PFC LCD

User manual

Power Factor Controller

MODBUS-RTU

The intelligent Power Factor Controller

Precaution for Safe use of Equipment

Please read the instructions carefully before operating the equipment. The following symbols will appear throughout this user manual to warn of potential dangers or hazardous situation that will arises while operating the equipment. Alfa will not be liable for any improper use of the equipment stipulated in this user manual.

The **DANGER**

symbol indicates improper use of the equipment by qualified personnel will result in serious injuries or death.

The **WARNING**

symbol indicates that potentially hazardous situation might arise if instructions are not followed that will result in serious injuries or death.

The **CAUTION**

symbol indicates that injuries to the user or damage to the equipment will happen if the stated instructions are not followed.

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1. Product Overview

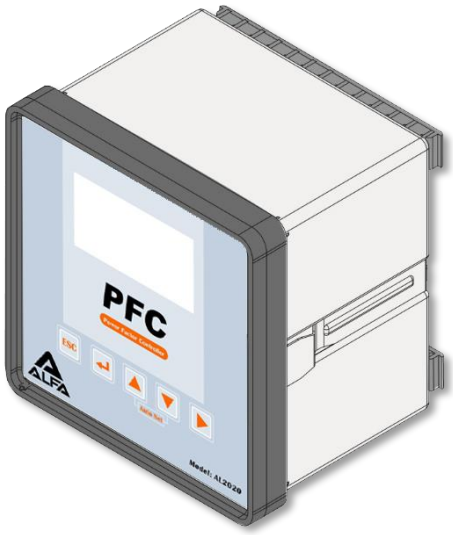
1.1. Introduction

Alfa's power factor controller PFCLCD also provides flexibility in configuring (or disabling) different levels of alarms. The alarms then can be linked to a dedicated signal contact to alert the users of potential issues such as under compensation (thus avoiding penalty charges from the utilities).

As the name suggest, Alfa's power factor controller PFCLCD provides the user with a 64 x 128 dot matrix LCD for displaying its various measurement parameters such as: power factor, voltage, current, THD, active, reactive, apparent power and temperature.

PFCLCD includes the automatic C/K and rated step size detection feature for ease of commissioning for typical inductive loads. Taking advantage of the dot matrix LCD, the PFCLCD also provides a guided step-by-step menu that enables fast setup.

The controller extends its connectivity by adopting the Modbus-RTU protocol. Through the use of RS485 standard protocol, the user will be able to network the controller with other IEDs that links to a center monitoring station.



1.2. Feature List

✓ 64 x 128 dot matrix LCD display with back lighting
✓ 12 output with capability to assign contact for signal alarm output and fan output
✓ Three phase compensation mode based on:
Optimum Demand
Micro-processor system for three-phase networks.
✓ 4 different switch factor:
value
circular
availability
In-Out
✓ Automatic detection of C/K and rated step value
✓ Automatic Current Transformer polarity correction
✓ Step-by-step guided commissioning
✓ No Voltage release
✓ Measurement Parameters:
Active, Reactive, Apparent Power, Missed reactive
Temperature
Phase Voltage and Phase Current
Power Factor
%THDV and %THDI
✓ Various configurable alarm settings (can be disable)
Over %THDI
Over %THDV
Over / Under Compensation
Over / Under Voltage
Over Temperature
✓ Alarm linked signal contact
✓ Programmable fan control
✓ Modbus-RTU communication support
✓ Storage of maximum values of grid parameters as well as switch-in times of particular capacitor contactors

Table 1 Feature list

2. SETTING UP THE PFC

2.1. Installation

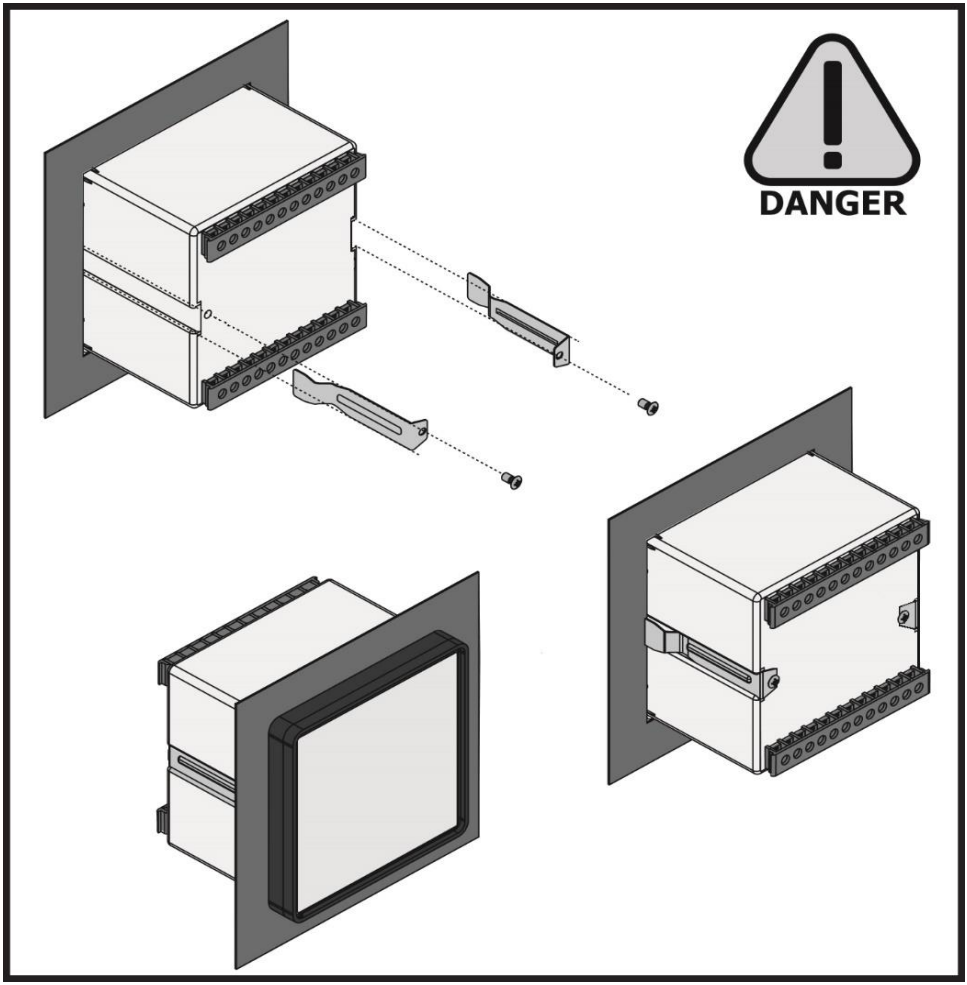


Figure 1 Installation

Please mount the regulator with sufficient spacing (at least 50mm clearance) between other electrical instruments. This is to prevent difficulty in accessing and wiring the regulator.

2.2. Wiring Diagram

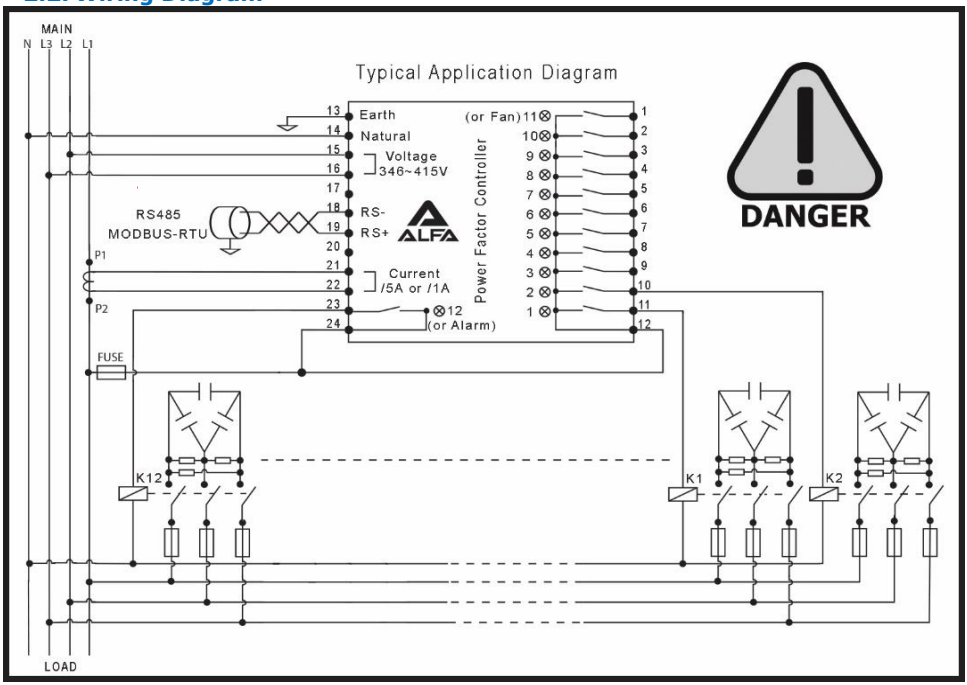


Figure 2 Wiring diagram

Note:
Product wiring will change from time to time. Detail wiring please refer to the wire connection in product label and manual.

Important comment:
When installing the current converter, care should be taken to ensure that the load current and capacitor-current flows through it. The outputs of the compensation network must be installed behind the current converter (in the direction of current flow).

2.3. Quick Commissioning

The PFC is pre-programmed with the most common parameters as its factory default setting. Users are normally not required to change any setting upon commissioning. For quick commissioning when the PFC is switched on power, after the boot process (where the Alfa logo is displayed) the start screen is the first screen which will be displayed as shown in Figure 4.

Figure 3 PFC start screen

Press ▲ and ▼ simultaneously to start automatic setting.

Figure 1 CT primary value

Note:

If you set up CT factor the shown value will be nominal value of capacitor steps.

Figure 5 Request Password

Then enter password (The default password is 0000) and press ↵ , if the password was correct the PFC start automatic set up process.
First PFC switched off all capacitor steps and then initialize.

Figure 6 Initialize to start

After expiration of the auto-initialization, the controller starts the recognize automatically the step sizes of the capacitors. Settings of C/K value and the switching sequence is not required.

Figure 7 Turn on Capacitor1

The Unit switched on and switched off capacitor steps one by one and display Measured value

Figure 8 Turn off Capacitor1

This process is done for all capacitor steps and at the end of process unit display number of detected steps. (steps that have none zero value)

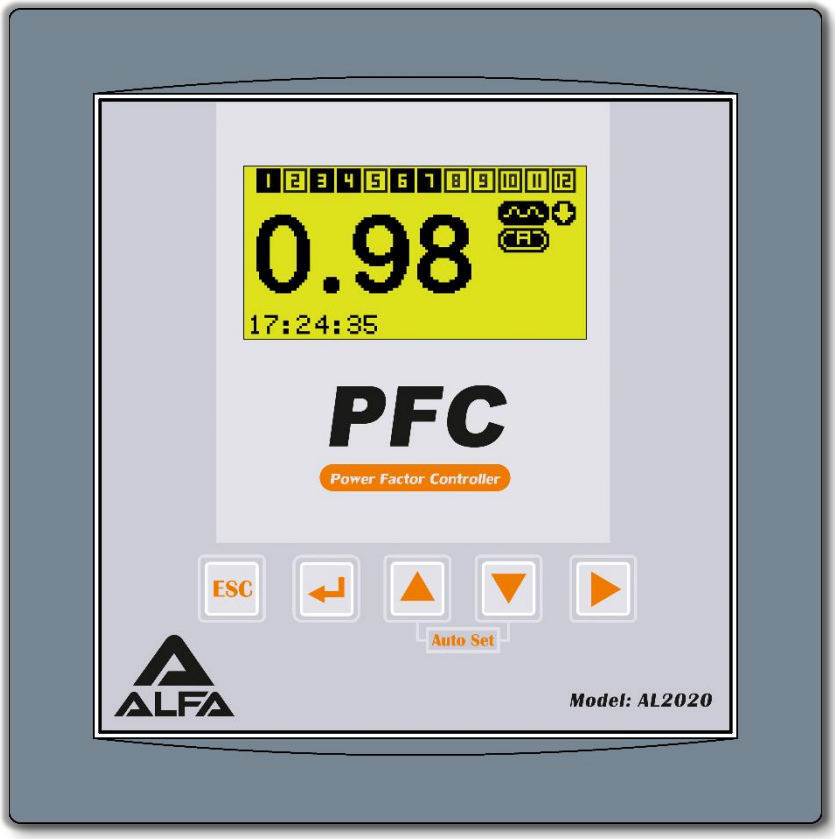
Figure 9 Number of detected capacitors

If the detected capacitors are zero or less than actual steps number, we should try to troubleshoot the system, in other way the PFC start its normal operation and compensate the network.

Note:

- It is not necessary to arrange capacitor steps in any sequence or from smallest one to biggest.
- Between capacitor steps empty steps are allowed.
- Automatic CT Polarity Correction

3. DISPLAY



3.1. PF Mode

Figure 10 Measurement Screen in PF mode

Figure 11 Measurement Screen in PF mode

Note:
LP means the current is zero.

3.2. ALL Parameters Mode

Figure 12 Measurement Screen in ALL mode

By pressing the ▲ or ▼ button, user can cycle between different parameters

Figure 13 Measurement Screen in ALL mode

Note:
User can change Display Mode in welcome -> Setting -> Display Mode to ALL or PF

3.3. Legends for the screen icons

1. 1 … 12 Inactive (open) outputs
2. 1 … 12 Active (closed) outputs
3. demand to switch ON step(s)
4. demand to switch OFF step(s)
5. H Over Harmonic Occurred (THDI or THDV)
6. C Over or Under compensate
7. U Over or Under Voltage
8. T Over temperature
9. Inductive PF
10. Capacitive PF
11. A Automatic mode (steps are switched automatically according settings)
12. M Manual mode (steps can be switched manually)
13. Fan Relay is ON (if enabled)
14. K Alarm Relay is ON (if enabled)
15. All steps disconnected for protection (if enabled)

3.4. General Measurement

Designation	Unit	Description	Accuracy
PF		Power Factor	± 0.02
I	A	RMS Current	± 1 %
U	V	RMS Voltage L-L	± 1 %
P	KW	Active Power	± 2 %
Q	Kvar	Reactive Power	± 2 %
S	KVA	Apparent Power	± 2 %
D	Kvar	Missing power to reach the target PF	± 2 %
T	°C	Unit ambient temperature	± 1 °C
THDU	%	Total harmonic distortion on voltage L-L	± 1 %
THDI	%	Total harmonic distortion on current	± 1 %
Clock		(optional)	

Table 2 Measurements Description

4. MENU OPERATION

If the user requires any changes in the setting, the setting up feature will provide the user setting all the mandatory parameters for the controller to function properly. In start screen press ESC button until Figure 13 displayed.
In the center of the screen the five icons (Measurements, Settings, Automatic Set, About, Restore Defaults) represent the five root-level menu.

Note:
You can go through icons by ▲ , ▼ or ▶ keys. Press ↵ to enter each icons sub menu.

4.1. Measurement

Figure 14 Welcome icons

If press ↵ when Measurement icon is highlighted PFC returns measurement screen.

Note:
Press ▲ or ▶ to move next icon and press ▼ to back previous icon.

4.2. Setting (Password Protected)

Figure 15 Setting icon selected

Press ↵ to enter setting menu Enter password (The default password is 0000).

Figure 16 Request password for setting

Note:
Press ▲ to increase and ▼ to decrease blinked digit and press ▶ to go to next digit and finally press ↵ to enter number.

4.2.1. Display

Figure 17 Display icons

First icon is for display settings Press ↵ to enter Display sub menu

4.2.1.1. Display Mode

Figure 18 ALL Mode selected

Press ↵ to change display mode to PF or ALL mode

Figure 19 PF Mode selected

In ALL mode, PFC in main screen display all of measurement parameters in detail but in PF mode only power factor with large font displayed.

4.2.1.2. Buzzer on/off

Figure 20 Buzzer is on

Press ↵ to change internal Buzzer to ON or OFF

Figure 21 Buzzer is off

4.2.1.3. Backlight Time

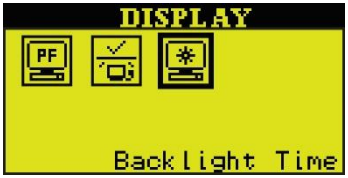


Figure 22 Backlight Time

Press ↵ to edit backlight on time

Figure 23 Backlight Time value

The backlight will go to off for the purpose of energy saving and component duration. if any key does not be touched for a period time the backlight goes off. The on time can be set from 1 to 120 Minute. As in Figure 23, the setting time of the backlight by default is 10 minute so backlight will automatically go to off if there is no touch on the keys in 10 minute.

Note1:

Press ▲ to increase and ▼ to decrease blinked digit and press ▶ to go next digit and finally press ↵ until save the number , Press ESC key to discard modification.

Note2:

To exit current menu and return to previous menu press ESC.

4.2.2. CT Factor

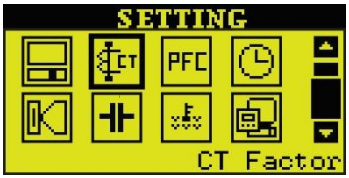


Figure 24 CT Factor icon

The second icon is for CT (current transformer) ratio settings press ↵ to enter CT Factor menu

4.2.2.1. CT Primary

Figure 25 CT Primary

Press ↵ to edit CT primary rating current, the unit is Amp.

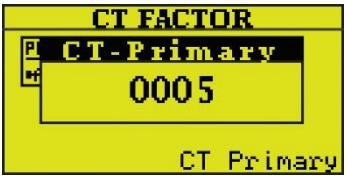


Figure 26 CT Primary value

CT primary value is an integer from 5A to 8000A.

4.2.2.2. CT Secondary

Figure 27 CT Secondary

Press ↵ to edit CT secondary value, the unit is Amp.

Figure 28 CT Secondary value

CT secondary value is 1A or 5A.

4.2.3. PFC Setting

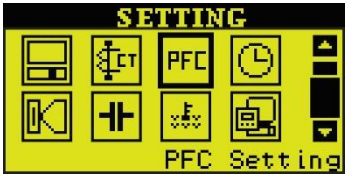


Figure 29 PFC Setting icon

The third icon is for PFC settings, press ↵ to enter PFC settings sub menu.

4.2.3.1. Discharge Time

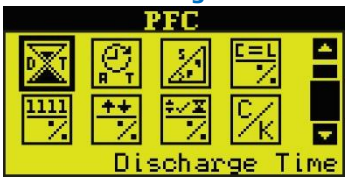


Figure 30 Discharge Time

Press ↵ to edit Discharge time, the unit is second

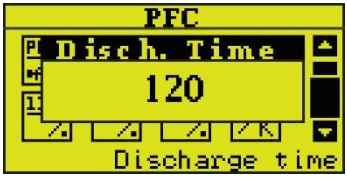


Figure 31 Discharge time value

This setting prevents the reconnection of the same capacitor before it is fully discharged. This parameter is usually set based on the discharge time of the largest capacitor size in used.

4.2.3.2. Action Time

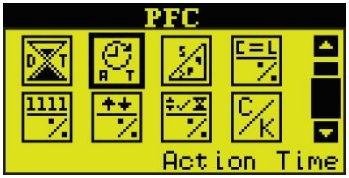


Figure 32 Action Time

Press ↵ to edit Action Time value, the unit is second.

Figure 33 Action Time value

The Action Time setting controls the reaction time for the controller to switch. The reaction time to switch is dependent on the demand, step size and the action time setting. A small demand, large step size and a high action time setting will result in a slower switching whereas a large demand, small step size and a small action time setting will result in a faster switching speed. The action time is counted dynamically as the demand changes providing an optimal action time.

Note:
In variable network to avoid more action, set this time to higher values.

4.2.3.3. Target PF

Figure 34 Target PF

Press ↵ to edit Target PF value

Figure 35 Target PF value

The target PF value can be set between 0.00 inductive and 0.00 capacitive. (+) numbers indicate an inductive PF and (-) numbers indicate a capacitive PF.
The controller will switch the capacitor banks on and off, attempting to achieve this set value.

Note:
There are four factor to adjust network reactive, in this PFC user can have weighted them to bold each strategy of correction, and can define them from 0% to 100% as their importance for correction.

- Value effect
- Circular effect
- IN-OUT effect
- Availability effect

4.2.3.4. % of Value Effect

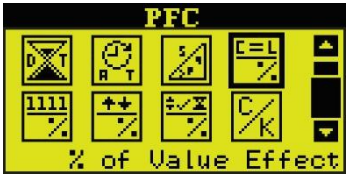


Figure 36 % of Value Effect

Press ↵ to edit value effect in percent

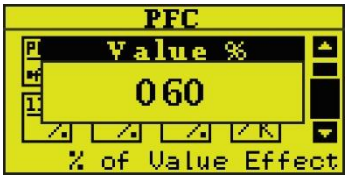


Figure 37 % of Value Effect percent value

If you adjust value factor effect to a high value, the PFC tries to select the best combination that closer to needed reactive. This maybe increase number of switched on and switched off capacitors.

4.2.3.5. % of Circular Effect

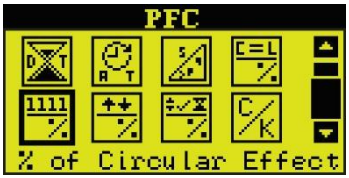


Figure 38 % of circular Effect

Press ↵ to edit circular effect in percent

Figure 39 % of circular Effect percent value

If you adjust circular factor to a high value, the PFC tries to select best combination that include with steps with fewer contacts count.
Higher circular value increases the lifetime of capacitors by balancing the stress among all the contactors.

4.2.3.6. % of IN-OUT Effect

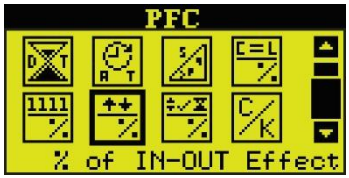


Figure 40 % of IN-OUT Effect

Press ↵ to edit IN-OUT effect in percent

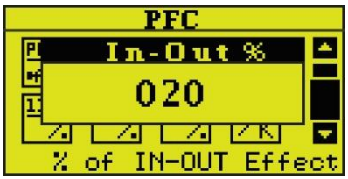


Figure 41 % of IN-OUT Effect percent value

If you adjust IN-OUT factor to a high value, the PFC tries to select combination that with minimum switch in or switch out capacitors to reach target PF.

4.2.3.7. % of Availability Effect

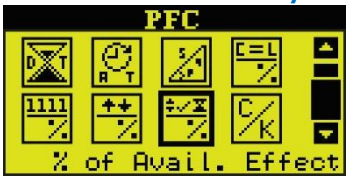


Figure 42 % of Availability Effect

Press ↵ to edit availability effect in percent

Figure 43 % of Availability Effect percent value

If you adjust availability factor to a high value, the PFC tries to select best combination that have minimum wait time for unused capacitors that are in discharge time.

4.2.3.8. C/K

Figure 44 C/K

Press ↵ to edit C/K value

Figure 45 C/K percent value

C/k:
starting current of the PFC Controller. It is usually set equal to 2/3 = 65 % of the current of the capacitor step (Istep).
It represents the threshold current value for the PFC to switch on or off a capacitor step. The C/k Hysteresis can be programmed from 1% to 100%.
Percentage value of Istep above and below which determine the sensitivity of the switching process as Figure 46.
The lower of percentage, the higher the sensitivity

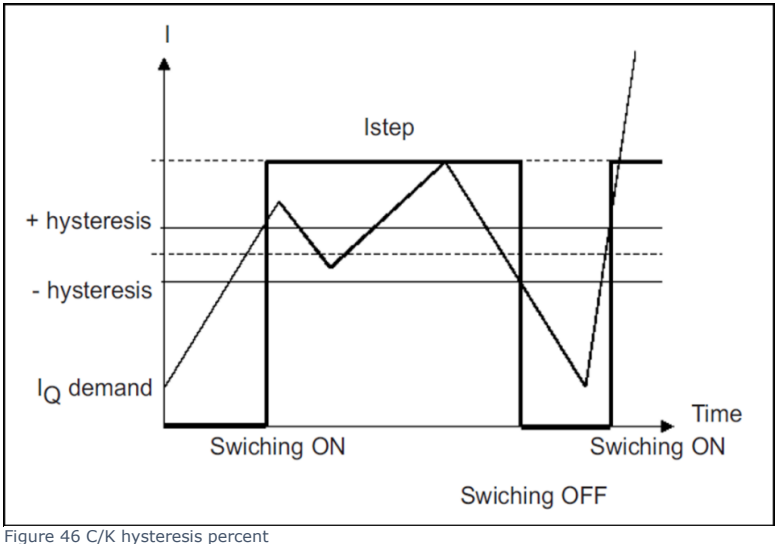


Figure 46 C/K hysteresis percent

4.2.3.9. PFC Operation

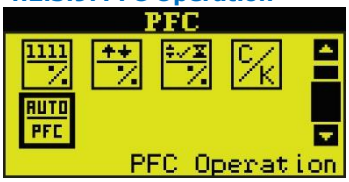


Figure 47 PFC Operation is AUTO

Press ↵ to change display mode to PF or ALL mode

Figure 48 PFC Operation is MANUAL

AUTO: (default)
PFC decides on the number of steps required to reach the target PF based on user setting (target PF, C/k, ...)

MAN:
This mode allows the user to control the power factor manually.

Note:
After a power outage, once the power returns the PFC starts in the Mode previously selected.

4.2.4. Clock*

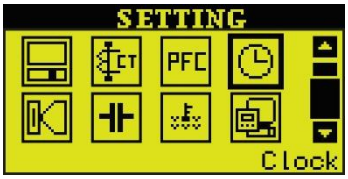


Figure 49 Clock

Press ↵ to enter Clock Setting menu

*If PFC Equipped with RTC

4.2.4.1. Date Type

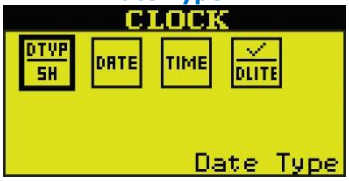


Figure 50 Date Type is SHAMSI

Press ↵ to change date type to SH(shamsi) or M(miladi).

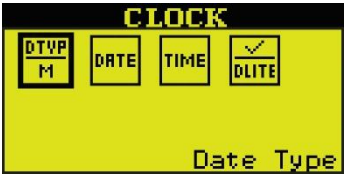


Figure 51 Date Type is MILADI

4.2.4.2. Date

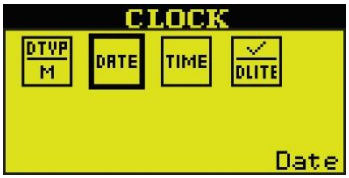


Figure 52 Date

Press ↵ to adjust date according date type

Figure 53 Date value

4.2.4.3. Time

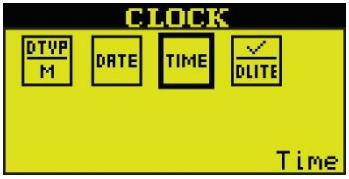


Figure 54 Time

Press ↵ to adjust unit clock

Figure 55 Time value

4.2.4.4. Daylight Saving

Figure 56 Daylight Saving is enable

Press ↵ to enable or disable daylight saving future.

Figure 57 Daylight Saving is disable

4.2.5. Alarm & Protection

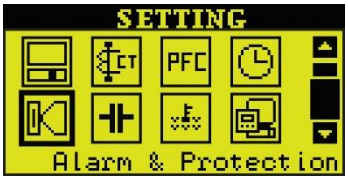


Figure 58 Alarm & Protection

Press ↵ to enter Alarm and Protection setting menu

4.2.5.1. Alarm Relay on/off

Figure 59 Alarm Relay is off

Press ↵ to enable or disable alarm relay

Figure 60 Alarm Relay is on

User can assign relay 12 as alarm output. If alarm relay was disable PFC can use this relay output as normal capacitor step.
User can use separate common on port number 24 for alarm contact, in normal use of relay 12 port 24 must be connect to port 12 (relays common).
When an enabled alarm condition is detected This contact activates (closed) and alarm symbol will be shown on display.

4.2.5.2. Items

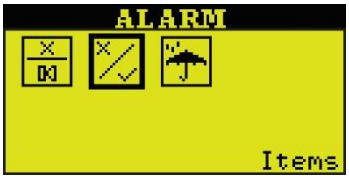


Figure 61 Items

Press ↵ to enter PFC alarm items setting menu

4.2.5.2.1. Over/Under Voltage

Figure 62 Over/Under Voltage is disable

Press ↵ to enable or disable over / under voltage item

Figure 63 Over/Under Voltages is enable

4.2.5.2.2. Over/Under Compensate

Figure 64 Over/Under Compensate is disable

Press ↵ to enable or disable over / under compensate item

Figure 65 Over/Under Compensate is enable

4.2.5.2.3. Over THDI

Figure 66 Over THDI is disable

Press ↵ to enable or disable over THDI item

Figure 67 Over THDI is enable

4.2.5.2.4. Over THDV

Figure 68 Over THDV disable

Press ↵ to enable or disable over THDV item

Figure 69 Over THDV enable

4.2.5.2.5. Over Temp

Figure 70 Over Temperature is disable

Press ↵ to enable or disable over temperature item

Figure 71 Over Temperature is enable

Item	Icon	Default Set Value	Item Enable/ Disable	Alarm Relay		Alarm Icon	Protection Action	Protection Icon
				☒	☑			
Over/ Under Voltage	U	420V/ 340V	☑ OV-U	-	closed	☒	All the capacitor steps switched off	
			☒ OV-U	-	-	-	-	-
Over/ Under compensate	C	Target PF	☑ OV-C	-	closed	☒	-	
			☒ OV-C	-	-	-	-	-
Over THDI	H	20%	☑ THDI	-	closed	☒	All the capacitor steps switched off	
			☒ THDI	-	-	-	-	-
Over THDV	H	10%	☑ THDV	-	closed	☒	All the capacitor steps switched off	
			☒ THDV	-	-	-	-	-
Over Temp	T	80°C	☑ TEMP	-	closed	☒	All the capacitor steps switched off	
			☒ TEMP	-	-	-	-	-

Table 3 Alarm and Protection function of PFC

Over Voltage:
Measured voltage exceeds the set level.

Under Voltage:
Measured Voltage drops the set level.

Under Compensate:
All the capacitors are connected and the power factor is lower than the set power factor.

Over Compensate:
All the capacitors are disconnected and the power factor is higher than the set power factor.

Over THD:
Measured THDV or THDI exceeds the set level

When Event having occurred and alarm relay is enabled an alarm icon appears on the LCD display and alarm relay closes immediately for 10 second and then deactivated for 20 second and check again if event disappear or not for next alarm report.

Once a protection level is reached and protection item of occurred event was enabled a protection icon appears on the display and all capacitor steps switched off PFC Resumes normal behavior after 10 minute.

4.2.5.3. Levels

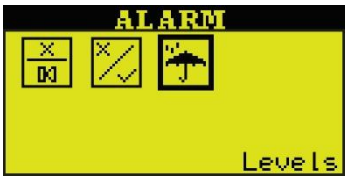


Figure 72 Levels

Press ↵ to enter PFC protection Levels menu

Protection levels:

To set the levels of protection against under voltage, over voltage, prohibitive harmonics of THDI and THDV, over temperature.

4.2.5.3.1. Over Voltage Level

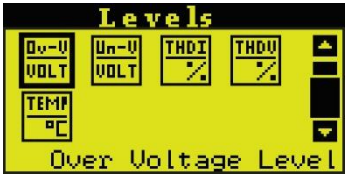


Figure 73 Over Voltage Level

Press ↵ to edit over voltage level

Figure 74 Over Voltage Level value

4.2.5.3.2. Under Voltage Level

Figure 75 Under Voltage Level

Press ↵ to edit under voltage level

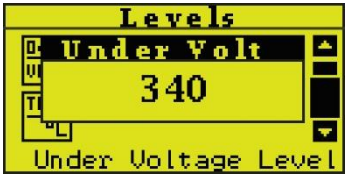


Figure 76 Under Voltage Level value

Recommended values:
Under Voltage Value (Vmin) < 0.8 Nominal Voltage
Over Voltage Value (Vmax) > 1.2 Nominal Voltage
If the system voltage exceeds Vmax limit or is under Vmin limit, all steps are disconnected.

4.2.5.3.3. Over THDI Level

Figure 77 Over THDI Level

Press ↵ to edit over THDI level

Figure 78 Over THDI Level value

4.2.5.3.4. Over THDV Level

Figure 79 Over THDV Level

Press ↵ to edit over THDV level

Figure 80 Over THDV Level value

Note:
Maximum permissible harmonic levels according to EN50160 and EN61000-2-2 standards:
Total Harmonic Voltage Distortion THDV: max 8%
Total Harmonic Current Distortion THDI: max 20%

4.2.5.3.5. Over Temp Level

Figure 81 Over Temperature Level

Press ↵ to edit over temperature level

Figure 82 Over Temperature Level value

4.2.6. Capacitor Sizes

Figure 83 Capacitor Sizes

Press ↵ to enter PFC capacitor sizes menu

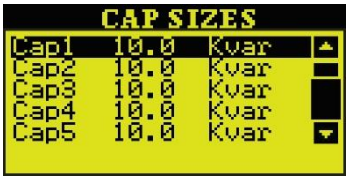


Figure 84 Capacitor Sizes list

Press ↵ to edit capacitor size in Kvar

Figure 85 Capacitor1 Size

Without the automatic size-detection user can enter the nominal step size. The input is done in Kvar and is related to nominal voltage. The adjustment must be done separately for each output.

Note:
Before the step size is set, must be set the correct current transformer ratio. After a step size has been entered, should the current transformers ratio will not change because
these changes affect the set step size. Hand-programmed "normal" steps will be overwritten by the automatic step size detection.

4.2.7. Fan

Figure 86 Fan

Press ↵ to enter PFC Fan setting menu

The PFC is equipped by default with a temperature sensor. The fan is controlled via one of the switching outputs (output 11).

4.2.7.1. Fan Relay on/off

Figure 87 Fan Relay is off

Press ↵ to enable or disable Fan Relay

Figure 88 Fan Relay is on

4.2.7.2. Set Point

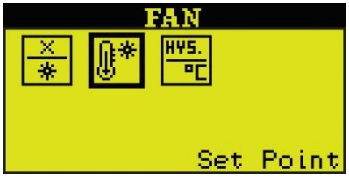


Figure 89 Set Point

Press ↵ to edit set point value In °C.

Figure 90 Set point value

Set Point are basically will be lower than protection level of temperature. When a warning level is reached, following actions will occur:

- the fan/warning relay is activated: the NO contact will close.
- the icon is displayed.

4.2.7.3. Hysteresis

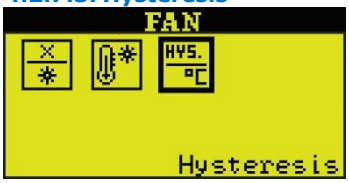


Figure 91 Hysteresis

Press ↵ to edit hysteresis value

Figure 92 Hysteresis value

4.2.8. MODBUS

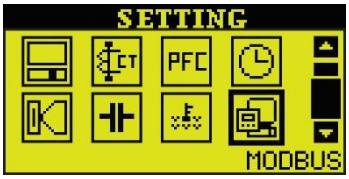


Figure 93 MODBUS

Press ↵ to enter PFC Modbus menu

By selecting and validating the Modbus-RTU protocol, the PFC can communicate in a Modbus supervision system.
All PFC parameters as well as the PFC measurements are accessible.

4.2.8.1. Baud Rate

Figure 94 Baud Rate

Press ↵ to adjust the communication speed (bits/second).

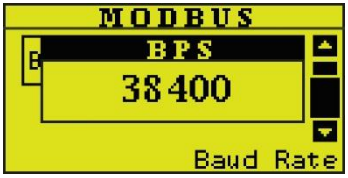


Figure 95 Baud Rate value

Baud rate setting page the asynchronies communication setting of the PFC is 8 data bit, no parity, 1 start bit and 1 stop bit. Baud rate could be one of the six, 1200, 2400, 4800, 9600, 19200, 38400.

4.2.8.2. Slave Address

Figure 96 Slave Address

Press ↵ to adjust the address of the Modbus-RTU slave. It is any digit number from 1 to 247

Figure 97 Slave Address value

Slave address: The Modbus master will refer to this address for each query / answer transaction with this PFC.

4.2.9. Logger

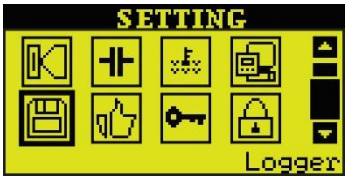


Figure 98 Logger

Press ↵ to enter PFC logger menu

The event logging function allows the user to log each significant measured item (see Figure100 here below) since last clearance:
- the maximum value
- the switching counts

the PFC starts recording the maximum value and switching counts automatically until it is reset.

4.2.9.1. Maximums

Figure 99 Maximums

Press ↵ to enter PFC maximum values menu

Figure 100 Maximum values List

Press ↵ to reset maximum value of any item.

Figure 101 Voltage Maximum value RESET

4.2.9.2. Contactors Counter

Figure 102 Contactors Counter

Press ↵ to enter PFC Contactors counter logger
The PFC is counting the operations of the switching outputs and displays them in this menu.

Figure 103 Contactors Counter List

Press ↵ to Reset switching counters for all stages to zero individually.

Figure 104 Contactor1 Counter value RESET

Note:
A switching counter may only be reset after the corresponding contactor has been replaced!

4.2.10. Test Function

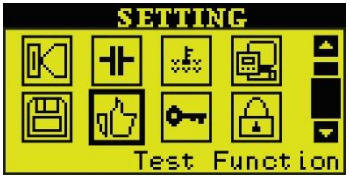


Figure 105 Test Function

Press ↵ to enter PFC test function menu
This sub-menu allows the user to test each relay of the PFC.

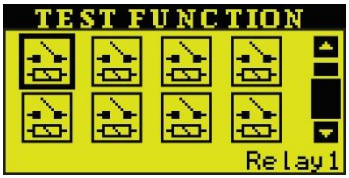


Figure 106 Relay1 is off

Press ↵ to switched on or off any (from 12) output relay

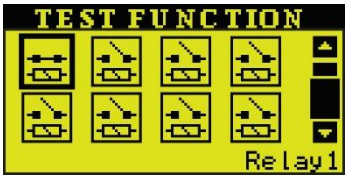


Figure 107 Relay1 is on

4.2.11. Change Password

Figure 108 Change Password

Press ↵ to change password

Figure 109 New Password value

As a protection against mal-operation some setting has an access code.
Factory setting is 0000, The password can be changed by user.

4.2.12. Factory (Password Protected)

Figure 110 Factory

This menu is only usable in factory for repair and calibration purpose.

4.3. Automatic Set (Password Protected)

Figure 111 Automatic Set

Press ↵ to start automatic, detect and measurement of installed capacitor steps

Figure 112 Automatic Set Password

Then enter password (The default password is 0000) and press ↵ , if the password was correct the PFC start automatic set up process.
First PFC switched off all capacitor steps and then initialize.

Figure 113 Automatic Set Initialize

After expiration of the auto-initialization, the controller starts the recognize automatically the step sizes of the capacitors. Settings of C/K value and the switching sequence is not required.

Figure 114 Automatic Set switch on Cap1

The Unit switched on and switched off capacitor steps, one by one and display Measured value

Figure 115 Automatic Set shows Cap1 value

Note:
If you set up CT factor the shown value will be nominal value of capacitor steps.

Figure 116 Automatic Set Shows Number of Detected Capacitor Steps

This process is done for all capacitor steps and at the end of process unit display number of detected steps. (steps that have none zero value)
If the detected capacitors are zero or less than actual steps number, we should try to troubleshoot the system, in other way the PFC start its normal operation and compensate the network.

Note:
- It is not necessary to arrange capacitor steps in any sequence or from smallest one to biggest.
- Between capacitor steps empty steps are allowed.
- Automatic CT Polarity Correction

4.4. About

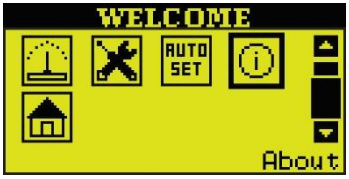


Figure 117 About

Press ↵ to enter PFC about menu
This menu gives PFC serial number, software version, hardware version, time of use (hour), Unit ID, Production date.

Figure 118 About Information List1

By pressing the ▲ or ▼ button, user can cycle between different parameters

Figure 119 About Information List2

4.5. Restore Default (Password Protected)

Figure 120 Restore Default

Press ↵ to reset to default factory setting

Figure 121 Restore Default Password

Figure 122 Restore Default Process

Figure 123 Restore Default Finished

Note:
By selecting and validating the Restore default icon, all the values of the PFC parameters are reset to their default values (see appendix C).

5. COMUNICATION

5.1. Communication Setup

The communication port and protocol of PFC are RS485 and Modbus-RTU. The terminals of communication are RS-, RS+. Up to 32 devices can be connected on a RS485 bus. Use good quality shielded twisted pair cable, AWG22 (0.5mm2) or larger. The overall length of the RS485 cable connecting all devices cannot exceed 1200m (4000ft). PFC is used as a slave device of master like PC, PLC, data collector or RTU. If the master does not have RS485 communication port, a converter has to be used. Normally a RS232/RS485 or USB/RS485 is adopted.

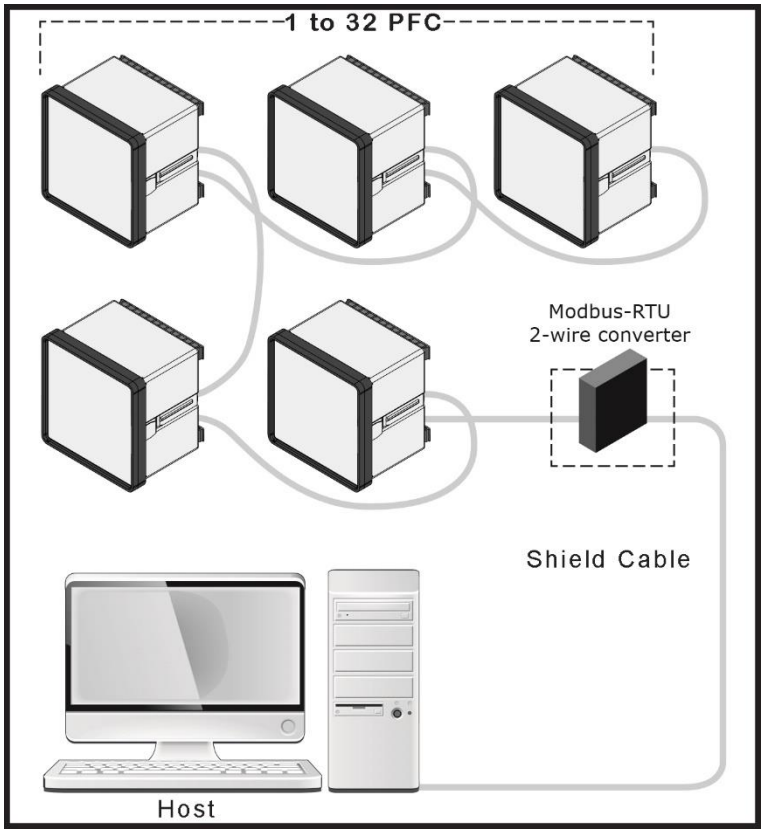


Figure 123 communication wiring

5.2. Introducing Modbus Protocol

The Modbus RTU protocol is used for communication in PFC. The data format and error check method is defined in Modbus protocol. The half-duplex query and respond mode is adopted in Modbus protocol. There is only one master device in the communication net. The others are slave devices, waiting for the query of the master.

5.3. Transmission mode

The mode of transmission defines the data structure within a frame and the rules used to transmit data. The mode is defined in the following which is compatible with Modbus RTU Mode*.

Coding System	8-bit binary
Start bit	1
Data bits	8
Parity	no parity
Stop bit	1

Table 4 Byte format

*Modbus is trademark of Modicon, Inc.

5.4. Framing

Address	Function	Data	Check
8-Bits	8-Bits	N x 8-Bits	16-Bits

Table 5 MODBUS frame over Serial Line

Address Field:

The address field of a message frame contains eight bits. Valid slave device addresses are in the range of 1~247 decimal. A master addresses a slave by placing the slave address in the address field of the message. When the slave sends its response, it places its own address in this address field of the response to let the master know which slave is responding.

Function Field:

The function code field of a message frame contains eight bits. Valid codes are in the range of 1~255 decimal. When a message is sent from a master to a slave device the function code field tells the slave what kind of action to perform.

Code	Meaning	Action
0x03	Read Holding Registers	Obtain current binary value in one or more registers
0x06	Write Single Register	Place specific binary values into a register
0x10	Write Multiple registers	Place specific binary values into a series of consecutive Multiple-Registers

Table 6 Function Code

Data Field:

The data field is constructed using sets of two hexadecimal digits, in the range of 0x00 to 0xFF hexadecimal. The data field of messages sent from a master to slave devices contains additional information which the slave must use to take the action defined by the function code. This can include items like discrete and register addresses, the quantity of items to be handled, and the count of actual data bytes in the field. For example, if the master requests a slave to read a group of holding

registers (function code 03), the data field specifies the starting register and how many registers are to be read. If the master writes to a group of registers in the slave (function code 0x10 hexadecimal), the data field specifies the starting register, how many registers to write, the count of data bytes to follow in the data field, and the data to be written into the registers.
If no error occurs, the data field of a response from a slave to a master contains the data requested. If an error occurs, the field contains an exception code that the master application can use to determine the next action to be taken. The data field can be nonexistent (of zero length) in certain kinds of messages.

Error Check Field:
Messages include an error's checking field that is based on a Cyclical Redundancy Check (CRC) method. The CRC field checks the contents of the entire message. It is applied regardless of any parity check method used for the individual characters of the message. The CRC field is two bytes, containing a 16bit binary value. The CRC value is calculated by the transmitting device, which appends the CRC to the message.
The receiving device recalculates a CRC during receipt of the message, and compares the calculated value to the actual value it received in the CRC field If the two values are not equal, an error results. The CRC is started by first preloading a 16-bit register to all 1's. Then a process begins of applying successive 8-bit bytes of the message to the current contents of the register. Only the eight bits of data in each character are used for generating the CRC. Start and stop bits, and the parity bit, do not apply to the CRC. During generation of the CRC, each 8-bit character is exclusive ORed with the register contents. Then the result is shifted in the direction of the least significant bit (LSB), with a zero filled into the most significant bit (MSB) position. The LSB is extracted and examined.
If the LSB was a1, the register is then exclusive ORed with a reset, fixed value.
If the LSB was a0, no exclusive OR takes place. This process is repeated until eight shifts have been performed. After the last (eighth) shift, the next 8-bit byte is exclusive ORed with the register current value, and the process repeats for eight more shifts as described above. The final contents of the register, after all the bytes of the message have been applied, is the CRC value. When the CRC is appended to the message, the low-order byte is appended first, followed by the high-order byte.

5.5. Format of the communication

Explanation of frame:

Slave address	Function	Starting Address Hi	Starting Address Lo	Number of Registers Hi	Number of Registers Lo	CRC Lo	CRC Hi
0x01	0x03	0x00	0x01	0x00	0x21	0xD4	0x12

Table 7 Explanation of frame

5.6. Read Holding Registers (Function Code 0x03)

Query:

This function allows the master to obtain the measurement results or settings of PFC. Table 9 is an example to read the CT primary and CT secondary value from slave device number 1, the data address of ct_p is 0x3006H and ct_s is 0x3007H.

Slave address	Function	Starting Address Hi	Starting Address Lo	Number of Registers Hi	Number of Registers Lo	CRC Lo	CRC Hi
0x01	0x03	0x30	0x06	0x00	0x02	0x2B	0x0A

Table 8 Read ct_p and ct_s query message

Response:

The PFC response includes the PFC address, function code, quantity of data byte, data, and error checking. An example response to read ct_p and ct_s is: ct_p = 0x0064H (100), ct_s = 0x0005H (5) is shown as Table 10.

Slave address	Function	Byte Count	Register value Hi	Register value Lo	Register value Hi	Register value Lo	CRC Lo	CRC Hi
0x01	0x03	0x04	0x00	0x64	0x00	0x05	0x7B	0xEF

Table 9 Read ct_p and ct_s message

5.7. Write Single Register (Function Code 0x06)

Query:

Function 0x06 allows the user to modify the contents of one Register. Any Register that exists within the PFC writable memory can have its contents changed by this message. The example below is a request to a PFC number 1 to Preset CT primary to 1250, while its Hex Value 0x04E2H. ct_p data address is 0x3006H.

Slave address	Function	Register Address Hi	Register Address Lo	Registers Value Hi	Registers Value Lo	CRC Lo	CRC Hi
0x01	0x06	0x30	0x06	0x04	0xE2	0xE4	0x42

Table 10 Preset ct_p

Response:

The normal response is an echo of the request, returned after the register contents have been written.

Slave address	Function	Register Address Hi	Register Address Lo	Registers Value Hi	Registers Value Lo	CRC Lo	CRC Hi
0x01	0x06	0x30	0x06	0x04	0xE2	0xE4	0x42

Table 11 Writes single register response message

5.8. Write Multiple Registers (Function Code 0x10)

Query:

Function 0x10 allows the user to modify the contents of Multi-Register. Any Register that exists within the PFC writable memory can have its contents changed by this message.

The example below is a request to a PFC number 1 to Preset CT primary to 1250, while its Hex Value 0x04E2H and CT secondary to 5 with one query. ct_p data address is 0x3006H and ct_s is 0x3007H.

Slave address	Function	Starting Address Hi	Starting Address Lo	Quantity of Registers Hi	Quantity of Registers Lo	Byte Count	Registers Value Hi	Registers Value Lo	Registers Value Hi	Registers Value Lo	CRC Lo	CRC Hi
0x01	0x10	0x30	0x06	0x00	0x02	0x04	0x04	0xE2	0x00	0x05	0x46	0x81

Table 12 Preset ct_p and ct_s

Response:

The normal response returns the function code, starting address, and quantity of registers written.

Slave address	Function	Starting Address Hi	Starting Address Lo	Quantity of Registers Hi	Quantity of Registers Lo	CRC Lo	CRC Hi
0x01	0x10	0x30	0x06	0x00	0x02	0xAE	0xC9

Table 13 Writes multiple registers response message

6. MAINTANENCE

6.1. Cleaning

If the cleaning is restricted only to the front of the closed control cabinet, it is not necessary to isolate the PFC from the power supply, but in this case also only a dry cleaning cloth may be used.

There are no user serviceable parts on this product. Please do not open the product, as opening it will void the warranty. Please contact your nearest sales representative if the product requires any service or repair.

Getting Technical Support

For technical support, you can obtain assistances via:

Address	:	No.16, Golestan Building Tabriz, IRAN.
Tel	:	+98 41 3553 8103,4
Fax	:	+98 41 3553 3738
Website	:	www.zilug.com

7. APPENDIX

7.1. APPENDIX A PFC Specification

CURRENT INPUT	
Nominal Current	5 A rms
Operating Limits	0.01-6 A rms
Rated frequency	50 Hz
VOLTAGE INPUT (EACH PHASE with respect to neutral)	
Nominal Voltage	230 VAC
Operating Limits	0 - 277 V L-N
Consumption	0.05 VA
Rated Frequency	50 Hz
AUXILIARY	
Auxiliary Input Voltage Range	85-265 V rms
Rated Voltage Range	110-230V rms
Consumption	10 VA max
Rated Frequency	50 Hz/ 60 Hz
RELAY OUTPUT	
Number of outputs	12
Contact arrangement	NO contact type
Contact rating	5 A , 250 VAC (COS φ = 1)
Expected electrical life	100,000 operations at rated current
Expected mechanical life	5 x 10^6 operations
CONTROL RANGE	
Target Power factor	0.00 Inductive – 0.00 Capacitive
C/K setting	Automatic detect
Action Time	1 – 120 s
Discharge Time	1 – 240 s
Switching program	Automatic/ Manual
Fan Setting	Temperature / None
Signal Contact	Linked to 5 different programmable alarm / None
ALARM SETTING RANGE	
%THDI or THDV%	1 – 100 % / OFF
Over Voltage	100 – 500 V/ OFF
Under Voltage	100 – 500 V/ OFF
Over/Under Compensate	On / OFF
Over Temperature	50 – 100 °C / OFF
DISPLAY	
%THDI and %THDV	0 – 500 %
Missed Reactive Power	0 – 1000 KVAR
Active power	0 – 1000 KW
Reactive power	0 – 1000 KVAR
Apparent power	0 – 1000 KVA
Voltage	0 – 300 VAC
Current	0.00 – 10.0 A rms
Temperature	0 – 100 °C
Power Factor	-1.00 – 1.00
MECHANICAL	
Mounting	Panel mounting
Dimension (h x w x d)	144mm x 144mm x 91mm
IP Protection	IP54 Front Panel, IP20 Meter Body
Approximate weight	1.2 kg

Table 14 PFC specification

Dimension:

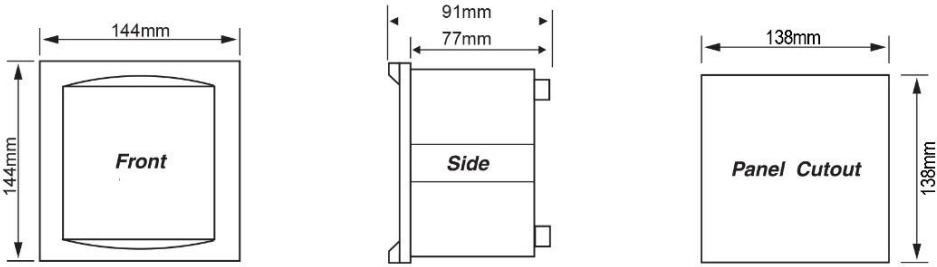


Figure 124 Dimension

Front of panel in 138 mm × 138 mm cutout to IEC 61554, held by eight retaining lugs at the corners of the casing.

7.2. APPENDIX B Address table of PFC

Address	Parameter	Range	Object Type	Type of access
Basic Measurements (0x1000 to 0x1100)				
0x1000	Voltage L-L	0~65535	word	R
0x1001	Current	0~65535	word	R
0x1002	Apparent Power	0~65535	word	R
0x1003	Active Power	-32768~32767	word	R
0x1004	Reactive Power	-32768~32767	word	R
0x1005	Missing Reactive Power	-32768~32767	word	R
0x1006	THDV	0~500	word	R
0x1007	THDI	0~500	word	R
0x1008	Power Factor	-1000~1000	word	R
0x1009	Temperature (1°C resolution)	0~65535	word	R
0x100A	Load Type RT (L/C/R)	76/67/82	word	R
0x100B	Alarm (ON = 1 ; OFF = 0)	0~1	word	R
0x100C	Protection (ON = 1 ; OFF = 0)	0~1	word	R
0x100D	Over/Under Voltage (ON = 1 ; OFF = 0)	0~1	word	R
0x100E	Over THDI or THDV (ON = 1 ; OFF = 0)	0~1	word	R
0x100F	Over/Under compensate (ON = 1 ; OFF = 0)	0~1	word	R
0x1010	Over Temperature (ON = 1 ; OFF = 0)	0~1	word	R
0x1011	Internal Battery Status* (ON = charging ; OFF = Full)	0~1	word	R
0x1012	Year (Miladi)*	2000~2099	word	R
0x1013	Month (Miladi)*	1~12	word	R
0x1014	Day(Miladi)*	1~31	word	R
0x1015	Hour*	0~23	word	R
0x1016	Minute*	0~59	word	R
0x1017	Second*	0~59	word	R
Read and Write capable settings(0x3000~0x4000)				
0x3000	Slave address	1~247	word	R/W
0x3001	Baud rate (1200-2400-4800-9600-19200-38400bps)	1200~38400	word	R/W
0x3002	Type of date (shamsi:0 and miladi:1)	0~1	word	R/W
0x3003	Daylight Saving(Enable = 1 ; Disable = 0)	0~1	word	R/W
0x3004	Light time for LCD backlight (minute)	1~120	word	R/W
0x3005	Buzzer(ON = 1 ; OFF = 0)	0~1	word	R/W
0x3006	CT primary	5~8000	word	R/W
0x3007	CT secondary	1 or 5	word	R/W
0x3008	Type of Display (FULL = 1 ; SIMPLE = 0)	0~1	word	R/W
0x3009	Alarm Relay(ON = 1 ; OFF = 0)	0~1	word	R/W
0x300A	Over/Under Voltage Alarm (enable = 1 ; disable = 0)	0~1	word	R/W
0x300B	Over/Under Compensate Alarm (enable = 1 ; disable = 0)	0~1	word	R/W
0x300C	Over/Under Temperature Alarm (enable = 1 ; disable = 0)	0~1	word	R/W
0x300D	Over THDI Alarm (enable = 1 ; disable = 0)	0~1	word	R/W
0x300E	Over THDV Alarm (enable = 1 ; disable = 0)	0~1	word	R/W
0x300F	Over Voltage Level	100~500	word	R/W
0x3010	Under Voltage Level	100~500	word	R/W
0x3011	Over Temperature Level	50~100	word	R/W
0x3012	Over THDI Level	5~100	word	R/W
0x3013	Over THDV Level	5~100	word	R/W
0x3014	Fan Relay(ON = 1 ; OFF = 0)	0~1	word	R/W
0x3015	Fan control Set Point	1~100	word	R/W
0x3016	Fan control hysteresis value	1~20	word	R/W
0x3017	PFC action time second	1~120	word	R/W
0x3018	PFC operation(Auto = 0 ; Manual = 1)	0~1	word	R/W

0x3019	Number of steps	1~12	word	R/W
0x301A	PFC Discharge Time second	1~240	word	R/W
0x301B	PFC target Power Factor	-100~100	word	R/W
0x301C	Percent of PFC correction offset	1~100	word	R/W
0x301D	Percent of availability effect on correction	1~100	word	R/W
0x301E	Percent of contactor count effect on correction	1~100	word	R/W
0x301F	Percent of number of in or out effect on correction	1~100	word	R/W
0x3020	Percent of value effect on correction	1~100	word	R/W
0x3021	PASSWORD	0000~9999	word	R/W
0x3022	Unit ID letter(8)	ASCII	word	R/W
0x3023	Unit ID letter(7)	ASCII	word	R/W
0x3024	Unit ID letter(6)	ASCII	word	R/W
0x3025	Unit ID letter(5)	ASCII	word	R/W
0x3026	Unit ID letter(4)	ASCII	word	R/W
0x3027	Unit ID letter(3)	ASCII	word	R/W
0x3028	Unit ID letter(2)	ASCII	word	R/W
0x3029	Unit ID letter(1)	ASCII	word	R/W
0x302A	Status of logger (START: 1 and STOP: 0)**	0~1	word	R/W
0x302B	Sample time for logging (second)**	1~900	word	R/W
0x302C	Type of logging (FIFO:0 and FILL and HOLD:1)**	0~1	word	R/W
0x302D	Contactor1 Counter	0~65535	word	R/W
0x302E	Contactor2 Counter	0~65535	word	R/W
0x302F	Contactor3 Counter	0~65535	word	R/W
0x3030	Contactor4 Counter	0~65535	word	R/W
0x3031	Contactor5 Counter	0~65535	word	R/W
0x3032	Contactor6 Counter	0~65535	word	R/W
0x3033	Contactor7 Counter	0~65535	word	R/W
0x3034	Contactor8 Counter	0~65535	word	R/W
0x3035	Contactor9 Counter	0~65535	word	R/W
0x3036	Contactor10 Counter	0~65535	word	R/W
0x3037	Contactor11 Counter	0~65535	word	R/W
0x3038	Contactor12 Counter	0~65535	word	R/W
0x3039	Value of Capacitor1	0~9999	word	R/W
0x303A	Value of Capacitor2	0~9999	word	R/W
0x303B	Value of Capacitor3	0~9999	word	R/W
0x303C	Value of Capacitor4	0~9999	word	R/W
0x303D	Value of Capacitor5	0~9999	word	R/W
0x303E	Value of Capacitor6	0~9999	word	R/W
0x303F	Value of Capacitor7	0~9999	word	R/W
0x3040	Value of Capacitor8	0~9999	word	R/W
0x3041	Value of Capacitor9	0~9999	word	R/W
0x3042	Value of Capacitor10	0~9999	word	R/W
0x3043	Value of Capacitor11	0~9999	word	R/W
0x3044	Value of Capacitor12	0~9999	word	R/W
0x3045	Relay1 status (ON = 1 ; OFF = 0)	0~1	word	R/W
0x3046	Relay2 status (ON = 1 ; OFF = 0)	0~1	word	R/W
0x3047	Relay3 status (ON = 1 ; OFF = 0)	0~1	word	R/W
0x3048	Relay4 status (ON = 1 ; OFF = 0)	0~1	word	R/W
0x3049	Relay5 status (ON = 1 ; OFF = 0)	0~1	word	R/W
0x304A	Relay6 status (ON = 1 ; OFF = 0)	0~1	word	R/W
0x304B	Relay7 status (ON = 1 ; OFF = 0)	0~1	word	R/W
0x304C	Relay8 status (ON = 1 ; OFF = 0)	0~1	word	R/W
0x304D	Relay9 status (ON = 1 ; OFF = 0)	0~1	word	R/W
0x304E	Relay10 status (ON = 1 ; OFF = 0)	0~1	word	R/W
0x304F	Relay11 status (ON = 1 ; OFF = 0)	0~1	word	R/W
0x3050	Relay12 status (ON = 1 ; OFF = 0)	0~1	word	R/W
Read only settings(0x4000~0x5000)				
0x4000	Hardware version	0~9999	word	R

0x4001	Software version	0~9999	word	R
0x4002 0x4003	Serial Number Hi word Serial Number Lo word		Double word	R
0x4004	Production Year	2014~2050	word	R
0x4005	Production Month	1~12	word	R
0x4006	Production Day	1~31	word	R
0x4007 0x4008	Time of use of UNIT Hi word (Hour) Time of use of UNIT Lo word (Hour)		Double word	R
Write only settings(0x5000~0x6000)				
0x5000				W
0x5001	Clear all counter of contactors(CLEAR = 1)	1	word	W
0x5002				
0x5003	Clear Statistics(CLEAR = 1)	1	word	W
0x5004	RTC Second*	0~59	word	W
0x5005	RTC Minute*	0~59	word	W
0x5006	RTC Hour*	0~23	word	W
0x5007	RTC Day*	1~31	word	W
0x5008	RTC Month*	1~12	word	W
0x5009	RTC Year*	2014~2050	word	W
0x500A	Reset Unit (RESET = 1)	1	word	W

Table 15 Metering data address table

*, ** If included

Parameter	Relationship	Unit
V	U = R / 10	Volt(V)
I	I = R x (ct_p / ct_s) / 10	Amp(A)
P	P = R × (ct_p / ct_s)	Watt(W)
Q	Q = R × (ct_p / ct_s)	Var
S	S = R × (ct_p / ct_s)	VA
Delta	D = R × (ct_p / ct_s)	Var
PF	PF = R / 100 if PF=2 -> PF=LP	NA
Load Type (L/C/R)	ASCII of L, C, R	NA
THDI , THDV	THD = R / 10	%
Capacitor sizes	Size = R / 10	Kvar

Table 16 Measuring data convert table

7.3. APPENDIX C Setting Parameters

CONTROL SETTING PARAMETERS	DEFAULT VALUE	UNIT
Password	0000	
Daylight saving	Enable	
Date type	Shamsi	
Step Number	12	
Discharge Time	120	Second
Action Time	15	Second
Target PF	1.00	
C/K	65	%
% of Value Effect	60	%
% of Circular Effect	12	%
% of IN-OUT Effect	20	%
% of Availability Effect	8	%
PFC Operation	AUTO	
CT Primary	5	A
CT Secondary	5	A
Display Mode	PF	
Buzzer	ON	
Backlight Time	10	Minute
Baud Rate	38400	Bps
Slave Address	1	
Alarm Relay	OFF	
Over/Under Voltage	Disable	
Over/Under Compensate	Disable	
Over THDI	Disable	
Over THDV	Disable	
Over Temperature	Disable	
Over Voltage Level	420	V
Under Voltage Level	340	V
Over THDI Level	20	%
Over THDV Level	10	%
Over Temperature Level	80	°C
Fan Relay	OFF	
Fan Set Point	50	°C
Fan Hysteresis	5	°C
Capacitor1 to Capacitor12 Sizes	1.0	Kvar
Unit ID	"ALFA-PFC"	8 Char

Table 17 Setting Parameters and default values

7.4. APPENDIX D Calculations

✓ Capacitor power rating single-phase:

$$Q_C = C.v^2.2\pi f_n$$

✓ Capacitor power rating with delta connection:

$$Q_C = 3.C.v^2.2\pi f_n$$

✓ Capacitor phase current:

$$i = \frac{Q_c}{V.\sqrt{3}}$$

✓ The active power is given by the formula:

$$P = v.i.\cos\varphi$$

✓ The reactive power is given by the formula:

$$Q = v.i.\sin\varphi$$

✓ Calculation of power factor cos φ and tan φ:

$$\cos\varphi = \frac{P}{S}$$

$$\tan\varphi = \frac{Q}{P}$$

$$\cos\varphi = \sqrt{\frac{1}{1+\tan\varphi^2}} \quad \cos\varphi = \sqrt{\frac{1}{1+\left(\frac{Q}{P}\right)^2}}$$

✓ If the target power factor cos φ has been specified, the capacitor power rating can be calculated from the following formula. The reactive power Qc corrected by the capacitor is given by the difference between the inductive reactive power Q1 before correction and the reactive power Q2 after correction

$$Q_C = Q_1 - Q_2$$

$$Q_C = P.\left(\tan\varphi_{actual} - \tan\varphi_{target}\right)$$

✓ Total Harmonic Distortion for Voltage:

$$\%THDv = \sqrt{\sum_{n=2}^{\infty}\left(\frac{{v_n}^2}{{v_1}^2}\right)}$$

Vn = nth order harmonic rms voltage
V1 = fundamental rms voltage

✓ Total Harmonic Distortion for Current:

$$\%THDi = \sqrt{\sum_{n=2}^{\infty}\left(\frac{{i_n}^2}{{i_1}^2}\right)}$$

in = nth order harmonic rms current
i1 = fundamental rms current