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POWER FACTOR CONTROLLERS
ERN 11206 / 11214

Operating Manual

Contents:

*Warning: in order to see and print the display messages correctly, you have to get the *7 segment font* and paste it in the Windows/fonts directory of your computer. It is free on the Internet.*

1. Installation

1.1. Physical Installation

The controller is built in a plastic box to be installed in a distribution board panel. The instrument's position must be fixed with locks.

Natural air flow should be provided inside the distribution board cabinet, and near the instrument. In particular, please get sure that there is no heating source below the instrument, in order to get correct temperature data.

1.2. Connection

The controller is provided with screw-on connectors placed on the rear side. Typical wiring examples are shown at the end of this manual. Maximum wire cross section is 2.5 square millimetres.

1.3. Power Supply

Supply voltage is required in the range of technical specification data.

The supply voltage is to be connected to terminals 4 (***L1***) and 3 (***N***) and externally protected (see chapter *Protection* below).

The power supply terminal 4 (***L1***) is internally connected to the common pole of output relays. It is necessary to work out the power supply protection and the output contactor's power as well.

1.4. Protection

The EN 61010-1 standard (section 6.12.2.1) requires that the instrument must be equipped with a disconnecting device in the power supply circuit (a switch). It has to be located very near to the instrument and easily reachable by the operator. The disconnecting device must be marked as such. A circuit breaker for nominal current of 10 amp makes a suitable disconnecting device. Its function and working positions, however, must be clearly marked.

Since the controller's inbuilt power supply is of pulse design, it draws a momentary peak current on powerup, which is in order of magnitude of amperes. This fact needs to be kept in mind when selecting the primary protection devices.

1.5. Measurement Current

Metering current transformer (CT) outputs connect to terminals 1 (***k***) and 2 (***l***): terminal 1 is ***k*** and terminal 2 is ***l***.

A metering current transformer of nominal output current 5 or 1 A can be used. The metering current transformer's ratio must be entered when setting up the instrument for proper measured values display (parameters 12, 13 – see further below).
In ERN 11206-11214 models, the connector features a screw lock to prevent accidental pull-out.

1.6. Error Indication

Non-standard events can be reported by one of last two output relays (if they are not used for control). It is necessary to set such relay function properly (parameter 26 further below).

1.7. Output Relays

The instrument has 6 - 14 output relays (depending on controller model). The relays' contacts go to terminals 19 through 32). The relays' common contacts are internally connected to power supply terminal ***L*** (No. 3). When an output relay contact closes, the power supply voltage appears at the corresponding output terminal.

2. First Use

2.1. First Use

The instrument's installation is fully automatic. In most cases it is enough to switch the power supply on; the controller by itself detects both the connection configuration and the value of each connected compensation section, and it begins to control. If required, it is possible to check the settings and to modify some parametres.

At switch-on, display test runs first. The display temporarily shows:

- type of controller (e.g. Er06)
- firmware version (e.g. 1.2)
- type of measurement voltage set (U=Ln or U=LL)
- metering current transformer secondary side nominal value set (I =5A or I = 1A)

Then the automatic connection configuration detection process starts.

If no measurement voltage is detected, U=0 will flash on the display.

2.2 Automatic Connection Configuration Detection Process

The controller's default measurement voltage and current connection parameters are set as follows:

- type of measurement voltage set to phase voltage ("LN**,** parameter 15)
- method of connection of U and I not defined (parameter 16)
- compensation system nominal voltage $\mathbf{U_{NOM}}$ set to 230 V (parameter 18)

As the method of connection is not defined, the controller carries out automatic connection detection process. For the controller to be able to start this process, the following conditions must be met:

- controller operation is not disabled (i.e. the ***Manual*** LED is dark)
- controller is in the control mode, i.e. the numeric display mode is ***Measurement***

If the conditions are met, the controller starts the automatic connection detection process.

The process may have up to seven steps. The controller makes four measuring attempts in each step in which it consecutively connects and disconnects sections 1 through 4. At the same time, it assumes that power factor capacitors are connected to at least two of the sections (if any choke connected to sections 1 through 4, detection process fails). The two following messages are shown on the numerical display, one after another, in each measurement attempt:

1. step number in format APnn(**A**utomatic **P**hase detection, nn... attempt number)
2. attempt result, e.g. L 1-0

If the controller measures identical values repeatedly in each attempt, it considers the connection detected and quits carrying out further steps. If the measurement results are different from each other in a particular step, the controller carries out another measurement step.

The following conditions must be met for successful automatic connection configuration detection process:

- type of measurement voltage is set correctly (phase, "LN" or line, "LL" – parameter 15)
- at least two power factor capacitors are connected to sections 1 through 4 and no power factor choke is connected to these sections

The controller measures the measurement voltage value for the whole of the automatic connection configuration detection process. It evaluates this voltage's average value at the end of the process and selects the compensation system nominal voltage $\mathbf{U_{NOM}}$ (parameter 18) as the nearest value of the following choice of nominal voltages.

Tab. 2.1 : Choice of nominal voltages

58 V	100 V	230 V	400 V	500 V	690 V

Type of connection detected is shown on the numeric display for a moment after successful completion of the automatic connection configuration detection process, the selected $\mathbf{U_{NOM}}$ nominal voltage, the true power factor value in the power system, and thereafter the instrument starts the control process or it starts the automatic section power recognition process.

If the automatic connection configuration detection process is not completed successfully, the numeric display shows flashing P=0□. It is, in such a case, necessary to enter the type of connection manually or to re-enter **----** (= not defined) in editing parameter 16 and thus restart the automatic connection configuration detection process. Otherwise the controller changes over to a waiting mode and it repeats the automatic connection configuration detection process in 15 minutes automatically.

If the actual nominal voltage in the compensation system differs from the value entered in parameter 18 in the automatic connection configuration detection process, the parameter can be corrected to its actual value when the process has finished.

The automatic connection configuration detection process can be interrupted at any time by switching the numeric display mode to ***Parameters***. The automatic connection configuration detection process will start again from scratch on return to instantaneous value display mode.

2.3. Automatic Section Power Recognition Process

The controllers come with enabled function of automatic section power recognition process (parameter 20 set to A) as default setting. The controller starts the automatic section recognition power process on powerup (connection of power supply voltage) with this setting, provided none of the outputs (in parameter 25) has a valid power value; this happens if a new controller is installed for the first time or after its initialization). The process can also be started without interrupting the power supply voltage connection, by editing parameter 20 to value 1 or by controller initialization (see further below).

For the controller to be able to start the automatic section power recognition process, the following conditions must be met:

- controller automatic operation is not disabled (i.e. the ***Manual*** LED is dark)
- controller is in control mode, i.e. the numeric display mode is ***Measurement***
- connection mode of measurement U and I is defined (parameter 16)

If these conditions are met, the controller starts the automatic section power recognition process.

The process may have three or six steps. The controller consecutively connects and disconnects each output in each step. While doing that, it measures the effect of connection and disconnection on total reactive power in the power system. From the values measured the power of each section is determined.

The following messages are shown one after another in each measurement attempt on the numeric display:

1. Step number in format **AC-n** (n... step number).
2. Sectional power measured in kvars; the **nominal** power value of the section under measurement is displayed, that is the value that corresponds to nominal voltage $\mathbf{U_{NOM}}$ of the compensation system as specified in parameter 18. If the metering current transformer turns ratio has been entered (parameters 12 and 13), or, if measuring voltage via a metering voltage transformer, the voltage transformer's turns ratio as well (in parameter 17), sectional power in the power system is shown (that is at the metering current transformer primary side, or metering voltage transformer primary side). If the metering current transformer primary side (parameter 12), or metering voltage transformer primary side (parameter 17) is not defined, sectional power in the metering current transformer's, or the metering voltage transformer's, secondary side is shown.

If the controller does not succeed in determining a section's value, it does not show it. This condition occurs if reactive power value in the power system fluctuates considerably due to changes in load.

After carrying out three steps, evaluation is carried out. If each measurement carried out provides sufficiently stable results, the automatic section power recognition process is completed. Otherwise the controller carries out three more steps.

A requirement for successful automatic section power recognition process is a fairly stable condition of the power system. In other words, while connecting or disconnecting a section, the reactive load power must not vary as much as, or even more than the reactive power of the section under test. Otherwise the measurement result is unsuccessful. As a rule of thumb, the section values are recognized the more precisely, the lower the load is in the power system.

On successful completion of automatic section power recognition process, the controller checks whether at least one capacitive section has been detected and, if so, it starts control. Otherwise the controller goes to the waiting mode and after 15 minutes it starts the automatic section power recognition process again.

At this phase it is recommended to preset a CT ratio (parameters 12, 13) and to check recognized section values in the side branch of parameter 25. A positive power value means a capacitive section, negative value means inductive section. If the value could not be recognized, "**----**" is shown. Each value recognized can be edited manually.

If the automatic section power recognition process can not be completed successfully or none of the sections recognized is capacitive, flashing **C=0** is shown on the numeric display and the ***Alarm*** signal is activated at the same time. In such an event, it is necessary to enter each section's value manually (see description further below) or by editing parameter 20 enter value **A** (= carry out the automatic section recognition power process) or **1** and thus force another start of the automatic section power recognition process.

The automatic section power recognition process can be stopped any time by switching the display mode to ***Parameters***. On return to the instantaneous value display mode the automatic section power recognition process will be started over again.

3. Description

3.1 Measurement Values

The display mode which the controller enters on power-up is displaying instantaneous values. You can switch to parameter display mode by pressing the ***P*** button.

The controller enters the instantaneous display mode automatically in about 30 seconds from the moment you stop pressing control keys (or in five minutes if control time is displayed – see description of parameter 46).

3.2 Tree framework: main branch

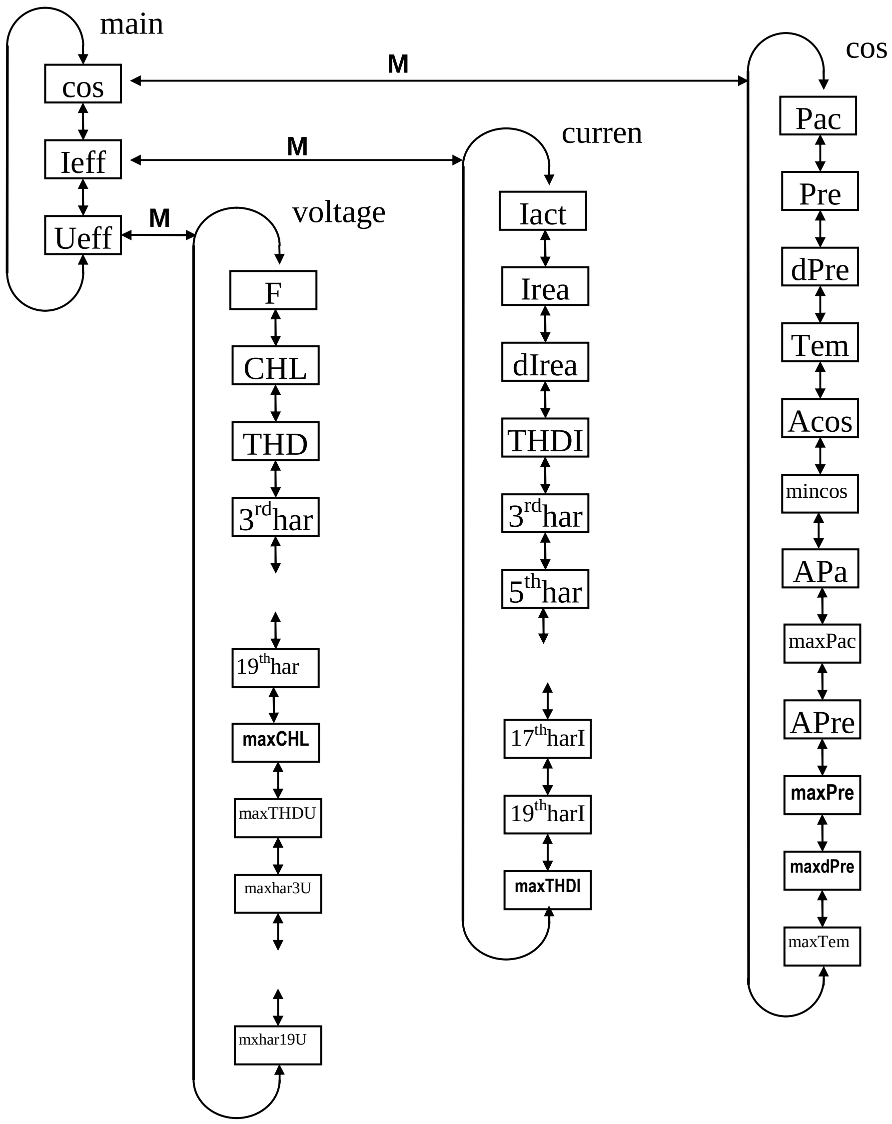
One LED, ***COS*** or ***A*** or ***V**,* is always lit in the instantaneous display mode. These LEDs identify the value group displayed. Instantaneous values displayed are organized in branches – see Figure 3.1. The main branch contains these main instantaneous values: **cos**, **Ieff** and **Ueff**. Moreover, it contains the parameter list. You can switch between the displayed values using the ▲, ▼ buttons.

Tab. 3.1 : List of Measurement Quantities – Main Branch

abbrev.	quantity	unit
cos	Instantaneous power factor. The value corresponds to the ratio of instantaneous active component to instantaneous total power fundamental harmonic value in the power system. A positive value means inductive power factor, negative means capacitive power factor.	-
Ieff	Instantaneous current effective value in the power systems (including higher harmonic components).	A / kA *
Ueff	Instantaneous voltage effective value in the power system (including higher harmonic components). By default shown in volts. If the measurement voltage is connected via a metering transformer, in kilovolts.	V (kV)

* … in A as default; flashing decimal point indicates value in kA

Fig. 3.1 : Instantaneous value and parameters display – framework



3.2.1 Tree framework: COS branch

Instantaneous power values as well as recorded average, maximum and minimum values of selected quantities are shown in the COS Branch. Power is displayed as three-phase values (single-phase power values multiplied by three). Reactive power values are prefixed with L for positive values and C for negative values.

Tab. 3.2 : List of Measurement Quantities – COS Branch

Abbrev.	display	quantity	unit
Pac	PAC	Instantaneous fundamental harmonic active power (**P**ower **ac**tive).	kW / MW *
Pre	PrE	OInstantaneous fundamental harmonic reactive power (**P**ower **re**active).	kvar / Mvar *
dPre	dPrE	Instantaneous fundamental harmonic reactive power difference to achieve target power factor (**D**elta **P**ower **re**active).	kvar / Mvar *
Temp	°C / °F	Instantaneous temperature (in the distribution board cabinet, at the controller). Displayed in degrees Celsius or Fahrenheit, as specified in parameter 58.	℃ nebo ℉
Acos	ACOS	Average power factor over the time specified in parameter 56 (**A**verage **cos**).	-
mincos	nCOS	Minimum power factor in the power system achieved since last clear. The evaluation window is specified in parameter 57.	-
APac	APAC	Average fundamental harmonic active power in the power system over the time specified in parameter 56 (**A**verage **P**ower **ac**tive).	kW / MW *
maxPac	mPAC	Maximum fundamental harmonic active power achieved since last clear. The evaluation window is specified in parameter 57 (**M**aximum **P**ower **ac**tive).	kW / MW *
APre	APrE	Average fundamental harmonic reactive power in the power system over the time specified in parameter 56 (**A**verage **P**ower **ac**tive).	kvar / Mvar *
maxPre	mPrE	Maximum fundamental harmonic reactive power achieved since last clear. The evaluation window is specified in parameter 57 (**M**aximum **P**ower **re**active).	kvar / Mvar *
maxdPre	mdPr	Maximum fundamental harmonic reactive power difference to achieve target power factor in the power system achieved since last clear. The evaluation window is specified in parameter 57 (**M**aximum **D**elta **P**ower **re**active).	kvar / Mvar *
maxTemp	m°C / m°F	Maximum temperature recorded since last clear. The evaluation is based on temperature one-minute moving averages (**M**aximum **Temp**erature).	℃ or ℉

* … in kW-, kvar- units as default; flashing decimal point indicates value in MW, Mvar

The recorded values are divided by their nature into three groups:

1. Average values **Acos**, **APac**, **APre**

   These are average values of power factor, active and reactive power. The depth of average can be set in parameter 56 from 1 minute to 7 days.

2. Maximum and minimum values **mincos**, **maxPac**, **maxPre**, **maxdPre**

   - **mincos** – evaluated as a ratio of fundamental harmonic active and reactive power moving averages. The moving average window size can be specified in parameter 57 from 1 minute to 7 days. The minimum value is recorded and displayed. Evaluation is conditioned by the corresponding average current being at least 5% of the nominal load as determined from the CT turns ratio primary value (parameter12) else the value is ignored (the value is not recorder for minimum loads).
   - **maxPac**, **maxPre** – the maximum values of fundamental harmonic active and reactive power moving averages. The average window size can be specified in parameter 57 from 1 minute to 7 days.
   - **maxdPre** – the maximum value of fundamental harmonic absent reactive power moving average. As opposed to the absent reactive power instantaneous value, **dPre**, which is the difference between the actual and required reactive power, irrespective of the instantaneous condition of the controller's closed outputs, **maxdPre** is only evaluated if the required reactive power exceeds the system's control capacity (that is the total power of all compensation banks, or sections), and its value is determined as a difference between this control capacity and required power (if the control capacity is sufficient, the **maxdPre** value is zero). The moving average window size can

be specified in parameter 57 from 1 minute to 7 days.

3. Maximum temperature **maxTemp**

The temperature moving average maximum value. The moving window depth is fixed at 1 minute.

The above described recorded values can be cleared, each group separately – when clearing a value, all other values in the same groups are cleared too. Clearing values is explained in the Editing chapter further down.

3.2.2 Tree framework: A branch

All quantities related to current are shown in this branch. The **maxTHDI** value can be cleared manually.

Tab. 3.3 : List of Measurement Quantities – A Branch

abbrev.	display	quantity	unit
Iact	ACt	Instantaneous active current fundamental harmonic component (**act**ive).	A / kA *
Irea	rEA	Instantaneous reactive current fundamental harmonic component (**rea**ctive); ***L*** indicates inductive, ***C*** indicates capacitive polarity.	A / kA *
dIrea	drEA	Instantaneous reactive current fundamental harmonic component difference to achieve the target power factor in the power system (**D**elta **rea**ctive).	A / kA *
THDI	tHd	Instantaneous level of power system current's total harmonic distortion (**T**otal **H**armonic **D**istortion) – shows the ratio of current higher harmonic components content, up to the 19th harmonic, to the level of fundamental harmonic.	%
3.÷19. har	H3÷ 19	Instantaneous current harmonic component level in the power system.	%
maxTHDI	mtHd	Maximum THDI value achieved since last clear. The evaluation is based on THDI one-minute moving averages.	%

* … in A as default; flashing decimal point indicates value in kA

3.2.3 Tree framework: V branch

This branch shows all the quantities related to voltage. They are commonly used quantities. The maximum values can be cleared manually. Clearing any of these values clears all the other maximum values within this branch.

Tab. 3.4 : List of Measurement Quantities – V Branch

abbrev.	display	quantity	unit
F	F	Instantaneous voltage fundamental harmonic component frequency.	Hz
CHL	CHL	Instantaneous value of Capacitor Harmonic Load factor.	%
THDU	tHd	Instantaneous level of power system voltage's total harmonic distortion (**T**otal **H**armonic **D**istortion) – shows the ratio of current higher harmonic components content, up to the 19th harmonic, to the level of fundamental harmonic.	%
3.÷19.har	H3÷ 19	Instantaneous level of harmonic component voltage in the power system.	%
maxCHL	mCHL	Maximum CHL value achieved since last clear. The evaluation is based on CHL one-minute moving averages.	%
maxTHDU	mtHd	Maximum THDU value achieved since last clear. The evaluation is based on THDU one-minute	%

		moving averages.	
3. ÷ 19. maxharI	mH3÷ 19	Maximum value of voltage harmonic component achieved since last clear. The evaluation is based on harmonic component one-minute moving averages.	%

3.3 Controller Parameters

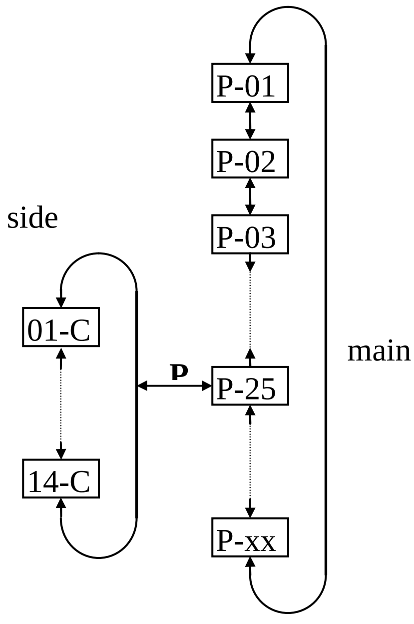
You can view controller parameters by pressing the **P** button. First the parameter number shows momentarily and then its value does. The parameter number flashes momentarily every five seconds for better orientation.

The parameters are organized into three main groups:

- Controller's functions affecting parameters. These parameters can be set to direct the control process. There are target power factor, control period, reconnection delay time, etc.
- Controller's current condition parameters. This is the alarm (parameter 40), error condition (parameter 45), and control time (parameter 46). These parameters are set by the controller and identify nonstandard or error conditions. They monitor the control process in detail.
- Total connection events recorded and connections of each compensation bank, or section (parameters 43 and 44, respectively). These values are set by the controller and the operator can only clear them.

The parameters are organized by ordinal number in the main branch – see Figure 1.3. Some of the parameters (parameter 25 – sectional power, 26 – fixed sections, 30 – alarm setting, 40 – state of alarm, 43 – total connected times, 44 – number of sections connected) are located on side branches for easier navigation. You can switch to a side branch with selected parameters by pressing button ***P*** (parameters) and switch back to the main branch in the same way. Side branch parameter displayed are identified by a dash between the parameter number and value. For example: in the main branch, while showing parameter 26 (fixed sections), you will see **01 C** (section 1 is a capacitive compensation one); if you want to display the conditions of the other sections, you have to switch the display to the side branch by pressing button ***P***; the display will change to **01–C** and now you can move up and down the branch, through all sections' values. Pressing button ***P*** again returns display to the main branch (the dash disappears).

Fig. 3.2 : Parameter Display – Framework



Pressing button ***M*** (measurement) returns to the instantaneous value display mode. The controller gets back to this mode automatically in about 30 seconds from the last press of button.

Exception: In the ***Manual*** mode the parameter values cannot be viewed, while pressing the ***P*** button instantaneous output values are displayed.

3.4 Test and Error Messages

In the instantaneous value display mode a test or error message pops up in place of a power factor value in some situations. In these situations, if the value shown does not represent power factor, the ***COS*** LED flashes.

3.5 Indication LEDs

Besides the numeric display and adjacent LEDs, ***COS*** , ***A*** , ***V***, the front panel is equipped with some more LEDs.

3.5.1 Output State Indication

The array of LEDs below the display shows the current state of output relays. Each LED is assigned a number from 1 to 14, and if lit, indicates closed contacts of the corresponding output relay.

If a LED is flashing, the controller is going to connect the output, and it is waiting for the delay time to elapse. The output relay contacts are open and they will be closed as soon as the reconnection delay time is over.

An exception is the power-up display test to check correct operation of all display elements. In this test the display shows tESt and all indication LEDs come on. All output relays stay open while the test is running.

3.5.2 Trend Indication

These LEDs show how big is the deviation of the true instantaneous reactive power in the power system from optimum reactive power which would correspond to the required power factor.
If the deviation is smaller than half of the reactive power of the smallest capacitor, both LEDs are dark. If the deviation is greater than half, but smaller than the reactive power of the smallest capacitor, the corresponding LED flashes. If lagging (undercompensation), the ***IND*** LED flashes; if leading (overcompensation), the ***CAP*** LED flashes. If the deviation exceeds the value of the smallest capacitor, the corresponding LED is permanently lit.

Exceptions to these LEDs' meanings are the following situations:

- measurement U and I method of connection is not defined (parameter 16)
- automatic connection configuration is in progress
- automatic section power recognition is in progress

If the method of connection is not defined, both LEDs flash; they are dark in the other two situations.

3.5.3 Manual Mode Indication

Flashing ***Manual*** LED indicates that the controller is in the manual mode. The regulator's control function is disabled.

If this LED is dark and display is in the ***Measurement*** mode, the controller is in its standard control mode or it is carrying out automatic connection configuration or automatic section power recognition process.

3.5.4 Backfeed (Power Export) Indication

The ***Export*** LED indicates the power transmission direction. If it is dark, the power is flowing from the assumed power supply to the appliance. If the LED is lit, the power is flowing in the opposite direction.

3.5.5 Alarm Indication

An ***Alarm*** relay can be used for non-standard events signalling. This relay's operation can be set up as described further below (parameter 30).

The ***Alarm*** LED indicates this relay's condition, that is if the ***Alarm*** relay's output contact is closed, the LED flashes.

4. Setup

To achieve optimum compensation in accordance with character of the controlled load, the regulator is set up by parameters that rule its operation. Detailed specification of all parameters can be found in chapter 6.

4.1 Parameter Editing

The controller's parameters are set to default values, which are listed in the table of chapter 6. To achieve optimum compensation results, it is sometime necessary to change some of the values in correspondence with particular requirements; in other situations it is at least necessary to enter the measurement voltage type (phase or line) and current transformer ratio, while installing the instrument.

If parameter edit is enabled (see next chapter), you should proceed as follows:

1. Find the parameter you want to edit by pressing the ▲, ▼ buttons repeatedly.
2. Press the ***P*** button and hold it down until the display starts flashing.
3. Release the ***P*** button and set the desired value with the ▲, ▼ buttons. Some values can be incremented or decremented continuously by holding down the ▲or ▼ button.
4. When the desired value is displayed, press the ***P*** button. The value is saved in the controller's memory, the display stops flashing and editing is thus complete.

4.2 Clearing Recorded Measurement Values

Recorded measurement values can be cleared in a similar way:

1. Scroll to the value you want to clear using the ▲, ▼ and ***M*** buttons.
2. Press the ***M*** button and hold it pressed until the displayed value starts flashing.
3. Release the ***M*** button and by pressing the ▲or ▼ button change display to show CLr (= clear). The next press of the ***M*** button clears the value.

Clearing a value clears all the other values in its group and starts over their evaluation.

4.3 Enable / Disable Parameter Edit

When shipped, the controller has the Parameter Edit feature enabled, that is the parameters can be edited freely on power supply voltage connection as desired. After being put in operation, Parameter Edit can be disabled to protect the controller against unauthorized changes to its mode of operation.

To see if Parameter Edit is disabled or enabled, check parameter 00. It can contain the following:

Ed=0 .... edit disabled

Ed= 1 .... edit enabled – parameters can be edited, recorded values can be cleared

If Parameter Edit is locked, you can unlock it using the following procedure, which is similar to editing the controller's parameters:

1. List parameters with buttons ▼ , ▲ up to parameter 00 . - Ed=0 is displayed (the controller must not be in the ***Manual*** mode).
2. Press ***P*** button and hold it down until the last character on the display starts flashing. A digit between 0 and 9 will be shown on the last digit position. As an example you can imagine 5 is displayed so the display shows Ed=5 with the 5 flashing.
3. Press the following sequence: ▼ , ▲ , ▲ , ▼ . If 5 was shown as the last display digit, it would change to 4 - 5 - 6 - 5, so the same value is shown at the end as at he beginning.
4. Press ***P*** button . The display will show Ed= 1, indicating correct password and enabled Parameter Edit while clearing recorded measurement values.

The digit shown while entering the unlocking keypress sequence is random generated by the controller and it is not important for its correctness (it is there only to confuse). Only the sequence of pressed buttons is important.

Parameter Edit mode is enabled until it gets disabled by the operator. Parameter Edit enabled or disabled conditioned is retained in the instrument even on power off.

Parameter Edit can be disabled in a way analogous to enabling it but you press buttons different from the correct unlocking keypress sequence.

4.4 Manual Mode

When installing or testing the controller it is sometimes required to check the function of each compensation section or it is necessary to put the automatic control process out of operation for a rather long time.

In such situations, you can switch the controller to a mode in which it only carries out measurements and displays the values. You can switch to this mode by pressing buttons ***M*** and ***P*** and holding them down simultaneously for about 6 seconds (until the ***Manual*** LED starts flashing). You can switch back to the automatic control mode in the same way.

You **cannot** view or edit the controller's parameters in the ***Manual*** mode – you can only close or open each controller's output.

On switching the regulator to the ***Manual*** mode, the outputs stay in the state they were in during the control process before switching over the modes. You can then change the states of the outputs manually – after pressing the ***P*** button the state of the corresponding output is shown (for example 01-0, which means output 1 is off – contacts open) and you can scroll through them all using the ▲, ▼ buttons and edit them very much like the instruments' parameters. The outputs' states change while being edited, respecting the specified reconnection delay time.
If the controller is in the ***Manual*** mode and there is a supply voltage failure, the ***Manual*** mode is resumed on power recovery. At this, all outputs that were on before the failure get switched on one by one again (the states of outputs are remembered).

Warning ! Alarm actuation (parameter 30) is disabled in ***Manual*** mode!

4.4.1 Manual Intervention in Control Process

In order to be able to check the controller's response to a control deviation change, it is possible to connect or disconnect a section by operator's manual intervention, not only in the ***Manual*** mode but also within the automatic control process.

While holding button ***M*** pressed down you can connect or disconnect a section using buttons ▲and ▼ and watch the controller's response to the change of condition. Each button press connects or disconnects one compensation section, always the one with the smallest value (exception: in the linear switching mode the order of connecting/disconnecting is specified in description of parameter 21). Reconnection delay time is respected when connecting.

If the controller is left in the automatic control mode, it will carry out evaluation and control intervention after the control time has elapsed thus putting the unbalanced conditions in the power system back to a compensated state.

4.5 Controller Initialization

In some situations it may be necessary to put the controller back to its manufacturer default settings. You can do this using controller *initialization*. After initialization has been run, the initial test starts too, that means the controller carries out all the operations as if the power supply voltage is applied for the first time.

By initialization the controller's parameters are set to the values shown as default in chapter 6, except the following ones:

- metering current transformer nominal secondary value (13)
- type of measurement voltage (phase or line, 15)
- instrument address, communication rate and protocol in instruments with communication interface (50, 51, 52)

These parameters remain unchanged, as specified before initialization.

The counters of connection time and switching operations (parameters 43, 44) are not affected by initialization too.

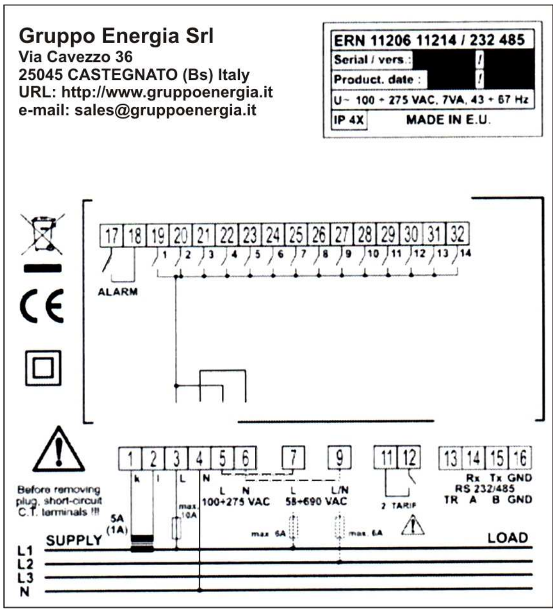
The controller initialization is actuated by pressing the ***M***, ***P*** and ▼ buttons simultaneously and holding them down for about 6 seconds. The controller will first disconnect all connected sections and run the initial test – this is when you release the buttons. Then it will carry out the actual initialization routine and since the parameter 16 is not defined, it will start the automatic connection configuration process.

Warning! The ***Manual*** mode is terminated on initialization if active! The controller is always set to the automatic control mode after initialization!

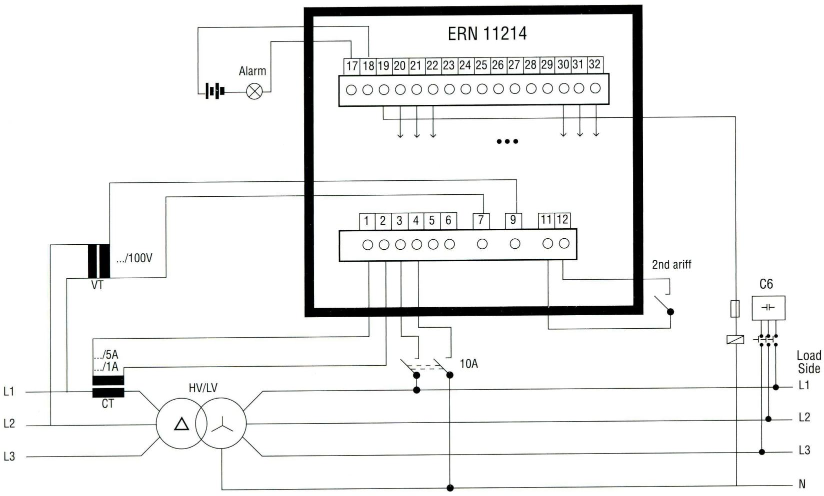
For further specifications, please see Cap.7

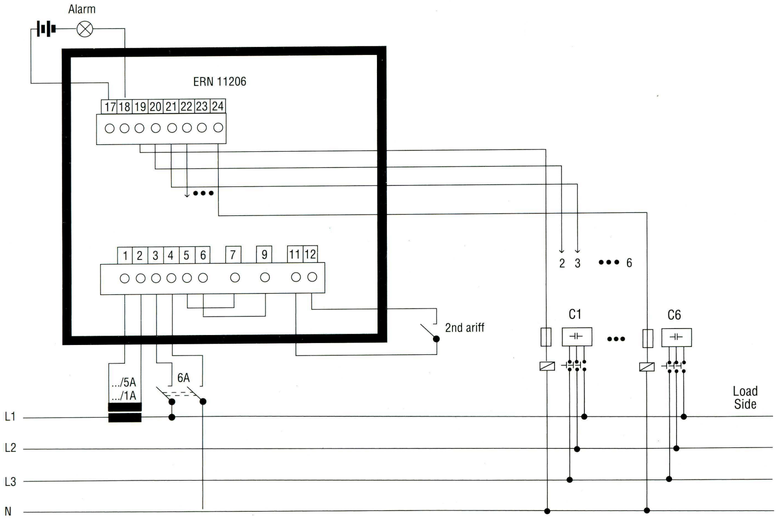
5. Wiring

Rear Side Label



Wiring Examples





6. GE ERN Series Parameters Specification

Table 6.1: GE ERN Series Parameters

#	name	range	step	default	Comment
0	parameter edit enable/disable	0 / 1	—	1	see Enable / Disable Parameter Editing
1	target power factor (metering rate 1)	0.80 L ÷ 0.80 C	0.01	0.98 L	
2	control time when undercompensated (metering rate 1)	5 sec ÷ 20 min	—	3 min	No “L”: control time reduction by squared proportion “L”: linear control time reduction.
3	control time when overcompensated (metering rate 1)	5 sec ÷ 20 min	—	30 sec	No “L”: control time reduction by squared proportion “L”: linear control time reduction
4	control bandwidth	0.000 ÷ 0.040	0.005	0.010	
6	metering rate 2 enable/disable	0 – 1 – E	—	0	
7 ÷ 10	like parameters 1 ÷ 4, but for metering rate 2	the same as parameters 1 ÷ 4	—	—	not shown unless metering rate 2 is enabled
12	metering current transformer primary side nominal value	5 ÷ 9950 A	5	none	
13	metering current transformer secondary side nominal value	1 A ÷ 5 A	—	5	
14	reconnection delay time	5 sec ÷ 20 min	—	20 sec	
15	measurement voltage type – phase-neutral or phase-phase	LN (phase) – LL (line)	—	LN	This parameter’s correct setting is essential for automatic connection configuration detection process.
16	method of connection of U and I	6 combinations	—	none	see parameter description
17	VT turns ratio	no VT or 10 ÷ 5000	—	--- (no VT)	VT nominal primary to secondary voltage ratio
18	compensation system nominal voltage U_{NOM}	50 ÷ 750 V x VT turns ratio	—	230 / 400 V	controller establishes this value within automatic connection configuration detection process
20	automatic section power recognition process	A (auto) – 0 (no) – 1 (yes)	—	A	
21	switching program, linear switching mode	12 typical combinations or “L“	—	none	0 means individual section setting. Not shown if automatic section power recognition process is enabled.
22	smallest capacitor nominal power (C/k value calculated for metering current transformer primary side)	(0.007 ÷ 1.3 kvar) x CT ratio x VT ratio	0.001	none	Value corresponds to U_{NOM} specified (parameter 18) Not shown if automatic section recognition is enabled.
23	number of capacitors	1 ÷ 14	—	6 / 8 / 14	Not shown if automatic section power recognition process is enabled.
25	sectional nominal power	(0.001 ÷ 5.5 kvar) x CT ratio x VT ratio	0.001	none	Value corresponds to U_{NOM} specified (parameter 18) positive for capacitive sections (lead), negative for chokes (lag)
26	fixed sections	regulated or 0 / 1 / F / H / A	—	all regulated	„F“,/ „H“ / „A“ for 2 highest sections only „A“ for GE ERN 11005, ERN 11007 only
27	power factor limit for compensation by choke	0.80 lag to 0.80 lead	0.01	none	No compensation by chokes takes place unless this parameter is specified.
30	alarm setting	0 / indication only / actuation only / indication and actuation	—	indication and actuation from undercurrent, voltage signal absence or section error	1... undercurrent 2... overcurrent 3... loss of voltage 4... undervoltage 5... overvoltage 6... THDI > 7... THDU > 8… CHL > 9… compensation error 10… export 11… no. of connections > 12… section error 13… overheated 14… external alarm
31 ÷ 37	alarm thresholds: undervoltage, overvoltage, THDI, THDU, CHL, number of connections and temperature	—	—	—	Ranges and units as in Table 4.7 not displayed if the alarm not set up

40	alarm instantaneous condition				Indicates current state of alarm.
43	section connection time (in thousands of hours)				display range 0.001 to 130
44	number of section connections (in thousands)				display range 0.001 to 9999
45	instrument failure condition				
46	instantaneous condition of control time				time until next control intervention in seconds
50	instrument address	1 ÷ 255	1	1	
51	communication rate	600 ÷ 9,600 Bd	—	9,600	
52	communication protocol	GE(P0) / Modbus-RTU(P1)	—	GE(P0)	
55	power system frequency	A (auto) – 50 Hz – 60 Hz	—	A (auto)	
56	average value evaluation moving window size	1 minute ÷ 7 days	—	7 days	applies to average values of Acos, APac, APre
57	minimum and maximum value evaluation moving window size	1 minutes ÷ 7 days	—	15 minutes	applies to these minimum and maximum values: mincos, maxPac, maxPre, maxdPre
58	Celsius/Fahrenheit temperature display mode	°C – °F	—	°C	
59	cooling enable threshold	+10 ÷ +60 °C	1 °C	+40 °C	not displayed if cooling output not specified
60	heating enable threshold	-30 ÷ +10 °C	1 °C	-5 °C	not displayed if heating output not specified

6.1 Parameter 01/07 – Target Power Factor

The value of target power factor for metering rate 1 (parameter 01) or metering rate 2 (parameter 07) can be specified in the range from 0.80 lag to 0.80 lead.

If a more precise setting is required around power factor equal to 1.00, you can specify the phase shift angle from +10 to –10 degrees instead of the power factor value. The phase shift angle setting mode is scrolled to by pressing the ▲ key while editing the parameter until the phase shift angle value required is displayed, which is marked with a degree symbol, for example 10° means +10°.

If the parameter is specified as a phase shift angle in degrees, the bandwidth on high loads is displayed in degrees too (see parameter 04/10 further below).

6.2 Parameter 02/08 – Undercompensation Control Time

The value for metering rate 1 (parameter 02) or metering rate 2 (parameter 08) can be specified in the range from 5 seconds to 20 minutes: 0.05 - 0.10 - 0.15 - 0.20 - 0.30 - 0.45 -1.0 - 1.30 - 2.0 - 3.0 - 4.0 - 5.0 - 7.0 - 10.0 - 15.0 - 20.0 (the number before decimal point specifies minutes, that after decimal point specifies seconds). The value specifed determines the frequency of control interventions under the following conditions:

- instantaneous power factor is more inductive than the value required – undercompensated
- the difference between reactive power instantaneous value in the power system and optimum value, which corresponds to the target power factor setting (= control deviation), is just equal to the smallest capacitive section current (C/k_{MIN})

If the parameter value is set to say 3.0 and the above mentioned conditions are met in the power system, the controller calculates optimum compensation and carries out control intervention every 3 minutes.

The time mentioned gets shorter in proportion to the instantaneous control deviation. If control time without preceding character "L" is set, it gets shorter as square of control deviation over the smallest capacitive section value (C/k_{MIN}). If the control time with preceding character "L" is specified, it gets shorter in proportion to this ratio ("L" = Linear, causes slower response to large deviations). Rising control deviation can decrease this value to the minimum control time of 5 seconds.

On the contrary, if the control deviation is smaller than the smallest capacitive section current (C/k_{MIN}), control time gets twice as long. If the control deviation falls further under half of the smallest capacitive section current value (C/k_{MIN}), no control interventions take place.

6.3 Parameter 03/09 – Overcompensation Control Time

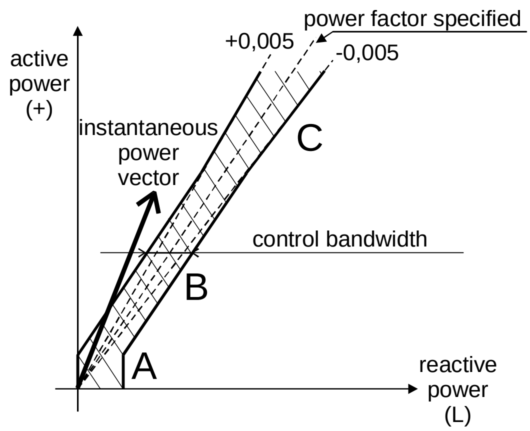
The value for metering rate 1 (parameter 03) or for metering rate 2 (parameter 9) determines the frequency of control interventions, very much like in parameter 02/08 described above. There is a difference though: it only applies if the instantaneous power factor is more capacitive than that required, that is it is overcompensated.

The control time operation in proportion to control deviation magnitude is the same as with parameter 02/08 described above.

6.4 Parameter 04/10 – Control Bandwidth on High Loads

Using this parameter you can specify the control bandwidth on high loads (see Figure 6.1). The value entered specifies the range of reactive power in the C zone which constitutes condition considered as compensated, making the controller stop control interventions.

Figure 6.1: Standard Control Bandwidth



On low loads (zone A) and on medium loads (zone B), the control bandwidth is constant and corresponds to the C/k_{min} value – the band follows the power factor slope specified at width ± $(C/k_{MIN})/2$. On high loads (zone C) the bandwidth increases so its limits correspond to adjustable deviation from the target power factor. The standard bandwidth value in this zone is 0.010 or ± 0.005 – this condition is shown in Figure 6.1. If thus, for example, the target power factor is specified as 0.98, reactive power corresponding to power factor from 0.975 to 0.985 will be considered compensated condition in zone C.
The control bandwidth can be increased to 0.040 or decreased to 0.000 on high loads. Control bandwidth increase may especially be useful in systems with large control range – avoiding uselessly precise control on high loads reduces the number of control interventions which results in longer contactor service life. If the parameter values is decreased to 0, the control bandwidth corresponds to value C/k_{min} (constant, not widening).

Note: On low loads, the control bandwidth is “bent” (zone A) to prevent undesired overcompensation (the illustration is a simplification).

If the target power factor (parameter 01/07) is specified in degrees as phase shift angle, the bandwidth on high loads is also displayed in degrees.

6.5 Parameter 06 – Metering Rate 2 Operation

The GE ERN controllers feature two sets of the above described control parameters.

Parameter 6 decides if the control process uses the first set of basic control parameters, 1 through 4, only or if, under certain circumstances, the second set of parameters, 7 through 10 (metering rate 2) is used as well.

By default parameter 6 is set to *0* and only parameters 1 through 4 of the parameters described above are applied; parameters 7 through 10 are not significant in such an event, so they are not shown.

GE ERN 11206-11214 controllers allow changing the above described basic control parameters while compensation is in progress, triggered by external signal (relay contact). They have a metering rate 2 request input for this operation, to which an insulated contact or optocoupler can be connected. If you set the parameter to *1*, the controller will start evaluating metering rate 2 requests and, depending on the input’s instantaneous condition, use parameters 1 through 4 or 7 through 10.

The decimal point after the last character then indicates whether metering rate 2 request is active. If it is dark, metering rate 2 request is not active and only parameters for metering rate 1 apply. On the contrary, lit decimal point indicates active metering rate 2 request and the controller uses parameters specified for metering rate 2.

The metering rate 2 function can further be set to value E. In this event the second set of control parameters is used for active power export, that is if active power flows from appliance to source.

6.6 Parameters 12,13 – Metering Current Transformer (CT) Ratio

You can specify metering current transformer nominal primary value in amperes using parameter 12. The value range is from 5 to 9950.

This parameter (12) is not specified (---- shown) by default. With this setting, all values that are current- or power- related , that is measured values of instantaneous effective, active and reactive currents and power, and further the C/k_{MIN} value (parameter 22) and power in each section (parameter 25), are shown in the magnitude to which they are transformed at the metering current transformer secondary side. The parameter's value specified does not affect the controller's control operation, it only affects displayed values that are related to current or power. Therefore the value may be specified later, after the automatic section power recognition process, without having to start this process again.

Parameter 13 selects metering current transformer nominal secondary current. You can choose from 5A and 1A. **Warning!!! Unlike parameter 12, this parameter must be set correctly for controller's proper operation!** The controller determines whether the current input is overloaded evaluating this parameter and instantaneous current value. The controller may stop operation undesirably or, contrariwise, this operation disablement will not work when it should (see description of parameter 30, alarm from overcurrent).

Parameter 13 setting will be kept even on controller *initialization* (see description further below).

6.7 Parameter 14 – Reconnection Delay Time

It is used to ensure sufficient discharge of a capacitive section prior to reconnection. It can be set in range 5 seconds to 20 minutes to one of the values 0.05 - 0.10 - 0.15 - 0.20 - 0.30 - 0.45 -1.0 - 1.30 - 2.0 - 3.0 - 4.0 - 5.0 - 7.0 - 10.0 - 15.0 - 20.0 . The format is the same as in parameters 2 and 8.

6.8 Parameters 15, 16 – Type of Measurement Voltage and Connection Configuration

Parameter 15 determines if the measurement voltage connected is phase (phase-neutral, U=Ln, default value) or line (phase-phase, U=LL). If the measurement voltage is connected to the power supply transformer's side which is opposite to measurement current connection, the connection configuration value must be set in accordance with transformer type – see description in a separate chapter further below.

Connection configuration parameter must definitely be set correctly in installation, even if automatic connection configuration detection process is assumed to take place. Otherwise the power factor measured will be evaluated with errors!

If the parameter value is specified as phase voltage (U=Ln), the controller also presets the compensation system's nominal voltage value U_{NOM} (parameter 18) to 230 V. If the parameter value is specified as line voltage (U=LL), the U_{NOM} (parameter 18) is preset to 400 V.

The connection configuration parameter (15) value set will be kept even on controller *initialization* (see description further below).

Parameter 16 determines the method of measurement voltage connection with respect to measurement current, that is between which phases or phase and neutral wire the measurement voltage is connected. It is assumed that the metering current transformer is in phase 1 and its orientation (terminals k, l) corresponds to real orientation supply –> appliance. The method of connection is specified as one of six combinations shown in Table 6.2.

Table 6.2: Measurement voltage connection

phase measurement voltage -U=Ln		Line measurement voltage - U=LL	
#	connection	#	connection
1	L1-0	1	L1-L2
2	L2-0	2	L2-L3

3	L3-0	3	L3-L1
4	0-L1	4	L2-L1
5	0-L2	5	L3-L2
6	0-L3	6	L1-L3

Notes:

- It is assumed that the metering current transformer is in phase 1 and its orientation (terminals k, l) corresponds to real orientation supply –> appliance.
- The method of connection is shown as x–y where x represents the phase connected to controller's terminal ***L*** and y represents the phase connected to controller's terminal ***N/L*** (0 represents the neutral wire).

If the method of connection value is entered as not specified (---- value), the automatic connection configuration detection process is started, with exception of case when *linear switching mode* (see parameter 21) is set. In such case the process is not started and it is necessary to set the method of connection manually.

If the type of connection (phase or line, parameter 15) is changed, the method of connection (parameter 16) is automatically set to the unspecified value.

6.8.1 Setting Type of Connection Configuration if Measuring at Power Supply Transformer's Opposite Sides

If the measurement current signal is from the power supply transformer's side which is opposite to measurement voltage signal side, the transformer phase angle is conclusive for correct parameter 15 setting. This value specifies the angle between voltage vectors of corresponding phases at primary and secondary sides. The transformer phase angle can be in the range from 0 to 11, corresponding to phase angles from 0 to 330 degrees (in steps of thirty degrees).

Provided the measurement voltage signal is connected **in accordance** with the type of transformer (that is phase measurement voltage is connected to controller with wye, or star, connection or line measurement voltage with delta connection), it is necessary to set **phase** type of connection with **even** transformer phase angle value and **line** type of connection with **odd** transformer phase angle value.

If the measurement voltage signal is connected **in disaccordance** with the type of transformer, the opposite rule applies: **line** connection with **even** transformer phase angle or **phase** connection with **odd** transformer phase angle.

Determining parameter 15 explained in practical examples:

Example 1:

Compensation is to be provided for consumption supplied via a **Dy1** transformer while line measurement voltage will be taken from its primary side (D stands for delta connection) and measurement current signal from a metering current transformer at the power supply transformer's secondary side (y stands for wye, or star, connection).

determining type of connection (parameter 15):

1. The transformer's primary side is delta-connected and line primary voltage will be connected to the controller (usually via a metering voltage transformer with nominal output voltage 100 V AC) — this means the measurement voltage will be connected **in accordance** with the type of transformer.
2. Since the measurement voltage is connected **in accordance** with the type of transformer and the transformer phase angle (1) is **odd**, you set the type of measurement voltage connection configuration to **line**. (If the transformer phase angle was even or if the measurement voltage was not connected in accordance with the type of transformer, you would specify phase connection configuration).

Example 2:

Compensation is to be provided for consumption supplied via a **Yy6** transformer while the line measurement voltage will be taken from its secondary side (y stands for wye, or star, connection) and measurement current signal from a metering current transformer at the power supply transformer's primary side (Y stands for wye, or star, connection again).

determining type of connection configuration (parameter 15):

1. The transformer's secondary side is wye-connected, but the line secondary voltage will be connected to the controller — this means the measurement voltage will be connected **in disaccordance** with the type of transformer.
2. The measurement voltage is connected **in disaccordance** with the type of transformer and the transformer phase angle (6) is **even**, so you set parameter 15 to **line**. (If the measurement voltage was connected in accordance with the type of transformer, you would set phase connection).

If in doubt about correctness of determining the type of connection, experimental validation is convenient: after automatic connection configuration detection process you can usually compare the power factor value shown by the controller with information on the billing electricity meter (ratio of revolutions of active and reactive electricity meters). If in discrepancy, you have to set the type of connection configuration to the other value and repeat the validation test.

6.9 Parameter 17 – Metering Voltage Transformer (VT) Turns Ratio

This parameter allows specifying the voltage transformer turns ratio from 10 to 5000 or it can be set as unspecified.

Parameter is unspecified by default: "- - - " is displayed. In this event it is assumed that the measurement voltage is connected directly. Measurement voltage values are then displayed in volts.

If the measurement voltage is connected via a voltage transformer, its turns ratio can be specified in this parameter (example: if a voltage transformer with conversion 35kV/100V is used, 350 is entered). If no voltage transformer turns ratio is specified, all voltage and power measurement values as well as U_{NOM} (parameter 18), C/k_{MIN} (parameter 22), and each section's power (parameter 25) displayed as transformed to the voltage transformer's secondary side. If the voltage transformer turns ration is specified correctly, the aforementioned values are displayed as values corresponding to the voltage transformer's primary side and voltages are shown in kilovolts.

The value specified in parameter 17 does not affect the controller's control operation in any way; it only affects displayed values that are voltage or power. Therefore the value may be specified later, after the automatic section power recognition process, without having to start this process again.

6.10 Parameter 18 – Compensation System Nominal Voltage (U_{NOM})

Parameter U_{NOM} determines the compensation system nominal voltage in volts or, if the voltage transformer turns ration value is entered in parameter 17, in kilovolts. It is phase voltage or line voltage, depending on the type of measurement voltage (parameter 15).

If the type of connection is specified manually (parameter 15), parameter U_{NOM} is preset to its default value – for phase voltage (U=Ln) U_{NOM} is preset to 230 V, for line voltage (U=LL) to 400 V. The actual U_{NOM} value is further entered by the controller **within each automatic connection configuration detection process** to one of the values in Table 3.1 depending on the measurement voltage value.

Unless the compensation system nominal voltage value is untypical, it is usually not necessary to change the U_{NOM} value recognized. If otherwise, the parameter value can be edited from 50 to 750 V (if voltage transformer conversion is used, the value is displayed in kV after conversion).

Undervoltage and overvoltage alarm threshold values (parameter 31,32) are related to the U_{NOM} value.

The U_{NOM} parameter value can by at any time later edited without affecting each section's actual power value (parameter 25). Sections' actual power values (for example as they were detected in the latest automatic section power recognition process) are kept in the controller, only their displayed *nominal* values, which are related to the U_{NOM} value, are affected.

6.11 Parameter 20 – Automatic Section Power Recognition Process

The controllers are shipped with default setting of enabled automatic section recognition power process (parameter 20 set to A, AC=A). With this setting, the controller carries out the automatic section power recognition process on controller powerup (introduction of power supply voltage) if none of the compensation sections is specified at a valid power value (see parameter 25). This condition always takes place with the first installation or *initialization* of the controller or after unsuccessful previous automatic section power recognition process. If at least one of the compensation sections is at valid power value, the automatic section power recognition process is not carried out.

If the parameter is set to 1, the controller carries out the automatic section recognition power process every time the controller is powered up, irrespective of the section values having been recognized before or not.

The process can also be started without interrupting power supply voltage, by editing parameter 20 to value 1 or by controller initialization (see further below).

If the automatic section power recognition process is enabled, it makes no sense to set parameters 21 through 24, therefore these parameters are not shown.

The automatic section power recognition process can be disabled by setting parameter 20 to **0**. In such an event, sections' values must be entered using parameters 21 through 24.

Comment : If *linear switching mode* (see parameter 21) is set, the automatic section power recognition process cannot be enabled.

6.12 Parameter 21, 22 – Switching Program, Selection of Linear Switching Mode and Smallest Capacitor (C/k_{MIN}) Nominal Power

If the Automatic Section Power Recognition Process is disabled, these parameters allow entering the value of each section or setting the "Linear Switching Mode".

If you select one of the preset combinations for parameter 21 as shown in Table 6.3, you select a "switching program" that specifies the ratios of all capacitor sections' values.

When selecting a switching program, the capacitors have to be connected to the controller's outputs in sequence where the lowest weight capacitor is connected to output 1. The number of capacitors connected needs entering in parameter 23. If this number is more than 5, the controller assumes the weights of sections 6 and higher are the same as the weight of section 5.

Table 6.3: Switching Program

#	combination	displayed	#	combination	displayed
1	1:1:1:1:1	1111	7	1:2:2:2:2	1222
2	1:1:2:2:2	1122	8	1:2:3:3:3	1233
3	1:1:2:2:4	11224	9	1:2:3:4:4	1234
4	1:1:2:3:3	1123	10	1:2:3:6:6	1236
5	1:1:2:4:4	1124	11	1:2:4:4:4	1244
6	1:1:2:4:8	11248	12	1:2:4:8:8	1248

If none of the preset combinations corresponds to the the combination required, you can enter each section's value as you desire by editing parameter 25. In such an event, parameter 21 value automatically becomes undefined, ---, which means "*individual switching program*". Parameter 22 thus loses its meaning and it is therefore not displayed.

Having selected the switching program as shown in Table 4.3, you still need to specify the nominal power value of the smallest (corresponding to weight 1) capacitor C/k_{MIN} (parameter 22) in kvar (although the controller measures in single phase, the value corresponds to the three-phase capacitor total value). CT ratio (parameters 12, 13) and U_{NOM} nominal voltage (parameter 18), possibly also VT ratio (parameter 17), values have to be already correctly specified in the instrument prior to entering the aforementioned smallest capacitor power value – only then the smallest capacitor's nominal value specified is actual.

The smallest capacitor nominal value is to be taken from its identification plate or checked by measuring its phase current with a clamp-on ammeter. Table 6.4 shows phase current values for the most usual three-phase compensation capacitors.

Table 6.4: Capacitor's Phase Current Value (for Us=400V)

Q [kvar]	2	3.15	4	5	6.25	8	10	12.5
I [A]	2.9	4.6	5.8	7.2	9.0	11.6	14.5	18.1
Q [kvar]	15	20	25	30	40	50	60	100
I [A]	21.7	28.9	36.1	43.4	57.8	72.3	86.7	144.5

If parameter 21 is set to **L** , no switching program is selected (section values have to be entered in parameter 25) and the *linear switching mode* is enabled to switch harmonic filters. In this mode the controller connects or disconnects compensation sections in the linear fashion, which means:

- always the lowest in order not yet connected compensation section(s) is/are connected
- always the highest in order connected compensation section(s) is/are disconnected

Each section that is not permanently connected or permanently disconnected is considered a compensation section involved in the control process.

On setting the Automatic Section Power Recognition Process (parameter 20) to either **A** or **I**, the linear switching mode is disabled.

Warning ! It is strongly recommended not to activate linear switching mode at standard power factor compensation applications, otherwise quality of control process will be decreased.

6.13 Number of Capacitors

If entering capacitors' currents manually using the switching program and smallest capacitor power (parameters 21, 22), it is also necessary to enter the number of capacitors connected – parameter 23. The value can be set within the range from 1 to the controller's number of outputs.

If using a smaller number of capacitors than the type of controller allows, it is necessary to connect the capacitors to outputs starting with output 1 (that is the unconnected outputs will be those with the highest ordinal numbers).

If the controller outputs are not all used for capacitor connections, the unused outputs can be used to connect compensation chokes. The controller assumes that the chokes are connected from the lowest free output up (that is starting with the section following the last capacitor output connected).

These chokes' currents can be entered in parameter 25, for each choke separately (careful, a choke's current must be entered as a negative value – positive polarity currents are considered capacitive sections by the controller!)

6.14 Parameter 25 – Compensation Section Nominal Power

Nominal power of each compensation output can be edited in the side branch of this parameter if necessary.

The values are displayed in kilovolt-ampere reactive, kVAr, and they correspond to the **nominal three-phase power** of the relevant section under voltage corresponding to the compensation system nominal voltage U_{NOM} (parameter 18) value specified. To have the values correspond to the actual section (capacitor or inductance) compensation power, the current transformer turns ration must be specified correctly as well (parameters 12, 13) or voltage transformer turns ratio (parameter 17) must. If these turns ratios are not specified, the section power values are displayed as if the turns ratio is 1.

Capacitive sections are shown as positive, inductive sections as negative values. If a section's current is not known (for example because of successful completion of the automatic section power recognition process), the ---- value is shown. In such an event, as well as in the event of section current zero value, the controller does not use the corresponding control output.

The controller is shipped with default setting of the automatic section power recognition process enabled (parameter 20 set to A). The automatic section power recognition process is started on introducing the power supply voltage, and after the process is complete, you can check or edit the recognized currents in the side branch of parameter 25.

Each section's nominal power can be changed even if it has been entered manually using the switching program and smallest capacitor current (parameters 21, 22).

If a section's value is shown with a flashing decimal point, it means:

- decimal point flashing **slowly** (about once a second), the section has not been accurized yet – see description of the mechanism to accurize sections in the relevant chapter further below
- decimal point flashing **fast** (about three times a second), the section has been disabled and the controller is not using it – see description of the mechanism to section disablement in the relevant chapter further below

If you change the U_{NOM} value (parameter 18), the controller will keep the actual section power value (for example from the latest automatic section power recognition process), only their displayed *nominal* value, reflecting the changes to U_{NOM}, will change.

6.15 Parameter 26 – Fixed Sections, Switching Cooling and Heating, Alarm

Any controller output can be set as fixed. In such a situation the output is permanently connected or disconnected. The two highest outputs can further be used to switch cooling and heating, and in case of GE ERN 11005-11007 models for alarm signalling too. The controller does not use sections set up this way for power factor control.

6.15.1 Fixed Sections

A fixed output **maintains its preset condition** (that is connected or disconnected) with the following exceptions:

- the controller is switched to the ***Manual*** mode
- a selected nonstandard condition occurs while the alarm's corresponding actuation function has been set (for details see alarm description further below)

A fixed section (one set as permanently connected) is **only** disconnected if the alarm has been activated because of crossing over the threshold level of the quantity selected for a specified time (for details see description of alarm functions further below).

By default all controller's outputs are set as controlled, not fixed. In such an event they are shown for example as follows:

0 1-C .... output 1 is controlled and it is a capacitive section (capacitor)

12-L .... output 12 is controlled and it is an inductive section (choke)

Each section's value can be set to 0 or 1 that is 0 1-0 or 0 1- 1, respectively, is displayed and the corresponding output becomes a fixed one – it stays permanently disconnected or permanently connected.

6.15.2 Alarm Signalling

The two highest outputs can be used for Alarm state signalling. For one of the outputs to be used as Alarm relay, it is necessary to set the output to one of following :

- 8-A .... output 8 set to Alarm signalling; if Alarm state active, the output is **opened**
- 8-A. .... (= „A“ with decimal point) output 8 set to Alarm signalling; if Alarm state active, the output is closed

When Alarm function set, Alarm state is indicated not only by ***Alarm*** LED, but by opening/closing of appropriate relay too.

6.16 Parameter 27 – Limit Power Factor for Compensation by Choke

This parameter specifies power factor value at which the controller starts using, besides capacitive sections, inductive compensation sections for compensation as well – chokes (if available).

If the power factor measured is more inductive (current more lagging) than the value specified in this parameter, the controller uses only capacitive sections (capacitors) to control compensation.

If the power factor in the power system changes so that it is more capacitive (current more leading) than the limit value for compensation by choke, the controller starts using combination of capacitive and inductive compensation sections for compensation.

By default this parameter's value is set as undefined (- .- - displayed) in a shipped controller or after its initialization. With this setting the controller does not use chokes that are available (such sections are permanently disconnected) and it does not even detect available chokes in the automatic section power recognition process.

Compensation by chokes is described in more detail in an appropriate chapter further below.

6.17 Parameter 30 – Alarm Setting

GE ERN line controllers feature two alarm type functions that are independent of each other:

- alarm indication
- alarm actuation

6.17.1 Alarm Indication

In order to indicate non-standard compensation conditions, the instruments feature an ***Alarm*** LED in the front panel and an Alarm relay potential-free contact accessible at a connector in the rear panel. In GE ERN 11005-11007 models, that are not equipped with the dedicated Alarm relay, it is possible to use any of highest two outputs for Alarm signalling (see parameter 26).

Indication of a non-standard condition occurrence shows as flashing ***Alarm*** LED and closed Alarm relay contact. In standard condition this LED is dark and the relay contact open. In GE ERN 11005-11007 models, the relay state polarity can be set in advance, but it is always opened if voltage outage occurs.

Non-standard condition, at which alarm should be indicated, can be specified in the side branch of parameter 30. Any of the eight conditions shown in Table 6.5 can trigger the alarm indication.

Alarm indication from any nonstandard condition can be selected by editing such a condition in the side branch of parameter 30. The settings can take 4 different values:

1. 01-0... condition 1 (undercurrent) is not indicated (neither does it trigger actuation – see description further below)
2. 01-5... condition 1 (undercurrent) is indicated (but it does not trigger actuation)
3. 01-A... condition 1 (undercurrent) is not indicated (but it triggers actuation)
4. 01-2... condition 1 (undercurrent) is indicated (and it triggers actuation)

Alarm indication can be set for any other condition in the same manner as shown for condition 1 in the above example. For some conditions, alarm actuation can be specified besides indication (see description further below).

Alarm indication can be triggered by one or a combination of some conditions specified. Alarm indication will be triggered when the condition has been detected continuously for the time specified in Table 6.5 as the 1st value; the 2nd value (after „/“) defines elapse time to stop alarm indication after the condition disappears. The condition that has triggered alarm indication can then be checked in the alarm status (in the side branch of parameter 40).

Table 6.5: Alarm – Indication

#	condition	Description	minimum delay of activation / deactivation
1	**undercurrent**	current at metering current transformer's secondary side under minimum measurement current	5 / 5 seconds
2	overcurrent	current at metering current transformer's secondary side over 120% of nominal value setting (6 A / 1.2 A)	immediately
3	**voltage failure**	measurement voltage not detected (< 30 Veff)	5 / 5 seconds
4	undervoltage	voltage one-minute moving average value lower than the undervoltage threshold specified (parameter 31)	maximum 1 minute (depends on the extent of undervoltage)
5	overvoltage	voltage one-minute moving average value higher than the overvoltage threshold specified (parameter 32)	maximum 1 minute (depends on the extent of overvoltage)
6	THDI >	THDI one-minute moving average value higher than the THDI threshold specified (parameter 33); works on loads 5% and higher	maximum 1 minute (depends on the level of THDI)
7	THDU >	THDU one-minute moving average value higher than the THDU threshold specified (parameter 34)	maximum 1 minute (depends on the level of THDU)
8	CHL >	CHL one-minute moving average value higher than the CHL threshold specified (parameter 35)	maximum 1 minute (depends on the level of CHL)

9	compensation error	power factor fifteen-minute moving average value outside range 0.9L to 1.00; works on loads 5% and higher	maximum 15 minutes (depends on the level of power factor)
10	export	negative active power one-minute moving average value detected (flow of power from appliance to source)	maximum 1 minute (depends on the level of active power)
11	number of switching operations exceeded	number of connects and disconnects od a section has exceeded the limit setting	immediately
12	**section error**	permanently wrong section value detected in compensation (usually section failure)	5 connections + 5 disconnections
13	overheated	temperature one-minute moving average value higher than the temperature threshold specified (parameter 37)	maximum 1 minute (depends on the level of temperature)
14	external alarm	second metering rate input switched on	5 / 5 seconds

Note: Conditions shown above in bold type are set by default.

Unlike alarm actuation described below, alarm indication setting has no effect on the instrument’s control process.

Besides conditions mentioned above, alarm indication will also be triggered by a condition when at least one nonzero capacitive section has not been specified (when entering section values manually) or identified (in the automatic section power recognition process). Under this condition, flashing C=0 is shown on the numeric display.

6.17.2 Alarm Actuation

Independently of the alarm indication function, you can set alarm actuation for some of the nonstandard conditions. Actuation means intervention in the control process, especially interruption of controller operation, usually with subsequent disconnection of compensation sections. See list of actuations in Table 4.6.

If you require that the controller respond to occurrence of an above nonstandard condition with its corresponding actuation as shown in the table, you have to set the condition of choice in the side branch of parameter 30 to A or 2 (see previous chapter).

Conditions not shown in this table do not trigger any actuations, hence they can not be set this way either.

Table 6.6: Alarm – actuation

#	condition	minimum delay of activation / deactivation	Actuation
1	**undercurrent**	10 / 5 seconds	disconnection of all sections except fixed ones
3	**voltage failure**	immediately / 5 seconds	disconnection of all sections
4	undervoltage	maximum 1 minute (depends on the extent of undervoltage)	disconnection of all sections
5	overvoltage	maximum 1 minute (depends on the extent of overvoltage)	disconnection of all sections
6	THDI >	maximum 1 minute (depends on the level of THDI)	disconnection of all sections
7	THDU >	maximum 1 minute	disconnection of all

		(depends on the level of THDU)	sections
8	CHL >	maximum 1 minute (depends on the level of CHL)	disconnection of all sections
10	power export	maximum 1 minute (depends on the level of active power)	disconnection of all sections except fixed ones
12	**section error**	5 connections + 5 disconnections	section disablement (see description in chapter below)
13	overheated	maximum 1 minute (depends on the level of temperature)	disconnection of all sections
14	external alarm	immediately / 5 seconds	disconnection of all sections

Note: Conditions shown above in bold type are set by default.

6.18 Parameters 31 through 37 – Alarm Indication/Actuation Limits

If indication or actuation from a condition shown in Table 6.7 is set up, you also need to specify the relevant quantity's limit value exceeding which triggers the indication or actuation. The table shows parameter numbers where the limits are stored, limit setup ranges, and limit default values.

Number of switching operations limit (parameter 36) is shown in thousands.

If neither indication nor actuation from either of the two conditions has been set, the corresponding limit value is not shown.

Table 6.7: Alarm Limits

#	condition	limit – parameter number	Limit setup range	standard value
4	undervoltage	31	50 ÷ 100 % U_{NOM} (par. 18)	80 %
5	overvoltage	32	100 ÷ 200 % U_{NOM} (par. 18)	110 %
6	THDI >	33	1 ÷ 300 %	20 %
7	THDU >	34	1 ÷ 300 %	10 %
8	CHL >	35	80 ÷ 300 %	130 %
11	number of switching operations exceeded	36	10 ÷ 2000 x thousand of switching operations	1000
13	overheated	37	20 ÷ 60 ℃	45 ℃

6.19 Parameter 40 – Alarm Status

If an indication function from a nonstandard condition is set (see description of parameter 30 – alarm setting), you can view alarm's current status in the side branch of parameter 40.

Indication can be triggered by any of the nine conditions shown in Table 4.5. Parameter 40 is used for detailed identification of condition that has triggered alarm indication. Alarm indication has been triggered by those conditions whose value is 1.

6.20 Parameters 43, 44 – Total Section Connection Time and Section Switching Operations

In the side branch of these parameters you can check the time that each section has been connected for (parameter 43) and the switching operations for each section (parameter 44) since last reset.

The total section connection time is shown in thousands of hours. If the number is low, you can view it at accuracy in the order of hours. Maximum value is 130 thousand hours.

The number of switching operations is shown in thousands. If the number is low, the value is shown with a decimal point so that you can view it at accuracy in the order of single events, tens or hundreds of switching operations. Maximum value is 4 million switching operations.

The numbers are kept in the controller's non-backed up memory and stored in backed up memory about every eight hours where it is maintained even on power supply outage. The numbers from the last eight–hour interval are lost on voltage failure or controller initialization.

If a section's contactor is replaced, the relevant output's switching operation counter can be cleared by editing it.

6.21 Parameter 45 – Type of Controller Error

The controller carries out self-diagnostic tests in regular intervals during the compensation process. You can check the diagnostics' results in this parameter.

It shows E-00 if no errors have occurred. If the value is other than zero, the controller has identified an error. Such a condition does not necessarily mean the controller is out of operation — in such an event the controller supplier must be contacted and told about the identification value of the type of error shown. Using this value, a specialist will then decide about the method of solving the problem.

6.22 Parameter 46 – Control Time

When optimising controller parameter settings, it is sometimes required to monitor control time in detail. You can view the control time's current value in this parameter – it is shown in seconds as countdown to the next control intervention.

For monitoring the control time to make sense, the control operation must not be halted — therefore the control operation is enabled while viewing this particular parameter. Another difference while viewing this parameter is automatic jump back to display of values measured; this automatic jump takes only place after having viewed the control time for about 5 minutes from the last button press (it takes place as soon as in about 30 seconds while viewing any other parameters).

6.23 Parameters 50, 51, 52 – Instrument Address, Communication Rate and Communication Protocol

These parameters are only important in instruments featuring remote communication interface.

When setting up remote communication you have to specify the instrument's address (parameter 50) to one of the values from 1 to 253 (addresses 0, 254, and 255 are dedicated to special functions – do not use them). If a number of instruments are connected to the communication line, each instrument must have a different address.

The communication rate (parameter 51) can be set to one of the values: 4800, 9600, 19200 Bd.

The standard communication program uses a proprietary communication protocol, "GE". The protocol is set as default in parameter 52, as P0. To facilitate implementation within user applications, the Modbus-RTU protocol can be used as well. The protocol can be set as P 1n / P 1E / P 1O (non parity / even parity / odd parity).

The specified values will be kept even on controller's *initialization* (see description further below).

6.24 Parameter 55 – Power System Frequency

In order to obtain correct evaluation of measurement values, connected voltage and current sampling must be derived from the power system frequency. The controller measures the frequency on basis of voltage signal zero crossover rate. Voltage and current sampling then takes place in accordance with this parameter setting as follows:

F= A.... continuous sampling derived from measured frequency value (default setting)

F=50.... fixed sampling for power system frequency 50 Hz

F=60.... fixed sampling for power system frequency 60 Hz

Setting to A is optimum in most situations. Sampling of signals under measurement is continuously governed by measured frequency 10-second moving window average within the range from 43 to 67 Hz.

If the voltage signal is distorted to a degree when frequency can not be measured with sufficient accuracy, you can set up the parameter to 50 or 60. The measurement signals are then sampled at the specified fixed rate with no regard to the measured frequency.

6.25 Parameters 56, 57 – average, maximum, minimum value evaluation window size

Besides displaying instantaneous measurement quantities, the controller also evaluates and records average and extreme (maximum/minimum) values. The evaluation window size for maximum THD, CHL, harmonic components, and temperatures is fixed (1 minute) while it can be specified in the range from 1 minute to 7 days for the other quantities, as shown in Table 6.8.

At the default setting shown above, the quantities Acos, APac, and APre contain the values of average power factor, average active power, and average reactive power, respectively, for the last 7 days.

Similarly the mincos, maxPac, maxPre, and maxdPre quantities contain the minimum values of 1-minute moving averages if power factor, maximum value of 1-minute moving averages of active power, maximum value of 1-minute moving averages of reactive power, and maximum value of 1-minute moving averages of difference between actual and required reactive power, respectively, since last reset.

Table 6.8: average and extreme power and power factor value evaluation window sizes

param.	Description	default value
56	window size for evaluation of average power factor, Acos, and average power, APac, APre.	7 days
57	window size for evaluation of minimum power factor, mincos, and maximum power, maxPac, maxPre, and maxdPre	15 minutes

Moving window size can be selected of 1 – 15 – 1H – 8H – 1d – 7d , that is 1 minute – 15 minutes – 1 hour – 8 hours – 1 day – 7 days. On changing the evaluation moving window size, the relevant average and extreme values are automatically cleared and the evaluation restarted.

6.26 Parameter 58 – Temperature Display °C / °F

This parameter specifies if the temperatures measured are displayed in degrees Celsius or Fahrenheit.

The measurement quantities of instantaneous temperature (Temp), maximum temperature (maxTemp) and parameters overheating alarm limit (parameter 37), heating switching threshold (parameter 59), and cooling switching threshold (parameter 60) are all displayed using the unit specified and indicated with symbols °C or °F.

6.27 Parameters 59, 60 – Cooling and Heating Switching Thresholds

Of an output is set up to switching cooling or heating in parameter 26, you can specify the switching temperature threshold required in parameter 59 or 60. The switching temperature hysteresis is about 5°C. The ranges and default thresholds are shown in Table 4.1.

If none of the output is set up to switching cooling or heating, the corresponding threshold is not used or displayed.

7. Further Specifications

7.1 Section Value Accuracy

If the controller is set up to automatic section power recognition process, it means that parameter 20 is set to AC=A , or AC= 1, and it carries out the automatic section power recognition process on the first initialization or reinitialization or on resuming power after a power failure.

After successful completion of the automatic section power recognition process, it records all the measured power values and starts the control process. All measured power values are tagged as “not yet precise”. A sections, the value of which is not yet precise, can be identified by **slowly** flashing decimal point (as opposed to fast flashing decimal point to identify a disabled section – see description further below).

The controller measures the sections continually within the control process as they are connected and disconnected. It evaluates the average value measured for each not-yet-precise section and, when having received about 100 values, it rewrites the original section value, which was obtained in the automatic section power recognition process, with it. At the same time it tags the section as “precise” and stops further accuracy evaluation of such a section.

This way, possible inaccuracies in the automatic section power recognition process are removed.

If the sections' values are specified manually (using the switching program and smallest capacitor power or by editing section value in parameter 25), no subsequent accuracy evaluation takes place. Neither is the accuracy of choke sections, if present, carried out.

If the automatic section power recognition process is enabled, the accuracy evaluation process can be automatically started anytime during the control process as well. If the controller detects that a compensation capacitor has repeatedly been showing a value different from that measured in the automatic section power recognition process and the difference is not in order of magnitude (that is in the interval from a half to double value) from the value recorded in the controller, the accuracy evaluation process for such a section will start. Thus effects of changes in compensation capacitor values, for example as a consequence of the forming process after installation or due to aging etc., can be eliminated.

7.2 Faulty Section Indication and Disablement

In the alarm setting (parameter 30) you can choose alarm indication or actuation from detecting a faulty section (section error).

If at least one of these functions has been set, the controller continually checks reactive power changes in the power system during the control process as the sections are connected and disconnected and compares them with each section's power recorded. If connecting and disconnecting a section does not repeatedly result in adequate change to reactive power in the power system (or a change to reactive power measured is very different from the capacitor's value recorded), the controller tags such a section as faulty and, if relevant alarm actuation has been set, it will disable the section and stop using it in further compensation temporarily.

Alarm indication can be used for section disablement indication (see description of parameter 30). If alarm actuation is not set, the controller will only tag the faulty section, trigger alarm indication, but will keep using the section in compensation. A particular faulty section can be identified by **fast** flashing (about three times a second) decimal point in the section value display in the side branch of parameter 25 (as opposed to slowly flashing decimal point identifying not-yet-precise section – see description in chapter above).

A section that has been temporarily disabled is periodically, about every five days, checked by including it in compensation for one switching operation. If the controller detects a relevant response in the power system (within adequate allowance) to connecting the section, it will include the section in the control process again and, if the automatic section power recognition process is enabled, it will run the accuracy evaluation process for it too. This way, for example, a repaired section is automatically included in compensation (after replacing section fuse, for instance).

If the controller does not put a disabled section back to compensation automatically, such reinsertion in the control process will take place in the following situations:

- power supply interruption or controller initialization (see description further below)
- editing the section's value or one of parameters 21 through 23 (switching program, smallest capacitor value, number of capacitors).
- automatic section power recognition process

Faulty section indication and disablement can only be set for capacitive sections – choke sections, if present, are not checked.

7.3 Compensation by Choke

The instrument allows connecting chokes for power system decompensation. The decompensation system can be built as combined, in which case both chokes and capacitors are connected to the controller, or only chokes are connected. If there are no capacitors used in the system, the control rate is derived from power of the smallest choke connected.
Compensation by choke is conditioned by compensation by choke power factor limit value setting

(parameter27) within a range from 0.8 lag to 0.8 lead. If this parameter is not defined (- .- - shown), compensation by choke does not take place (if chokes are available at some of the outputs, these outputs are permanently disconnected).

If the compensation by choke power factor limit value is specified as a valid setting, a choke is connected in the following situation:

- controller has disconnected all capacitive sections
- power factor is still more capacitive (leading) than that required and also more capacitive than the compensation by choke power factor limit value specified
- this condition has lasted for five times longer than the overcompensation control time (parameters 3, 9)
- a choke is available at least at one output and it has such a value that after its connection it will be possible to control the power factor to desired value using a combination of capacitive sections, that is large undercompensation will not occur after its connection

If a number of chokes are available to the controller, the most suitable one, depending on their values, is connected, and another one is connected if the above described situation has lasted for another five times longer than overcompensation control time specified.

If a combination of chokes are connected and undercompensation occurs, such a number of chokes are disconnected after a normal undercompensation control time has elapsed (parameters 2, 8), which prevent overcompensation.

It is recommended that decompensation chokes to be connected to outputs 5 and higher. Outputs 1 through 4 are reserved for capacitive sections, since the controller uses these outputs in the automatic connection configuration detection process. Nevertheless, even the outputs 1 through 4 can be used for chokes – but the automatic detection process cannot be used and parameter 16 must be set manually in such case.

The automatic section power recognition process can also be used to determine values of the chokes connected, but the compensation by choke limit power factor (parameter 27) must be specified at a valid value prior to this. If this parameter value has not been specified (- .- - shown), connected chokes will not be detected.

After controller initialization, parameter 27 value is not specified, so compensation by choke is disabled by default.

7.4 Control Interruption

If the controller is in the automatic control mode (not in the ***Manual*** mode), one of the values measured is shown on the numeric display (***Measurement*** display mode) and the controller carries out control process based on the values measured and parameter settings.

If you switch to parameter display, the control process will be interrupted. Output relays will stay in the state they were at the moment of switching over the display mode. The controller assumes the operator wants to check or change some of the parameters and it does not change the state of outputs until this has been finished (provided no nonstandard conditions, such as measurement voltage failure, have occurred, of course). At the moment of switching back to display mode, the instrument continues the control process.

If the operator did not switch back to the ***Measurement*** display mode, the controller would switch to the mode automatically in about thirty seconds from the last button press.

An exception is showing the control time (parameter 46) – in this event the control interrupted will resume for operator to be able to check control process operation. The display will switch to showing instantaneous values after about 5 minutes automatically.

Analogously to control interruption, the automatic connection configuration detection process or automatic section power recognition process will be interrupted by the above mentioned procedure if in progress. It, however, starts over from the beginning again once resumed.

7.5 Capacitor Harmonic Load factor (CHL)

One of the measurement quantities is Capacitor Harmonic Load, CHL, factor. This quantity expresses the total load of capacitors by current and with alarm actuation enabled, it can be used in protection of the capacitors against overload. This factor’s definition follows.

Compensation capacitors’ service life depends on not exceeding operation limits. One of the limits is capacitor’s maximum current. This may be exceeded with voltage harmonic distortion due to a capacitor’s inductance being a function of the frequency.

If voltage in not distorted (sinus), the capacitor current is

$$Ic = \frac{U}{Zc} = \frac{U}{1/2\pi fC} = 2\pi fCU \qquad [A] \qquad [1]$$

where :

Ic.... capacitor current [A]
U.... capacitor voltage [V]
Zc... capacitor impedance [Ω]
f.... frequency [Hz]
C... capacitor capacity [F]

If the voltage is distorted, the current flowing through a capacitor forms as the sum of current harmonic component vectors

$$\vec{I}c = \sum_{i=1}^{n} \vec{I}i \qquad [A] \qquad [2]$$

and magnitude of each harmonic component is pursuant to formula [1]

$$Ii = 2\pi fi\, C\, Ui = 2\pi (f_f \times i)\, C\, Ui \qquad [A] \qquad [3]$$

where :

i.... order of harmonic [-]
Ii.... current of i^{th} harmonic component [A]
Ui... voltage of i^{th} harmonic component [V]
fi.... frequency of i^{th} harmonic component [Hz]
f_f.... fundamental harmonic frequency [Hz]

According to formula [3], the magnitude of current of each harmonic component is proportional to a multiple of voltage and its order (Ui x i) of harmonic. Consequently, the total harmonic distortion, which is defined as

$$THD_U = \sqrt{\sum_{i=2}^{N} \left(\frac{U_i}{U_1} \right)^2} \qquad [\%] \qquad [4]$$

where:

THD_U… voltage total harmonic distortion [%]
Ui......... voltage of i^{th} harmonic component [V]
U_1…..... voltage of fundamental harmonic component [V]

is not suitable as a criterion of capacitor current overload due to harmonic distortion, because it does not respect distribution of harmonic components across their spectrum.

Therefore the capacitor harmonic load factor is defined as follows

$$CHL = \sqrt{\sum_{i=1}^{N} \left(\frac{iU_i}{U_{NOM}} \right)^2} * 100 \qquad [\%] \qquad [5]$$

where :

CHL… capacitor harmonic load factor [%]
i........... order of harmonic [-]
Ui........ voltage of i^{th} harmonic component [V]
U_{NOM}… nominal voltage [V]

This factor value does respect, besides respecting each harmonic component's voltage value, the distribution of harmonic components of different orders across their spectrum and it addresses the effect of voltage values. It is thus a more convenient value to determine the total load of a capacitor by current. If the nominal value voltage is undistorted, this factor is at value of 100%. The following table shows CHL factor values for a few selected scenarios of harmonic distribution at fundamental harmonic component nominal value.

Table 7.1: Examples of CHL factor values for selected distributions of voltage harmonic components (U_1=U_{NOM})

No.	voltage harmonic component levels [%]									CHL
	3rd	5th	7th	9th	11th	13th	15th	17th	19th	[%]
1	2.5	3.5	2.5	1.0	2.0	1.5	0.8	1.0	0.5	110
2	3.5	4.5	3.5	1.2	2.5	2.0	1.0	1.5	1.0	118
3	5.0	6.0	5.0	1.5	3.5	3.0	0.5	2.0	1.5	133
4	5.5	6.5	5.5	2.0	4.0	4.0	1.8	2.3	1.8	146
5	8.0	9.0	8.0	6.0	7.0	7.0	2.3	4.0	3.5	208

Example 3 (CHL = 133%) corresponds to voltage harmonic distortion limits as specified in EN 50160.

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7.6 Text Messages

In the measurement value display mode, a text message may appear in some situations instead of the instantaneous power factor value. Table 7.2 shows a list of these messages.

Table 6.10: List of text messages

message	Meaning	comment
AHOY tESt n206 1.2 U=Ln I =5A	initial sequence after power up or initialization - type of controller - firmware version - type of measurement voltage specified (phase, phase-neutral) - metering current transformer nominal secondary value specified	controller carries out self-diagnostics parameter 15 parameter 13
U=0	measurement voltage not present or its fundamental harmonic component lower than minimum value	controller in waiting mode
I =0	measurement current absent or lower than minimum value	controller in waiting mode
APnn	automatic connection configuration detection process in progress	process can have 1 to 7 steps
P=0	automatic connection configuration detection process has failed and method of connection of measurement voltage and current (parameter 16) has not been defined	automatic connection configuration detection process will run again in about 15 minutes automatically or parameter 16 value can be entered manually
AC-n	automatic section power recognition process in progress	process can have 3 or 6 steps
C=0	no capacitors have been successfully detected in automatic section power recognition process or in manual section value specification mode (parameter 20), parameters 21 through 26 have not been set properly or all capacitive sections have been automatically disabled because of error (parameter 25) or they are set as fixed (parameter 26)	if automatic section power recognition process is set, it will be automatically repeated in about 15 minutes or you can specify values of parameters 21 through 26 manually