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NOVAR 2600
Three-Phase Power Factor Controllers
& Power Analyzers

Operating Manual

Document revision	Release date	Valid for versions			
		hardware	bootloader	firmware	ENVIS
1.3	15.6.2020	2.6	4.0	3.0.33	1.8

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1. General

This manual comprises description of NOVAR 2600 three-phase power factor controllers.

The controllers are based on precise and powerful three-phase measurement & evaluating core and combine multifunctional panel meter and power quality analyzer with power factor control functionality in the same box.

The built-in meter can be optionally equipped with memory for datalogging of measured quantities and various events in the network thus the instruments can be used for long time network data recording.

For on-line monitoring, the controllers can be provided with remote communication interface.

The controllers can be delivered in various modifications : with various numbers of outputs & inputs, optional datalogging capabilities and communication interfaces. Depending on it the instruments support only basic functions or additional functions too.

1.1 Common features

Power Factor Control

- individual phase power factor control capability using single- / two- / three-phase capacitors and chokes
- selectable power factor control strategy : both three- and single-phase control / three-phase control only / three independent single-phase controls
- up to 18 output sections, relay or solid-state
- controller's speed of response independently programmable for conditions of undercompensation and overcompensation
- the preset speed of response increases in proportion to instantaneous control deviation, that is either with the value squared or in direct proportion to the ratio of the control deviation to the smallest section value (O_{MIN})
- adjustable control range to reduce the number of control interventions in systems with a wide control range at high loads
- combined mains compensation & decompensation capability
- selectable two-rate operation controlled with active power level or external signal (optional input)
- automatic output section recognition, any combination of the output sections possible
- continuously checks output sections in the control process. When failure is detected repeatedly, disables the faulty section and possibly actuates alarm.
- periodically rechecks the temporarily disabled sections and on positive test result (for example when replacing a section's burnt fuse link), it enables them again automatically
- wide assortment of independently settable alarm's warning and actuation functions (undervoltage, overvoltage, undercurrent, overcurrent, THDU limit overflow and more)

Measurement & Evaluation

- three measurement wide range voltage inputs, star / delta / Aron connection
- three measurement current inputs for xxx/ 5A or xxx /1A CTs connection
- sampling rate 128/96 samples/period, 10/12 periods evaluation cycle (200 ms at 50/60 Hz)
- continuous (gap-less) measurement of voltage and current
- evaluation of harmonic components up to 40^{th}
- fixed window / floating window / thermal average values of all evaluated quantities with minimum & maximum values registration
- built-in electricity meter :
  - four-quadrant three tariff electricity meter
  - single phase and three phase energies
  - maximum of average active power value (power demand)
- built-in thermometer

Design

- 144x144 mm plastic box for panel mounting
- LCD graphic display, 5 keys
- digital input (7- & 16-output models only)
- optional input for external Pt100 temperature sensor

Communication (Selected Models Only)

- optional remote communication interface (RS 485 / Ethernet)
- optional USB 2.0 communication port for fast data acquisition, configuration and firmware upgrades
- proprietary protocol with free data acquisition software ENVIS
- MODBUS RTU and MODBUS TCP protocols for simple integration with third party SCADA software
- embedded webserver (for instruments with Ethernet interface)

Datalogging Capabilities (Selected Models Only)

- battery backed real time circuit (RTC)
- selection of aggregation intervals from 1 second up to 24 hours
- high memory capacity for programmable recording of aggregated measurement values
- automated electricity meter readings at preselected time intervals

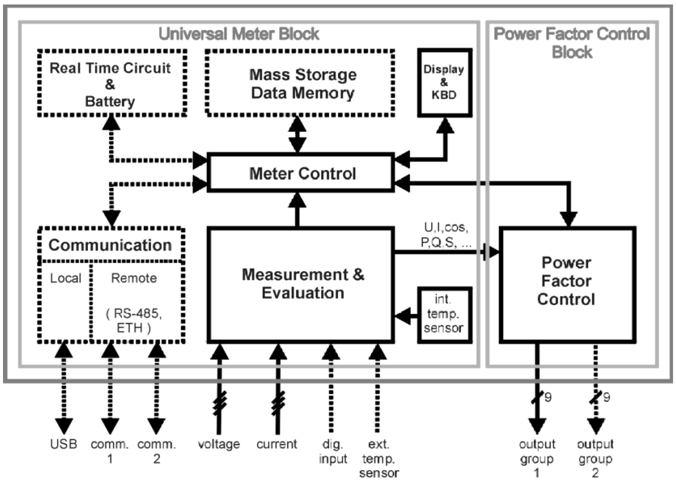
1.2 Operation

From point of view of function the NOVAR 2600 power factor controllers consist from two main blocks.

The first of them is universal three-phase meter. The meter can be optionally equipped with battery backed real time circuit, additional memory for datalogging, various communication interfaces etc., forming powerful network analyzer.

The second part of the instrument is power factor control block. The block uses measured data from the meter block; except of this, both of the blocks operate autonomously.

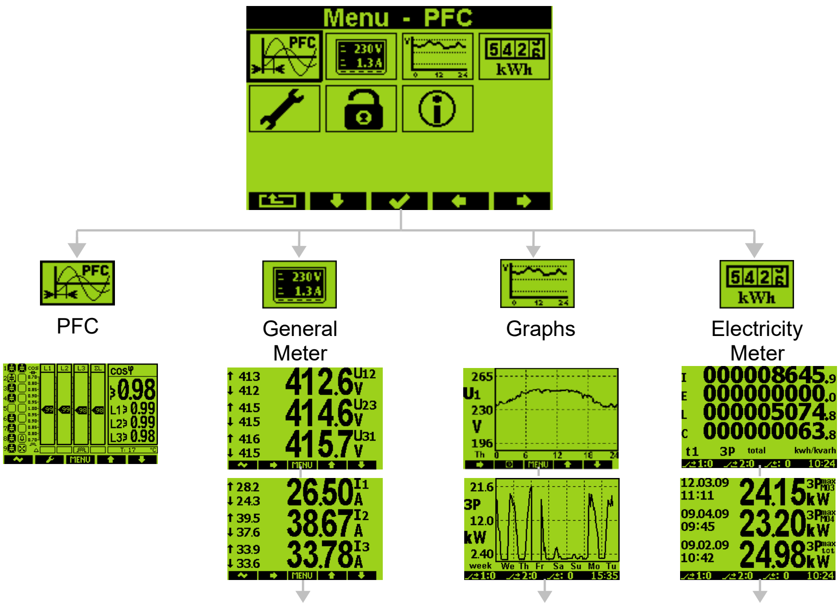
Fig. 1.1: NOVAR 2600 Block Diagram



After an activation of supply voltage, the instrument accomplishes internal diagnostics, updating of internal database of measured data and then it starts to measure and display actual measured data. Simultaneously, the power factor control blocks starts and tries to keep power factor as near as possible to the preset value by connecting optimal combination of compensation elements to the network.

All of actual measured and evaluated data can be observed on the instrument's display. Navigation through the screens is intuitive with arrow keys. The data are arranged in row of screens according navigation maps below.

Fig. 1.2 : NOVAR 2600 Display – Main Menu



2. Installation

2.1.1 Physical

The instrument 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 circulation should be provided inside the distribution board cabinet, and in the instrument's neighbourhood, especially underneath the instrument, no other instrumentation that is source of heat should be installed.

2.2 Instrument Connection

2.2.1 Power Supply

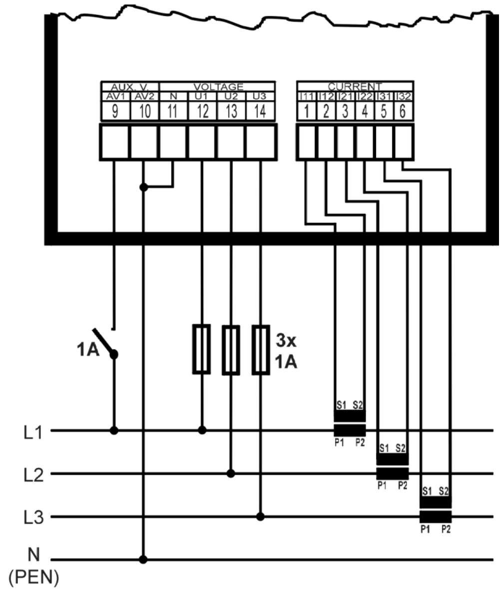
The instrument requires an AC or DC voltage power supply as specified in technical parameters. The supply inputs are isolated from other circuits of the instrument.

It is necessary to connect an auxiliary supply voltage in the range as declared in technical specifications table to the terminals **AV1** (No. 9, L) and **AV2** (No.10, N). In case of DC supply voltage the polarity of connection is generally free, but for maximum electromagnetic compatibility the grounded pole should be connected to the terminal **AV2**.

The supply voltage must be connected via a disconnecting device (switch - see installation diagram). It must be situated directly at the instrument and must be easily accessible by the operator. The disconnecting device must be labelled as the disconnecting device of the equipment. A two-pole circuit breaker with the C-type tripping characteristics rated at 1A may be used for the disconnecting device; however its function and position must be clearly marked (symbols „O" and „I" according to EN 61010 – 1). If one of the supply signals is neutral wire N (or PEN) usually a single breaker in the line branch is sufficient.

Since the instrument'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.

Fig. 2.1: Typical star (3Y) connection, mains 3 x 230/400 V



2.2.2 Measured Electrical Quantities

2.2.2.1 Measured Voltages

Measured voltages in wye (star), delta or Aron connection connect to terminals **VOLTAGE / N** (No. 11), **U1** (No. 12), **U2** (No. 13), and **U3** (No. 14). Phase rotating direction is free.

Types of connections are stated in the following table.

Tab. 2.1: Connection of the measured voltages – VOLTAGE group of terminals

Terminal VOLTAGE	Type of connection		
	wye-star (Y)	delta (D)	Aron (A)
U_1	L1-phase voltage	L1-phase voltage	L1-phase voltage
U_2	L2-phase voltage	L2-phase voltage	L2-phase voltage
U_3	L3-phase voltage	L3-phase voltage	L3-phase voltage
U_N	neutral wire voltage	-	-

It is advisable to protect the supply leads by 1A safety fuses.

The type of voltage and currents connection must be entered in *Installation* parameters : the code shows the amount of connected phases, **3Y** means three-phase connection in wye (star), **3D** in delta. **3A** means Aron connection. For **1Y3** or **1D3** setup, the instrument operates in, so called, *single phase mode* – see description in appropriate chapter below..

In the case of indirect connection via the measuring voltage transformers, it is necessary to enter this matter (connection **Mode**) and the values of the VT ratios during the setup of the instrument.

2.2.2.2 Measured Currents

The instruments are designed for indirect current measurement via external CTs only. Proper current signal polarity (S1 & S2 terminals) must be observed. You can check the polarity by the sign of phase active powers on the instrument display (in case of energy transfer direction is known, of course).

The CT-ratio must be set. in *the Installation* group of parameters (see below).

The I2 terminals stay free in case of the Aron (A) connection.

To get better precision when using overweighted CTs, you can apply more windings of measured wire through the transformer. Then you must set the multiplier parameter (see below). For standard connection with 1 winding, the multiplier must be set to 1.

The current signals from 5A or 1A (or 0.1A for the „X/100mA“ models) instrument current transformers must be connected to the **CURRENT** connector terminal pairs **I11 – I12**, **I21 – I22**, **I31 – I32** (No. 1÷6).

A particular connector is provided with a screw lock to prevent an accidental pullout and possible unwanted disconnection of the current circuit.

A connection cable maximum cross section area is 2.5 mm^2.

2.2.3 Outputs

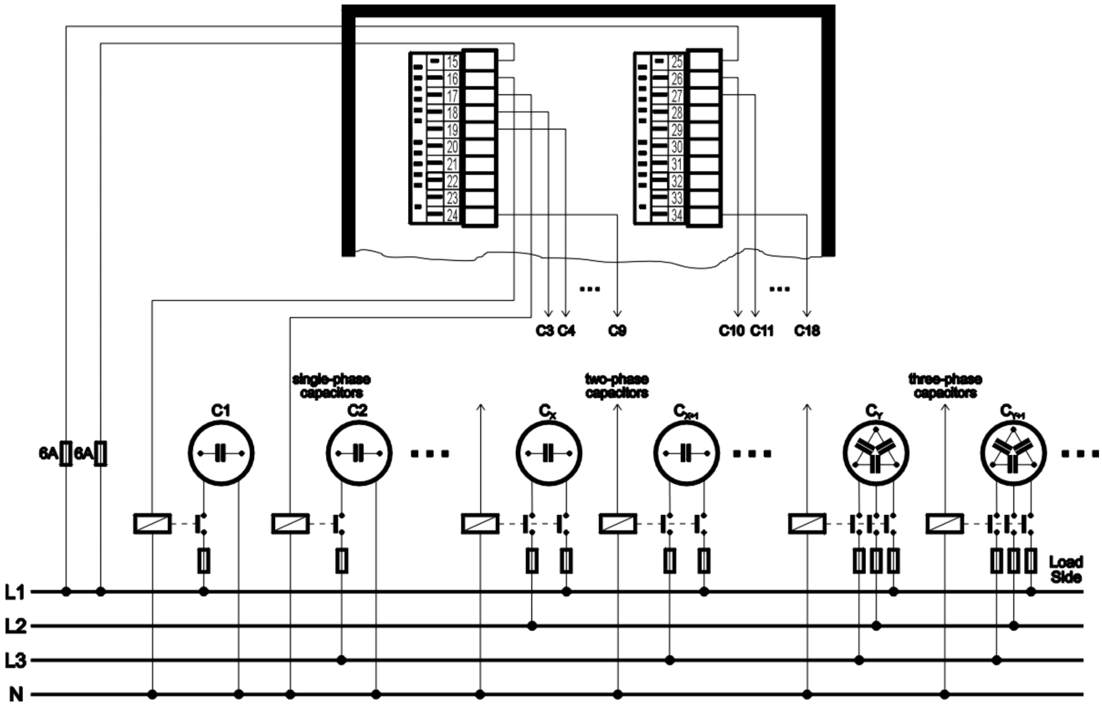
Instruments can have up to 18 relay ("R"- models) or transistor ("T"-models) outputs. For models with more than 9 outputs, the outputs are arranged in two output groups. The groups are isolated from each other.

Each group has one relay common pole terminal **C1**, **C2** (No.15 and 25) and up to nine individual relay output terminals **1.1** through **1.9** (No.16 ÷ 24) for group No. 1 and **2.1** through **2.9** (No.26 ÷ 34) for group No. 2.

2.2.3.1 Relay Outputs

Any combination of compensation capacitors or chokes (three-phase, two-phase or single -phase) can be connected to the instrument outputs via appropriate contactors.

Fig. 2.2: Output connection, various types of capacitors



If not of all outputs used, you can use upper three relay outputs for alarm signalling or for heating/cooling control (see example wirings further below).

2.2.3.2 Transistor Outputs

The “T”-models are equipped with up to 18 MOSFET-type transistor outputs.

These outputs are designed to connect to thyristor switches’ input otpocouplers via limiting resistors. This is reflected in limit parameters of the transistor outputs as well (see technical specifications).

Voltage of magnitude usual for relay outputs connection is forbidden !!!
Otherwise, the instrument can be damaged !!!
Respect maximum voltage and current rating - see technical specifications.

The transistor outputs must be powered from the switching module’s power supply or from an external power supply giving about 24 V DC and protected with a 1 A. It is recommended to connect negative pole of the supply to the common terminals **C1**, **C2** (No.15 and 25), but the polarity is free generally.

Any combination of compensation capacitors or chokes (three-phase, two-phase or single -phase) can be connected to the instrument outputs via appropriate switching modules. If not of all outputs used, you can use upper three outputs for alarm signalling or for heating/cooling control (due to the nature of outputs commonly via an auxiliary relay).

2.2.4 Digital Input

The models with 7 or 16 outputs are equipped with the digital input. It can be used for the 2[nd] tariff control of power factor control process, for time synchronization or for electricity meter tariff control.

Use terminals **D1A** (No. 23) and **D1B** (No. 24) for the digital input connection – see wiring examples in appropriate chapter further below. The input is isolated from other instrument circuitry.

To activate the output apply voltage of specified range to the terminals.

ATTENTION !!! The "T"-output type models input voltage range of the digital input is customized for 12 to 48 V DC control voltage - see table of technical parameters. It differs from the "R"-output type models and it must be taken into account.. Voltage exceeding maximum allowable may cause the instrument damage !!!

2.2.5 External Temperature Sensor

Some models are equipped with the **EXT. TEMP** external temperature sensor connector for measurement of external temperature.

The input is designed for three-wire connection to a resistive temperature Pt100-type sensor. Connect the sensor to the terminals No. 44 (**TA**), 45 (**TB**) and 46 (**G**) according example drawing below.

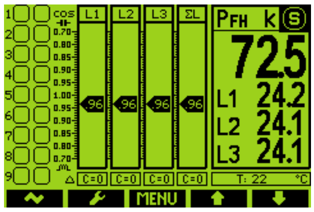
In case of two-wire connection, connect the sensor to the terminals **TA** and **TB** and short-circuit the **TB** terminal with the **G** terminal. Note that the sensor cable loop impedance must be as low as possible (each 0.39 Ohms means additional measurement error of 1 ºC).

The temperature sensor can be ordered as the instrument's optional accessory.

3. Commissioning

3.1 Setup

When switching on the power supply, the instrument will display manufacturer's logo for short time and after that, usually *the power factor control* screen is displayed :



As neither output types nor reactive power sizes of individual outputs are known now, the instrument gets into the *standby* mode, which is signalled by flashing S-indicator in the upper right corner of the screen.

If both all of measuring voltages are present and all of measured currents reach at least minimum level, the instrument tries to start *automatic output recognition* (*AOR*) process that is presented with *„Automatic Output Recognition will be started in XX seconds“* message; if the message appears, cancel the process with the ×-button.

At this moment, before we let this process run it is necessary to set group of parameters - so called *Installation* group - that are essential for proper operation of the instrument :

- mode of connection (direct measuring or via metering voltage transformers)
- type of connection (star, delta, Aron)
- ratios of CT and VT and their multipliers (if used)
- nominal voltage U_{NOM} and nominal frequency f_{NOM}
- I_{NOM}, P_{NOM} (not mandatory, but recommended)

3.1.1 Measured Electrical Quantities Installation Setup

For the proper data evaluation it is necessary to set all of the *Installation Setting* group parameters.

- **Connection Mode** determines if voltage signals are connected directly or if voltage transformers are used.
- **Connection Type** needs to be set according network configuration – wye (or star, **Y**) or delta (**D** , if neutral voltage potential not connected). Usually, all of three phases are connected so choose **3-Y** or **3-D**. For Aron connection set **3-A**. For single-phase connection, set **1Y3** or **1D3**.
- **CT**- ratios must be specified, in case of "**via VT**" connection mode **VT**-ratios too.

  The VT-ratios must be set in form *Nominal primary voltage / Nominal secondary voltage* . For higher primary voltage values *the U-multiplier* must be used too.

  CT ratios can be set in form either …/ 5A or …/ 1A.
- **I-** and **U-Multiplier** - You can modify the CT- / VT-ratio with this parameter. For example, to get better precision when using overweighted CTs, you can apply more windings of measured wire through the transformer. Then you must set the multiplier. For example, for 2 windings applied, set the multiplier to 1/2 = 0.5 .

  For standard connection with 1 winding, the multiplier must be set to 1.

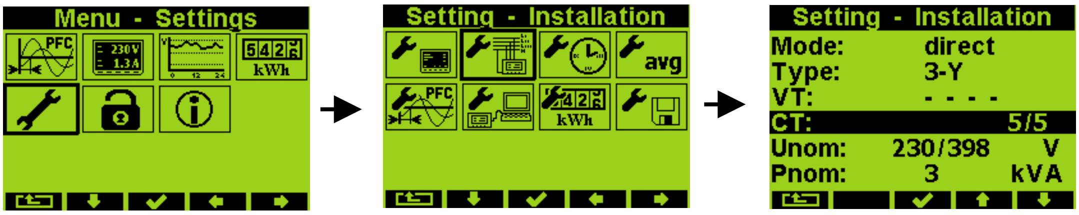
- **Nominal frequency** f_{NOM} - the parameter must be set in compliance with the measurement network nominal frequency to either 50 or 60 Hz.
- **Nominal Voltage U_{NOM}, Nominal Current I_{NOM}, Nominal Power P_{NOM}** - For the presentation of quantities in percent of nominal value, alarms operation, voltage events detection and other functions it is necessary to enter also the nominal (primary) voltage U_{NOM}, nominal current I_{NOM} and nominal apparent three-phase power (input power) of the connected load P_{NOM} (in units of kVA) Although the correct setup has no effect on measuring operation of the instrument, it is strongly recommended to set at least the U_{NOM} correctly.

  Correct setting of the I_{NOM} and the P_{NOM} is not critical, it influences percentage representation of powers and currents and statistical processing of measuring in the software only. If measured network node rating is not defined, we recommend to set their values, for example, to the nominal power of source transformer or to the maximum supposed power estimated according current transformers ratio, etc.

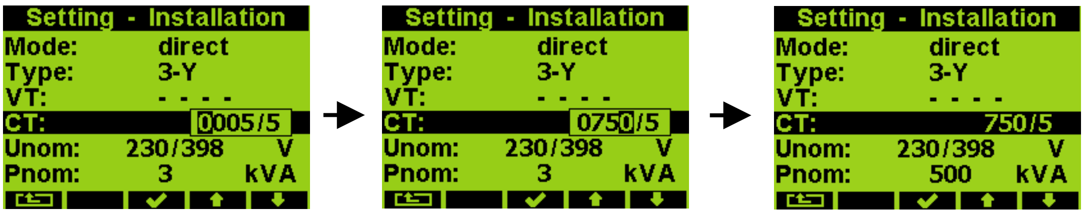
  The U_{NOM} is displayed in form of phase/line voltage.

3.1.1.1 Setup Example

Following example explains how to adjust the CT ratio :
Assuming that the conversion of used CT for inputs of current L1 to L3 is 750/5 A. To edit the parameters, press the MENU button, navigate to the **Menu-Settings** with the buttons ► and ◄ and then choose it with the ✓button. In the **Setting** window choose **Setting-Installation** option. The **Setting-Installation** window appears :



In the window navigate down to the current transformer ratio parameter (CT) and choose with the ✓button.



Now you can type new value of the parameter : with the ► button you can move from a digit to another one and to set each digit to target value using the ▲ and ▼ buttons. At the end press the ✓button and the parameter is set.

You can set other parameters in the same way.

After all of the parameters correctly set, return back to t*he power factor control* screen with the (escape) button and confirm saving of changes with he ✓-button.

Now you can browse through displayed actual values in the right part of the screen with ▲ and ▼ buttons and check if they correspond with reality.

For proper CT connection checking, you can use phasor diagram screen (see the meter block) or the CT connection test (see description further below).

After all of measured quantities checked, it is time to set the power factor control (PFC) parameters.

3.1.2 PFC Setup

In *the Setting* menu, navigate to and select *the PFC Setting.* Or, from main PFC screen, simply push the button.

3.1.2.1 PFC Control Setup

In *the PFC Control Setting* window you can set basic control parameters such like target power factor etc. But first at this phase, it is essential to set t*he power factor control strategy* :

- ***3p+1p*** … set this strategy if both three-phase and individual single phase power factors need to be controlled
- ***3p*** … set this strategy if three-phase power factor control only is required
- ***3*1p*** … set this strategy if all of single-phase power factors to be controlled individually without any relation to each other (3 separately running single-phase control processes, usable for single phase outputs only)

Other parameters can be modified later. Escaping the window you must confirm made changes again.

Finally, the last step is PFC output setup.

3.1.2.2 PFC Output Setup

In *the PFC Output Setting* window, scroll down and - if required - modify preset *discharge time for set 1*. It is necessary especially at high voltage compensation systems where discharge time in range of minutes must be set.

Optionally, you can set any of three highest outputs as alarm or fan or heating switch (for details see description further below).

Now you can finally set output types and sizes. The most comfortable way to do this is by using *Automatic Output Recognition (AOR)* process : scroll to ***Recognizer*** and edit its value to ***Run*** . After confirmation, a message informing about the process to be started appears and 10 seconds interval starts to count down. If not cancelled the AOR process starts after the interval expires.

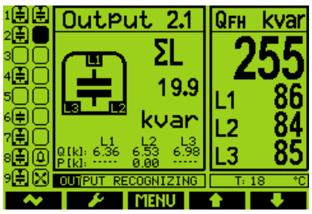
If load is low or disconnected at all, the default undercurrent (***I<*** *) alarm actuation forces the controller into the standby state. In such case the AOR process cannot be started. Therefore, it is necessary to switch this alarm actuation temporarily off (and to return it back after the AOR-process passes).*

3.1.2.3 AOR Process

After being started, the AOR screen appears. First of all, all of control outputs (i.e. excluding the fixed ones and optional alarm/fan/heating ones) are disconnected, step by step.

Then the instrument waits until discharge time of the outputs just disconnected expires - such not-discharged outputs are identified with decreasing shadow filling. During this, *Output 1.1* message flashes in the headline, that means that the instrument waits till output No. 1.1 is ready to use.

After all of the outputs discharged, the instrument starts to switch the outputs step by step. After each of the step is switched off, its type and size is displayed for short time :



After the process passes, new recognized output data are stored into the instrument's memory.

Then, in case that :

- at least one valid output (capacitor or choke) was found
- the instrument is not switched into the *manual* mode
- no alarm action is active
- voltage and current higher than measurable minimums at least in one of phases

the instrument starts to control power factor to preset value.

If the undercurrent (**I<** *) alarm was disabled for the AOR-process to be able to pass without any load in the network do not forget to reenable it back !!!*

You can found detailed AOR process description in appropriate chapter below.
The instrument includes a row of other parameters – their description is stated in following chapters.

4. PFC Block

4.1 Basic Functions

NOVAR 2600 power factor controllers are fully automatic instruments that allow optimum control of reactive power compensation.

Control is provided in all four quadrants and its speed depends on both control deviation value and its polarization (overcompensation / undercompensation). Connecting and disconnecting power factor capacitors is carried out in such a way that achieving the optimum compensation condition is by a single control intervention at minimum number of sections connected. At the same time, the instrument chooses relay sections with regard to their even load and preferably connects those that have been disconnected for the longest time and the remanent charge of which is thus minimum.

Within the control process the instrument continually checks the relay compensation sections. If a section's outage or change in value is detected, the section is temporarily disabled from control under relevant setting. The section temporarily disabled is periodically tested and enabled for control again when possible.

Wide assortment of the instrument's alarms can be used both for indication and protection of the compensation elements. It is, for example, possible to preset the THD and the CHL threshold levels at which the controller disconnects all compensation sections thus preventing their damage. Besides that, the most adverse values are recorded into the instrument's memory for subsequent analysis.

Besides the power factor capacitors, it is possible to connect power factor chokes (power system decompensation). Any output can be set as fixed, the three highest outputs can also be used as alarm output or to connect the cooling or heating circuits.

The controllers can be equipped with different numbers of outputs up to 18.

4.2 Manipulation and Setting

4.2.1 PFC Screen

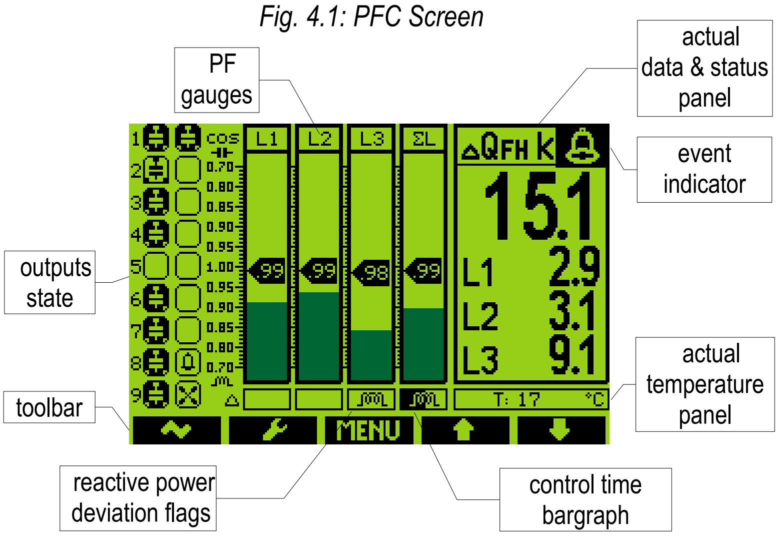
For power factor control checking, special PFC screen serves. It gets complex and well-arranged information about the compensation system actual state.

To show the screen, select appropriate icon from *the Main Menu*.

The PFC screen comprises following groups :

- *outputs state* … actual state of the outputs
- *PF gauges* … gauges indicating actual single-phase and three-phase power factor values
- *actual data&status* panel … multifolder panel with all of quantities' actual values necessary for power factor control checking
- *event indicator* … indicates important events (flashing)
- *actual temperature* panel … actual internal & optionally external temperature
- *reactive power deviation flags* … individual phase & total three-phase PF-control deviation flags combined with control time bargraph(s)
- *toolbar* … determines actual function of individual buttons

Fig. 4.1: PFC Screen



4.2.1.1 Outputs & Digital Input State

There are two columns of icons indicating actual state of individual outputs (and the digital input, optionally) on the left side of the screen. The first (left) column corresponds to the output group No. 1, the second column corresponds to the output group No. 2.

The icons primary information is actual *output state* (the output additional information removed from the icons for this example) :

- … open output
- … closed output

The models with 7 and 16 outputs are equipped with one digital input too. Its state is indicated as follows :

- … inactivated digital input
- … activated digital input

4.2.1.2 Outputs State Additional Information

Icons bear additional information of particular outputs.

Firstly, the icon design determines *the output type* :

- … zero (or unknown) output; the output has zero reactive power (probably unconnected output or with reactive power below the instrument sensitivity)
- , , … single-phase capacitors C1, C2, C3 (the number corresponds to appropriate phase number)
- , , … two-phase capacitors C12, C23, C31
- … three-phase capacitor C123
- , , ...single-phase chokes L1, L2, L3
- , , … two-phase chokes L12, L23, L31
- … three-phase choke L123

- … general impedance Z (individual phase impedance components do not match to any above noted standard C- or L-type outputs)
- … alarm output
- … fan output
- … heater output

Secondly, actual discharge time of any disconnected output can be checked from appropriate output icon (output type information removed from the icons for this example again) :

- … open output, fully discharged
- … open output, not fully discharged

At the not-discharged output icon, the dark filled area represents remanent charge of the output – it corresponds to the output *actual discharge time* and gradually drops down. This scheme is relevant for capacitor, general and unknown impedance type outputs only, not used for choke type outputs.

If the output error detection alarm is set, outputs with unmatched size (wrong or damaged) are detected and temporary removed from control process. Then the alarm gets active and appropriate outputs are marked with crossing :

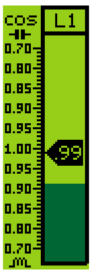
- … defective output

Finally, fixed outputs, i.e. the outputs permanently switched off or on, are marked with shadowed icons :

- … fixed output, permanently off

Such outputs are not used for power factor control.

4.2.1.3 Power Factor Gauges



For permanent and easy survey of actual power factor, both individual phase (L1, L2, L3) power factor gauges and three-phase (ΣL) power factor gauge are displayed in the central part of the screen.

If a power factor value is out of the gauge range, the gauge pointer stops at the scale margin. If the power factor cannot be evaluated at all (for example at zero load), the pointer is suppressed.

Furthermore, the power factor actual value is displayed inside the gauge pointer. The value format can be either *cos φ* , *tan φ* or *φ* - you can switch to desired format with the button as described further below.

The second additional information is actual relative load. Level of apparent power of the phase (S1, S2, S3) or total three phase apparent power (3S) relative to preset nominal power $\mathbf{P_{NOM}}$ is displayed as shadowed column at background of the gauge.

For example, if the $\mathbf{P_{NOM}}$ (three-phase) is set to 100 kVA, equivalent nominal phase apparent power is 33.3 kVA that would represent full L1, L2 and L3 gauge height. As about one third of the column height only on the L1 example above, the actual load of the phase L1 is about 33.3 / 3, i.e. 10 kVA, approximately.

4.2.1.4 Control Deviation Flags

Just below the power factor gauges there are control deviation flags – three particular ones for each phase L1, L2, L3 a one total three-phase (ΣL) flag.

These flags show the magnitude of deviation of the instantaneous reactive power in the power system from tolerable reactive power range defined by the specified value of required power factor and control bandwidth. Numeric value of this quantity, *the ΔQfh*, can be viewed at appropriate folder of *the actual data&status panel* (described further below).

If the deviation is smaller than a half of the reactive power value of the smallest output, the flag is suppressed (balanced state). If the deviation is greater than a half of, but smaller than the reactive power value of the smallest output, the corresponding flag flashes — if lagging (undercompensation, positive ΔQfh value), the (choke) flag flashes; if leading (overcompensation, negative ΔQfh value), the (capacitor) flag flashes. If the deviation exceeds the value of the smallest output, the corresponding flag is shown permanently.

The flags are evaluated both individually for each phase by corresponding phase deviation (considering the smallest corresponding phase reactive power component) and for total three-phase outlet.

Exceptions to these flags' meanings occur at the following situations when *the ΔQfh* deviation cannot be evaluated :

- if corresponding measurement phase voltage is below instrument sensitivity, the ***U=0*** message is displayed instead
- if corresponding measurement phase voltage is correct, but corresponding measurement current is below instrument sensitivity, the ***I=0*** message is displayed instead
- if both corresponding measurement phase voltage and current are correct, but no control output with non-zero reactive power value is preset, the ***C=0*** message is displayed instead

During all of the situations above, the power factor control cannot be executed and the controller gets into *the Standby* mode.

4.2.1.5 Control Time Bargraph

At the control deviation flags' background, actual state of control time in form of horizontal bargraph is displayed.

Power factor control passes discontinuously as a sequence of *control interventions*. The period between two consecutive control interventions is called *control time*.

Depending on preset *control strategy* (see further below), one control time only or more times are counted down. If the ***3p*** strategy is set, one common ("three-phase") control time is evaluated and its bargraph shown in the ΣL control deviation flag field. For the ***3p+1p*** or ***3x1p*** strategies, three individual control times for each independently controlled phase are evaluated and their bargraphs shown in corresponding L1, L2, L3 control deviation flag fields.

As soon as the control deviation exceeds one half of appropriate smallest output power, the control time counter is filled with appropriate preset control time value (depending on the deviation polarity) and starts to count down. At the same time, appropriate control time bargraph starts to grow to the right. Over time, the control deviation flag field background is fully filled, that means that the control time counter has expired. Just after that new control intervention occurs and the control process continues again from the beginning.

If the control deviation drops down below one half of the smallest output power, the control time counter is refilled with the preset control time, the countdown stops and the appropriate bargraph is cleared. But there are two exceptions to this – if :

- either at least one control choke (or, generally, inductive character section) is switched on,
- or there is very low load in the network

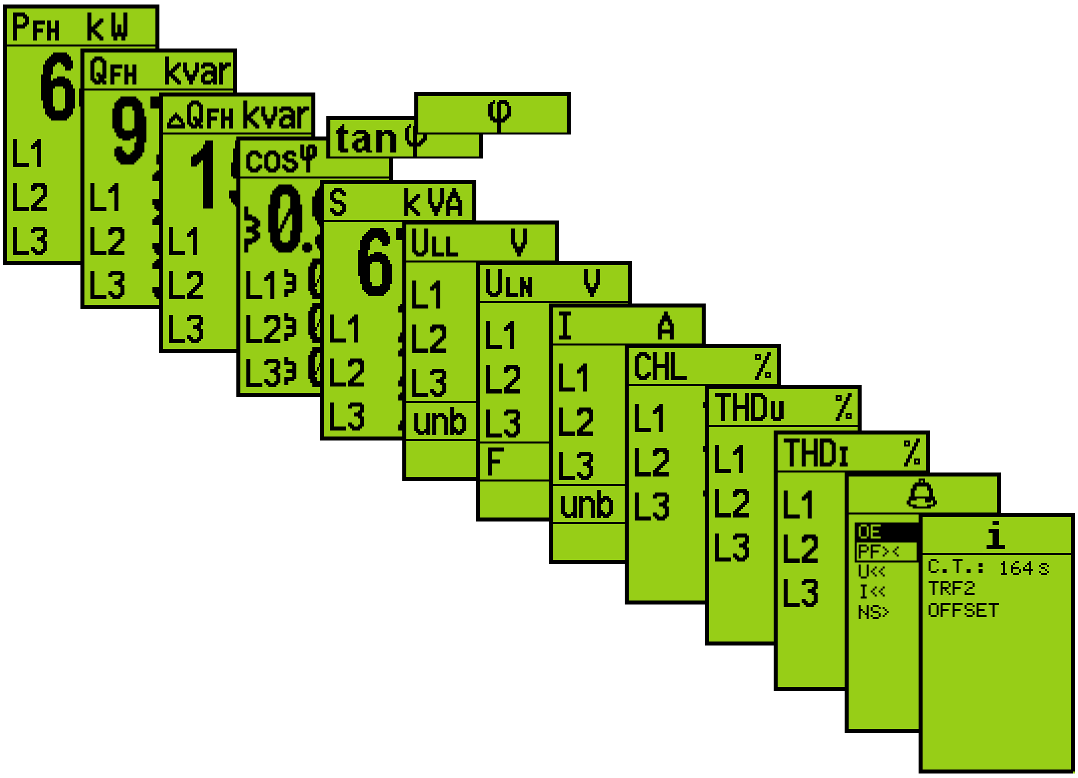
the control time counts down at minimum rate even during balanced state.

4.2.1.6 Actual Data & Status Panel

At the panel you can observe all of essential actual network quantities and state of power factor control process.

The data are arranged in folders and you can list through them with the ▲ and ▼ buttons. Power factor format can be selected using the button (described further below).

Fig. 4.2: Actual Data & Status Panel Folders



4.2.1.6.1 Actual Data Folders

Particular folders contain following actual data :

- ***Pfh*** … fundamental harmonic active power
- ***Qfh*** … fundamental harmonic reactive power
- ***ΔQfh*** … control deviation – difference between fundamental harmonic reactive power and target reactive power corresponding to preset target power factor
- ***cos φ*** / ***tan φ*** / ***φ*** ... fundamental harmonic power factor in form of “cos”, “tan” or angle, respectively
- ***S*** … apparent power
- U_{LL} , unb_U … line voltage (effective value) and voltage unbalance
- U_{LN} , ***F***… phase voltage (effective value) and frequency
- ***I***, unb_I … current (effective value) and current unbalance
- ***CHL*** … capacitor harmonic load
- THD_U … total harmonic distortion of voltage
- THD_I … total harmonic distortion of current

Most of the quantities' meaning and evaluation formulas can be found in the appropriate chapter of the general meter block description further below.

For special PFC-block related data understanding, such like *ΔQfh*, *cos φ / tan φ / φ* or *CHL*, see *the Special PFC-Block Related Data Meaning & Evaluation* chapter.

4.2.1.6.2 Alarms Folder

At *the alarms folder*, all of processed alarms are listed. The *processed alarms* term means the alarms with preset *indication* or *actuation* function. Other alarms with reset both i*ndication* or *actuation* function are not processed and, therefore, not listed in the folder.

Each of the alarms can be listed in following form expressing its actual state (t*he undercurrent* alarm used in the example) :

- I<< … plain text = the alarm processed, but neither indication nor actuation activated
- I<< … framed = the alarm indication is activated at present, the actuation not activated
- I<< … negative = the alarm actuation is activated

The alarms are sorted according their actual level of activation : the alarms with activated actuation first, then the indicating alarms and the non-active alarms at last.

4.2.1.6.3 Info Folder

i The info folder contains other information about power factor control process in progress.

The actual control time counter state or the general controller state is displayed in the first row :

- C.T.:--- … the controller in control state, control process in progress, balanced state, control time inactive
- C.T.: 164 s … the controller in control state, control process in progress, unbalanced state, actual control time counter state is displayed; if more control times are processed, the minimum value of the control time counters is displayed
- STANDBY … the controller in control state, but control process aborted due to some event - the controller gets into *the standby* state
- MANUAL … the controller in manual state – no control takes place

In the next rows, following information can occur :

- TRF2 … tariff 2 control is processed, but inactive at present
- TRF2 … tariff 2 control is processed and active at present
- EXPORT …export of active power - the power is just flowing in opposite direction, i.e. from the assumed appliance to the power supply
- OFFSET … *control with offset* is set (for details see further below)

4.2.1.7 Actual Temperature Panel

T: 24 °C Just below the actual data & status panel, there is particular panel with actual temperature.

The instrument measure temperature inside the distribution board cabinet with its inbuilt temperature sensor. Such temperature is marked as ***Ti*** (internal).

Instrument models equipped with temperature sensor input can measure "external" temperature ***Te*** too – in such case the panels shows both of the values.

4.2.1.8 Event Indicators

In special cases a flashing indicator can appear at upper right corner of the data & status panel. It indicates following events :

- … *standby state*. If the controller in the control state and power factor control process cannot by carried on for some reason the standby indicator appears
- … *temporary standby state* with time expiration indication. The controller can be forced into the temporary standby state by operator manual intervention. After fixed time period, normal control process is restored automatically. The period actual state can be checked by sinking shadow area in the indicator icon.
- … *alarm indication* activated. At least one alarm indication has got active. Then, detailed alarm specification can be found in the alarm folder of the data & status panel.
- … *manual state*. The controller in the manual state, no power factor control is carried on. The outputs' state is frozen and can be changed manually only.

4.2.1.9 Toolbar

The toolbar consists of five "softkeys", i.e. buttons with context dependent function. Besides the general function MENU, ▲ and ▼ buttons (their function is described in the meter block part of the manual), the PFC screen toolbar has another two special function buttons.

4.2.1.9.1 Multifunction / button

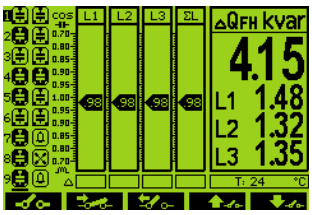
When the button pressed, a pull up menu rolls over the display temporary. By multiple fast pressing of the button, a desired action can be selected and after the button being released the selected action is executed.

There are two options to select :

- Standby<>Cntrl … *control ↔ standby toggle switch*. When power factor control process is running you can interrupt it by forcing the standby mode temporary – the temporary standby indicator appears and the control process is frozen for one minute. With the same procedure you can switch the controller back to the control state, otherwise it will occur automatically after the period expires.
- cosφ<>tanφ<>φ … *power factor format switch*. Actual power factor value format in the data & status panel and the power factor gauges can be set to cos, tan or angle format.

The functions described above cannot be used when the controller in *the manual state*. In such case the leftmost button has different function, namely *the manual output control* . As long as the button keeping pressed, the buttons' icons changes and selected output cursor appears in the outputs state area :

Fig. 4.3 : Manual Output Control



Now, the buttons' meanings are :

- … switch the selected output on
- … switch the selected output off
- … select the previous output
- … select the next output

Actual output cursor position on the example is 1.1 which is given by :

- the number 1 is inverse, i.e. the first output of an output group is selected
- actually selected group is marked with the bar below the group icon column, which is No.1 now (the left column)

When you want, for example, to switch the output No. 1.6 navigate with the button to the output No. 6. Now, you can switch the output No. 1.6 on by pressing the button or switch it off with the button. Note that all of not fully discharged outputs are blocked against switching on.

As soon as the button released, the manual output control process is cancelled.

You can use the manual output control not only in the manual state but even during power factor control state as well, which can be usable for control process checking. For this, press the button and keep it pressed – after approx. 3 seconds, the pull up menu disappears and the button icon switches to the , which means the manual output control gets active. Now you can toggle the outputs in the same way as in the manual state. But note that the power factor control process is still running on the background and manual interventions can be corrected back by the simultaneous control process. For the same reason you cannot change fixed outputs and zero outputs state because being under control of the control process.

4.2.1.9.2 PFC Setup Direct Access Button

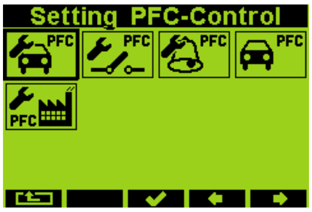
As the NOVAR 2600 controllers are complex instruments, their presetable parameters are for better orientation hierarchically arranged into several groups that are accessible in standard way via *main menu*.

But during power factor control systems installation, commissioning and checking it is usually necessary to check or to modify the parameters affecting power factor control process frequently and standard access to the parameters may prove cumbersome. Therefore, direct access to the PFC setup parameters from the main PFC screen was implemented using the button.

4.3 PFC Setup Parameters

You can get into the ***PFC Setting*** menu from the main menu via ***Settings*** → ***PFC Setting*** , or simply by pushing the button. ***The PFC Setting*** menu appears :

Fig. 4.4 : PFC Setting Menu



The complete PFC setting consists of a series of parameters arranged into three groups : ***the PFC Control***, ***the PFC Outputs*** and ***the PFC Alarms*** . Next two options in the menu are ***the Control <-> Manual*** state toggle and ***the PFC Factory Setting*** utility.

By selection of any of the first three icons appropriate parameter group list appears. You can browse throw them using the the ▲ and ▼ buttons. Some subgroups of parameters are arranged hierarchically in sublevels – push the ✓button to entry into a sublevel and the (escape) button to return back.

If the instrument is not locked you can edit parameter values. Select desired parameter and push the ✓button – the parameter edit window appears where you can set the value. Then push the ✓button again and the new value is stored. But note that, for now, new values of the parameter group are restored into a temporary memory only, real parameter values are not yet changed now ! After all necessary parameters in the group edited you can escape from the parameter group. Only now the change confirmation message "***Save changes ?***" appears and only when confirmed with the ✓button all of the parameter changes in the group come in effect at once. Otherwise, the changes are thrown and the parameters stay unchanged.

4.3.1 PFC Control Setup

4.3.1.1 Target Power Factor for Tariff 1/2

The value of target power factor for tariff 1 and tariff 2 can be specified in one of three formats :

- ***cos φ*** ...cosinus of the voltage and current phasors angle; range -0,80 ÷ 0.80
- ***tan φ*** ...tangens of the voltage and current phasors angle; range -0,75 ÷ 0.75
- ***φ*** ...voltage and current phasors angle in degrees; range -35° ÷ +35°

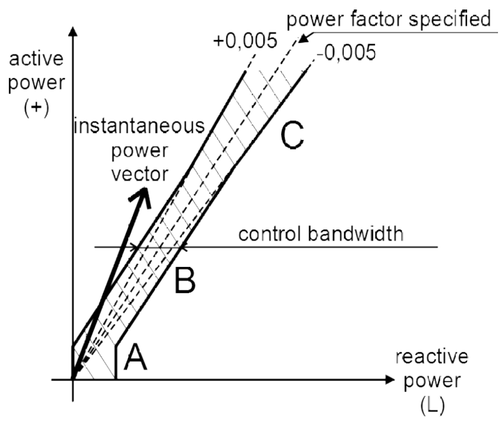
Negative value means lagging power factor, the positive one leading power factor.

4.3.1.2 Control Bandwidth on High Loads for Tariff 1/2

Using this parameter you can specify the control bandwidth on high loads (see Figure 4.5). 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.

On low loads (zone A) and on medium loads (zone B), the control bandwidth is constant and corresponds to the $\boldsymbol{O_{MIN}}$ value (reactive power of the minimum output) – the band follows the power factor slope specified at width ±($\boldsymbol{O_{MIN}}$)/2. On high loads (zone C) the bandwidth increases so its limits correspond to adjustable deviation from the target power factor. For the cosinus target power factor format , the standard bandwidth value in this zone is 0.010 or ± 0.005 – this condition is shown in the figure. 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.

Fig. 4.5 : Standard Control Bandwidth



The control bandwidth format is the same as the target power factor. It can be set in range 0.000÷0.040 if the target power factor format is *cosinus*; if the format is *tangens* or *angle* , the control bandwidth range is 0.000÷0.030 or 0÷15°, respectively.

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 $\boldsymbol{O_{MIN}}$ (constant, not widening).

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

Tab 4.1 : PFC Control Setup – Overview of Parameters

Parameter	Setup Range	Default Setup	Comment
target PF (tariff 1)	- 0.80 ÷ 0.80 (cos)	0.98 (cos)	Other available formats : „tan“, „φ“
control bandwidth (tariff 1)	0.000 ÷ 0.040 (cos)	0.010 (cos)	
control time at undercompensation-UC (tariff 1)	5 sec ÷ 20 min	3 min	No “L”: control time reduction by squared proportion “L”: linear control time reduction.
control time at overcompensation-OC (tariff 1)	5 sec ÷ 20 min	30 sec	
offset power (tariff 1)	any	0	Value corresponds to U_{NOM} specified; p displayed when *offset control* set only.
tariff 2 control	0 / dig. input / power / table	0	
parameter set according No.1 ÷ 5 for tariff 2	the same as parameters 1 ÷ 5	-	Displayed when *tariff 2 control* set only.
tariff 2 control power	0 ÷ 120 % P_{NOM}	0	Displayed when *tariff 2 control* set to *power* only.
control strategy	3p+1p / 3p / 3*1p	3p+1p	
choke control	0 / mixed / non-mixed	0	
choke control limit power factor	- 0.80 ÷ 0.80 (cos)	1.0	Displayed when *choke control* set to *mixed* only.
offset control	0 / 1	0	

4.3.1.3 Control Time for Tariff 1/2

The values for tariff 1 and tariff 2 can be specified in the range from 5 seconds to 20 minutes. It can be set different for undercompensation (marked as ***UC***) and overcompensation (***OC***) cases.

The value specified determines the frequency of control interventions under the following conditions:

- instantaneous power factor is either more inductive than the value required – undercompensated – or more capacitive – overcompensated
- the difference between reactive power instantaneous value in the power system and optimum value, which corresponds to the target power factor setting (= control deviation, ***ΔQfh***), is just equal to the smallest output reactive power (O_{MIN})

If the parameter value is set to say 3 minutes 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 output reactive power (O_{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 ***ΔQfh*** control deviation is smaller than the smallest output reactive power (O_{MIN}), control time gets twice as long. If the control deviation falls further under half of the smallest capacitive section current value (O_{MIN}), no control interventions take place.

The control time (or times) flow and actual state can be checked on the control time bargraph(s) and in the info folder of the data & status panel.

4.3.1.4 Offset Power for Tariff 1/2

These parameters are meaningful when *offset control* parameter (see below) is activated only. Unless this control mode is active, they do not appear.

The parameters specify *nominal value of the offset (three-phase) reactive power* for tariff 1, respectively for tariff 2. In the parameter sublevel, you can specify not only the 3-phase reactive power value but the "offset power type" as well, in exactly the same way as compensation section powers.

Positive value of the power means capacitive offset power, negative value means inductive offset power. So if, for example, an offset control is required due to a front-end capacitor, you must specify positive offset power value. The controller will then intentionally undercompensate at its connection node just by the size of the specified offset power value.

Like the section powers, their values correspond to nominal three-phase power (i.e. at voltage corresponding to the preset compensation system nominal voltage $\mathbf{U_{NOM}}$). The actual value of the offset power is, as well as for capacitor and choke powers, dependent on the actual network voltage.

4.3.1.5 Tariff 2 Control

The controllers feature two sets of the above described control parameters. Each of the sets – marked as ***1*** and ***2*** - comprise following parameters :

- target power factor
- control bandwidth
- control times (*UC* and *OC*)
- offset power

The tariff 2 control parameter decides if the control process uses the first set of basic control parameters only or if, under certain circumstances, the second set of parameters for tariff 2 is used as well. The parameter can be set to :

- ***Off*** … the controller uses tariff1 parameters set only, the tariff 2 set parameters are irrelevant
- ***Input*** … actual tariff set is controlled by external signal. If the controller's digital input *is not activated* the *tariff1* set is used; if the controller's digital input *is activated* the *tariff2* set is used. This option is relevant only for controllers equipped with digital input.
- ***Power*** … actual tariff set is controlled by actual three-phase fundamental harmonic active power ***3Pfh*** . For details see *the tariff 2 control power* parameter description further below.
- ***Table*** … actual tariff set is controlled by *the electricity meter tariff zone table* and actual real time counter (RTC) *time* (for details, see electricity meter description in the general meter block part of the manual). If the *tariff1* is active the *tariff1* set of parameters is used. For *any of all of other tariffs* is active the *tariff2* set is used. This option is relevant only for controllers equipped with the RTC.

By default, *the tariff 2 control* parameter is off. The tariff 2 set of parameters is not significant in such an event, so the parameters are not shown.

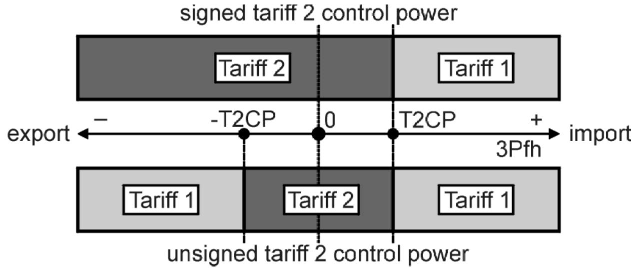
If the tariff 2 control parameter is not off, you can check which tariff set of parameters is currently active in the info folder of the data & status panel.

4.3.1.6 Tariff 2 Control Power

If *the tariff 2 control* parameter is set to ***Power*** , the 2nd set of the parameters listed above apply as soon as actual three-phase fundamental harmonic active power ***3Pfh*** drops below the preset level of the tariff 2 control power parameter. This limit value is set in percent of preset nominal power $\mathbf{P_{NOM}}$**.**

If the tariff 2 control power parameter is entered as positive value the controller interprets it as **“unsigned”** limit value of power. In such case the tariff 2 applies as soon as *absolute value* of the ***3Pfh*** power drops below preset level “T2CP”, i.e. inside the middle zone positioned symmetrically to both sides of zero power axis **-** see the lower tariff zone bar on the following figure.

Fig. 4.6 : Tariff 2Control Power Specification Options



On the contrary, if *the tariff 2 control* parameter is entered as negative the controller takes it as **“signed”** limit value of power. In such case the tariff 2 parameters applies as soon as positive ***3Pfh*** power drops below the preset level “T2CP” and keeps applied downto zero level and farther to all negative halfplane **-** see the upper tariff zone bar.

If the power value is set as “signed” it is indicated with foregoing “S” character (for example “S 10% of $\mathbf{P_{NOM}}$“).

4.3.1.7 Control Strategy

Power factor control is carried out by network operator requirements, mostly according local electric energy distributor billing scheme. Usually, only three-phase power factor is essential; but in some applications individual phase power factors must be controlled.

Accordingly, the power factor *control strategy* parameter must be set to one of following options :

- ***3p*** … three-phase power factor control only is controlled (regardless single-phase power factor values)
- ***3p+1p*** … both three-phase power factor and individual single-phase power factors are controlled (default setting)
- ***3*1p*** … all of single-phase power factors are controlled individually without any relation to each other (usable for single phase outputs only)

If the ***3p*** strategy is set the total three-phase (ΣL) value of control deviation ***3ΔQfh*** is determinative for power factor control process **-** both for the the ΣL control time management and for control intervention evaluation. The ΣL control time bargraph only works in such case.

At other settings, individual single phase control deviations control corresponding phase control times and their behaviour can be checked on the phase control time bargraphs (the ΣL control time bargraph is disabled).

If the ***3p+1p*** strategy is set, new control intervention occurs as soon as any of the phase control times expires. The common control intervention is evaluated to achieve optimal power factor in all of phases.

The ***3*1p*** strategy is designed for independent single-phase power factor control. Three phase control times are evaluated simultaneously and when expired, separate corresponding phase control intervention is evaluated and executed. This strategy can be used when single-phase type compensation sections (outputs) only are connected.

When 3p+1p strategy is set the non-mixed choke control mode cannot be used..

4.3.1.8 Choke Control

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. The control deviation evaluation and the control time countdown is derived from power of the smallest capacitor or of the smallest choke, whichever is less.

Any single-phase, two-phase and three-phase decompensation chokes can to be connected to any of outputs. But in case of combined decompensation systems, it is recommended to connect capacitors to the outputs 1.1÷1.4 in order *the CT-test* (see further below) can be optionally used.

By default, the choke control is set as ***Off*** in a shipped controller or after its initialization. With this setting the controller does not use chokes (or, generally, sections with inductive character) that are available - such sections are permanently disconnected. Furthermore, neither available chokes in the automatic output recognition (AOR) process are detected.

In order the AOR process to determine values of the chokes connected and the controller to use the chokes for power factor control, *the choke control* parameter must be activated first : either ***mixed*** or ***non-mixed*** choke control mode must be set.

4.3.1.8.1 Mixed Choke Control

Usually, one or few chokes only are installed in combined compensation systems. To reach sufficient precision of power factor control, a suitable set of capacitors are added to the choke(s) and controller freely combines both the chokes and the capacitors as needed to reach preset target power factor. We will call this mode as *mixed* mode.

If the mixed mode set, note that *the choke control limit power factor* parameter setting affects the control operation too (see below).

If the mixed mode set, a choke is connected under the following circumstances:

- controller has disconnected all capacitive sections
- power factor is still more capacitive (leading) than that required and also more capacitive than the choke control limit power factor value specified (exception: while offset control activation, this limit is neglected)
- 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 the undercompensation control time has elapsed, which prevent overcompensation.

4.3.1.8.2 Non-Mixed Choke Control

There exist some applications (such as renewable resources power plants) where continuous power factor control in some range, usually symmetric to both sides from neutral value of 1, is required. In such cases the same or similar sets of both capacitors and chokes are installed.

The mixed choke compensation mode is often unsuitable for such installations. Therefore, so called *non-mixed mode* is implemented, that differs from the mixed one in following :

- during one control step, the controller switches combination of chokes to reach optimal power factor
- the controller never combines capacitors with chokes (first, it switches all of capacitors off, then switches chokes on and vice versa)

The choke control limit power factor parameter setting is irrelevant for this control mode, therefore it is not displayed.

The non-mixed mode cannot be set together with the 3p+1p control strategy.

4.3.1.9 Choke Control Limit Power Factor (for Mixed Choke Control)

In mixed choke control mode, 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 choke control limit value, the controller starts using combination of capacitive and inductive compensation sections for compensation.

Exception: This rule does not apply when offset control (see below) is activated ! In this case, the value of measured power factor is not essential and the controller uses both capacitive and inductive sections, regardless of its value. This is true even if the offset power value is set to zero.

4.3.1.10 Offset Control

In some cases it may be necessary to control "shifted" by a certain value of reactive power. A typical example is an installation of a power transformer compensating capacitor permanently connected to the transformer before the controller CT, or an installation of long power cable with not-negligible parasitic capacity. In such cases, so called *offset control* can be used.

As default, the parameter is off (✖). In this setting, the offset control is disabled and the controller maintains the preset target power factor value.

If you set it to ✓, the offset control is activated with following consequences:

- ***OFFSET*** message appears in the info folder of the data & status panel which indicates that the offset control is active
- *offset power for tariff 1* (and , optionally, *for tariff2* too) parameters appear and can be set in the PFC control setup group of parameters
- after the power factor control deviation (i.e. reactive power difference to achieve target power factor) is evaluated, the controller adds to it appropriate preset offset power value. Therefore, it controls to this “shifted” reactive power.

Example:

A compensation capacitor with a nominal value of 5 kvars is permanently connected to a power transformer, which is before the controller CT. It is required to control the target power factor of 1.00, which is to be registered by an electricity meter, measuring whole transformer load. Then the controller must then set as follows:

- set target power factor to 1.00
- turn the offset control on (✓)
- set the offset power to 5 kvars

When, for example, an active load of 15 kW occurs, then balanced state will be reached at power factor of approximately 0.95 (measured by the controller). This value corresponds to the ratio of 5kvar / 15 kW. In other words, the controller will intentionally undercompensate by 5 kvar at the connected network point in order the target power factor of 1.00 to be reached in the electricity meter connection point, where the permanent capacitor comes to the effect.

When the offset control is activated, the choke control limit power factor parameter value gets irrelevant.

4.3.2 PFC Output Setup

4.3.2.1 Compensation Section Type, Nominal Power and Control State

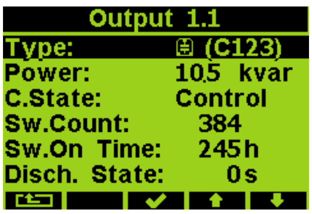
All of the sections' (=outputs') fundamental characteristics are listed at the beginning of the PFC output setup group. Each of the rows corresponds to particular output and contains:

- the output number (1.1 ÷ 1.9 for the output group 1, 2.1 ÷ 2.9 for the output group 2)
- the output actual state and type in the form of the same output icon as on the PFC screen
- the output nominal three-phase reactive power

Fig. 4.7 : Outputs' Setting Screen

If you need more detailed information about the output or to edit any of the output parameter, enter into sublevel with the ✓ button. Detailed output parameter screen appears as follows :

Fig. 4.8 : Individual Output Parameter Screen



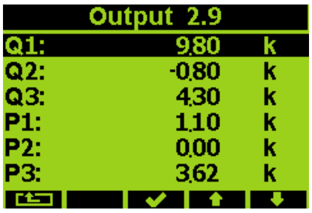
In the first two rows, there are shown again the output type and its nominal three-phase reactive power. To set any of these parameters correctly you must specify the output type first : scroll to the output type and push the ✓ button. A pop-up menu with assortment of available output types appears and now you can selected desired one. After confirmation with the ✓ button, new output type is assigned. Now you can modify the output reactive power.

These parameters can be set automatically using the AOR process. For manual setting, the manual output type & power filler can be used too – see below.

If an output was detected and marked as defective (for details see the output error alarm description),after being edited this assignment is cancelled and the output is reincluded into power factor control process by editing any of the two parameters.

The output reactive power is specified as a single number representing total three-phase reactive power in (usually) kvars. For standard output types you can simply edit this one number only.
For general impedance output type Z ( ) you can edit all of the output phase power vector components – three reactive power components (Q1÷Q3 for phases L1 ÷L3) and corresponding three active powers (P1÷P3).

Fig. 4.9: General Impedance (Z) Power Editing



If you set the phase power component values of a general impedance output to a combination that is characteristic for any of standard type outputs the output type will be reclassified to the standard type output after the editing is finished automatically.

Moreover, the upper three outputs can be set as following types :

- ***Fan***, ***Heater*** *…* the output is used for fan/heater control. Then threshold temperatures ***On-Temp.*** and ***Off-Temp.*** must be specified.
- ***Alarm*** ... the output is used for alarm signalling. Then ***Active State*** (on/off) must be specified. If more outputs are set as alarm ones the outputs are numbered as AR1÷AR3 (Alarm Relay). Then, in the alarm setting you can select required affected relay for each alarm event.

Next, there is *the output control* state parameter that can be set to :

- ***Control*** … the output is used for power factor control process
- ***Fixed-On*** … after the controller being powered, the output, after preset discharge time expires, is switched on and kept permanently closed. It is not used for the power factor control process. The only case when such output is switched off is any of appropriate alarm actuation activation.
- ***Fixed-Off*** … the output is permanently switched off, so it is not used for the power factor control process.

During the AOR process or if circular or linear switching mode is set, the fixed outputs are taken as non-existent and they are simply skipped.

Next, there are listed :

- ***Sw. Count*** … the output switching operations count since the last clearing. The value is important for connected contactor lifetime estimation and is checked by *the NS> alarm*. In case of the contactor replacement you can clear the counter by its editing and selection the ***Clear*** option.

  By checking frequency of switching you can tune other power factor control parameters optimally during the compensation system commissioning.

The value is taken in account during power factor control intervention evaluation in order the contactors to be loaded as uniformly as possible.

- ***Sw. On Time*** … the output switch-on time since the last clearing. The value is important for connected compensation capacitor (if any) lifetime estimation. In case of the capacitor replacement you can clear the counter by its editing and selection the ***Clear*** option.

  The value is taken in account during power factor control intervention evaluation in order the capacitors to be loaded as uniformly as possible.
- ***Disch. Time Counter*** … actual time remaining to the output discharge in seconds (relevant for capacitor character outputs only). The value is refreshed by preset *discharge time* (see below) whenever the output is switched off. Until expired, the output is temporary blocked in off-state and cannot by used by power factor control process.

To return back to the main PFC output setup group parameter list use the button.

Tab 4.2 : PFC Output Setup – Overview of Parameters

Parameter	Setup Range	Default Setup	Comment
output No.1.1 ÷ 2.9 type, nominal power and state	- type 0 / C / L / Z / alarm / fan / heating - power any - state control / fixed-on / fixed-off	0 / 0 / control	Value corresponds to U_{NOM} specified.
discharge time (set1)	5 sec ÷ 20 min	20 sec	
output set 2	0 / 1.2 ÷ 2.9	0	
discharge time (set2)	5 sec ÷ 20 min	20 sec	Displayed when *output set* is set only.
switching mode	intelligent / linear / circular	intelligent	
automatic output recognizer (AOR) starting	auto / 0	auto	

4.3.2.2 Discharge Time for Output Set 1/2

All of capacitor-character outputs are protected against early reconnection for preset discharge time after being switched off. During this time, the control process lets such outputs off and even manual attempts for closing such outputs are blocked.

As default, *the output set 2* parameter (see below for details) is off. Then, *the discharge time for output set 1* is relevant only and used for all of outputs. *The discharge time for output set 2* parameter is not displayed at all.

If *the set 2* parameter is active, *the discharge time for output set 2* parameter appears and can be set and used for *output set* No. 2.

4.3.2.3 Output Set 2

With this parameter you can divide the controller outputs into two so called “sets”. Then some output parameters can be specified individually for each of the sets.

As default, *the **Set 2*** parameter is ***Off*** . In such case all of outputs are comprised into *set 1* and *the set 2* does not exists.

The output set 2 parameter can be set to any outputs from No. 1.2 up. If, for example, set to the output No. **1.7**, two sets are defined :

- **set 1** comprises 6 outputs from No. **1.1** through **1.6**
- **set 2** comprises outputs from **1.7** up, i.e. remaining (at maximum) 12 outputs No. 1.7 through 1.9 and 2.1 through 2.9

In other words *the set 2* parameter defines beginning output of the set 2.

For now, only *the discharge time* parameters can be set individually for the two sets. There can be more of such parameters in the next firmware versions.

4.3.2.4 Switching Mode

In most of applications it is recommended to let the controller to use the compensation steps during power factor control process without any limitations. In such case, it optimizes usage of the outputs in order to reach maximum whole compensation system lifetime.

In special cases you can force the controller to keep particular sequence of outputs' switching with *the switching mode* parameter setting :

- ***Intelligent*** … No limitation for the switching sequence. The controller uses the outputs optimally. Default, recommended for most of applications.
- ***Circular*** … In this mode the controller connects or disconnects compensation sections in the circular fashion, which means:
    - always the ouput that was disconnected first (i.e. that is disconnected for the longest time) is connected first
    - always the ouput that was connected first (i.e. that is connected for the longest time) is disconnected first

  This switching mode can be usually used only if compensation outputs of the same type and power, otherwise power factor control process will not work optimally
- ***Linear*** … 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

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

The sections with non-zero reactive power only that are *not permanently connected or permanently disconnected or used for alarm, fan or heater control* are considered compensation sections involved in the control process (“control sections”). That means that for both circular and linear switching modes, when the controller selects next sections to be switched on or off, the remaining „non-control sections“ are simply skipped.

When selecting the linear switching mode, the AOR is disabled and cannot be launched on - the sections' types and powers must be set manually.

4.3.2.5 AOR – Automatic Output Recognizer

With the automatic output recognition (AOR) process, the controller can detect both the output types (capacitor / choke, single/two/three/phase) and their reactive power sizes itself, without having to enter them manually.

The parameter setting options are :

- ***Off*** … The AOR process is never launched automatically
- ***Auto*** … The AOR process is launched automatically under certain circumstances (see below)

Furthermore, with the third option – ***Run*** – you can launch the AOR process manually (if all necessary conditions are fulfilled). By this, the basic parameter setting (either *off* or *auto*) stays unchanged – *the run* is “single-shot” command only and doesn't change the AOR parameter setting.

The AOR process can be successfully launched under following conditions :

- measurement voltage, at minimum value required, is connected

- no alarm action is activated

If these conditions are met, the controller starts the AOR process :

- automatically if the AOR parameter is set to ***Auto*** and the controller is in the control state (i.e. it is not in the manual state); the process is automatically restarted each 15 minutes until at least one compensation section with non-zero reactive power is recognized
- if being launched manually with ***the Run*** command in the AOR setting

The AOR process is described in details in corresponding chapter below.

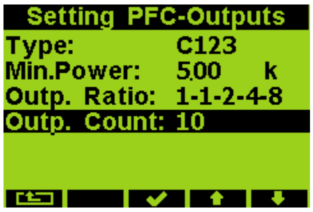
4.3.2.6 Manual Output Type & Power Filler

This is not any of controller parameters – it is a tool for easy manual mass setting of the compensation sections' (outputs) types and powers.
If :

- although recommended, the AOR process cannot be used for the sections recognition, and
- all of the compensation sections are of the same type, and
- the compensation sections powers are in any of the most usual ratios,

you can use *the manual output type & power filer.*

Fig. 4.10 : Manual Filler



After entering the tool, in the window you can set the output type and minimum (nominal) output reactive power (***O_{MIN}***), then select one of predefined output ratio and, finally, specify total number of outputs.

When escaping the window, you must either confirm or cancel execution of the mass output setting.

If you confirm the execution, the controller checks the minimum output reactive power value (***O_{MIN}***) by comparing it with the instrument measurement sensitivity. If the value entered is too low, the warning message appears, for example :

The value is too low – minimum value is 6.5 kvar.

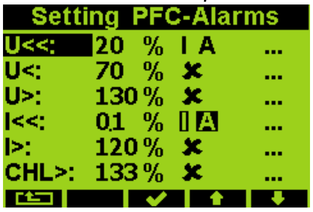
In such case all of the outputs' powers are cleared and you must enter a correct value again !

If the ***O_{MIN}*** value is correct, the controller fills preset number of outputs' types and powers, starting from the output No. 1.1 up, with preset type and appropriate weight of power. Powers of the outputs corresponding to weights 6 and higher are set to the same size as the weight 5. Both control and fixed outputs are filled; only the outputs preset as alarm or fan/heater control are left unaffected.

4.3.3 PFC Alarm Setup

The controllers evaluate various nonstandard conditions (such like measured quantities' extreme values) and, by the PFC alarm setting, various *alarms* can be activated.

Fig. 4.11 : PFC Alarm Setup – Main Level



Each of the alarms has two functions :

- alarm indication (***I***)
- alarm actuation (***A***)

If an indication function is set you need to set affected alarm outputs too, i.e. for each alarm event to choose which alarm output(s) will be used for signalling of particular alarm event. Up to three alarm outputs (AR1÷AR3) can be set and each alarm event can influence arbitrary combination of the alarm outputs.

If ***the alarm indication*** is set and appropriate alarm condition keeps fulfilled for preset time, the alarm indication gets active which means :

- flashing alarm indicator appears in the upper right corner of the PFC screen. In the info folder of the data & status panel, the particular alarm specification appears – the active indication alarm is framed (for example for the undercurrent alarm)
- if any of outputs is set as alarm output (see the output control state setup description above), all of affected alarm outputs switch to preset active state that is indicated with corresponding alarm output icon (= open output; = closed output)

Unlike alarm actuation described below, the alarm indication function has no effect on the PFC control process.

For most of the alarm events, you can set ***the alarm actuation*** function too. The actuation means intervention in the control process, mostly interruption of controller operation, usually with subsequent disconnection of all compensation outputs and mostly fixed outputs too.

For phase-type control quantities (see further below), the alarm actuation works selective : if an alarm condition appears at, say, phase L2 only, only compensation sections that have non-zero reactive power component of L2-phase are disconnected. Other sections, such like C1, C3, C13 etc. type sections (that have zero L2 reactive power component) are not affected by the alarm activation and they still stay used for power factor control process.

Tab 4.3 : PFC Alarms

alarm mark	alarm event	control quantity / event	limit setting range	activation (/ deact.) delay	default setting **I**ndication, **A**ctuation	notes
U<<	voltage loss	U_{LN} (1 period)	20% of U_{NOM} (fixed)	0.02 sec / 5 sec(fixed)	- **I** + **A**	simultaneous disconnection
U<	undervoltage	U_{LN} / U_{LNAVG}	20÷100% of U_{NOM}	1 sec ÷ 20 min	U_{LN} / 70 % / 1 min	
U>	overvoltage	U_{LN} / U_{LNAVG}	100÷200% of U_{NOM}	1 sec ÷ 20 min	U_{LN} / 130 % / 1min	
I<	undercurrent	I / I_{AVG}	0÷25.0 % of In *)	1 sec ÷ 20 min	I / 0.1 % / 5 sec **I** + **A**	fixed sections not affected by actuation
I>	overcurrent	I / I_{AVG}	100÷140 % of In *)	1 sec ÷ 20 min	I / 120 % / 1 min	indication only
CHL>	CHL limit exceeded	CHL / CHL_{AVG}	80÷300 %	1 sec ÷ 20 min	CHL/133 % / 1min	
THDU >	THDU limit exceeded	THDU / $THDU_{AVG}$	1÷300 %	1 sec ÷ 20 min	THDU /10 % / 1min	
THDI>	THDI limit exceeded	THDI / $THDI_{AVG}$	1÷300 %	1 sec ÷ 20 min	THDI / 20 % / 1min	
P><	P limit exceeded / drop	Pfh / Pfh_{AVG}	0÷99 %	1 sec ÷ 20 min	0 % / 5 sec	fixed sections not affected by actuation
PF><	PF control failure - PF control deviation out of contr. b'width	ΔQfh / ΔQfh_{AVG}	-	1 sec ÷ 20 min	ΔQfh_{AVG} / 5 min **I**	indication only
NS>	number of switching operations exceeded	number of switching operations	1÷9999 thousands	immediatel y(0 sec)	100 **I**	indication only
OE	output error	section failure	0÷99 % of reading	3 ÷ 15 consecut. occurr'nces	20 %; 10 **I** + **A**	
T1>< **T2><**	temperature exceeded / drop	**Ti**(internal) / **Te**(external)	-40 ÷ +60 °C	1 sec ÷ 20 min	>+45 °C / 1 sec >+35 °C / 1 sec	
EXT	external alarm active	digital input state	-	0.02 sec / 5 sec(fixed)	-	simultaneous disconnection
OoC	out of control	PF control process not running	-	1sec ÷ 20min / imm'tely	15 min	indication only
RCF	remote control failure	remote control process state	-	1sec ÷ 20min / imm'tely	1 min	indication only
PF>	PF control failure – overcompensated	PFfh / $PFfh_{AVG}$	cos : 0.00(C/L) ÷ 1.00	1 sec ÷ 20 min	PFfh / 1.00 / 1 min	indication only
PF<	PF control failure – undercompensated	PFfh / $PFfh_{AVG}$	cos : 0.00(C/L) ÷ 1.00	1 sec ÷ 20 min	PFfh / 0.95L / 1 min	indication only

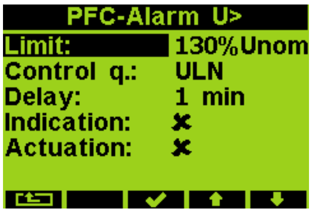
Note : *) In ... CT secondary rated current; 5A or 1A according the CT-ratio setup

The beginning of the PFC alarm setup group main level screen is displayed on Fig. 4.11. You can scroll through all the alarms and check their main setup and actual state. In each row there is shown :

- *alarm mark* … for example the *U*<< means voltage loss alarm
- *preset control quantity limit* (in any) … control quantity value threshold; for example 20% of appropriate nominal value
- *alarm indication and actuation setting and actual state* … ✖ = neither indication nor actuation processed (switched off); ***I*** = indication is processed (set on); ***A*** = actuation is processed; inverse ***I*** or ***A*** means that the appropriate alarm function is currently active

For details of any alarm, enter into sublevel with the ✓ button. For example, you see the overvoltage alarm (*U*>) setting on the picture below.

Fig. 4.12 : PFC Alarm Setup – "U>" Alarm Details



In the particular detailed alarm setup screens you can edit individual setup parameters. Excluding the main parameters described above, there may be set in addition :

- *control quantity* … if a quantity size alarm event type, you can mostly select if the actual value ($\mathbf{U_{LN}}$, for the alarm example discussed) of the quantity or corresponding average value ($\mathbf{U_{LNAVG}}$, see description in the meter block part of this manual) is used for the alarm condition evaluation
- *delay* … minimum duration of continuous alarm condition occurrence before the alarm state gets active. With certain exceptions that applies for both activation and deactivation.

Alarm indication can be set (✓) or switched off (✖). For most of the alarms you can set the actuation too – for a better overview of the alarm state, the alarm indication is usually set too automatically.

Overview of all of alarms is shown in tab. 4.3.

Alarm actuation usually causes disconnection (step-by-step) of all of affected compensation sections, including the fixed ones. Due to this the controller gets into standby state. Exceptions of this rule are listed in individual alarm overview below.

4.3.3.1 Standard Type Alarms

Standard type alarms are controlled by appropriate control quantity – you can usually choose either actual value or averaged value (for the quantities description, see the meter block chapter further below).

Then you can set the quantity limit and the alarm reaction delay; it is mostly valid for both activation and deactivation.

The standard type alarms are :

- **U<** … undervoltage alarm
- **U>** … overvoltage alarm
- **I<** … undercurrent alarm
- **I>** … overcurrent alarm
- **CHL >** … CHL limit exceeded alarm

- **THDU >** … Total Harmonic Distortion of voltage alarm
- **THDI >** … Total Harmonic Distortion of current alarm
- **P><** … active power exceeded/drop alarm
- **PF><** … PF control failure alarm
- **PF>, PF<** … overcompensation/undercompensation alarm

There are following exceptions in the standard type alarms behaviour :

- **I<, P><** … When the undercurrent actuation gets active, fixed sections stay unaffected.
- **I>, PF>, PF<** … Indication can be set only (no actuation function).
- **P><** … Function can be set to signed or unsigned control quantity value to be evaluated in the same way as *the tariff 2 control power* parameter (see above). Depending on this, either standard value or absolute value of active power value is compared with the preset limit.
- **PF><** … Power factor control deviation ΔQfh is checked for the PF control alarm. But there is not any presetable limit; the alarm gets active as soon as the PF control deviation exceeds actual control bandwidth (usually one half of the reactive power value of the smallest output) for preset delay time.

  The alarm has no actuation function.

4.3.3.2 Fast Actuation Reaction Alarms

These alarms have special common features :

- actuation reaction time is 20 ms (fixed)
- affected outputs are disconnected immediately (during 20 milliseconds) and all at once (not step-by-step)
- deactivation delay of the actuation is 5 seconds (fixed)

The fast alarms are :

- **U<<** … measuring voltage loss alarm. Both the alarm limit and the alarm control quantity are fixed – 20% of preset U_{NOM} voltage and the actual U_{LN} phase (line-to-neutral) voltage, respectively – they cannot be changed.
- **EXT** … external alarm. The alarm gets active as soon as appropriate voltage (see tech. specifications) is applied to the instrument's digital input terminals. It can be used only at controller models equipped with the digital input, of course.

4.3.3.3 NS> - “Number of Switching Operations Exceeded” Alarm

You can use this alarm for contactors wear-out indication.

The indication limit can be set in thousands of switchings. Number of switching operations of individual outputs are checked permanently and as soon as any of the outputs exceeds preset limit, the alarm indication gets active.

After the contactor replacement, the corresponding output switching counter can be cleared manually.

The alarm has no actuation function.

4.3.3.4 OE - “Output Error” Alarm

This alarm is intended for faulty section indication and disablement.

If at least the alarm indication is 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 preset in its memory. All of the single -phase reactive power components are checked individually.

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 section power value), the controller tags such a section as faulty and, if the alarm actuation has been set too, it will disable the section and stop using it in further compensation temporarily. Such section is tagged with its icon crossed ( ,for example).

If the alarm actuation is not set, the controller will only tag the faulty section, trigger alarm indication, but will keep using the section in compensation process.

Following parameters can be set :

- ***Limit – rdg*** … maximum allowed single-phase power difference component in percent of the power value ("reading"); default value is 20%.
- ***Delay*** … minimum number of consecutive following out-of-tolerance measurement events of the same tolerance polarity to force the alarm active (number of switchings on/off)

For example, for the alarm setting above, if the three-phase output power is 10 kvars (i.e. corresponding single phase power is 3.33 kvars) the single-phase rdg-component is

10000 / 3 x 0.2 = 667 vars

Real deviation tolerance is slightly bigger: approx. 700 vars. That means if the controller detects the output phase power size approximately lower than 3333-700=2633 vars or higher than 3333+700=4033 vars it classifies the output power out of tolerance.

If preset number of consecutive out-of-tolerance detections of particular section with the same tolerance polarity occurs, i. e. the output response was continuously lower (or higher) for preset times, the alarm gets active; the output is tagged and - depending on the alarm setting - it is disabled too.

The section that has been temporarily disabled is periodically, about every four 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 back in the control process again. In 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 reinclusion in the control process will take place in the following situations:

- power supply interruption or controller initialization
- editing the section's type or the section's value
- new automatic output power recognition (AOR) process

4.3.3.5 T1>< (T2><) - "Temperature Exceeded/Drop" Alarm

These two fully independent alarms use temperature as their control quantity. You can use

- either **Ti ... internal temperature** . This temperature is measured with the sensor which is built inside the instrument.
- or **Te ... external temperature** . This temperature is measured with an external Pt100-type temperature sensor. Such sensor is available as optional accessory a can be connected to appropriate instrument models only (that are equipped with the sensor connector).

The alarm functionality is similar to the standard type alarms. The only difference is that you can set not only the threshold temperature (limit) but the polarity of its deviation too (**>** or **<**). Therefore, the alarm can be activated by both overheating (> limit) and overcooling (< limit).

4.3.3.6 OoC - "Out of Control" Alarm

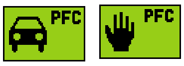
This alarm can be used for signalling of states when power factor control doesn't run. Such states can be :

- the controller is switched into the manual state
- the controller is switched into the control state, but power factor control process doesn't take place due to any cause such like :
  - the instrument is forced into *the standby* state (see below for details)
  - automatic output recognition (AOR) process in progress
  - the CT connection test in progress

If such state lasts continuously for preset delay time, the alarm gets active. As soon as the power factor control process resumes the alarm is deactivated immediately.

4.3.3.7 RCF - "Remote Control Failure" Alarm

This alarm will serve for remote control problem signalling in future. Now it is not functional.



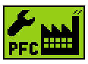
4.3.4 Control / Manual State Indicator and Switch

The icon does not comprise any parameters but it indicates one of two instrument main states – t*he control state* or *the manual state*.

By selection of the icon, you can toggle from the control state to the manual state and vice versa. Confirmation of such command is required first and after that the instrument state changes. The selected state and, in case on the manual state the last outputs' states too are kept even if power loss occurs.

If the instrument is in the manual state, corresponding flashing indicator  appears at the main power factor control screen.

For details of the main controller states, see appropriate chapter further below.



4.3.5 Power Factor Block Factory Setting

With this option you can force all of the parameters of the power factor control block into the default values. Overview of the default setting follows. The alarm parameters default setup can be found in appropriate table above.

Tab 4.4 : Control Parameters Default Setup

parameter	default setup
target PF 1 / 2	cos; 0.98
control bandwidth 1 / 2	(cos) 0.010
control time – undercomp. 1 / 2	3 minutes
control time – overcomp. 1 / 2	30 seconds
offset power 1 / 2	0 kvars
tariff 2 control	off
tariff 2 control power	0 %
control strategy	3p+1p
choke control	off
choke control limit	(cos) 1.00
offset control	off

Tab 4.5 : Output Parameters Default Setup

parameter	default setup
output 1.1÷ 2.9 type / power / state	zero / 0 kvars / control
discharge time 1/ 2	30 seconds
output set 2	off
switching mode	intelligent
output recognizer	auto

4.4 PFC Block Operation

After powerup, initial test runs first. During this, the manufacturers logo is displayed momentarily.

After the test the controller returns into one of two main states corresponding to the state last state set (the last state is registered in non-volatile memory)

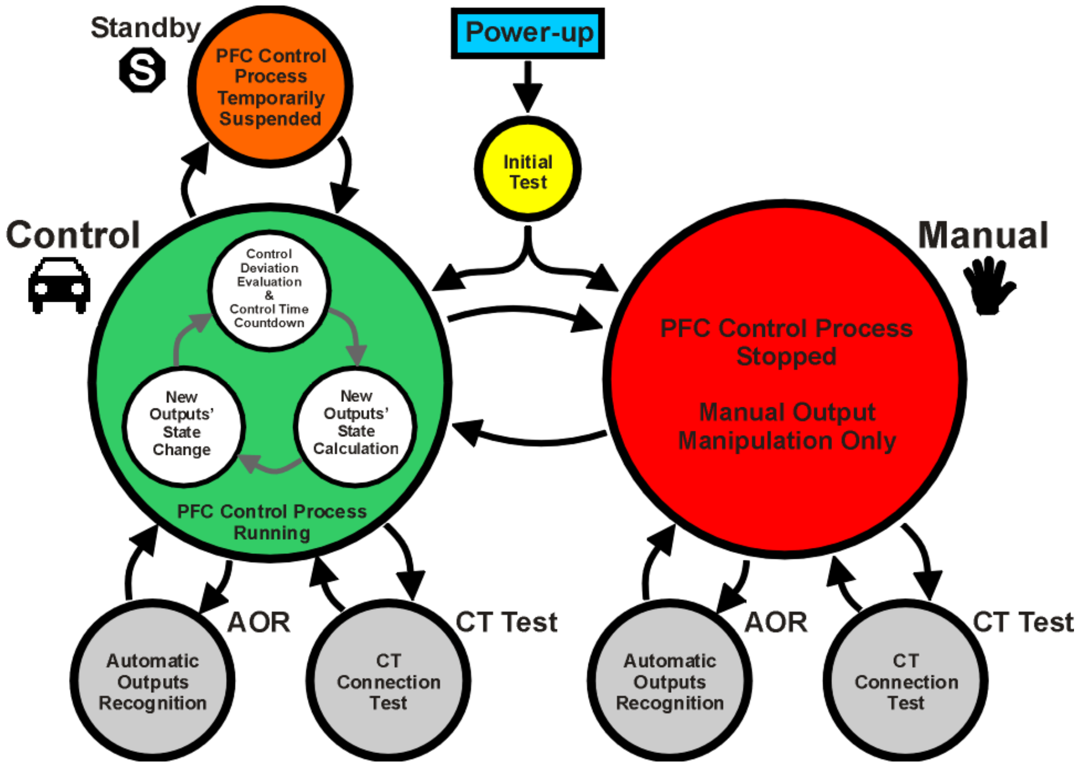
- ***Control state*** … The instrument performs power factor control process; if, for some reason, it can not perform it, it gets into the standby state temporarily.
- ***Manual state*** … the instrument does not perform power factor control process; manual output manipulation is allowed for testing purposes.

4.4.1 Control State

In the control state, the controller carries out its standard task – the power factor control process. The process consists of three basic steps performed over and over again :

- evaluation of reactive power control deviation and, depending on its magnitude, control time countdown
- as soon as the control time expires, new combination of outputs is calculated
- then the new combination is applied to the outputs

Fig. 4.13 : PFC Controller Main Operating States



This sequence can be temporarily suspended due to either operator manual intervention or automatically by the controller for some reason. Then the controller can gets temporarily to one of following „substates“ :

- *standby state* (indicated with flashing S)
- *automatic output recognition* (AOR) process

- *CT connection test*

There can be various reasons causing the controller goes to the standby state :

- fundamental component of measuring voltage or current is below the instrument sensitivity causing that power factor cannot be evaluated; this is indicated with the ***U=0*** or the ***I=0*** message in the control deviation flags area
- no control section (output) available (all of the sections have zero reactive power or are set as fixed sections); indicated with the ***C=0*** message in the control deviation flags area
- control sections are forced off due to active actuation of any alarm; in such case the alarm indicator flashes
- the controller switched manually to standby state temporarily – the standby indicator with sinking time expiration level appears in such case

As soon as the events causing the standby state pass, standard power factor control process resumes automatically.

4.4.2 Manual State

For testing purposes, especially during the first controller installation, you can switch the controller into the manual state. Push the button, then select the icon and push the ✓ button.

If any of outputs are on, question ***Disconnect outputs ?*** appears. If confirmed, the controller disconnects all of outputs, otherwise actual state of the outputs stays unchanged. Then he controller switches to the manual state.

The manual state is indicated with the flashing indicator. No power factor control takes place, state of the outputs stay unchanged. They are restored into this state even after a power failure. But the outputs can be temporarily switched off due to any alarm actuation if appropriate event occurs.

During this state, you can manipulate with the outputs manually using the leftmost button in the same way as in the control state that is described in *the Multifunction* / *button* chapter above. When switching any of outputs on, the preset discharge time is respected, so the output cannot be reswitched until its discharged time expires.

After the testing finished, switch the controller back into the control state using the same procedure as when entering the manual state.

4.4.3 Automatic Output Recognition (AOR) Process

The controller can recognize types and sizes of compensation capacitors or chokes connected to its outputs automatically using this process.

If the *AOR – Automatic Output Recognizer* parameter is set to *auto* , the controller launches this process automatically if :

- it is switched into the control state and is not in the standby state
- none of the control compensation outputs is specified at a non-zero power (all of the control outputs reactive powers are zero)
- main PFC screen is displayed

The process can be started manually too. You can launch it not only in the control state but in the manual state as well. For this, in *the PFC output* parameter group scroll to *Recognizer* and edit its value to *Run*.

If any chokes are used in the compensation system, the Choke Control parameter must be set first; otherwise, all of chokes (or any inductive character type outputs) will be recognized as zero outputs.

If the CT-ratio is not set (or its value is 5/5 A or 1/1 A), call for the CT-ratio setting appears before the AOR- process is launched. When this call is ignored and the CT-ratio is not set properly the power values of outputs recognized during the AOR-process will be incorrect.

As soon as the process is initiated, the information message appears in the main PFC screen :

Fig. 4.14 : AOR Start Message

Automatic Output
Recognition will be started
in 10 secs

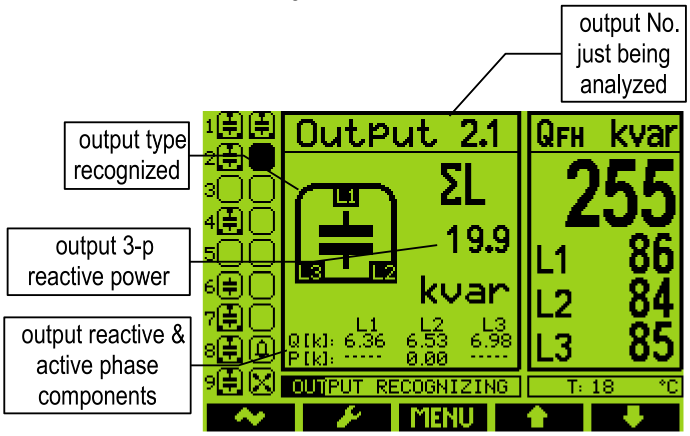
During following 10 seconds, you can either cancel the start command with the ✖ button or to skip the message timeout with the ✓ button to start the AOR process immediately. Or you can simply let the timeout to expire and then the AOR process starts.

First of all, all of control outputs (i.e. excluding the fixed ones and optional alarm/fan/heating ones) are disconnected, step by step. Actual state of the outputs can be watched on left part of the screen :

- … disconnected output, fully discharged, unknown (or zero) type
- … disconnected output, not fully discharged
- … connected output

Then the instrument waits until discharge time of the outputs just disconnected expires - such undischarged outputs can be identified with decreasing shadow filling. During this, *Output 1.1* message flashes in the headline, that means that the instrument waits till output No. 1.1 is ready to use.

Fig. 4.15 : AOR Process Screen



After all of the outputs discharged, the instrument starts to switch the outputs step by step. After each of the step is switched off, its type and size is displayed for short time. From the example above you can find :

- the output No. 2.1 that was just measured was recognized as three-phase capacitor with total (ΣL) reactive (nominal) power of 19.9 kvars
- individual phase powers of the capacitor are 6.36/6.53/6.98 kvars
- the output No. 2.2 is just being tested (switched on)
- up till now, outputs No. 1.1, 1.2, 1.4, 1.7, 1.8. 1.9 and 2.1 have been recognized as three-phase capacitors
- outputs No. 1.3, 1.5 and 2.2 ÷ 2.7 have been recognized as “zero outputs” (with no reactive power response)

- output No. 1.6 was recognized as non-standard capacitor, out-of-tolerance or possibly damaged (its phase components doesn't match any standard capacitor type); it can be caused by wrong particular measurement too and the type can be reclassified later in the process
- output No. 2.8 is alarm output; output No. 2.9 is fan output; both of them are switched off now

*Note : The recognized output powers are not displayed as actual power values but **the nominal power** values, that is the values that correspond to the preset nominal voltage U_{NOM} of the network.. It is supposed that the metering current transformer ratio and the metering voltage transformer ratio, if any, are set correctly.*

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

After carrying out three rounds, partial evaluation is carried out. If measurements in the rounds carried out provides sufficiently stable results, the AOR process is completed. Otherwise the controller carries out up to three more rounds.

A requirement for successful AOR process is sufficiently stable condition of the power system – while connecting or disconnecting a section, the reactive load power must not change by a value which is comparable with, or even greater than, the reactive power value 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.

Ongoing AOR process can be interrupted at any point either manually by pushing the button or by any of alarm actuations. In such case, the recognized data are neglected and output setting is not updated.

On completion of the total process, the controller saves recognized output types and sizes into its memory. Then it returns into the state from which it was initiated. If it is the control state and at least one section with non-zero total reactive power has been detected, the controller starts power factor control.

Otherwise, if the previous AOR process unsuccessful (no valid outputs found or cancelled prematurely), the process is automatically relaunched each approximately 15 minutes again in the control mode.

It is strongly recommended to check recognized section values after the AOR process has passed. If any doubt about the recognized values you can start the AOR process again or, if necessary, to edit the section values manually. It is often necessary at the lowest power sections especially when the AOR process run while high load at the network – such sections can be recognized as zero outputs and needs to be set manually.

*Sometimes it is necessary to start the AOR process at disconnected load (or at zero load)– for example ,when testing a compensation switchboard before its expedition to a customer. If the default controller undercurrent (**I<**) alarm actuation is set the controller gets into the standby state in such case and the AOR process cannot be started. Therefore, it is necessary to switch this alarm actuation temporarily off (and to return it back after the AOR-process passes).*

4.4.4 CT Connection Test

For proper instrument operation, right current inputs' connection is crucial requirement. The inputs' phase order must correspond to connected voltage signals and, furthermore, their polarity must respect orientation of used current transformers (k/l terminals).

The CT connection test is simple tool for right current transformers' connection analysis. It uses the first four compensation outputs for detection of individual phase current angles. The only condition must be fulfilled for the CT test usage : either ***three-phase*** or ***single-phase*** compensation ***capacitors*** are connected to ***the first four control outputs***. If, for example, two-phase capacitors or any chokes connected to the outputs, the CT test gets fail results !

If inappropriate compensation elements connected to the first four outputs,you can set such outputs temporary to ***the fixed-off*** *control state; then the instrument will use for the CT test the next four outputs that are set as* ***the control*** *outputs.*

The CT test can be launched manually only. Navigate to the last option of *the Control* group of the PFC setting and select ***the CT Test***. After the command being confirmed, the information screen appears :

Fig. 4.16 : CT Test Info Message

CT Connection Test
(1-p or 3-p capacitors supposed
at the first 4 control outputs)
will be started in
10 secs

During following 10 seconds, you can either cancel the start command with the ✖ button or to skip the message timeout with the ✔ button to start the CT test immediately. Or you can simply let the timeout to expire and then the CT test starts.

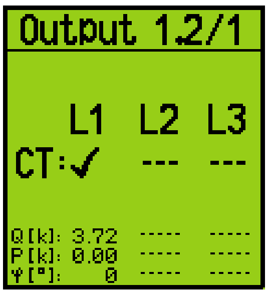
The CT test window shows information about individual phase current inputs' connection. At the beginning of the test, following message is shown :

	L1	L2	L3
CT :	**- - -**	**- - -**	**- - -**

The dashes mean that the test result is not yet ready now.

First of all, the first four of control outputs are disconnected, step by step. Then the instrument waits until discharge time of the outputs just disconnected expires - such undischarged outputs can be identified with decreasing shadow filling. During this, *Output 1.1* (for example) message flashes in the headline, that means that the instrument waits till output No. 1.1 is ready to use.

Fig. 4.17 : CT Test Window



When the outputs used for the testing are discharged, the instrument starts to switch the outputs step by step. After each of the step is switched off, the result of reactive and active powers and evaluated current signal angle of individual phases appears at the bottom of the CT test window. If the measurement is not successful, dashes appear instead the test results (this is not unusual that such results appear, especially if high power load in the network or if the powers of outputs that are used of testing are low, compared to the network load).

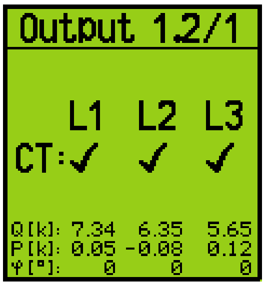
The test can have up to six rounds with four testing steps each. After each step, the measurement results of individual phases are analyzed. If the results of any phase is sufficiently stable, detected current signal connection information is shown in the main line, as can be seen in the picture above in the L1 phase result. The connection information can be one of following :

Tab. 4.6: CT Test Results

CT connection test result	meaning	action required
✓	correct connection	none (both phase and polarity correct)
R	correct phase, reverse polarity	swap the current input wires
→	wrong phase, correct polarity	move wires to **the next** phase current input, keep the polarity
←	wrong phase, correct polarity	move wires to **the previous** phase current input, keep the polarity
R→	wrong phase, reverse polarity	swap the wires and move them to **the next** phase current input
R←	wrong phase, reverse polarity	swap the wires and move them to **the previous** phase current input
- - -	unsuccessful measurement	recheck the connection

As soon as the connection detected at all of phase inputs, the CT test finishes. If all of current signals connected correctly the test result looks like this :

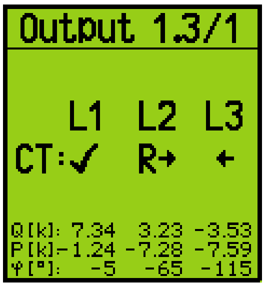
Fig. 4.18 : CT Test Result – All of the Inputs Connected Correctly



Then you can close the window by pressing of any key, otherwise the window closes automatically after one minute delay.

If the inputs are not connected correctly, the CT test result can look, for example, like this :

Fig. 4.19 : CT Test Result – the L2 and L3 Inputs Wrong Connected



In such case it is necessary to reconnect the current signals :

- let the L1input unchanged

- disconnect the wires connected to the instruments L2 input, swap them and connect to the L3 input
- disconnect the wires connected to the L3 input and connect them to the L3 input (while keeping their polarity)

Then launch the CT test again to be sure the intervention was successful.

If polarity of all of current inputs correct and there is necessary to move two or three inputs to another phase it is usually simpler to move appropriate voltage inputs instead, because you need not to short-circuit the CT outputs, there is only one wire at each voltage input and they can be usually simply temporary disconnected with front-end protection fuses or breakers.

If the instrument does not succeed in the detection of connection of any of phases even after the sixth round pass, the test is finished with unsuccessful measurement result (**- - -**). It could occur due to various causes :

- considerable power fluctuations in load during the test; start the test again when the load is more stable
- reactive powers of compensation elements connected to the first control outputs are too low in compare with actual network load; start the test again after the load drops down or set the outputs temporarily to the fixed-off state to force the controller to use other outputs with higher power
- compensation elements connected to the first control outputs are not single-phase or three-phase capacitors; try the same modification as in the previous point
- if, for example, single phase capacitors of C1 and C2 type only are connected to the outputs, the connection cannot be detected in the L3 phase; try the same modification as in the previous point

Ongoing CT test can be interrupted at any point either manually by pushing the button or by any of alarm actuations.

4.4.5 Single-Phase Mode

You can use this mode for three-phase network compensation when one current signal only (from a CT installed at one of phases) is available. A precondition for the correct function is approximately symmetrical load in all three phases.

The controller operates in the single-phase mode when the *type of connection* (in t*he Installation* group of parameters) is set to **1Y3** or **1D3** .

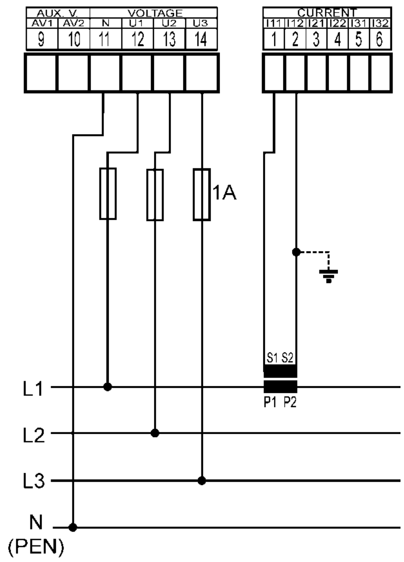
4.4.5.1 Connection

Connect the current signal to **I11** and **I12** (No. 1, 2) terminals of the **CURRENT** connector. Other current inputs stay free, signal of their inputs is not measured.

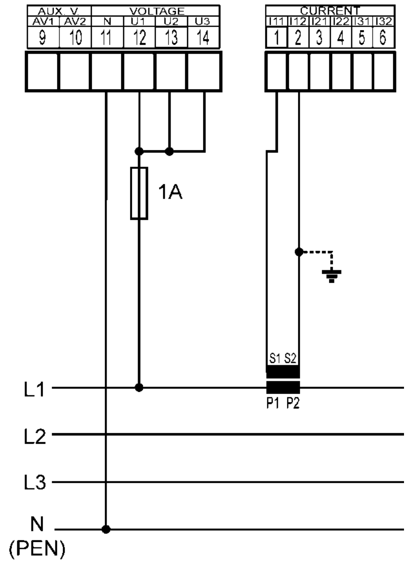
Voltage signals must be connected to all of three voltage inputs. For networks with neutral wire, connection of all three phase voltages and neutral wire is recommended (*1Y3* connection type). If it is not possible connect any of phase voltages to the U1, U2 and U3 inputs together.

Fig. 4.20 : Single-Phase Connection to Networks with Neutral Wire - Examples

***1Y3** connection type*
recommended wiring



***1Y3** connection type*
alternative wiring

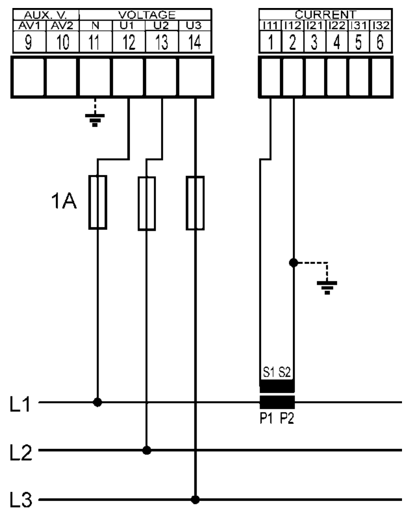


For networks without neutral wire, it is possible to connect all three voltages; then set *1Y3* connection as at previous cases.

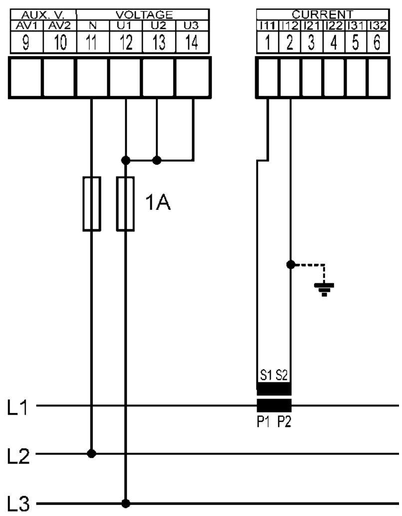
If one line-to-line voltage signal only is available it must be connected in different way : connect it to the U1 and N terminals and set 1D3 connection type. The U2 and U3 inputs must be connected together with the U1.

Fig. 4.21 : Single-Phase Connection to Networks without Neutral Wire - Examples

***1Y3** connection type*



***1D3** connection type*



Be careful not to exceed maximum input voltage according the technical parameters when the 1D3 connection type !!! Take into account that the network line-to-line voltage is connected to the instrument line-to-neutral input !!!

4.4.5.2 Setup

In *the Installation* group of parameters following two parameters must be set.

4.4.5.2.1 Connection Type 1Y3 / 1D3

If network **phase-to-line** voltage is connected to the U1 (No.12) and N (No. 11) terminals, or such voltage appears on internal voltage divider when the N terminal is free, the **1Y3** connection type must be set.

If network **phase-to-phase** voltage is connected to the U1 and N the **1D3** must be set.

Connection type parameter must be set correctly even if use of the automatic connection detection process (ACD) is supposed. Otherwise result of the process would fail and measured powers and power factor would be false !

4.4.5.2.2 Angle of Voltage Connected to the U1 Input (*U1-Angle*)

In the single-phase mode, the controller evaluates three-phase power factor on the basis of the voltage connected to the U1 input and a current connected to the I1 input only.

Generally, it is not necessary to connect voltage(s) and current of the same phase; for example, you can connect the L1-phase current and the L2- or the L3-phase voltage, even with opposite polarity.

If a line-to-line voltage is connected, or line-to-neutral voltage of different phase than current, or the voltage and current signal with opposite polarity, there exists phase shift between the voltage and the current signals even at power factor equal to 1. Controller must respect this angular displacement, so it must be specified correctly, otherwise it would evaluate wrong power factor.

The value of the angular displacement is defined as a combination of measurement network phases connected to the U1 and N controller terminals. It is assumed that the CT is mounted in the L1 phase of measured network and its orientation (terminals S1, S2) corresponds to real orientation supply ->load . The angle of voltage is then assigned one of six combinations shown in the table below.

Tab. 4.7 : U1 Angle – Setup Options

1Y3 connection type (phase-to-neutral voltage – LN)		1D3 connection type (phase-to-phase voltage – LL)	
No.	U1 angle	No.	U1 angle
1	L1-0 (0°)	1	L1-L2 (-30°)
2	L2-0 (120°)	2	L2-L3 (90°)
3	L3-0 (-120°)	3	L3-L1 (-150°)
4	0-L1 (180°)	4	L2-L1 (150°)
5	0-L2 (-60°)	5	L3-L2 (-90°)
6	0-L3 (60°)	6	L1-L3 (30°)

Notes :

- CT supposed in the L1 phase with correct orientation (S1, S2 terminals)
- the U1 angle expressed as „x-y“ where the „x“ means the phase connected to the U1 terminal and the „y“ phase connected to the N terminal (=0)

If the current signal is from opposite side of the power supply transformer than the voltage signal, the U1 angle must be set with respect to the transformer phase angle.

4.4.5.2.3 ACD Process – Automatic Connection Detection

The type of connection must be set always manually.

The U1 angle can be set manually too, but we strongly recommend to use automatic setup – *the ACD process* (Automatic Connection Detection). This process not onlz detects and sets the U1 angle, but network nominal votage U_{NOM} as well.

*For the ACD process usage following condition must be fulfilled : either **three-phase** or **single-phase** compensation **capacitors** are connected to **the first four control outputs**. If, for example, two-phase capacitors or any chokes connected to the outputs, the CT test gets fail results !*

*If inappropriate compensation elements connected to the first four outputs,you can set such outputs temporary to **the fixed-off** control state; then the instrument will use tor the ACD process the next four outputs that are set as **the control** outputs.*

Following conditions must be fulfilled for the ACD process launch :

- *connection type* is set to 1Y3 or 1D3
- *U1 angle* is not defined (---)
- *switching mode* is not set to *linear*
- main PFC screen is displayed

The controller launches this process automatically after powerup (if it is not in *the standby* state due to any of alarms).
The process can be started manually too. You can launch it not only in the control state but in the manual state as well. For this, in *the Installation* parameter group scroll to *the U1 angle* and set it as undefined (---).

As soon as the process is initiated, the information message appears in the main PFC screen :

Fig. 4.22 : ACD Start Message

Automatic Connection

Detection process will be started in 10 secs

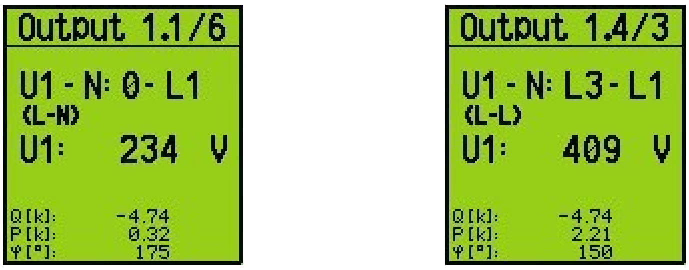
During following 10 seconds, you can either cancel the process launch with the ✖ button or to skip the message timeout with the ✓ button to start the ACD process immediately. Or you can simply let the timeout to expire and then the ACD process starts.

First of all, the first four *control* outputs are disconnected, step by step. Then the instrument waits until discharge time of the outputs just disconnected expires. During this, *Output 1.1* message flashes in the headline, that means that the instrument waits till output No. 1.1 is ready to use.
After all of the outputs discharged, the instrument starts to switch the four outputs step by step. After each of the step is switched off, following information appears :

- *U1 angle* found (0-L1, for example)
- U1 voltage (234 V)
- in the bottom reactive and active powers of the outputpři typu zapojení 1D3 power found and corresponding angle between voltage and current phasors

Fig. 4.23 : ACD Process – Successful Step Result

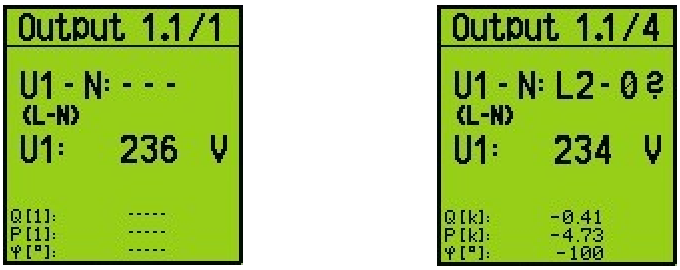
at 1Y3 connection type *at 1D3 connection type*



When 1Y3 connection type is set the controller supposes a line-to-neutral voltage (L-N, left screen) is connected; when 1D3 connection type a line-to-line voltage (L-L, right screen) is expected.

If unsuccessful step occurs usually dashes appear (left screen below). Such steps are not unusual especially when reactive power in measured network fluctuates strongly.

Fig. 4.24 : ACD Process – Unsuccessful Step Results



There may be cases where the angle measured with a permissible tolerance does not match any of expected options. Then estimated angle with question mark appears (right screen).

If unsuccessful steps with the same results and the question mark repeat frequently, the most likely cause is incorrectly set connection type. Check it and try to start the process again.

Ongoing ACD process can be interrupted at any point either manually by pushing the button or by any of alarm actuations. In such case, the recognized data are neglected and neither U1 angle nor U_{NOM} setting is updated.

The process can have up to 12 rounds with four steps each. After each step, the measurement results are analyzed. If the results are sufficiently stable, the process is finished and the results are displayed.

Fig. 4.25 : ACD Process – Results

The End is shown in the process headline and found U1 angle is displayed.

Furthermore, estimated network nominal voltage U_{NOM} appears in the second line. According voltage measured at the U1 input during the process the nearest value according following table is chosen.

Tab. 4.8 : The Most Common Nominal Voltages

58 V	*100 V*	*230 V*	*400 V*	*480 V*	*690 V*

On successful completion of the total process, the controller saves recognized U1 angle and nominal voltage U_{NOM} into its memory. Then it returns into the state from which it was initiated. If it is the control state the AOR process follows usually. Before this, we recommend to check stored values in *the Installation* group of parameters and to correct them, optionally.

Otherwise, if the ACD process unsuccessful (the U1 angle not detected) or canceled prematurely no parameters are updated and the process is automatically relaunched each approximately 15 minutes again in the control mode.

If the first sections have very low powers the ACD process can fail especially while high load at the network. Then start the process again (by resetting the U1 angle to ---) or, if necessary, set it and the U_{NOM} manually.

*Sometimes it is necessary to start the ACD process at disconnected load (or at zero load)– for example ,when testing a compensation switchboard before its expedition to a customer. If the default controller undercurrent (**I<**) alarm actuation is set the controller gets into the standby state in such case and the ACD process cannot be started. Therefore, it is necessary to switch this alarm actuation temporarily off (and to return it back after the ACD-process passes).*

4.4.5.3 Operation

Behaviour of the controller in the single-phase mode differs from the standard in :

- I2 and I3 currents are not measured, their THDI and harmonic components are not evaluated
- powers and power factor are evaluated only on basis of U1 voltage and I1 current : measured single-phase power is multiplied by 3 and considered as three-phase power, measured single-phase power factor is considered as three-phase power factor
- single-phase powers and power factors are not evaluated
- voltages are measured normally, i.e. all of three phases; their THDUs, CHLs and harmonics are evaluated too, but the U2 and U3 values have no effect on the three-phase powers and power factor. Voltage controlled alarms run normally for all of three phases (this is why we recommend to connect all of three voltage phases even in the single-phase mode).
- at *the 1D3* connection type, measured voltages are considered as line-to-line voltages; line-to-neutral voltages are calculated from the line-to-line ones by dividing constant 1.73 (V3)
- control strategy is fixed *3p*
- if *the U1 angle* is set as undefined, the ACD process is launched
- the CT-test is irrelevant and cannot be launched

4.4.6 Special PFC-Block Related Quantities's Meaning & Evaluation

General quantities' meaning and evaluation formulas can be found in the appropriate chapter of the general meter part description further below.

In the PFC-block, basic measured values necessary for the power factor control are aggregated. Furthermore, some additional special quantities are used. Description of the quantities follows.

4.4.6.1 Values Used for Power Factor Control Evaluation and Aggregation

Powers Pfh and Qfh of individual phases are basic quantities used for power factor control. Values of the quantities are evaluated each measurement cycle. Then they are internally **averaged with floating 5 seconds long window** for usage in power factor control with contactor-type outputs. Such power values are not displayed, but essential quantities for power factor control – PF control deviations ΔQfh – are evaluated from them. In the same way, compensation reserves RC and RL are evaluated.

Therefore, the control deviations and the power factor control intentionally do not react on short power factor deflections that cannot by compensated with contactor-type outputs.

4.4.6.2 ΔQfh – PF Control Deviation

This is crucial quantity for the PF control process. Its value indicates surplus reactive power (of fundamental harmonic component) in the network that must be compensated to reach preset target power factor. If the value is positive (inductive character) the controller connects compensation capacitors of appropriate power to the network; if negative (capacitive character), the controller tries to add compensation chokes.

Target fundamental harmonic component reactive power of phase L1:

$$Qfh_{T1} = Pfh_1 * tg\varphi_T$$

where :

Pfh1 … phase L1 fundamental harmonic active power

φ_T … preset target angle between fundamental voltage and current phasors

When target power factor is specified in the *cosφ* format it can be declared :

Target angle (between fundamental U & I phasors) : $\varphi_T = \arcsin(cos\varphi_T)$

Then, target fundamental harmonic component reactive power (of phase L1) is :

$$Qfh_{T1} = Pfh_1 * tg(\arcsin(cos\varphi_T))$$

Finally, the control deviation of phase L1 : $\Delta Qfh_1 = Qfh_1 - Qfh_{T1}$

where :

Qfh1 … phase L1 fundamental harmonic reactive power

Total three-phase control deviation : $\sum \Delta Qfh = \Delta Qfh_1 + \Delta Qfh_2 + \Delta Qfh_3$

4.4.6.3 Cosφ / Tanφ / φ – Power Factor

The fundamental harmonic component power factor value processed in the PFC-block can be presented not only in *the cosφ* format but as *the tanφ* or simply as *the φ* too.

The power factor character in the PFC-block is marked with either -icon (inductive character) or -icon (capacitive character).

4.4.6.4 CHL – Capacitor Harmonic Load Factor

This quantity was designed and implemented in order compensation capacitors protection against current overload to be possible simply. If appropriate alarm actuation is set the controller disconnects the sections from a network as soon as the CHL-factor exceeds preset limit value.

Compensation capacitors' service life depends on not exceeding of operation limits. One of the limits is capacitors'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

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

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

$$Ic=\sum_{i=1}^{n} Ii$$ [A]

and magnitude of each harmonic component is pursuant to the first formula

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

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 the formula, 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

$$THD_U=\frac{1}{U1}\sqrt{\sum_{i=2}^{N} Ui^2}*100$$ [%]

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

$$CHL=\frac{1}{U_{NOM}}\sqrt{\sum_{i=1}^{N} i*Ui^2}*100$$ [%]

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, 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 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.

Tab. 4.7: 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.

4.4.6.5 RC, RL – Compensation Reserve Powers to Reach Target Power Factor

With the compensation reserve powers RC and RL you can check if installed compensation power, i.e. total reactive power sum of all installed compensation capacitors and chokes is sufficient to keep preset target factor or not.

The reserve values are not visible in the PF-control screen ; you must switch to general meter actual data and scroll down into power values group to check them.

The reserves are defined as follows :

Capacitive reserve power of phase L1 : $RC_1 = \sum Q_{COFF1} - \sum Q_{LON1} - \Delta Qfh_1$

Inductive reserve power of phase L1 : $RL_1 = \sum Q_{CON1} - \sum Q_{LOFF1} + \Delta Qfh_1$

where :

$\sum Q_{COFF1}$ … sum of L1-phase capacitive-type reactive power components of the control*) outputs being just switched off (capacitive reactive power of an output considered as positive)

$\sum Q_{CON1}$ …. sum of L1-phase capacitive-type reactive power components of the control*) outputs being just switched on

$\sum Q_{LON1}$ …. sum of L1-phase inductive-type reactive power components of the control*) outputs being just switched on (inductive reactive power of an output considered as negative)

$\sum Q_{LOFF1}$ …. sum of L1-phase inductive-type reactive power components of the control*) outputs being just switched off

ΔQfh_1 .... control deviation reactive power of L1-phase

*) *The outputs that have non-zero reactive power and that are not set as fixed outputs are considered as the control outputs (including the outputs that are temporary disabled due to OE-alarm actuation).*

Then, three-phase reserves are :

Capacitive three-phase reserve reactive power : $\sum RC = RC_1 + RC_2 + RC_3$

Inductive three-phase reserve reactive power : $\sum RL = RL_1 + RL_2 + RL_3$

If any reserve is positive that means that there are still one or more outputs that can switched on or off to reach target power factor in the network.

On the contrary, negative reserve means that actual control deviation cannot be compensated; the negative RC/RL value contains size of missing capacitive/inductive compensation power. That means is such case the compensation system is undersized and other capacitors/chokes should be installed.

When checking a compensation system capacity usually at least one week long period is observed. You can use registered maximum and minimum of the reserve average values for this :

1. Check all of the compensation outputs' values and target power factor to be set properly.
2. Check and, if necessary, set suitable average method and evaluation period of the **P/Q/S**-group (to which the RC/RL reserves belong ; see average values setup).
3. Switch to the general meter actual values and scroll to three-phase power values. Push the ► button until **3dQ/3RL/3RC** option is selected - then window with actual three-phase control deviation and reserve powers appears.
4. With the button switch to 123.4 avg -icon, i.e. to average values.
5. Now clear up till now registered maximum&minimum power values : press the ► button repetitive until **Clear** option is selected, then at the confirmation window press the ✓button.
6. Now let the controller running for reporting period (usually at least one week). After that, check new registered maximum and minimum average values of reserve powers.

Fig. 4.20 : Compensation Reserves - Sufficient

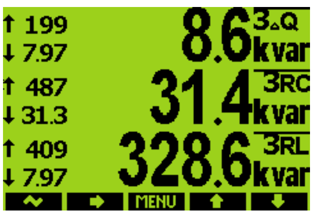
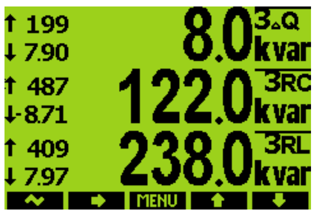


Fig. 4.21 : Compensation Reserves - Insufficient Capacitive Reserve



For compensation reactive power capacity assessment, registered minimum values of both reserves are decisive. On example on Fig. 4.20, registered minimum of three-phase capacitive reserve is 31.3 kvars, minimum of inductive reserve is 7.97 kvars. As both of them are positive the system compensation power is sufficient.

If any of reserve minimum values is negative as example on the next figure shows, reactive power of magnitude that the controller could not compensate appeared sometimes in the network during the testing period. As *the 3RC* minimum average value is negative, the capacity of compensation capacitors is not sufficient ; 8.71 kvars of capacitors missed. Similarly, as *the 3RL* minimum average value is positive, no additional compensation chokes are necessary.

You can use the compensation reserves not only for checking the capacity of existing compensation system, but for any new compensation system dimensioning too : Install single instrument (without any of compensation sections connected) at the network where new compensation system to be projected . Then perform the reserve check as described above; set target power factor only but let all of the compensation outputs set as zero outputs and switch the controller into the manual state. After observed period, according registered negative minimums of the RC / RL reserves you can size the compensation system capacity.

When you use an instrument model equipped with built-in real time circuit for compensation reserve measurement you will get the reserve minimums and maximums including their time stamps too.

5. Meter Block

5.1 Basic Functions

The meter block - universal three-phase meter - is key part of the instrument.

All of usual electric quantities like line-to-line and phase voltages, currents, active, reactive and apparent powers, power factors, voltage and current THDs and harmonic components, active and reactive energy, average power maximums, frequency etc. are evaluated. Furthermore, temperature is measured with built-in sensor. Optionally, the second temperature can be measured with an external Pt100 sensor at appropriate instrument models.

The instruments are fitted with inputs for connection of three voltage signals, three fully isolated current signals (for use with external CTs with 5 A_{AC} or 1 A_{AC} nominal secondary current) and separate AC/DC power supply input. They can be used in both low voltage and high voltage power grids.

The instruments feature three-rate tariff four-quadrant electricity meter with maximum average active power (maximum demand) registration. Advanced models store all results for actual and last month too and a separate archive dedicated for automated meter readings can record actual status in preselected intervals.

Optionally, the instruments can be equipped with battery backed real time circuit, additional memory for datalogging, RS-485/Ethernet and USB communication interfaces, forming powerful network analyzer.

Basic specifications of the instrument can be set up by using the inbuilt keyboard and the display. Therefore the instrument can be used as a multifunction panel-mounting measuring instrument without computer application.

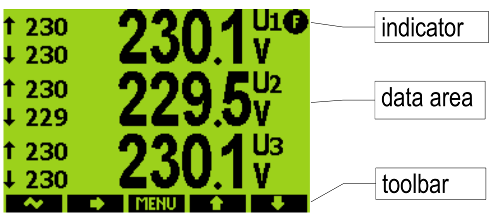
With the ENVIS program supplied as standard you can, via any of communication link, adjust the instrument and transfer recorded data. In addition to the instrument adjustment, ENVIS program allows you to display, view and archive the measured courses in the graphic form, as well as a number of other features.

5.2 Meter Block Manipulation and Setting

5.2.1 Data Area – Status Bar - Toolbar

Instrument's screen consists of two parts : *a data area* and *a toll bar area*.

Fig. 5.1: Data Area, Toolbar



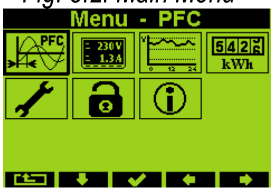
The toolbar determines function of individual buttons and changes dynamically by a context.

In special cases a flashing indicator can appear at upper right corner of the data area. It indicates following cases :

- … Frequency measurement not yet finished or out of range. In such cases measured signals are scanned according preset nominal frequency **f_{NOM}** and measured values can be incorrect. Check **f_{NOM}** parameter setting.
- … At least one of voltage or current input overloaded
- … Remote communication in progress. This indicator is suppressed approx. 10 seconds after any button pushing.

5.2.2 Main Menu

Fig. 5.2: Main Menu



By pressing the MENU button, a *Main menu* window appears. With the ▶ and ◀ buttons you can browse through the menu and select a desired action with the ✓button or return back using the (escape) button.

Although all other buttons but the MENU button are context dependent and variable, the MENU button is accessible from nearly every window which helps to quick orientation. Excluding the PFC block icon, the menu options consist of :

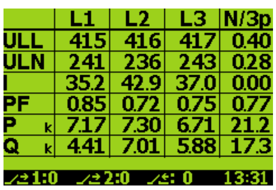
- Actual data group (all of measured data in both numeric and graphic form)
- Daily and weekly graphs of main quantities
- Electricity meter data group (electric energy and maximum demand values)
- Instrument setting (presetable parameters)
- Instrument lock
- Information (instrument type & serial number, memory usage state etc.)

5.2.2.1 Actual Data Group

Actual values in numeric form appear when *Actual data* group is selected as default (see Fig. 3.11). Navigation through the actual values branch is intuitive using the navigation buttons. For detailed description of the actual values presentation see chapter *Display Actual Values Evaluation and Aggregation* further below.

All the values are identified with a quantity name and a quantity unit. An *U/I/P/Q summary* window is an exception – the quantity unit is not displayed (only a **k** / **M** / **G** multiplier is). At the last column, which is marked **3p** , values of following quantities are displayed :

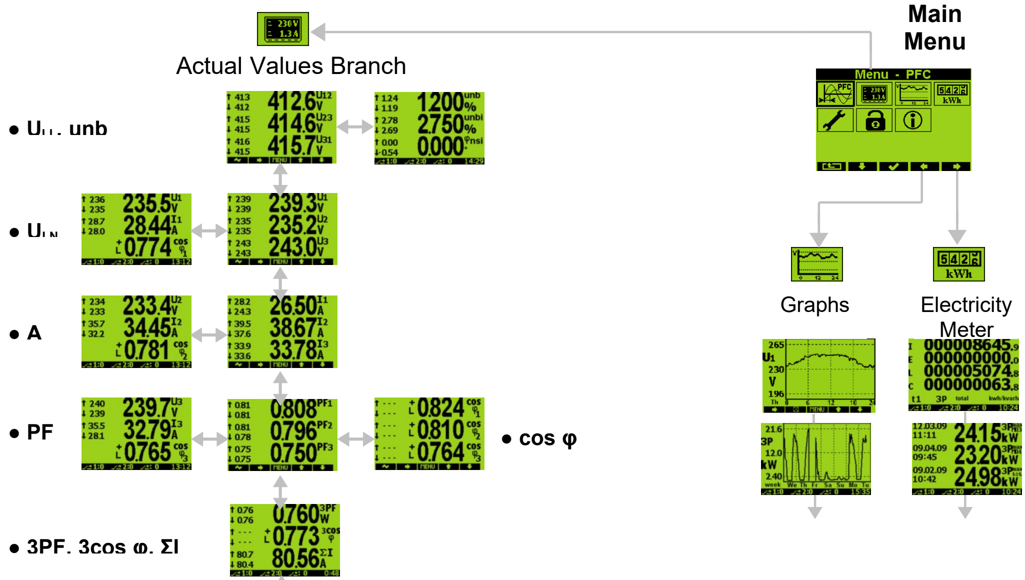
Fig. 5.3 : Actual Data Summary Window

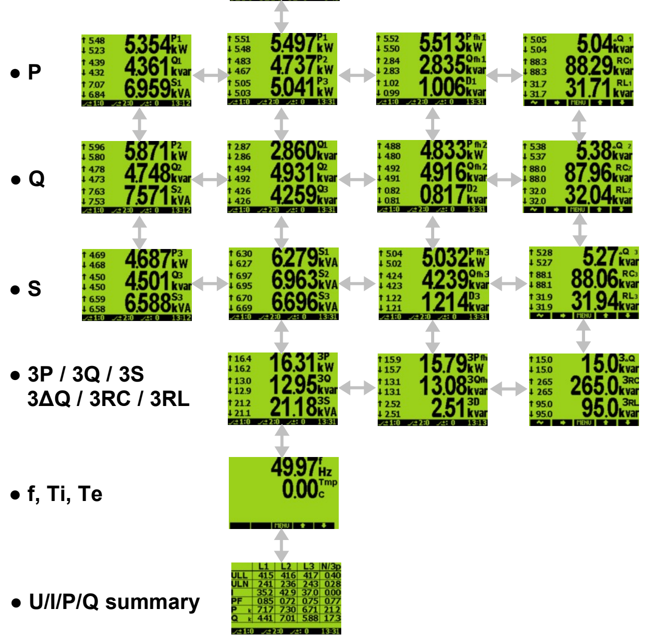


Tab. 5.1: Summary Window 3p Column Quantities

row	3p column quantity
U_{LL}	**unb_U** - voltage unbalance
U_{LN}	-
I	**ΣI** - I1+I2+I3
PF	**3PF** – three-phase power factor
P	**3P** – three-phase active power
Q	**3Q** – three-phase reactive power

Fig. 5.4 : Meter Actual Data Navigation Chart





Legend:
Uxy/Ux.... line/phase voltage (x/y...1,2, 3)
unb...voltage unbalance
unbi/φnsi...current unbalance & its negative sequence angle
Ix...phase current
ΣI...I1+I2+I3
PF/3PF... single-phase / three-phase real power factor
cosφ/3cosφ... single-phase / three-phase fundamental harmonic power factor
P/Q/S/D.. active / reactive / apparent / distortion power
Pfh/Qfh … fundamental harmonic active / reactive power
ΔQx ... power factor control deviation (ΔQfh)
RCx/RLx ... capacitive/inductive power factor control reserve reactive power
3P/3Q/3S/3D/3Pfh/3Qfh/3ΔQx/3RC/3RL.... three–phase P/Q/S/D/Pfh/Qfh/ΔQ/RC/RL
f...... frequency
Ti / Te … internal / external temperature
THDU/THDI...voltage / current total harmonic distortion

Electricity meter group :
energy I... active work-import (demand)
energy E... active work-export (delivery)
energy L... reactive work-inductive
energy C... reactive work-capacitive
3MD ... maximum three–phase active power demand

- Actual Data Display Mode Switch

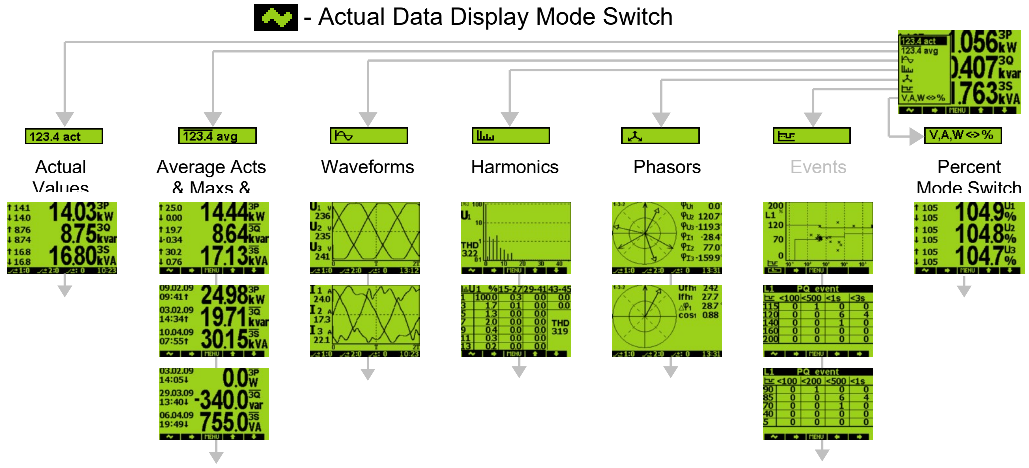


Fig. 5.5 : Actual Data Display Mode Switch

The actual data group comprises other actual data presentations that are accessible with the button - so called *actual data display mode switch* . When pressed, a pull up menu rolls over the display temporary. By multiple pressing of the button a desired actual data subgroup can be selected and displayed :

- 123.4 act — Actual values – values of all measured quantities in numeric format.
- 123.4 avg — Average values – average values of main measured quantities including their maximums & minimums. For detailed description see chapter *Display Average Values Evaluation and Aggregation* further below.
- Waveforms – actual wave shapes of all measured voltages and currents.
- Harmonics – actual harmonic components of all voltage and current signals in both numeric and graphic (histogram) formats. For detailed description see chapter *Harmonics and THD Presentation.*
- Phasors – diagrams of voltage and current fundamental harmonic phasors. A phase sequence can be checked here too (indicated as **1-2-3** or **1-3-2**).

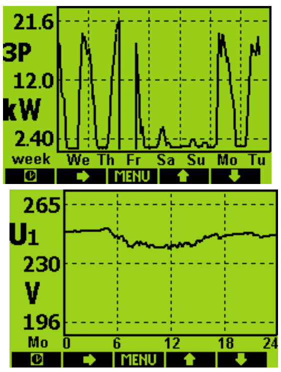
With the last option of the display mode switch – **V,A,W↔%** – voltage, current and power quantities expression can be switched between basic units and percent relative to preset nominal voltage $\mathbf{U_{NOM}}$ and nominal power $\mathbf{P_{NOM}}$.

5.2.2.2 Daily and Weekly Graphs

This option is supported by instrument models equipped with RTC & additional memory only.

A one-week history of main measured quantities (such as voltages, currents, powers and power factors) is registered in the instrument's memory cyclic buffer. Individual courses can be displayed for rough check (for detailed check at a PC a main archive is intended, see appropriate chapters further below).

Fig. 5.6 : Weekly Graph, Daily Graph



With the button, either whole week or specified day of the passed week can be selected – on the graph, the day is identified with its shortcut (Mo = Monday, for example). Excluding of seven passed days, so called S-day and M-day can be viewed too.

The S-day is a predefined day of year. The S-day record refreshes once per year only. The M-day is the day when maximum 15-minute average value of **ΣI** occurred. Both the S-day date can be preset and the M-day record can be cleared via communication link with ENVIS program only. For details see the ENVIS program manual.

With the ► button desired group of quantities can be selected. For listing through the selected group, use the ▲ and ▼ buttons.

5.2.2.3 Electricity Meter Data Group

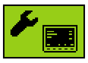
The electricity meter group comprises registered electric energy and maximum active power demand values. For detailed explanation see chapter *Energy Data Presentation* further below.

5.2.2.4 Instrument Setting

In this group most of presetable parameters can be viewed and edited. Other parameters can be accessed via communication link from a PC using ENVIS program only.

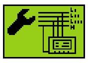
If any of setting window is viewed, an instrument automatically reswitches to actual data display during an approx. 1 minute if no manipulation with buttons is carried out.

Following chapters explain the meaning of particular groups of parameters.



5.2.2.4.1 Display Setting

- **Contrast** … LCD display contrast in range 0÷100 %
- **Backlight** … LCD display backlight can be set as permanently on (**on**) or to auto-off mode (**auto**), in which it is switched off automatically during approx. 2 minutes if no button is pressed to decrease the instrument power dissipation.
- **Language** … Except the basic English version, other national versions can be selected
- **Display refresh cycle** … Actual values refresh period. For details see chapter *Display Actual Values Evaluation and Aggregation*.
- **Display Resolution** … Actual data format can be set to 3 or 4 significant figures (exception : not applicable for electric energy values).



5.2.2.4.2 Installation Setting

All parameters of this group are explained in chapter *Measured Electrical Quantities Installation Setup*. above (*the Commissioning* part).

5.2.2.4.3 Clock Setting

This setting is relevant for instrument models equipped with a real time circuit (RTC).

- **Date** & **Time** … Local date and time.
- **Time Zone** … The time zone should be set according location of an instrument during installation. Correct setting is essential for proper local time interpretation.
- **Daylight Saving** … This option controls automatic winter/summer local time switching.
- **Time Synchronization** … As the built-in real time circuit has limited accuracy while free running, with this option it is possible to keep the RTC time in synchronism with an external precise time source. The RTC can be synchronized by :
  - **Pulse Per Second / Minute** (**PPS / PPM**) … A digital input is used for time synchronization from an external source at this case. The instrument sets the RTC to the nearest second or minute as soon as a synchronization pulse is detected. Second-, Minute-, quarter-hour- or hour- synchronization pulses are accepted.
  - **NMEA Message** ...If an instrument is equipped with the RS-232 or RS-485 remote communication interface an external (usually GPS-based) time receiver can be connected to. The receiver must be set to transmit the “ZDA”- or “RMC ”-message (NMEA 0183 protocol). The communication interface must be set appropriately (usually 4800 Bd, 8 bits, 1 stopbit).

- **NTP Server** ...The option can be used if an instrument is equipped with the Ethernet communication link and a NTP-server is available in the network.Set IP-adress of the server. Then time synchonization is performed every hour.
- **Network Frequency** … For this option, the nominal frequency f_{NOM} parameter must be set properly. Otherwise the synchronization will not work.

***Warning** : When editing clock parameters, it must be taken into account that internal data archives are affected : when changing the date or time, **all archives are cleared** !*

5.2.2.4.4 Average Values Processing Setting

In this parameter group average values processing for both of ***U/I*** -group and ***P/Q/S*** -group of measured quantities can be set. Detailed explanation can be found in the chapter *Average Values Evaluation* further below.

5.2.2.4.5 Remote Communication Setting

Communication parameters for various interface types differ from each other :

COM (RS-485) interface :

- **Communication Address**
- **Communication Rate** …Communication rate in Bauds (Bd).
- **Data Bits** … Set to 8 for KMB protocol; when parity bit is used (Modbus, usually) set to 9
- **Parity** … Set to 8 for KMB protocol; for Modbus, usually set to 9
- **Stop Bits** … Set (usually) to 1

Ethernet interface :

- **DHCP** ... activation of dynamic IP-address allocation.
- **IP Address** …Internet protocol address.
- **Subnet Mask** …Subnet mask.
- **Default Gateway** …Default gateway.
- **KMB-port** … Communication port used for KMB protocol communication.
- **Web-port** … Communication port used for webserver communication.
- **Modbus-port** … Communication port used for Modbus protocol communication.

5.2.2.4.6 Embedded Electricity Meter Setting

In this group parameters concerning electric energy registration and maximum active power demand processing can be set. For detailed parameter description see the chapter *Embedded Electricity Meter* further below.

5.2.2.4.7 Archiving Setting

This setting is relevant for instrument models equipped with additional datalogging capability only.

To check correct setup of the main archive, it is possible to visualize its settings in this sub-menu. All items are read only and can be changed via a communication link from a PC with ENVIS program only. On the panel it is possible to check record period, separate options for quantities and phases, preset S-day date etc. Quantities with extensive options such basic quantities or separate powers are displayed in separate screens which can be opened on lines with "**...**" symbol.

5.2.2.5 Instrument Lock

Three levels of locking to allow protection against unauthorized access are implemented. The active protection level is symbolized in *the main* menu by three different states of the ***Lock*** icon :

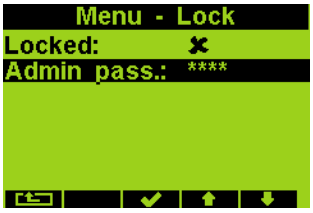
- **Unlocked** – anyone with physical access to the instrument can freely set-up and configure all parameters in the instrument, clear archives and other persistent data or reset counters. In this state anyone can also lock the instrument.
- **User Locked** – fixed *user password* (PIN) is required if the instrument configuration is changed or there is a request to clear any of the data.
- **Admin Locked** – user defined *admin password* (PIN) is required if the instrument configuration is changed or there is a request to clear any of the data.

5.2.2.5.1 Locking

If the instrument is unlocked, you can lock it to either user or admin mode.

To lock the instrument into the user locked mode, simply switch in the **Menu-Lock** window the lock from ✖ to ✓. Then escape from the window with the button and confirm saving of changed state.

To lock the instrument into the admin locked state, in the **Menu -> Lock** window press the button ▼ ,



keep it pressed and then press the . Then normally hidden admin password option appears. Choose it and type the new admin password code – the value must be different from 0000. Then escape from the **Menu-Lock** window with the button and confirm saving of changed state. The admin locked state is indicated with the "A"-character inside the lock icon.

Warning ! Store the admin password code at the secure place to be able to unlock the instrument later in case the code is forgotten !

5.2.2.5.2 Unlocking from the User Locked State

To unlock the instrument, switch in ***Menu -> Lock*** the lock state back from ✓ to ✖ by entering user password. The value of this password is fixed and equal to the last four digits of the serial number of the instrument. This serial number can be found in device display under **Menu -> Info -> Serial number** .

Then escape from the **Lock** window with the button and confirm saving of changed state.

5.2.2.5.3 Unlocking from the Admin Locked State

To unlock the instrument, switch in **Menu -> Lock** the lock state back from ✓ to ✖ by entering correct admin password. Then escape from the **Menu-Lock** window with the button and confirm saving of changed state.

Note, that such unlocking is temporary and the instrument will switch to the admin locked state automatically approx. 15 minutes after last pressing of any button. To avoid this you need to set the admin password code to value 0000 (in the same way as the locking as described above). Only after that the instrument state changes to permanently unlocked state.

Note : In case the admin password is lost, visits manufacturer's website at www.kmbsystems.eu and follow instructions to obtain the alternate unlock code.

5.2.2.6 Instrument Information

The instrument identification and actual status are listed in this group. The information are split up to three windows that can be browsed through with the ► button.

5.2.2.6.1 Info – General Window

- **Instrument Model** & **Serial Number** … Instrument hardware model & serial No.
- **Instrument Hardware, Firmware** & **Bootloader Versions** …Instrument hardware & firmware specification.
- **Object Number** … Measured node specification (preset by ENVIS program for data identification).
- **Vbatt** … backup battery voltage (if equipped).
- **Error Code** … Indicates some instrument's hardware or setting problem. At normal state equals to 0. In case of detection of any error it contains a number in the range 1 ÷ 255 created as the sum of binary weights of up to eight possible causes. The following table provides overview of them and recommended action:

Tab 5.2 : Instrument Errors

error No.	weight	meaning	action
1	2	instrument setup error	set the instrument (optimally with the ENVIS program, if possible) to the *default setting*; if the error appears again send the instrument to a service organization for repair
2	4	calibration error	the instrument must be recalibrated – send to a service organization
4	16	RTC error	in *the time setup window* (or better with the ENVIS program, if possible), set actual date&time; if the error appears again send the instrument to a service organization for repair
7	128	archive data error	clear all of the archives with the ENVIS program; if the error appears again send the instrument to a service organization for repair

5.2.2.6.2 Info – Archive Status

This screen is relevant for models with datalogging capability only.

At this submenu actual state of individual archive buffers can be checked. Detailed information of each buffer can be viewed with the button : actual record item pointer, total capacity of the buffer in data record items and corresponding start and end date of the buffered archive are available.

At the last row actual number of internal flash memory bad sectors is displayed. During instrument's lifetime some blocks (up to several tens) of the memory can get wrong. The flash memory blocks are permanently checked and in case of failure the wrong block is no longer used and replaced with a spare block.

5.2.2.6.3 Info – Producer

At this submenu there is producer's logo and website URL-address only.

5.3 Description of Operation

5.3.1 Method of Measurement

The measurement consists of three processes being performed continuously and simultaneously: frequency measuring, sampling of voltage and current signals and evaluation of the quantities from the sampled signals.

5.3.1.1 Voltage Fundamental Frequency Measurement Method

The voltage fundamental frequency is measured continuously and evaluated every 10 seconds. Logical sum of all voltage signals is led through a low-pass filter and then processed.

The fundamental frequency output is the ratio of the number of integral mains cycles counted during the 10 second time clock interval, divided by the cumulative duration of the integer cycles.

If value of frequency is out of measuring range, such state is indicated with flashing indicator F at upper right corner of the actual data window.

5.3.1.2 Voltage and Current Measurement Method

Both voltage and current signals are evaluated continuously as required by IEC 61000-4-30, ed. 2 standard. The unitary evaluation interval, *a measurement cycle*, is a ten / twelve (value behind slash is valid for f_{NOM} = 60 Hz) *mains cycles* long period (i.e. 200 ms at frequency equal to preset f_{NOM}), which is used as a base for all other calculations.

The sampling of all voltage and current signals is executed together with the frequency of 128 / 96 samples per mains cycle. The sampling rate is adjusted according to the frequency measured on any of the voltage inputs **U1**, **U2**, **U3**. If the measured frequency is in measurable range at least on one of these inputs, then this value is used for subsequent signal sampling. If the measured frequency is out of this range, the preset frequency value (f_{NOM}) is used and measured values may be incorrect.

When exceeding the measuring range of any voltage or current, the instrument indicates overload by indicator > at upper right corner of the actual data window.

Effective values of voltages and currents are calculated from sampled signals over the measurement cycle using formulas (examples for phase No. 1) :

Phase voltage (effective value) :

$$U1=\sqrt{\frac{1}{n}\sum_{i=1}^{n}U1i^2}$$

Line voltage (effective value) :

$$U12=\sqrt{\frac{1}{n}\sum_{i=1}^{n}(U1i-U2i)^2}$$

Current (effective value) :

$$I1=\sqrt{\frac{1}{n}\sum_{i=1}^{n}I1i^2}$$

where : i .... sample index

n .... number of samples per measurement cycle (1280 / 1152)

Ui_1, Ii_1 ... sampled values of voltage and current

Phase Current Sum :

$$\sum I=I_1+I_2+I_3$$

The data for the longer measurements are aggregated from these measurement cycles. Long time interval starts after the RTC tick occurrence at the beginning of the next measurement cycle time interval. This principle enables to configure other intervals up to 2 hours for datalogging purposes.

Measured phase voltages U_1 to U_3 correspond to the potential of terminals **VOLTAGE / U1** to **U3** towards the terminal **VOLTAGE / N**.

Three current signals - I_1, I_2, I_3 - are measured. Another current is calculated from samples of directly measured ones as negative vector sum of all measured current vectors (Kirchhoff rule). The calculated current is referenced as $\mathbf{I_{PEN}}$. The $\mathbf{I_{PEN}}$ value is available on a PC via communication with ENVIS program only.

Measuring voltage inputs impedance is in range of units of MΩ. If no signal connected (for example when protection fuse is blown), due to parasite impedance of power supply input a parasite voltage of up to tens of volts can appear on the measuring voltage inputs. In such case the instrument can show non-zero voltages !

5.3.1.3 Harmonics and THD Evaluation Method

Entire spectrum of harmonic components and THD is evaluated discontinuously - periodically every second from 10 / 12 mains cycles long signal according to IEC 61000-4-7 ed.2 as harmonic sub-groups (H_{sg}).
Following quantities are evaluated :

Harmonic components of voltage and current up to 50th order : Uih_1, Iih_1
(i …. order of harmonic component)

Absolute angle of voltage harmonic component phasor : φUih_1

Current harmonic component phasor angle relative to phasor Ufh_1 : φIih_1

Relative angle between correspondent voltage and current phasors : $\Delta\varphi i_1$

Total harmonic distortion of voltage : $$THD_{U1}=\frac{1}{U1h1}\sqrt{\sum_{i=2}^{40} Uih1^2}*100\,\%$$

Total harmonic distortion of current : $$THD_{I1}=\frac{1}{I1h_1}\sqrt{\sum_{i=2}^{40} Iih_1^2}*100\,\%$$

5.3.2 Power, Power Factor and Unbalance Evaluation Method

Power and power factor values are calculated continuously from the sampled signals according to formulas mentioned below. The formulas apply to basic type of connection – wye (star).

Active power : $$P_1=\sum_{k=1}^{40} U_{k,1}*I_{k,1}*cos\Delta\varphi_{k,1}$$

Reactive power : $$Q_1=\sum_{k=1}^{40} U_{k,1}*I_{k,1}*sin\Delta\varphi_{k,1}$$

where : k … harmonic order index, odd components only
$U_{k,1}$, $I_{k,1}$ … the k^{th} harmonic components of voltage and current (of phase 1)
$\Delta\varphi_{k,1}$ ... angle between the k^{th} harmonic components $U_{k,1}$, $I_{k,1}$ (of phase 1)
(these harmonic components of U and I are evaluated from each measurement cycle)

Apparent power : $$S_1=U_1*I_1$$

Power factor : $$PF_1=\frac{|P_1|}{S_1}$$

Three-phase active power: : $\sum P = P_1 + P_2 + P_3$

Three-phase reactive power : $\sum Q = Q_1 + Q_2 + Q_3$

Three-phase apparent power : $\sum S = S_1 + S_2 + S_3$

Three-phase power factor : $\sum PF = \frac{|\sum P|}{\sum S}$

Fundamental harmonic component quantities :

Fundamental harmonic power factor : $\cos\Delta\varphi_1$ (or $\tan\Delta\varphi_1$, $\Delta\varphi_1$, optionally)

Fundamental harmonic active power : $Pfh_1 = Ufh_1 * Ifh_1 * cos\Delta\varphi_1$

Fundamental harmonic reactive power : $Qfh_1 = Ufh_1 * Ifh_1 * sin\Delta\varphi_1$

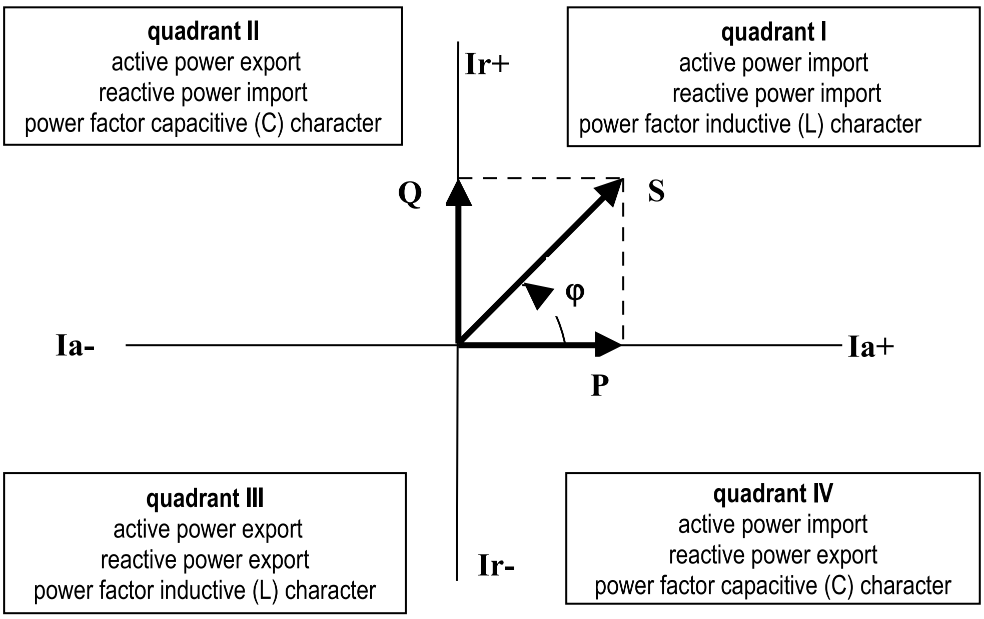
Fundamental harmonic three-phase active power : $\sum Pfh = Pfh_1 + Pfh_2 + Pfh_3$

Fundamental harmonic three-phase reactive power : $\sum Qfh = Qfh_1 + Qfh_2 + Qfh_3$

Fundamental harmonic three-phase power factor : $\sum cos\Delta\varphi = \cos(arctg(\frac{\sum Qfh}{\sum Pfh}))$

Powers and power factors of the fundamental harmonic component (cos φ) are evaluated in 4 quadrants in compliance with the standard IEC 62053 – 23, apendix C, see Fig. 5.7.

Fig. 5.7: Identification of consumption- supply and the character of reactive power according to phase difference



For outright specification of the quadrant, the power factor of the fundamental harmonic component – **cos φ** – is expressed according to the graph with two attributes :

- *a sign* (**+** or **-**), which indicates polarity of active power
- *a character* (**L** or **C**), which indicates the power factor character (the polarity of reactive power relative to the active power)

You can find the control deviation power ΔQfh and the compensation reserve powers RC and RL evaluation formulas in the PFC-block description.

Voltage and current unbalance evaluation is based on negative/positive sequences of voltage and current fundamental harmonic components :

Voltage unbalance : $$unb_U = \frac{voltage\ negative\ sequence}{voltage\ positive\ sequence} * 100\,\%$$

Current unbalance : $$unb_I = \frac{current\ negative\ sequence}{current\ positive\ sequence} * 100\,\%$$

Current negative sequence angle : φnsI

All of angle values are expressed in degrees in range [-180.0 ÷ +179.9].

5.3.2.1 Temperature

Both the internal temperature ***Ti*** and the external temperature ***Te*** (at selected models only) are measured and updated each approx. 10 seconds.

5.3.3 Measured Values Evaluation and Aggregation

As described above, measured values are evaluated according to IEC 61000-4-30 ed.2, based on continuous (gap-less), 10 / 12 mains cycles long intervals (measurement cycle) processing.

Further aggregation of the actual values from this evaluation is used to obtain values for displaying and recording.

5.3.3.1 Actual Values Evaluation and Aggregation

Actual (instantaneous) values of measured quantities, that can be viewed on instrument's display, are evaluated as average of integral number of measurement cycle values per *display refresh cycle*.

The display refresh cycle is presetable in range 2 ÷ 20 measurement cycles , corresponding approx. to 0.4 ÷ 4 seconds display refresh cycle duration.

Maximum (marked as ↑) and minimum (↓) measurement cycle values registered during the display refresh cycle interval are displayed too.

Fig. 5.8: Actual Data Display Refresh Cycle Setting

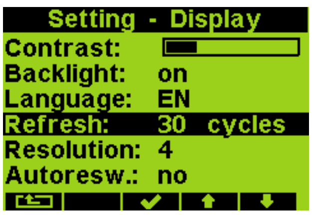
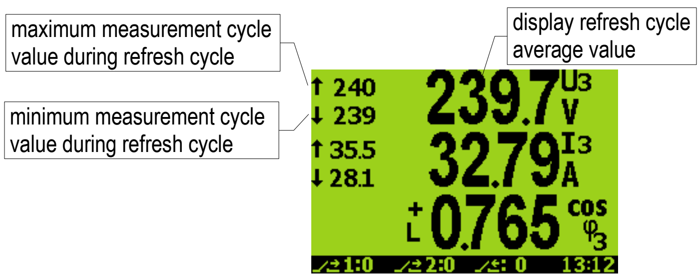


Fig. 5.9: Actual Data



Exceptions :

- frequency – the value is refreshed each frequency measurement cycle (see above)

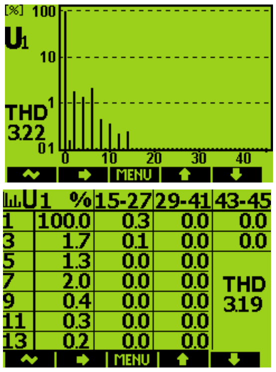
- harmonic components, THD and unbalance – the last measurement cycle values are displayed (no averaging)
- temperature – the value is refreshed each temperature measurement cycle (see above)

Actual values, read from an instrument via a communication link for monitoring purposes are evaluated from one – the last – measurement cycle only.

Neither maximum nor minimum of cosφ values are evaluated due to special character of the quantity. Similarly, these extreme values are not evaluated at frequency, harmonics&THD and temperature values either due to a specific measurement method.

5.3.3.1.1 Harmonics and THD Presentation

Fig. 5.13 : Harmonics



Harmonic components in both numeric and graphic format can be viewed at *Actual data* group. At the numeric format – a table – a value of Total Harmonic Distortion (THD) is displayed too. You can list through all measured phase voltage and current signal harmonics with the ▲ and ▼ buttons.

With the ► button you can switch between :

- voltage and current signals using **U↔I** switch
- absolute (volts, amps) or relative (percentual) harmonic values expression using **V,A↔%** switch
- graphic and numeric representation using ↔**123** switch
- odd and event harmonics (at numeric format only) using **2-4-6↔1-3-5** switch

If current harmonics are displayed in numeric format and expressed in amperes, their values are extended with a sign. The sign indicates if a current phasor of appropriate harmonic is delayed after its voltage phasor (positive value) or if the current phasor foreruns the voltage one (negative value). This information can be useful for a harmonic distortion source location.

5.3.3.2 Average Values Evaluation

From measurement cycle values, average values of all basic quantities are calculated. Following parameters can be set to control the way of averaging :

- averaging method, which can be set to one of :
    - fixed window
    - floating window
- averaging period in range from 1 second to 1 hour

When **the fixed window** averaging is set, values are calculated from fixed block intervals. The values are updated at the end of every interval. Beginnings of the intervals are synchronized to the nearest whole time (for example, when averaging period is set to 15 minutes, the average values are updated four times per hour in xx:00, xx:15, xx:30 and xx:45).

When **the floating window** averaging method is applied, an exponential function simulation is used to get the thermal dependence. Unit step time response depends on the preset averaging period – during this period, an average value reaches about 90 % of unit step amplitude.

Average values processing can be set independently for two groups of quantities : so called **U/I** -group and **P/Q/S** -group. Following table lists processed quantities of both groups.

Tab. 5.2 : Average Values Groups

Average values group	Averaged quantities
“ U / I ”	U_{LL}, U_{LN}, I, f, analog input
“ P / Q / S ”	P, Q, S, PF, Pfh, Qfh, cosφ, ΔQfh, RC, RL

To display average values, while in actual data window press the button several times until 123.4 avg - option is selected. Average values are marked with a bar over quantity name (see below).

Fig. 5.10 : Average Data Processing Setting

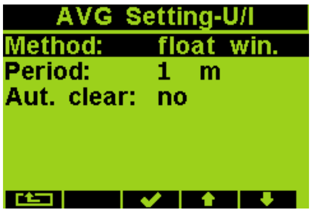
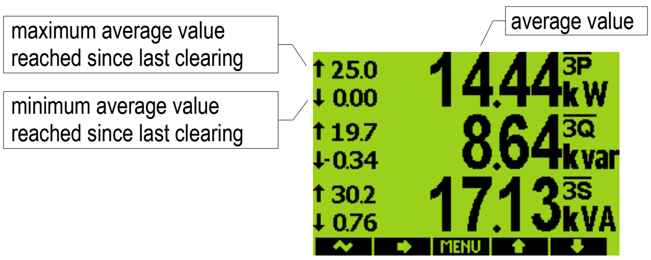


Fig. 5.11 : Average Data



5.3.3.2.1 Maximum and Minimum Average Values

Maximum and minimum values of average values are registered into the instrument's memory; in case of appropriate instrument models including the date & time of their occurrence.

Fig. 5.12 : Maximums of Average Values

The maximums&minimums are displayed on the left side of average values window - maximum value is identified with the ↑ symbol and minimum value with the ↓ symbol.

To view their time stamps, press the ► button until, for example **Max** is selected. Maximum average value window appears. On the left of each maximum value, its time stamp is displayed. The symbol ↑ after the time data means that the displayed value is maximum. You can display minimum average values in similar way.

The maximum and minimum registered values can be cleared either manually or -at the instrument models equipped with the RTC - automatic clearing can be set.

To clear the values manually, press the ► button until **Clear** option is selected. Then at the confirmation window press the ✓button.

To activate automatic clearing of maximums/minimums of average values, set the automatic clear period (the last option at window on Fig. 5.10).

Only the appropriate group (U/I or P/Q/S) of average maxs/mins is affected by single clearing ! Each group must be cleared or set individually

If the instrument is locked, resetting is not possible.

5.3.3.3 Recorded Values Aggregation

At models equipped with datalogging capability all of measured and evaluated data can be optionally archived into the instrument's memory. The record period is presetable in a wide range and aggregated data are archived.

The shortest aggregation interval is 1s while the longest configurable interval is 2 hours. If seconds are selected then intervals are aggregated according to cycle count at actual frequency. Intervals longer than one minute are aggregated according to a real time tick.

Where applicable not only the average value but minimum and maximum values over aggregation interval can be stored too.

5.3.4 Embedded Electricity Meter

For electric energy measurement, stand-alone unit – *electricity meter* - is implemented inside instruments. Energies are evaluated in compliance of the IEC 62053-24 standard : active energy from full harmonic spectrum and reactive energy from the fundamental harmonic component only.

Except of electric energy, maximum active power demands are registered in the unit.

5.3.4.1 Electric Energy Processing

Measured values of electrical energy are recorded separately in four quadrants : active energy consumed (**I**, import), active energy supplied (**E**, export), reactive energy inductive (**L**) and reactive energy capacitive (**C**). Both single-phase and three-phase energies are processed.

In addition at selected models, three-phase energies are evaluated in three preset tariff zones (time of use). The actual tariff can be controlled either by an actual RTC time using preset tariff zone table with one hour resolution or by an external signal through a digital input.

Internal energy counters have sufficient capacity in order not to overflow during the whole instrument lifetime. On the instrument's display only 9 digits can be viewed – therefore, after energy value exceeds 999999999 kWh/kvarh, instrument's display format automatically switches to MWh/Mvarh, then to GWh/Gvarh.

At selected models, electricity meter data can be periodically archived with a preset registering interval into the instruments memory and can be analysed later after being downloaded into a PC.

5.3.4.2 Maximum Demand Registration

From the instantaneous measured values of all active powers the instrument evaluates their average values per preset period using preset averaging method. In the electricity meter unit, such quantities are called *actual demands* (**AD**). Note that the actual demands are processed individually and their averaging period is presetable independently on standard average values ($\mathbf{P_{AVG}}$).

Their maximum values reached since the last clearing are called *maximum demands* (**MD**).

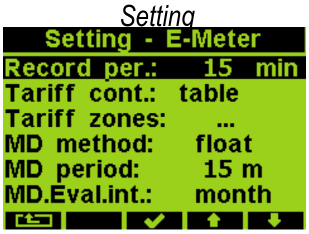
The AD values are not displayed on the instrument display – only their registered three-phase maximums **3MD** are.

The total maximums can be cleared independently of standard average maximums/minimums.

5.3.4.3 Setting

Main parameters determining electricity meter unit function can be set manually. By selecting appropriate icon a **Setting – Elmeter** window appears. **Record period** is an automated meter reading interval that defines how often the electricity meter state is stored into the memory (at selected models only). The electricity meter history can be later downloaded into a PC and analysed.

Fig. 5.14 : Electricity Meter Setting



Actual tariff can be controlled either by actual local time using the *tariff zones table* or by a digital input. In case of **table** selection, a day long timetable for 3 different tariff selections with hourly resolution can be defined.

In case of **digital input** selection, the digital input specifies actual tariff – open state means tariff 1, closed state tariff 2. Tariff 3 is not used at this case.

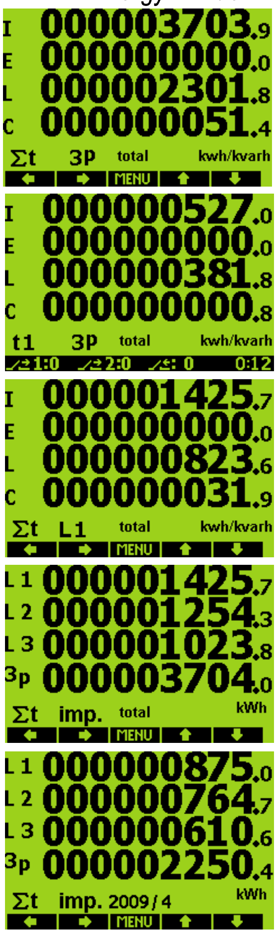
Tariff zones table can opened and set by selection of **Tariff zones** option.

Next, electricity meter group power demand (AD, Actual Demand) **averaging parameters** can be specified. With **the evaluation interval of maximum demand**, the period of maximum demand (MD) registration in range 1 day up to 1 year can be set (see $3MD_{CX}$, $3MD_{LX}$ presentation below).

5.3.4.4 Energy Presentation

Electricity meter energy data are situated in a separated window, which is accessible via the main menu.

Fig. 5.15 : Electricity Meter – Energy Window



As default actual three-phase (**3p**) energies registered since last clearing up to now (**total**) for all tariff zones (**Σt**) appear : imported active energy (**I**), exported active energy (**E**), imported reactive energy (= inductive, **L**) and exported reactive energy (capacitive, **C**), as shown on the uppermost screen at left.

With the ◄ button outline of registered energies for individual tariff zones can be listed (2nd screen).

With the ► button, single-phase energies can be displayed using **1p** ↔ **3p** toggle switch (3rd screen). In this case you can select energies of individual phases L1, L2, L3 with the ◄ button or display overview of both single-phase energies and three-phase energy in specified quadrant, for example imported active energies with **Active-Import** option, as shown on the 4th screen.

Besides the total energies (that means energy values registered since last clearing up till now), state of registered values at the end of previous month can be viewed with **Act.**↔ **Last Month** toggle switch of the ► button (5th screen). The last month window is indicated by the month specification, for example **2009/4** , which means March of year 2009.

Finally, registered energies can be recalculated using preset tariff rates to money values in Euros with **kWh**↔**EUR** toggle switch.

Tariff zones and appropriate Euro tariff rates can be set via a communication link using a PC with ENVIS program.

Energy counters can be cleared either manually or with a remote PC. Manual clearing can be invoked with the ► button by **Clear** option and confirmed with the ✓button.

5.3.4.5 Maximum Demand Presentation

While in the electricity meter energy window you can switch to the maximum active power demand window with the ▼ or ▲ button.

Fig. 5.16 : Maximum Demand Window

Only three-phase maximums with their time stamps are displayed. In the first row there is total maximum demand **3MD**, i.e. maximum of the 3AD reached since last maximum clearing. You can check this clearing time with the ► button – by **Clear** option selection, the clearing confirmation window appears and last maximum power demand clear time and current averaging parameters setting can be checked. If you don't want to clear the registered maximums , push the ✖button, otherwise the ✓ button.

In the 2nd row there is maximum of the 3AD reached during the last evaluation interval – $\mathbf{3MD_{LX}}$ (L=last). The "X"-index depends on the evaluation interval preset value : D=day, W=week, M=month, Q=quarter, Y=year. In the 3rd row there is maximum of the 3AD reached during just passing evaluation interval : $\mathbf{3MD_{CX}}$ (C=current).

The last two values are available at instrument equipped with an RTC only.

The entire information, including phase values of both AD and MD, can be obtained from a PC with ENVIS program.

5.3.5 Inputs

Depending on the model type, instruments can be equipped with :

- one digital input
- one Pt100 temperature sensor input (Te)

The digital input can be used for :

- state monitoring
- time synchronization
- electricity meter tariff control
- tariff control in the PFC block

In case the digital input is used for time synchronization, *clock setting* parameters need to be set properly – see *Clock setting* chapter.

In case the digital input is used for the electricity meter tariff control, follow the *Electricity Meter Setting* chapter instructions.

6. Computer Controlled Operation

Monitoring the currently measured values and the instrument setup can be done not only on the instrument panel but also using a local or remote computer connected to the instrument via a communication link. Such an operation is more comfortable, and it also allows you to use all the options of the instrument, such as adjusting the inputs/outputs or setup and the monitoring of courses recorded into the internal memory of the instrument, which it is not possible from the panel of the instrument.

Following chapters describe instrument communication links from the hardware point of view and embedded webserver only. The detailed description of ENVIS program can be found in the program manual.

6.1 Communication Links

6.1.1 Local Communication Link

Instruments can be equipped with a serial interface USB 2.0, on the front panel. Using this interface, adjusting the parameters of the instrument and the transmission of data into a portable computer can be accomplished. It requires to interconnect the instrument with the PC using the appropriate communication cable (type USB-A, see optional accessory list).

Considering the fact that the instruments can be also equipped with a remote communication link, the described communication link is called *Local*.

6.1.2 Remote Communication Links

The instruments may be optionally equipped with the remote communication link for operation of the instrument via a remote computer. Subsequently, this computer can execute a remote adjusting of the instrument and transmission of current or recorded data.

The type of interface can be either RS-485 or Ethernet. Appropriate connector is situated at the rear panel. It is supposed the cable for remote communication link to be provided by customer.

One or more instruments can be connected to the remote PC via this link. Each instrument must have an adjusted proper remote communication address and protocol. These specifications can be set manually or by the computer via a local communication link in ENVIS program.

The remote communication link is always isolated from the internal circuits of the instrument.

Selected models can be equipped with the second communication link RS-485.

6.1.3 RS-485 Interface (COM)

Up to 32 instruments at a maximum distance of 1,200 metres can be connected to this interface. Used signals : **A+** , **B-** , **G** , and optionally **A2+** , **B2-**, **G2** .

Each instrument must have a different communication address within the range of 1 to 253 preset during the installation.

A 232/485 or USB/485 level converter connected to a standard serial port must be installed on the computer side. The converter must provide an automatic communication flow direction switching function. For suitable converters see optional accessory list.

Tab. 6.1 : RS-485 Remote Communication Links Wiring

COM1 interface		COM2 interface	
signal	terminal No.	signal	terminal No.
A	41	A2	44
B	42	B2	45
G	43	G2	46

Both of the links are insulated both from the instrument internal circuitry and mutually too, terminals No. 43 and 46 *are not connected internally !*

6.1.3.1 Communication Cable

For common applications (cable length up to 100 metres, communication rate up to 9,600 Bd) the selection of the right cable is not crucial. It is practically possible to use any shielded cable with two pairs of wires and to connect the shielding with the Protective Earth wire in a single point.

With cable lengths over 100 metres or with communication rates over 20 kilobits per second, it is convenient to use a special shielded communication cable with twisted pairs and a defined wave impedance (usually about 100 Ohm).Use one pair for the **A+** and **B-** signals and the second pair for the **G** signal.

6.1.3.2 Terminating Resistors

The RS-485 interface requires impedance termination of the final nodes by installation of terminating resistors, especially at high communication rates and long distances. Terminating resistors are only installed on the final points of the link (for example one on the PC and another on the remotest instrument). They are connected between terminals **A+** and **B-**. Typical value of the terminating resistor is 120 Ohm.

6.1.4 Ethernet (IEEE802.3) Interface

Using this interface the instruments can be connected directly to the local computer network (LAN). Instruments with this interface are equipped with a corresponding connector RJ- 45 with eight signals (in accordance with ISO 8877), a physical layer corresponds to 100 BASE-T.

Type and maximum length of the required cable must respond to IEEE 802.3.

Each instrument must have a different IP- address, preset during the installation. The address can be set from the instrument panel or you can use the ENVIS-DAQ program. For detection of actual IP-address you can use *the Locator* function.

Furthermore, you can set the DHCP function for dynamic IP-address allocation.

6.2 Communication Protocols

The remote communication link parameters must be set according chapter *Remote Communication Setting* - see above.

6.2.1 KMB Communications Protocol

This manufacturer proprietary protocol is used for communication with ENVIS program. Number od data bits must be set to 8.

6.2.2 Modbus-RTU Communications Protocol

For the chance of easier integration of the instrument to the user's program, the instrument is also equipped with the Modbus - RTU communications protocol. A detailed description of the communications records can be found in an appropriate manual.

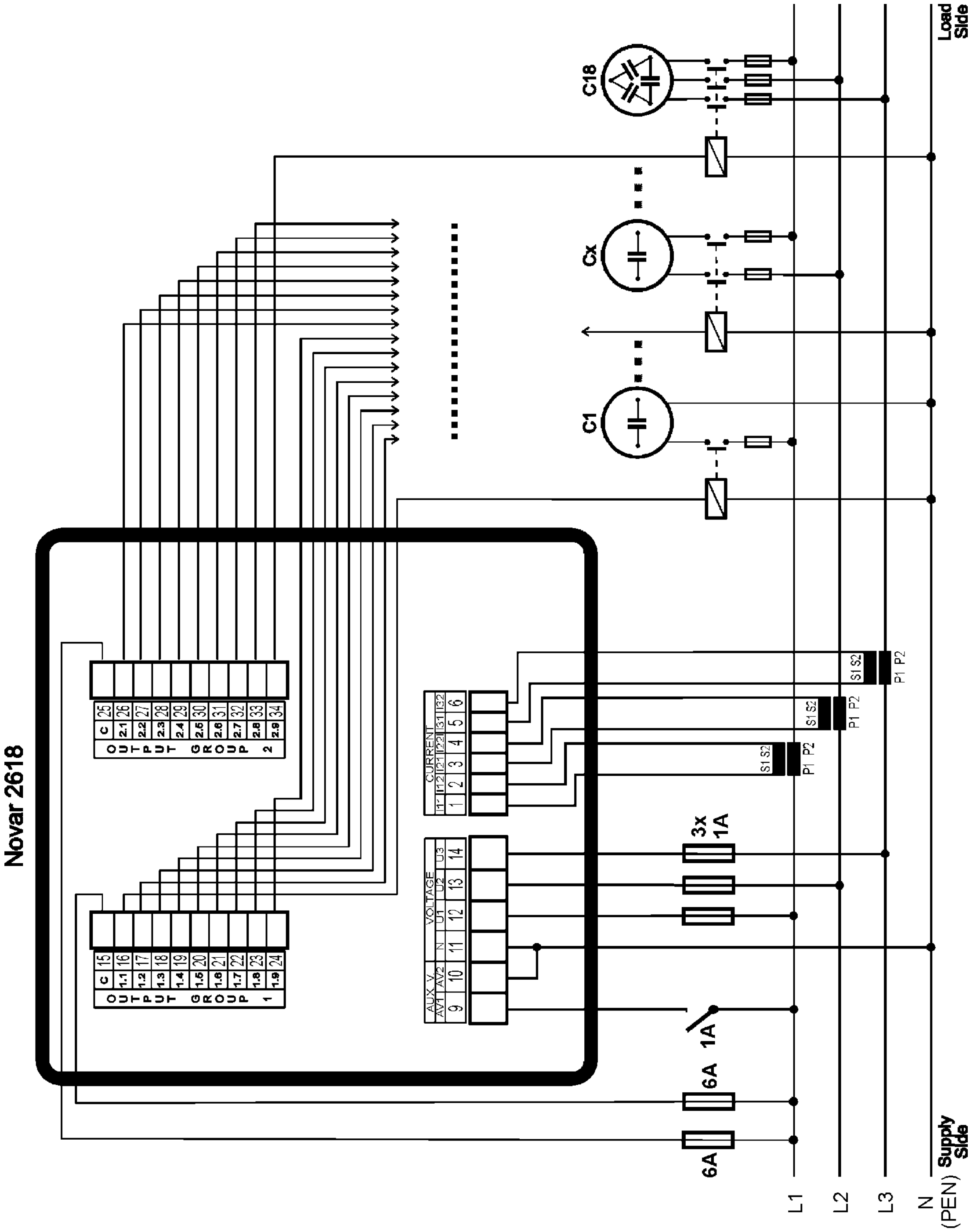
6.3 Embedded Webserver

All of instruments with Ethernet remote communication interface are equipped with an embedded webserver, thus both all of main measured values and the instrument setting can be viewed with a standard web browser. It requires to set properly the instrument remote communication parameters and to connect it to the network. Then in the web browser enter appropriate IP-address of the instrument and information from the instrument appears as shown on Fig. 6.1.

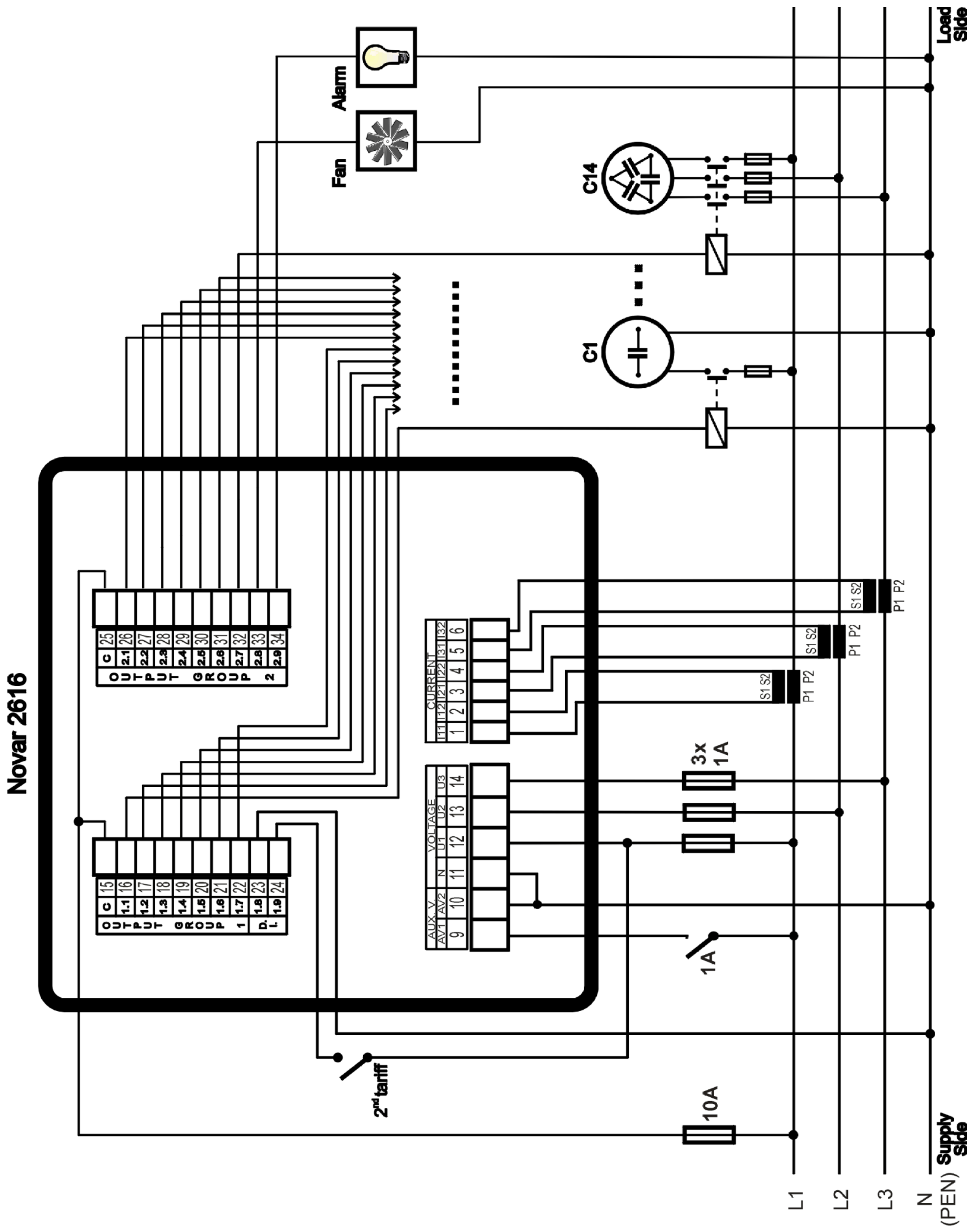
Fig. 6.1.: Webserver

7. Examples of Connections

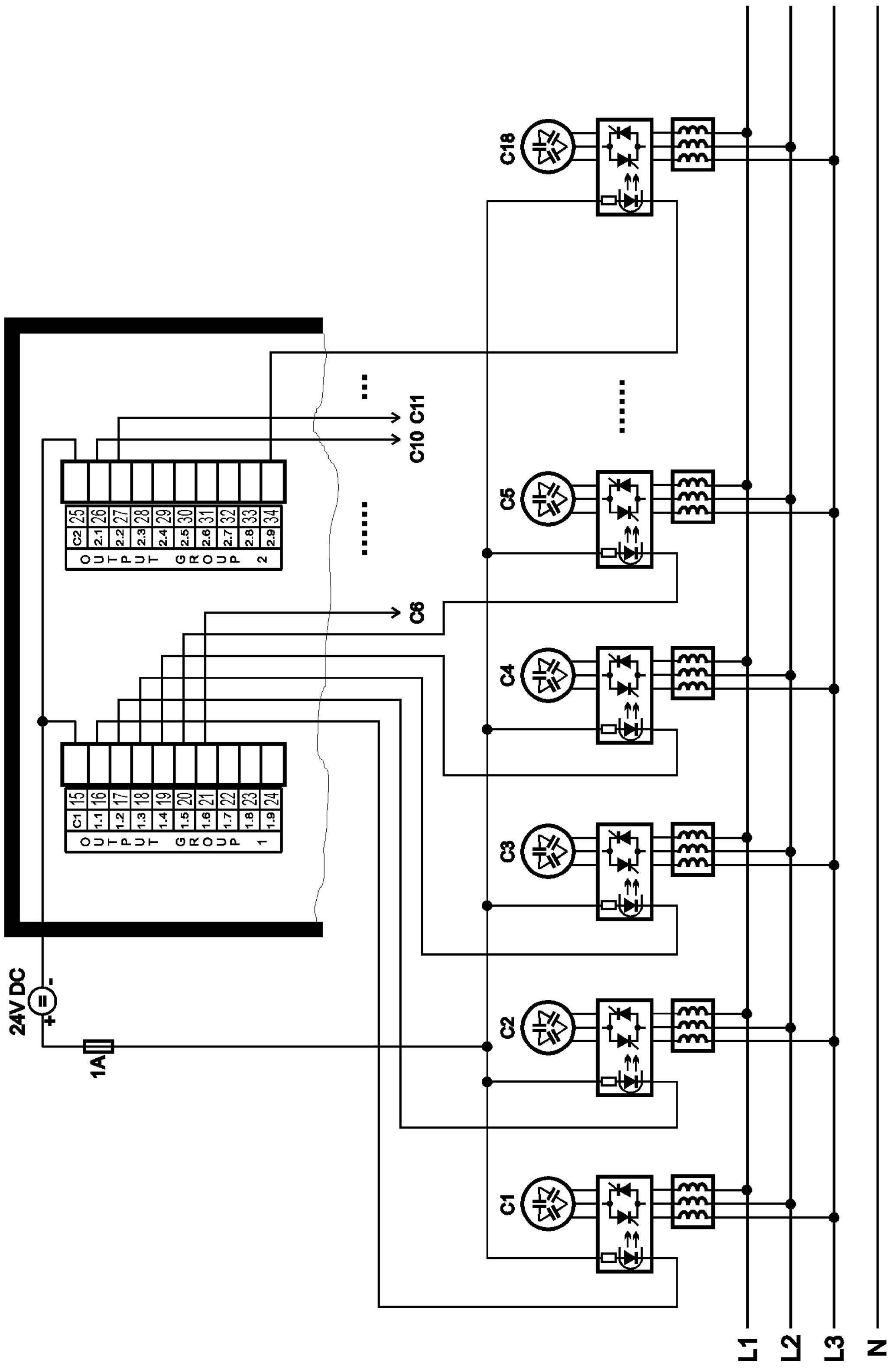
NOVAR 2600 Typical Installation
TN-Network, Direct Star ("3Y") Connection
18 Contactor Sections



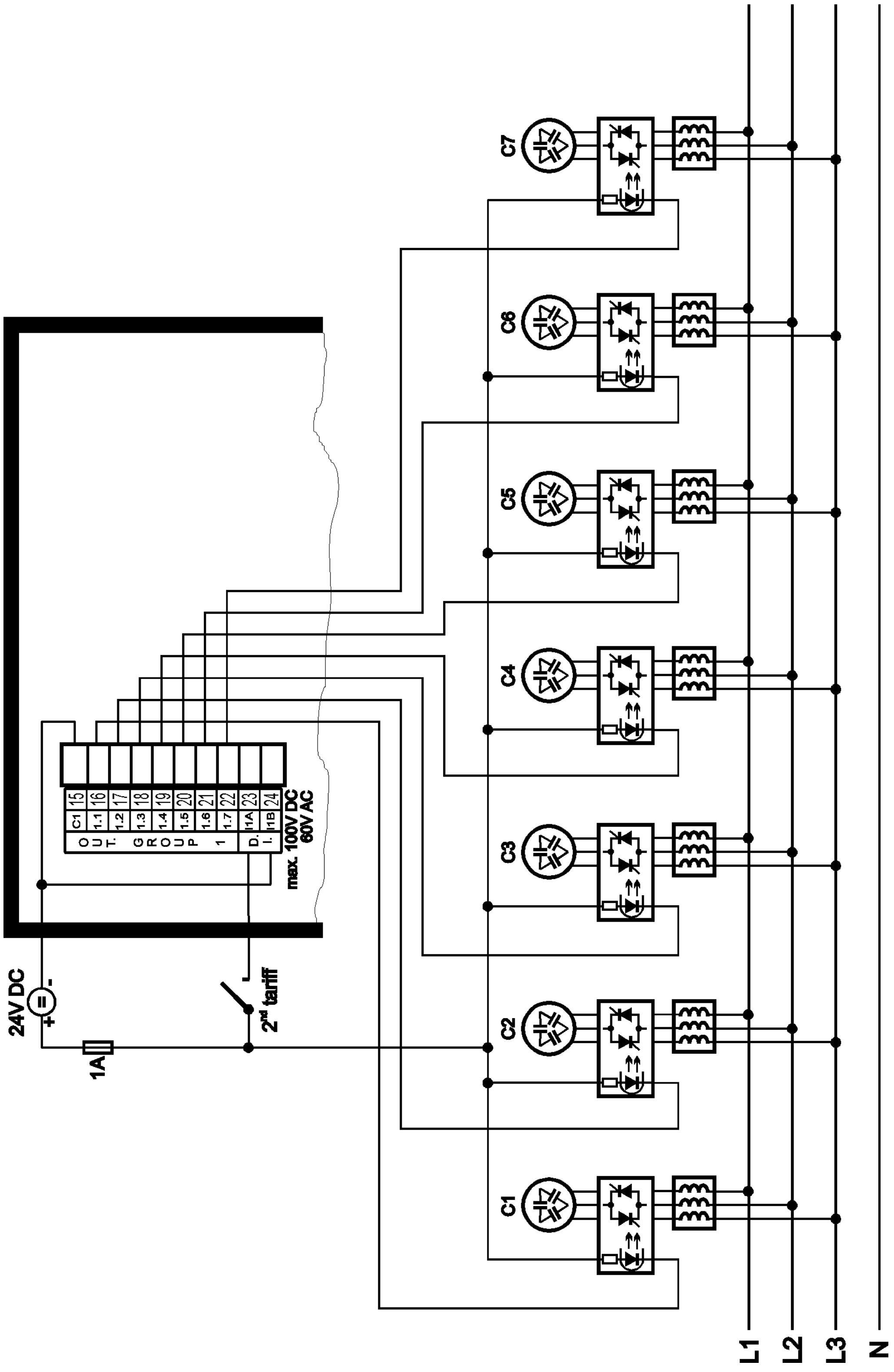
NOVAR 2600 R16 Typical Installation
TN-Network, Direct Star (“3Y”) Connection
14 Contactor Sections
2nd Tariff Control, Fan, Alarm



NOVAR 2600 T18 – Typical Installation



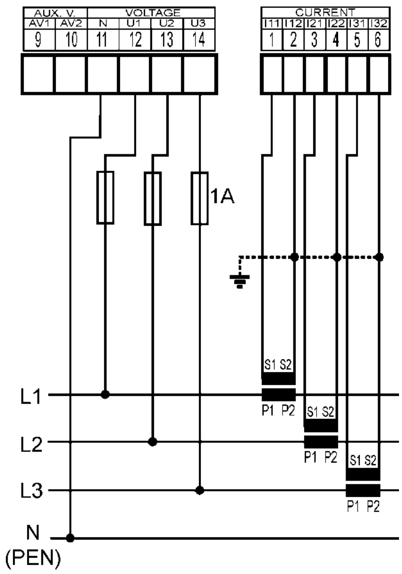
NOVAR 2600 T7 – Typical Installation



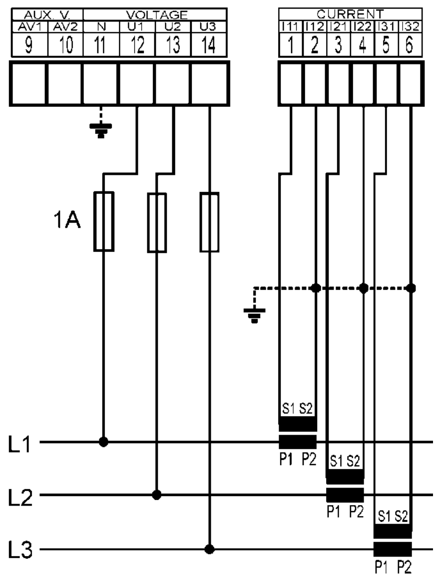
NOVAR 2600 – Measured Signal Connection Examples

Three-Phase Connections

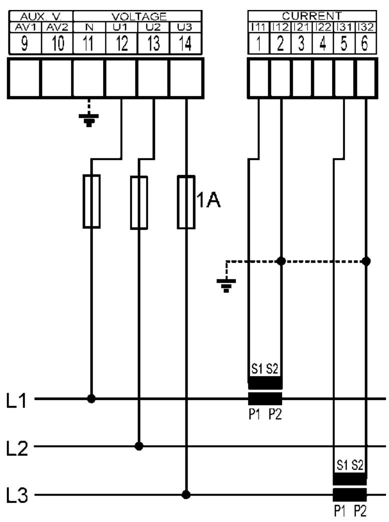
TN Network
Direct Star (“3Y”) Connection



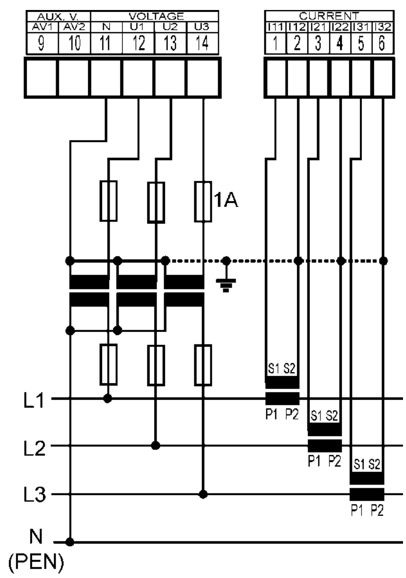
IT Network
Direct Delta (“3D”) Connection



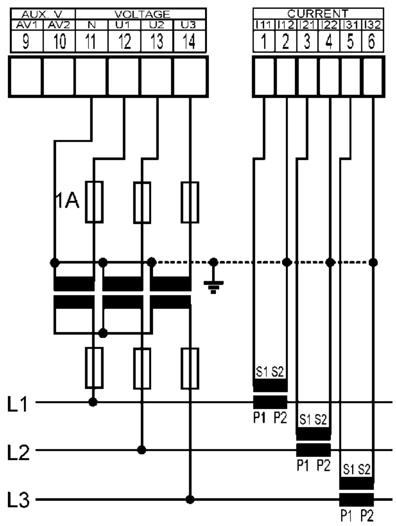
IT Network
Direct Aron (“3A”) Connection



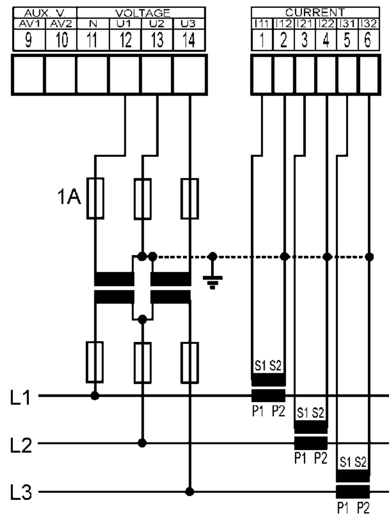
TN Network
Star (“3Y”) Connection via VT



IT Network
Delta ("3D") Connection via VT
(VT to Line-to-Neutral Primary Voltage)

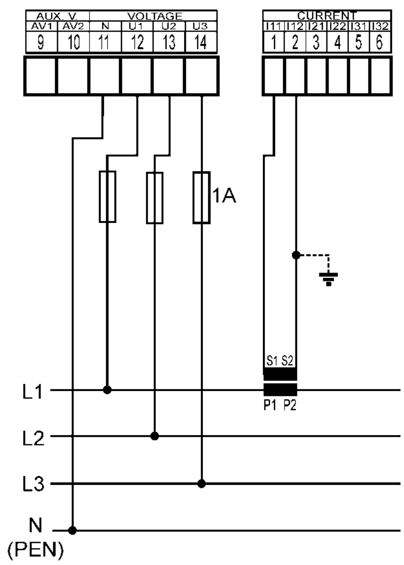


IT Network
Delta ("3D") Connection via VT
(VT to Line-to-Line Primary Voltage)

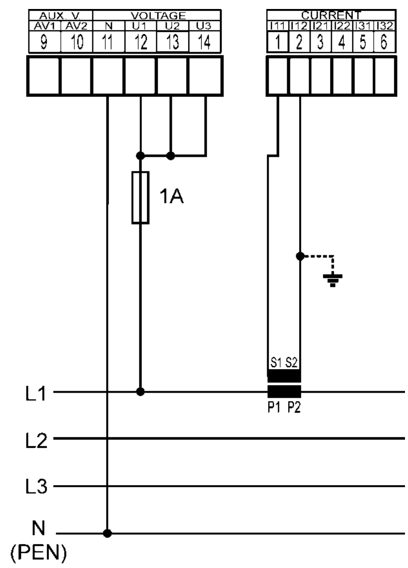


Single-Phase Connections to Three-Phase Networks

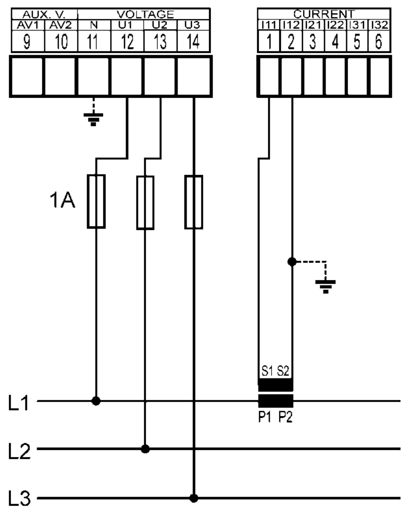
TN Network
1Y3 Connection Type
(recommended wiring)



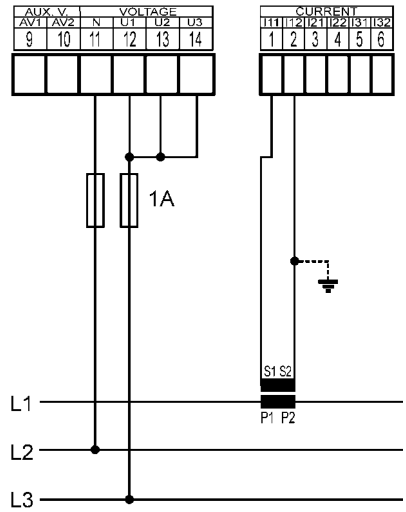
TN Network
1Y3 Connection Type



IT Network
1Y3 Connection Type

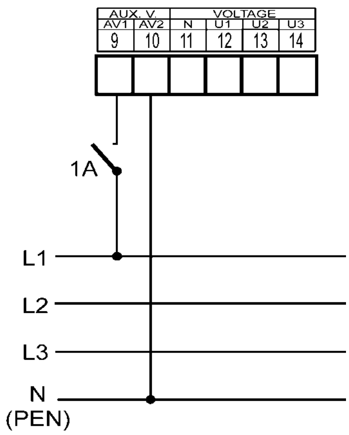


IT Network
1D3 Connection Type

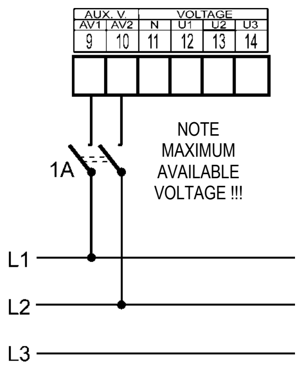


NOVAR 2600 – Power Supply Options

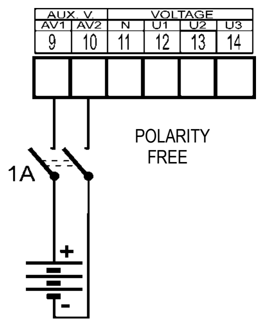
Line-to-Neutral Voltage
AC Power Supply



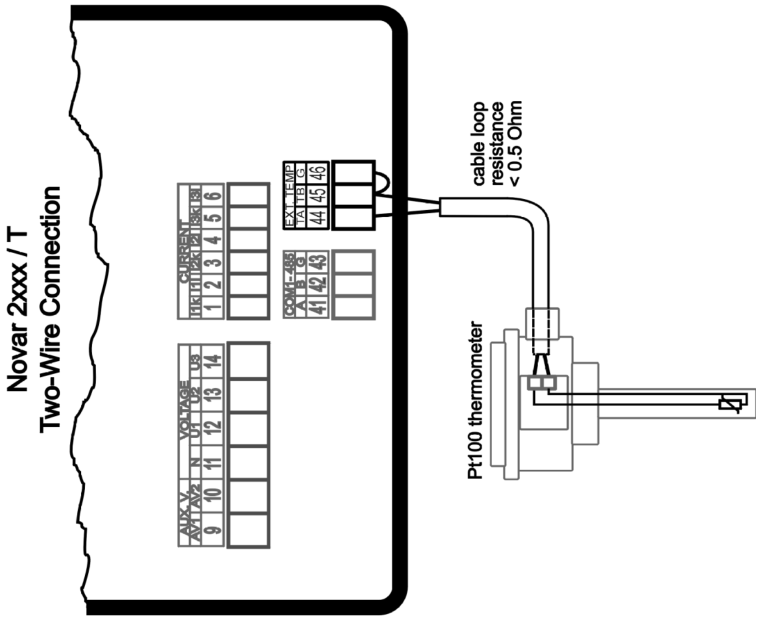
Line-to-Line Voltage
AC Power Supply

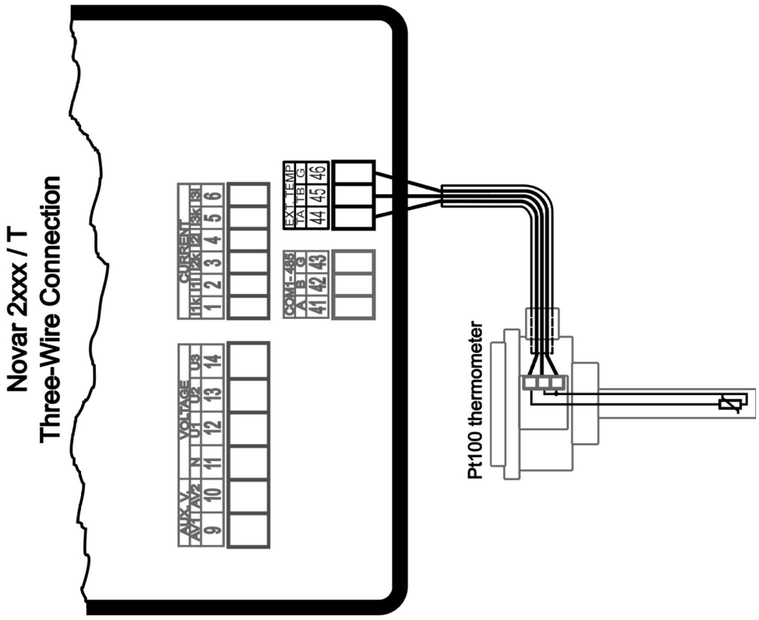


DC Power Supply

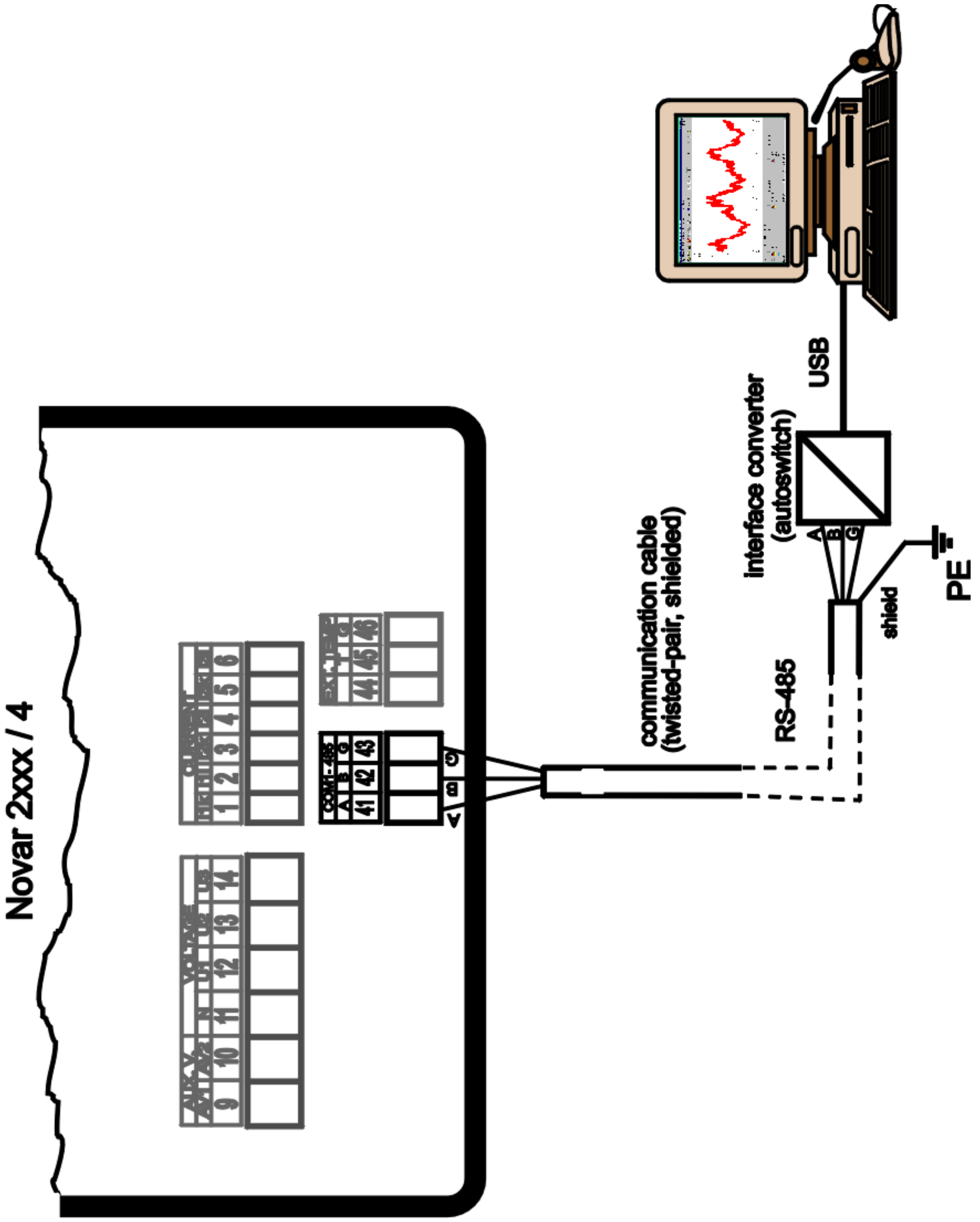


NOVAR 2600 T – External Temperature Sensor Connection





NOVAR 2600 4 – RS485 Remote Communication Connection



8. Manufactured Models and Marking

NOVAR 2600 R18 N L U 4T

Instrument class

NOVAR 2600 = 3-ph automatic PF controller, 144×144mm, LCD

Outputs

R09 = 9 relay outputs
R16 = 16 relay outputs + 1 digital input
R18 = 18 relay outputs
T18 = 18 transistor outputs

Relay Voltage Rating

N = max. 250 VAC
H = max. 400 VAC / 220 VDC

Data logging

N = max. & min. values registering, electricity meter readout
L = programable datalogging, 512MB of internal memory

Local communication interface

U = USB communication interface

Remote communication interface and ext. thermometer input

N = USB
4 = USB, RS-485
4T = USB, RS-485, Pt100 external thermometer input
E = USB, Ethernet
E4 = USB, Ethernet, RS-485
ET = USB, Ethernet, Pt100 external thermometer input

9. Technical Specifications

Auxiliary Voltage	
nominal aux. voltage range	100 ÷ 415 V_{AC} / 40 ÷ 100 Hz or 100 ÷ 500 V_{DC}, polarity free
aux. voltage range	75 ÷ 500 V_{AC} / 40 ÷ 100 Hz or 90 ÷ 600 V_{DC}, polarity free
power	20 VA / 8 W
overvoltage cathegory for voltage up to 300V_{AC} for voltage over 300V_{AC}	 III II
pollution degree	2
connection	isolated, polarity free

Measured Quantities	
Frequency	
f_{NOM}– nominal frequency	50 / 60 Hz
measuring range	40 ÷ 70 Hz
measuring uncertainty	± 10 mHz
Voltage	
measuring range U_{L-N}	10 ÷ 625 V_{AC}
measuring range U_{L-L}	20 ÷ 1090 V_{AC}
measuring uncertainty (t_A=23±2°C)	+/- 0.05 % of rdg +/- 0.02 % of rng
temperature drift	+/- 0.03 % of rdg +/- 0.01 % of rng / 10 °C
measurement category	300V CAT III 600V CATII
permanent overload	1000 V_{AC}
peak overload (U_{L-N} / 1 sec.)	2000 V_{AC}
burden power, impedance	< 0.05 VA Ri = 6 MΩ
Voltage Unbalance	
measuring range	0 ÷ 10 %
measuring uncertainty	± 0.3
Harmonics & Interharmonics (up to 50thorder)	
reference conditions	other harmonics up to 200 % of class 3 acc. to IEC 61000–2-4 ed.2
measuring range	10 ÷ 100 % of class 3 acc. to IEC 61000–2-4 ed.2
measuring uncertainty	twice the levels of class II acc. to IEC 61000–4-7 ed.2
THDU	
measuring range	0 ÷ 20 %
measuring uncertainty	± 0.5

Measured Quantities	
Current	
measuring range	0.005 ÷ 7 A_{AC}
meas. uncertainty (t_A=23±2°C)	+/- 0.05 % of rdg +/- 0.02 % of rng
temperature drift	+/- 0.03 % of rdg +/- 0.01 % of rng / 10 °C
measurement category	150V CAT III
permanent overload	7.5 A_{AC}
peak overload - for 1 second, max. repetition frequency > 5 minutes	70 A_{AC}
burden power (impedance)	< 0.5 VA (Ri < 10 mΩ)
Current Unbalance	
measuring range	0 ÷ 100 %
measuring uncertainty	± 1 % of rdg or ± 0.5
Harmonics & Interharmonics (up to 50th order)	
reference conditions	other harm. up to 1000 % of class 3 acc. to IEC 61000–2-4 ed.2
measuring range	500 % of class 3 acc. to IEC 61000–2-4 ed.2
measuring uncertainty	Ih <= 10% I_{NOM} : ± 1% I_{NOM} Ih > 10% I_{NOM} : ± 1% of rdg
THDI	
measuring range	0 ÷ 200 %
measuring uncertainty	THDI <= 100% : ± 0.6 THDI > 100% : ± 0.6 % of rdg

Measured Quantities - Temperature	
T_I - (internal sensor, measured value affected by the instrument power dissipation)	
measuring range	- 40 ÷ 80°C
measurement uncertainty	± 2 ºC
T_E – External Pt100 Temperature Sensor Input (optional, alternatively with communication interface COM2)	
measuring range	- 50 ÷ 150 º
measurement uncertainty	± 2 ºC (three-wire connection)

Measured Quantities – Power, Power Factor, Energy	
Active / Reactive Power, Power Factor (PF), cos φ ($P_{NOM} = U_{NOM} \times I_{NOM}$)	
reference conditions "A" : ambient temperature (t_A) U, I for active power, PF, cos φ for reactive power	 23 ± 2 °C U = 80 ÷ 120 % U_{NOM}, I = 1 ÷ 120 % I_{NOM} PF = 1.00 PF = 0.00
act. / react. power uncertainty	± 0.5 % of rdg ± 0.005 % P_{NOM}
PF & cos φ uncertainty	± 0.005
reference conditions "B" : ambient temperature (t_A) U, I for active power, PF, cos φ for reactive powe	 23 ± 2 °C U = 80 ÷ 120 % U_{NOM}, I = 1 ÷ 120 % I_{NOM} PF <= 0.87 PF <= 0.87
act. / react. power uncertainty	± 1 % of rdg ± 0.01 % P_{NOM}
PF & cos φ uncertainty	± 0.005
temperature drift of powers	+/- 0.05 % od rgd +/- 0.02 % P_{NOM} / 10 °C
Energy	
measuring range	corresponds to U & I measuring ranges 4 quadrant energy counters for both active and reactive energies
active energy uncertainty	class 0.5S acc. to EN 62053 – 22
reactive energy uncertainty	class 1S acc. to EN 62053 – 24

Function Characteristics according to IEC 61557-12
U_{NOM} = 300 ÷ 415 $V_{STŘ}$, I_{NOM} = 5 A

Symbol	Function	Class	Measuring range	Notes
P	total effective power	0.5	0 ÷ (21.6 * U_{NOM}) W	
Q_A, Q_V	total reactive power	1	0 ÷ (21.6 * U_{NOM}) var	
S_A, S_V	total apparent power	0.5	0 ÷ (21.6 * U_{NOM}) VA	
E_a	total active energy	0.5	0 ÷ (21.6 * U_{NOM}) Wh	
E_{rA}, E_{rV}	total reactive energy	2	0 ÷ (21.6 * U_{NOM}) varh	
E_{apA}, E_{apV}	total apparent energy	0.5	0 ÷ (21.6 * U_{NOM}) VAh	
f	frequency	0.05	40 ÷ 70 Hz	
I	phase current	0.5	0.005 ÷ 6 A_{AC}	
I_N	neutral current measured	–	–	
I_{Nc}	neutral current calculated	0.5	0.005 ÷ 18 A_{AC}	
U_{LN}	line-to-neutral voltage	0.5	0.2 ÷ 1.2 * U_{NOM}	
U_{LL}	line-to-line voltage	0.5	0.2 ÷ 1.2 * U_{NOM} * v3	
PF_A, PF_V	power factor	0.5	0 ÷ 1	
P_{st}, P_{lt}	flicker	5	0.4 ÷ 10	1, 2)
U_{dip}	voltage dips	0.5	0.05 ÷ 1 * U_{NOM}	2)
U_{swl}	voltage swells	0.5	1 ÷ 1.2 * U_{NOM}	2)
U_{tr}	transients overvoltage	–	–	
U_{int}	voltage interruption	1	0 ÷ 0.05 * U_{NOM}	2)
U_{nba}	voltage unbalance (amp.)	0.5	0 ÷ 10 %	4)
U_{nb}	voltage unbalance (ph.&amp.)	0.5	0 ÷ 10 %	
U_h	voltage harmonics	2	up to 50^{th} order	1)
THD_u	voltage total harm. distortion (rel. to fund.)	2	0 ÷ 20 %	1)
$THD\text{-}R_u$	voltage total harm. distortion (rel. to RMS)	2	0 ÷ 20 %	1, 4)
I_h	current harmonics	2	up to 50^{th} order	1)
THD_i	current total harm. distortion (rel. to fund.)	2	0 ÷ 200 %	1)
$THD\text{-}R_i$	voltage total harm. distortion (rel. to RMS)	2	0 ÷ 200 %	1,4)
M_{SV}	mains signalling voltage	2	0 ÷ 0.2 * U_{NOM} f_{Msv} : 100 ÷ 3000 Hz	1, 3)

Notes : 1) …according to IEC 61000-4-7 ed.2
2) … with optional firmware module „PQ S“
3) … with optional firmware module „RCS“
4) … value available via communication link only, not displayed

Instrument Characteristics according to IEC 61557-12	
power quality assessment function	PQI-S
classification according to par. 4.3 direct voltage connection voltage connection via VT	 SD SS
temperature according to par. 4.5.2.2	K55
humidity + altitude according to par. 4.5.2.3	< 95 % - noncondensation conditions < 3000 m
active power/energy function performance class	0.5

Outputs & Digital Input		
Relays („R“-output type models)		
type	N.O. contact	
load rating standard models	$250\ V_{AC}$ / 4 A	
“H” models	$250\ V_{AC}$ / 4 A $110\ V_{DC}$ / 0.5 A $220\ V_{DC}$ / 0.2 A	
Transistors („T“-output type models)		
type	Opto-MOS	
load rating	max. $100\ V_{DC}$ / 100 mA	
Digital Input		
	„R“-output type models	„T“-output type models
type	optoisolated, bipolar	
maximum voltage	$265\ V_{AC}$ ($460\ V_{AC}$ for overvolt. cat. II)	$80\ V_{DC}$ / $50\ V_{AC}$
voltage for “logical 0“ / “logical 1“	<= $30\ V_{AC}$ / >= $90\ V_{AC}$	< $3\ V_{DC}$ / > $10\ V_{DC}$
input power (impedance)	< 0.4 VA (Ri = 200 kΩ)	1 mA @ 10V / 5 mA @ 24V / 10 mA @ 48V

Other Specifications	
instrument classification	class B in compliance with IEC 61000-4-30 ed. 2
meas. voltage loss & external alarm response time (output disconnect.)	<= 20 ms
operational temperature :	- 20 to 60°C
storage temperature	- 40 to 80°C
operational and storage humidity	< 95 % - non-condensable environment
EMC – immunity	EN 61000 – 4 - 2 (4kV / 8kV) EN 61000 – 4 - 3 (10 V/m up to 1 GHz) EN 61000 – 4 - 4 (2 kV) EN 61000 – 4 - 5 (2 kV) EN 61000 – 4 - 6 (3 V) EN 61000 – 4 - 11 (5 periods)
EMC – emissions	EN 55011, class A EN 55022, class A (not for home use)
RTC (option) accuracy backup battery capacity	 +/- 2 seconds per day > 5 years (without supply voltage applied)
local communication port (option)	USB 2.0
remote comm. port No. 1 (option)	RS-485 / 2400÷460800 Bd / protocols KMB, Modbus-RTU or Ethernet 100 Base-T / DHCP, webserver, Modbus-TCP
remote comm. port No. 2 (option, alternatively with external temperature sensor input)	RS-485 / 2400÷460800 Bd / protocols KMB, Modbus-RTU
display	backlit LCD, graphic, 240 x 160 pixels
protection class front panel back panel	 IP 40 (IP 54 with cover sheeting) IP 20
dimensions front panel built-in depth installation cutout	 144 x 144 mm 80 mm 138^{+1} x 138^{+1} mm
mass	max. 0.8 kg

10. Maintenance, Service

The NOVAR 2600 instruments do not require any maintenance in their operation. For reliable operation it is only necessary to meet the operating conditions specified and not expose the instrument to violent handling and contact with water or chemicals which could cause mechanical damage.

In selected models, the built–in CR2450 lithium cell can backup the memory and real time circuit for more than 5 years without power supply, at average temperature 20°C and load current in the instrument less than 10 µA. If the cell is empty, it is necessary to ship the instrument to the manufacturer for battery replacement.

In the case of failure or a breakdown of the product, you should contact the supplier at their address:

Supplier :

Manufacturer :

KMB systems, s.r.o.

Dr. M. Horákové 559

460 06 LIBEREC 7

Czech Republic

Phone+420 485 130 314

Fax +420 482 736 896

E-mail: kmb@kmb.cz

Website: www.kmbsystems.eu

The product must be in proper packaging to prevent damage during transit. A description of the problem or its symptoms must be delivered together with the product.

If a warranty repair is claimed, the warranty certificate must be sent in. In case of an out-of-warranty repair you have to enclose an order for the repair.

Warranty Certificate

Warranty period of 24 months from the date of purchase is provided for the instrument, however, no longer than 30 months from the day of dispatch from the manufacturer. Problems in the warranty period, provably because of faulty workmanship, design or inconvenient material, will be repaired free of charge by the manufacturer or an authorized servicing organization.

The warranty ceases even within the warranty period if the user makes unauthorized modifications or changes to the instrument, connects it to out-of-range quantities, if the instrument is damaged due to ineligible or improper handling by the user, or when it is operated in contradiction with the technical specifications presented.

Type of product: **NOVAR**..............................

Serial number...

Date of dispatch: ....

Final quality inspection: ....

Manufacturer’s seal:

Date of purchase: ....

Supplier’s seal: