage rating and phase rotation check is successful, and the auxiliary transformer tap setting has been adapted to the network voltage, auxiliary power can be applied to the active filter. It is advised however to first:

- install and connect the optional temperature probes to the main control board (if present), (Cf. Section 7.11.1.);
- restore the protective grid before applying voltage to the filter.

When the auxiliary fuse holder is closed and power is applied to the filter, the filter fans will start running and the filter controllers will be activated:

- The LEDs on the main controller board will be activated as per Table 5.12. If the µcontroller LED DL4 and the DSP controller LEDs (DL1-DL3) do not blink at the same speed, the filter ratings have been set up wrongly in the controller (Cf. Section 10.4.)
- The LEDs on the domino board will be activated as per Table 5.13.
- The PQF-Manager will initialize and show the Welcome-screen (Cf. Figure 8.1.)

If the voltage level or phase rotation is incorrect, the installation should be corrected before applying power to the filter to avoid potential filter malfunctioning and/or damage.

10.4. Step 3: Basic commissioning parameters set up (using PQF-Manager)

In order to set up the basic commissioning parameters with the PQF-Manager, navigate to [/Welcome/Settings/Commissioning] (Cf. Section 8.7.2.) An overview of the main menus of the PQF-Manager is given in Figure 8.2.

If the window or some of its items are locked (i.e. a small symbol or symbol is present on the screen), the hardware and/or software lock has been engaged. Refer to Section 8.4. for more information on these features and for guidelines on how to unlock the filter setting menu's.

In the commissioning window, the following basic parameters have to be specified:

- The network characteristics (Cf. Section 8.7.2.1.):
  The parameters to enter are the nominal network voltage and frequency.

- The unit ratings (Cf. Section 8.7.2.2.):
  This set up has to be revised during the commissioning and if an extension is added on site at a later stage.

If modification of the filter unit ratings settings is required, attention must be paid that the order in which the unit ratings are entered in the controller, corresponds to the order in which the units are physically present in the filter master slave configuration.

The master is always the first unit. The next unit can be found by following the optical fiber link that goes from the first unit domino board to the second unit domino board etc.

WARNING: Setting up a wrong filter rating configuration may lead to filter malfunction and/or damage.

- The CT settings:
  The CT settings can in many cases be automatically detected or can be entered manually. Section 10.5. discusses the automatic and manual CT detection procedure.

When using the automatic CT identification procedure, the filter will automatically deactivate any harmonics and reactive power/balancing settings that may have been made prior to starting the identification procedure. The commissioning engineer must reprogram these settings as discussed later in this procedure.

- The Derating parameter:
  If the filter is installed at locations higher than 1000 m or is running under ambient temperature conditions higher than 40°C, the filter has to be derated. For more information on how to calculate the derating required and how to enter the derating value, refer to Section 8.7.2.4.

Remarks:
- Although the user requirements for harmonic filtering and reactive power compensation/balancing can be set up from the commissioning window this should not be done before the filter has been started successfully for the first time (Cf. Section 10.6.)
- If digital I/O and/or the alarm contact has been cabled on the PQF-Manager or if external temperature probes have been connected to the filter main controller board, the appropriate software settings have to be made. This has to be done in the 'Customer settings' menu ([/Welcome/Settings/Customer set.]). Refer to Section 8.7.1.2. for detailed information on how to set up digital I/O, alarms and warnings.
- In order to change the temperature unit used by the system, go to [/Welcome/Settings/Customer set./Temp unit].
- For setting up advanced filter functions such as the autorestart feature (after power outage), the filter standby feature (which stops the IGBTs when the load requirement is low), the system clock, the external communication protocol (Modbus or Printer-PC) and the software lock, refer to Section 8.7.3.

If the CTs have been set up correctly at this stage, go to step 4 (Section 10.6.). Otherwise, consult Section 10.5. for background information on the automatic and manual CT detection procedure.

10.5. Automatic and manual CT detection procedure

WARNING:	**Do not filter harmonics or do reactive power compensation/balancing when the CTs have not been set up correctly. Failure to adhere to this guideline will result in erratic filter operation.**

Refer to Section 7.7. and Section 7.8. for the CT selection and installation guidelines.

WARNING:	**Before programming or detecting the CTs, make sure that:** **- The CTs have been connected to the filter CT terminal X21.** **- All shorting links in the CT path have been removed (i.e. on the CTs, on the filter CT terminal X21, …)**

CT shorting links are provided with the filter for servicing purposes, but they are not installed by default on the X21 terminal.

The CT settings can be detected with the automatic CT detection feature or in a conventional way. The automatic CT detection approach allows to compensate for physical connection errors in software.

10.5.1. Automatic CT detection procedure

The automatic CT detection procedure and the precautions to take when using it are explained in detail in Section 8.7.2.3.

Section 10.5.2. discusses a way to check the CT installation if the automatic CT detection procedure is not used or does not find the correct results.

NOTE:	**When the automatic CT detection procedure is started, the filter will automatically deactivate all user requirements for filtering, reactive power compensation and balancing. After the procedure has finished, the user has to reprogram these parameters into the filter.**

10.5.2. Manual CT detection procedure

Refer to Section 8.7.2.3. for guidelines on how to enter data when using the manual CT setup.

The following procedure will allow you to check the CT connection. This step only has to be executed if the CT setup could not be detected automatically.

WARNING:	**The secondary circuit of a loaded CT must never be opened. Otherwise extremely high voltages may appear at its terminals which can lead to physical danger or destruction of the CT.**

10.5.2.1. PQF connection diagram

Figure 10.1. shows the standard connection diagram for the PQF (Cf. Section 8.7.1.) It must be noted that:

- L1, L2 and L3 rotation must be clockwise.
- The CTs must be on the supply (line) side of the PQF.
- The CT monitoring a phase must be connected to the filter CT terminal dedicated to the same phase.
- One secondary terminal of the CT must be earthed.

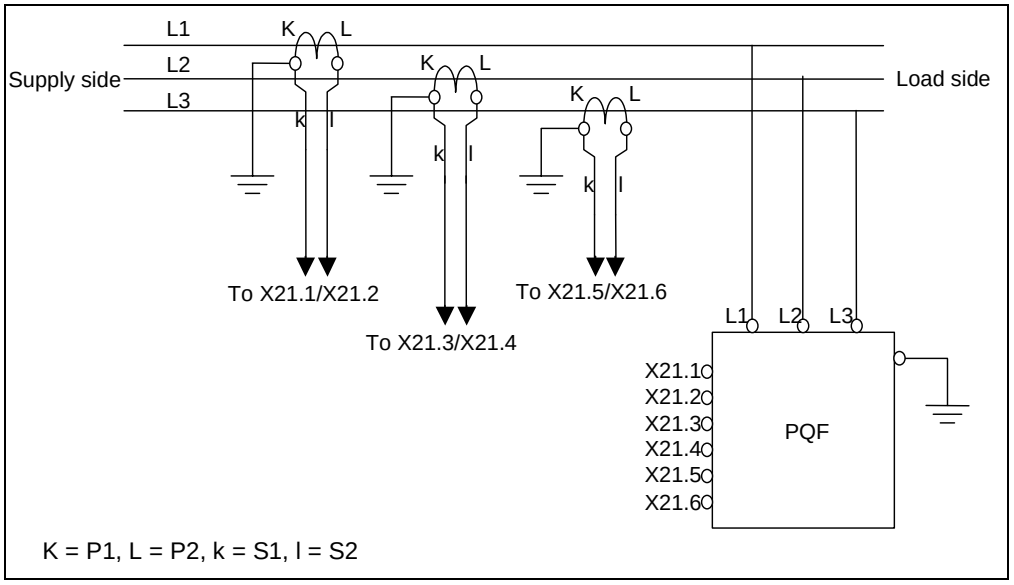


Figure 10.1. Basic CT connection diagram

It is also seen that terminal X21.1 and X21.2 are related to the CT located in phase L1, terminal X21.3 and X21.4 are related to the CT located in phase L2 and terminal X21.5 and X21.6 are related to the CT located in phase L3.

10.5.2.2. Material needed and hypotheses for correct measurements

A two-channel scopemeter with one voltage input and one current input is needed. Adequate sensors are also needed. A power analyzer like the Fluke 41B can also be used.
Some minor knowledge of the load is also required. For instance, the method explained below is based on the fact that the load is inductive and not regenerative (i.e. the load current lags by less than 90° the phase voltage). If a capacitor bank is present, it is better to disconnect it before making measurements in order to ensure an inductive behavior of the load. It is also assumed that the load is approximately balanced.

Remark: Other ways to check the CT installation manually are:

- To use the waveform displays of the PQF-Manager. In this it should be noted that all waveforms displayed are synchronized on the rising edge zero crossing of the voltage V (L1-L2). Note however that this approach requires some experience.
- To use the commissioning tool in the PQF-Link software. More information on this approach can be found in the PQF-Link manual.

10.5.2.3. Checking the correct connection of the CTs with a two-channel scopemeter

- The first channel of the scopemeter must be connected to the phase voltage referenced to the neutral or to the ground if the neutral is not accessible.
- The second channel must measure the associated current flowing from the network to the load as seen by the CT input of the PQF.

10.5.2.3.1. Measurement of the CT in phase L1 (Figure 10.2.)

- For the voltage measurement (channel 1), the positive (red) clamp must be connected to the phase L1 and the negative clamp (black) must be connected to the neutral (ground).
- For the current measurement (channel 2), the clamp should be inserted into the wire connected on terminal X21.1 and the arrow indicating positive direction of the current should point towards the PQF. Do not forget to remove the shorts on the CT secondary (if present) before making the measurement.

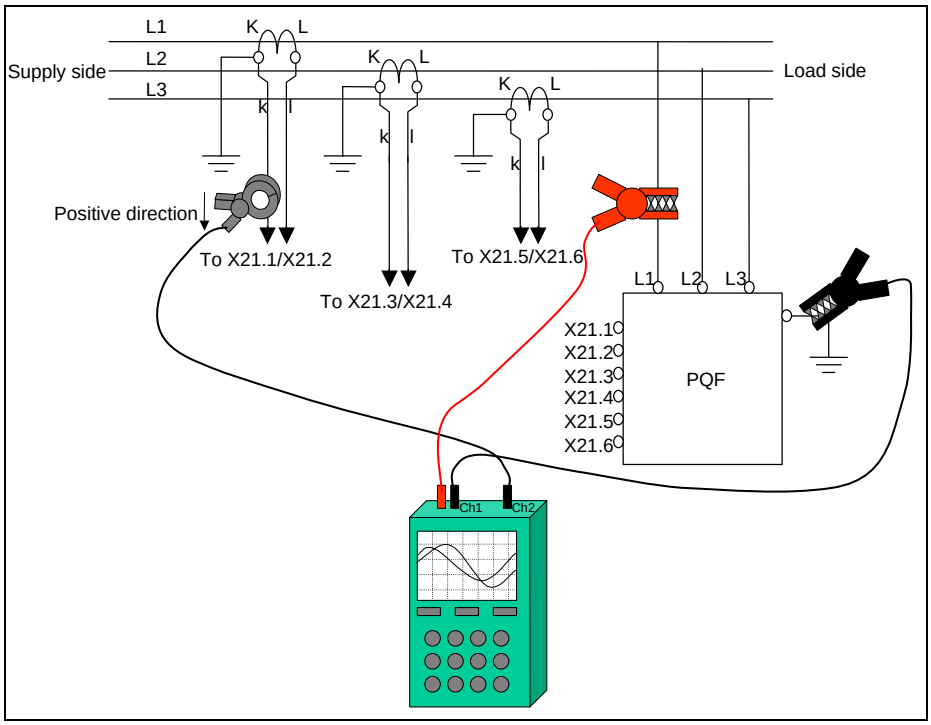


Figure 10.2. Connection of the scopemeter for checking the CT in phase L1

On the scopemeter screen, two waveforms should appear. The voltage waveform should be approximately a sine wave and the current waveform would normally be a well-distorted wave because of harmonic distortion. Usually, it is quite easy to extrapolate the fundamental component as it is the most important one (Figure 10.3.)

Remark: If the earthing of the system is bad, the phase to ground voltage may appear like a very distorted waveform. In this case, it is better to measure the phase-to-phase voltage (move the black clamp to the phase L2) and subtract 30° on the measured phase shift.

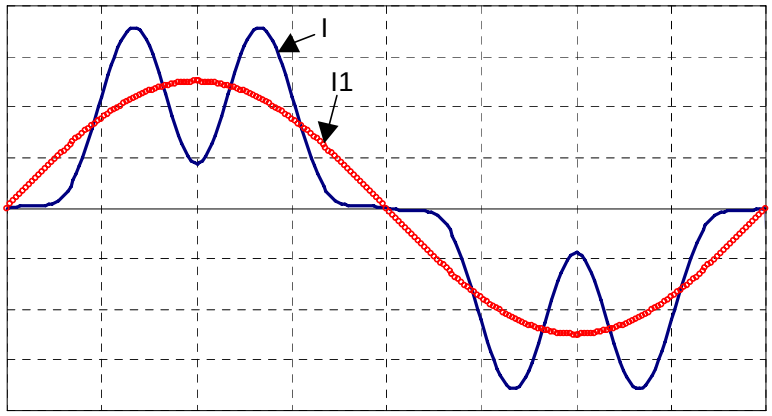


Figure 10.3. Extrapolation of the fundamental component from a distorted waveform

From the fundamental component of both signals, the phase shift must then be evaluated (Figure 10.4.). The time T between zero crossing of the rising (falling) edge of both traces must be measured and converted to a phase shift by the following formula:

$$\varphi = \frac{\Delta T}{T1} * 360°$$ where T1 is the fundamental period duration.

For an inductive and non-regenerative load, the current signal should lag the voltage by a phase shift lower than 90°.

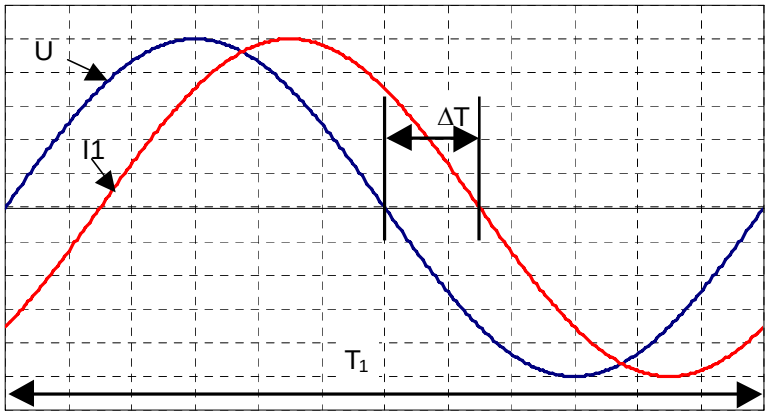


Figure 10.4. Phase shift evaluation between two waveforms

10.5.2.3.2. Measurement of the CT in phase L2 and L3 (Figure 10.5. and Figure 10.6.)

The same operations as those described in the previous paragraph must be repeated with the phase L2 (Figure 10.5.) and phase L3 (Figure 10.6.).

For a balanced load (which is usually the case in most of the three phase systems), the phase shift should be approximately the same for all the three phases.

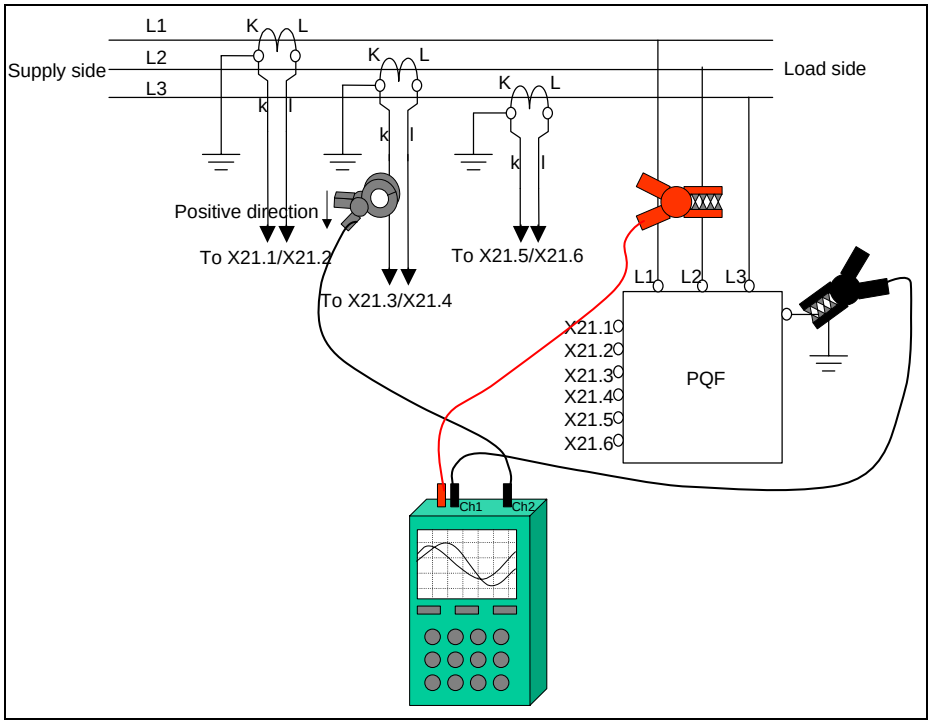


Figure 10.5. Connection of the scopemeter for checking CT in phase L2

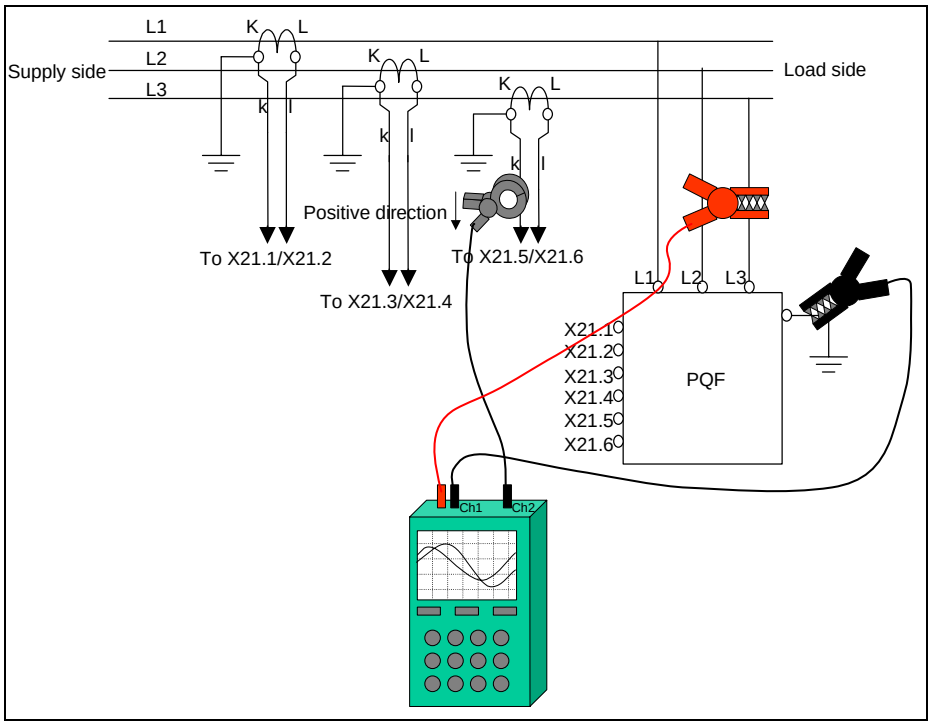


Figure 10.6. Connection of the scopemeter for checking CT in phase L3

10.5.2.3.3. Checking the correct connection of the CTs with two current probes

If the main bus bar is available and all security rules are taken, it is possible to use the two-channel scopemeter in order to see if the current measured through the CT is matching the real current in the bus. Connecting the current probes as shown on Figure 10.7. The two traces must be in phase and of the same shape (the magnitude could be different as the gains are different) if the wiring is correct.

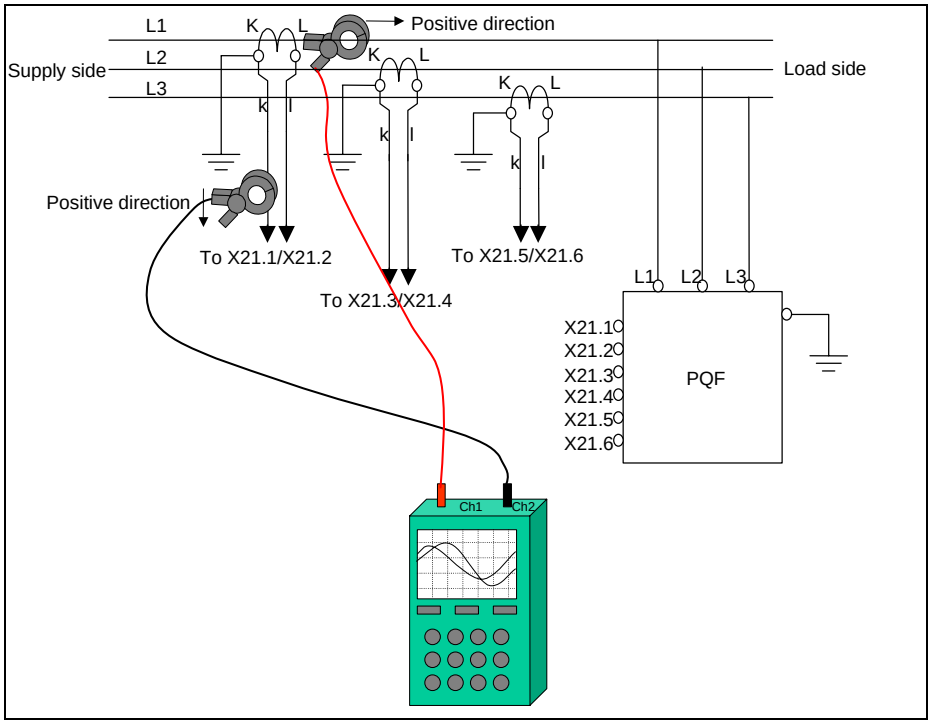


Figure 10.7. Connection of the scopemeter for checking the CT in phase L1 by comparing the currents

This operation has to be repeated for the remaining two phases for a complete check. The current probes have to be changed accordingly.

10.5.2.4. Checking the correct connection of the CTs with a Fluke 41B

The Fluke 41B is a power analyzer that allows measurements of one voltage and one current wave. Unfortunately, the device does not allow simultaneous display of both waveforms on the screen. However, it is possible to synchronize the triggering on either the voltage or on the current. All phase shift measurements are then referenced to the chosen origin. To read directly the phase shift between the fundamental components, just select the spectrum window of the signal which is not chosen as the origin. The instrument must be configured for single-phase measurements.
The probes must be connected as shown on Figure 10.2., Figure 10.5. and Figure 10.6.

10.6. Step 4: Before starting the filter

Before switching the filter ON, ensure that all harmonics and reactive power compensation/balancing options have been deselected.

- For deselecting all harmonics of the main filter settings at once go to [/Welcome/Settings/Customer set./Main settings/Deselect all].
- For deselecting all harmonics of the auxiliary filter settings at once go to [/Welcome/Settings/Customer set./Auxiliary settings/Deselect all].
- For deselecting the reactive power compensation option of the main filter settings disable the option ‘PFC type’ in [/Welcome/Settings/Customer set./Main settings/Main PFC/Bal.].
- For deselecting the load balancing option of the main filter settings disable the option ‘Balance load’ in [/Welcome/Settings/Customer set./Main settings/Main PFC/Bal.].
- For deselecting the reactive power compensation option of the auxiliary filter settings disable the option ‘PFC type’ in [/Welcome/Settings/Customer set./Auxiliary settings/Aux. PFC/Bal.].
- For deselecting the load balancing option of the auxiliary filter settings disable the option ‘Balance load’ in [/Welcome/Settings/Customer set./Auxiliary settings/Aux. PFC/Bal.].

For more information on the main and auxiliary settings concept, refer to Section 8.7.1.1.

10.7. Step 5: Start the filter

The PQFI contains a motorized circuit breaker that is controlled by the filter controller. Therefore it should always be set to automatic mode for normal filter operation.

WARNING:	**Under no circumstances close the circuit breaker manually. Failure to adhere to this guideline may result in physical danger and in filter damage.**

With all harmonics and reactive power compensation/balancing deselected, you can start the filter.
In order to do this with the PQF Manager:

- Press Esc repeatedly until the 'Welcome' screen is displayed.
- Highlight the filter start/stop menu ('PQF' item in the list). In this menu, the 'START' indication should be present.
- Press OK. The filter will ask confirmation and then it will start. The main breaker should close within 240 seconds. One second after closing, the IGBTs will start and the filter will work under no load condition.
- The 'START' indication in the start/stop menu changes in a 'STOP' indication once the filter is running.

Detailed information on the filter start/stop menu can be found in Section 8.5.

Remarks:

- If the start/stop menu reads 'ACK. FAULT' (i.e. 'acknowledge fault'), the filter has encountered a fault that needs to be corrected before the filter can be started. Refer to Chapter 13 for troubleshooting the problem.
- If the filter when activating the start menu displays a message to indicate that it is remote control mode, the filter either has to be started by remote control or the remote control mode has to be deactivated. More information about the remote control functionality is given in Section 7.10.1. and Section 8.7.1.2.

10.8. Step 6: Generate filter load

Once the filter is connected to the supply and is running, some filter load can be generated to verify if the filtering is performing well.

When a harmonic load is present, the filtering performance can be tested by selecting a harmonic, e.g. of order 11, and verifying if it is filtered properly.

- For setting up the filter's main harmonics selection go to [/Welcome/Settings/Customer set./Main settings/Main harmonics].
- For setting up the filter's auxiliary harmonics selection go to [/Welcome/Settings/Customer set./Auxiliary settings/Aux. Harmonics].

NOTE:	**If two master units are fed from the same CTs, perform this test for different harmonic orders (e.g. H11 and H13) on both units to avoid interference problems.**

For more information on the main and auxiliary settings concept and on the setting up of harmonics, refer to Section 8.7.1.1.

Once the harmonic is selected, analyze the spectrum of the line currents to see if the selected harmonic is filtered. Refer to Section 8.6.2. for more information on displaying measurement results. If the harmonic is not filtered properly (e.g. if it is amplified), deselect the harmonic and refer to Chapter 13 for troubleshooting the problem.

When harmonic load is not present, the filter can be tested by generating static reactive power. Initially a low value can be set which can then be gradually increased to the nominal filter rating.

- For setting up the filter's main reactive power feature go to [/Welcome/Settings/Customer set./Main settings/Main PFC/Bal.].
- For setting up the filter's auxiliary harmonics selection go to [/Welcome/Settings/Customer set./Auxiliary settings/Aux. PFC/Bal.].

Set the 'PFC Type' item to 'Static cap.' And choose the desired value for the item 'Q static'.

For more information on the main and auxiliary settings concept, refer to Section 8.7.1.1.

Once the reactive power is selected, analyze the filter current. Refer to Section 8.6.2. for more information on displaying measurement results. Refer to Chapter 13 in case of problems. Disable the reactive power setting after the test if it is not required by the user.

10.9. Step 7: Set up the user requirements

If everything goes well at this stage, the user requirements for harmonic filtration and reactive power compensation/balancing can be set up. Both main and auxiliary settings can be programmed if desired.
By default the filter is set up to take into consideration the main settings only.

- Select the desired filter mode.
- Select the harmonics and the curve level.
- Select the reactive power and balancing settings.

Background information on all the items discussed above is given in Section 8.7.1.1.

NOTE:	**If two master units are fed from the same CTs, respect the following guidelines for best performance** **1. Select different harmonics on both units.** **2. If 1 above if not possible, put one filter in Mode 1 and the other filter in Mode 3.**

At this stage, verify the functioning of the settings made for the digital I/O if possible (e.g. remote control, local start/stop buttons).

Remarks:

- Refer to Chapter 13 for troubleshooting problems.

- Filter running at 100% load while RMS current rating is not attained.
  Under exceptional conditions it is possible that the active filter is showing a 100% load indication whereas its nominal RMS current rating is not yet attained. This is because the filter has reached an operating limit other than the RMS current limit. Possible other limits are:
  - Temperature limit due to a too high ambient temperature or a failing cooling system.
  - Peak current limit due to an a-typical peak current requirement of the load.
  - Peak voltage limit due to an a-typical DC-link voltage requirement of the load or due to a high network voltage.

  Under all these conditions, the filter will run in limited mode and may not attain 100% of its nominal current rating.

- Harmonics put in 'standby' by the filter system:
  When selecting a harmonic that has not been selected before, the filter will identify the network characteristics for this harmonic. After this process, the filter will launch the filtering process for the component considered. If during the network identification process for a given harmonic a special (problematic) condition is encountered, the system puts the component in 'standby'. In that case the harmonic selected is not filtered for the time being. Special network conditions include extremely high impedance of the supply network or extremely low impedance towards the load. When consulting the harmonic selection table of the PQF-Manager, harmonics put in 'standby' can be recognized by the label 'S' that is displayed in the harmonic selection column (which reads otherwise either 'Y' or 'N'). The following possibilities exist to bring a harmonic out of standby:
  - The user restarts a network identification process by changing the 'S' indication into a 'Y' indication in the harmonic selection table.
  - The filter automatically restarts an identification process on all harmonics that were put in standby previously when a successful identification of another harmonic is made. As a result, the harmonic considered will be automatically filtered when the network conditions allow for this.

- If plain capacitors (i.e. capacitor banks not incorporated detuning reactors) are present in the network it is recommended to switch them off or change them into detuned banks (Cf. Section 7.8.7.) Sometimes, the commissioning engineer is faced with an installation where both an active filter and plain capacitors are present however. While this is an ill advised and a technically unsound situation, ABB has acknowledged that in this case also the active filter should aim to give an optimal performance. For this reason the control software of the filter incorporates a Stability Detection Program (SDP) that aims to increase the filter performance in this type of applications.

  In installations where plain capacitors are present and cannot be switched off or changed to detuned capacitor banks, adhere to the recommendations below for optimal results.
  - Implement the installation given in Figure 7.25. as opposed to the installation given in Figure 7.26. In Figure 7.25. the capacitor bank is connected between the transformer and the filter CTs as a result of which the filter measures only the load current. In Figure 7.26. the filter measures also the capacitor bank current. While in the case of Figure 7.26. the SDP will also work, it will be slightly less efficient since the influence of the capacitors will be spread over a much wider frequency bandwidth. Harmonic filtering in the affected bandwidth may be interrupted more often for parameter optimization, this leading to a less optimal filtering performance.
  - Ensure that the filter is in Mode 3.

- In installations where detuned banks are present, it is recommended not to select harmonic orders below the tuning frequency of the detuned banks. Table 10.2. indicates the harmonics recommended to be deselected for different types of detuned banks.

Table 10.2. Recommended harmonics to be deselected for different detuned bank types

Detuned bank type	Harmonics recommended to be deselected
5.67 %	2, 3, 4
6 %	2, 3, 4
7 %	2, 3
14 %	2

For other types of detuned bank please contact your ABB Service provider to evaluate the resonance frequency and the harmonics that are recommended to be deselected.

When background distortion is present on the network and detuned capacitor banks are installed adjacent to the active filter but connected downstream of the filter CTs, filter resources will be lost. To overcome this, it is recommended to either connect the detuned capacitor bank upstream of the filter CTs or to use the CT connection approach shown in Figure 7.27.

Please do not forget to fill in the commissioning report for future reference.

10.10. Commissioning report

The commissioning report is designed to help the person in charge of the commissioning.
Before installation and operation of the PQF, read the relevant sections of the Instruction Manual.

ABB	**Project:**
LV Active Filters PQF	**Issued by:**
Commissioning report	**Date:**
	Page 1 of 7

10.10.1. Filter identification

Active filter type[(a)]				
Global ratings[(a)]	**Maximum voltage (V)**			
	Total current (A)			
System serial number[(a)]				
Common cable entry cubicle	**Present/not present**			
Unit ratings/serial number[(b)]		**Rating (A)**	**Serial number**	**Article code**[(a)]
	Unit 1 (M)			
	Unit 2			
	Unit 3			
	Unit 4			
	Unit 5			
	Unit 6			
	Unit 7			
	Unit 8			
Software version[(c)]	**PQF-Manager software**			
	µcontroller software			
	DSP software			
Installation location				

Remarks:
(a) Read from main identification tag located on the master cubicle door.
(b) Read on identification tag located at the inside and outside of each cubicle door.
(c) After the filter has been commissioned, navigate with the PQF-Manager to [/Welcome/About PQF].

10.10.2. Inspection on site – verification of the active filter after installation

Ambient conditions	**OK/NOK**
• Check the ambient temperature (< 40°C) (if > 40°C, derating is required)	
• Check the installation altitude (< 1000 m) (if > 1000 m, derating is required)	
• Check the ventilation (room and enclosure)	
• Ensure that no sources of conductive dust are present	
Internal connections[(a)]	
• Disconnect the filter from the supply including the auxiliary circuit (disconnection recommended by upstream protection)	
• Remove filter internal protection grid	
• Change auxiliary transformer primary tap setting to correspond to network nominal voltage rating[(b)]	
• Wiring of main and auxiliary circuit	
• Tightness of all electrical connections	
• Connectors properly plugged in	
• Fixation of components	
• Clearances	
• Cooling fans running freely	
• PQF-Manager power supply connection to distribution board	
• PQF-Manager CAN Bus connection to distribution board	
• Earth interconnection between different units	
• Digital control interconnection flat cable between different units	
• Optical link between domino boards of different units	
• Earth interconnection	
Installation[(a)]	
• Check cross-sections of power supply cables (L1-L2-L3)	
• Check cross-section of protective conductors (PE) (> = 16 mm²) connected to each cubicle and between cubicles.	
• Check tightness of conductor fixations	
• The material of busbars, terminals and conductors must be compatible (corrosion)	
• Check the setting and operation of the protective apparatus	
• Check rated current of the power supply cable fuses (if applicable)	
• Check the cabling of the digital I/O (if present)	
• Check the voltage in accordance with the specification	
• Check the phase rotation order at the filter power terminals (with filter auxiliaries off) (clockwise)[(b)]	
• Check visually the current transformers	
- Ratio	
- Installed at the right side (feeding-side of the active filter)	
• Remove all jumpers of all current transformers (CTs and SCTs)	
• Remove all jumpers of the CT connection terminal X21 (if present)	
Remarks: (a) Refer to Section 10.2. of the manual for more information on this topic. (b) Refer to Section 10.3. of the manual for more information on this topic.	

10.10.3. Programming

Apply voltage to the filter[a]	
• Restore the filter internal protection grid	
• Close auxiliary circuit fuse box	
• Close filter door	
• Apply voltage to the active filter (restore upstream protection)	
• Control board LEDs light up and blink	
• PQF-Manager booting and showing 'Welcome' screen	
• Fan(s) start(s) running	
Program equipment[b]	
• Network characteristics	
- Supply voltage (V)	
- Supply frequency (Hz)	
• Unit ratings	
- Unit 1 (A)	
- Unit 2 (A)	
- Unit 3 (A)	
- Unit 4 (A)	
- Unit 5 (A)	
- Unit 6 (A)	
- Unit 7 (A)	
- Unit 8 (A)	
• CT position and ratio	
- Automatic detection feature used	YES/NO
- Filter terminal 'Input 1' is connected to the CT (including sign)[c]	Line 1, 2, 3, -1, -2, -3
- Filter terminal 'Input 2' is connected to the CT (including sign)[c]	Line 1, 2, 3, -1, -2, -3
- Filter terminal 'Input 3' is connected to the CT (including sign)[c]	Line 1, 2, 3, -1, -2, -3
- Ratio of CT installed in line L1 (R, U)	
- Ratio of CT installed in line L2 (Y, V)	
- Ratio of CT installed in line L3 (B, W)	
• Derating factor (temp > 40°C or altitude > 1000 m or…)	
- Rating (%)	
• Configure digital inputs if applicable[d]	
• Configure digital outputs if applicable[e]	
• Configure programmable warnings if applicable[f]	
• Configure programmable alarms if applicable[g]	

Remarks:

[a] Refer to Sections 10.4. and 10.5. of the manual for more information on this topic.
[b] Navigate with the PQF-Manager to [/Welcome/Settings/Commissioning] or use PQF-Link.
[c] Encircle the correct setting. Negative values imply inversed CT orientation or cabling.
[d] Navigate with the PQF-Manager to [/Welcome/Settings/Customer set./Digital inputs].
[e] Navigate with the PQF-Manager to [/Welcome/Settings/Customer set./Digital outputs].
[f] Navigate with the PQF-Manager to [/Welcome/Settings/Customer set./Warnings].
[g] Navigate with the PQF-Manager to [/Welcome/Settings/Customer set./Alarms].

ABB	**Project:**
LV Active Filters PQF	**Issued by:**
Commissioning report	**Date:**
	Page 4 of 7

10.10.4. Testing (with load)

Before starting the filter	**OK/NOK**
• Deselect all harmonics and reactive power/balancing[(a)]	
Start the filter[(b)]	
While the filter is running[(c)]	
• If harmonic load is present, select for example the 11th harmonic	
• Check the line current (Irms, 11th harmonic level and waveforms)	
• If harmonic load is not present, generated static capacitive power	
• Check the filter currents (fundamental current level)	
Set up the user requirements for harmonics and reactive power/balancing[(d)]	
• Check the line currents (Irms, THDI and waveforms)	
• Check the line voltage (Vrms, THDV and waveforms)	

Remarks:
(a) Refer to Section 10.6. of the manual for more information on this topic.
(b) Refer to Section 10.7. of the manual for more information on this topic.
(c) Refer to Section 10.8. of the manual for more information on this topic.
(d) Refer to Section 10.9. of the manual for more information on this topic.

ABB	**Project:**
LV Active Filters PQF	**Issued by:**
Commissioning report	**Date:**
	Page 5 of 7

10.10.5. Programmed parameters

Activate

Main	
Auxiliary	
Ext. Input	

Filter mode

Main settings	1		2		3	
Auxiliary settings	1		2		3	

Reactive power compensation

Main settings (Main PFC/Bal.)		**Auxiliary settings (Aux. PFC/Bal.)**	
PFC type		PFC type	
Disabled		Disabled	
Static ind.		Static ind.	
Q static (kvar)		Q static (kvar)	
Static cap.		Static cap.	
Q static (kvar)		Q static (kvar)	
Dyn. ind.		Dyn. ind.	
Target cos φ		Target cos φ	
Dyn. cap.		Dyn. cap.	
Target cos φ		Target cos φ	
Balance load		Balance load	
Disabled		Disabled	
L-L		L-L	

Harmonics

	Main settings (Main PFC/Bal.)					**Auxiliary settings (Aux. PFC/Bal.)**			
	H. Order	Selected YES	Selected NO	Curve (A)		H. Order	Selected YES	Selected NO	Curve (A)
1	3				1	3			
2	5				2	5			
3	7				3	7			
4	11				4	11			
5	13				5	13			
6	17				6	17			
7	19				7	19			
8	23				8	23			
9	25				9	25			
10	29				10	29			
11	31				11	31			
12	35				12	35			
13	37				13	37			
14	41				14	41			
15	43				15	43			
16	47				16	47			
17	49				17	49			
18	9				18	9			
19	15				19	15			
20	21				20	21			

ABB	**Project:**
LV Active Filters PQF	**Issued by:**
Commissioning report	**Date:**
	Page 6 of 7

Alarms		**Warnings**	
Protection levels		**Warning levels**	
T1 prot.		T1 warn.	
T1 prot. del		T2 warn.	
T2 prot.		V. min. warn.	
T2 prot. del		V. max. warn.	
Prog. alarms		Imbalance	
Prog. alarm 1		Ground fault	
Prog. alarm 2		T IGBT warn.	
Prog. alarm 3		T crtl war.	
Alarm delay		**Prog. warnings**	
Alarm rst del.		Prog. warn. 1	
		Prog. warn. 2	
		Prog. warn. 3	
		Warning delay	
		Warn. rst del.	

Digital Inputs		**Digital Outputs**	
Dig. In 1		Dig. Out 1	
Dig. In 2		Dig. Out 2	
		Dig. Out 3	
		Dig. Out 4	
		Dig. Out 5	
		Dig. Out 6	

Start-Stop set.		**Communication**	
Stdby status		Protocol	
Standby level		Modbus	
Stdby del off		Baud rate	
Standby hyst		Parity	
Stdby del con		Stop bit	
Auto start		Slave Address	
Auto st. del.		Modbus lock	

	Project:
LV Active Filters PQF	**Issued by:**
Commissioning report	**Date:**
	Page 7 of 7

10.10.6. Comments

	Commissioning Engineer	**Customer's representative**
Name		
Signature		
Date		

11. Operating instructions

11.1. What this chapter contains

This chapter contains the user operating instructions for the active filter. It is assumed that the filter has been installed and commissioned correctly (cf. previous chapters). The following operations are discussed:

- Starting and stopping the filter
- Modifying the user requirements
- Changing the system temperature unit and PQF-Manager contrast
- Consulting filter measurements
- Consulting filter statistics and manufacturer data
- Filter behavior on faults – retrieving error information

Note that in the context of this manual, the PQF-Manager is used to operate the filter. Background information on the PQF-Manager can be found in Chapter 8.

Alternative ways to operate the filter are:

- Using the optional PQF-Link software. Refer to the 'PQF-Link installation and user's guide' for more information on this subject.
- Using Modbus communication. Refer to Chapter 9 for more background information on this subject and to the information provided by your system integrator.

WARNING:	**High AC and DC voltage may be present in the filter panel. Do not touch any filter parts unless you have ascertained that they do not carry dangerous voltage levels.**

11.2. Starting and stopping the filter

The PQFI contains a motorized circuit breaker that is controlled by the filter controller. Therefore the circuit breaker should always be set to automatic mode for normal filter operation.

WARNING:	**Under no circumstances close the circuit breaker manually. Failure to adhere to this guideline may result in physical injury and/or in filter damage.**

Normally, the commissioning engineer has set up the filter and the desired filter requirements. As a result, the user only has to start and stop the filter. Detailed information on the filter start/stop menu can be found in Section 8.5.

11.2.1. Starting the filter with the PQF-Manager

In order to start the filter with the PQF-Manager follow the instructions given below:

- Ensure that power is supplied to the filter and that the filter auxiliaries are 'on' (auxiliary fuse holder contains good fuses and is closed).

- Press Esc on the PQF-Manager repeatedly until the 'Welcome' screen is displayed.
- Highlight the filter 'start/stop' menu ('PQF' item in the list). In this menu, the 'START' indication should be visible.
- Press OK. The filter will ask confirmation and then it will start. The main breaker should close within 240 seconds. One second after closing, the IGBTs will start and the filter will work under no load condition.
- The 'START' indication in the 'start/stop' menu changes in a 'STOP' indication once the filter is running.

Remarks:

- If your filter is equipped with bulb indicators, the bulb corresponding to the present filter state will be on.
- If the 'start/stop' menu reads 'ACK. FAULT' (i.e. 'acknowledge fault'), the filter has encountered a fault that needs to be corrected before the filter can be started. Refer to Chapter 13 for troubleshooting the problem.
- If the filter when activating the start menu displays a message to indicate that it is remote control mode, the filter either has to be started by remote control or the remote control mode has to be deactivated. More information about the remote control functionality is given in Section 7.10.1. and Section 8.7.1.2.
- If the hardware lock and/or the Modbus lock has/have been engaged, the filter cannot be started nor stopped. In order to see which lock(s) has/have been engaged push OK when the 'start/stop' menu is highlighted. A message will appear to indicate which lock(s) has/have to be disengaged. If authorized, disengage the relevant lock.
  - The hardware lock can be disengaged by pushing the blue button present at the bottom rear of the PQF-Manager. More information on the filter menu locking facilities is given in Section 8.4.
  - The Modbus lock can be disengaged in the menu [/Welcome/Settings/Installation set./Communication/Modbus/Modbus lock]. More information on the Modbus lock is presented in Section 9.6.

When power is applied to the filter and it is started, the following startup sequence is conducted:

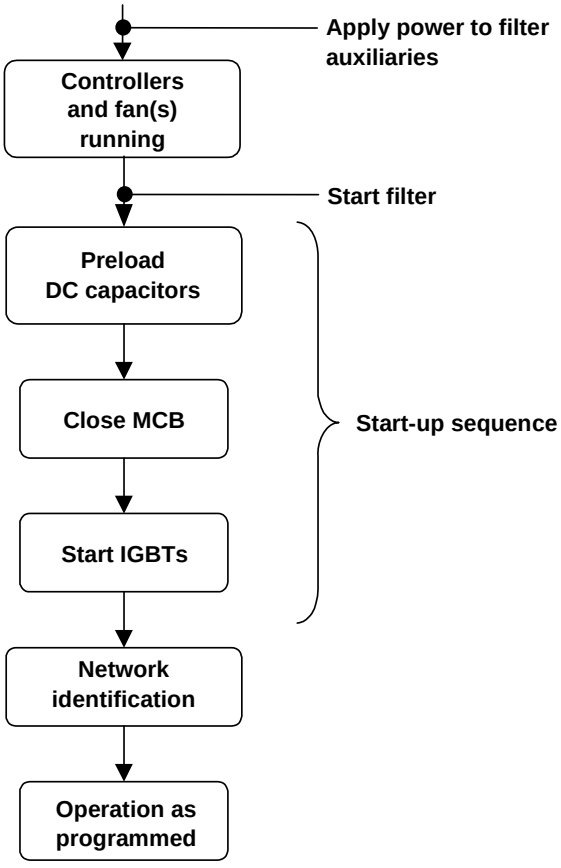


Figure 11.1. Filter start-up sequence when power is applied and the start command is given

In Figure 11.1. it may be seen that:
- The fans start running as soon as the auxiliary circuit power is switched on.
- The start-up sequence consists of the preloading of the DC capacitors, the closure of the filter breaker and the starting of the IGBTs.
- A network identification may be done after the start-up sequence has finished. This network identification will always be done when harmonic components were selected and the filter was powered down before or when new harmonic components have been selected. The network identification may also be done automatically during normal filter operation if the filter controller has noted a big change of network impedance.
- At the end of the start up procedure, the filter will work as programmed.

Remark: Filter running at 100% load while RMS current rating is not attained.
Under exceptional conditions it is possible that the active filter is showing a 100% load indication whereas its nominal RMS current rating is not yet attained. This is because the filter has reached an operating limit other than the RMS current limit. Possible other limits are:
- Temperature limit due to a too high ambient temperature or a failing cooling system.
- Peak current limit due to an a-typical peak current requirement of the load.
- Peak voltage limit due to an a-typical DC-link voltage requirement of the load or due to a high network voltage.

Under all these conditions, the filter will run in limited mode and may not attain 100% of its nominal current rating.

11.2.2. Stopping the filter with the PQF-Manager

In order to stop the filter with the PQF-Manager follow the instructions given below:
- Press Esc on the PQF-Manager repeatedly until the 'Welcome' screen is displayed.
- Highlight the filter 'start/stop' menu ('PQF' item in the list). In this menu, the 'STOP' indication should be present.
- Press OK. The filter will ask confirmation and then it will stop. The main breaker will open and the filter will launch an automatic DC capacitor discharge procedure. This procedure decreases the DC capacitor voltage below 50 Vdc in a very short time (< 30 s).
- The 'STOP' indication in the start/stop menu changes in a 'START' indication once the filter is stopped.

Remarks:
- If your filter is equipped with bulb indicators, the bulb corresponding to the present filter state will be on.
- If the 'start/stop' menu reads 'ACK. FAULT' (i.e. 'acknowledge fault'), the filter has encountered a fault. Refer to Section 11.7. and Chapter 13 for troubleshooting the problem.

WARNING:	**In case the filter stops operating due to a fault, the automatic active DC bus discharge procedure will not be activated. This implies that very high voltages may be present on the DC capacitors for a long time in that case. Do not touch any live parts unless you have ascertained that no dangerous voltage levels exist in the filter.**

- If the filter when activating the stop menu displays a message to indicate that it is remote control mode, the filter either has to be stopped by remote control or the remote control mode has to be deactivated. More information about the remote control functionality is given in Section 7.10.1. and Section 8.7.1.2.
- If the hardware lock and/or the Modbus lock has/have been engaged, the filter cannot be started nor stopped neither by the local button nor by remote control. In order to see which lock(s) has/have been engaged push OK when the 'start/stop' menu is highlighted. A message will appear to indicate which lock(s) has/have to be disengaged. If authorized, disengage the relevant lock.

- The hardware lock can be disengaged by pushing the blue button present at the bottom rear of the PQF-Manager. More information on the filter menu locking facilities is given in Section 8.4.
- The Modbus lock can be disengaged in the menu [/Welcome/Settings/Installation set./Communication/Modbus/Modbus lock]. More information on the Modbus lock is presented in Section 9.6.

The stop sequence conducted when a stop command is given can be derived from the following flow chart.

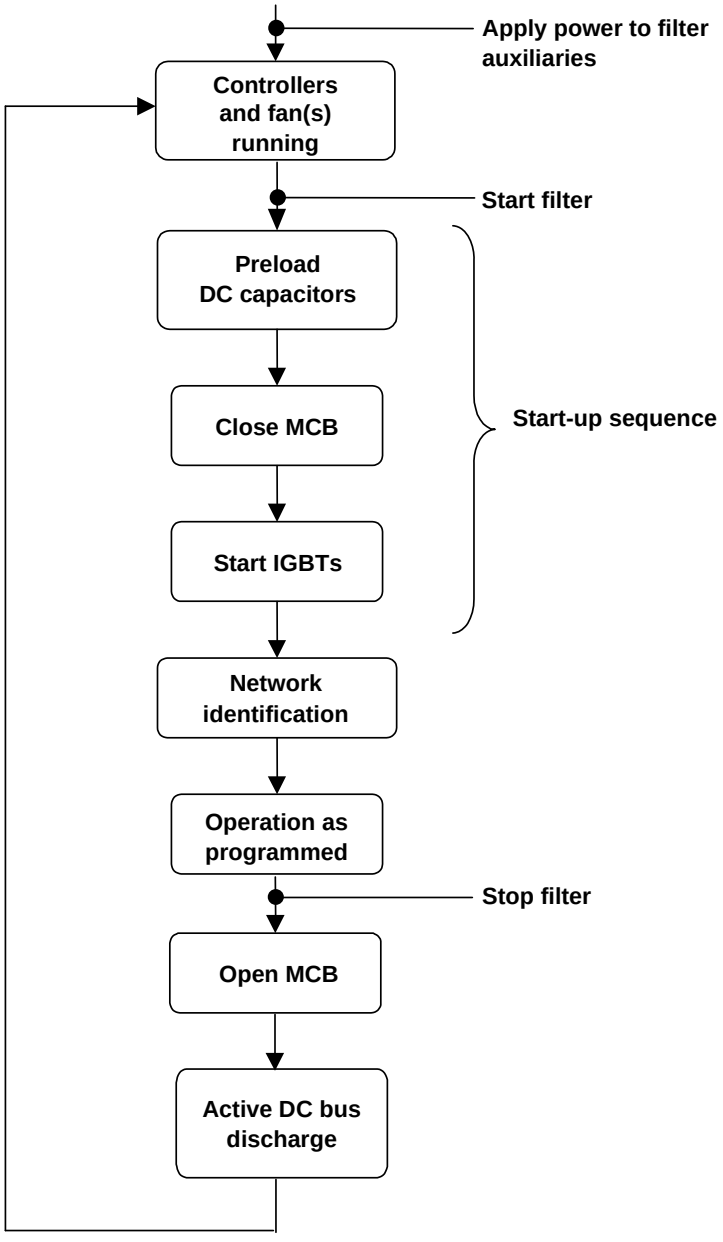


Figure 11.2. Filter operation sequence when no fault is present

Apart from the automatic active DC bus discharge procedure that is only executed when no filter fault is present, the DC bus also incorporates discharge resistors that can discharge the DC bus in 10 minutes.

11.3. Modifying the user requirements

Providing that the filter locks have not been engaged, the user can change the customer settings to better suit his needs. These settings can be accessed in the PQF-Manager menu [/Welcome/Settings/Customer set.].

The user requirements can be divided into the following categories:
- Setting up the filter mode, the harmonic requirements and the reactive power requirements. Refer to Section 8.7.1.1. for detailed information on these topics.
- Setting up alarms, warnings and digital I/O. The digital I/O allows configuration of the filter to operate in remote control mode etc. Refer to Section 8.7.1.2. for detailed information on these topics.

NOTE:	**If two master units are fed from the same CTs, respect the following guidelines for best performance** **1. Select different harmonics on both units.** **2. If 1 above if not possible, put one filter in Mode 1 and the other filter in Mode 3.**

Advanced user requirements have to be set up in the 'installation settings' menu ([/Welcome/Settings/Installation set.]). These advanced functions include:
- the autorestart function (after power outage).
- the standby function to switch off the IGBTs when the load requirement is low.
- the system clock setup.
- the external communication setup for Modbus or PC-printer communication.
- the software lock activation and password setup for filter protection purposes.

Refer to Section 8.7.3. for detailed information on these topics.

It is recommended that the advanced functions be set up by a skilled commissioning engineer.

11.4. Changing the system temperature unit and PQF-Manager contrast

If desired the system temperature unit can be changed from °C to °F or vice versa. This is done in [/Welcome/Settings/Customer set./Temp unit].

In addition, the PQF-Manager contrast can be changed in [/Welcome/Settings/Customer set./Contrast].

11.5. Consulting filter measurements

In order to consult the measurements done by the filter system, go to [/Welcome/Measurements].
The complete list of measured items is discussed in Section 8.6.

11.6. Consulting filter statistics and manufacturer data

In order to consult the filter statistics, go to [/Welcome/PQF Monitoring]. This menu allows to monitor the filter load and to get an idea of its operating point compared to the nominal rating of the filter. In addition, logged warnings, faults and events can be retrieved for troubleshooting the filter operation and any abnormal network conditions. Also, an indication is given of fan running hours and filter running hours.
The 'PQF Monitoring' menu is discussed in depth in Section 8.8.

In order to obtain background manufacturer data on your PQF, go to [/Welcome/About PQF]. This menu gives basic data on the filter. This data includes:
- Basic manufacturer settings such as filter type, maximum voltage rating and filter serial number. These settings can be accessed in [/Welcome/About PQF/Manufacturer set.]
- Firmware version numbers for the PQF-Manager, the μcontroller and the DSP controllers.

When communicating with your ABB representative on a specific filter, please provide always the data shown in the 'About PQF' menu.

11.7. Filter behavior on fault – retrieving error information

Under normal conditions the filter is either running or stopped and the PQF-item in the PQF-Manager 'Welcome' screen shows the message 'START' or 'STOP'. In this case, if the filter is stopped it can be started and if it is running it can be stopped. The start and stop commands will be stored in the event log accessible in [/Welcome/PQF Monitoring/Event logging].

All faults that occur are stored in the same event log. A fault can either be non-critical or critical.

- A non-critical fault is a transient fault (e.g. a voltage spike). When a non-critical fault occurs the filter may stop the switching of the IGBTs momentarily (< 40 ms) but they will automatically restart. The only way to pick up this type of fault is to analyze the event log. Given the transient/random character of this type of fault, the filter performance will hardly deteriorate when it occurs.

- A critical fault is a fault that after occurrence cannot be successfully automatically cleared by the system within a reasonable time. The time frame considered depends on the error type. If the fault is considered critical by the system, the label 'Critical' will be shown in the event logging window. In addition, the PQF-item in the PQF-Manager 'Welcome' screen will show the label 'ACK. FAULT'. Note however that if the fault disappears fast, this label disappears too. Depending on the type of critical fault and the number of occurrences, the filter, when running, may either:
  - Stop (open the breaker) and await user intervention. In this condition the alarm contact of the PQF-Manager will switch on after a programmable delay and the 'Armed' indicator[(a)] will be OFF. The green LED on the main controller board (Cf. Table 5.12. item 17, LED DL5) will be off and the red LED on (Cf. Table 5.12. item 17, LED DL6). The user has to acknowledge the fault (with the PQF-Manager via Modbus or via remote control) before the filter can be restarted.
  - Stop (open the breaker) and restart automatically if the fault disappears. If stopped, the alarm contact of the PQF-Manager will switch on after a programmable delay and the 'Armed' indicator[(a)] will be ON. The green LED on the main controller board (Cf. Table 5.12. item 17, LED DL5) will be ON and the red LED will be OFF (Cf. Table 5.12. item 17, LED DL6). If it takes a long time before the fault disappears, the user may decide to give a filter stop command. This is done by highlighting the 'PQF ACK. FAULT' item in the 'Welcome' menu and selecting OK twice. After this, the 'Armed' indicator[(a)] will be OFF. The green and red LED on the main controller board (Cf. Table 5.12. item 17, LEDs DL5 and DL6) will be OFF too.
  - Stop briefly without opening the breaker and continue filtering when the error has disappeared. This is essentially the same case as the one described above but the error phenomenon disappears faster than the time required to generate a breaker opening command.

  If the filter is OFF and an external critical errors occur, these errors are also reported in the event log. As long as a critical fault condition exists (e.g. permanent undervoltage on one phase) the display will show the message 'ACK. FAULT' and the filter will refuse to start; The 'Armed' indicator on the PQF-Manager will be OFF and both the green and red main controller LEDs will be OFF too.

In general the occurrence of transient faults is no problem for the proper operation of the active filter. Only when an error becomes 'critical', a problem may exist.

Remark:

- [(a)] By default, the 'Armed' indicator is associated with the fourth digital output contact (cf. Table 5.7. and Table 5.8.) The digital output contact monitor at the top of the PQF-Manager display (Cf. Figure 8.1. item 3) can be used to check the status of the digital output. Alternatively, the digital output considered can be wired to monitor the 'Armed' indicator by distance (cf. Section 7.10.4.)

If 'ACK. FAULT' is present on the PQF-Manager display, look at the 'Armed' indicator (By default mapped to the 4th digital output of the PQF-Manager) or the green LED DL5 on the main controller board to know whether the filter will restart automatically after clearance of the problem or not.
- 'Armed' indicator/Green LED DL5 ON: The filter waits for the problem to disappear and then restarts automatically (unless the user acknowledges the fault).
- 'Armed' indicator/Green LED DL5 OFF: The filter is permanently stopped and the customer has to solve the problem, acknowledge the fault and restart the filter manually.

- If the filter is in remote control operation and the message 'ACK. FAULT' is present on the PQF-Manager, the fault can be acknowledged by sending a 'STOP' command by remote control (low signal). Alternatively, the remote control functionality can be disabled by disabling the corresponding digital input functionality. Then, the fault can be acknowledged locally.

Refer to Chapter 13 for advanced troubleshooting of the filter.

12. Maintenance instructions

12.1. What this chapter contains

This chapter contains the maintenance instructions for the active filter. Although your PQF has been designed for minimum maintenance, the following procedure should be carefully followed to ensure the longest possible lifetime of your investment.

WARNING:	**All maintenance work described in this chapter should only be undertaken by a qualified electrician. The safety instructions presented in Chapter 2 of this manual must be strictly adhered to.**

WARNING:	**High AC and DC voltages may be present in the filter panel. Do not touch any filter parts unless you have ascertained that they do not carry dangerous voltage levels.**

WARNING:	**Under no circumstances close the circuit breaker manually. Failure to adhere to this guideline may result in physical injury and/or in filter damage.**

12.2. Maintenance intervals

Table 12.1. lists the routine maintenance intervals recommended by ABB. Depending on the operating and ambient conditions, the intervals of Table 12.1. may have to be reduced. Announced intervals assume that the equipment is operating under ABB approved operating conditions (Cf. Chapter 14).

Table 12.1. Filter maintenance intervals recommended by ABB

Maintenance	Intervals	Instructions
Standard maintenance procedure	Depending on the dustiness/dirtiness of the environment, every 6 to 12 months.	Section 12.3.
Cooling fan(s) change	Every four years (35000 hours)	Section 12.4.
DC capacitor change 208 V ≤ Ue ≤ 480 V (Voltage group V1)	Every twenty years	Section 12.5.
DC capacitor change CE filters: 480 V < Ue ≤ 690 V (Voltage group V2) cULus filters: 480 V < Ue ≤ 600 V (Voltage group V2)	 Every ten years Every ten years	Section 12.5.

For convenience Section 12.6. presents a maintenance template that can be used by the maintenance engineer.

12.3. Standard maintenance procedure

12.3.1. Step 1: Check the ambient temperature conditions

With the filter running, check the ambient temperature conditions and make sure that they are similar to the conditions at the commissioning stage. If higher temperatures are present, this may indicate a problem with the switch room cooling/ventilation system. Ensure that the filter derating factor ([/Welcome/Settings/Installation set./Rating]) corresponds to the ambient conditions observed. If the ambient temperature is higher than 40°C, the filter should be derated (Cf. Section 6.2.)

12.3.2. Step 2: Record the filter operating status

- With the filter running, check and note the filter load graphs ([/Welcome/PQF Monitoring/Filter load]). Pay special attention to the temperature graph. If this one is around 100% and the other load indicators are relatively low, this could indicate that the filter is limiting its output because it is experiencing a cooling (fan) problem. If in doubt, assign the 'T Limit' indicator to a spare digital output ([/Welcome/Settings/Customer set./Digital Outputs]). This way, the digital output monitor at the top of the PQF-Manager screen will be on if the filter is limiting its output current due to temperature problems. By default, the 'T Limit' indicator is assigned to digital output 5 of the PQF-Manager.
- Make a note of the PQF-operation hours ([/Welcome/PQF monitoring/PQF operation]) and the fan-operation hours ([/Welcome/PQF Monitoring/Fan operation]). If the fan operation indicator shows a multiple of 35000 hours, it is recommended that the fans be replaced (Cf. Section 12.4.). Pay attention to any noise that could indicate fan failure.
- Browse the 'event logging' menu ([/Welcome/PQF monitoring/Event logging]) to spot any abnormal events that may have occurred.
- Make a note of the total number of faults that the system has recorded over time ([/Welcome/PQF monitoring/Number of errors]).

12.3.3. Step 3: Shut the filter down

- Switch the filter off and remove the power supply to the filter.
- Open the auxiliary circuit fuse box.
- Wait at least 10 minutes for the discharge of the DC capacitors.
- Ensure that the DC capacitors have completely discharged before going to step 4. Normally this should take negligible time thanks to the active discharge functionality.

12.3.4. Step 4: Inspect and clean the filter

- Inspect the filter visually for any condition that could indicate an abnormal filter stress (e.g. bulbs not on if they have to be, abnormal noises, abnormal appearance/color of components and wires).
- Remove all dust deposits in and around the filter. Pay special attention to the fans and the heatsinks. Indeed, the heatsink picks up dust from the cooling air and the PQF might run into overtemperature faults if the heatsink is not cleaned regularly. Pay special attention to this item if the filter has experienced shut downs due to over temperature in the past.
- Ensure that no loose particles are left in the fan that could obstruct their free rotation.
- Ensure that the control cards are free of dust. If necessary remove dust from them with a soft brush or a vacuum cleaner.

12.3.5. Step 5: Check the condition of the filter breakers, contactors and fuses

- Ensure that the breakers are OK and that contactors can move freely.
- If bad fuses are found, replace them. If the fuse in one phase is bad, it is good practice to change the fuses of all phases. More information on the fuses to use is given in Table 7.6.-Table 7.7.-Table 7.8.-Table 7.9. The details of the domino board fuses are given in Table 5.10. item 18.

12.3.6. Step 6: Check the tightness of the electrical and mechanical connections

- Ensure that all electrical connections are properly fixed and that connectors are properly plugged in. Remove oxidation traces of pin connectors if present. To this effect a small stiff brush can be used.
- Check the mechanical fixation of all components and retighten if necessary.

12.3.7. Step 7: Correct any abnormal conditions found

If required, refer to Chapter 13 for advice on troubleshooting the filter.

12.3.8. Step 8: Restart the filter

- Reapply power to the filter and close the auxiliary circuit fuse box. Verify that the fans start running and the control boards and PQF-Manager are activated.
- Restart the filter. If major servicing work has been done it is recommended to follow the commissioning instructions (cf. Chapter 11) for restarting the filter.
- Verify the filter performance.

12.4. Fan replacement

The cooling fans' lifespan is between 4 and 7 years typically, depending on the usage and ambient temperature. Check the actual fan operating hours with the PQF-Manager ([/Welcome/PQF monitoring/Fan operation]).

Fan failure is often preceded by increasing noise from the bearings and rise of the heatsink temperature despite cleaning. It is recommended to replace the fan once these symptoms appear. Contact your ABB service provider for replacement fans for your system.

In order to exchange the main IGBT cooling fans, follow the instructions below:

- Ensure that the power to the filter is switched off and that there is no residual voltage left in the filter panel (e.g. DC capacitors).
- Remove the electrical connection of the fans considered by unplugging the relevant wires of the X23 terminal. Figure 12.1. shows the terminal layout and pin assignment. Figure 12.2. can be used to locate the relevant items.
- Remove the fan mechanically by unscrewing its fixation screws which are located at the left and right side of the fans in the aluminum fan outlet. Note that in order to have access to the fixation screws of the middle fan (Figure 12.2. item 4), the outside fans have to be removed first.
- Remove the relevant fan capacitor by unscrewing it from the filter baseplate.
- Replace the components, fix them mechanically and make the electrical connections. Refer to the fan label to know which fan wire has to be connected to which X23 terminal. Ensure that the electrical connections of the fan and the fan capacitors are correct before powering on the system.

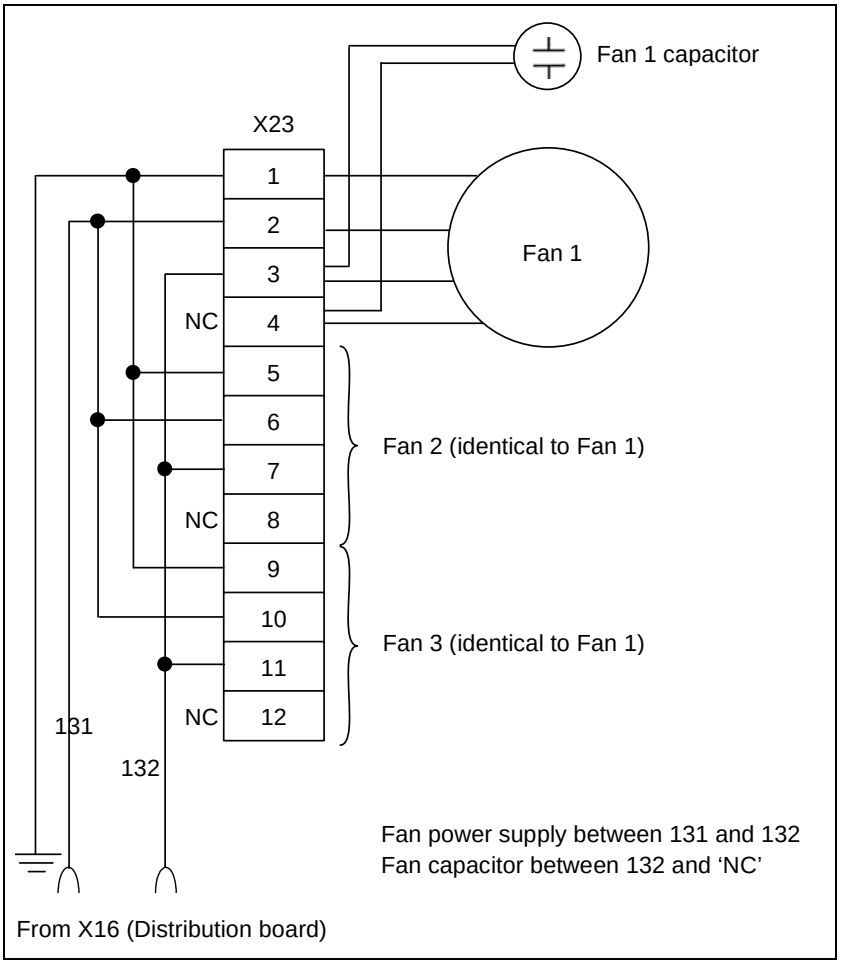


Figure 12.1. X23 pin layout and connection diagram

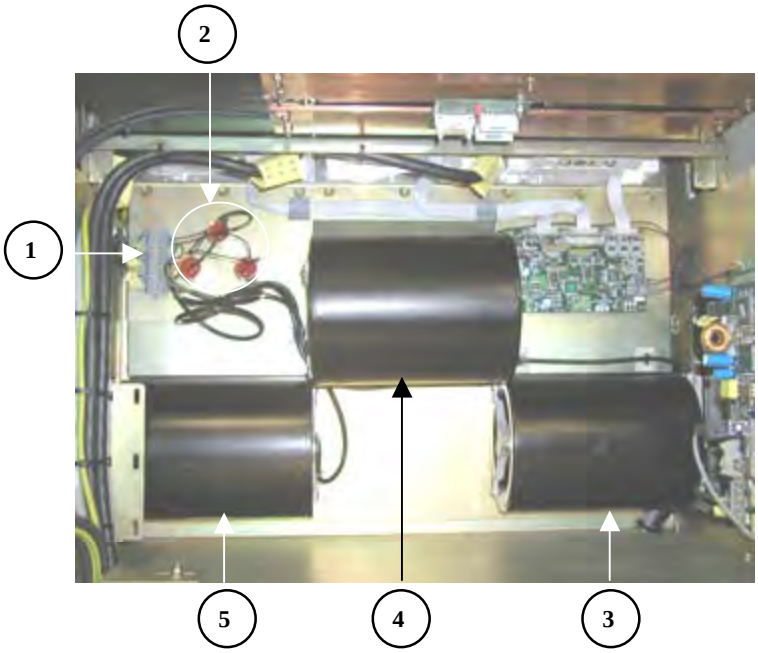


Figure 12.2. Overview of IGBT cooling fan related items

The components description is given in Table 12.2.

Table 12.2. IGBT cooling fan related items description

Item	Description
1	X23 terminal block
2	Fan capacitors
3	IGBT cooling fan of phase L3
4	IGBT cooling fan of phase L2
5	IGBT cooling fan of phase L1

Apart from the main IGBT cooling fans, the filter may incorporate a small air blower in the filter door or at the cubicle top. These fans have an operating life of about 60000 hours. In order to replace these fans switch off the power to the cubicle, remove the electrical connections and subsequently remove the fan physically. Proceed in reverse order for adding a new fan.

12.5. DC capacitor change

The active filter DC link contains DC capacitors. Their service lifetime is 20 years (208 V ≤ Ue ≤ 480 V) or 10 years (480 V < Ue ≤ 690 V for CE filters and 480 V < Ue ≤ 600 V for cULus filters) depending on filter loading and ambient temperature. The DC capacitors used do not require reforming. Announced service lifetime assumes that the filter is operating under ABB approved conditions (Cf. Chapter 14).

It is not possible to predict a capacitor failure. Contact your ABB service provider if capacitor failure is suspected. Replacement kits are available from ABB. Do not use other than ABB-specified spare parts.

12.6. Servicing report

The Servicing Report is designed to help the person in charge of servicing.

ABB	**Project:**
LV Active Filters PQF	**Issued by:**
Servicing report	**Date:**
	Page 1 of 4

12.6.1. Filter identification

Active filter type[a]				
Global ratings[a]	**Maximum voltage (V)**			
	Total current (A)			
System serial number[a]				
Common cable entry cubicle	**Present/not present**			
Unit ratings/serial number[b]		**Rating (A)**	**Serial number**	**Article code[a]**
	Unit 1 (M)			
	Unit 2			
	Unit 3			
	Unit 4			
	Unit 5			
	Unit 6			
	Unit 7			
	Unit 8			
Software version[c]	**PQF-Manager software**			
	µcontroller software			
	DSP software			
Installation location				

Remarks:
[a] Read from main identification tag located on the master cubicle door.
[b] Read on identification tag located at the inside and outside of each cubicle door.
[c] After the filter has been commissioned, navigate with the PQF-Manager to [/Welcome/About PQF].

ABB	**Project:**
LV Active Filters PQF	**Issued by:**
Servicing report	**Date:**
	Page 2 of 4

12.6.2. Standard maintenance procedure

Ambient conditions and derating condition (filter running)	
• Check the ambient temperature (< 40°C) (if > 40°C, derating is required)	
• Check the installation altitude (< 1000 m) (if > 1000 m, derating is required)	
• Check the ventilation (room and enclosure)	
• Ensure that no conductive dust is present in the filter panel	
• Derating factor (temperature > 40°C or altitude > 1000 m)	
- Rating (%)	
Filter operating status record (filter running)	
• Filter load graphs	
- Vdc load (%)	
- Ipeak load (%)	
- Irms load (%)	
- Temp (%)	
• Filter running in derated mode due to temperature limitation?	
- Temp-load around 100% and other load indicators low? (Y/N)	
- 'T-Limit' indicator on digital output monitor on? (digital output 5 by default) (Y/N)	
If answer if 'Y' to any of the two questions above, check filter cooling.	
• PQF operation hours	
• Fan operation hours	
If fan operation hours are multiple of 35000, exchange fans.	
• Event logging window	
- Abnormal events present? (Y/N)	
If 'Y', describe them in the 'comments' section of this report.	
• Total number of faults recorded by the system	
Describe them in the 'comments' section of this report.	
Shut down the filter, remove supply to the unit and open auxiliary fuse box	
• Ensure that components do not carry dangerous voltage levels anymore.	
Inspect and clean the filter	
• All components/cabling looks OK? (Y/N)	
IF 'N', describe the problems in the 'comments' section of this report.	
• Remove all dust deposits in and around the filter (fans, heatsinks, control board, …)	
• Remove fan obstructions. Fans running freely? (Y/N)	
IF 'N', fans may have to be replaced.	
Condition of filter breaker, contactors and fuses	
• Breaker is OK? (Y/N)	
• Contactors can move freely? (Y/N)	
• Fuses are OK? (Y/N)	
If 'N', describe the problems in the 'comments' section of this report.	
Tightness of electrical and mechanical connections	
• Check tightness of all electrical connections	
• Check the mechanical fixation of all components	
Retighten connections/fixations if necessary	
Correct the outstanding problems	
Restart the filter	
• Close the auxiliary circuit fuse box	
- Control board LEDs light up	
- PQF-Manager booting	
- Fan(s) start(s) running	
Start the filter	
If major servicing work has been done, follow the commissioning instructions to start the filter.	

ABB	**Project:**
LV Active Filters PQF	**Issued by:**
Servicing report	**Date:**
	Page 3 of 4

12.6.3. Special service actions

Fan replacement	
• Which fan?	
• Fan operation hours?	
DC capacitor replacement	
• Filter operating hours?	
• Ambient filter conditions?	
Describe in the 'comments' section of this report.	

ABB	**Project:**
LV Active Filters PQF	**Issued by:**
Servicing report	**Date:** **Page 4 of 4**

12.6.4. Comments

	Servicing Engineer	**Customer's representative**
Name		
Signature		
Date		

13. Troubleshooting guide

13.1. What this chapter contains

This chapter presents the troubleshooting guide for the active filter. The filter fault treatment procedure is described. Also, an overview of possible errors is given. Finally, recommendations are made on how problems may be resolved.

WARNING:	**All troubleshooting and repair work described in this chapter should only be undertaken by a qualified electrician. The safety instructions presented in Chapter 2 of this manual must be strictly adhered to.**

WARNING:	**High AC and DC voltages may be present in the filter panel. Do not touch any filter parts unless you have ascertained that they do not carry dangerous voltage levels.**

WARNING:	**Under no circumstances close the circuit breaker manually. Failure to adhere to this guideline may result in physical injury and/or in filter damage.**

WARNING:	**Some checks may have to be made with the supply on and the filter doors opened. These tests must be carried out only by authorized and qualified personnel, in accordance with the local regulations. Apply the safety guidelines that are presented in Chapter 2. Failure to adhere with the safety guidelines may result in lethal physical injury.**

13.2. Fault treatment procedure

All faults that occur are stored in the filter event log and are analyzed by the filter controller. The event log is of the circular type and can store up to 200 events. It can be accessed through [/Welcome/PQF Monitoring/Event logging]. Background information on the event logging display is given in Section 8.8.2.

A fault can either be non-critical or critical.

- A non-critical fault is a transient fault (e.g. a voltage spike). When a non-critical fault occurs the filter may stop the switching of the IGBTs momentarily (< 40 ms) but they will automatically restart. The only way to pick up this type of fault is to analyze the event log. Given the transient/random character of this type of fault, the filter performance will hardly deteriorate when it occurs.

- A critical fault is a fault that after occurrence cannot be successfully automatically cleared by the system within a reasonable time. The time frame considered depends on the error type. If the fault is considered critical by the system, the label 'Critical' will be shown in the event logging window. In addition, the 'PQF'-item in the PQF-Manager 'Welcome' screen will display the label 'ACK. FAULT'. Note however that if the fault disappears fast, this label disappears too.

Depending on the type of critical fault and the number of occurrences, the filter, when running, may either:

- Stop (open the breaker) and await user intervention. In this condition the alarm contact of the PQF-Manager will switch on after a programmable delay and the 'Armed' indicator[(a)] will be OFF. The green LED on the main controller board (Cf. Table 5.12. item 17, LED DL5) will be off and the red LED on (Cf. Table 5.12. item 17, LED DL6). The user has to acknowledge the fault (with the PQF-Manager, via Modbus or via remote control) before the filter can be restarted.

- Stop (open the breaker) and restart automatically if the fault disappears. If stopped, the alarm contact of the PQF-Manager will switch on after a programmable delay and the 'Armed' indicator[(a)] will be ON. The green LED on the main controller board (Cf. Table 5.12. item 17, LED DL5) will be ON and the red LED will be OFF (Cf. Table 5.12. item 17, LED DL6). If it takes a long time before the fault disappears, the user may decide to give a filter stop command. This is done by highlighting the 'ACK. FAULT' item in the 'Welcome' menu and selecting OK twice. After this, the 'Armed' indicator[(a)] will be OFF. The green and red LEDs on the main controller board (Cf. Table 5.12. item 17, LED DL5) will be OFF too.
- Stop briefly without opening the breaker and continue filtering when the error has disappeared. This is essentially the same case as the one described above but the error phenomenon disappears faster than the time required to generate a breaker opening command.

If the filter is OFF and a critical error occurs (e.g. network undervoltage), the errors will also be reported in the event log. As long as a critical fault condition exists (e.g. permanent undervoltage on one phase) the display will show the message 'ACK. FAULT' and the filter will refuse to start. The 'Armed' indicator on the PQF-Manager will be OFF and both the green and red main controller LEDs will be OFF too.

When pressing 'ACK. FAULT' the filter will display a message relevant to the problem. It also shows a list of the most recent critical faults that have been recorded.

Remarks:

- [(a)] By default, the 'Armed' indicator is associated with the fourth digital output contact (cf. Table 5.7. and Table 5.8.) The digital output contact monitor at the top of the PQF-Manager display (Cf. Figure 8.1. item 3) can be used to check the status of the digital output. Alternatively, the digital output considered can be wired to monitor the 'Armed' indicator by distance (cf. Section 7.10.4.)

- If the filter is in remote control operation and the message 'ACK. FAULT' is present on the PQF-Manager, the fault can be acknowledged by sending a 'STOP' command by remote control (low signal). Alternatively, the remote control functionality can be disabled by disabling the corresponding digital input functionality. Then, the fault can be acknowledged locally.

Figure 13.1. shows the error treatment procedure in flowchart format.

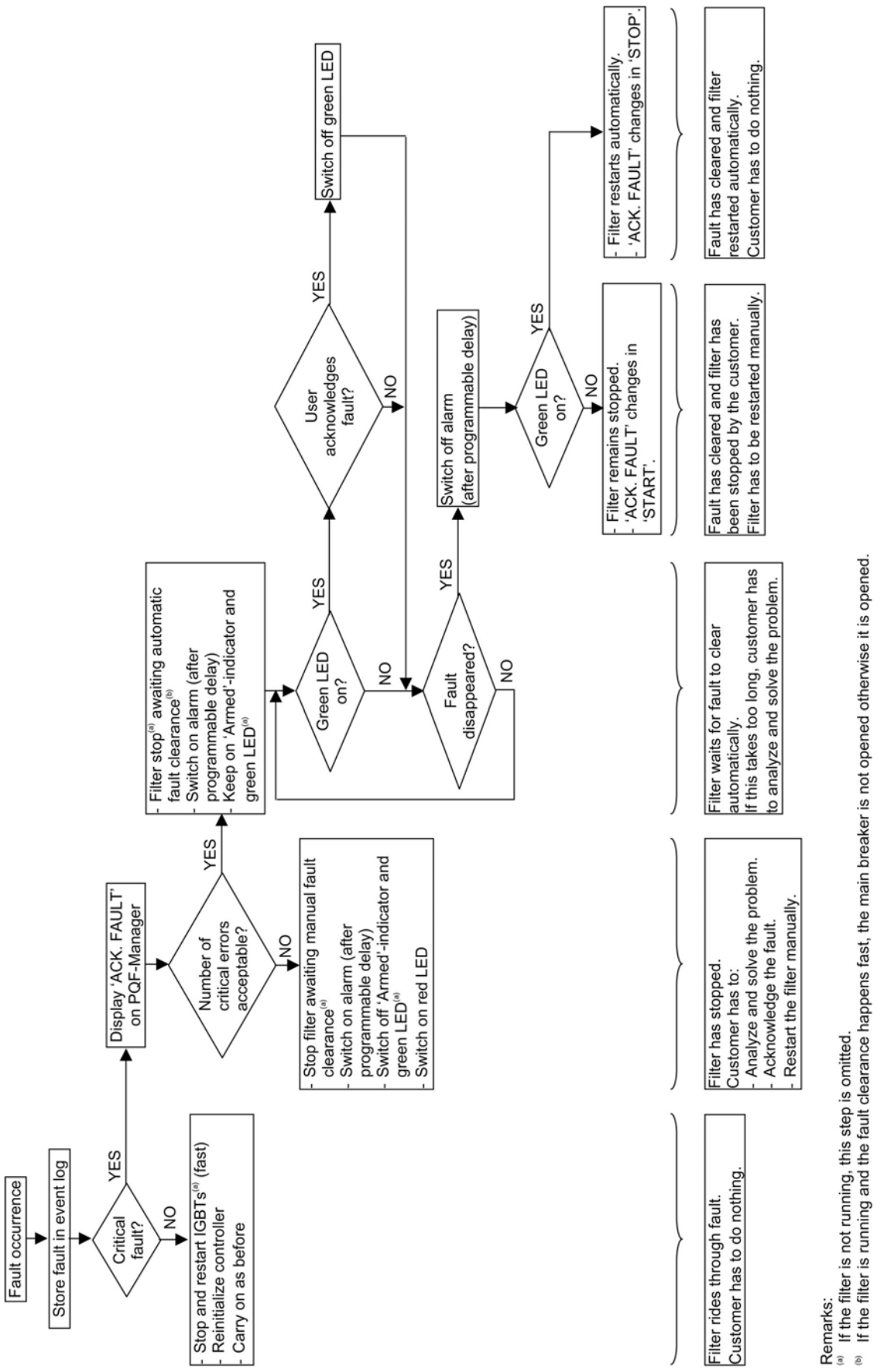


Figure 13.1. PQF error treatment procedure in flowchart format

In general the occurrence of transient faults is no problem for the proper operation of the active filter. Only when an error becomes 'critical', a problem may exist.

If 'ACK. FAULT' is present on the PQF-Manager display, look at the 'Armed' indicator (by default mapped to the 4th digital output of the PQF-Manager) or the green LED DL5 on the main controller board to know whether the filter will restart automatically after clearance of the problem or not.
'Armed' indicator/Green LED DL5 ON: The filter waits for the problem to disappear and then restarts automatically (unless the user acknowledges the fault).
'Armed' indicator/Green LED DL5 OFF: The filter is permanently stopped and the customer has to solve the problem, acknowledge the fault and restart the filter manually.

13.3. Tools required for on site interventions

13.3.1. Intervention classification and tools description

An on-site intervention for the active filter is sometimes needed. This section lists the minimum tool requirements for different intervention purposes starting form a very simple commissioning visit to a detailed intervention on a filter when problems have occurred. Of course, the list is of the generic type. Not all items in the list will always be used during an intervention, but they might be required. The main reason for having the complete set of items in the list is to ensure that all visits made on site are efficient and the customer problem is solved correctly and quickly.

It is reminded that an intervention must only be made by people having sufficient knowledge of the product and that are aware of the dangers always related with electrical apparatus. Safety and attention are top priorities to keep in mind.

The intervention types are classified in three categories starting from the less demanding one to the most demanding one.
- A very simple intervention: e.g. a filter parameter change requested by the customer.
- A normal intervention: e.g. a filter commissioning.
- An enhanced intervention: e.g. a filter components replacement.

13.3.2. Tools description for a very simple intervention

A very simple intervention can be for example a change of some filter parameters upon the customer's request. The only purpose of an ABB representative on site is to guarantee a correct setting of all parameters of the filter to get optimum performance level.

Normally, such a visit does not require any mechanical tools as no intervention on the filter is supposed to take place. No deep technical background is needed either. This type of intervention can normally be done by any LVNQ sales agent who is familiar with the product and the way its settings can be changed.

The person performing the intervention should have at least the following items:
- A complete documentation set of the PQF including this manual. All the documents are normally present in the filter cubicle.
- A mobile phone and the local ABB representative phone number for the case that questions arise during the visit to which the answer is not directly found in the manual.
- A portable PC with the latest version of the filter communication software in case the intervention engineer wants to use the PC to set up the filter. The latest software version can be obtained on demand from BEJUM.

An additional very interesting tool is a digital camera in order to take pictures of any particular phenomena observed during the visit. Also, the serial printer can be used to print out setup data.

Obviously, if the customer requests an intervention report with measurements, measurement devices must be added to the above list.

13.3.3. Tools description for a normal intervention

A normal intervention can be for example the commissioning of a filter that has just been installed, a regular maintenance of the filter unit or the troubleshooting of an apparent filter problem where a first inspection has indicated that there is no physical damage to the unit (e.g. component failure).

The people in charge of this type of intervention should have at least the following tools:

- A complete documentation set of the PQF including this manual. All the documents are normally present in the filter cubicle.
- A mobile phone and the local ABB representative phone number for the case that questions arise during the visit to which the answer is not directly found in the manual.
- A portable PC with the latest version of the filter communication software in case the intervention engineer wants to use the PC to set up the filter.
- A multi-meter with suitable voltage leads and a current probe.
- A scopemeter with at least two channels and all accessories allowing measurements at the network voltage level. The scopemeter can be any type of oscilloscope equipment with a bandwidth sufficient to observe phenomena up to 10-20 kHz.
- A harmonic measurement device, with suitable current and voltage probe, able to analyze at least up to order 49. As an example, a Fluke 43B is suitable. The scope function and the harmonic analysis function is sometimes integrated in one device.
- A tool allowing the measurement of the correct phase rotation sequence. This can be done with a scopemeter (Cf. Section 10.5.2.3.) or with a phase rotation controller.
- A complete set of mechanical tools (pliers, screwdrivers…)
- A set of cable ends and suitable crimping device for control cables.
- The material electricians usually need in their day-to-day business, including all safety equipment.

An additional interesting tool is a digital camera in order to take pictures of any particular phenomena observed during the visit (e.g. transportation damages, electrical and mechanical connections, picture of the installation for the commissioning/intervention report, …) Also, the serial printer can be used to print out setup data.

13.3.4. Tools description for an enhanced intervention

Such an intervention can be for example the replacement of a major failed component, the replacement of electronic parts after a failure with apparent physical hardware damages, … Often, this kind of intervention will follow after a first visit that has allowed the identification of the damaged items. These items must of course be available on site before the intervention starts and are not included in the below list.

WARNING:	**An enhanced intervention must only be performed by well-trained and skilled people. Lethal voltages may be present in the filter in many places, so the necessary precautions must be taken.**

The tools needed for this type of intervention are essentially the same as the tools discussed in Section 13.3.3. However, spare parts and cabling material need to be added.

13.3.5. Spare part list for normal and dedicated filter servicing

A standard set of spare parts should include the parts presented in Table 13.1.

Table 13.1. Standard set of spare parts for normal and dedicated filter servicing

Ref.	Description	Order code	Recommended quantity
1	Spare fuses for auxiliary circuit (208-480 V – CE version only)	10.420.00472	3
2	Spare fuses for auxiliary circuit (480-690 V – CE version only)	10.420.07009	3
3	Spare fuses for auxiliary circuit (208-600 V – cULus version only)	10.420.07926	3
4	Spare fuses for distribution board	10.420.06906	2
5	DC link fuses for master slave interconnection (slave units only)	10.420.07099	2
6	Surge arresters for cULus version	10.570.08606	3
7	Fan kit (middle)	20.079.87012	1
8	Fan kit (side)	20.079.87013	1
9	Door fan V230 170M3/H 17W 21302	10.460.07203	1
10	PQF-Manager filter controller	20.075.86724	1
11	Main controller analogue board ABB 100	20.910.87567	1
12	Main controller digital board ABB 110	10.580.06909	1
13	Distribution board	20.075.86247	1
14	IGBT interface domino board ABB 120	10.580.06910	1
15	AC voltage measurement board	20.075.86191	1
16	DC voltage measurement board	20.075.86710	1
17	Kit optical fiber link	20.079.87010	1
18	Kit flat cables for master/slave cubicle	20.079.87021	1
19	Power supply 24V 200W for PQFI 320A/450A	10.570.06741	1
20	Power supply 24V 100W for PQFI 180A/250A	10.570.05441	1

13.4. Troubleshooting guide

13.4.1. Verification of the system LEDs

As a first phase of troubleshooting make a record of the status of the filter system LEDs.

Provide the LED status information to the ABB service provider when discussing a potential filter problem.

- Main controller board LEDs:
  Figure 5.12. (items 15, 16 and 17) can be used to locate the main controller board LEDs.
  Table 5.12. (items 15, 16 and 17) explains the meaning of the LEDs and their status for normal operation.
- IGBT interface domino board LEDs:
  Figure 5.13. (item 8) can be used to locate the domino board LEDs.
  Table 5.13. (item 8) explains the meaning of the LEDs and their status for normal operation.
- Distribution board LEDs:
  Figure 5.10. (item 19) can be used to locate the distribution board LEDs.
  Table 5.10. (item 19) explains the meaning of the LEDs and their status for normal operation.

13.4.2. Fault tracing

Table 13.2. Power supply problems

Symptom	Cause	What to do
All the indicator LEDs on the electronic cards (LEDs) remain OFF. No display on PQF-Manager. Fan(s) not running.	The active filter (auxiliaries) is/(are) not energized.	• Check if the protection (circuit breaker, disconnector, …) feeding the active filter is switched on. • Check if the auxiliary fuse box (Q2) is closed and the fuses are OK. • Check that the 230V auxiliary voltage is arriving at the distribution board (X2). • Check that the distribution board fuses are OK. • Check the mains and auxiliary supply voltages.
After applying the auxiliary power to the system, all controller board LEDs are functioning normally but none of the fans start or they run at low speed. The fans do not exhibit mechanical failure problems.	• Fan voltage supply is too low. • The tap setting on the auxiliary voltage transformer is set at a too high level.	• Check the tap setting of the auxiliary voltage transformer (T1) and adapt if necessary. • Check the supply voltage to see that it is within the tolerance range of the nominal filter settings.
After applying the auxiliary power to the system, the filter fan runs properly but the controller board LEDs are not functioning.	The 24 Vdc power supply feeding the controller boards has failed.	• Check the 24 V power supply (U2) feeding the control boards. • Check the feeding cable between the distribution board (X15) and the 24 V power supply. • Check the feeding cable from the 24 V power supply to the distribution board (X14).
After applying auxiliary power to the system, the main controller board LEDs are functioning properly but the domino board LEDs are off.	No power supply to the domino board or domino board faulty.	• Check the power supply connection between the distribution board (X11) and the domino board. • If the 24 V power supply is OK, then the domino board is probably faulty. Check the filter event log and refer to Table 13.3. for guidelines on how to proceed. Possibly, the domino board has to be changed.
After applying auxiliary power to the system, the fan is running, the PQF-Manager shows the message 'Initializing communication. Please wait… the domino green LED(s) is/are on, but none of the LEDs of the main controller board is functioning.	No power supply to the main controller board or main controller board faulty.	• Check the power supply connection between the distribution board (X9) and the main controller board. If the 24 V power supply is OK, then the main controller board is probably faulty. Change the main controller board.

Table 13.3. Abnormal states of the controller board LEDs (after auxiliary power is applied to the system)

Symptom	Cause	What to do
The four yellow main controller board LEDs are blinking but the three DSP controller LEDs (DL1-DL3) are blinking twice as slow as the µcontroller LED (DL4). The PQF-Manager shows 'ACK. FAULT' and gives error message 'Bad rating parameters'.	The filter parameters entered by the commissioning engineer are not consistent with the filter configuration reported by the controllers.	• Check the commissioning parameters and correct where necessary. (Cf. Chapter 10).
The red LED DL6 on the main controller board is on.	The filter is stopped due to an unacceptably high number of critical errors.	• Check the filter event log to analyze the critical errors. Refer to Table 13.4. to know what to do in order to solve the problem reported. • After resolving the problem, the fault has to be acknowledged and the filter has to be restarted manually.
One of the four controller LEDs (DL1-DL4) on the main controller board is not blinking while the other ones are.	One of the controllers is not starting up properly. Eventually the red LED DL6 will switch on.	• Check the optical fibers and ensure that they are properly connected. • Check the filter event log to analyze the critical errors. Refer to Table 13.4. to know what to do in order to solve the problem reported. Most likely the controller board has to be replaced. • After changing the main controller board, the filter has to be recommissioned.
The main controller board LEDs are functioning correctly, the domino board green LED is off or is shining bright.	The optical link is not operational or the domino board is faulty.	• Check the optical fibers and ensure that they are properly connected. • Check the filter event log to analyze the critical errors. Refer to Table 13.4. to know what to do in order to solve the problem reported. The domino board may have to be replaced.
The main controller board LEDs are functioning correctly, the domino board yellow LED is not blinking at the same speed as the main controller board LEDs.	The domino board is not functioning properly or the optical fiber is not properly connected.	• Check the optical fibers and ensure that they are properly connected. • Check the filter event log to analyze the critical errors. Refer to Table 13.4. to know what to do in order to solve the problem reported. The domino board may have to be replaced.
The main controller board LEDs are functioning correctly, the domino board red LED is on.	• Overcurrent or overtemperature reported by the IGBT-module. • Power supply failure of the IGBT-driver or failure of the IGBT module. • Hardware problem domino/optical link not synchronized.	• Check the filter event log to analyze the critical errors. Refer to Table 13.4. to know what to do in order to solve the problem reported. The domino board or the IGBT bridge may have to be replaced.

Table 13.4. Fault messages reported by the DSP controllers of the filter and troubleshooting tips

Fault message	Cause	What to do
Bad parameters	The filter parameters entered by the commissioning engineer are not consistent with the filter configuration reported by the controllers.	• Check the commissioning parameters and correct where necessary. (Cf. Chapter 10)
Bad message sequence	Internal system error	• Contact your ABB service provider. Most likely the controller software has to be upgraded or the main controller card replaced.
Bad CT connection	The automatic CT detection procedure has encountered a problem during the CT identification process.	• Check that the CTs are installed on the supply side of the filter. • Check that the CTs are not shorted. • Check that the overall CT ratio (including summing CTs) is smaller than 20000/5. • Set up the CTs manually (Cf. Section 10.5.)
CT input overload	The CT inputs on the main controller card are overloaded.	• Check that the CTs installed have a high enough rating to cover the load current including inrush currents due to motor starts etc.
DC overvoltage (SW)	The DC software overvoltage protection has been triggered.	• Check the DC voltage measurement board (A2) and its flat cable connection to the main controller board. • Check the connection between the DC voltage measurement board and the DC capacitors. • Check flat cable connections between the domino boards and the IGBT module. • Analyze network voltage stability (amplitude and phase). • Disable reactive power compensation and balancing options to see if the problem persists. • Deselect the high frequency components to free DC bus resources and to see if the problem persists.
DC overvoltage (HW)	The DC hardware overvoltage protection has been triggered.	• Check the DC voltage measurement board (A2) and its flat cable connection to the main controller board. • Check the connection between the DC voltage measurement board and the DC capacitors. • Check flat cable connections between the domino boards and the IGBT module. • Analyze network voltage stability (amplitude and phase). • Disable reactive power compensation and balancing options to see if the problem persists. • Deselect the high frequency components to free DC bus resources and to see if the problem persists.
DC undervoltage (SW)	The DC software undervoltage protection has been triggered.	• Check the DC voltage measurement board (A2) and its flat cable connection to the main controller board. • Check the connection between the DC voltage measurement board and the DC capacitors. • Check the flat cable connections between the domino boards and the IGBT module. • Analyze network voltage stability (amplitude and phase). • Disable reactive power compensation and balancing options to see if the problem persists.
Ground fault	A ground fault has been detected.	• Check the equipment for possible connections to earth.

Fault message	Cause	What to do
IGBT check cooling	The software IGBT temperature protection has been triggered.	• Check the cooling of the filter system (fans and air flow, heatsink). • Check the cooling of the location where the filter is installed (air conditioning system etc.) • Ensure that the correct derating factor is applied noting the ambient temperature and altitude.
IGBT over temp (HW)	The hardware IGBT temperature protection has been triggered.	• Check the cooling of the filter system (fans and air flow, heatsink). • Check the cooling of the location where the filter is installed (air conditioning system etc.) • Ensure that the correct derating factor is applied noting the ambient temperature and altitude. • Check the flat cables between the IGBTs and the domino board. • Inspect the IGBT modules and DC capacitors for physical damage.
IGBT permanent	The IGBT module reports an error that cannot be cleared by the system. This error can be due to peak overcurrent, too low control voltage for the IGBT drivers or IGBT module failure.	• Identify domino for which the red LED is on. • Inspect the corresponding IGBT module (bridge and DC capacitors) for visual traces of damage. If they are present, exchange the IGBT module. Verify also the DC bus fuses. • Verify flat cable connection between the domino board and the IGBTs. • Ensure that the domino power supply is around 24 V. If significantly lower, check the 24 V power supply and the wiring between this supply and the domino board.
IGBT temporary	The IGBT modules report a transient error that could be automatically cleared by the system. This error can be due to peak overcurrent or a too low control voltage for the IGBT drivers.	If the errors occur sporadically and the system rides through, nothing has to be done. If the system does not ride through (too many transient errors in a short time): • Verify that the filter CTs are properly installed and are not shorted. • Verify that the unit current ratings and order programmed at the commissioning stage corresponds to the rating and order physically present. • Verify the filter cooling system and check the IGBT-temperature using the PQF-Manager. • Desactivate harmonic and reactive power requirements and see if the problem persists. • Inspect the items discussed for the 'IGBT permanent' message.
Loss of phase	The system has detected a loss of supply on at least one phase.	• Measure the three line voltages and check if they are within limits. • Measure the line voltages (e.g. voltmeter) and compare them with the line voltages given by the filter (PQF-Manager or PQF-Link). • Check the AC voltage measurement board (A1) for loose connections and component damage. • Check the connections between the auxiliary fuses and the AC voltage measurement board. • Check the flat cable connection between the AC voltage measurement board and the main controller board. • Check the filter parameters (Cf. Chapter 10). • For cULus filters, check whether the surge arresters are OK.

Fault message	Cause	What to do
No synchronization	• The system cannot synchronize on to the network. • The supply frequency has changed too much or too fast. • No/low voltage measured during filter initialization. • Wrong frequency set up	• Measure the network frequency and its variation, and check if they are within limits. • Check the phase rotation (only in case of modification at the installation). • Ensure that the AC voltage is properly measured. Do the checks discussed for the 'Loss of phase' fault. • Verify that the frequency set up at the commissioning stage corresponds to the frequency of the network. (Cf. Chapter 10). • Reset the system by powering off and on again.
• Optical clock lost • Optical link no synchro • Optic Lnk Rx frame mis.	The system has detected a problem with the optical link.	• Check that all the optical link fibers are connected properly between the boards. • Check the optical link fibers for damage. • Ensure that the minimum radius for bending the optical link fibers is 35 mm. • Check that the main controller board LEDs are functioning normally. • Check the status of the domino LEDs. • Check the power supply to the domino board. • If the problem persists, contact your ABB service provider. The control cards may have to be replaced or the controller software upgraded.
Out of mains freq. Limit	The system has detected that the network frequency is out of range.	• Measure the network frequency and check if it is within limits. • Check the phase rotation (only in case of modification at the installation). • Ensure that the AC voltage is properly measured. Do the checks discussed for the 'Loss of phase' fault.
Overvoltage RMS	The RMS value of the supply voltage measured with the AC voltage measurement board is higher than the acceptable maximum value.	• Measure the three line voltages and check if they are within limits. • Measure the line voltages (e.g. voltmeter) and compare them with the line voltages given by the filter (PQF-Manager or PQF-Link). • Ensure that the nominal voltage settings in the filter correspond to the voltage actually present on the network (Cf. Chapter 10). • Check the AC voltage measurement board (A1) for loose connections and component damage. • Check the connections between the auxiliary fuses and the AC voltage measurement board. • Check the flat cable connection between the AC voltage measurement board and the main controller board.

Fault message	Cause	What to do
• Overvolt. Transient (HW) • Overvolt. Transient (SW)	The hardware or software transient network overvoltage protection has been triggered.	If the errors occur sporadically and the system rides through, nothing has to be done. If the system does not ride through (too many transient errors in a short time): • Measure the line voltages with a device capable of measuring the peak voltage (e.g. scopemeter) and verify that this value is within acceptable limits. • Measure the RMS value of the network voltage and compare with the line voltages given by the filter (PQF-Manager or PQF-Link). • Check the AC voltage measurement board (A1) for loose connections and component damage. • Check the connections between the auxiliary fuses and the AC voltage measurement board. • Check the flat cable connection between the AC voltage measurement board and the main controller board. • Check the earthing of the cubicle.
Overcurrent RMS	The system has detected RMS overcurrent in the filter.	• Verify that the filter CTs are properly installed and are not shorted. • Verify that the unit current ratings and order programmed at the commissioning stage corresponds to the rating and order physically present. • Verify the filter cooling system and check the IGBT temperature using the PQF-Manager. • Deactivate harmonic and reactive power requirements and see if the problem persists.
• Overcurrent peak (HW) • Overcurrent peak (SW)	The hardware or software peak current protection has been triggered.	• Verify that the filter CTs are properly installed and are not shorted. • Verify that the unit current ratings and order programmed at the commissioning stage corresponds to the rating and order physically present. • Verify the filter cooling system and check the IGBT temperature using the PQF-Manager. • Deactivate harmonic and reactive power requirements and see if the problem persists.
Preload problem	The DC capacitors could not be preloaded at startup. The voltage increase on the DC capacitors during the preload phase is not high enough.	• Measure the three line voltages and check if they are within limits. • Verify the preload circuit and its control (including preload contactor K1). • Inspect the DC-bus for traces of damage that may have caused a short circuit on the DC side of the IGBT module or on the DC voltage measurement board.
Unbalanced supply	The supply network imbalance is out of range.	• Measure the three line voltages and check if they are within limits including the imbalance limit. • Measure the line voltages (e.g. voltmeter) and compare them with the line voltages given by the filter (PQF-Manager or PQF-Link). • Check the AC voltage measurement board (A1) for loose connections and component damage. • Check the connections between the auxiliary fuses and the AC voltage measurement board. • Check the flat cable connection between the AC voltage measurement board and the main controller board. • Check the earthing of the cubicle.

Fault message	Cause	What to do
Undervoltage RMS	The RMS value of the supply voltage measured with the AC voltage measurement board is lower than the acceptable maximum value.	• Measure the three line voltages and check if they are within limits. • Measure the line voltages (e.g. voltmeter) and compare them with the line voltages given by the filter (PQF-Manager or PQF-Link). • Check the AC voltage measurement board (A1) for loose connections and component damage. • Check the connections between the auxiliary fuses and the AC voltage measurement board. • Check the flat cable connection between the AC voltage measurement board and the main controller board. • For cULus filters, check whether the surge arresters are OK.
Unstable mains frequ.	The network frequency is varying too fast.	• Measure the network frequency and its variation, and check if they are within limits. • Check the phase rotation (only in case of modification at the installation). • Ensure that the AC voltage is properly measured. Do the checks discussed for the 'Loss of phase' fault.
Wrong phase rotation	The supply network feeding the filter has the wrong phase rotation.	• Check the phase rotation of the filter supply. • Measure the three line voltages and check if they are within limits. • Measure the line voltages (e.g. voltmeter) and compare them with the line voltages given by the filter (PQF-Manager or PQF-Link). • Check the AC voltage measurement board (A1) for loose connections and component damage. • Check the connections between the auxiliary fuses and the AC voltage measurement board.
Remark: If the problem persists, contact your ABB service provider. Provide him with all the relevant information, i.e. Filter serial number and type, status of the control LEDs, Error messages displayed and filter behavior.		

Table 13.5. Fault messages reported by the μcontroller of the filter and troubleshooting tips

Fault message	Cause	What to do
Breaker/Cont trip	The system has detected a main circuit breaker (MCB) trip. This can be due to: • The MCB trips due to overcurrent. • The MCB trips due to undervoltage. • The MCB trips due to DC bus interlink protection activation. • The MCB trips due to surge arrester protection activation • The MCB is not functioning properly or the control wires are not properly connected. • One or more bus end connector(s) is/are missing.	• Verify if a red LED on any of the domino boards is on. • Inspect the corresponding IGBT module (bridge and DC capacitors). If a faulty IGBT module is detected, replace the whole IGBT module. • Verify if traces of short circuit exist that can explain overcurrent in the system. • Verify the DC bus interlink protections (if present). • Verify the voltage of the supply to see if an undervoltage condition exists. • Verify the surge arrester protection (if present). • Verify the breaker control connection between the breaker and terminal X1 of the distribution board. • Verify that a bus end connector is present on the distribution board (X8) on the last filter cubicle. • If no surge arrester is installed, verify that a bus end connector is installed at X19 of the distribution board. • If no DC bus protection feedback is installed, verify that a connector terminator is installed at X3 of the distribution board (master cubicles only). • Verify the undervoltage release of the breaker.
Class B fault	Internal system error	• Reset the filter by switching off and on the power. If the problem persists, contact your ABB representative. The controller card must probably be replaced.
Com. Problem (CAN bus)	Communication problem between the PQF-Manager and the main controller board.	• Check the CAN-bus connection between the PQF-Manager and the distribution board terminal X12. • Check the CAN-bus connection between the distribution board terminal X9 and the main controller board terminal X34. • Check the 230 V power supply to the PQF-Manager.
Com. Problem (RS-232)	Communication problem between the main controller board and the external PC	• Ensure that the PQF-Link cable is properly connected. • Contact your ABB service provider.
• Corrupted DSP code • Corrupted uC code	Internal system error	• Reset the filter by switching off and on the power. If the problem persists, contact your ABB representative. The controller card must probably be replaced or the controller software upgraded…
Ctrl overtemperature	The system detected an overtemperature of the main controller board.	• Verify the ambient temperature and the cooling of the filter (dust filters, fans, heatsinks, …) • If the ambient conditions and the filter cooling is ok, the main control board is suspect. Contact your ABB service provider. The main control board may have to be replaced.
• DSP 1 watchdog • DSP 2 watchdog • DSP 3 watchdog	Internal system error	• Reset the filter by switching off and on the power. If the problem persists, contact your ABB representative. The controller card must probably be replaced or the controller software upgraded.
• Ext. over-temperature1 • Ext. over-temperature2	The system detected an overtemperature on the probe connected to X1/T1 or X2/T2 of the main controller board.	• Verify that relevant trip/alarm settings have been made with the PQF-Manager. • Verify that the temperature probes are at a location where the temperature is at the desired location (e.g. not at a hot spot). • Verify the cooling of the system (dust filters, fans, heatsink, ambient temperature, …)

Fault message	Cause	What to do
• Flash memory corrupted • NMI fault • Parameters corrupted • Power supply fault	Internal system error	• Reset the filter by switching off and on the power. If the problem persists, contact your ABB representative. The controller card must probably be replaced.
Preload time-out	The DC capacitors could not be preloaded in an acceptable time.	• Measure the three line voltages and check if they are within limits. • Verify the preload circuit and its control (including preload contactor K1). • Inspect the DC-bus for traces of damage that may have caused a short circuit on the DC-side of the IGBT-module or on the DC voltage measurement board.
• Real time clock problem • Stack overflow fault • Stack underflow fault • Uncategorized fault • Watchdog fault	Internal system error	• Reset the filter by switching off and on the power. If the problem persists, contact your ABB representative. The controller card must probably be replaced.
Remark: If the problem persists, contact your ABB service provider. Provide him with all the relevant information, i.e. Filter serial number and type, status of the control LEDs, Error messages displayed and filter behavior.		

Table 13.6. Other filter indications and behavior with corresponding troubleshooting tips

Symptom	Cause / State	What to do
The filter is working at 100% of its nominal capacity because the load requirement is asking this.	The harmonic stress on the network is still too high.	• Install additional filter units to reduce the stress further.
	The harmonic stress on the network is sufficiently low.	• The filter can be kept running in this condition.
The filter is working at 100% of its nominal capacity while the load is only at a fraction of the filter rating.	There is a problem in the CT connections or a hardware problem.	• Check the CT installation (CT location, CT shorts, …) • Check the connection between the CT terminal block X21 and the main controller terminals X4..X9. • Measure the line currents and compare them with the line currents given by the filter (PQF-Manager or PQF-Link).
	There is a software problem.	• Stop the filter, switch off the power of the auxiliaries and switch it on again. Restart the filter and see if the problem is solved. • If the problem persists, contact your ABB service provider.
	The filter has been asked to generate static reactive power.	• Verify the reactive power settings of the filter.
The filter is working at 100% load indication while its nominal RMS current rating is not attained.	Other limit than the RMS current limit has been attained. Temperature limit due to a too high ambient temperature or a failing cooling system.	• Check the ambient temperature and ensure that it complies with the filter specifications. • Check the filter cooling system.
	Other limit than the RMS current limit has been attained. Peak voltage limit due to an a-typical DC-link voltage requirement, due to a high network voltage, or due to a high demand of high frequency harmonics.	• Check the DC voltage level measurement on the PQF Manager when the filter is switched off. If the value reduces to 0, then the filter is functioning normally. • Check the network voltage level for excessive values. If the network voltage is not excessive than the limitation is due to a combination of load requirement with network voltage requirement. Resources may be freed by setting curve values (for high frequency components).
	Other limit than the RMS current limit has been attained. Peak current limit due to an a-typical peak current requirement of the load.	• Verify the filter current waveforms reported by the filter with an external monitoring equipment. If the waveform is similar then the filter is functioning normally. Else, the filter internal measurement system may be faulty. Contact your ABB service provider.

Symptom	Cause / State	What to do
The filter is running but it is unstable (oscillating behavior)	There is a problem in the CT connections or a hardware problem	• Check the CT installation (CT location, CT shorts, …) • Check the connection between the CT terminal block X21 and the main controller terminals X4..X9. • Measure the line currents (e.g. ammeter) and compare them with the line currents given by the filter (PQF-Manager or PQF-Link).
	Presence of (detuned) power capacitor banks or plain capacitors (LV or MV).	• Refer to Section 7.8.7. and Section 10.9. for precautions to take when plain capacitors are present in the network.
	The filter is installed on a very weak network.	• Make sure that the filter is operating in Mode 3. • If the problem persists, contact your ABB representative.
	Two master units are fed from the same CTs. The setup guidelines for this installation setup has not been implemented.	• Select different harmonics on both filters. • If the above is not possible, ensure that one filter is operating in Mode 1 and the other filter is operating in Mode 3.
The filter is running with low load indication and the load harmonics are not filtered.	The harmonics are not selected, the curve setting is very high or the harmonics are put in 'filter-standby' by the system.	• (Re)select the harmonics, check the curve levels and ensure that the correct settings are active (Main/Auxiliary)
	The line currents measured by the filter via the CTs are lower than the real load currents.	• Check the CT cabling for problems (CT-installation, CT-shorts, …) • Check the CT settings set up in the PQF-Manager
	The filter is in standby-mode, the IGBTs are not switching.	• Check the standby mode settings to ensure that they represent realistic values.
	The filter (CTs) is/are not installed in a central position and therefore the filter does not eliminate the harmonics of all the loads.	• Check that the CTs are installed at the desired location.
When selecting a harmonic, the filter attempts to identify it but after a while it is put in standby. The letter 'S' appears in the harmonics selection list. The harmonic is not filtered.	The network conditions do not allow for the harmonic to be filtered at present or there is a CT-problem.	• Check the CT-setup. • Reselect the harmonic to see if the problem persists. • Leave the harmonic in standby. The filter will automatically restart identifying/filtering it when another harmonic component is successfully (re)identified.
The ' ACK. FAULT'-message is present on the PQF-Manager. The alarm contact switches on after some delay.	The filter has stopped due to an error.	• Acknowledge the fault to see a list of most recent critical errors. • Look in the filter event log for more information on which errors have occurred. • Refer to the Table 13.4. and Table 13.5. for more information on these errors and for guidelines on how to troubleshoot them.

Symptom	Cause / State	What to do
The THDV increases when the filter is running.	• The background distortion is in antiphase with the load distortion.	• Check the background distortion.
	• The filter is in an incorrect state.	• Stop the filter and reset it by switching off and on the power.
Remark: If the problems persist, contact your ABB service provider. Provide him with all the relevant information, i.e. filter serial number and type, status of the control LEDs, error messages displayed and filter behavior.		

14. Technical specifications

14.1. What this chapter contains

This chapter contains the technical specifications of the active filter PQFI.

14.2. Technical specifications

The PQFI is an active filter for three phase networks with or without neutral for filtering of non zero-sequence harmonics and reactive power compensation including balancing between phases.

Table 14.1. Technical specifications

Installation location	
Indoor installation on firm foundations in a clean environment	
Altitude	Nominal output at 0 to 1000m (3300ft) above sea level (for derating refer to Table 6.1.)
Minimum temperature	-5°C (23°F) non condensing
Maximum temperature	40°C (104°F) (for derating refer to Table 6.1.)
Recommended maximum average temperature (over 24 h)	35°C (95°F)
Relative humidity	Max. 95% non condensing
Contamination levels (IEC 60721-3-3)	Chemical class 3C2 (for more information refer to Table 6.1.) Mechanical class 3S2 (for more information refer to Table 6.1.)
Vibration (IEC 60068-2-6)	Max. 0.3mm (2-9Hz) Max. 1m/s^2 (9-200Hz)
Shock (IEC 60068-2-27)	40m/s² - 22ms
Filter installation information	
Standard degree of protection	IP21 (IP20 open door) For other protection classes, see options.
Dimensions per power unit (appr.)	
CE version	W x D x H: 800 x 600 x 2150 mm (without base frame)
cULus version	W x D x H: 1400 x 600 x 2250 mm (with base frame)
Weight per power unit cubicle (unpacked) CE version	
• Network voltage: 208 V ≤ Ue ≤ 480 V (Voltage group V1) • Unit rating: 250 A	520 kg
• Network voltage: 208 V ≤ Ue ≤ 480 V (Voltage group V1) • Unit rating: 450 A	640 kg
• Network voltage: 480 V < Ue ≤ 690 V (Voltage group V2) • Unit rating: 180 A	540 kg
• Network voltage: 480 V < Ue ≤ 690 V (Voltage group V2) • Unit rating: 320 A	640 kg
Weight per power unit cubicle (unpacked) cULus version	
• Network voltage: 208 V ≤ Ue ≤ 480 V (Voltage group V1) • Unit rating: 250 A	630 kg

• Network voltage: 208 V ≤ Ue ≤ 480 V (Voltage group V1) • Unit rating: 450 A	750 kg
• Network voltage: 480 V < Ue ≤ 600 V (Voltage group V2) • Unit rating: 180 A	650 kg
• Network voltage: 480 V < Ue ≤ 600 V (Voltage group V2) • Unit rating: 320 A	750 kg
Color	RAL 7035 (light gray) Other colors on request.
Mechanical installation	Floor fixation, lifting lug provided
Cable entry method	
CE version	Bottom cable entry Common cable entry cubicle on request
cULus version	Top or bottom cable entry
CT requirements	3 CTs are required (Class 1.0 or better) Filter burden: 5 VA 15 VA burden for up to 30 m of 2.5 mm² cable 5 A secondary rating CTs must be installed in closed loop configuration
Airflow requirements	A minimum of 2100 m³/h cooling air has to be supplied to each cubicle.
Network voltage characteristics	
Network voltage ratings	208 V ≤ Ue ≤ 480 V between phases (Voltage group V1) 480 V < Ue ≤ 690 V between phases (Voltage group V2) [(b)]
Network voltage tolerance	+/- 10 %
Network frequency	50 Hz or 60 Hz
Network frequency tolerance	+/- 5 %
Maximum rate of frequency variation	20%/s
Maximum phase jump of network voltage	30°
Network voltage distortion	Maximum 20% phase to phase
Minimum network fault level	2 MVA
Voltage notch limits	According to IEEE519-1992, dedicated systems category Notch depth: ≤ 50% Notch area: ≤ 76*U V*µs Connection requirement: z_{load} (%) ≥ S_{load}/S_{trafo} * z_{trafo} (%) where: S_{load}: Notch producing load power S_{trafo}: Transformer nominal power z_{trafo}: Transformer impedance in % z_{load}: Impedance between notch producing load and filter connection point (% in load base)
Line voltage imbalance	Maximum 2% of phase to phase voltage
Surge withstand capability with optional surge arrester	According to IEC1643-1
Insulation voltage (Ui)	
• Network voltage: 208 V ≤ Ue ≤ 480 V (Voltage group V1)	480V
• Network voltage: 480 V ≤ Ue ≤ 690 V (Voltage group V2) [(b)]	690V for CE version 600V for cULus version
Auxiliary circuit voltage (internally derived)	230 Vrms (+/- 10%)
Neutral connection systems	Not applicable
EMC-Environment class (according to IEC 60439-1) (CE version only)	2
Compliance with standards	

General construction aspects	EN-60439-1 (1999)
EMC immunity (CE version only)	EN/IEC 61000-6-2, Industrial level
EMC emissions (CE version only)	EN/IEC 61000-6-4, Class A
Filter characteristics	
RMS output current per power unit type (50Hz or 60Hz network)	
• Network voltage: 208 V ≤ Ue ≤ 480 V (Voltage group V1)	Unit type 1 (M25, S25): 250 A Unit type 2 (M45, S45): 450 A
• Network voltage: 480 V < Ue ≤ 690 V (Voltage group V2) [(b)]	Unit type 1 (M18, S18): 180 A [(a)] Unit type 2 (M32, S32): 320 A [(a)]
Modularity	Up to 8 power units/filter (possible to use different power unit ratings of the same voltage group.) One power unit per cubicle.
Harmonics that can be filtered	20 harmonics individually selectable in the range 2^{nd} – 50^{th} harmonic order
Degree of filtering	Programmable per harmonic in absolute terms
Filtering efficiency	Better than 97% of filter rating typically
Response time	< 0.5 ms instantaneous 40 ms typically (10% - 90% filtering)
Reactive power	Static/dynamic Power factor programmable from 0.6 (inductive) to 0.6 (capacitive)
Load balancing	Off Line to line balancing (3-W mode)
Setting possibilities	Main and auxiliary settings functionality. Three possible filter modes that allow to set different priorities
Start and stop settings	Local/remote control functionality. Filter standby functionality. Auto restart after power outage functionality.
Digital inputs	2 multi purpose digital inputs on PQF-Manager. Vlow: 0 Vdc, Vhigh: 15-24 Vdc, driving current: 13 mA@ 24Vdc (Rint = 1.88 kΩ). Can be used to implement remote control functionality, start/stop buttons and switching between main and auxiliary settings.
Digital outputs	6 multi purpose (NO) digital outputs on PQF-Manager. Maximum continuous ac rating: 440 Vac/1.5 A Maximum continuous dc rating: 110 Vdc/0.3 A Common rating: 9A/terminal, totaling 18 A Can be used to monitor the filter state (e.g. filter on/off or specific filter warnings/alarms) and the network state.
Alarm contact	1 universal alarm contact with two complimentary outputs (NO/NC) on PQF-Manager. Triggered by any fault. Maximum continuous rating: 250 Vac/1.5 A
Filter losses (maximum values)	
• Network voltage: 208 V ≤ Ue ≤ 480 V (Voltage group V1) • Unit rating: 250 A	≤ 5.2 kW
• Network voltage: 208 V ≤ Ue ≤ 480 V (Voltage group V1) • Unit rating: 450 A	≤ 11 kW
• Network voltage: 480 V < Ue ≤ 690 V (Voltage group V2) [(b)] • Unit rating: 180 A	≤ 7.1 kW
• Network voltage: 480 V < Ue ≤ 690 V (Voltage group V2) [(b)] • Unit rating: 320 A	- [(c)]
Phase to earth resistance	200 kΩ/filter system
Noise intensity	

• Network voltage: 208 V ≤ Ue ≤ 480 V (Voltage group V1) • Unit rating: 250 A	70 dBA typically
• Network voltage: 208 V ≤ Ue ≤ 480 V (Voltage group V1) • Unit rating: 450 A	78 dBA typically
• Network voltage: 480 V < Ue ≤ 690 V (Voltage group V2) [(b)] • Unit rating: 180 A	70 dBA typically
• Network voltage: 480 V < Ue ≤ 690 V (Voltage group V2) [(b)] • Unit rating: 320 A	78 dBA typically
Communication	Through PQF-Manager display. Through Modbus RTU (with optional adapter). Through RS-232 port with dedicated optional software (PQF-Link).
Programming	Through PQF-Manager display. Through RS-232 port with dedicated optional software (PQF-Link).
Fuse information	
Auxiliary circuit fuses (CE version): Vsupply: 208 V ≤ Ue ≤ 480 V Vsupply: 480 V < Ue ≤ 690 V	 French Ferrule 10 x 38 gG/gl, 16A, 500V, Isc ~120kA French Ferrule 14 x 51 gG/gl, 16A, 690V, Isc ~80kA
Auxiliary circuit fuses (cULus version): Vsupply: 208 V ≤ Ue ≤ 600 V	 NAPF 10 x 38 Fast Acting, 15A, 600V, Isc ~200kA
Distribution board fuses	5 x 20T, 10A / 250V
DC link protection fuses	Ferraz Schawmut, French Standard PSC, Size 70, 350A, Ref W300491
Surge arrester fuses (CE version)	Size 0, 125A, gG/gL, with striker
Surge arrester fuses (cULus version)	OVR 15-660 US
Options	
PQF-Link software	
Common cable entry cubicle (1200A) (CE version only)	
IP41 execution (filter derating of 10% has to be applied)	
Base frame (100 mm height) for single unit (CE version only)	
Modbus kit (RS-485 based)	
Printer (RS-232 based, including thermal paper and battery)	
Surge arresters (CE version only)	
Space heaters	
Temperature probe 3 m	
Temperature probe 10 m	
Base frame for complete unit (CE version only)	
Reinforced output filter for networks beyond IEEE519-1992, dedicated systems category	

Remark:

[(a)] If the nominal system voltage is higher than 600V (Ue > 600V) the current rating of PQFI units in this voltage range may be derated automatically depending on the load conditions for ambient temperatures higher than 30°C (86°F).

[(b)] cULus version of PQFI are limited to 600 Vrms.

[(c)] Not available at time of printing.

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2GCS211013A0070 2006-07-24

3. Drawings

4. Inspection and Test Results

SJ ELECTRIC

TEST BEFORE YOU TOUCH

№ 10464

TEST SHEET

CUSTOMER NAME: BRISBANE WATER **SWITCHBOARD ID:** HARMONIC FILTER **DATE:** 29/9/09.

CUSTOMERS ADDRESS: OLDFIELD RD. **JOB No.:** WT6000X

C/B NO.	CABLE SIZE	C/B SIZE	N NO.	CIRCUIT DESCRIPTION	VISUAL INSPECTION	CORRECT CIRCUIT CONNECTION	EARTH CONT.	A - E MΩ	N - E MΩ	A - E VOLTS	A - N VOLTS	ø - ø VOLTS	RCD TEST mA	RCD TEST mS	Fault loop Impendance measurement
69	150mm²	400A	N9	HARMONIC FILTER	PASS	PASS	0.05	+200	+200	240V	240V	415	n/a	n/a	
				SUPPLY											
				HARMONIC FILTER											
n/a	6c+E 2.5mm	n/a	n/a	CT CABLE	PASS	PASS	0.05	+200.	—	—	—	—	—	—	

TEST EQUIPMENT: MEGGA / MULTI **NAME:** PETER CROSS

SERIAL NO: 5128005 / 595690174 **LIC NO:** 53791

TEST DUE DATE: 29/1/10 / 29/1/10. **SIGNATURE:**

THIRD PARTY COMMISSIONING

Product Details

Client:	SJ Electrics	**Type**	PQFI	
Project:	Oldfield Rd PS	**Ratings**	Maximum Voltage [V]	480
Product:	PQF Active Filter		Total Current [A]	250
Manufacturer:	Condensator Dominit	**Serial Number**		
		Software version	PQF Manager software	v1.9.r0
Issued by:	Tim Makris		ucontroller software	v0.1.r15
Date of commissioning:	29/09/2009		DSP software	v4.0r13

Installation Inspection

Ambient conditions	OK.
Ventilation	OK however recommend to shorten custom door vent cover.
Environment	Dust on floor. Recommend to clean and also inject foam into cable entry section to stop vermin.

Electrical Connections

Power wiring	OK
Control wiring	None used
CT wiring and rotation	L1 = Input 1
	L2 = Input 2
	L3 = Input 3
	Rotation consistent
CT Ratio L1 measured	241
CT Ratio L2 measured	241
CT Ratio L3 measured	243

Programming

Rating %	85%			
Digital I/O	Not in use			
Filter Mode	Mode 1 - Filtering to Curve priority			
Harmonic Order Selected	5th	17th		
	7th	18th		
	11th	23rd		
	13th	25th		
Comments	Unit has been initially programmed to allow lower harmonic amps than what is necessary. Harmonic order curve will need to be adjusted to suit worst case demand conditions for the pumping station.			

Measurements

Background THVD%	1.10%	
Load	70kW, single pump VSD on partial load.	
	Filter OFF	Filter ON
Amps: 5th [A]	59	1
Amps: 7th [A]	38	1
THDI%	85%	approx. 8%
THVD%	2.10%	1.40%

5. Compliance Certificates

SJ ELECTRIC PTY LTD
Queensland

Ref: Test Certificate P178.doc

TEST CERTIFICATE

SJ Electric (Qld) Pty. Ltd.
19 Elliot Street.
Albion Qld. 4010
R.E.C. 7623

Attention: Wendy Wong

Level 2 TC Beirne Centre, 315 Brunswick Street Mall, Fortitude Valley Q 4006

Work performed for Brisbane Water at SP178 at Oldfield Rd under contract BW: 70103-06/07-023 (SJ Electric Job Number WT400039)

Installation Tested.
New Harmonic filter.

Test Date
29/09/09

Testing.
The certificate certifiy's that the electrical installation to the extent it is affected by the electrical work has been tested to ensure it is electrically safe and is in accordance with the requirements of the wiring rules and the electrical safety regulation 2002. C.J. Holmes (endorsee to electrical contracting license 7623)

Signed.