Varlogic NRC12

Power factor controller

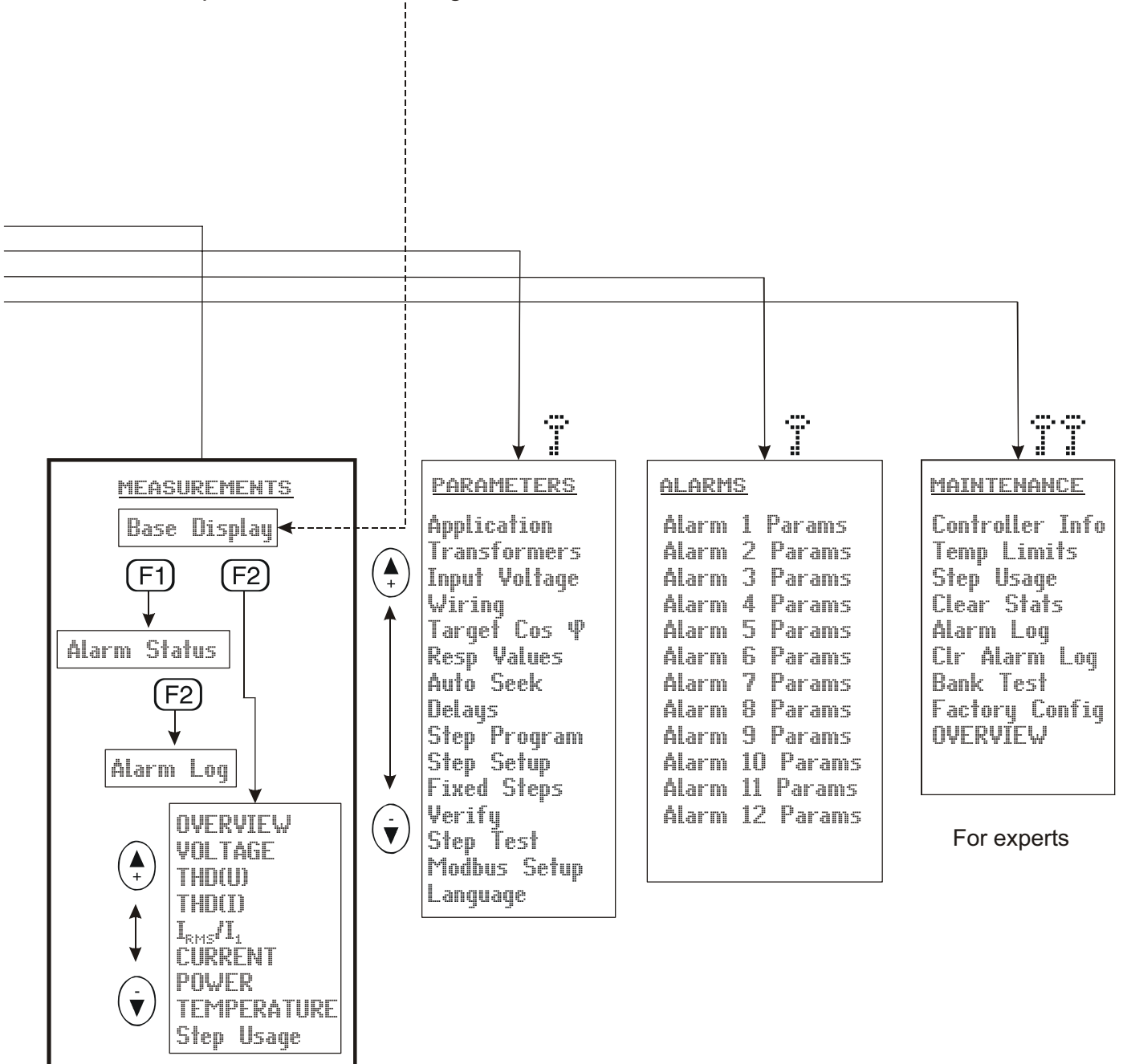User manual

Merlin Gerin

<u>Menu Structure</u>

<u>First Startup</u>   <u>Startup after preconfiguration</u>

| Language selection | | Language selection |

(enter) <u>Main Menu</u>   (enter)   (enter) <u>Main Menu</u>

```
BANK PRECONF
AUTO SETUP
MANUAL SETUP
MEASUREMENTS
PARAMETERS
ALARMS
MAINTENANCE
```

```
COMMISSIONING
AUTO SETUP
MANUAL SETUP
MEASUREMENTS
PARAMETERS
ALARMS
MAINTENANCE
```

(enter)

```
BANK PRECONF

Language
Application
Input Voltage
Wiring
Target Cos Ψ
Delays
Step Program
Step Setup
```

For bank builders

```
COMMISSIONING

Language
Transformers
Target Cos Ψ
Verify
```

```
AUTO SETUP

Transformers
Input Voltage
Target Cos Ψ
Search
```

```
MANUAL SETUP

Application
Transformers
Input Voltage
Wiring
Target Cos Ψ
Resp Values
Delays
Step Program
Step Setup
Verify
```

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Startup after commissioning

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THDI
I_{RMS}/I_1
CURRENT
POWER
TEMPERATURE
Step Usage

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Transformers
Input Voltage
Wiring
Target Cos φ
Resp Values
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Delays
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Step Setup
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Power Factor Controller NRC12 USER'S MANUAL

Table of Contents

1. General

1.1 Safety

The following precautions must be taken into account when installing and operating the controller

- The installation of the controller must be performed by a qualified electrician
- Do not touch the connectors when the controller is energized, make sure that the operating voltage is disconnected before touching any parts located on the rear side of the controller
- Do not open a live current circuit, this may cause dangerous overvoltages. Always short circuit the current transformer (CT) before replacing or removing the controller installed in a bank.
- Do not open the controller casing, there are no user serviceable parts inside
- External computing devices connected to the communication connector of Power Factor Controller have to comply with the standard IEC 60950-1

For better understanding of the terminology used, please refer to the Glossary (chapter 8) at the end of this manual.

1.2 Environmental conditions

The controller is designed for the following environmental conditions:
- Indoor use
- Altitude up to 2000 m
- Ambient temperatures within 0°…+60°C
- Maximum relative humidity 80 percent for temperatures up to 31°C decreasing linearly to 50 percent relative humidity at 40°C
- Mains supply voltage fluctuations not to exceed –20/+15 percent of the nominal voltage
- Transient overvoltage for the Mains supply according to installation categories III (IEC 61010-1)
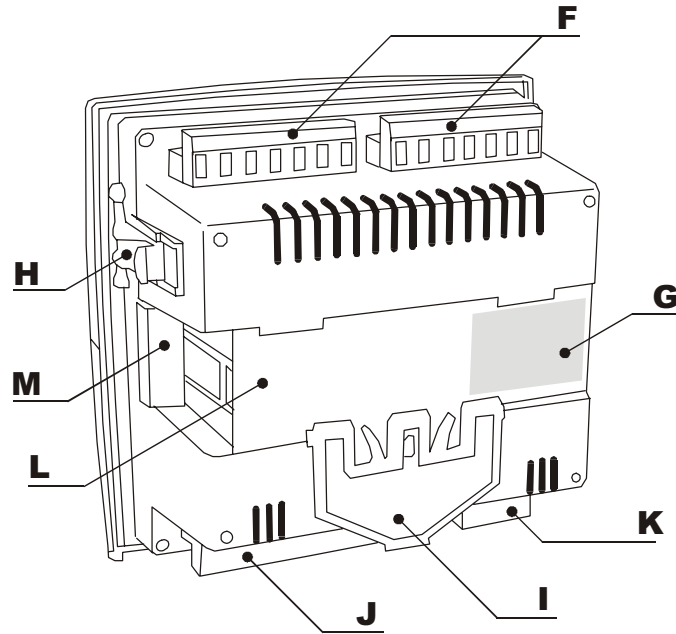- Pollution degree 2 (IEC 61010-1)

1.3 Description

Front view:
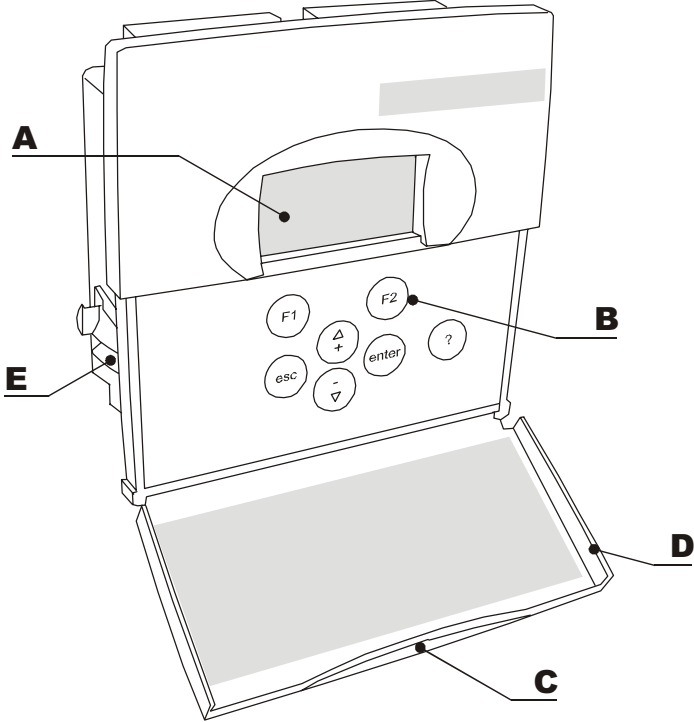
Legend

A	Display
B	Keys
C	Opening of door
D	Door
E	Mounting bracket for panel mounting installation

Rear view:

Legend

F	Step output connectors
G	Name plate
H	Mounting bracket for panel mounting installation
I	Fixing spring for DIN-rail mounting
J	Current, voltage, temperature sensor and target cos φ connection inputs
K	Fan ✛ and alarm outputs
L	DIN-rail mounting installation area
M	Controller Communication Adapter (CCA-01) cover ⚠

Side view:
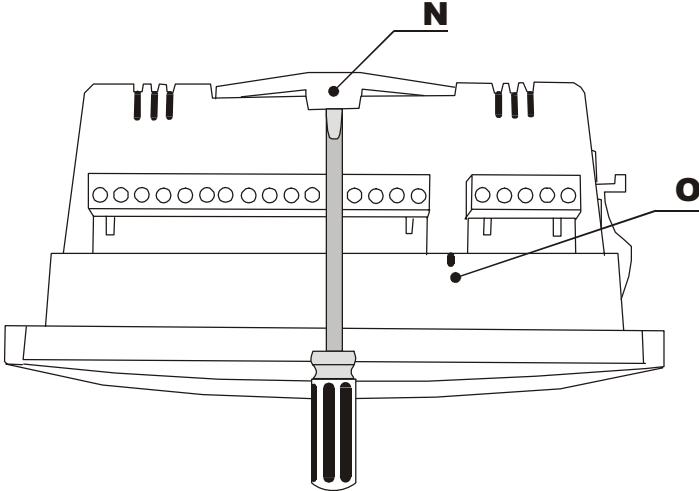
Legend

N   DIN-rail fixing spring
O   Air inlet for temperature measurement

See Chapter 9 for technical details.

2. Installation

The controller is designed for either panel (cut-out 138 x 138 mm) or DIN-rail installation. It is locked to a panel by a side fitting springs or to the rail by a screwdriver-operated fixing spring.

There are two ways of connecting the controller to the network.

❖ Voltage LN (Line – Neutral)   ⇒ CT on the same line phase as voltage measurement. For LN wiring Voltage setting should be L1-N and Current setting should be L1.

❖ Voltage LL (Line – Line)   ⇒ CT normally on the remaining phase (normally phase L1). For LL wiring Voltage setting should be L2-L3 and Current setting should be L1.

Separated inputs exist for measurement voltage ("U_1" and "U_2") and supply voltage ("0V" and "110V"/"230V"/"400V"). The controller can automatically correct incorrect measurement connection when *Auto Setup* is selected from the main menu.

External temperature sensor can be installed close to the devices to be watched and connected to inputs "T1" and "T2". The cable used needs to be certified to national requirements relevant to controller installation voltage.

Alternative target cos φ can be controlled by using external relay contact connected between inputs "φ1" and "φ2". The cable used needs to be certified to national requirements relevant to controller installation voltage.

Caution: For application in HV network, look first at chapter 6.3

Control switch of capacitorbank switches the power to the controller.

In ambient temperature of 60°C the temperature class of connection wires must be at least 80°C.

Notes on installation:

A switch or circuit-breaker shall be included in the building installation. It shall be in close proximity to the equipment and within easy reach of the operator. It shall be marked as the *disconnecting device* for the equipment. An equipment switch or circuit-breaker employed as a disconnecting device shall comply with relevant requirements of IEC 60947-1 and IEC 60947-3.

Overcurrent protection devices such as fuse or miniature circuit breaker with a rating of no more than 10 A shall be connected in supply conductors. The overcurrent protection devices need to be certified to national requirements.
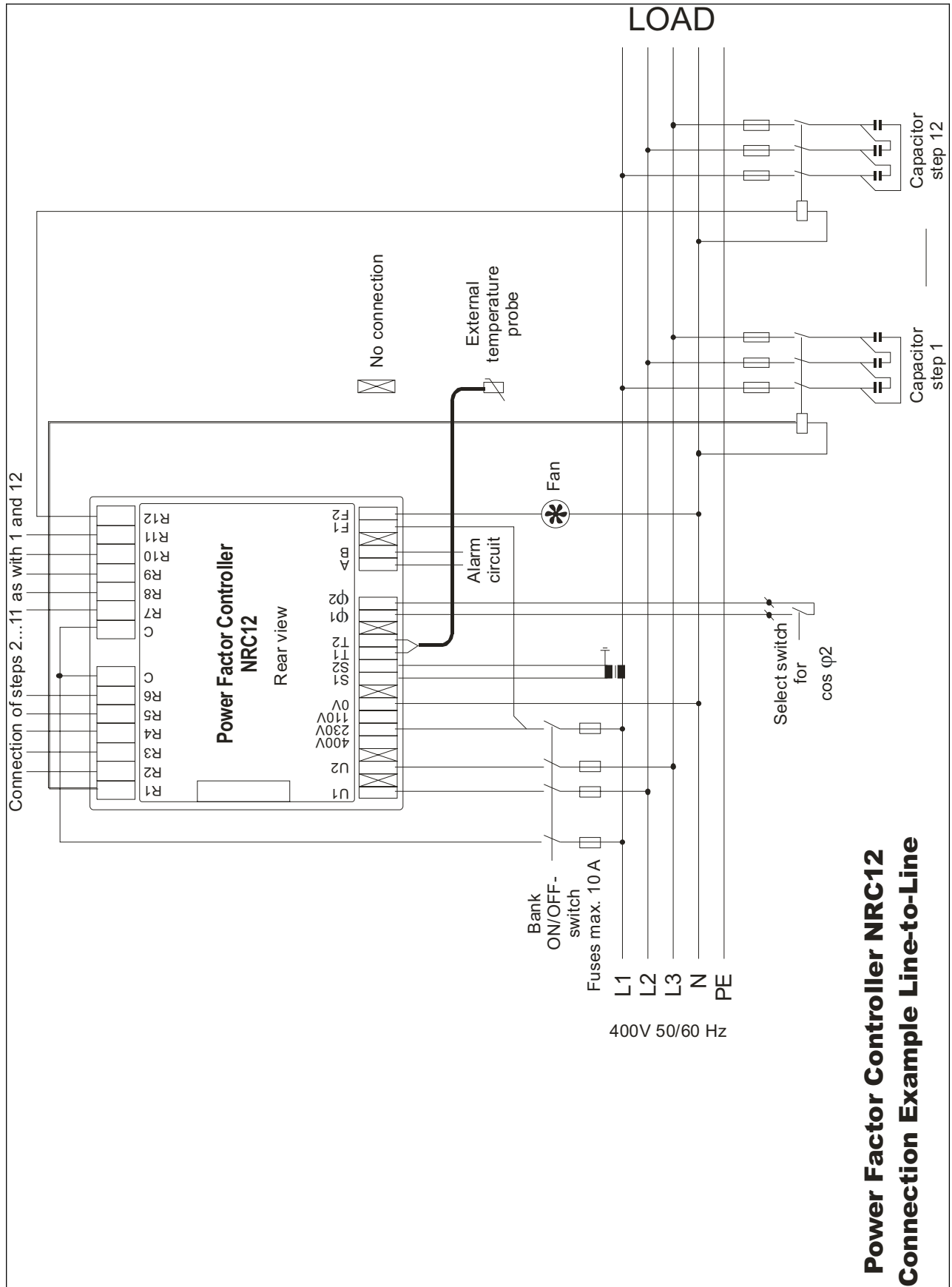
Figure 1-1: Controller connection example Line-to-Line (LL)
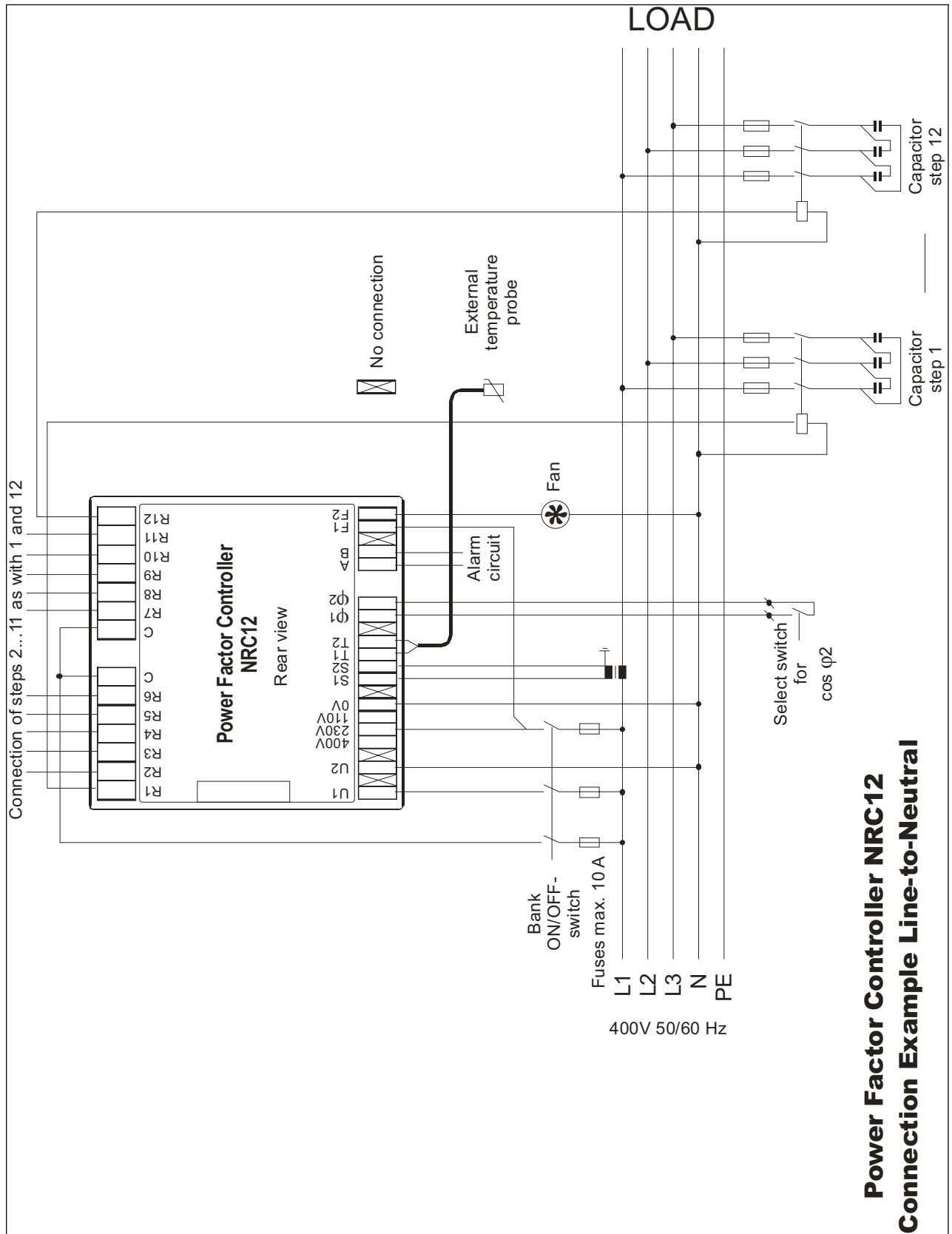
Figure 1-2: Controller connection example Line-to-Neutral (LN)

3. Display

The controller is equipped with a backlighted dot matrix display with a resolution of 128 x 64 pixels.

Essential indicators:
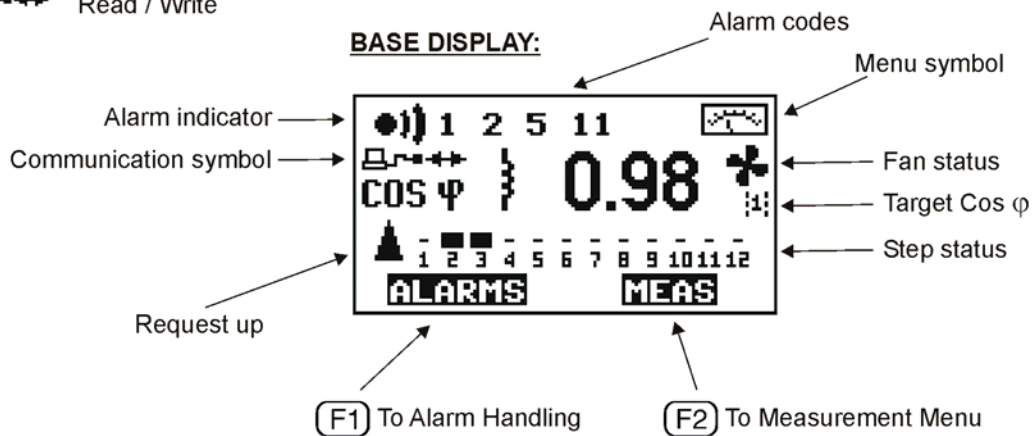
Figure 2: Display layout and symbols

4. Start-up Procedure

Before connecting power, check the wiring of all controller terminals. Check carefully for correct operating voltage. Selection of wrong voltage input can permanently damage the controller.

After the first power switch-on, the controller will automatically ask for the language setting of the menu.
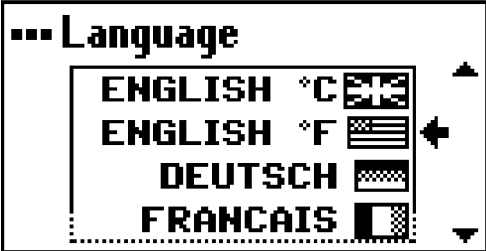
Figure 3: Language setting dialog

At any time press (?)-button for help screen.

5. Menu Operations

5.1 General

<u>Navigation between different menu levels</u>

As a precaution against accidental use, the access of certain menus has been protected by a keylock, which is a special sequence of keystrokes enabling the use the particular menu item. Code lock is automatically closed after the home delay (5 minutes from last keystroke).

<u>Keylock Type 1</u>
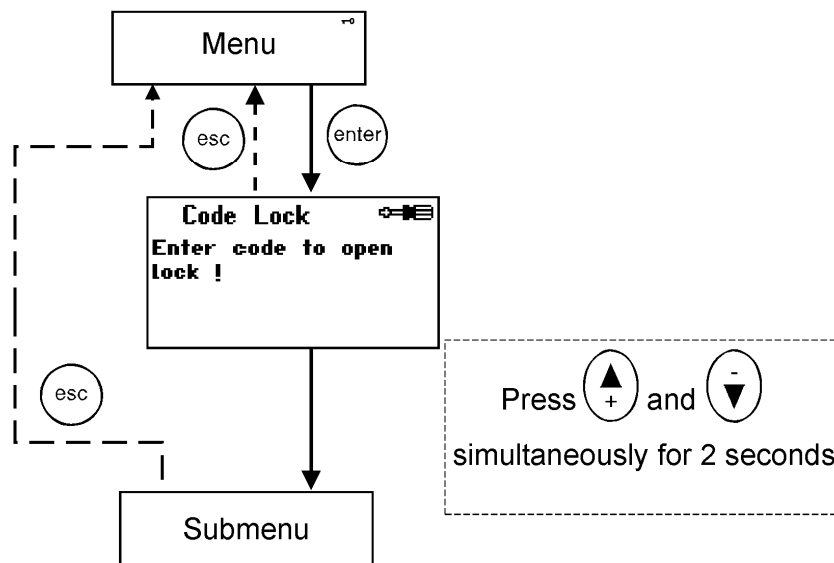
<u>Keylock Type 2</u>
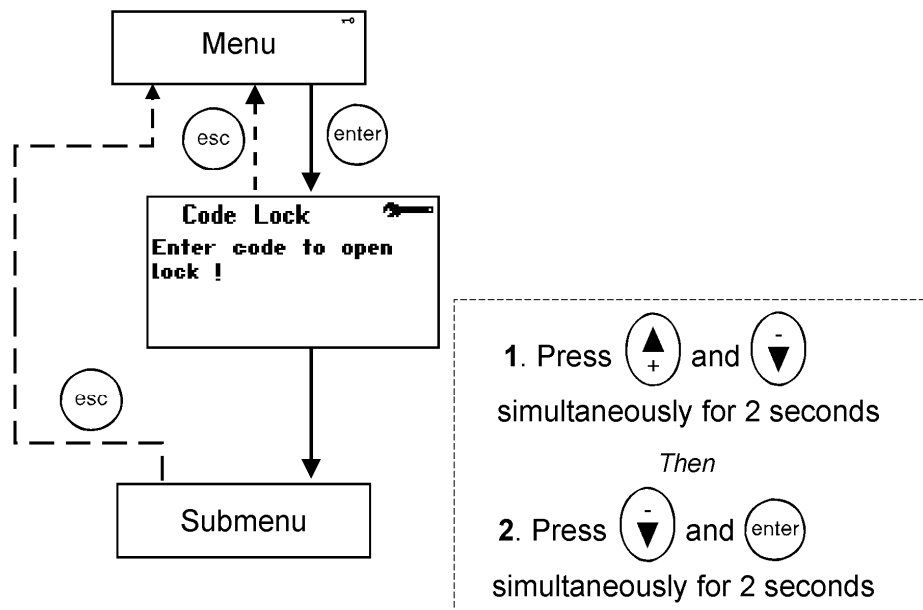
<u>Figure 4</u>: Entering a submenu with a keylock

Adjusting a value

Single parameter editor

To editor

enter →

Cancel adjustment ←···· esc

Item A

▲ + Increase / Previous value

▼ - Decrease/ Next value

enter → Adjustment done Save the value

Multiparameter editor

F1 Previous Item

To editor

enter →

Cancel adjustment ←···· esc

Item A

Item B

PREV   NEXT

▲ + / ▼ -

▲ + / ▼ -

Increase / Previous value

Decrease / Next value

enter → Adjustment done Save the values

F2 Next Item
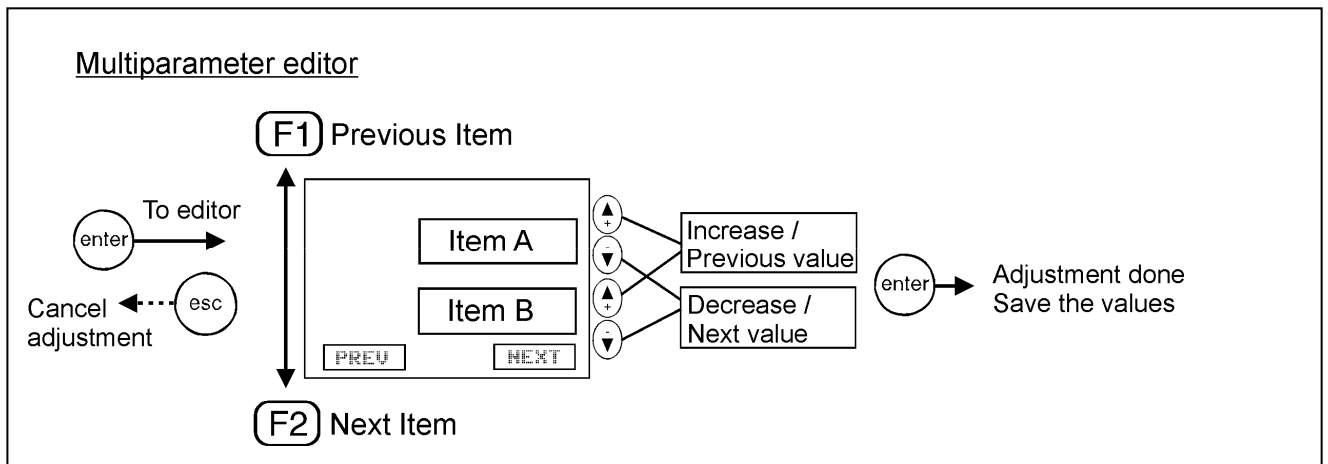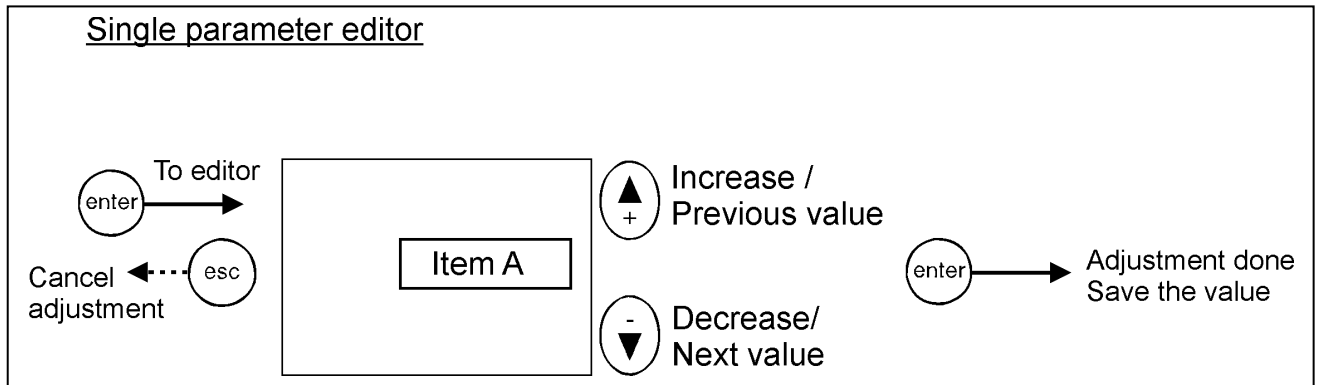
Figure 5: Adjusting a value

For faster increasing/decreasing hold the button down.

Using controller help

At any time pressing ⟨?⟩ -button provides information and browsing help for the current controller screen.

? →

←···· ?

Language
Language selection for menus.
▲ and ▼ choose.
ENT accept the value and move to the next parameter ▼

▲ + Scroll up

▼ - Scroll down
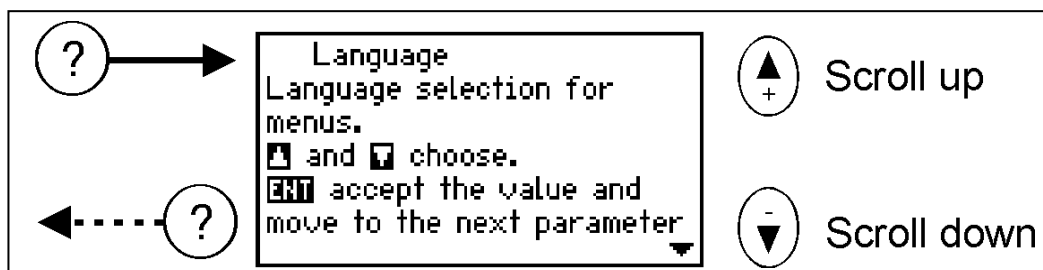
Figure 6: Using controller help

5.2 Main Menu

The main menu contains all basic submenus required to set up and operate the controller.

Which menu to choose?
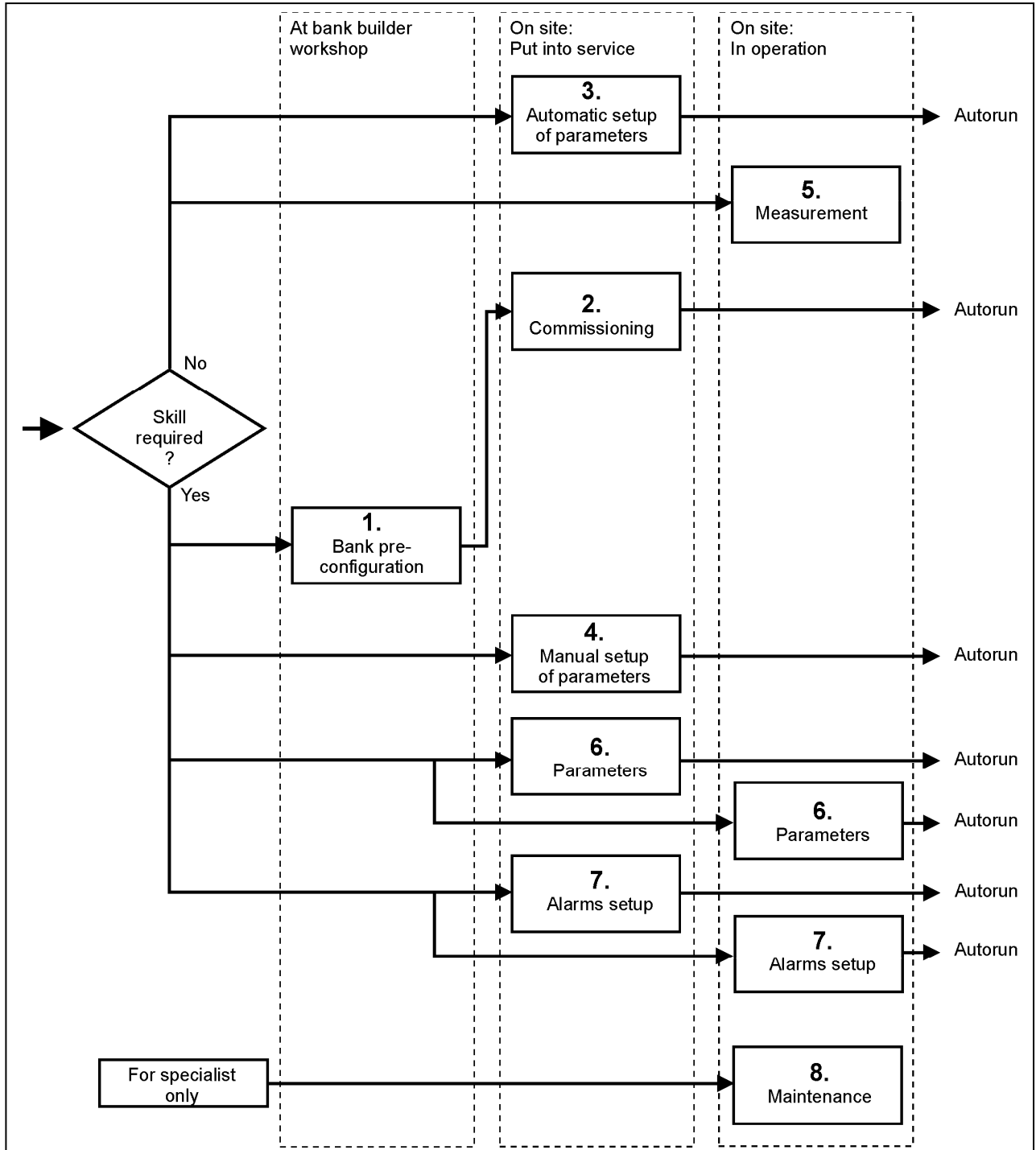
Figure 7: Required skills and menu selection

If bank preconfiguration is properly done, commissioning does not require any special skill.
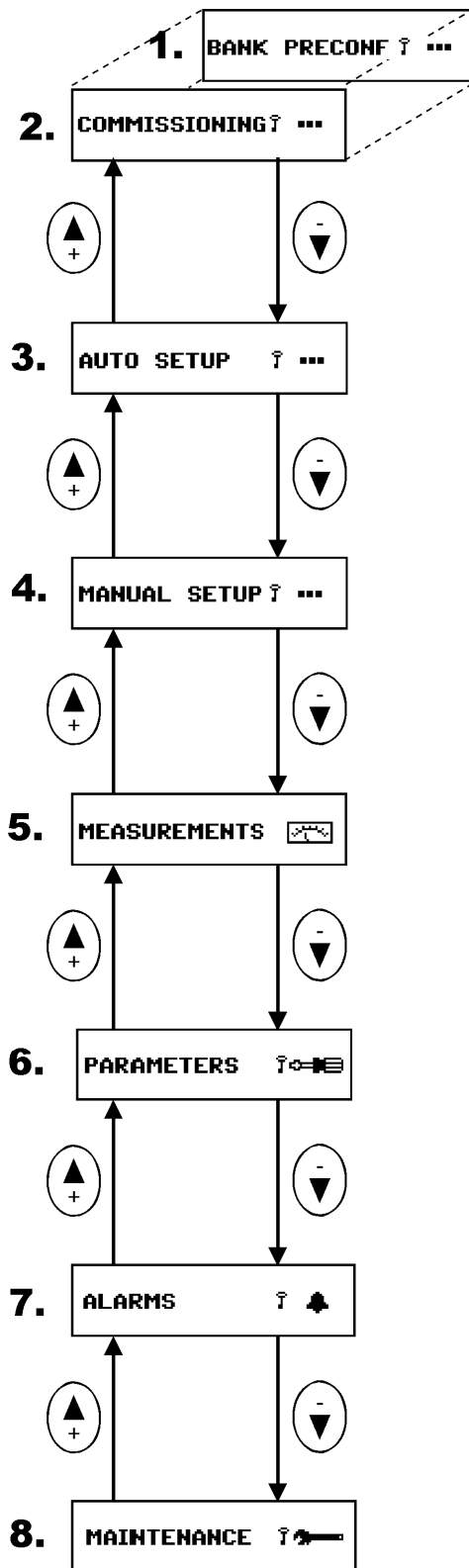
(1) Bank pre-configuration
When factory settings have not been changed, this menu provides the means of pre-configuring the bank at the workshop. After pre-configuration, this menu topic is replaced by **(2) Commissioning**, by which the controller is taken into service.

(3) Automatic setup of parameters
In the event that the controller has not been pre-configured, an inexperienced user can automatically set up all the characteristics of the bank and bring it into service.

(4) Manual setup of parameters
In the event that the controller has not been pre-configured, an experienced user can manually set up all the characteristics of the bank and bring it into service.

(5) Measurement
The measurement menu contains the most common measurements taken from the network and provides some information about the bank. This is a read-only menu.

(6) Parameters
At any time, an experienced user can access the most common operating parameters from this menu. Unlike the configuration and setup sequences, this is a menu allowing a free and unrestricted entry into all its items and should be used when an occasional parameter access is needed.

(7) Alarm settings
To show status and adjust the parameters of alarms.

(8) Maintenance
The maintenance menu provides useful information about the usage of the bank, capacitors and contactors. Auxiliary settings and action have also been provided. This menu is basically intended for use by the manufacturer's maintenance team.

Figure 8: Main menu

5.3 Bank Pre-Configuration

This menu item is a forced sequence, meaning that all items must be accessed before the pre-configuration takes place.

NOTES: 1) Do not use the Bank Pre-Configuration menu for HV network applications
2) Select "Cancel" at the end of Bank Pre-Configuration menu if 1st step is fixed

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The sequence can be interrupted by pressing (esc) key. See Glossary (chapter 8) for definitions.
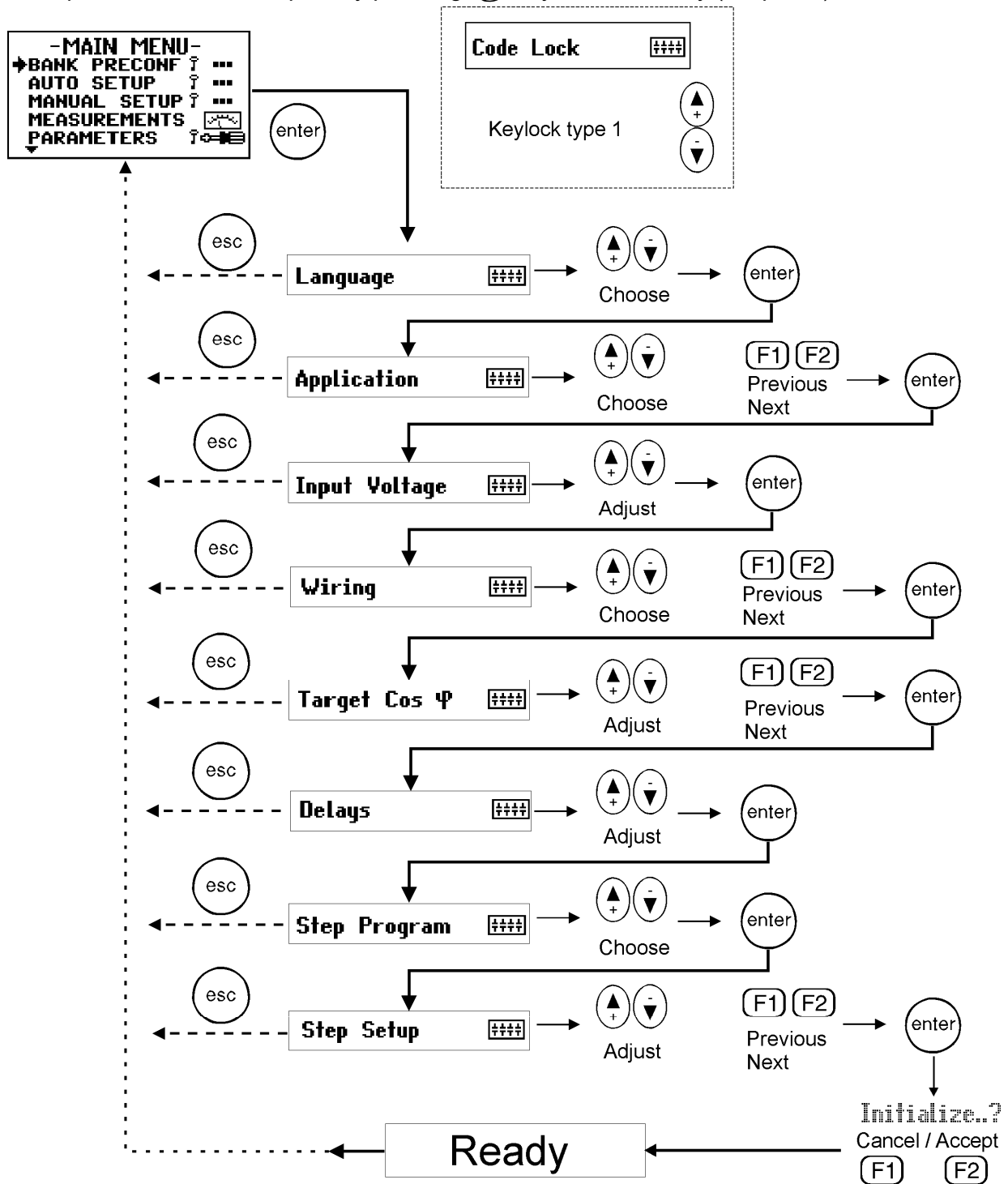
Figure 9: Bank pre-configuration

5.4 Commissioning

5.4.1 Commissioning sequence

A pre-configured controller is put into service by this menu. The sequence contains an automatic C/K value detection and and automatic parameter verification to check that the manually entered parameters comply with the network.

See Glossary (chapter 8) for parameter definitions.

NOTE: *The use of Commissioning menu is forbidden on HV network applications.*
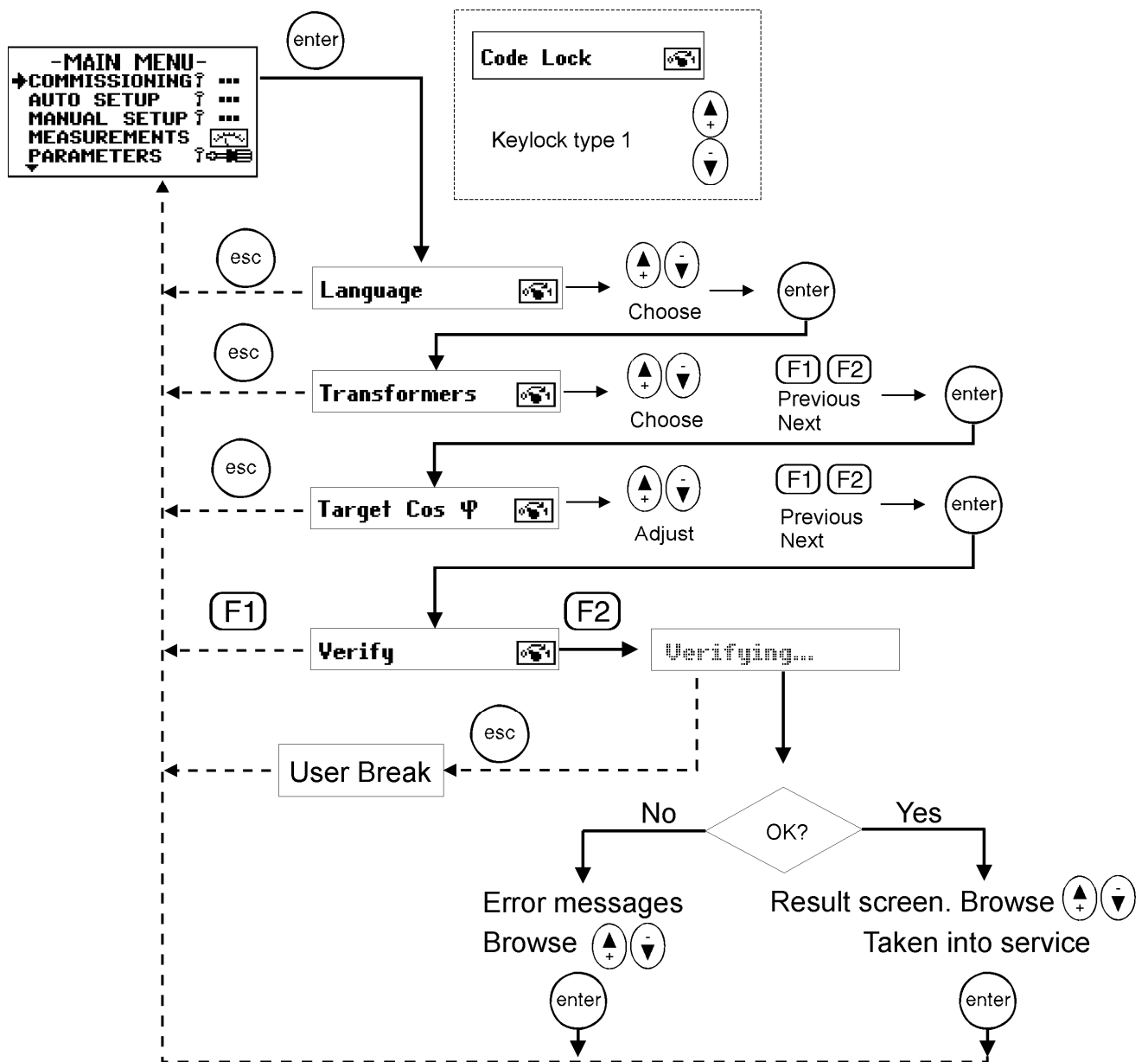
Figure 10: Commissioning

5.4.2 List of errors

What to do in case of error ?

Error codes can help you to identify a problem and make corrections.

Code	Meaning	Action to do
1 Unstable network	Unstable network: The controller is unable to verify/search parameters due to excessive load variations on the network.	❖ Enter the parameter settings manually using *Parameters* menu. ❖ Rerun the commissioning sequence
2 Step too small	Step size too small: The effect of the 1st step cannot be measured. CT oversized, wrong wiring, inoperative steps.	❖ Check wiring, CT, condition of capacitor steps (1st step)
3 Sequence not found	Sequence not found: Step ratio does not match available step sequences.	❖ Check the condition and sizes of steps ❖ Check the contactors and step wiring.
4 Step too large	Step size too large: The ratio of measured step compared with the 1st step is too large. Step sequence cannot be resolved.	❖ Check the condition and sizes of steps and contactors
5 Use manual setup	Non-relevant autosetup process with this bank configuration.	❖ Use manual setup to confirm or correct the information obtained by autosetup.
6 - 8	Reserved	
9 Wiring error	Wiring verify error: Controller wiring not correct.	❖ Check the wiring of voltage- and current inputs ❖ Check the *Wiring* setting from *Parameters* menu
10 Step count error	Step count verify error: The *Number of Steps* setting is incorrect.	❖ Check the *Number of Steps* setting ❖ Check the number of steps in the bank and the condition of steps
11 Step sequence err	Step sequence verify error: The step size ratios differ from the selected step sequence.	❖ Check *Step Sequence* setting ❖ Check step sizes used in the bank
12 C/K value error	C/K value verify error.	❖ Check the response value used ❖ Check the size of 1st step in the bank

Disconnected bank disables Verify and Search functions and "Alarm with shutdown"-text will be shown in the Verify / Search - result screen.

5.5 Auto Setup of Parameters

The auto setup sequence is intended for inexperienced users so they can commission the bank with minimal prior knowledge. The user need only input three of the most common parameters and then launch an automatic search for the other parameters.

Auto setup forces application setting to 4-quadrant, step program to optimal, and disables step size monitoring. C/K-value, step setup and wiring are detected automatically. The automatic detection is unavailable if fixed steps are set.

NOTE: The use of Auto Setup of Parameters menu is forbidden on HV network applications.

In the event of error, see the error table on previous page.
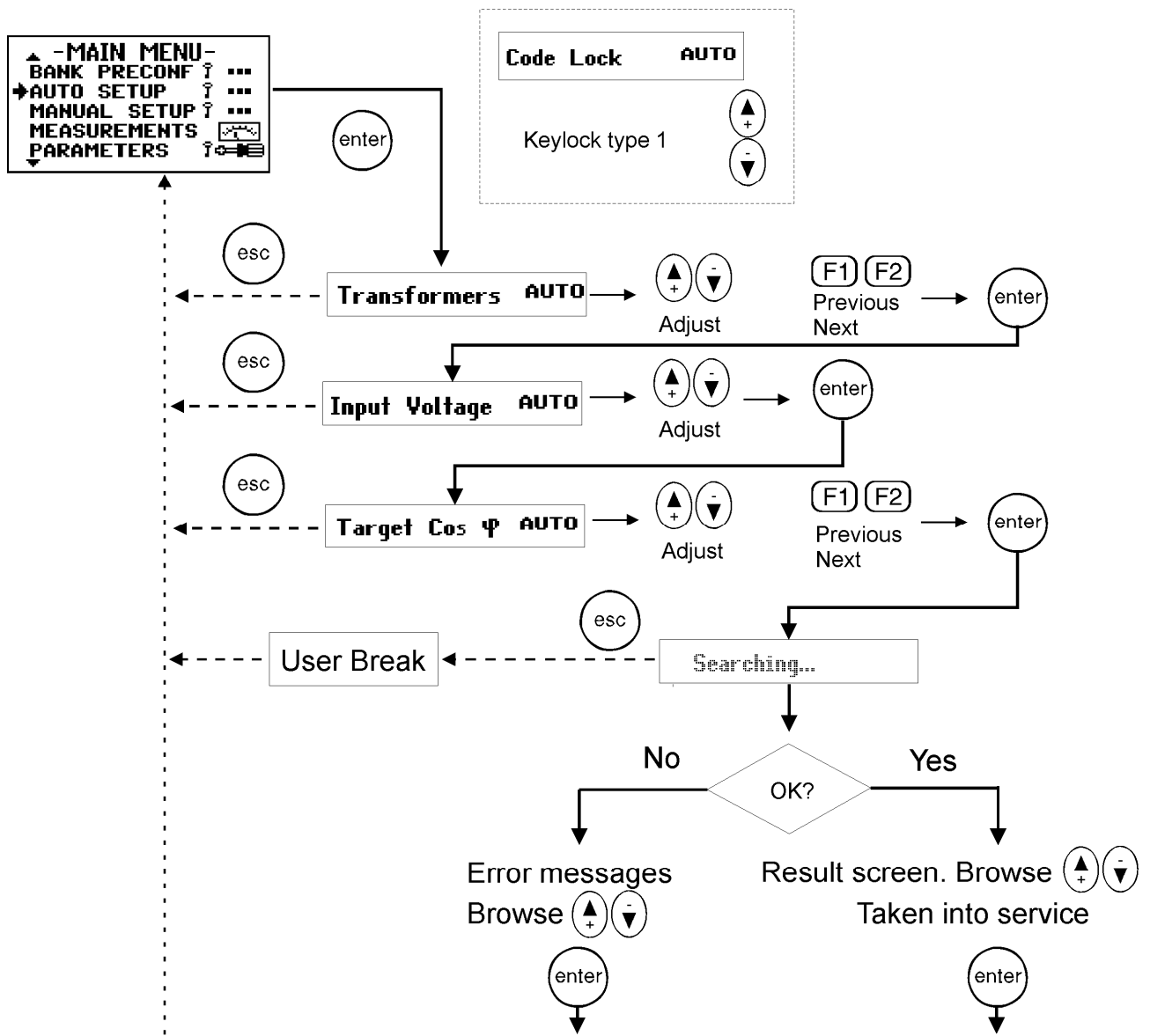
Figure 11: Auto setup of parameters

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5.6 Manual Setup of Parameters

The manual setup sequence is intended for experienced users. There are nine important parameters to input before the controller can be taken into service. This sequence is completed by an automatic verification of the parameters entered in this sequence.

This menu item is a forced sequence, meaning that all items must be accessed before the validation of the setup takes place. The sequence can be interrupted by pressing (esc) key.

See Glossary (chapter 8), for parameter definitions.

In case of error in verification, refer to error table, page 20.

NOTE: The use of verification in Manual Setup of Parameters is forbidden on HV network applications.
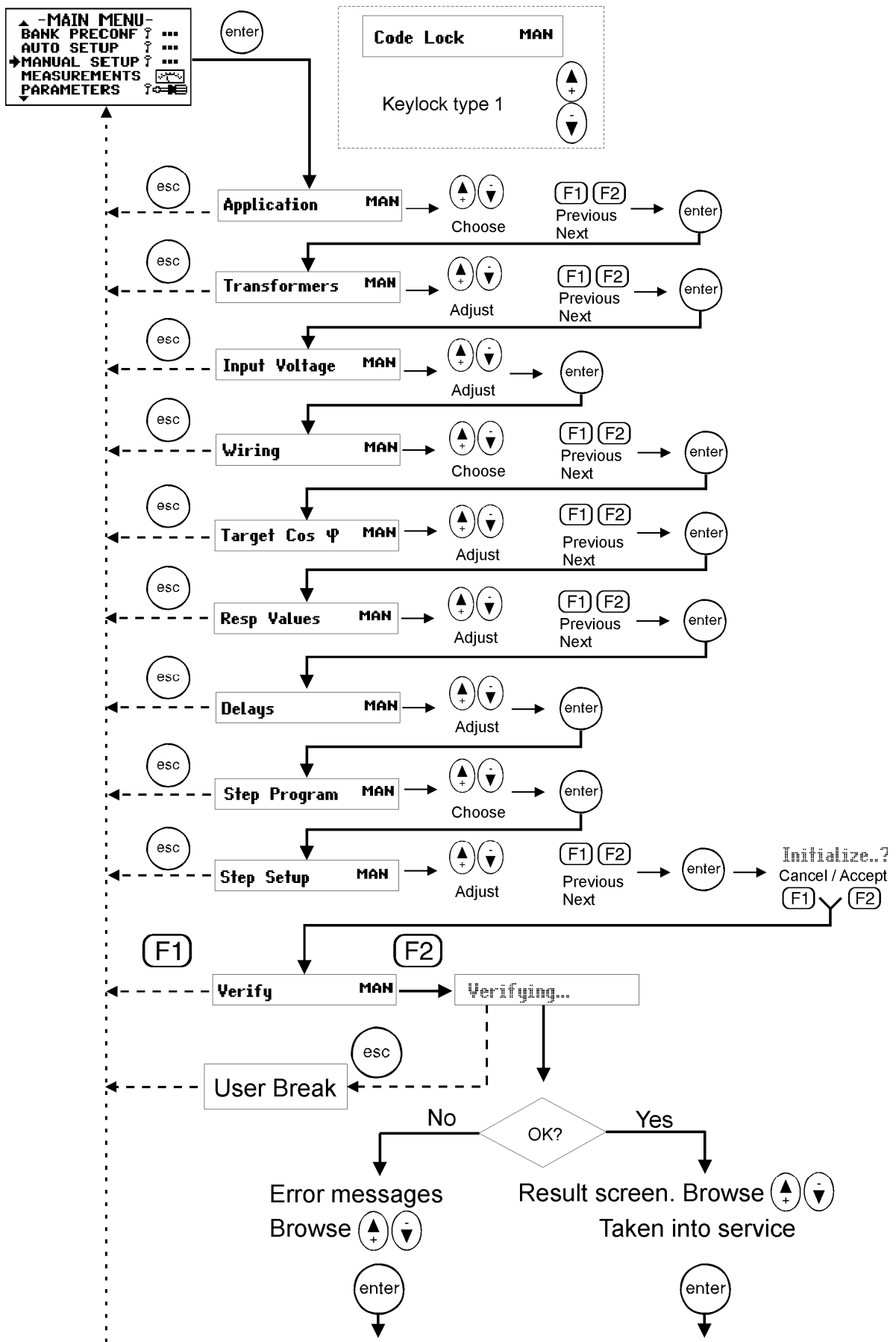
Figure 12: Manual setup of parameters

5.7 Measurement Menu

The measurement menu contains the most common measurements taken from the network. This is a read-only menu, only the selection on some displayed measurements is possible.
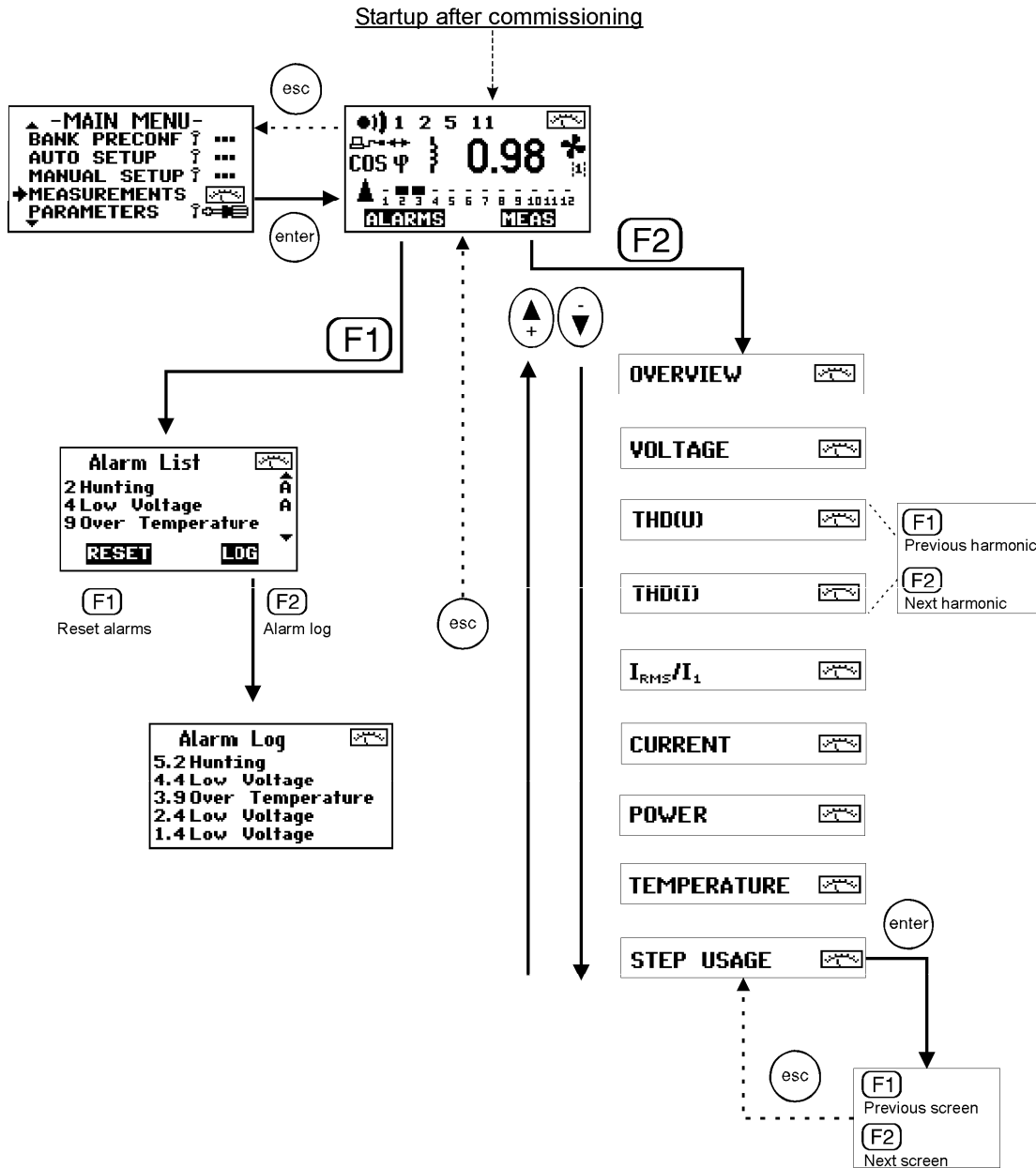
Figure 13: Measurement menu

Measurement Explanations:

Screen	Item	Description
Alarm List		List of detected alarms. A = Active alarm.
Alarm log		Log of 5 latest alarms. Alarm log can be cleared using "Clear Alarm Log"-function in Maintenance menu.
OVERVIEW	U_1	Input voltage (V_{LL} Line to Line or V_{LN} Line to Neutral)
	THD(U)	Total harmonic distortion of voltage
	I_{RMS}/I_1	Capacitor overload factor
	Q	Reactive power
	Temp	Internal temperature

Screen	Item	Description
VOLTAGE	U₁	Input voltage (V_{LL} Line to Line or V_{LN} Line to Neutral) and voltage limits. If nominal value is not standard, graphical display is in % scale.
	THD(U)	Total harmonic distortion of voltage and alarm limit for it.
THD(U)		Total harmonic distortion of voltage and harmonic components.
THD(I)		Total harmonic distortion of current and harmonic components.
I_{RMS}/I_1		Capacitor overload factor (measured current ratio to nominal current at nominal voltage) and alarm limit for it.
CURRENT	Active	Active current of CT primary (phase current)
	Reactive	Reactive current of CT primary
	Apparent	Apparent current of CT primary
POWER	Active	Active power (3-phase total power)
	Reactive	Reactive power
	Apparent	Apparent power
TEMPERATURE	Internal	Internal temperature, fan limit and alarm limit.
	External	External temperature, only present if external temperature sensor connected.
STEP USAGE		Number of step connections and usage hours
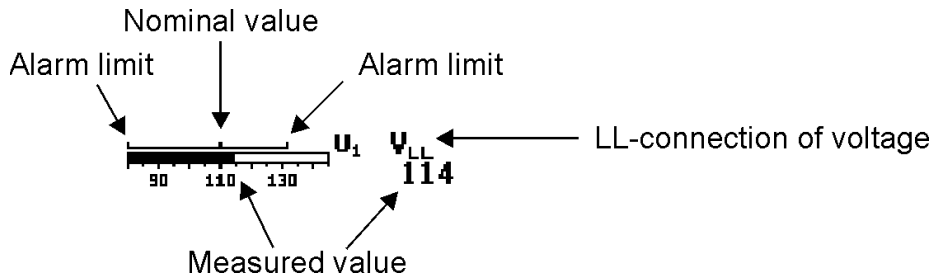
Figure 13-2: Measured value and alarm limits
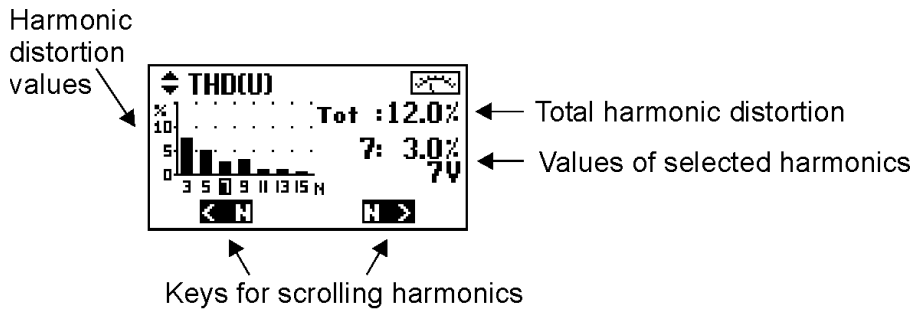
Figure 13-3: Graphs showing voltage harmonics
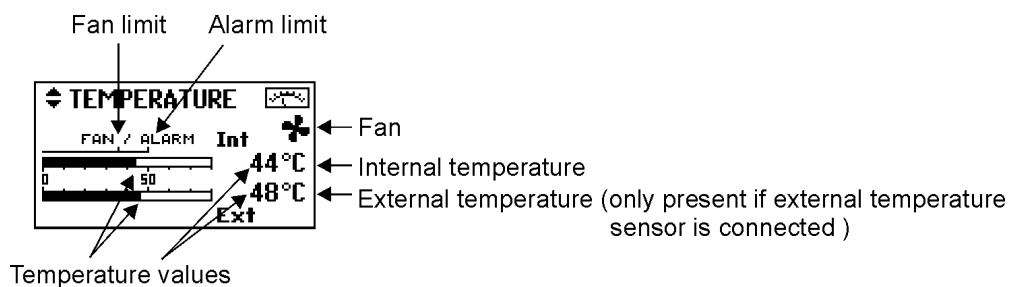
Figure 13-4: Temperature values and fan status

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5.8 Parameters

CAUTION: *In case of installation in a HV bank (with VT), you must adjust the default factory settings. The reconnection delay must be changed to a larger value (e.g. 600 secs) to prevent destruction of capacitors.*

The most common operating parameters can be accessed from this menu.

Unlike the configuration and setup sequences presented earlier in this text, this is a menu allowing a free and unrestricted entry into all of its items and should be used when occasional parameter access is needed. Restart the controller after major changes in parameters.

To start the step size monitoring, set number of steps, step sequence and the size of the 1st step (reactive power and voltage), initialize the measurement (asked when exiting the editor). If wanted, set the alarm on from the alarm menu. If the step size is set to 0 the step size monitoring is disabled.

Step size monitoring cannot be used when

❖ loads change constantly and rapidly
❖ if the 1st step is very small compared to total measurement scale
❖ if HV application is selected (automatically disabled)

Fixed steps cannot be monitored or verified. Setting 1st step fixed disables also search and seek functions.

See Glossary (chapter 8), for parameter definitions.

In case of error in verifying, refer to error table, page 20.
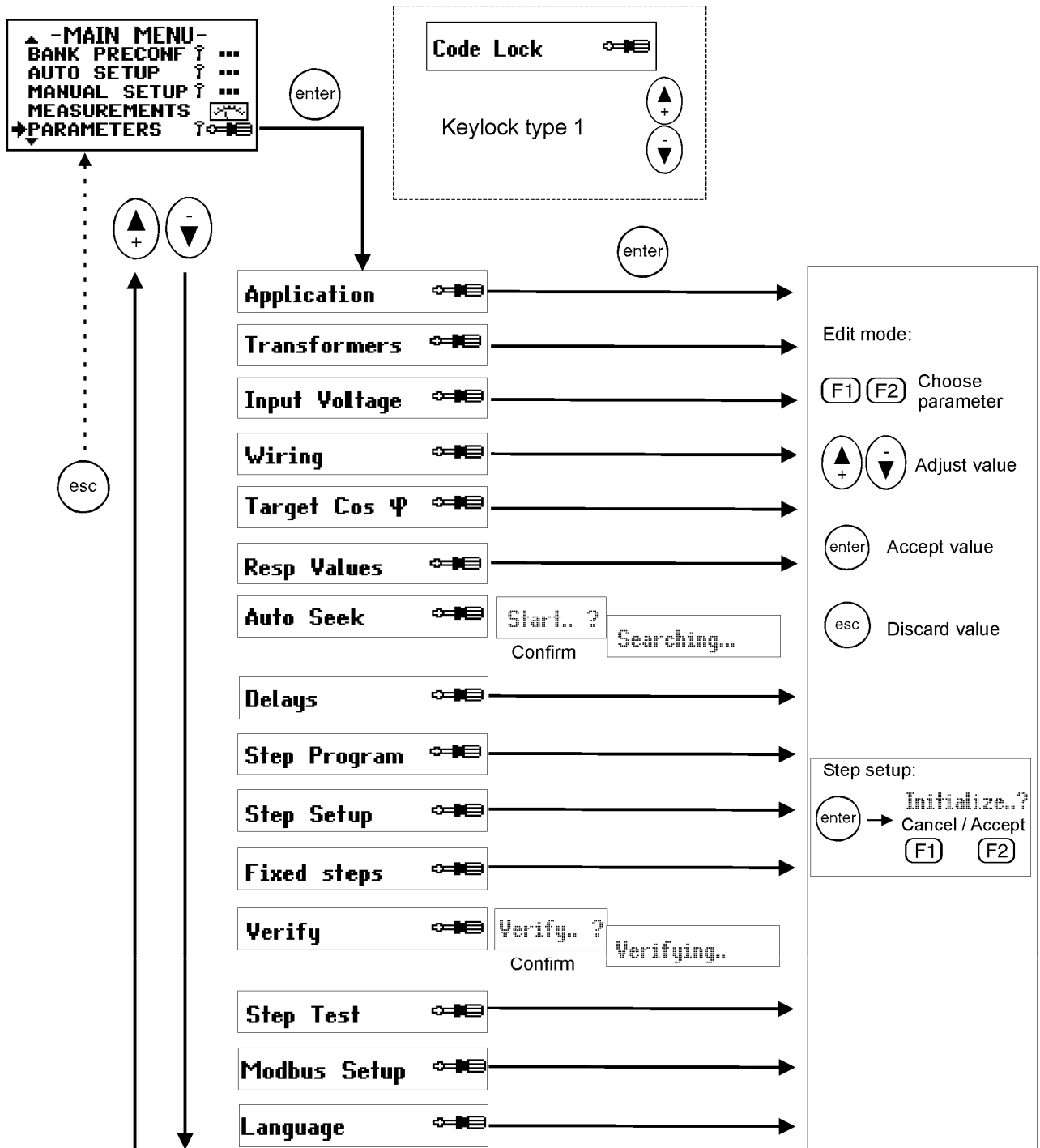
Figure 14: Parameters

Parameter Explanations:

Screen	Item	Description
Application	2 Quadrant	2 quadrant application: Only use of power, the most common situation.
	4 Quadrant	4 quadrant application: Power generation possible. Application is forced to 4-quadrant in Auto Setup.
	100-700V 0,5-50kV (VT) 10-400kV (VT)	Network voltage range of application.

Screen	Item	Description
Transformers	CT	Current transformer: primary and secondary current.
	VT	Voltage transformer ratio. Used if voltage range with VT selected.
Input Voltage		Nominal input voltage reference value at input voltage terminals U_1 and U_2. For voltage alarms. In VT application, the secondary voltage is entered and the calculated primary voltage is displayed.
Wiring	Voltage Phase	Location of voltage measurement: L2-L3, L3-L1, L1-L2, L1-N, L2-N or L3-N. Detected in Auto Setup and Auto seek, checked with verify function. See also Installation (chapter 2).
	CT Phase	Location of current measurement: L1, L2 or L3. Detected in Auto Setup and Auto seek, checked with verify function. See also Installation (chapter 2).
	CT Polarity	Detected in Auto Setup and Auto seek, checked with verify function. DIRECT = Normal polarity of current measurement REVERSE = Inverted polarity of current measurement AUTO = Automatic current polarity detection, disabled in 4 quadrant applications.
Target Cos Ψ	Cos Ψ 1	Primary Target Cos φ (normally used when control input is open), 0.80 ind - 0.90 cap
	Cos Ψ 2	Secondary Target Cos φ (selected by closing relay input), 0.80 ind - 0.90 cap. Symbol in Base Display shows the status of control relay.
Resp Values	Inductive	C/K-value for inductive reactive power, 0.01 - 1.99. Calculate using a formula or get from C/K value table. Detected in Auto Setup and Auto seek, or manually if wanted. Checked with verify function.
	Capacitive	C/K-value for capacitive reactive power, 0.01 - 1.99. Calculate using a formula or get from C/K value table. Detected in Auto Setup and Auto seek, or manually if wanted. Checked with verify function.
Auto Seek		Automatic C/K-value seek, connects and disconnects first step several times. *Do not use on HV network applications!*
Delays	Reconnection	10s - 900s. Reconnection delay and response delay. Reconnection delay is used to protect the step capacitors (don't use too short values). Response delay, the minimum time between changes in steps, is defined as 20 % of reconnection delay, min 10 s. The default value corresponds to capacitors with internal discharge resistors 50V 1 min. Reconnection is faster when using Optimal step program.
Step Program		(Forced to Optimal in Auto Setup). Normal, suitable for step sequence 1.2.4.4.4 Circular 1.1.1, suitable for step sequence 1.1.1.1.1 Circular 1.2.2, suitable for step sequence 1.2.2.2.2 Stack, suitable for step sequence 1.1.1.1.1 Optimal, suitable for several step sequences
Step Setup	Num of Steps	Number of steps, 1 -12. Detected in Auto Setup, checked with verify function.
	Step Seq	Step sequence (needed for optimal stepping program, step size monitoring function and alarm 12). Detected in Auto Setup, checked with verify function.

Screen	Item	Description
	1ˢᵗ Step	Size of first step at given voltage level (next parameter) 1kvar - 400kvar, for step size monitoring. 0 = step size monitoring disabled. See Alarms Menu (chapter 5.9) / Alarm 12
	Voltage	Nominal voltage of step (the line-to-line voltage)
Fixed Steps		A: Automatic (default) 0: Step fixed OFF 1: Step fixed ON Steps set fixed are not included in any automatic functions. Fixed steps and Optimal Stepping Program cannot be used together.
Verify		Automatic verification of C/K, steps and wiring. In case of an error refer to error table, page 20. *Do not use in HV network applications!*
Step Test		Manual connection of steps for testing
Modbus Setup	Status	2 digits containing correct message total counter + 2 digits containing faulty message counter + 2 digits containing replied message counter.
	Mode	The use of controller's communication. NONE = Communication disabled READ = Communication reads information READ/RESET = Communication reads information and resets alarms. READ/WRITE = Communication reads and writes information
	Address	Modbus slave address of the controller
	Bits/s	Bit rate used for data transmission
Language		Language selection of user interface

5.9 Alarms Menu

In Alarms menu, each individual alarm can be enabled or disabled. Alarms 1-11 are enabled and alarm 12 is disabled as default. Alarm screen also shows whether the alarm is active or passive.

Also, some alarm triggering levels can be adjusted. Disconnection of steps due to alarms 2, 9, 10 can be enabled or disabled from alarm settings.

Once an alarm condition is detected, the corresponding alarm number is shown at the upper part of the display, and the alarm symbol becomes visible. The alarm relay is also activated.

Alarm indications can be reset in base display alarm dialog (F1), this clears all passive alarms. If alarm condition is still active, the alarm cannot be reset.

List of alarm descriptions and limits:

Alarm No.	Alarm	Description	Limit, limit adjustment
1	Out of Steps	No steps left to connect. Network is still inductive and request for more steps exist.	
2	Hunting	Continuing more/fewer step request detected.	10 min
3	Abnormal Cos φ	Current flows, but cos φ out of range.	Ind. < 0.50, cap. < 0.80
4	Low voltage		80%
5	Over Compensation	No steps left to disconnect, network is still capacitive.	
6	Wrong frequency	Frequency detected at startup neither 50 Hz nor 60Hz.	+- 2 Hz of nominal at startup
7	Over Current		115% of nominal
8	Over Voltage		110%(30 min) or 120%(1 min)
9	Over Temperature	If external temperature sensor is installed, only external temperature is watched.	Temperature limit setting, default 50°C
10	Too High THD(U)	Harmonic distortion of voltage over limit.	THD(U) limit setting, default 7%.
11	Cap Overload	Harmonic distortion or resonance polluted current, overload factor I_{RMS}/I_1 over limit.	I_{RMS}/I_1 limit setting, default 1.5.
12	Cap Output Low	Capacitance is measured and watched during connection and disconnection. Step sizes must be configured for step size monitoring (see Parameters/Step Setup).	Capacitor value < 75 % nominal

List of alarm causes and actions:

Alarm No.	Alarm	Possible cause	Controller action
1	Out of Steps	Wiring or LL/LN definition error Undersized bank	
2	Hunting	Too small C/K value Wrong program choice Defective capacitors	If disconnection in alarm setup is ON disconnects bank for 10 minutes. No disconnection as default.
3	Abnormal cos φ	Wiring mistake Over capacitive network (welded contactors) Too low current	
4	Low voltage		Disconnection till voltage returns
5	Over Compensation	Wiring or LL/LN definition error Improper use of fixed steps	
6	Wrong frequency	Wrong or unstable network frequency detected at startup	Stop regulation. No automatic restart
7	Over Current	Undersized CT	
8	Over Voltage		Temporary disconnection of steps during alarm and delay after that.
9	Over Temperature	Ambient temperature too high Defective cooling system	Temporary disconnection of steps during alarm and delay after that, if disconnection in alarm setup is ON. Disconnection as default.
10	Too High THD(U)	Harmonic pollution Resonance	Temporary disconnection of steps during alarm and delay after that, if disconnection in alarm setup is ON. No disconnection as default.
11	Cap Overload	Harmonic distortion, resonance	Temporary disconnection of steps during alarm and delay after that.
12	Cap Output Low	Defective capacitor	∷ -marks in Base Display

In case of Alarm 12 user can set the defective capacitor Fixed OFF to clear the alarm situation.
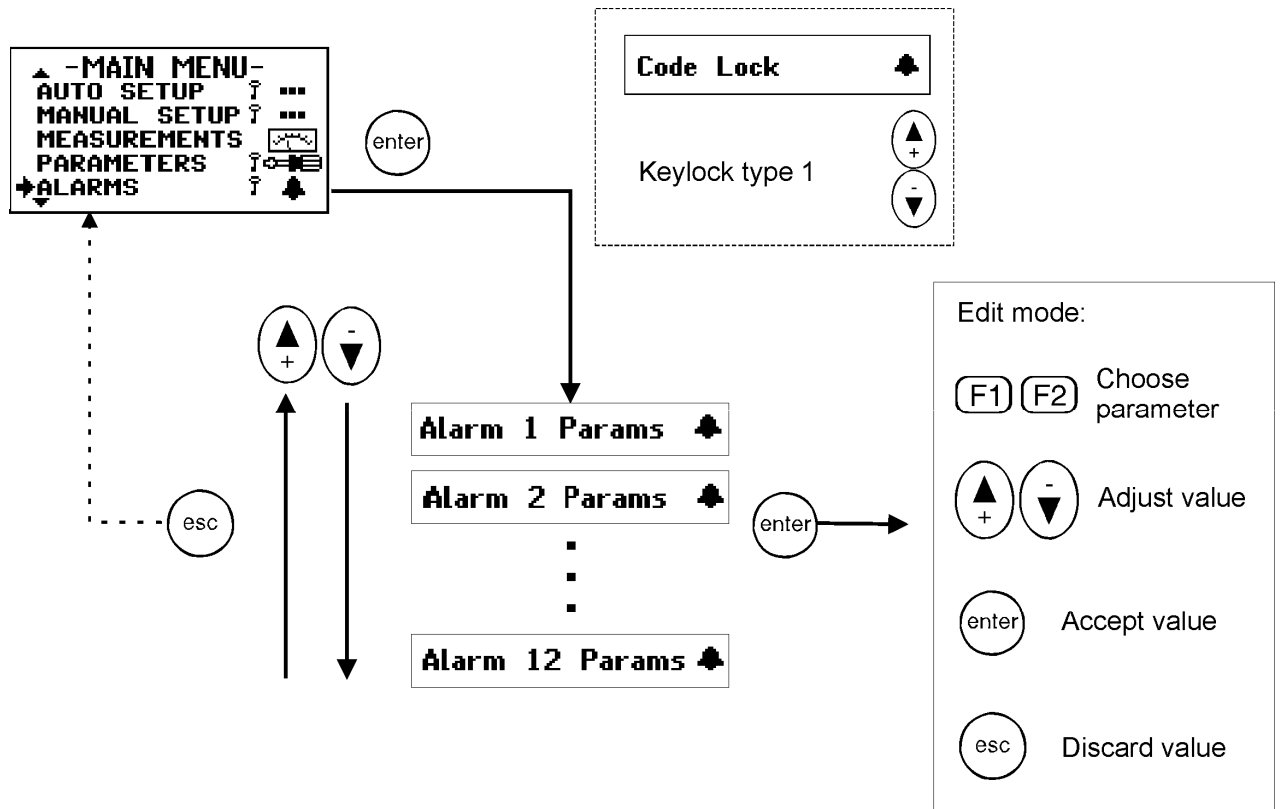
Figure 15: Alarms menu

Alarm contacts are
- closed when the controller is not energized,
- opened when the controller is energized without alarm
- closed when the controller is energized with active alarm

Alarm parameter explanations:

Item	Description
Alarm Status	ACT = Alarm active and triggered
	PAS = Alarm passive
Mode	ENABLED = Alarm ON
	DISABLED = Cannot cause an alarm under any conditions. The other settings of the alarm have no effect.
Disconnection	For alarms 2, 9 & 10.
	ON = Bank shut down in case of alarm
	OFF = No shutdown
Limit	Alarm detection limit for alarms 9, 10 & 11.

5.10 Maintenance menu

The maintenance menu provides useful information about the usage of the bank, capacitors and contactors. Also, some auxiliary settings have been provided.

CAUTION: This menu access is dedicated to specialists.
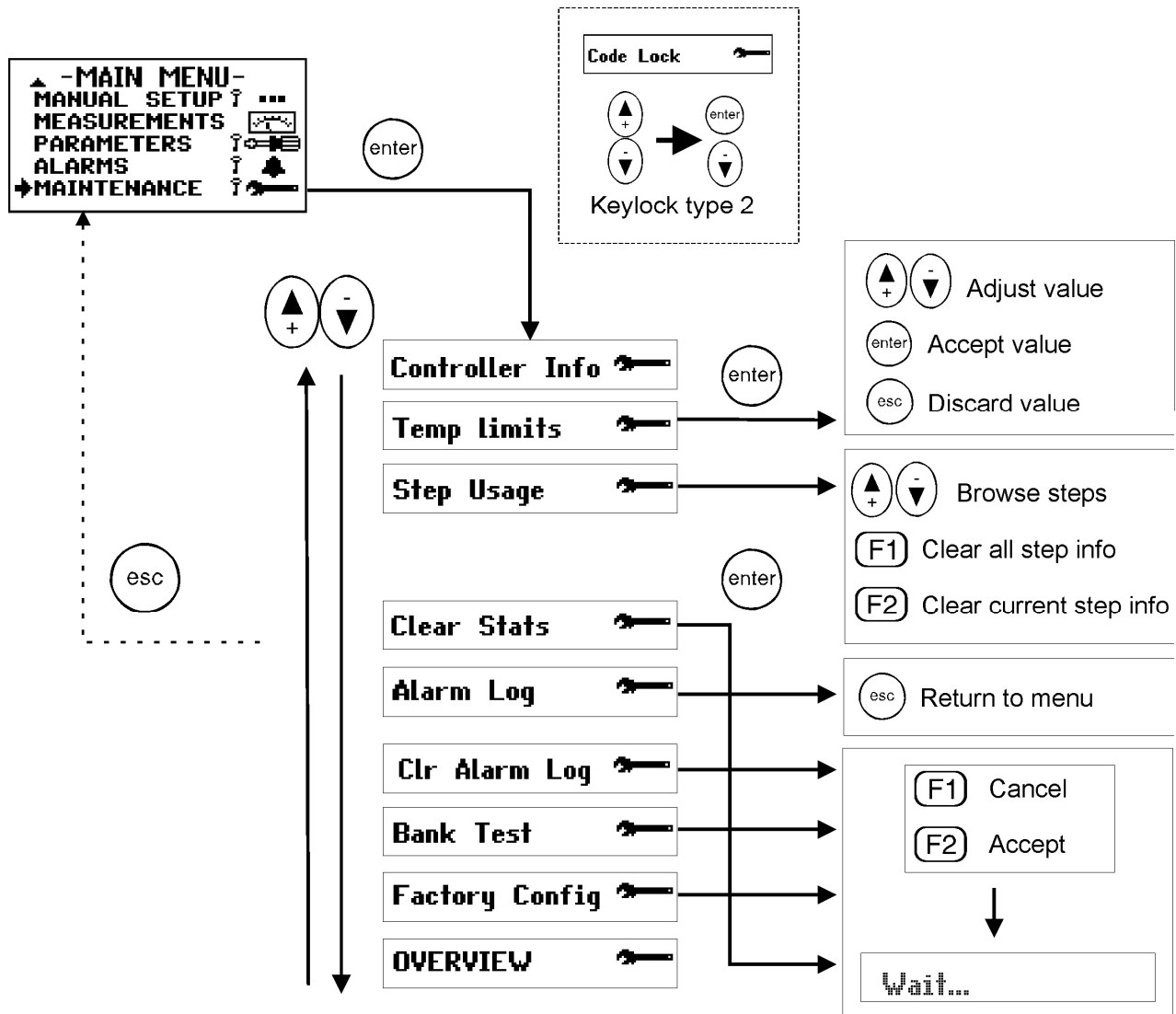
Figure 16: Maintenance menu

Maintenance explanations:

Screen	Item	Description
Controller info	S/N	Serial number
	Program vers	Software version
	Uptime	Power on hours
Limit Settings	Alarm limit	Display for temperature alarm limit
	Fan offset	Fan offset setting, fan limit = alarm limit - offset
	Fan limit	Display for fan temperature limit. If external temperature sensor is installed, fan is controlled by external temperature.
Step Usage		Connections of steps, usage hours display and possibility of clearing.
Clear Stats		Clear step statistics and alarm log.
Alarm Log		Log of 5 latest alarms
Clr Alarm Log		Clear alarm log
Bank Test		Each step is automatically connected and disconnected in turn. This facilitates testing of the operation of each capacitor step contactor. *To be used only for testing offline capacitors! Do not use on HV network applications!*
Factory Config		Restore controller factory settings

6. Miscellaneous

6.1 Stepping programs

The controller's algorithm will try to reach the target cos φ inside a tolerance area dependant upon the C/K value, *figure 18*. It reaches the value by switching on or off available relevant steps.

The regulation program choice follows the steps definition :

a) Stack Program (linear) :
All capacitor steps are of equal size (i.e :1.1.1.1). The operation sequence obeys to a *last-in-first-out* (LIFO) principle. The first step connected will be the last one to be disconnected and vice versa. See Table 1.

b) Normal program (2+ linear)
Normal program can be used on bank whose step ratio is 1.2.4.4.. The linear sequence starts with the 3rd step. The two first steps are used as fine-tuning. The controller always start by switching the first step then the second. Other steps are used successively See Table 2.

c) Circular 1:1:1 program
All capacitor steps are of equal size (i.e :1.1.1.1). The operation sequence obeys the first-in-first-out (FIFO) principle. With this stepping program the amount of on- and off-connections at each step will eventually be the same. The first step connected will be the first one to be disconnected and vice versa. Then a circular sequence is followed. In order to operate correctly, the number of steps programmed into the controller must strictly comply with the number of physical steps See Table 3.

d) Circular 1:2:2 program (1+Circular)
Circular B program can be used on a bank whose step ratio is 1.2.2.2. The first step is used as tuning after the activating limit is exceeded. The circular sequence starts with the 2nd step. See Table 4.

e) Optimal Program :

The optimal program operates with many step configurations:

1.1.1.1.1	1.1.2.2.2	1.1.2.3.3	1.1.2.4.4	1.2.2.2.2
1.2.3.3.3	1.2.3.4.4	1.2.3.6.6	1.2.4.4.4	1.2.4.8.8

The target cos φ power is reached using the fewest number of steps in minimal time. Like the circular program, this algorithm equalizes the usage of largest steps.

This program uses optimally selected step sizes when approaching the target power and at the same time the response delays are shortened, particularly if there is a large requirement for compensation power or if the network suddenly becomes capacitive. As circular program, this stepping program keeps the usage of steps even.

Optimal program is disabled with fixed steps and vice versa.

Step demand	Step number					
	1	2	3	4	5	6
+	X					
+	X	X				
+	X	X	X			
+	X	X	X	X		
+	X	X	X	X	X	
+	X	X	X	X	X	X
-	X	X	X	X	X	
-	X	X	X	X		
-	X	X	X			
-	X	X				
+	X	X	X			
+	X	X	X	X		
+	X	X	X	X	X	
-	X	X	X	X		
-	X	X	X			
-	X	X				
-	X					

Table 1: Stack program - Operation sequence 1:1:1:1

Step demand	Step number					
	1	2	3	4	5	6
+	X					
+	X	X				
+	X	X	X			
+	X	X	X	X		
-		X	X	X		
-		X	X			
+	X		X	X		
+	X	X	X	X		
+	X	X	X	X	X	
-		X	X	X	X	
-			X	X	X	
-			X	X		
-		X				

Table 2: Normal program - Operation sequence 1:2:4:4

Step demand	Step number					
	1	2	3	4	5	6
+	X					
+	X	X				
+	X	X	X			
+	X	X	X	X		
-		X	X	X		
-			X	X		
+			X	X	X	
+			X	X	X	X
-				X	X	X
-					X	X
+	X				X	X
+	X	X			X	X
-	X	X				X

Table 3: Circular A program - Operation sequence 1:1:1

Step demand	Step number					
	1	2	3	4	5	6
+	X					
+	X	X				
+	X	X	X			
-		X	X			
+	X	X	X			
+	X	X	X	X		
-		X	X	X		
-			X	X		
-				X		
+	X			X		
+	X			X	X	
+	X			X	X	X
+	X	X		X	X	X
-		X		X	X	X
-		X			X	X
-		X				X

Table 4: Circular B program - Operation sequence 1:2:2

Comparison between normal and optimal program:

Normal program will reach the cos φ target value by successive connection/disconnection of capacitors corresponding to the smallest step value.

Optimal program will reach the target cos φ value by successive connection/disconnection of capacitors corresponding to the highest relevant and available step value.

Optimal Stepping Programm

Uncompensated reactive power

Compensated reactive power

Step sizes : 1:2:4:4

Connection of steps

+4
+4
+4
+1

Steps on : 4
Steps on : 4+4+4+4+1
Steps on : 4+1

-4
-4
Disconnection of steps
-4

Normal Stepping Programm

Step sizes : 1:2:4:4

+1
+2
+4
+4
+4
+1

Steps on : 4
Steps on : 4+4+4+4+1
Steps on : 4

-1
-2
-4
-4
-4
-1
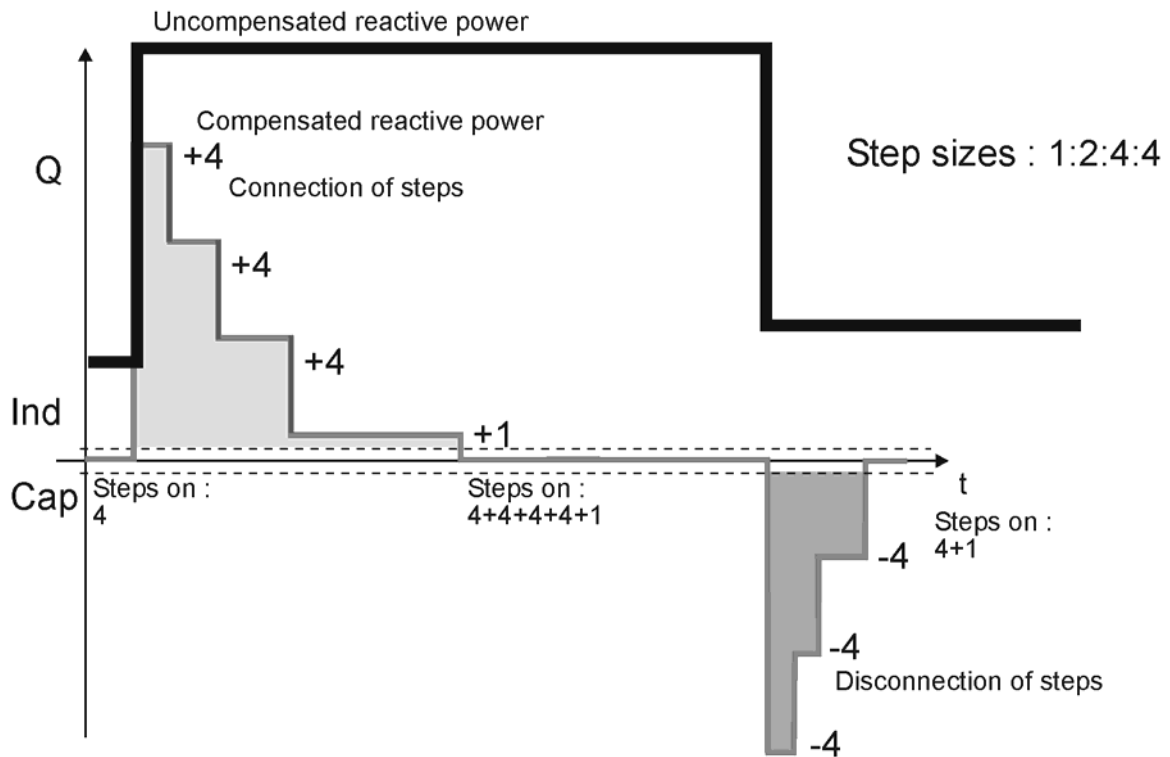
Figure 17: Regulation example - Optimal vs. Normal

6.2 Manual calculation of response value

Normally the response value, more generally known as the C/K value, is set automatically as a part of the *Auto Setup* sequence, but there are cases when these values must be entered manually. The correct value can be calculated using an equation requiring the 1st step size (in vars), line-to-line voltage of the network used (in volts) and the CT ratio as follows

$$C/K = \frac{Q_1}{I_1/5A \times U_{LL} \times \sqrt{3}}$$

where Q_1 = size of 1st step in vars
U_{LL} = line-to-line voltage in volts
$I_1/5A$ = CT ratio (alternative : $I_1/1A$)

Alternatively, the C/K value can be taken from the table below (valid for 400 V networks)

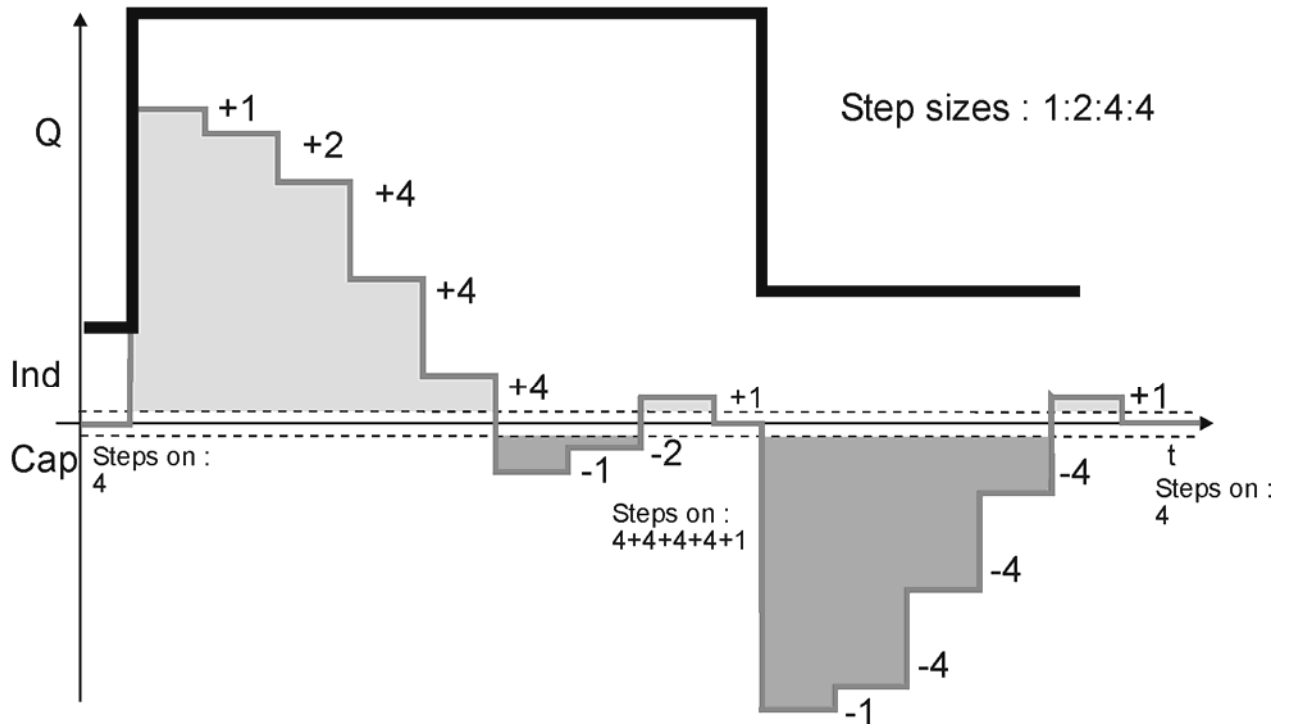| 1st step (kvar)	20	30	40	60	80	100	120	160	200	300	400	500	600		/1
	50	100	150	200	300	400	500	600	800	1000	1500	2000	2500	3000	/5
5	0,72	0,36	0,24	0,18	0,12										
7,5	1,08	0,54	0,36	0,27	0,18	0,14	0,11								
10	1,44	0,72	0,48	0,36	0,24	0,18	0,14	0,12							
12,5	1,80	0,90	0,60	0,45	0,30	0,23	0,18	0,15	0,11						
15		1,08	0,72	0,54	0,36	0,27	0,22	0,18	0,14	0,11					
18,5		1,34	0,89	0,67	0,45	0,33	0,27	0,22	0,17	0,13					
20		1,44	0,96	0,72	0,48	0,36	0,29	0,24	0,18	0,14	0,10				
25		1,80	1,20	0,90	0,60	0,45	0,36	0,30	0,23	0,18	0,12				
30			1,44	1,08	0,72	0,54	0,43	0,36	0,27	0,22	0,14	0,11			
37,5			1,80	1,35	0,90	0,68	0,54	0,45	0,34	0,27	0,18	0,14	0,11		
40			1,92	1,44	0,96	0,72	0,58	0,48	0,36	0,29	0,19	0,14	0,12	0,10	
50				1,80	1,20	0,90	0,72	0,60	0,45	0,36	0,24	0,18	0,14	0,12	
60					1,44	1,08	0,87	0,72	0,54	0,43	0,29	0,22	0,17	0,14	
75					1,80	1,35	1,08	0,90	0,68	0,54	0,36	0,27	0,22	0,18	
90						1,62	1,30	1,08	0,81	0,65	0,43	0,32	0,26	0,22	
100						1,80	1,44	1,20	0,90	0,72	0,48	0,36	0,29	0,24	
120							1,73	1,44	1,08	0,87	0,58	0,43	0,35	0,29	
150								1,80	1,35	1,08	0,72	0,54	0,43	0,36	
200									1,80	1,44	0,96	0,72	0,58	0,48	

Table 5: C/K-values for 400 V network

The reactive power between limits corresponding to response value is adjusted by successive connections (or disconnections) of steps.
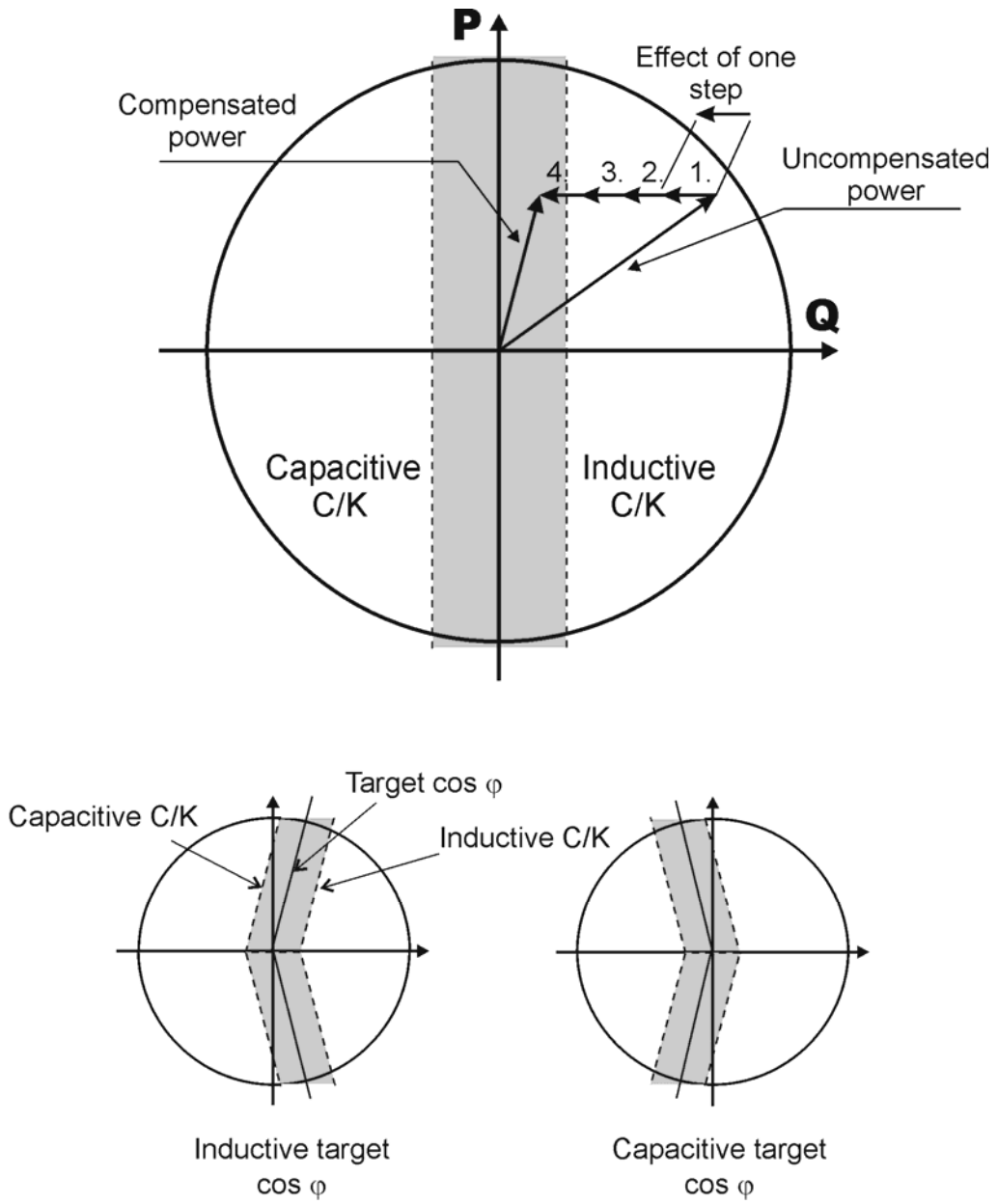
Figure 18: Compensation example and consequences

6.3 High voltage application of NRC12

CAUTION:	In case of installation in a HV bank (with VT), you must adjust the default factory settings. The reconnection delay must be changed to a larger value (e.g. 600 secs) to prevent destruction of capacitors.

The controller can be used in HV networks, if the following points are taken into account. Connections must employ VT and CT with respect to the figure 19.

The application menu has two voltage ranges for HV applications: 0.5 - 50 kV and 10 - 400 kV. The lower voltage range has finer VT ratio resolution and range than the higher voltage range.

Safety (or reconnection) delay must be adapted to the value of the discharge resistors of the capacitors, the most usual value is 600 seconds (10 minutes). The controller's default reconnection delay is adapted for LV use. Using too short a reconnection delay may damage the capacitors.

Important:

❖ the whole commissioning process must be performed using the Parameter menu
❖ the commissioner should not use Bank Pre-Configuration, Manual Setup and Commissioning menus
❖ the use of Auto Setup menu is strictly forbidden to prevent capacitor destruction
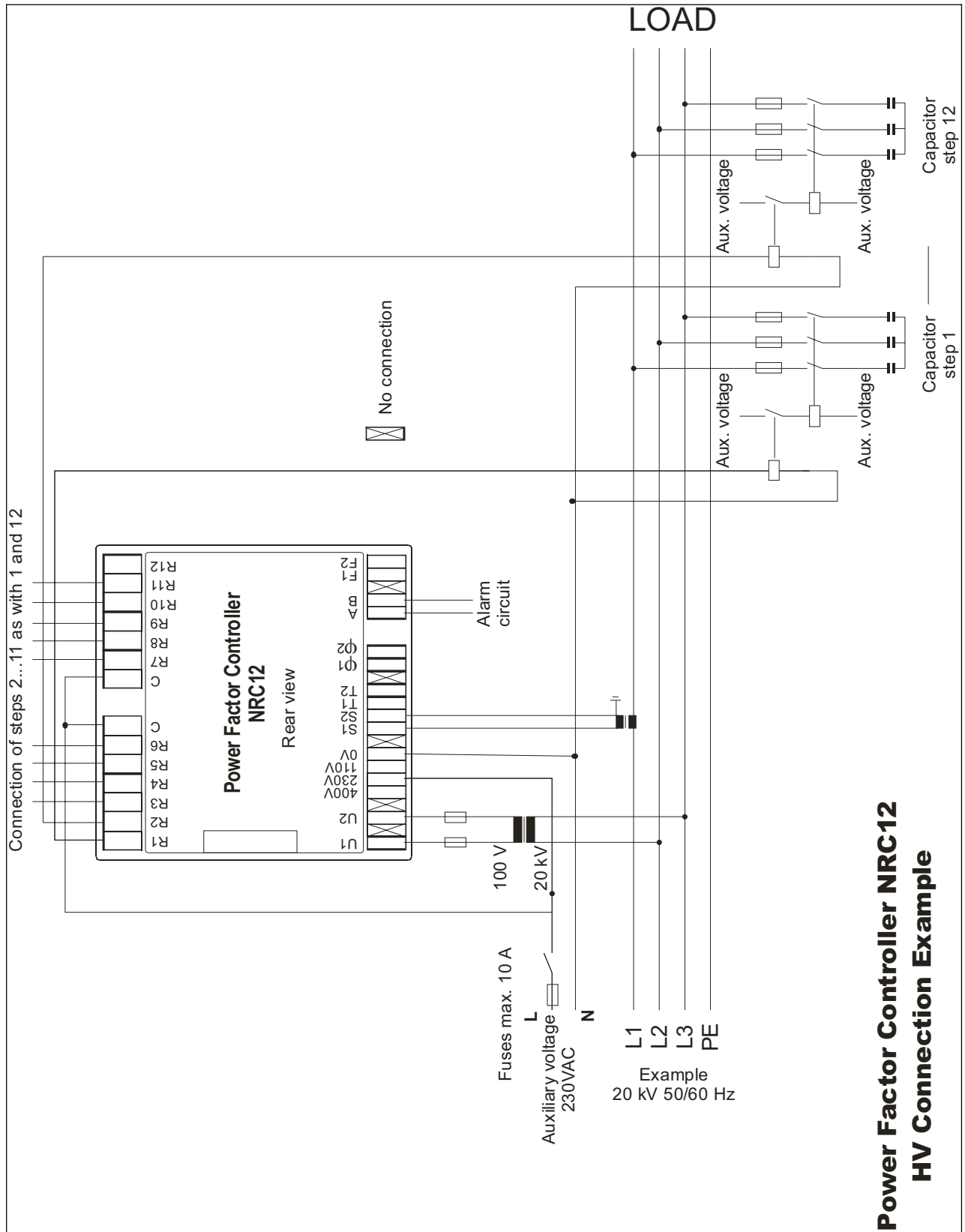❖ do not use "Verify" or "Auto Seek" on HV network applications!

Figure 19: HV use of the controller

7. Options

7.1 External Temperature Sensor

The controller has terminals T1/T2 for external temperature sensor. With the external temperature probe the temperature in a critical point in a capacitor bank can be monitored with the controller. The external temperature measurement overrides the internal temperature in fan and alarm monitoring. The External Temperature Sensor can be purchased as an option and installed into the capacitor bank.

Do not touch the connectors when the controller is energized, make sure that the operating voltage is disconnected before touching any parts located on the rear side of the controller
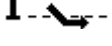
7.2 Controller Communication Adapter

The controller is equipped with a communication port to connect the controller to a remote master. The communication connector is covered to ensure electrical safety during the operation of the controller. The Controller Communication Adapter (CCA-01) can be purchased as an option and is installed into the controller according to installation instructions supplied with the CCA-01.

Always switch off the power from the controller before installation. Make sure that the communication connector is always covered, either with CCA-01 adapter or the original cover before switching on the power. Touching an uncovered connector with the power applied may lead to an electrical shock.

8. Glossary

Display information	Description	Min value	Default value	Max value
I ⟋ (symbol)	Current too high			>1,10× I_{nom}
I ⟍ (symbol)	Current too low. All steps are disconnected in 2 quadrant application.	<0,025× I_{nom}		
U ⟍ (symbol)	No Input Voltage.			
1st STEP (Step Setup)	Size and voltage of 1st step (the line-line voltage of capacitor) for step size monitoring. 0 = step size monitoring disabled. See Alarms Menu (chapter 5.9) / Alarm 12	0 kvar 200V	0 kvar 400V	400 kvar 800V
ADDRESS (Modbus Setup)	The Modbus slave address of the controller	1	1	247
ALARM LIST	List of detected active (A) and passive alarms. Reset clears passive alarms.			
ALARM LOG	Log of 5 latest alarms			
ALARMS	Alarm Menu			
ALARM STATUS	ACT = Alarm active and triggered PAS = Alarm passive.			
APPLICATION	Power flow and network voltage level of the capacitor bank. 2 quadrant = only power consumption (typical situation). 4 quadrant = power generation possible. Application is forced to 4 quadrant in Auto Setup.	2 quadrant 100-700 V	2 quadrant 100-700 V	4 quadrant 10-400 kV (VT)
AUTO SEEK	Automatic search of C/K response value			
AUTO SETUP	Automatic Setup Sequence			
BANK PRECONF	Bank Pre-configuration Sequence			
BANK TEST	Bank Test: each step is automatically connected and disconnected in turn. This facilitates testing of the operation of each capacitor step contactor. *To be used only for testing offline capacitors! Do not use in HV network applications!* See also *Step Test*.			
BITS/S (Modbus Setup)	Data transmission speed of the controller	1200	9600	38400
CAPACITIVE (Resp Values)	Response value for the capacitive side of the target cos φ. Normally set up automatically by the controller. Detected in Auto Setup and Auto seek, or manually if wanted. Checked with verify function.		See "C/K".	
CCA	The controller has a connector for CCA communication module (option).			
CIRCULAR 1.1.1	Circular stepping program for sequence 1.1.1.1.1.1			
CIRCULAR 1.2.2	Circular stepping program for sequence 1.2.2.2.2.2			
C/K	Response value. Can be manually set up or automatically searched by the controller.	0,01	0,50	1,99
CLEAR STATS	Clear Statistics			
CLR ALARM LOG	Clear Alarm Log			
COMMISSIONING	Commissioning Sequence			
COS φ 1 (Target cos φ)	Target cos φ value 1 (normally used)	0,8ind	1.00	0,9cap
COS φ 2 (Target cos φ)	Target cos φ value 2 (selected by control input)	0,8ind	1.00	0,9cap
CT (Transformers)	Current Transformer setting, xxx/5 or xxx/1	25/1 25/5	1000/5	6000/1 6000/5
CT PHASE (Wiring)	Example: CT phase L1. Current connected to phase 1. Detected in Auto Setup and Auto seek, checked with verify function. See also Installation (chapter 2).		L1	

Display information	Description	Min value	Default value	Max value
CT POLARITY (Wiring)	Current polarity selections: DIRECT = direct connection REVERSE = inverted connection AUTO = automatic polarity (controller identifies polarity in 2 quadrant applications, disabled in 4 quadrant)		AUTO	
DISCONNECTION (Alarm Paras)	Disconnection of steps in case of alarm, ON/OFF		ON 9 OFF 2,10	
EXT	External temperature. Present only if external temperature sensor connected.			
FACTORY CONFIG	Restore Factory Settings			
FAN OFFSET (Temp Limits)	Fan temperature offset (adjustable) Fan switch-on limit is offset degrees lower than temperature limit.	0°C	20°C	50°C
FIXED STEPS	Fixed steps: each step can be manually fixed ON (1)or OFF (0). In search, seek and verify functions a fixed step is always skipped and considered OK. If 1st step is fixed search, seek and verify functions are disabled.	0	A (automatic)	1
INDUCTIVE (Resp Values)	Response value for the inductive side of the target cos φ. Normally set up automatically by the controller. Detected in Auto Setup and Auto seek, or manually if wanted. Checked with verify function.		See "C/K".	
INPUT VOLTAGE	Nominal input voltage reference value at input voltage terminals U_1 and U_2. For voltage alarms.	80V	400V	800V
INT	Internal temperature			
I_{RMS}/I_1	Capacitor overload factor			
LANGUAGE	Language Selection for menus		English	
LIMIT (Alarm 9 Para)	Adjustable over temperature alarm limit. Fan switches ON some degrees under this (adjustable offset).	20 °C	50 °C	60 °C
LIMIT (Alarm 10 Para)	Maximum harmonic distortion of voltage (adjustable)	5%	7%	20%
LIMIT (Alarm 11 Para)	Capacity overload alarm limit (maximum I_{rms}/I_1 - value)	1,0	1,5	1,5
LL	Line to Line connection			
LN	Line to Neutral connection			
MAINTENANCE	Maintenance Menu (for experts)			
MANUAL SETUP	Manual Setup Sequence			
MEASUREMENTS	Measurements Menu			
MODE (Alarm Paras)	Alarm setup (enable / disable)			
MODE (Modbus Setup)	The use of controller's communication. NONE = Communication disabled READ = Communication reads information READ/RESET = Communication reads information and resets alarms. READ/WRITE = Communication reads and writes information		NONE	
NUM OF STEPS (Step Setup)	Number of used steps. Detected in Auto Setup, checked with verify function.	1	12	12
NORMAL	Normal stepping program for sequence 1.2.4.4.4.4			
OPTIMAL	Optimal stepping program, for many step sequences.			
PARAMETERS	Parameters Menu			
PRIMARY (Input Voltage)	Nominal network voltage in HV applications. Calculated form secondary voltage and VT ratio.			
PROGRAM VERS (Controller Info)	Software version			

Display information	Description	Min value	Default value	Max value
RECONNECTION (Delays)	Reconnection delay and response delay. Reconnection delay is used to protect the step capacitors (don't use too short values). Response delay, the minimum time between changes in steps, is defined as 20% of reconnection delay, min 10 s. The default value corresponds to capacitors with internal discharge resistors 50V 1 min. Response to multi-step changes is faster when using Optimal step program.	10s	50s	900s
SEARCH	Search (response value, step sizes and wiring)			
SECONDARY (Input Voltage)	Controller input voltage in HV applications	80V		150V
S/N (Controller Info)	Serial Number of the product (for internal manufacturer use)			
STACK	Linear stepping program for sequence 1.1.1.1.1.1			
STATUS (Modbus Setup)	2 digits containing correct message total counter + 2 digits containing faulty message counter + 2 digits containing replied message counter.			
STEP PROGRAM	Selection of suitable stepping program between (see *6.1 Stepping programs*). Stack Normal Circular 1.1.1 Circular 1.2.2 Optimal Forced to Optimal in Auto Setup.		Normal	
STEP SEQ (Step Setup)	Step Sequence setting defines step size ratios starting from the smallest first step. Detected in Auto Setup, checked with verify function. The alternatives are: 1.1.1.1.1.1 - 1.1.2.2.2.2 - 1.1.2.3.3.3 - 1.1.2.4.4.4 - 1.2.2.2.2.2 - 1.2.3.3.3.3 - 1.2.3.4.4.4 - 1.2.3.6.6.6 - 1.2.4.4.4.4 - 1.2.4.8.8.8 Step sequence setting is used with optimal stepping program, or if the step size monitoring is on. Step sequence is predefined with other programs and modification request are not then taken into account	1.1.1.1.1.1	1.1.1.1.1.1	1.2.4.8.8.8
STEP TEST	Step Test: each step can be manually connected and disconnected. This facilitates testing of the operation of each capacitor step contactor. See also *Bank Test*.			
STEP USAGE	Number of step connections and usage hours			
THD (I)	Total Harmonic Distortion of Current			
THD (U)	Total Harmonic Distortion of Voltage			
TRANSFORMERS	Contains CT setup, and VT setup in HV applications.			
UPTIME (Controller Info)	Uptime (Power On Hours)			
VERIFY	Automatic verification of parameters. Checks C/K value, steps and wiring. In case of an error refer to error table, page 20. *Do not use on HV network applications!*			
VT (Transformers)	Voltage Transformer ratio setting. 0.5 – 50 kV 10 – 400 kV	1.0 60	1.0	625.0 4000
VOLTAGE PHASE (Wiring)	Connections of voltage inputs. Example : Voltage phase L2-L3 (Voltage connected between phase 2 and 3) Detected in Auto Setup and Auto seek, checked with verify function. See also Installation (chapter 2).		L2-L3	

9. Technical specifications

Number of steps	12
Dimensions	155 x 158 x 80 mm
Frequency	50 Hz nominal (range 48...52 Hz)
	60 Hz nominal (range 58...62 Hz)
Measuring current	0…1 A or 0...5 A
Measuring voltage	80…690 V (nominal, max. 115%)
Displayed measuring power	100000 kVA
Nominal power consumption	13 VA
Supply voltages	110 V nominal, (range 88...130 V)
	230 V nominal, (range 185...265 V)
	400 V nominal, (range 320...460 V)
Relay inputs/outputs	250 V, 2 A
Display	Dot matrix display, resolution 64x128 pixels, backlighted
Protection class	IP41 front panel, IP20 rear part
Target cos φ -range	0,85 ind …1,00 … 0,90 cap
Response limits	0,01 … 1,99, symmetrical or asymmetrical
Reconnection delay	10…900 s
Response delay	20 % of reconnection delay, min. 10 s
Displayed measurements	cos φ, I_{act}, I_{react}, I_{app}, I_{RMS}/I_1, P, Q, S, THD(U) and voltage harmonics, THD(I) and current harmonics, internal and external temperature.
Installation method	Panel installation, DIN-rail installation
Casing	Impact resistant PC/ABS, UL94V-0
Operating temperature range	0…60°C
Alarm log	List of 5 last alarms
Step counters	Yes
Fan control with dedicated relay	Yes. 250 V AC, 8A
Alarm relay	Yes. 250 V AC, 8A
Accuracy (of FS)	I : 2%
	I_Q : 2%
	U/I-samples: 2%
	Phase: 1°
	Distortion: ± 3 dB (up to 15th)
	Internal temperature: ± 3°C
	External temperature: ± 2°C (option)
CT setting range	25/1 … 6000/1 or 25/5 … 6000/5
Power outage detection	Reaction time > 15 ms
Standards	IEC 61010-1
	IEC 61000-6-2
	IEC 61000-6-4
	UL 61010A-1
	IEC 60529
Communication	Modbus protocol using CCA-01 (option)

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