REFERENCE BOOK

POWER FACTOR REGULATOR

PFR-X-R / PFR-X-T

Power Factor Regulator PFR-X

Document history

Date	Name	Revision	Comment
22.07.09	Le	01	initial document release
25.01.10	Le	02	Examples added, changes to software version 1.04
16.06.10	Le	03	Add features of software version 1.06
09.02.11	Le	04	Add features of software version 1.08
14.06.16	RH	05	Content correction
13.03.17	RH	06	Content correction

ATTENTION!

Installation of the PFR-X must only be undertaken by technically qualified persons, since live terminals can cause electric shock.

The appropriate safety regulations in the country of installation must be strictly adhered to.

Equipment with damaged casing or terminals must not be used and must be disconnected from the mains supply immediately.

1 INSTALLATION AND CONNECTION

1) Check that the mains voltage and CT current input are suitable for the relay!

2) Disconnect panel from mains voltage, and check that the voltage is off

3) Ensure CT short-circuited or not in operation.

An open circuit CT produces a high voltage which endangers people and equipment. It will also damage the CT and affect ist accuracy.

4) Disconnect and remove any previous pfc-relay.

5) Mount PFR-X in the control panel with the two mounting clips. (cutout 138x138mm)

6) Connect the earth protection cable to 'PE' on PFR-X metal case.

7) Connect PFR-X according to wiring diagram.(CT/P1 towards incoming feeder, CT/P2 towards load!)

8) Remove short-circuit from CT

9) Connect mains voltage to panel.

10) If relay has been correctly connected and the mains voltage and CT output comply with the ratings and settings of PFR-X, the LCD will show AUTO and the control function will start automatically!

Power Factor Regulator PFR-X

1.1 Wiring diagram

PFR-X-R

power-input
utility

load

L1

X/1A or X/5A

L2

L3

| K | L | Um1 | Um2 | M | A | Interface | TTL |
| 15mA - 6A | | 90V - 550V | | | | | |

K1-K14

| ⏚ | T1 | T2 | MS | 1 | 14 | 1-14 |

K1   K14

external
temperature sensor
or temperature switch
(parallel use of sensor
and switch is possible)

signal:
in order
(life-contact)

up to 14
control exits

Controll exits can
be parametered
for fan controll

N

PE

PFR-X-T

power-input
utility

load

L1

X/1A or X/5A

L2

L3

Power Supply

| K | L | Um1 | Um2 | M | L | A | Interface | TTL |
| 15mA - 6A | | 90V - 550V | | | | | | |

| ⏚ | T1 | T2 | MS | LF | 1 | 12 |

Triggerinput
BEL-TSXX

external
temperature sensor
or temperature switch
(parallel use of sensor
and switch is possible)

signal:
in order
(life-contact)

Fan control

up to 12
control exits

N

PE

5

Power Factor Regulator PFR-X

1.2 Connection data

Meas.- Supply voltage	
	Combined measurement and Power supply Range 90-550V. Terminals UM1 / UM2 With using of VT a ratio can be adjusted. Range 1-350
Current measurement	
	Current measurement Range 15mA – 6A, Measurement transformer types x/1A or also x/5A can be used. Terminals K (S1) / L (S2) CT ratio is 1-9600 (Devices with Firmware before 1.04 had the adjustable range from 1-4000)
Regulation exits	
	Assembly with 4, 6, 8, 10, 12, 14 Regulation exits possible. Regulation exits volt free with common root. Terminals A 1-14. max. breaking capacity 5A/250VAC
Static outputs	
	Assembly with 6 or 12 static outputs possible. open-collector, breaking capacity: 8 – 48V DC / 100mA
Alarm contact	
	Opens in case of alarm and grid failure (can be changed by software). Terminals M / MS max. breaking capacity 5A/250VAC
Separate fan control (only PFR-X-T)	
	Closes terminals L / LF when exceeding temperature limit 1 max. breaking capacity 5A/250VAC
Temperature sensor / Digital Input	
	Temperature measurement or Digital Input to switch over to second COS φ. Terminals T1 / T2 Setting is explained in the Alarm menu.

2 COMMISSIONING

The PFR-X comes with factory settings which allows operation in 400V grid without any settings. Provided that, the connection is correct.

After applying voltage, the display shows the measured cosφ and displays „Auto". The measured cosφ should be inductive (displayed by a small „i" behind first line). With applying the voltage to the PFR-X the discharge blocking time for the capacitors starts (Factory setting 75 sec.). After the discharge blocking time the regulation starts. Stepsizes will be detected automatically. Control exits which are not used, become adjusted to step status "Fix-Off" after three switching cycles without success. This outputs are blocked for the control.

To display values which are depending on the current, it's necessary to adjust the ct ratio. This setting is not necessary for the control.

FAQ during Commissioning:

1)   No indication AUTO -> the relay does not switch
Cause: Relay is set to manual operation
In SETUP/100 menu the selection for PFC is on OFF or HOLD, temperature is too high, current < 15mA, voltage or THD U is out of tolerance.

2)   Indication U ALARM -> voltage out of tolerance
Check settings for nominal voltage (SETUP/Un) and voltage transformer (SETUP/Pt)

3)   Indication I Lo ALARM -> CT current < 15mA
Cause: connection error of CT; short-link of CT is not removed; CT-ration is too high compared to real current; no current

4)   Indication EXPORT -> kW export
if there is no real kW export, voltage and current connection to PFR-X has to be checked! See Wrong Connections / AI

5)   Wrong Cos j indication -> wrong connection
voltage and current connection to PFR-X has to be checked! See Wrong Connection / AI

6)   Steps switch in and then quickly switch out again
See Stepsize Detection / Defective Capacitors
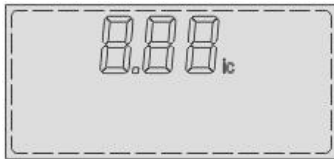
7)   Frequent switching of steps
size of capacitors has not been completly detected

Power Factor Regulator PFR-X

3 DISPLAY

On the right side of the display the actual chosen main menu is shown.

INFO: Capacitor database
AUTO: automatic control is running
MANUAL: manual mode
SETUP: setup menu

In the top menu level in the first line the actual cosφ is shown.
The i respectively the c indicates leading or lagging cosφ.
In submenu level the codes for the submenus or the abbreviations for the measured values are displayed.
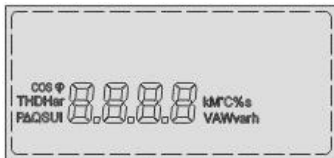
The second line shows measurement and set values with the corresponding units. Also the alarm codes which are shown during and alarm event are indicated there. All alarm codes are shown and explained in the table on the next page.

Active regulation outputs are shown in the bottom line. Steps which are detected as defective (three switching cycles without success) are blinking.

NT: COS φ 2 active
EXPORT: export of active energy

ALARM: blinking in case of alarm
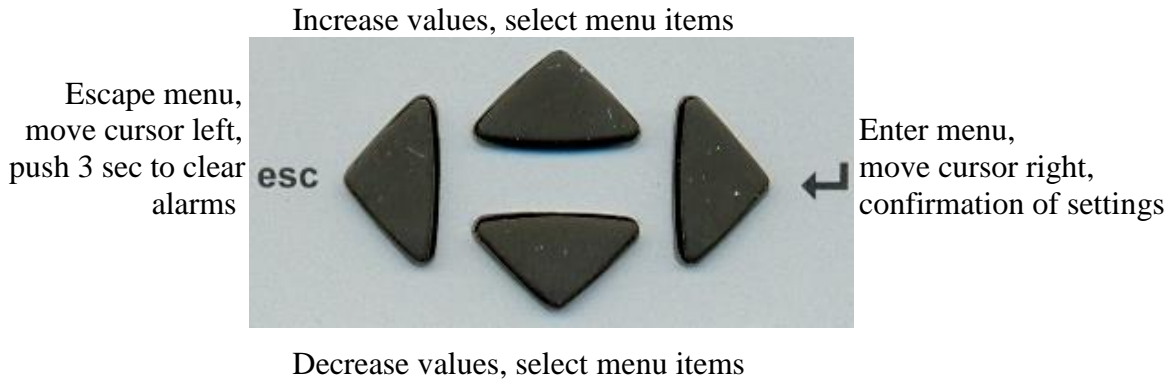
Power Factor Regulator PFR-X

In case of an alarm will flash alternately at PFR-X with "ALARM" an error code in the display. The table below gives an overview of all possible error codes.

To reset pending alarms hold the ◄ (esc) button pressed for 5 seconds.

U.U ALARM	measured voltage is outside the set tolerance
I I,LO ALARM	measured current is less than 15mA (check the short circuit bridge K and L and the entire current path
I IHo ALARM	measured current is to high
PFC ALARM	The controller cannot achieve the target COS φ
THDU ALARM	The set limit for the THD of the voltage is exceeded
StEP ALARM / StP 04 ALARM	One or more steps are broken. The defective step is blinking with the alarm message.
StPC ALARM / 0 0 ALARM	One or more step's have fallen below 70% of initial power. step number and error code will flash alternately. For devices with software version before 1.04 the alarm is triggered at 50% of initial power.
t.Hoo ALARM	The second temperature limit is exceeded. Stage were switched off successively.
oPHH ALARM	Set limit of operation hours has been exceeded
oPPC ALARM / 0 0 ALARM	Set limit of the max. allowable operation cycles, for one or more steps, has been exceeded.
Ao / Abrt	Abort of auto-initialization.

Power Factor Regulator PFR-X

4 OPERATION

4.1 Keys

Increase values, select menu items

Escape menu,
move cursor left,
push 3 sec to clear
alarms

Enter menu,
move cursor right,
confirmation of settings

esc

Decrease values, select menu items

4.2 Input of numerical values

Whenever the PFR-X prompts for the input of a value, the routine will be the same:

A preset-value will be displayed with the first (highest) digit blinking. This digit can now be changed by use of the ▲ and ▼ keys. Use the ▶ button to change to the next smaller digit. After changing, the next digit will be also blinking and can now be altered just like the first one. When arriving the last digit, press the ▶ key once more. This position allows to set multipliers M (Mega) or k (kilo). To store the value, press the ▶ key once more, and the new value will be saved and used.

For the case that a adjusted value cannot be stored respectively another value is shown after confirmation with ▶ button, it's possible that the adjusted value is outside of the allowed range. For further information's about possible ranges, please check the table on the last page.

At any time, one can go back to the menu he came from without changing the value by pressing the ◀ key. In this case the modified value will **not** be used!

5 MENU PFR-X

5.1 Measurement menu

All grey fields are hidden in the factory settings and will only appear if the CT ratio is set in the "SETUP" menu. For devices with software version before 1.04 the complete measurement menu is hidden and must be activated by adjusting the CT ratio.

1.00 i	1.00 i U 400 V Voltage L - L	1.00 i cosφ 0,999 Pf three digit
1.00 i INFO	1.00 i U 230 V Voltage L - N	PF 0,888 Power factor ratio P/S
1.00 i MANUAL	1.00 i I 40,45 A current in measured phase	APF 1.000 Average Power factor
1.00 i SETUP	1.00 i P 30,37 kW Active power 3 phase	F 50 Frequency
	1.00 i Q 82,89 Var Reactive power 3 phase	t 58 °C Temperature
	1.00 i ▲Q 80,08 control deviation in kvar	thi 88 °C Highest measured Temperature
	1.00 i S 30,68 kVar Apparent power 3 phase	OPH 188.9 h Counter operation hours
	1.00 i THD U 1,41 % Harmonic distortion U total	
	3 HarU 0,40 % Odd single harmonics 3 - 19	

5.2   Info (Step database)

In the "INFO" menu for each connected step the number of switching cycles, the current step size and the step size in relation to the initial step size is stored.

Using these data, conclusions can be drawn on the condition of the site and the condition of single step's. **Step sizes are shown in kVar only when in the CT ratio is set in "Setup" menu.**
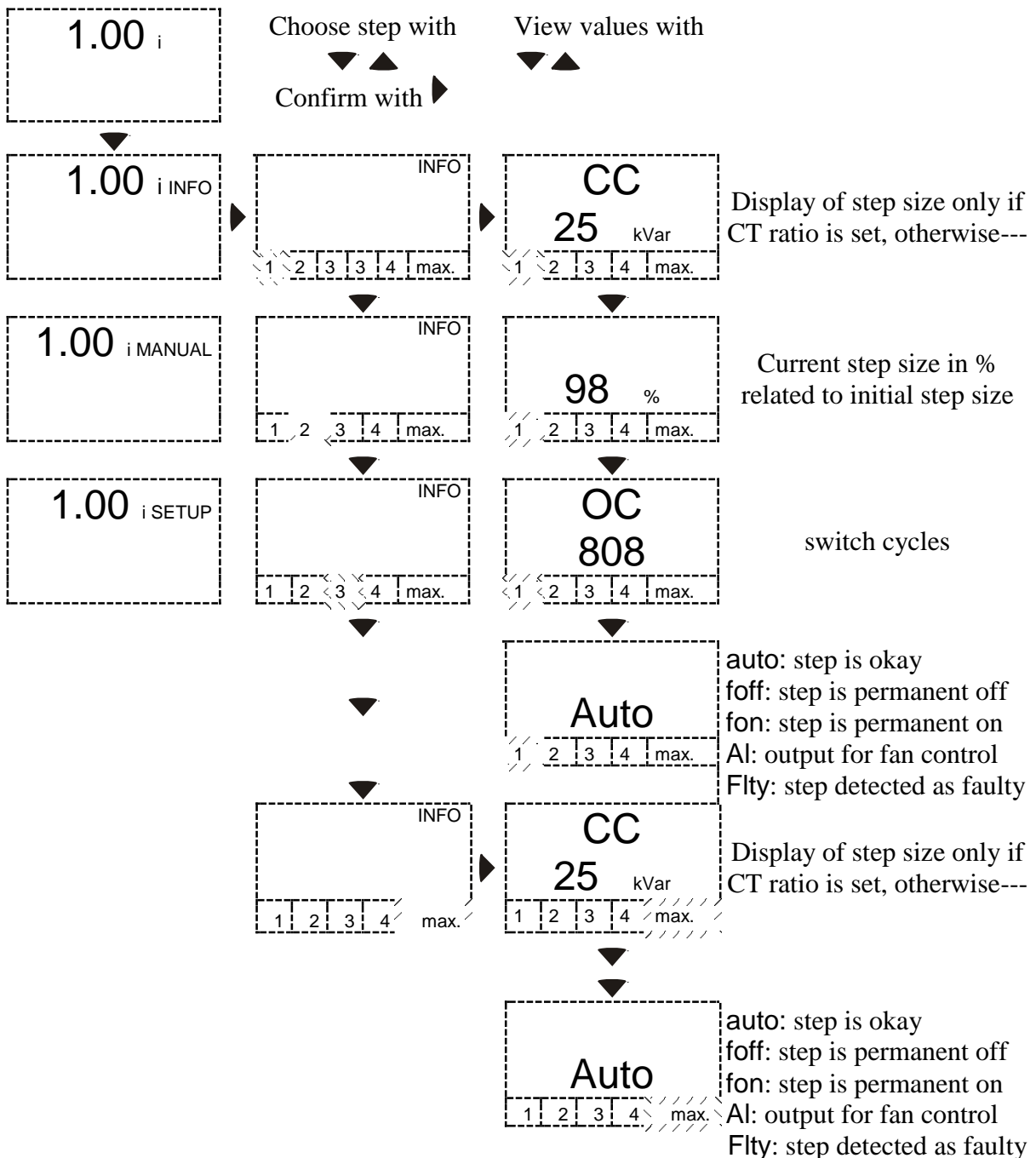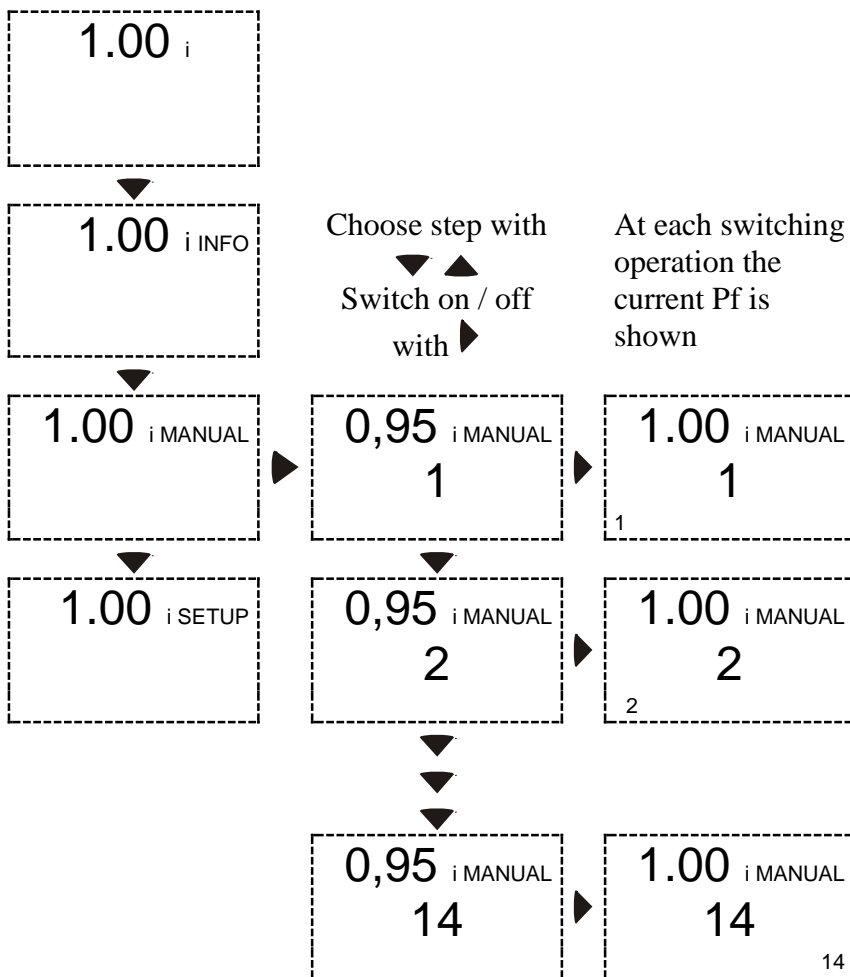
5.3 Manual (step switching manual)

To enter in manual mode, please select "manual" in main menu and push ► for 3 seconds. By entering this submenu the manual mode for the regulator is active. The automatic control is stopped and the exits can be switched manually. By the means of the ▼▲ -keys the referring step can be selected. Changing the switching state is possible by pushing the ►-key.

> [!] **Manual switching is only possible when measurement voltage is in allowed range. Otherwise over- and undervoltage protection will block this function. After switching off an active step the discharge time is active. Only after this time is over the step can be switched on manually again.**

```
  1.00 i


     ▼
  1.00 i INFO          Choose step with       At each switching
                           ▼ ▲               operation the
                       Switch on / off        current Pf is
     ▼                     with ▶             shown

  1.00 i MANUAL     ▶   0,95 i MANUAL    ▶   1.00 i MANUAL
                            1                     1
     ▼                                       1

  1.00 i SETUP          0,95 i MANUAL    ▶   1.00 i MANUAL
                            2                     2
                                             2
                            ▼
                            ▼
                            ▼
                        0,95 i MANUAL    ▶   1.00 i MANUAL
                            14                    14
                                                     14
```

5.4 Setup (Quick start menu)

```
1.00 i
```

To start the control, it's only necessary that the nominal voltage is correct.
All other settings are only for optimal adaptation to the conditions in the system and display system data. To change a setting, enter the setting by pushing the ▶ button. Change the value with ▼ ▲ and confirm with ▶ . When you start the auto-initialization the PFR-X checks the connection of the measurement and the exits. With these data, the regulation starts automatically.

```
1.00 i INFO
```

```
1.00 i MANUAL
```

```
1.00 i SETUP
```  ```
1.00 SETUP
```

```
Un SETUP
400
```
**Un = nominal voltage**
Setting of nominal voltage. From this value the upper and lower limits for voltage monitoring is calculated

```
ct SETUP
20
```
Input current transformer ratio
e.g. 250/5 = 50

```
pt SETUP
1
```
Input voltage transformer ratio when no VT is used the value is 1

```
ai SETUP
no
```
"Yes" the controller performs the auto-initialization again

```
pfc SETUP
on
```
"ON" automatic control
"OFF" control off
"HOLD" control freeze

```
cpi SETUP
1
```
Target COS φ of control

```
st SETUP
10
```
Interval between switching the steps

```
Out SETUP
```
Possible types of output:
auto: step is used for regulation
foff: step is permanent off
fon: step is permanent on
Al: output for fan control
Valid from Version 1.06.

# 6 EXPERT MENU PFR-X

To enter the PFR-X expert menu, select menu item "SETUP" and confirm with ▶(↵). Push ▼ or ▲ and enter the requested PIN (242) and confirm with ▶(↵). The submenus can be selected by pushing ▼ ▲ buttons. The expert menu of PFR-X is divided into six groups, where the menu items are logically grouped together.

The following groups exist:

**100 Quick start menu**

Contains all important points for commission.

**200 Measurement settings**

Contains settings to adapt the measurement of the PFR-X to the surrounding network conditions.

**300 Setup Control System**

The items in the menu "control system" allow an optimization of the control or an adaptation to specific site requirements.

**400 Setup Step Database**

In the step database, all settings and data are combined which are required to adjust and adapt the steps.

**500 Setup Alarm**

The alarm menu of PFR-X. Here, all the alarms and monitoring functions can be activated and the limits configured.

**600 Resetmenu**

Allows you to reset all settings made by the controller and stored data. Additionally, it contains the software version of the device (displayed from 1.04) and the possibility to change the password for the setup menu.

Power Factor Regulator PFR-X

## 6.1  100 Quick start menu

Contains all important points for commission:

### 100 Quick start menu

| MENU | FUNCTION | RANGE |
|---|---|---|
| Un | NOMINAL VOLTAGE = PHASE - PHASE | 100...241500 V |

Function of the setting of nominal voltage is to make a definition about the nominal voltage of the system. The threshold levels for under- and overvoltage are based on this as well as the ratings of the capacitor sizes in step database, which are used for control and monitoring. The capacitor sizes, which are stored in step database, are also rated to the nominal voltage.

| | | |
|---|---|---|
| Ct | CT-FACTOR | 1...9600 |

The CT FACTOR is the ratio of current transformer.
(e. g. 1000/5 = ratio 200).
At devices with software version 1.04 is the adjustment range from 1-4000.

| | | |
|---|---|---|
| Pt | VT-FACTOR | 1...350 |

VT FACTOR is the ratio of the voltage transformer.
If the regulator is connected directly to the measurement voltage without VT the value 1 has to be used.

| | | |
|---|---|---|
| Ai | AUTO-INITIALIZING START | Yes/No |

"YES" starts auto-initializing

Automatic initialization is switching all exits. During this test it can get information, which exits are working and it can correct the connection of the measuring channels for voltage and current by internal settings.
Automatic initialization can be started only when the voltage and current are ok. Steps with step type "FON" or "AL" will be not considered in case of new auto-initialization.

**AUTOMATIC INITIALIZATION is only able to work, when capacitors are used for compensation. If PFR-X has to switch reactors for compensation of capacitive load, this feature will cause failures. AI is working at best, when there are stable load conditions!**

At devices with software revision before 1.04, stages which are set to "FOFF" were not retested.

| | | |
|---|---|---|
| PFC | START / STOP / HOLD PF-CONTROL | On/Off/Hold |

Stopping the automatic control. The following options are available:
On:     Control in automatic mode
Off:    Control stops and active steps were disconnected successive
Hold:   Control Stops and active step's remain switched on.

If "OFF" or "HOLD" is selected, will appear in the display "PFC"
alternating with "OFF" or "HOLD". To start the control, select
"ON".

| CP1 | COS φ 1 | 0.70 c ...0.70 i |
|-----|---------|------------------|

This is the setting for target COSφ 1. It will be valid during normal
operation.

| St | SWITCH INTERVAL | 1...6500 s |
|----|-----------------|------------|

The switch interval is the time delay between switching steps in
regulation.

The switch interval has two different functions:

1. Protecting the contactors by reducing the number of
   switching cycles.

2. Building of the average of the reactive power in the time of
   the switch interval.

| Out | TYPE OF OUTPUT |
|-----|----------------|

With the exception of step type "flty" the follwing step types can be
selected:

- Auto = Step is used for normal regulation algorithm.

- Alarm = If the set temperature limit 1 is exceeded this step is
  switched as fan output.

- Fon = Step is permanently switched on (Step is still
  monitored and shut down in critical situations).

- Foff = Step is permanently switched off. Not used steps
  should be adjusted to this type to avoid unnecessary alarm.

- Flty = Step was switched three time without success and is
  not longer used for automatic control.

As "flty" stored steps can be set to desired step type in this menu.

### 6.2   200 Measurement settings

Contains settings to adapt the measurement of the PFR-X to the surrounding network
conditions.

**200 Measurement settings**

| MENU | FUNCTION | RANGE |
|---|---|---|
| 201 | NOMINAL VOLTAGE = PHASE - PHASE | 100...241500 V |
| | Function of the setting of nominal voltage is to make a definition about the nominal voltage of the system. The threshold levels for under- and overvoltage are based on this as well as the ratings of the capacitor sizes in step database, which are used for control and monitoring. The capacitor sizes, which are stored in step database, are also rated to the nominal voltage. | |
| 202 | CT-FACTOR | 1...9600 |
| | The CT FACTOR is the ratio of current transformer. (e. g. 1000/5 = ratio 200). At devices with software version 1.04 is the adjustment range from 1-4000. | |
| 203 | VT-FACTOR | 1...350 |
| | VT FACTOR is the ratio of the voltage transformer. If the regulator is connected directly to the measurement voltage without VT the value 1 has to be used. | |
| 204 | V-TOLERANCE | 0...100 % |
| | The setting of this value is in percent related to the nominal voltage. By means of the set value, the upper and lower limits of the permissible voltage range are calculated. e.g. 10% at 400V nominal voltage is a permissible range from 360V to 440V. | |
| 205 | CONNNECTION MEASUREMENT | Yes/No |
| | "YES" voltage measurement L-L<br>"NO" voltage measurement L-N<br><br>CONNECTION MEASUREMENT the setting if measuring of voltage is connected between two phases or between phase and neutral phase. It is normally detected automatically at every start of BLR-CM. This is done by comparing the setting NOMINAL VOLTAGE and the real measured voltage. This cannot be changed by hand. If the measured voltage is outside this tolerance, the measurement can be adjusted by hand. | |
| 206 | PHASE COMPENSATION | 0...345 |

The phase compensation enables the user to connect the current- and voltage measurement channels in any way. This compensation angle complies with the phase angle between connected active current and voltage. **This setting has to be made correct, because otherwise correct regulation is not possible! If the current transformer is connected inverted, additionally a phase compensation of 180° has to be respected.**

Is auto-initialization failed due to adverse network conditions, by hand a correction angle can be set or the incorrectly recognized can be corrected. Table 11.1 gives an overview of the connection options with corresponding phase angles.

| 207 | START AUTO-INITIALIZING | Yes/No |
|-----|--------------------------|--------|

"YES" starts auto-initializing

Automatic initialization is switching all exits. During this test it can get information, which exits are working and it can correct the connection of the measuring channels for voltage and current by internal settings.
Automatic initialization can be started only when the voltage and current are ok.

**AUTOMATIC INITIALIZATION is only able to work, when capacitors are used for compensation. If PFR-X has to switch reactors for compensation of capacitive load, this feature will cause failures. AI is working at best, when there are stable load conditions!**

Steps with step type "FON" or "AL" will be not considered in case of new auto-initialization.

At devices with software revision before 1.04, stages which are set to "FOFF" were not retested.

| 208 | AUTO-INITIALIZING BY REGULATOR RESTART | Yes/No |
|-----|-----------------------------------------|--------|

YES = after starting the PFR-X, a countdown is running. During this countdown it is possible to start auto-initializing by pushing ▶(↵ ).

"NO" the countdown is not shown. To start AI, you have to choose Quickstart SETUP.

| 209 | SYNCHRONISATION FREQUENCY | Auto/Fix50/Fix60 |
|-----|----------------------------|------------------|

For a high precision of the measurement, the sampling rate has to be synchronized to the frequency of the grid. Caused by commutation notches of mainsvoltage it is possible that the automatic synchronizing will not work reliable. This creates failures in measurement. To avoid these problems, the following settings can be done:

**Automatic synchronizing:**
For best measurement results, when mains voltage is without commutation notches.

**FIX-50HZ:** For a safe operation at 50Hz grid with bad mains quality.
**FIX-60HZ:** For a safe operation at 60Hz grid with bad mains quality.

| 210 | TEMPERATURE OFFSET (from software revision 1.04) | -10-10°C |
|---|---|---|

The temperature offset allows correction of temperature reading in a range -10°C to +10°C.

## 6.3  300 Setup Control System

The items in the menu "control system" allow an optimization of the control or an adaptation to specific site requirements.

### 300 Setup Control System

| MENU | FUNCTION | RANGE |
|---|---|---|
| 301 | CONTROL SENSITIVITY | 55...100 % |

Sensitivity is the switching threshold for switching-on or switching-off the capacitors in percent (%). The range of the sensitivity can be between 55% and 100% (factory setting is 60%. Due to this, the in following explanation 60% is used.).

Sensitivity is used for two checks:

1.  The controller is using sensitivity to check, if a switching operation is necessary or if it's possible.
    If the demand for compensation is bigger as 60% of the smallest for regulation available step, BLR-CM is selecting from step database, if there are suitable steps to switch.

2.  To avoid hunting, the controller is only using steps, which will not overshoot more than 40% (100%-60%) of its size.

| 302 | COS φ 1 | 0.70 c ...0.70 i |
|---|---|---|

This is the setting for target cosφ 1. It will be valid during normal operation.

| 303 | COS φ 2 | 0.70 c ...0.70 i |
|---|---|---|

Power Factor Regulator PFR-X

This is the setting for target cosφ 2. It will be valid when a switch over is caused by the digital input or another programmable action.

| 304 | COS φ 2 FOR P EXPORT | Yes/No |
|---|---|---|

"YES" the controller operates in P-export with the COS φ 2 as control target.
"NO" the controller operates in P-export with the COS φ 1.

| 305 | SWITCH INTERVAL | 1...6500 s |
|---|---|---|

The switch interval is the time delay between switching steps in regulation.

The switch interval has two different functions:

1. Protecting the contactors by reducing the number of switching cycles.

2. Building of the average of the reactive power in the time of the switch interval.

| 306 | SWITCH INTERVAL STEP EXCHANGE | 1...6500 s |
|---|---|---|

For step exchange a separate switch interval is used. This is the delay-time between switching-off an active step and switching-in the next step to get a better power-factor.

| 307 | ACTIVATE STEP EXCHANGE | Yes/No |
|---|---|---|

"YES" =  Step exchange is active.
"NO" = Step exchange is disabled.
Step exchange is supporting automatic control and combined filter control algorithm to reach an optimum result. If the controller detects that target-pf is not reached it starts searching for a step which gives better results. If step exchange is active, the controller can replace a switched-in step against a step which matches better, to reach the target.
This function helps to reach target COS φ more exactly, when capacitors have different sizes. If all capacitor banks have the same size, this function makes no sense.

| 308 | STEP RECOGNITION "OFF" | Yes/No |
|---|---|---|

"YES": Step sizes have to be programmed by hand. The step sizes have to be programmed by hand if:

1. When fast-oscillating load influences automatic stepsize recognition.

2. When recognition of defective steps is not wished

3. When capacitor contactors are switching with a delay of more than 200msec.

"NO" Stepsizes are detected and corrected automatically during normal operation. "Step recognition ON" is the factory setting. It allows monitoring of capacitor sizes and gives alarms when they are faulty. Stepsizes which are programmed manually will be overwritten by step recognition.

| 309 | BLOCKING OF DEFECTIVE CAPACITORS | Yes/No |
|---|---|---|

"YES" If a step is switched in three times without measurable network reaction, the controller is blocking the step and doesn't use it for the control.
Is a Step recognized to be defective, blinks in the display the corresponding output and in the step database and menu "403" it's displayed as step type "flty".
"NO" Steps are connected even if no network reaction is measurable. This results unnecessary switching cycles.
Steps that are stored as defective will be tested every 24 hours or after the controller is restarted.

| 310 | START / STOP / HOLD PF-CONTROL | On/Off/Hold |
|---|---|---|

Stopping the automatic control. The following options are available:
On:     Control in automatic mode
Off:     Control stops and active steps were disconnected successive
Hold:  Control Stops and active step's remain switched on.

If "OFF" or "HOLD" is selected, will appear in the display "PFC" alternating with "OFF" or "HOLD". To start the control, select "ON".

| 311 | CONTROL ALGORITHM | 1/2/3/4 |
|---|---|---|

1. **Automatic:** The controller is working with the principle of „Best Fit". Before a switching operation, all capacitor-sizes in step database are compared with control deviation. The available step which gives the best results will be switched.

2. **LIFO:** "Last In, First Out" The controller starts with regulation with step 1 and is switching further exits step-by-step. Switching-off is done vice versa.

3. **Combined Filter:** Special algorithm for combined filter banks with two different detuned ratings. The controller is working like in automatic mode with the principle "Best Fit". From odd numbered steps, there is at least or more of the capacitance connected as from even numbered steps. Threshold level of each step is checked separately. If steps different sizes, this can cause inaccuracy. Step recognition is working in this mode. If steps are detected as defective, they are skipped in this mode. If this is not accepted, the step recognition has to be deactivated and capacitor sizes have to be programmed manually.

4. **Progressive:** The controller switches if required, several steps in sequence with a shorter switching time. From software 1.04, the controller uses independently of the set switching time always 1 sec. as switching time. Furthermore, the automatic step size detection is disabled and the step sizes need to enter by hand. The input of the step sizes should be as accurate as possible, because the regulator would otherwise tend to oscillate. Leaving the "Progressive" algorithm and use a different algorithm, the set switching time is used the step size detection is re-enabled.

| 312 | OFFSET REACTIVE POWER | Ct*Pt*7000 |
|---|---|---|

OFFSET of reactive power in kvar. This feature allows compensating a permanent reactive load, which cannot be measured (e.g. a transformer).
**The offset of reactive power affects the readings of the following measuring values:**
**current, reactive power, control deviation, apparent power, power factor PF and cosφ.**

| 313 | ASYMMETRY FACTOR | -127...127 |
|---|---|---|

ASYMMETRY FACTOR of switch interval. The factor is the ratio between switch interval for switching on and switching off. Switch interval for step exchange is not affected by this setting.
X= 1 = equal

X = +2 to +127: delay switching off = switch interval multiplied by X

X = -2 to -127: delay switching on = switch interval multiplied by X

| 314 | Q CAPACITIVE STEPS TURN OFF | Yes/No |
|---|---|---|

"YES" As soon as a capacitive condition is recognized, the controller switches off without keeping the switching time, the necessary step power in order to prevent leading network conditions.
"NO" The controller works only with the set target COS φ.

## 6.4  400 Setup Step Database

In the step database, all settings and data are combined which are required to adjust and adapt the steps.

## 400 Setup Step Database

| MENU | FUNCTION | RANGE |
|------|----------|-------|
| 401 | DISCHARGE TIME | 5...1200 s |

The discharge time is defined once and is valid for all steps. The discharging time is a blocking time, becoming active after switching off a step. As long as this time is running this step is not available for the regulation. Discharging time should be adapted to the capacitor discharging unit.

| 402 | STEP NOMINAL VALUE | Ct*Pt*7000 |
|------|----------|-------|

If STEP RECOGNITION is not active, it is required to do this setting, to get proper function of the relay. The size of the capacitors can be programmed manually in kvar. Before this programming, CT FACTOR and NOMINAL VOLTAGE must be programmed correctly. A change of CT FACTOR or NOMINAL VOLTAGE is automatically changing the value of the capacitor size.
The programming can be done for each step individually in kvar. So there is no special sequence necessary. A step can be programmed as a capacitor (c) or as an inductor (i).

| 403 | STEP TYPE | Auto/Al/FOn/FOff |
|------|----------|-------|

With the exception of step type "flty" the follwing step types can be

Power Factor Regulator PFR-X

selected:

- Auto = Step is used for normal regulation algorithm.

- Alarm = If the set temperature limit 1 is exceeded this step is switched as fan output.

- Fon = Step is permanently switched on (Step is still monitored and shut down in critical situations).

- Foff = Step is permanently switched off. Not used steps should be adjusted to this type to avoid unnecessary alarm.

- Flty = Step was switched three time without success and is not longer used for automatic control.

As "flty" stored steps can be set to desired step type in this menu.If defective steps should not be locked, you must disable this function under the menu item "309".
Steps which are identified as defective will be tested again by the controller every 24 hours or after a restart.

---

**404**      **SWITCH CYCLES**                                        0...262000

The PFR-X is counting and showing the switching cycles of each step in the "Info" menu.  After a contactor has been exchanged, the switching cycles can be set to "0" in this menu.

### 6.5   500 Setup Alarm

The alarm menu of PFR-X. Here, all the alarms and monitoring functions can be activated and the limits configured.

## 500 Setup Alarm

| MENU | FUNCTION | RANGE |
|------|----------|-------|
| 501 | Reset Alarm manually | Yes/No |
| | "YES" Alarms (display and alarm relays) must be reset manually. **To reset upcoming alarms, hold the ◄ (esc) button pressed for 5 seconds.** "NO" As soon as the alarm condition is no longer valid, the alarms drop out. | |
| 502 | THD U Alarm | Yes/No |
| | "YES" The set THD threshold under menu "503" is monitored. Exceeding the set threshold will open the alarm contact and the display will show the message "ᵁᵀᴴᴰᵁ      ALARM". "NO" THD is not monitored. | |
| 503 | THD U Threshold | 1...200 % |
| | Input of the threshold for THD monitoring. | |
| 504 | THD U > Threshold = disconnect steps | Yes/No |
| | "YES" Exceeding the set threshold for THD will switch off all active steps successive. **Warning: Steps are only switched off when it is set at point 502 to "YES".** "NO" Exceeding the set threshold follows no action. | |
| 505 | Interval time before triggers THD U and Temperature threshold 2 | 1...255 s |
| | Interval time after exceeding the threshold for THD U or temperature threshold 2. | |
| 506 | Freeze control if I == 0 | Yes/No |
| | "YES" The measuring current drops below 15mA freezes the control. All active steps remains switched on. NO" Measuring current falls below 15mA, the controller shuts down all active steps successive. | |
| 507 | Service Alarm | Yes/No |
| | "YES" the alarm contact opens when the max set switching cycles for one or more steps have been exceeded or if the set threshold for operation hours are reached. "NO" no alarm when exceeding the max. switching cycles or operation hours. | |

| 508 | Max. switching cycles per step | 1...262000 |
|-----|-------------------------------|------------|

Threshold switching cycles for service alarm.
Display indication ⌀⌀Pᴸ    **ALARM**

| 509 | Max. operation hours | 1...65535 h |
|-----|---------------------|-------------|

Threshold switching cycles for service alarm.
Display indication ⌀⌀Pᴴ    **ALARM**

| 510 | Use temp. input as digital input | Yes/No |
|-----|----------------------------------|--------|

"YES" Temperature sensor is activated via a switch and causes a
switchover to COS φ 2 (HT / NT)
**Note: This menu item is locked against menu item "512". If the
temperature alarm is set to "Yes", this point will automatically
jump to "NO" and can not be altered.**
"NO" the temperature input works with plug-in temperature sensors
and monitors the in menu 513 and 514 adjustable temperature
thresholds. Parallel to the temperature sensor, a thermostat can be
connected. In this case, the controller displays "HIGH" for closed
state and "LOW" for open state.

| 511 | DI active at HIGH signal | Yes/No |
|-----|--------------------------|--------|

"YES" digital input is activated with closed terminals T1 & T2.
"NO" digital input is activated with open terminals T1 & T2.

| 512 | Temperature alarm | Yes/No |
|-----|-------------------|--------|

"YES" the controller monitors the temperature threshold 1 and 2 and
responses accordingly.
"NO" alarm disabled.

| 513 | Temperature threshold 1 | 3-74 °C |
|-----|-------------------------|---------|

By exceeding the temperature threshold 1 switches the controller as
"AL" declared step (fan on).

| 514 | Temperature threshold 2 | 4-75 °C |
|-----|-------------------------|---------|

When the temperature exceeds temperature threshold 2, the
controller switches all active steps ("AUTO" & "FON") from
compliance with the under menu item 505 adjusted time in
succession off. In addition, in the display appears "ᵗᵒᵒ    **ALARM**"
and the alarm contact is opened.

| 515 | Control alarm (target cos φ can not be archived) | Yes/No |
|-----|--------------------------------------------------|--------|

"YES" alarm is triggered after 75 time switching time with ▲Q>
smallest step (Over / under compensation). Controller opens the
alarm contact and indicates PFC    **ALARM** in the Display.
"NO" no monitoring for over / under compensation.

| 516 | Defective step alarm | Yes/No |
|-----|---------------------|--------|

Power Factor Regulator PFR-X

---

"YES" After 3 unsuccessful switching actions alarm is triggered.
The controller opens the alarm contact and indicates ⬚⬚⬚⬚ ALARM
/⬚⬚⬚⬚ ALARM in the display.
Steps recognized as defective flashing in the step indication.
"NO" alarm disabled.

---

| 517 | Step power loss alarm | Yes/No |
|-----|----------------------|--------|

"YES" If the current step size is less than 70% of the initial size, the
controller opens the alarm contact and indicates the error with output
number ⬚⬚⬚⬚ ALARM /⬚ ⬚ ALARM. in the display.
"NO" Power loss of the capacitors is not monitored.

## 6.6   600 Resetmenu

Allows you to reset all settings made by the controller and stored data. Additionally, it contains the software version of the device (displayed from 1.04).

### 600 Resetmenu

| MENU | FUNCTION | RANGE |
|---|---|---|
| 601 | Reset Settings | Yes/No |
| | Sets all settings made back to factory settings. | |
| 602 | Reset Step database | Yes/No |
| | Sets all step data back to factory settings. | |
| 603 | Reset operation hours | Yes/No |
| | Sets the counter for operation hours to "0" | |
| 604 | Reset average PF | Yes/No |
| | Reset the average PF. | |
| 605 | Reset max. Temperature | Yes/No |
| | Reset the highest measured Temperature. | |
| 606 | Reset alarms | Yes/No |
| | Reset all upcoming alarm. | |
| 607 | Display software version | |
| | contains the software version of the device (display from 1.04) | |
| 608 | Adjustment of the Setup password (from software 1.08) | |

Power Factor Regulator PFR-X

# 7 TECHNIAL DATA

| | |
|---|---|
| Measuring- and supply voltage: | 90 – 550V AC, single phase, 45-65HZ, 5VA, max. fuse 6A VT ratio from 1.-350.0 |
| Current measurement | 15mA – 6A, single phase, burden 20mOhm, CT-ratio from 1-9600 Before software version 1.04 the adjustable range is 1-4000 |
| Control exits | Relays: up to 14, n/o, with common point, max. fuse 6A breaking capacity: 250V AC / 5A<br><br>Static outputs: 6 or 12 static outputs possible. open-collector, breaking capacity: 8 – 48V DC / 100mA |
| Temperature measuring: | By NTC |
| Alarm contact: | Relay, volt free, life contact max. fuse 2A, breaking capacity: 250V AC / 5A |
| Fan control | By using one switching exit defined as "Alarm".<br><br>Devices with transistor outputs us the contacts L / LF for fan control. |
| Interface: | TTL, rear |
| Ambient temperature: | Operation: -20°C – 70°C, storage: -40°C – 85°C |
| Humidity: | 0% - 95%, without moisture condensation |
| Voltage class: | II, dirt class 3 (DIN VDE 0110, part 1 / IEC60664-1) |
| Standards: | DIN VDE 0110 part 1 (IEC 60664-1:1992) VDE 0411 part 1 (DIN EN 61010-1 / IEC 61010-1:2001) VDE 0843 part 20 (DIN EN 61326 / IEC 61326: 1997 + A1:1998 +A2: 2000) |
| Conformity and listing: | CE, UL, cUL, GOST-R |
| Connection: | Pluggable terminal block, screw type max. 4qmm |
| Case: | Front: instrument case PC/ABS (UL94-VO), Rear: metal |
| Protection class: | Front: IP50, (IP54 by using a gasket), Rear: IP20 |
| Weight: | ca. 0,6kg |
| Dimension: | 144x144x58mm h x w x d, cut out 138 (+0,5) x 138 (+0,5)mm |

# 8 TROUBLESHOOTING

| Fault | possible cause | Remedy |
|---|---|---|
| No indication in display | • aux. voltage missing | • Check the correct connection of power supply and correct if necessary. |
| Display "$\overset{0}{\underset{}{U}}\overset{0}{\underset{}{}}$  ALARM" | • Voltage outside tolerance | • Check measurement voltage<br>• Check nominal voltage and adjusted tolerance and correct if necessary. |
| Display "$\overset{0}{\underset{}{I}}$  $\overset{0}{\underset{}{I}}$  ALARM" | • Measured current is to small | • check connection of CT, probably there is a break in the line<br>• remove short circuit link of the CT |
| wrong display of current or voltage | • wrong transformer ratio | • Check settings of transformer ratios in the "SETUP" (100) menu and correct if necessary. |
| The power factor is displayed incorrectly. | • The connection detection was not performed.<br><br>• The phase angle was adjusted manually false.<br><br>• Offset reactive power is adjusted. | • Start "Ai" in "SETUP" menu.<br><br>• Check point 206 in the "EXPERTMENU" and correct the phase angle if necessary.<br><br>• With the compensation system, a transformer is compensated. The displayed Pf is in front of the transformer. The displayed Pf is in front of the transformer. |
| The power factor does not change after the switching of a step. | • CT incorrectly positioned. | • Check installation position of the current transformer according to wiring diagram (current of the load and the capacitors must be measured!). |
| Steps are switched off again. | • Capacitor defect | • Check capacitor, possible fuse, capacitor, or contactor defective. |

Power Factor Regulator PFR-X

| | | |
|---|---|---|
| Display<br>Ɓ   ƁƁ₀      ALARM" | • Current is higher than allowed. | • Check the current transformer secondary current and possibly replace it with matching current transformer. |
| Display<br>ƁᵖƁᵖƁₗ      ALARM" | • permanent over compensation | • Check settings (possibly step with step type "FON")<br>• Check contactors, contactor contact may bonded. |
| | • permanent under compensation | • Check capacitors and fuses.<br>• Dimensioning of the system examined. |
| Opposite regulation behaviour | • Current or voltage connections swapped. | • correct connection or adapt phase compensation. |
| Individual steps are not switched on or off. | • wrong setting | • Verify whether the steps were defined as Step type "FON" or "FOFF" (permanently on or off). |
| Steps are detected as defective.<br>Steps are switched off again. | • Step defective | • Check capacitor, possibly fuse, capacitor or contactor defective. |
| Steps are not switched. | • The steps are to large. | • The required reactive power is below the switching threshold. Switching threshold is 60% of the smallest available step. |

# 9 APPLICATIONS

## 9.1  Fan Control

The fan control is to be regulated through the PFR-X.

**Solution:**

If the PFR-X is equipped with a temperature sensor (option –L), can be via one of the switching exits, a fan to be controlled.

**Procedure:**

- Enable temperature alarm

In the expert menu item 512 set to "YES" (temperature alarm on).

- Set temperature thresholds

Set the following items 513 (temperature threshold 1) and 514 (temperature threshold 2the temperature thresholds. By exceeding the temperature threshold 1 is witched the fan output. When you exceed the temperature threshold 2, all steps are switched off to prevent overheating.

- Select fan output

Select item 403 in expert menu and adjust for the step which shall work as the fan output step type "AL".

**Features:**

In order to prevent hunting of the fan relay, the fan is turned off only at a temperature below the set limit by at least 3°C. If the PFR-X is equipped with a temperature sensor, the current cabinet temperature is displayed and the highest measured temperature is stored in thi. Parallel to the temperature sensor can be connected a thermostat. By close of the thermostat , the temperature limit 2 is activated.

## 9.2   Switching on COS φ 2 via digital input

By using a switch, the PFR-X will be switched to COS φ 2.

**Solution:**

Using the temperature input as digital input.

**Procedure:**

- Enable digital input

Set item 510 in expert menu to "YES".

- Using digital input as n/o or n/c

"YES" digital input is activated with closed terminals T1 & T2.

"NO" digital input is activated with open terminals T1 & T2.

**Features:**

The temperature input is used as a digital input, shows the controller at active input "high" and with not active input "low" instead of the temperature. The controller uses with active digital input the COS φ 2 and will show "NT" in the display.

### 9.3   Problems with the Step recognition.

The controller is used in a system with rapid changes in load conditions and has problems
with the automatic step recognition

**Solution:**
To solve this problem, the step sizes must be entered by hand, and the step recognition must
be turned off.

**Procedure:**
- Stop control.

Set item PFC to "OFF" in menu 100 (quick start menu).

- switch off Step detection.

Set item 308 to "Yes" (step recognition off) in the expert menu.

- enter step sizes.

Setting the nominal value of the capacitors connected at point 402 in the expert menu.

- Check step type

For problems with the step detection, it may happen that the connected steps will be stored
by the controller incorrectly as "FIX-OFF". Therefore, the step type of each step should be
controlled under the menu item "403". All steps of the automatic control used, must be
use the step type "AUTO".

**Features:**

By switching off the automatic step recognition, a step failure or power loss is not reported.
To monitor the system anyway, it is appropriate to enable the control alarm to be alerted in
case of failure timely. (See alarm menu)

## 9.4  Transformer compensation

The compensation of a transformer can be solved with the PFR-X in two ways:

### 9.4.1  Setting a reactive power offset

Setting reactive power offset. This is added to the required compensation power within the system.

**Procedure:**

Determine the required capacitive reactive power to compensate the transformer. Enter the calculated value in the menu item "312". Control will start immediately with the additional required reactive power.

**Features:**

The reactive power offset set here is always added to the measured reactive power. Therefore, it's always the Pf appears before the transformer. This means that the system can capacitive, but the measurement of the utility the required Pf recoded.

### 9.4.2  Mixed measurement:

By the current measurement on medium voltage side, is the from the transformer caused reactive power measured and regulated by the connected compensation system.
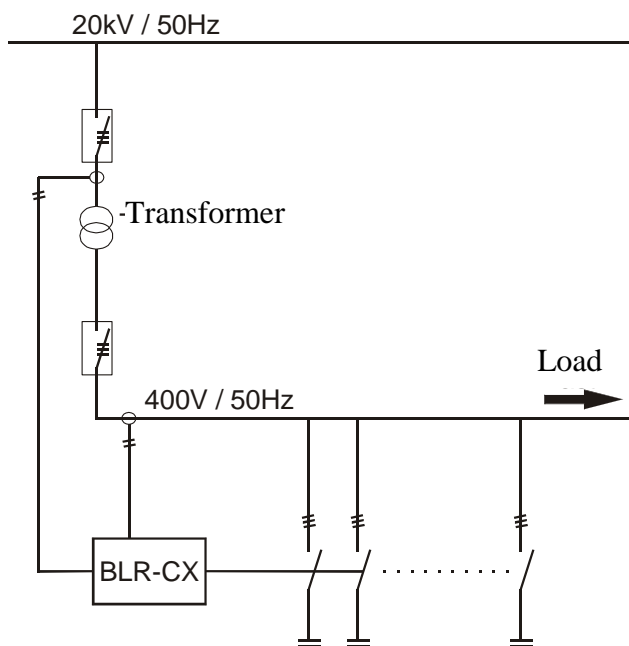
**Procedure:**

Connect the measurement of the controller as shown in the diagram adjacent. Then start the automatic initialization. The vector group ot the transformer is automatically considered.

**Connection:**

When auto-initialization will be aborted, under item 11.2, the most common transformer vector groups are listed.

## 9.5   Reset defective steps respectively add aditional steps

If the controller has a step recognized as defective (3 switching operations without result), it will be excluded for 24 hours from the regulation. After this period, the step is tested again from the controller. If the controller can detect the step it will again be included in the control. If not the step is blocked again for 24hours after 3 unsuccessful switching cycles. Defect steps are in the "INFO" menu with the step type "flty" marked and flashing in the step indication. When a compensation system need additional capacitors to be added, proceed as described below:

**Procedure:**

Select item "403" in expert menu and use the ▼ ▲ buttons to select the corresponding step. Confirm with ▶(↵ ) button and use the ▼ ▲ buttons to adjust step type "AUTO".

**Feature:**

If a step because of power loss greater than 30% is exchanged, it's appropriate for the step, to program the nominal step size by hand. Select the affected step in menu "402" and program the nominal step size.

If the alarm was triggered by a defective contactor should, upon the exchange took place, the accumulated switching operation under item "404" set to "0".

Power Factor Regulator PFR-X

# 10 CUSTOMER SETTINGS

| Menu | Factory setting | Customer setting | Menu | Factory setting | Customer setting |
|---|---|---|---|---|---|
| **100** | | | **400** | | |
| Un | 400 V | | 401 | 75 s | |
| Ct | 1 | | 402 | 5 var (1-max.) | |
| Pt | 1 | | 403 | AUTO (1-max.) | |
| Ai | NO | | 404 | 0 (1-max.) | |
| PFC | ON | | **500** | | |
| CP1 | 1 | | 501 | NO | |
| St | 10 s | | 502 | NO | |
| **200** | | | 503 | 20 % | |
| 201 | 400 V | | 504 | NO | |
| 202 | 1 | | 505 | 60 s | |
| 203 | 1 | | 506 | NO | |
| 204 | 10% | | 507 | NO | |
| 205 | NO | | 508 | 262 k | |
| 206 | 0 | | 509 | 65.5 k h | |
| 207 | NO | | 510 | NO | |
| 208 | YES | | 511 | NO | |
| 209 | AUTO | | 512 | NO | |
| **300** | | | 513 | 30 °C | |
| 301 | 60% | | 514 | 55 °C | |
| 302 | 1 | | 515 | 0 °C | |
| 303 | 0,95 i | | 516 | NO | |
| 304 | NO | | 517 | NO | |
| 305 | 10 s | | 518 | NO | |
| 306 | 2 s | | **600** | | |
| 307 | YES | | 601 | NO | |
| 308 | NO | | 602 | NO | |
| 309 | YES | | 603 | NO | |
| 310 | ON | | 604 | NO | |
| 311 | 1 | | 605 | NO | |
| 312 | 0 | | 606 | NO | |
| 313 | 1 | | 607 | 1.xx | |
| 314 | NO | | | | |

# 11 APPENDIX

## 11.1 Settings Phase-angle

| Voltage | L1-N | L2-N | L3-N | L1-N | L2-N | L3-N | L1-N | L2-N | L3-N |
|---|---|---|---|---|---|---|---|---|---|
| CT | L1 | L2 | L3 | L2 | L3 | L1 | L3 | L1 | L2 |
| Phase-angle | 0° | 0° | 0° | 240° | 240° | 240° | 120° | 120° | 120° |

| Voltage | L2-L3 | L3-L1 | L1-L2 | L2-L3 | L3-L1 | L1-L2 | L2-L3 | L3-L1 | L1-L2 |
|---|---|---|---|---|---|---|---|---|---|
| CT | L1 | L2 | L3 | L2 | L3 | L1 | L3 | L1 | L2 |
| Phase-angle | 90° | 90° | 90° | 330° | 330° | 330° | 210° | 210° | 210° |

## 11.2 Connections for mixed measurement

| Transformer vector group | CT | Voltage |
|---|---|---|
| Dy5 | L1 | L2-N |
| Dy5 | L2 | N-L3 |
| Dy5 | L3 | N-L1 |
| Yz5 | L1 | L2-N |
| Yz5 | L2 | N-L3 |
| Yz5 | L3 | N-L1 |
| Dx6 | L1 | L3-L2 |
| Dx6 | L2 | L2-L1 |
| Dx6 | L3 | L1-L3 |
| Yy6 | L1 | L3-L2 |
| Yy6 | L2 | L2-L1 |
| Yy6 | L3 | L1-L3 |
| Dy11 | L1 | N-L2 |
| Dy11 | L2 | L3-N |
| Dy11 | L3 | L1-N |
| Yz11 | L1 | N-L2 |
| Yz11 | L2 | L3-N |
| Yz11 | L3 | L1-N |

Power Factor Regulator PFR-X

Notes