

X80

user manual



Mikro[®] X80

Power Factor Regulator

MODBUS-RTU



Precaution for Safe use of Equipment

Please read the instructions carefully before operating the equipment. The following symbols will appear through out this user manual to warn of potential dangers or hazardous situation that will arises while operating the equipment. Mikro® 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 results 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.

Only qualified personnel shall install and operates Mikro®'s Power Factor Regulator.

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PRODUCT OVERVIEW

Introduction

Mikro[®]'s power factor regulator X80 is designed to detect and compensate displacement power factor caused by inductive load by switching in banks of capacitors. As oppose to traditional regulator that only measures reactive power on a single phase basis but compensates three phases, the X80's Three Phase model is a true three phase system as reactive power of all three phases are measured individually and compensated optimally.

Mikro[®] power factor regulator X80 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, Mikro[®]'s power factor regulator X80 provides the user with a 2 inch wide, 64 x 128 dot matrix LCD for displaying its various measurement parameters such as: frequency, voltage, current, THD, active, reactive, apparent power and temperature. The dot matrix LCD allows up to 31st voltage and current harmonics to be display in graphical and table form.

As per the other Mikro[®]'s power factor regulator series, it 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 X80 also provides a guided step-by-step commissioning menu that enables fast setup.

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

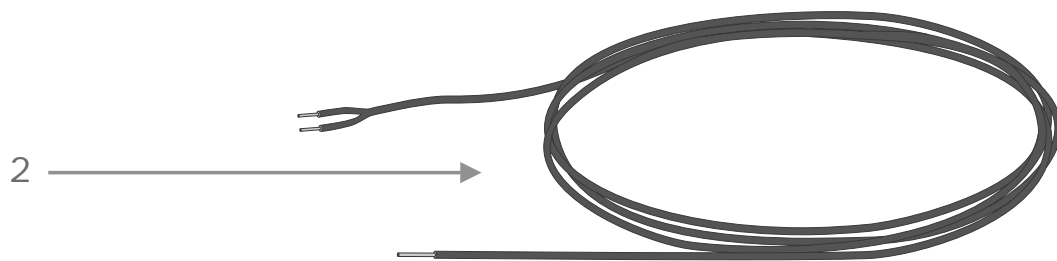
Feature List

2" inch, 64 x 128 dot matrix LCD display with back lighting
Three phase and single phase detection of reactive power
12 (or 8 for 8 step model) output with two additional independent contact for signal alarm output and fan output
Three phase compensation mode based on:
Optimum Demand
Selected Phase
Highest Load
5 different switch program:
Automatic
Linear
Four Quadrant
Rotational
Manual
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
Temperature
Phase Voltage and Phase Current
Frequency
Power Factor and Displacement Power Factor (Cos ϕ)
%THDV and %THDI
Various configurable alarm settings (can be disable)
%THDI
Under Compensation
Over Compensation
Under Current
Over Current
Under Voltage
Over Voltage
Over Temperature
Rated Step Detection Error
Current Transformer Polarity Error*
Alarm linked signal contact
Programmable fan control
Modbus-RTU communication support

* Available in single phase models only.

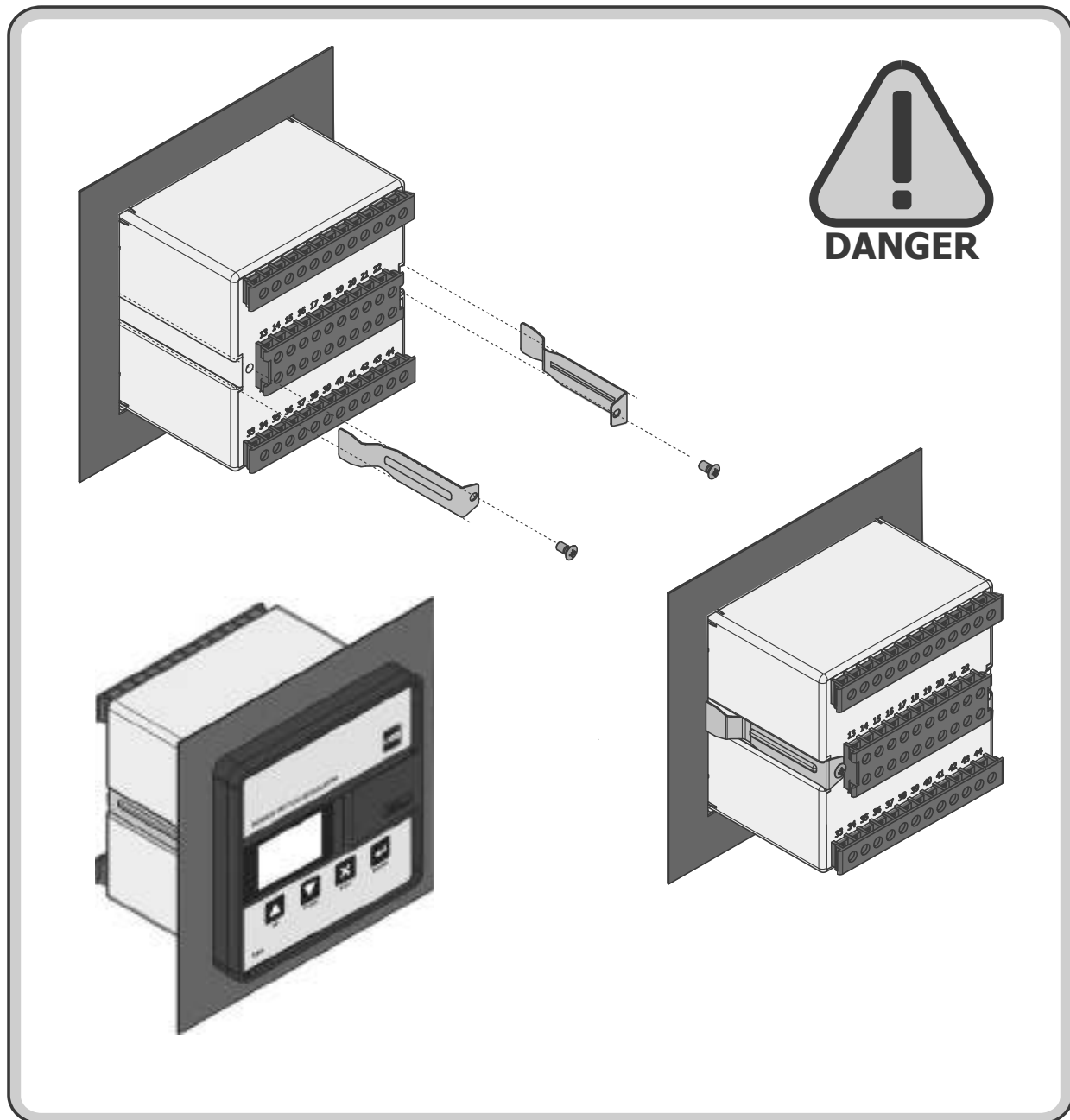
Packing List

No	Description	Quantity
1	X80 Power Factor Regulator	1
2	Thermistor	1
3	Thermistor holder	1



Setting Up The Regulator

Installation

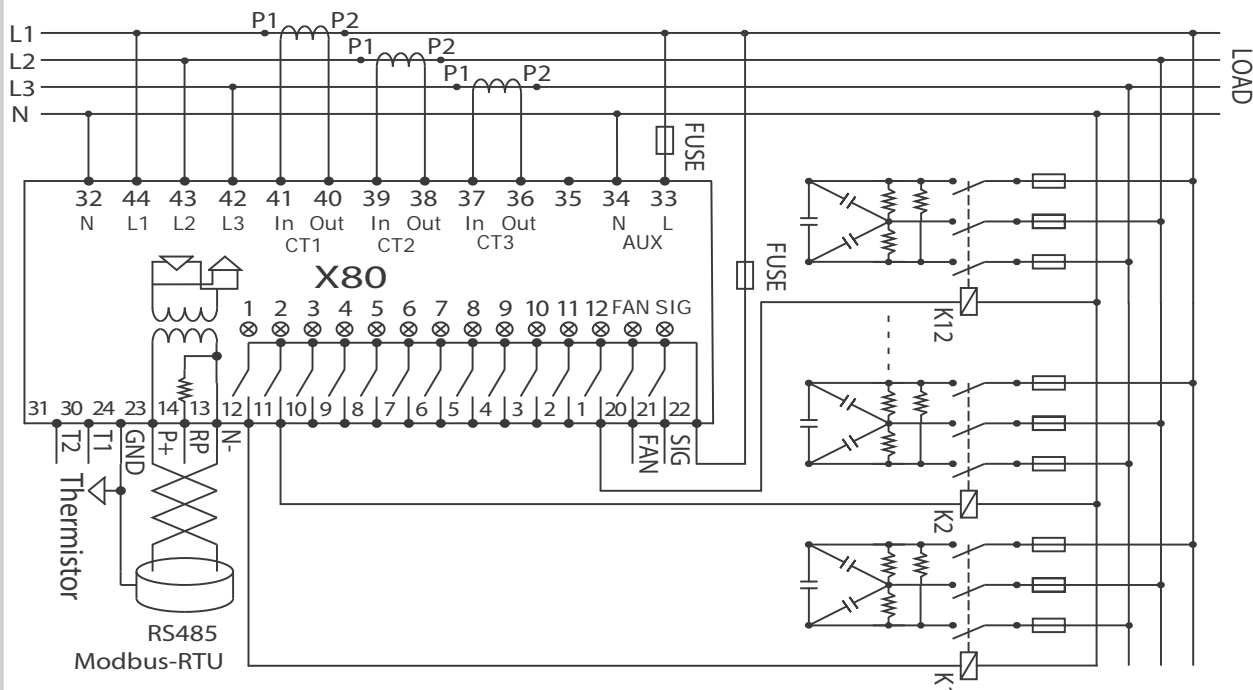


*Please mount the regulator with sufficient spacing (at least 50mm clearance) between other electrical instruments. This is to prevent difficulty in accessing and wiring the regulator.

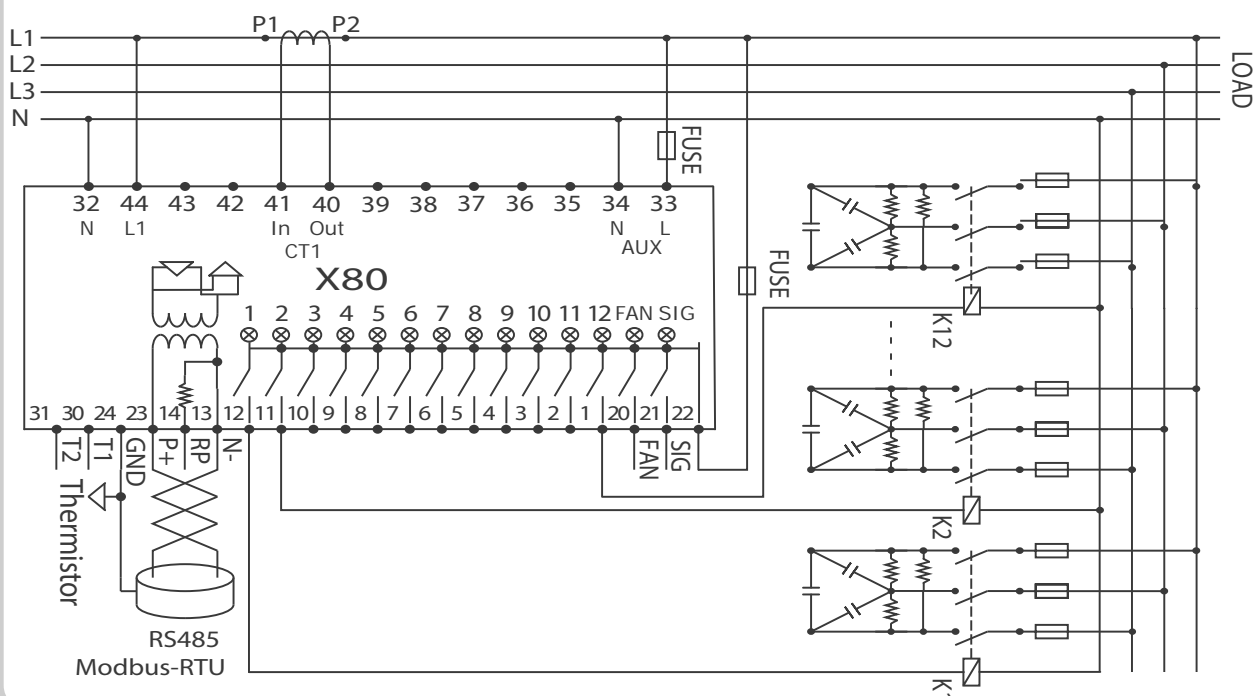
Wiring Diagram



X80 Connection diagram for 3 Phase 12 Step model

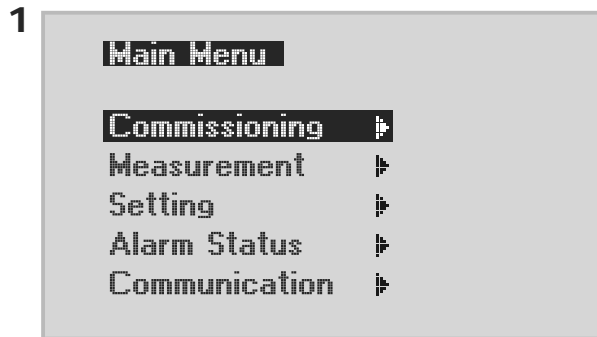


X80 Connection diagram for Single Phase 12 Step model



Quick Commissioning

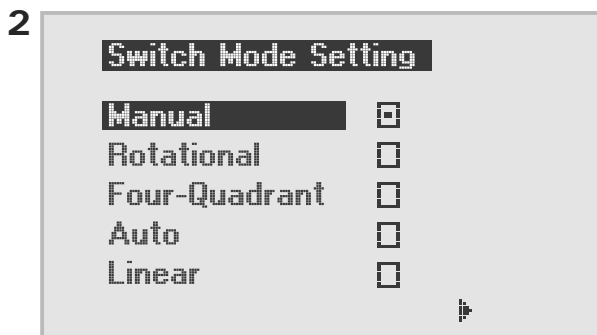
The regulator is pre-programmed with the most common parameters as its factory default setting. Users are normally not required to change any setting upon commissioning. If the user requires any changes in the setting, the quick commissioning feature will provide the user with a step-by-step guidance in setting up all the mandatory parameters for the regulator to function properly.



Press \leftarrow button from Home menu.



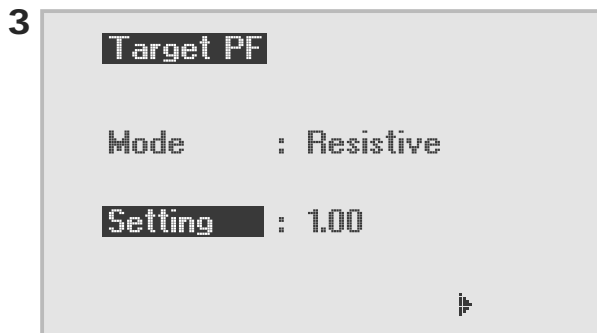
Press \leftarrow button, then press \uparrow or \downarrow to set the value. To navigate to the next page, press \uparrow or \downarrow to select " \blacktriangleright ", then press \leftarrow button.



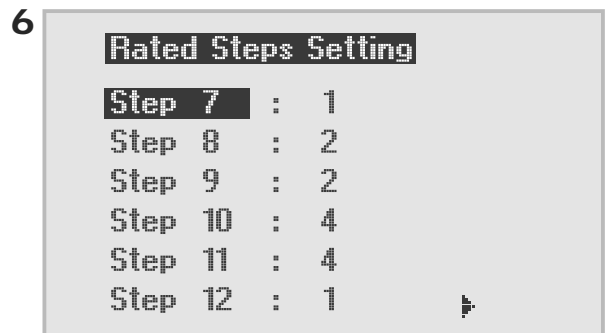
Press \leftarrow button to confirm your selection. To navigate to the next page, press \uparrow or \downarrow to select " \blacktriangleright ", then press \leftarrow button.



Press \uparrow or \downarrow button to navigate to the following pages.



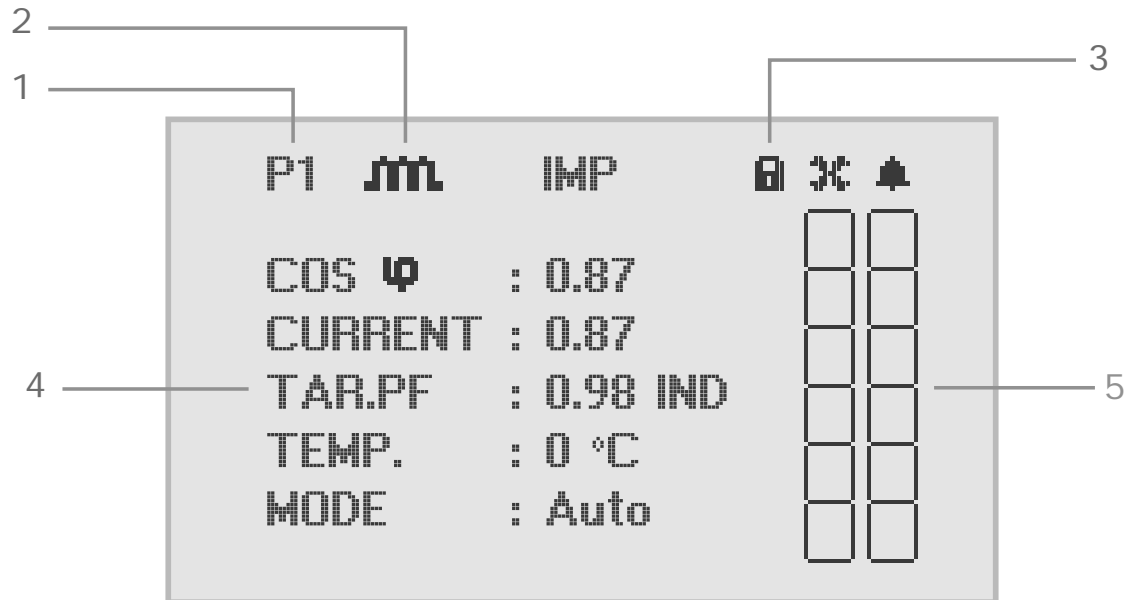
Press \leftarrow button, then press \uparrow or \downarrow to set the value. To navigate to the next page, press \uparrow or \downarrow to select " \blacktriangleright ", then press \leftarrow button.



Press \leftarrow button to confirm the selection, and then the press \uparrow or \downarrow to set the value. Back to the Main menu, press \uparrow or \downarrow to select " \blacktriangleright ", then press \leftarrow button.

DISPLAY

General Measurement



No	Description
1	Shows the phase that the regulator is currently measuring
2	Indicates the load condition (inductive or capacitive)
3	Alarm, Fan & Keylock status indication
4	Measurement (displacement power factor, current & temperature) and setting parameters (target power factor & switching program)
5	Shows the status of the outputs

NOTES:

By pressing the Exit button, user can cycle between different phases to display the respective phase parameters (applicable for three phase models).

Detail measurements of other power parameters such as phase voltages, phase currents, active power, reactive power, apparent power, frequency, alarm status and temperature can be intuitively access via the sub menu (measurements).

Alarm Status

When any of the alarm occurs, the regulator will display which of the alarm happen via the alarm status menu. The table below shows the details of the alarm activation/ de-activation timing.

Alarm		Delay Time	
Description	Symbol	Activate	Deactivate
Total Harmonic Distortion	%THDI	5 min	2.5 min
Under Current	Under Current	10 s	5 s
Over Current	Over Current	2 min	1 min
Under Voltage	Under Voltage	100 ms	5 s
No Voltage Release	No Volt. Release	instantaneous	instantaneous
Over Voltage	Over Voltage	15 min	7.5 min
Under Compensate	Under Comp.	15 min	7.5 min
Over Compensate	Over Comp.	15 min	7.5 min
Step Error	Step Error	-	-
CT Polarity Error	CT Error	10 s	5 s
Over Temperature	Temperature	5 min	2.5 min

Under Compensate Alarm

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

Over Compensate Alarm

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

Step Error Alarm

Step Error Alarm will be triggered if all the capacitor bank are detected to be invalid in Auto CK setting.

CT Polarity Error Alarm

Current Transformer Polarity Alarm will be triggered if the measured Active Power is negative due to wrong Current Transformer connection.

No Voltage Release Alarm

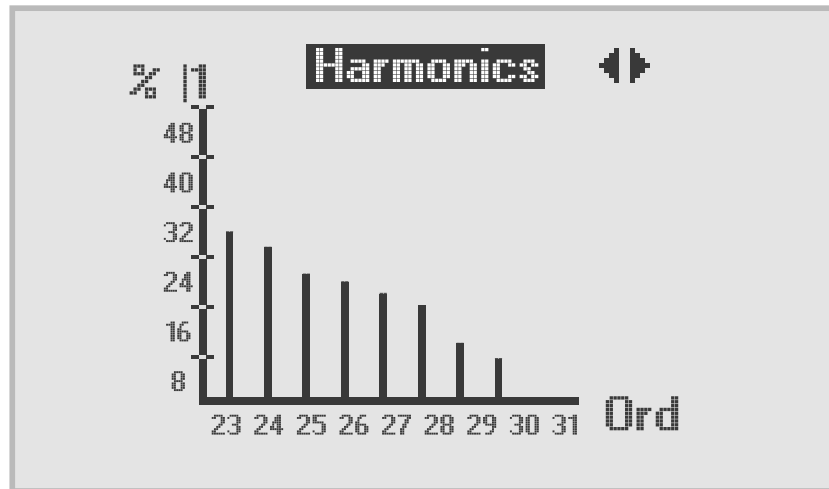
No Voltage Release Alarm will be triggered if the measured voltage is lower than 100V.

NOTES:

- There will be an alarm symbol blinking when any one of the alarm is being activated.
- The alarm status will show which of the alarms are activated.
- The Fan and Signal output contact will not be turn off when any of the alarms occurs.
- The signal contact output is programmable to link to the desired alarm signal.
- CT Polarity Alarm is not applicable for the Three Phase model.

Harmonics Table and Graph

The power factor regulator has the capability of displaying voltage and current harmonics up till the 31st order (fundamental frequency is considered to be 1st order). The regulator will display the harmonics frequency in graphical form (bar graph) or table form which shows the harmonics value in relative % to the fundamental frequency.



A table titled "Harmonics Table" showing the relative percentage of harmonics for various orders. The table has four columns: "Ord", "% |1", "Ord", and "% |1". The data is as follows:

Ord	% 1	Ord	% 1
2	28.0	6	20.0
3	31.0	7	19.0
4	27.0	8	11.0
5	23.0	9	8.9

Switching Program

This setting allows the user to configure the regulator to operate in one of the following switching algorithms:

1. MANUAL

This mode is typically reserved for testing the regulator when commissioning it for the first time. In this mode, the user can turn on and off the capacitor bank manually by pressing the ▲ or ▼ button. The ▲ Button will turns on and ▼ button will turns off the capacitor banks. The capacitor banks are switched in a first-in-first-out (FIFO) basis.

2. AUTOMATIC

The regulator selects the most appropriate step to switch in order to achieve the target power factor in the shortest reaction time within the minimum number of steps. For equal aging of capacitor and contactor the program will select the least used step to switch in or the most used step to switch out, if there are 2 or more equally rated steps.

3. ROTATIONAL

In this mode, the regulator switches the regulator in a first-in-first-out (FIFO) basis to achieve the target power factor.

4. FOUR-QUADRANT

This mode is the same as automatic switching mode with the exception of that it operates in both import power and export power (regenerative) conditions. There will be no automatic CT polarity correction in this mode.

5. LINEAR

In this mode, the regulator switches the regulator in a first-in-last-out (FILO) switching sequence to achieve the target power factor.

NOTES:

- For single phase model, in automatic, rotational and linear switch program, all the capacitor banks will be disconnected if the measured power flow is regenerative.
- For three phase model, three phase detection mode and in automatic, rotational and linear switch program, all the capacitor banks will be disconnected if the measured power flow is regenerative in any of the detected phases. If phase detect is either L1, L2, L3 or max load, the capacitor will be disconnected only if the selected phase is regenerative.

Target Power Factor

The user will be able to set the target displacement power factor value from 0.8 capacitive to 0.8 inductive. The regulator will switch the capacitor banks on and off, attempting to achieve this set value.

Sensitivity

The sensitivity setting controls the reaction time for the regulator to switch. The reaction time to switch is dependent on the demand, step size and the sensitivity setting. A small demand, large step size and a high sensitivity setting will result in a slower switching whereas a large demand, small step size and a small sensitivity setting will result in a faster switching speed. The reaction time is counted dynamically as the demand changes providing an optimal reaction time. Please refer to appendix D.2 for more details.

Reconnection Time

This setting prevents the reconnection of the same capacitor bank before it is fully discharged. This parameter is usually set based on the discharge time of the largest capacitor size in used. When a step is being turned on while the reconnection time is counting down, the LCD will display the blinking step indicating that particular step is pending to turn on.

C/K

The C/K value determines the threshold current value for the regulator to switch (On/Off). The C/K value is determined manually via table D.1.0 (Appendix D.1) base on the smallest capacitor bank size, system voltage and CT ratio. The regulator can automatically detect the C/K value by setting it to auto.

Rated Step Coefficient

The rated step setting allows the user to program the outputs in accordance to the installed capacitor bank size. When the step is set to be fixed, the output will be turn on and will not be part of the switching. If the C/K setting is automatic, the rated step size will be determined by the regulator.

Signal Contact

The signal contact feature provides a way to alert the user when an abnormality condition is detected in the system. The user can link the signal contact with any of the 10 alarms available individually or collectively. e.g. If the signal contact is linked with under compensate, the under compensate alarm is enabled. When the regulator detected an under compensate condition, the alarm will trigger and the signal contact will switch.

Fan

Mikro's PFRLCD regulator provides flexible settings for the fan output. There are four options that can be configured as below:

Setting	Description
None	Fan output permanently off.
Fixed On	Fan output permanently on.
Output On	Fan output will turn on when any of the output turns on (including fixed step).
Temperature (Setting range = 20 °C-35 °C)	Fan output will turn on when the temperature exceed user set value.

Alarm

The list of available alarm and its setting range are shown below:

Alarm Setting	Actions	Default setting	User Set Range
%THDI ¹	Disconnect all steps	50 %	20 – 300 % or OFF
Under Current ²		0.15 A	0.01 – 0.15 A or OFF
Over Current ¹		5.5 A	5.50 – 7.00 A or OFF
Under Voltage ²	Disconnect all steps	204 V	195 – 204 V or OFF
Over Voltage ¹		263 V	253 – 264 V or OFF
Under Compensate ⁵		OFF	ON/OFF
Over compensate ⁵		OFF	ON/OFF
Step Error ^{3,5}		OFF	ON/OFF
CT Polarity Error ⁴ (Single Phase only)		OFF	ON/OFF
No Voltage Release ⁶	Disconnect all steps	-	-
Over Temperature ¹	Disconnect all steps	65 °C	36 – 70 °C or OFF

¹ The measured value must exceed the set limit value to activate.

² The measured value must be lower than the set limit value to activate.

³ If all the rated steps are set to fixed, there will be no step error alarm.

⁴ There will be no CT polarity alarm in Four-Quadrant mode or Three Phase model.

⁵ In manual mode, there will be no under compensate alarm, over compensate alarm and step error alarm.

⁶ The alarm will activate if any of the phase is below 100 VAC.

Phase Detection

For the three phase model, the user has the options to select the method to detect and compensate the displacement power factor as desired. The user can choose to set L1, L2, L3, maximum load or three phases. For maximum load setting, the regulator will compensate base on the phase that has the maximum load. For the three phase setting, the regulator will calculate the demand for all 3 phases and consolidate it for optimum compensation.

Automatic CT Polarity Correction

The automatic CT polarity correction automatically corrects the reversed connection of the current transformer in terms of measured parameters and compensation calculation. This feature is not available for the four quadrant switching program as the regulator would not be able to distinguish the reversed connection of the current transformer. The automatic CT polarity correction is only available for single phase model.

Restore Default Settings

The user can reset to default factory setting by pressing all 2 buttons (down and up) simultaneously for 5 seconds. The user will have 3 options, reset settings, reset password and reset settings and password to choose from. Refer to appendix C for the factory default value.

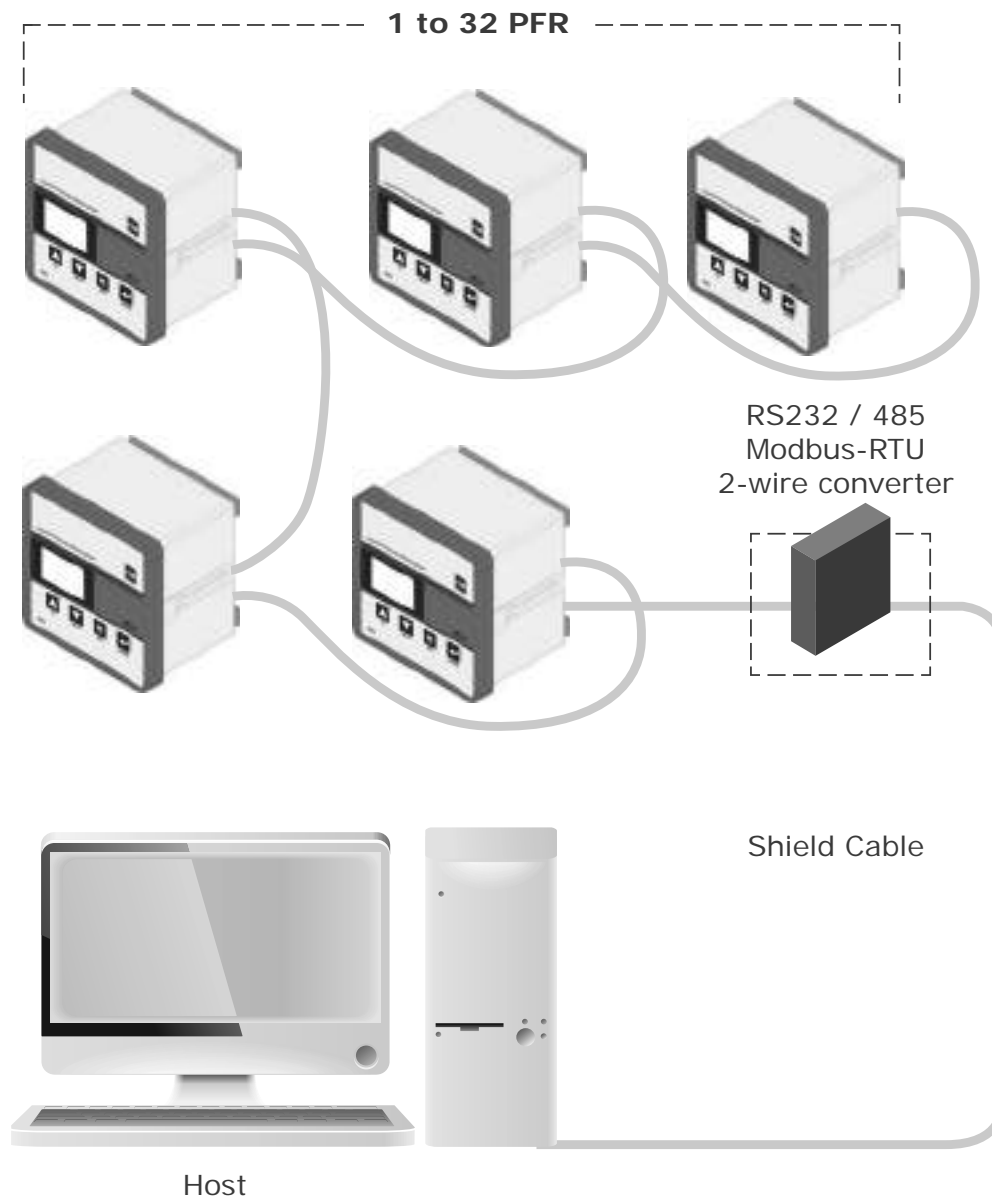
Password

When the regulator is locked, the user will be required to key in the password when attempting to change any settings of the regulator (the user will still be able to view the measurement parameters and alarm status). The user has the options to reset the password by pressing all 2 buttons (down and up) simultaneously for 5 seconds. The default password is 0,0,0,0. The regulator will lock when it is idle for more than 5 minutes (a lock symbol appear when locked).

COMMUNICATION

Communication Setup

The regulator supports the Modbus-RTU protocol. The protocol uses a master/slave method where the regulator is the slave device. The data's are transmitted serially via the RS485 protocol. The user can connect a RS485 to RS232 adapter to establish a communication through the PC serial port. The supported function codes are 03 (read holding register), 04 (read input register), 06 (write single register) and 16 (write multiple registers). The default parity mode is Even and None parity requires 2 stop bit. Refer to the connection diagram to setup the communication.



Remote Set

Enabling the Remote Set allows the remote terminal to read and write the power factor regulator setting via Modbus RTU, otherwise the setting data can only be read. Enabling feature can only be done at the panel unit.

Baudrate

There are 2 baudrates available for selection.

- 1) 9600bps
- 2) 19200bps

Parity Bit

There are 3 selections for parity bit set in data frame.

- 1) None
- 2) Odd
- 3) Even

Maintenance

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	:	Mikro Sdn Bhd No. 1, Jalan TP 7/7, Sime UEP Industrial Park, 40400 Shah Alam, Selangor, Malaysia.
Tel	:	+6 03 5192 7155
Fax	:	+6 03 5192 7166
Technical Hotline	:	1-800-88-1113 (Toll Free) +6 016 201 4801
Website	:	www.itmikro.com

APPENDIX A

Regulator Specification

CURRENT INPUT (EACH PHASE)	
Nominal Current	5 A rms
Operating Limits	0.01-10 A rms
Rated frequency	50 Hz or 60 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 or 60 Hz
Category	III *
THERMISTOR INPUT	
Thermistor Temperature range	0 – 100 °C
AUXILIARY	
Auxiliary Input Voltage Range	85-265 V rms
Consumption	10 VA max
Rated Frequency	50 Hz / 60 Hz
RELAY OUTPUT	
Number of outputs	14
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	0.80 Inductive – 0.80 Capacitive
C/K setting	0.03 – 1.20 / Automatic detect
Sensitivity	5 – 300 s/ Step
Reconnection time	5 – 240 s
Switching program	Automatic/ Manual/ Four-quadrant/ Rotational/ Linear
Rated step coefficient	0/ 1/ 2/ 3/ 4/ 5/ 6/ 8/ 12/ 16/ Fixed
Detection mode	L1 / L2 / L3 / Max Load / Three Phase
Fan Setting	Fixed on / Output On / Temperature / None
Signal Contact	Linked to 10 different programmable alarm / None
ALARM SETTING RANGE	
%THDI	20 – 300 % / OFF
Over Voltage	253 – 264 V/ OFF
Under Voltage	195 – 204 V/ OFF
Over Current	5.50 – 7.00 A/ OFF
Under Current	0.01 – 0.15 A/ OFF
Under Compensate	On / OFF
Over Compensate	On / OFF
**CT Polarity Error	On / OFF
Step Error	On / OFF
Over Temperature	36 – 70 °C / OFF

DISPLAY	
%THDI and %THDV	0 – 500 %
Harmonics Resolution	Up to 31st Harmonics
Active power	0 – 3000 W
Reactive power	0 – 3000 VAR
Apparent power	0 – 3000 VA
Voltage	0 – 300 VAC
Current	0.00 – 10.0 A rms
Temperature	0 – 100 °C
Frequency	45 – 65 Hz
Power Factor	-1.00 – 1.00
Displacement Power Factor	-1.00 – 1.00

*** This feature is not available in Three phase model.*

MECHANICAL	
Mounting	Panel mounting
Dimension (h x w x d)	144mm x 144mm x 122mm
IP Protection	IP54 Front Panel, IP20 Meter Body
Approximate weight	1.2 kg (for three phase model), 1 kg for (single phase model)
ENVIRONMENT CONDITIONS	
Temperature	-5 °C to +55 °C
Humidity	56 days at 93%RH and 40°C non-condensing
Pollution Degree	II
Dielectric Withstand	IEC61010-1
Altitude	2000 m
EMC	
ESD (Electrostatic Discharge)	IEC61000-4-2 CD Level II AD Level III
EFT (Electric Fast Transient)	IEC61000-4-4 Level III
Surge	IEC61000-4-5 Level II
Conducted Immunity	IEC61000-4-6 Level III
Magnetic Field Immunity	IEC61000-4-8 Level III
Radiated Field Immunity	IEC61000-4-3 Level III
Voltage Dip	IEC61000-4-11
Conducted and Radiated Emission	EN55011
Harmonics	IEC61000-3-2
Flicker Emission	IEC61000-3-3

** Overvoltage installation categories per IEC 61010-1. CAT III is classified as "from equipment in fixed equipment installations, e.g., installation panels, feeders and short branch circuits and lighting systems in large buildings".*

APPENDIX B

ModBus Table

FORMAT DEFINITION

FORMAT	TYPE	DESCRIPTION
F1	Power Measurement & Calibration	IEEE 754 single precision floating point representation. The floating point (4-bytes) data are transferred by means of first 2 bytes (Least significant) located at modbus address I, followed by the next 2 bytes (Most significant) at modbus address i+1
F2	3 phase Voltage and Current Harmonic Measurement	b15-b0: Unsigned Integer. The value is expressed as x/10 %. Eg. 1000 means 100.0%. negative value (-1) in harmonic indicates that the measured rms voltage is below 5% of the rated voltage (230v) ie. 11.5V or measured rms current is below 2% of the rated current (5A) ie 0.1A. Max value for Voltage harmonic and current harmonic is 5000 (500%). Harmonic value which is higher then 500% will be capped as 500%
F3	Product Information	High byte: First ASCII Character b15-b8: Unsigned Char. Low byte : Second ASCII Character b7-b0: Unsigned char
F4	Switching Program & C/K Setting	High byte: Switching Program b15-b12: don't care b11-b8 : 0: Manual 1: Rotational 2: Four-quadrant 3: Automatic 4: Linear Low byte: C/K Setting b7-b0: Unsigned Char. The valid range is from 3 to 121(AutoCk). The value is expressed as x/100 i.e. 3 means 0.03.

F5	Reconnection Time & Power factor Setting	<p>High byte: Reconnection time b15-b8 : Unsigned Char. The valid range is from 5 to 240.</p> <p>Low byte: Power Factor Setting b7-b0 : Unsigned Char. The valid range is from 80 to 120.</p> <table border="1"> <thead> <tr> <th>Cos φ</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>0.80 Ind</td> <td>80</td> </tr> <tr> <td>0.98 Ind</td> <td>98</td> </tr> <tr> <td>1.00 Res</td> <td>100</td> </tr> <tr> <td>0.98 Cap</td> <td>102</td> </tr> <tr> <td>0.80 Cap</td> <td>120</td> </tr> </tbody> </table>	Cos φ	Value	0.80 Ind	80	0.98 Ind	98	1.00 Res	100	0.98 Cap	102	0.80 Cap	120
Cos φ	Value													
0.80 Ind	80													
0.98 Ind	98													
1.00 Res	100													
0.98 Cap	102													
0.80 Cap	120													
F6	Rated Step Coefficient	<p>High byte: Step X* b15-b8: Unsigned Char. Valid values: 0, 1, 2, 3, 4, 5, 6, 8, 12, 16, 255(Fixed)</p> <p>Low byte Step X + 1* b7-b0: Unsigned Char. Valid values: 0, 1, 2, 3, 4, 5, 6, 8, 12, 16, 255(Fixed)</p> <p><i>* For 8 steps model, rated step coefficient for step 9-12 is not applicable</i></p>												
F7	Detection Phase Setting	<p>High byte: Detection Phase* b15-b12: don't care b11-b8: 0: L1 1: L2 2: L3 3: 3 Phase 4: Maximum load</p> <p>Low byte: Don't care</p> <p><i>*It is not applicable for single phase model</i></p>												
F8	Alarm setting for %THDI Limit	b15-b0 : Unsigned int. The valid range is from 20 to 300. 0 is for Off. The value is expressed in % i.e. 20 mean 20%.												
F9	Alarm setting for Under Current and Over Current Limit	<p>High byte: Under Current b15-b8 : Unsigned Char. The valid range is from 1 to 15. 0 is for Off. The value is expressed as x/100 i.e. 1 means 0.01.</p> <p>Low byte: Over Current b7-b0: Unsigned Char. The valid range is from 1 to 16. 0 is for Off. This value is expressed as (x + 54)/10. i.e. 1 means 5.5 & 11 means 6.5.</p>												

F10	Alarm setting for Under Voltage and Over Voltage Limit	<p>High byte: Under Voltage Limit b15-b8: Unsigned Char. The valid range is from 195 to 204. 0 is for Off.</p> <p>Low byte: Over Voltage Limit b7-b0: Unsigned Char. The valid range is from 1 to 12. 0 is for Off. This value is expressed as (x + 252. i.e 1 means 253 and 12 means 264.</p>
F11	Fan Temperature and Alarm setting for High Temperature Limit	<p>High byte: Fan Temperature Limit b15-b8: Unsigned Char. The valid range is from 20 to 35.</p> <p>Low byte: Over Temperature Limit b7-b0: Unsigned Char. The valid range is from 36 to 70. 0 is for Off.</p>
F12	Slave Address and Set Baud Rate	<p>High byte: Slave Address b15-b8: Unsigned Char</p> <p>Low byte: Set Baud Rate b7-b1: don't care b0: Baud Rate 0: 19200 bps 1: 9600 bps</p>
F13	Set Parity and Fan Setting	<p>High byte: Set Parity b15-b10: don't care b9-b8: 0: None 1: Odd 2: Even</p> <p>Low byte: Fan setting b7-b4: don't care b3-b0: b0: None b1: Fixed on b2: Output ON b3: Temperature</p>

F14	Signal Contact and Alarm Settings	<p>High byte: Signal contact (Alarm and None) b15-b11: don't care b10-b8: 1: Alarm 2: None</p> <p>Low byte : Alarm Settings for Under Compensate, Over Compensate, Step Error and CT polarity error b7-b4 : don't care b3-b0 : '0' = Off ; '1' = On b0: Under compensate b1: Over compensate b2: Step error b3: CT polarity error*</p> <p><i>*Only available in single phase model</i></p>
F15	Signal Contact Alarm Linkage 2 and Signal Contact Alarm Linkage 1	<p>Hight byte: Signal Contact Alarm Linkage 1 b15-b8: Unsigneid Char. '1': Linked to signal contact '0': Not linked to signal contact b8: %THDI b9: Under Current b10: Over Current b11: Under Voltage b12: Over Voltage b13: Under Compensate b14: Over Compensate b15: Step Error Alarm</p> <p>Low byte: Signal Contact Alarm Linkage 2 b7-b2: don't care b1-b0 : '1': Linked to signal contact '0': Not linked to signal contact b0: CT Polarity Error * b1: Over Temperature</p> <p><i>*Only available in single phase model</i></p>
F16	Sensitivity	b15-b0: Unsigned Int. The valid range is from 5 to 300.
F17	Reserved	b15-b0: Reserved

F18	Alarm Status	<p>High byte: Alarm Status High Byte b15-b8:</p> <ul style="list-style-type: none"> b8 : %THDI Alarm Status b9 : Under Current Alarm Status b10: Over Current Alarm Status b11: Under Voltage Alarm Status b12: Over Voltage Alarm Status b13: Under Compensate Alarm Status b14: Over Compensate Alarm Status b15: Step Error Alarm Status <p>Low byte: Alarm Status Low Byte b3-b0:</p> <ul style="list-style-type: none"> b0 : CT Polarity Alarm Status b1 : Temperature High Status Alarm b2 : Low Volt Release Alarm Status <p>b7-b4: don't care</p>
F19	Displacement PF	<p>b15-b0: Signed Integer from -100 to 100. The value is expressed as x/100. Eg. -86 means -0.86.</p>
F20	Step Output Status	<p>b15-b12: don't care b11-b0 :</p> <ul style="list-style-type: none"> '1': Step Off '0': Step On <p>example: b0 for step 1 status</p> <p>note: b8 to b11 is not applicable for 8 steps model.</p>

Modbus Database

Address		Description	Format	Unit
Dec	Hex			
Read Only		Product Information	Functions 4	
0	0000	Model Description 1 & 2	F3	00
1	0001	Model Description 3 & 4	F3	08
2	0002	Model Description 5 & 6	F3	00
3	0003	Model Description 7 & 8	F3	xx ¹
4	0004	Model Description 9 & 10	F3	xx ²
5	0005	Model Description 11 & 12	F3	xx ³
6	0006	Manufacturer 1 & 2	F3	
7	0007	Manufacturer 3 & 4	F3	
8	0008	Manufacturer 5 & 6	F3	
9	0009	Firmware Version 1 & 2	F3	
10	000A	Firmware Version 3 & 4	F3	
11	000B	Number Of Outputs	F3	xx ⁴
12	000C	Phase model	F3	xx ³
13	000D	Frequency model	F3	xx ⁵
14	000E	Reserved	F17	
15	000F	Reserved	F17	
16	0010	Reserved	F17	

NOTES:

¹ For 8 steps model, 'xx' = <space><space>
For 12 steps model, 'xx' = <space>'1'

² For 8 steps model, 'xx' = '80'
For 12 steps model, 'xx' = '20'

³ For single phase model, 'xx' = 'P1'
For three phase model, 'xx' = 'P3'

⁴ For 8 steps model, 'xx' = <space>'8'
For 12 steps model, 'xx' = '12'

⁵ For 50Hz model, 'xx' = '50'
For 60Hz model, 'xx' = '60'

Address		Description	Format	Unit
Dec	Hex			
Read Only		Measurement	Functions 4	
17	0011	Frequency	F1	Hz
19	0013	Phase Voltage A	F1	Vrms
21	0015	Phase Voltage B	F1	Vrms
23	0017	Phase Voltage C	F1	Vrms
25	0019	Phase Current A	F1	Irms
27	001B	Phase Current B	F1	Irms
29	001D	Phase Current C	F1	Irms
31	001F	Active Power Phase A	F1	W
33	0021	Reactive Power Phase A	F1	VAR
35	0023	Apparent Power Phase A	F1	VA
37	0025	Power Factor Phase A	F1	
39	0027	Active Power Phase B	F1	W
41	0029	Reactive Power Phase B	F1	VAR
43	002B	Apparent Power Phase B	F1	VA
45	002D	Power Factor Phase B	F1	
47	002F	Active Power Phase C	F1	W
49	0031	Reactive Power Phase C	F1	VAR
51	0033	Apparent Power Phase C	F1	VA
53	0035	Power Factor Phase C	F1	
55	0037	Total Active Power	F1	W
57	0039	Total Reactive Power	F1	VAR
59	003B	Total Apparent Power	F1	VA
61	003D	Total Power Factor	F1	
63	003F	Fundamental Active Power Phase A	F1	W
65	0041	Fundamental Active Power Phase B	F1	W
67	0043	Fundamental Active Power Phase C	F1	W
69	0045	Fundamental Reactive Power Phase A	F1	VAR
71	0047	Fundamental Reactive Power Phase B	F1	VAR
73	0049	Fundamental Reactive Power Phase C	F1	VAR
75	004B	Harmonic Active Power Phase A	F1	W
77	004D	Harmonic Active Power Phase B	F1	W
79	004F	Harmonic Active Power Phase C	F1	W
81	0051	Harmonic Reactive Power Phase A	F1	VAR
83	0053	Harmonic Reactive Power Phase B	F1	VAR

Address		Description	Format	Unit
Dec	Hex			
Read Only		Measurement	Functions 4	
85	0055	Harmonic Reactive Power Phase C	F1	VAR
87	0057	Total Voltage Harmonic Phase A	F1	Vrms
89	0059	Total Voltage Harmonic Phase B	F1	Vrms
91	005B	Total Voltage Harmonic Phase C	F1	Vrms
93	005D	Total Current Harmonic Phase A	F1	Irms
95	005F	Total Current Harmonic Phase B	F1	Irms
97	0061	Total Current Harmonic Phase C	F1	Irms
99	0063	Voltage A Harmonics 0	F2	%
100	0064	Voltage A Harmonics 1	F2	%
101	0065	Voltage A Harmonics 2	F2	%
102	0066	Voltage A Harmonics 3	F2	%
103	0067	Voltage A Harmonics 4	F2	%
104	0068	Voltage A Harmonics 5	F2	%
105	0069	Voltage A Harmonics 6	F2	%
106	006A	Voltage A Harmonics 7	F2	%
107	006B	Voltage A Harmonics 8	F2	%
108	006C	Voltage A Harmonics 9	F2	%
109	006D	Voltage A Harmonics 10	F2	%
110	006E	Voltage A Harmonics 11	F2	%
111	006F	Voltage A Harmonics 12	F2	%
112	0070	Voltage A Harmonics 13	F2	%
113	0071	Voltage A Harmonics 14	F2	%
114	0072	Voltage A Harmonics 15	F2	%
115	0073	Voltage A Harmonics 16	F2	%
116	0074	Voltage A Harmonics 17	F2	%
117	0075	Voltage A Harmonics 18	F2	%
118	0076	Voltage A Harmonics 19	F2	%
119	0077	Voltage A Harmonics 20	F2	%
120	0078	Voltage A Harmonics 21	F2	%
121	0079	Voltage A Harmonics 22	F2	%
122	007A	Voltage A Harmonics 23	F2	%
123	007B	Voltage A Harmonics 24	F2	%
124	007C	Voltage A Harmonics 25	F2	%
125	007D	Voltage A Harmonics 26	F2	%

Address		Description	Format	Unit
Dec	Hex			
Read Only		Measurement	Functions 4	
126	007E	Voltage A Harmonics 27	F2	%
127	007F	Voltage A Harmonics 28	F2	%
128	0080	Voltage A Harmonics 29	F2	%
129	0081	Voltage A Harmonics 30	F2	%
130	0082	Voltage A Harmonics 31	F2	%
131	0083	Voltage B Harmonics 0	F2	%
132	0084	Voltage B Harmonics 1	F2	%
133	0085	Voltage B Harmonics 2	F2	%
134	0086	Voltage B Harmonics 3	F2	%
135	0087	Voltage B Harmonics 4	F2	%
136	0088	Voltage B Harmonics 5	F2	%
137	0089	Voltage B Harmonics 6	F2	%
138	008A	Voltage B Harmonics 7	F2	%
139	008B	Voltage B Harmonics 8	F2	%
140	008C	Voltage B Harmonics 9	F2	%
141	008D	Voltage B Harmonics 10	F2	%
142	008E	Voltage B Harmonics 11	F2	%
143	008F	Voltage B Harmonics 12	F2	%
144	0090	Voltage B Harmonics 13	F2	%
145	0091	Voltage B Harmonics 14	F2	%
146	0092	Voltage B Harmonics 15	F2	%
147	0093	Voltage B Harmonics 16	F2	%
148	0094	Voltage B Harmonics 17	F2	%
149	0095	Voltage B Harmonics 18	F2	%
150	0096	Voltage B Harmonics 19	F2	%
151	0097	Voltage B Harmonics 20	F2	%
152	0098	Voltage B Harmonics 21	F2	%
153	0099	Voltage B Harmonics 22	F2	%
154	009A	Voltage B Harmonics 23	F2	%
155	009B	Voltage B Harmonics 24	F2	%
156	009C	Voltage B Harmonics 25	F2	%
157	009D	Voltage B Harmonics 26	F2	%
158	009E	Voltage B Harmonics 27	F2	%
159	009F	Voltage B Harmonics 28	F2	%

Address		Description	Format	Unit
Dec	Hex			
Read Only		Measurement	Functions 4	
160	00A0	Voltage B Harmonics 29	F2	%
161	00A1	Voltage B Harmonics 30	F2	%
162	00A2	Voltage B Harmonics 31	F2	%
163	00A3	Voltage C Harmonics 0	F2	%
164	00A4	Voltage C Harmonics 1	F2	%
165	00A5	Voltage C Harmonics 2	F2	%
166	00A6	Voltage C Harmonics 3	F2	%
167	00A7	Voltage C Harmonics 4	F2	%
168	00A8	Voltage C Harmonics 5	F2	%
169	00A9	Voltage C Harmonics 6	F2	%
170	00AA	Voltage C Harmonics 7	F2	%
171	00AB	Voltage C Harmonics 8	F2	%
172	00AC	Voltage C Harmonics 9	F2	%
173	00AD	Voltage C Harmonics 10	F2	%
174	00AE	Voltage C Harmonics 11	F2	%
175	00AF	Voltage C Harmonics 12	F2	%
176	00B0	Voltage C Harmonics 13	F2	%
177	00B1	Voltage C Harmonics 14	F2	%
178	00B2	Voltage C Harmonics 15	F2	%
179	00B3	Voltage C Harmonics 16	F2	%
180	00B4	Voltage C Harmonics 17	F2	%
181	00B5	Voltage C Harmonics 18	F2	%
182	00B6	Voltage C Harmonics 19	F2	%
183	00B7	Voltage C Harmonics 20	F2	%
184	00B8	Voltage C Harmonics 21	F2	%
185	00B9	Voltage C Harmonics 22	F2	%
186	00BA	Voltage C Harmonics 23	F2	%
187	00BB	Voltage C Harmonics 24	F2	%
188	00BC	Voltage C Harmonics 25	F2	%
189	00BD	Voltage C Harmonics 26	F2	%
190	00BE	Voltage C Harmonics 27	F2	%
191	00BF	Voltage C Harmonics 28	F2	%
192	00C0	Voltage C Harmonics 29	F2	%
193	00C1	Voltage C Harmonics 30	F2	%

Address		Description	Format	Unit
Dec	Hex			
Read Only		Measurement	Functions 4	
194	00C2	Voltage C Harmonics 31	F2	%
195	00C3	Current A Harmonics 0	F2	%
196	00C4	Current A Harmonics 1	F2	%
197	00C5	Current A Harmonics 2	F2	%
198	00C6	Current A Harmonics 3	F2	%
199	00C7	Current A Harmonics 4	F2	%
200	00C8	Current A Harmonics 5	F2	%
201	00C9	Current A Harmonics 6	F2	%
202	00CA	Current A Harmonics 7	F2	%
203	00CB	Current A Harmonics 8	F2	%
204	00CC	Current A Harmonics 9	F2	%
205	00CD	Current A Harmonics 10	F2	%
206	00CE	Current A Harmonics 11	F2	%
207	00CF	Current A Harmonics 12	F2	%
208	00D0	Current A Harmonics 13	F2	%
209	00D1	Current A Harmonics 14	F2	%
210	00D2	Current A Harmonics 15	F2	%
211	00D3	Current A Harmonics 16	F2	%
212	00D4	Current A Harmonics 17	F2	%
213	00D5	Current A Harmonics 18	F2	%
214	00D6	Current A Harmonics 19	F2	%
215	00D7	Current A Harmonics 20	F2	%
216	00D8	Current A Harmonics 21	F2	%
217	00D9	Current A Harmonics 22	F2	%
218	00DA	Current A Harmonics 23	F2	%
219	00DB	Current A Harmonics 24	F2	%
220	00DC	Current A Harmonics 25	F2	%
221	00DD	Current A Harmonics 26	F2	%
222	00DE	Current A Harmonics 27	F2	%
223	00DF	Current A Harmonics 28	F2	%
224	00E0	Current A Harmonics 29	F2	%
225	00E1	Current A Harmonics 30	F2	%
226	00E2	Current A Harmonics 31	F2	%
227	00E3	Current B Harmonics 0	F2	%

Address		Description	Format	Unit
Dec	Hex			
Read Only		Measurement	Functions 4	
228	00E4	Current B Harmonics 1	F2	%
229	00E5	Current B Harmonics 2	F2	%
230	00E6	Current B Harmonics 3	F2	%
231	00E7	Current B Harmonics 4	F2	%
232	00E8	Current B Harmonics 5	F2	%
233	00E9	Current B Harmonics 6	F2	%
234	00EA	Current B Harmonics 7	F2	%
235	00EB	Current B Harmonics 8	F2	%
236	00EC	Current B Harmonics 9	F2	%
237	00ED	Current B Harmonics 10	F2	%
238	00EE	Current B Harmonics 11	F2	%
239	00EF	Current B Harmonics 12	F2	%
240	00F0	Current B Harmonics 13	F2	%
241	00F1	Current B Harmonics 14	F2	%
242	00F2	Current B Harmonics 15	F2	%
243	00F3	Current B Harmonics 16	F2	%
244	00F4	Current B Harmonics 17	F2	%
245	00F5	Current B Harmonics 18	F2	%
246	00F6	Current B Harmonics 19	F2	%
247	00F7	Current B Harmonics 20	F2	%
248	00F8	Current B Harmonics 21	F2	%
249	00F9	Current B Harmonics 22	F2	%
250	00FA	Current B Harmonics 23	F2	%
251	00FB	Current B Harmonics 24	F2	%
252	00FC	Current B Harmonics 25	F2	%
253	00FD	Current B Harmonics 26	F2	%
254	00FE	Current B Harmonics 27	F2	%
255	00FF	Current B Harmonics 28	F2	%
256	0100	Current B Harmonics 29	F2	%
257	0101	Current B Harmonics 30	F2	%
258	0102	Current B Harmonics 31	F2	%
259	0103	Current C Harmonics 0	F2	%
260	0104	Current C Harmonics 1	F2	%
261	0105	Current C Harmonics 2	F2	%

Address		Description	Format	Unit
Dec	Hex			
Read Only		Measurement	Functions 4	
262	0106	Current C Harmonics 3	F2	%
263	0107	Current C Harmonics 4	F2	%
264	0108	Current C Harmonics 5	F2	%
265	0109	Current C Harmonics 6	F2	%
266	010A	Current C Harmonics 7	F2	%
267	010B	Current C Harmonics 8	F2	%
268	010C	Current C Harmonics 9	F2	%
269	010D	Current C Harmonics 10	F2	%
270	010E	Current C Harmonics 11	F2	%
271	010F	Current C Harmonics 12	F2	%
272	0110	Current C Harmonics 13	F2	%
273	0111	Current C Harmonics 14	F2	%
274	0112	Current C Harmonics 15	F2	%
275	0113	Current C Harmonics 16	F2	%
276	0114	Current C Harmonics 17	F2	%
277	0115	Current C Harmonics 18	F2	%
278	0116	Current C Harmonics 19	F2	%
279	0117	Current C Harmonics 20	F2	%
280	0118	Current C Harmonics 21	F2	%
281	0119	Current C Harmonics 22	F2	%
282	011A	Current C Harmonics 23	F2	%
283	011B	Current C Harmonics 24	F2	%
284	011C	Current C Harmonics 25	F2	%
285	011D	Current C Harmonics 26	F2	%
286	011E	Current C Harmonics 27	F2	%
287	011F	Current C Harmonics 28	F2	%
288	0120	Current C Harmonics 29	F2	%
289	0121	Current C Harmonics 30	F2	%
290	0122	Current C Harmonics 31	F2	%
291	0123	Alarm Status	F18	
292	0124	Displacement PF1	F19	
293	0125	Displacement PF2	F19	
294	0126	Displacement PF3	F19	
295	0127	Step Output Status	F20	

Address		Description	Format	Unit
Dec	Hex			
Read/Write		Control Parameters	Functions 3, 6, 16	
296	0128	Switching Program & C/K Setting	F4	
297	0129	Reconnection Time and Target Power Factor	F5	
298	012A	Rated Step 1 and 2	F6	
299	012B	Rated Step 3 and 4	F6	
300	012C	Rated Step 5 and 6	F6	
301	012D	Rated Step 7 and 8	F6	
302	012E	Rated Step 9 and 10	F6	
303	012F	Rated Step 11 and 12	F6	
304	0130	Detection Phase	F7	
305	0131	Alarm Setting for Under Current and Over Current	F9	
306	0132	Alarm setting for Under Voltage and Over Voltage	F10	
307	0133	Fan Temperature and Alarm Setting for Over Temperature Limit	F11	
308	0134	Set Slave Address and Baud Rate	F12	
309	0135	Set Parity and Fan setting	F13	
310	0136	Sensitivity	F16	
311	0137	Alarm setting for %THDI Limit	F8	
312	0138	Reserved		
313	0139	Signal Contact and Alarm Settings	F14	
314	013A	Signal Contact Alarm Linkage 2 and Signal Contact Alarm Linkage 1	F15	
315	013B	Reserved	F17	
316	013C	Reserved	F17	

APPENDIX C

Setting Parameters

CONTROL SETTING PARAMETERS	DEFAULT VALUE
Target Power factor	0.98 Inductive
C/K setting	Auto
Sensitivity	45 s
Reconnection time	30 s
Switching program	Auto mode
Rated step coefficient	1 for all steps
Detection mode	Max Load
Fan Setting	None
Signal Contact	None
ALARM SETTING PARAMETERS	DEFAULT VALUE
%THDI	50 %
Over Voltage	263 VAC
Under Voltage	204 VAC
Over Current	5.50 A rms
Under Current	0.15 A rms
Under Compensate	Off
Over Compensate	Off
CT Polarity Error	Off
Step Error	Off
Over Temperature	65 °C
COMMUNICATION SETTING PARAMETERS	DEFAULT VALUE
Slave Address	1
Baud Rate	19200 bps
Parity	Even
Communication Enable	Off

APPENDIX D

Calculations

D.1 C/K

(i) C /K equation:

$$C / K = \frac{Q \times 5}{\sqrt{3} \times V \times I} \approx \frac{2.88 \times Q}{V \times I}$$

Q = smallest capacitor step (VAR)
 V = nominal primary system voltage (V)
 I = primary rating of the current transformer (A)

Example:

If Q = 20kVAR, V = 415V, I = 850A
 then,

$$C / K = \frac{2.88 \times 20000}{415 \times 850} = 0.16$$

(i) Computed C/K value as show below:

C/K Value for 415V												
C.T Ratio	Smallest Capacitor in (kVAR)											
	5	10	12.5	15	20	25	30	40	50	60	100	150
30:5	1.16											
50:5	0.70											
75:5	0.46	0.93	1.16									
100:5	0.35	0.70	0.87	1.04								
150:5	0.23	0.46	0.58	0.70	0.93	1.16						
200:5	0.17	0.35	0.43	0.52	0.70	0.87	1.04					
250:5	0.14	0.28	0.35	0.42	0.56	0.70	0.83	1.11				
300:5	0.12	0.23	0.29	0.35	0.46	0.58	0.70	0.93	1.16			
400:5	0.09	0.17	0.22	0.26	0.35	0.43	0.52	0.70	0.87	1.04		
500:5	0.07	0.14	0.17	0.21	0.28	0.35	0.42	0.56	0.70	0.83		
600:5	0.06	0.12	0.14	0.17	0.23	0.29	0.35	0.46	0.58	0.70	1.16	
800:5	0.04	0.09	0.11	0.13	0.17	0.22	0.26	0.35	0.43	0.52	0.87	
1000:5	0.03	0.07	0.09	0.10	0.14	0.17	0.21	0.28	0.35	0.42	0.70	1.04
1500:5		0.05	0.06	0.07	0.09	0.12	0.14	0.19	0.23	0.28	0.46	0.70
2000:5		0.03	0.04	0.05	0.07	0.09	0.10	0.14	0.17	0.21	0.35	0.52
2500:5		0.03	0.03	0.04	0.06	0.07	0.08	0.11	0.14	0.17	0.28	0.42
3000:5			0.03	0.03	0.05	0.06	0.07	0.09	0.12	0.14	0.23	0.35
4000:5				0.03	0.03	0.04	0.05	0.07	0.09	0.10	0.17	0.26

Table D.1.0

D.2 Sensitivity

(i) C/K equation:

$$\text{Re action Time} = \frac{\text{Sensitivity}}{\text{required kVAR}} \times \text{smallest stepsize}$$

Example:

If $Q_{1st} = 15\text{kVAR}$, Sensitivity = 60s/step, $Q_{rq} = 15\text{kVAR}$

$$\text{Re action Time} = \frac{60}{15000} \times 15000 = 60\text{s}$$

If $Q_{rq} = 45\text{kVAR}$,

$$\text{Re action Time} = \frac{60}{45000} \times 15000 = 20\text{s}$$

Q_{1st} : smallest step size kVAR

Q_{rq} : required kVAR

D.3 Total Harmonic Distortion for Current (%THDI)

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

i_n = n^{th} order harmonic rms current
 i_1 = fundamental rms current

NOTES:

If the measured current falls below 2% of the rated current, the %THDI will display "---". This is because the regulator will not be able to obtain a reliable measurement to calculate the %THDI. For %THDI > 500%, %THDI will be capped at 500%

D.4 Total Harmonic Distortion for Voltage (%THDV)

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

V_n = n^{th} order harmonic rms current
 V_1 = fundamental rms current

NOTES:

If the measured voltage falls below 5% of the rated voltage, the %THDV will display "---". This is because the regulator will not be able to obtain a reliable measurement to calculate the %THDV. For %THDV > 500%, %THDV will be capped at 500%