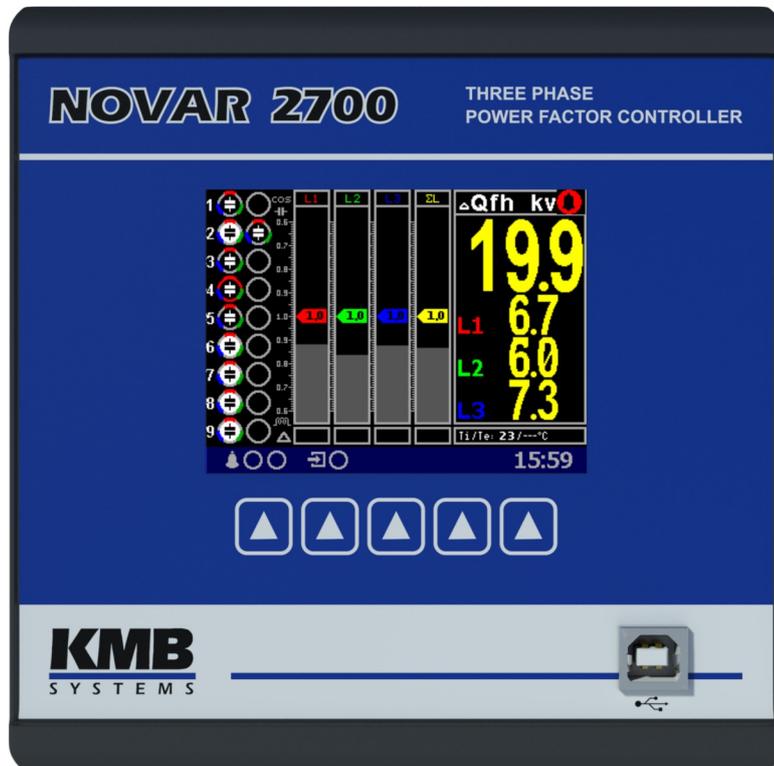


# NOVAR 2700

## Three-Phase Power Factor Controllers & Power Analyzers

### *Operating Manual*

Document revision	Release date	Valid for versions			
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# 1. General

This manual comprises description of NOVAR 2700 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 : either three- and single-phase control or three-phase control only
- up to 24 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 )
- grid support

### 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 288 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 128<sup>th</sup>/120<sup>th</sup>
- 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-TFT colour graphic display, 5 keys
- digital input
- optional input for external Pt100 temperature sensor

### Communication ( Selected Models Only )

- USB 2.0 communication port for fast data acquisition, configuration and firmware upgrades
- optional remote communication interface (RS 485 / Ethernet)
- 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 )

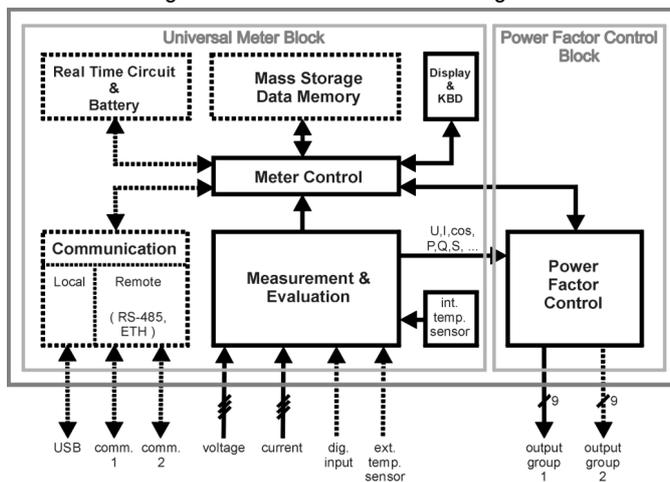
- battery backed real time circuit (RTC)
- selection of aggregation intervals from 1 second up to 24 hours
- high memory capacity for programmable recording of aggregated measurement values
- automated electricity meter readings at preselected time intervals

## 1.2 Operation

From point of view of function the NOVAR 2700 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.

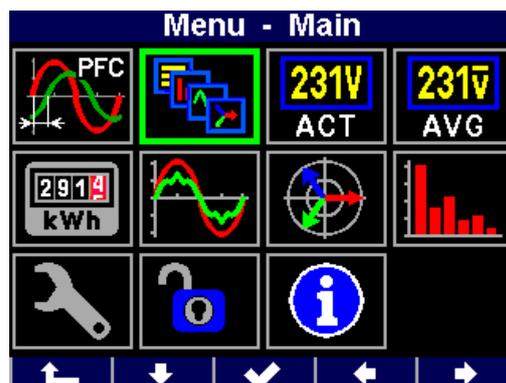
Fig. 1.1: NOVAR 2700 Block Diagram



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 2700 Display – Main Menu



## 2. Installation

This device is Group 1 and Class A according to EN 55011 (CISPR 11):

- Group 1: The device generates or uses radio frequency energy that is necessary for the internal function of the device itself.
- Class A: The device is suitable for use in all establishments other than domestic and those directly connected to a low-voltage power supply network that supplies buildings used for domestic purposes. There may be potential difficulties in ensuring electromagnetic compatibility in other environments due to conducted and radiated disturbances.

**WARNING:** This device is not intended for use in residential environments and may not provide adequate protection for radio reception in such environments (EN 55011, Ch. 5).

### 2.1 Meaning of the symbols used on instrument



Warning – read operating manual !



AC – alternating voltage



DC – direct voltage



CE marking guarantees compliance with the European directives and regulations



The instrument must not be disposed of in the normal unsorted municipal waste stream



Basic insulation instrument (protection class I)

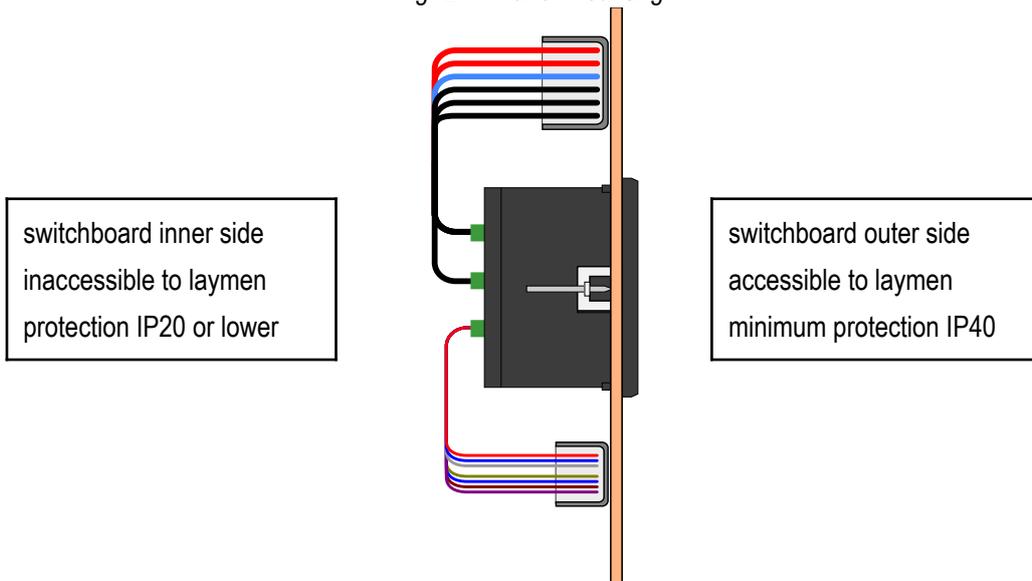


Double or reinforced insulation instrument (protection class II)

### 2.2 Physical

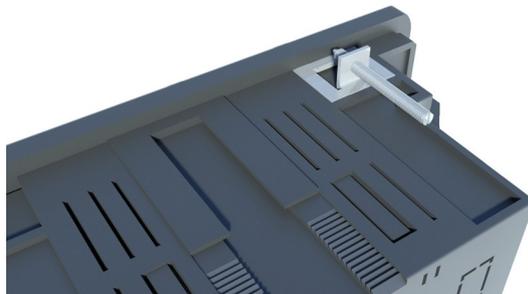
The instrument is built in a plastic box to be installed in a distribution board panel. As a rule, the panel is a part of a switchboard door - then the installation must be such that the switchboard door can be closed under all conditions of use. In any case, it must be ensured that only the front panel of the instrument is accessible to laypersons. Therefore, if the switchgear is located in an area accessible to laypersons, the switchgear door or panel must only be opened by means of a tool, or the door must be locked.

Fig. 2.1 : Panel Mounting



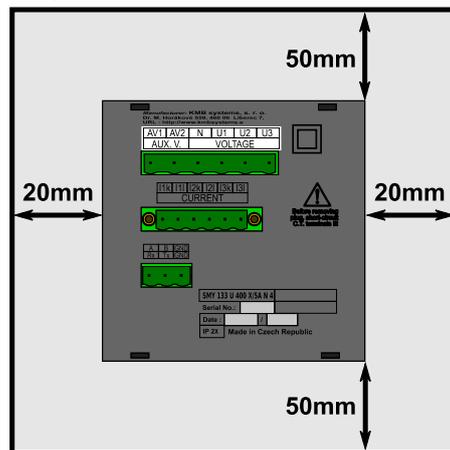
The instrument's position must be fixed with locks. Put the locks into square inserts placed diagonally on the top and bottom of the box and tighten the screws to the panel.

Fig.2.2: Fixation with locks detail



Natural air circulation should be provided inside the distribution board cabinet and in the instrument's neighbourhood no other instrumentation should be installed.

Fig. 2.3 : Space around the Instrument



Especially underneath the instrument, no other instrumentation that is source of heat should be installed or the temperature value measured may be false.

## 2.3 Instrument Connection

### 2.3.1 Power Supply

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

The supply voltage (in range according technical specifications) connects to terminals **X1** (No. 9 or 15) and **X2** (10 or 16). 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 **X2**.

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.

Recommended wire type :	H07V-U (CY)
Recommended minimum conductor cross-section :	1.5 mm <sup>2</sup>
Maximum conductor cross-section :	2.5 mm <sup>2</sup>

### 2.3.2 Measured Voltages

The phase voltages measured are connected to terminals **U1** (No.12), **U2** (13), **U3** (14), the common terminal to connect to the neutral wire is identified as **N** (11; it stays free at delta- (3-D) and Aron- (A) connections). Phase rotating direction is free.

It is suitable to protect the voltage lines measured for example with 1A fuses. Measured voltages can also be connected via instrument voltage transformers.

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.

Recommended wire type :	H07V-U (CY)
Recommended minimum conductor cross-section :	1.5 mm <sup>2</sup>
Maximum conductor cross-section :	2.5 mm <sup>2</sup>

### 2.3.3 Measured Currents

The instruments are designed for indirect current measurement via external CTs only.

The current signals from 5A or 1A instrument current transformers must be connected to the terminal pairs **I11**, **I12**, **I21**, **I22**, **I31**, **I32** (No. 1 – 6).

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 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.*

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

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

Recommended wire type:	H05V-U (CY)
Recommended minimum conductor cross-section :	2.5 mm <sup>2</sup>
Maximum conductor cross-section :	2.5 mm <sup>2</sup>

## 2.3.4 Outputs

Instruments can have up to 24 relay (“R”- models) or transistor (“T”-models) outputs. The outputs are arranged in three output groups. The groups are isolated from each other.

Each group has one relay common pole terminal **C1, C2, C3** ( No. 60, 70, 80 ) and up to nine individual relay output terminals **1.1** through **1.9** (No. 61 – 69) for group No. 1, **2.1** through **2.9** (No. 71 – 79) for group No. 2 and **3.1** through **3.6** ( No. 81 – 86) for group No. 3.

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).

### 2.3.4.1 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.

Recommended wire type:	H05V-U (CY)
Recommended minimum conductor cross-section :	1.5 mm <sup>2</sup>
Maximum conductor cross-section :	2.5 mm <sup>2</sup>

### 2.3.4.2 Transistor Outputs

The “T”-models are equipped with up to 24 MOSFET-type transistor outputs.

These outputs are designed to connect to thyristor switches’ input optocouplers 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 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, C3** (No.60, 70 and 80), but the polarity is free generally.

Recommended wire type:	H05V-U (CY)
Recommended minimum conductor cross-section :	0.5 mm <sup>2</sup>
Maximum conductor cross-section :	2.5 mm <sup>2</sup>

## 2.3.5 Digital Input DI5

Selected models are equipped with the digital input. It can be used for the 2<sup>nd</sup> tariff control of power factor control process, as the alarm input or for time synchronization.

Use terminals **DI51** (No. 93) a **CI5** (94) 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.

Recommended wire type:	H05V-U (CY)
Recommended minimum conductor cross-section :	1.5 mm <sup>2</sup>
Maximum conductor cross-section :	2.5 mm <sup>2</sup>

## 2.3.6 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 **T+**, **T-** and **Ts** (No. 95 – 97) according example drawing below.

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

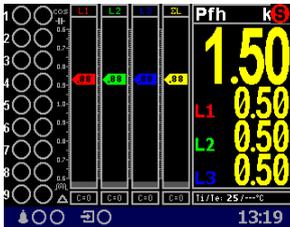
The temperature sensor can be ordered as the instrument's optional accessory.

Maximum conductor cross-section :	2.5 mm <sup>2</sup>
-----------------------------------	---------------------

## 3. Commissioning

### 3.1 Setup

After applying the supply voltage, a window of the current state of the power factor control, the so-called *main PFC window*, will usually appear. If the CT conversion has not yet been entered, a prompt to enter it will appear.



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, 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 **X**-button. If

the process has already started, stop it by pressing the button **S**.

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



#### 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 **1-Y**.
- **CT** – the CT ratio must be specified, in case of “via VT” connection mode **VT-ratio** too.

CT ratios can be set in form either .../ 5A or .../ 1A.

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

- **I- and U-Multipliers** - You can modify any CT- / VT-ratio with this parameters. 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.

When setting  $U_{NOM}$ , enter the phase voltage value.

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.

### 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 , navigate to the **Menu-Settings** with the buttons

and and then choose it with the . 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 .



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

You can set other parameters in the same way.

After all of the parameters of the group correctly set, return back to an actual data screen with the (escape) button and confirm saving of changes with the .

Now you can browse through displayed actual values with the and 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 the installation parameters set, 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 the *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

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).

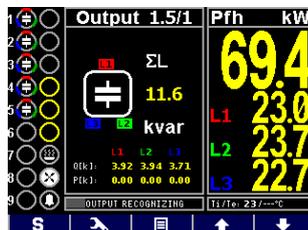
Now you can finally set output types and sizes. The most comfortable way to do this is by using *Automatic Output Recognition (AOR)* process : scroll to **Recognizer** and edit its value to **Run** . After confirmation, a message informing about the process to be started appears and 10 seconds interval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

### 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

the instrument starts to control power factor to preset value.

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 2700 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 24.

### 4.2 Manipulation and Setting



#### 4.2.1 PFC Screen

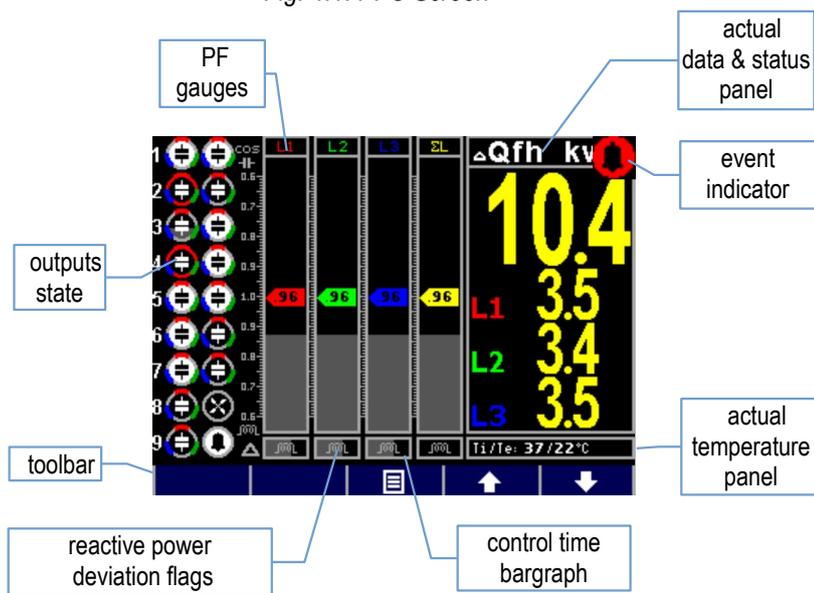
For power factor control checking, special PFC screen serves. It gets complex and well-arranged information about the compensation system actual state.

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 indicators* ... 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* :

- ... open output (fully discharged, black background)
- ... closed output (white background)
- ... open output not fully discharged (sinking gray background indicates level of discharge)

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.

Selected models 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

The 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

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

-  ... defective output (red outline)

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

-  ,  ... fixed output, permanently off / permanently on

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 (  $\Sigma L$  ) 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  $\cos \varphi$  ,  $\tan \varphi$  or  $\varphi$  - you can switch to desired format in *the PFC-Control* group of parameters, 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  $P_{NOM}$  is displayed as shadowed column at background of the gauge.

For example, if the  $P_{NOM}$  (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 (  $\Sigma L$  ) 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  $\Delta Q_{fh}$* , 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  $\Delta Q_{fh}$  value ), the  (choke) flag flashes; if leading (overcompensation, negative  $\Delta Q_{fh}$  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  $\Delta Q_{fh}$*  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  $\Sigma L$  control deviation flag field. For the **3p+1p** strategy, 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

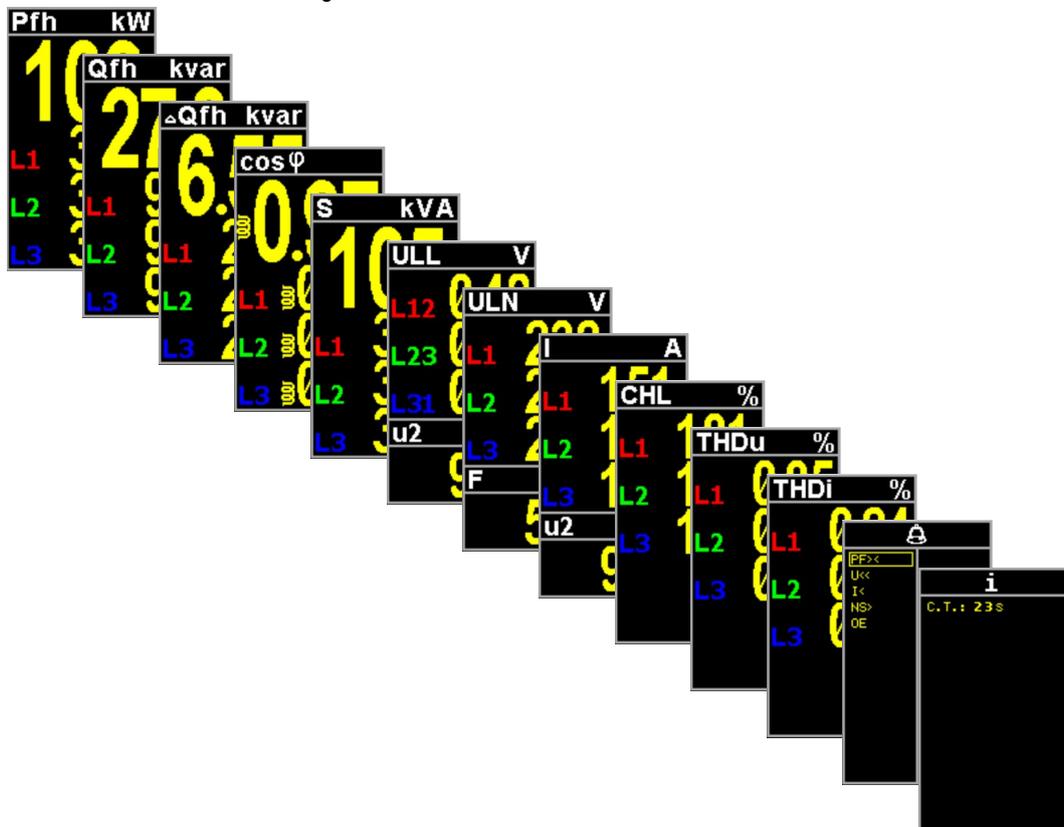
the control time counts down at minimum rate even during balanced state.

### 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 buttons  and . Power factor format can be selected in the *PFC-Control* group of parameters (described further below).

Fig. 4.2: Actual Data & Status Panel Folders



Most of the quantities' meaning and evaluation formulas can be found in the *Meter Block* chapter further below.

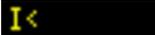
For special PFC-block related data understanding, such like  $\Delta Qfh$ ,  $\cos \varphi / \tan \varphi / \varphi$  or *CHL*, see the *Special PFC-Block Related Data Meaning & Evaluation* chapter.

#### 4.2.1.6.1 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 *indication* 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 ( the *undercurrent* alarm used in the example ) :

-  ... plain text = the alarm processed, but neither indication nor actuation activated
-  ... 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.

#### 4.2.1.6.2 Info Folder



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.: 23s** ... 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
- **FAST CONTR.** ... *accelerated control* in progress (see below)

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 )
- **OFFSET** ... *control with offset* in progress
- **GRID SUPPORT** ... *grid support* is set (but not active now, for details see further below )
- **GRID SUPPORT** ... *grid support* in progress

#### 4.2.1.7 Actual Temperature Panel



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 external 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 be 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 with the button. 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. With repetitive pushing of the , the *standby state* is cancelled immediately.
- ... *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.
- ... *grid support* in progress

### 4.2.1.9 Toolbar

The toolbar consists of five “softkeys”, i.e. buttons with context dependent function. Besides the general function buttons , and buttons, the PFC screen toolbar has another two special function buttons.

#### 4.2.1.9.1 Standby ↔ Control Toggle Switch

The switch works if the controller is not in the *Manual* state only.

When power factor control process is running, with the button 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.

If you press and hold the , after about 3 seconds the icon of the button changes to and it is now possible to manually control the outputs as described in the next chapter. However, since the regulatory process is still running in this case, the manual interventions made can subsequently be corrected by the ongoing regulatory process. For the same reason, the state of fixed and null outputs cannot be changed, as they are fully under the control of the control process.

#### 4.2.1.9.2 Manual Output Control

If the regulator is in *Manual* mode (or if it is in *Control* mode and we hold the button), the first button from the left has a different function: *manual output control*. If we **press and hold** this button , the icons of the buttons will change and the cursor of the selected output will appear in the 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 red, i.e. the first output of an output group is selected
- actually selected group is marked with the red 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 – see the previous chapter.

#### 4.2.1.9.3 PFC Setup Direct Access Button

As the NOVAR 2700 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 four groups : **the PFC Control**, **the PFC Outputs**, **the PFC Alarms** and **the PFC Grid Support** . Next two options in the menu are **the Control <-> Manual** state toggle and **the PFC Factory Setting** utility.

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 c. 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; displayed when <i>offset control</i> set only.
grid support setting (tariff1)	off / on	off	See chapter <i>Grid Support</i> below.
tariff 2 control	off / dig. input / power	off	
parameter set according No.1 - 6 for tariff 2	the same as parameters 1 – 6	-	Displayed when <i>tariff 2 control</i> is set only.
tariff 2 control power	0 - 120 % $P_{NOM}$	0	Displayed when <i>tariff 2 control</i> set to <i>power</i> only.
control strategy	3p+1p / 3p	3p+1p	
choke control	off / mixed / non-mixed	off	
choke control limit power factor	- 0.80 – 0.80 (cos)	1	Choke control limit power factor displayed when <i>choke control</i> set to <i>mixed</i> only.
offset control	off / on	off	
CT-test	-	-	Not real setup parameter - auxiliary parameter whereby it is possible to start the CT-test.
PF format	cos / tg / φ	cos	

By selection of any of the first three icons appropriate parameter group list appears. You can browse through them using 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  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

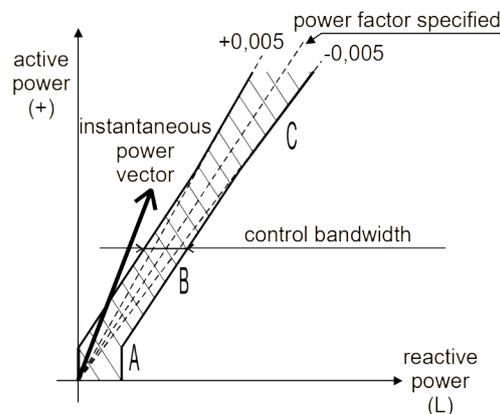
Negative value means lagging power factor, the positive one leading power factor.

### 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  $O_{MIN}$  value (reactive power of the minimum output) – the band follows the power factor slope specified at width  $\pm(O_{MIN})/2$ . On high loads (zone C) the bandwidth increases so its limits correspond to adjustable deviation from the target power factor. For the cosine target power factor format, the standard bandwidth value in this zone is 0.010 or  $\pm 0.005$  – 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  $0.000 \div 0.040$  if the target power factor format is *cosinus*; if the format is *tangens* or *angle*, the control bandwidth range is  $0.000 \div 0.030$  or  $0 \div 15^\circ$ , 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  $O_{MIN}$  (constant, not widening).

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

### 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,  $\Delta Q_{fh}$ ), 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  $\Delta Q_{fh}$  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.



*Regulators with transistor outputs (type "T") also enable so-called accelerated control - see chapter "Accelerated Control".*

#### 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  $U_{NOM}$ ). 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 Grid Support Setup for Tarif 1 a 2

See chapter *Grid Support* below.

#### 4.3.1.6 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
- grid support

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 :

-  ... 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.

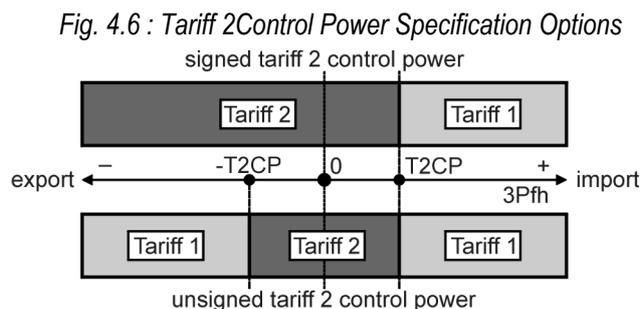
By default, *the tariff 2 control* parameter is off (). The tariff 2 set of parameters is not significant in such an event, so the parameters are not shown.

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.

### 4.3.1.7 Tariff 2 Control Power

If *the tariff 2 control* parameter is set to **Power** , the 2<sup>nd</sup> 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  $P_{NOM}$  .

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.



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 down to 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  $P_{NOM}$  “ ).

### 4.3.1.8 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 )

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

If the **3p+1p** strategy is set, individual single phase deviations control corresponding phase control times and their behaviour can be checked on the phase control time bargraphs (the  $\Sigma L$  control time bargraph is disabled). 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.



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

### 4.3.1.9 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.

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.

#### 4.3.1.9.1 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.

#### 4.3.1.9.2 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.*

#### 4.3.1.10 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.*

#### 4.3.1.11 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 kvar 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 kvar

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.*

### 4.3.1.12 PF Format

By default, the power factor is displayed and entered in **cos φ** format. The display in the PFC window can optionally be switched to the **tan φ** or **φ** format.  
The setting of this parameter affects the display of values only, it has no effect on power factor control.



## 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, 3.1 - 3.6 for the output group 3)
- 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 , new output type is assigned. Now you can modify the output reactive power.



*It is recommended to set these parameters 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 be used by power factor control process.

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

### 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*.

Tab 4.2 : PFC Output Setup – Overview of Parameters

Parameter	Setup Range	Default Setup	Comment
output No.1.1 through 3.6 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 <sub>NOM</sub> specified.
discharge time (set1)	5 sec - 20 min	20 sec	
output set 2	0 / 1.2 - 3.6	0	
discharge time (set2)	5 sec - 20 min	20 sec	Displayed when <i>output set 2</i> is set only.
switching mode	intelligent	intelligent	
automatic output recognizer (AOR) starting	auto / 0	auto	<i>Run</i> is not a parameter – serves for the AOR-process launch
manual filler	-	-	not a parameter - tool for easy manual bulk setting of outputs

### 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 exist.

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 all of other outputs from 1.7 up, i.e. remaining (at maximum) 18 outputs No. 1.7 through 1.9, 2.1 through 2.9 and 3.1 through 3.6

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

### 4.3.2.4 Switching Mode

The regulator uses individual stages optimally so that the maximum service life of the compensation system is achieved. This mode is labeled as **Intelligent**.

In special cases, it may be necessary to follow a certain switching sequence. Not implemented yet, planned in the future.

### 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 with the exception of **I<** and **P><** (the regulator ignores these alarms during the AOR, ACD and CT-test processes)

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 filler*.

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 the outputs' powers that are less than the specified minimum are cleared !

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.

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.

Fig. 4.11 : PFC Alarm Setup – Main Level

Setting PFC-Alarms			
U<<	20 %	I A	...
U<	70 %	✗	...
U>	130 %	✗	...
I<	0.1 %	I A	...
I>	120 %	✗	...
CHL>	133 %	✗	...
THDU>	10 %	✗	...
THDI>	20 %	✗	...
P><	0.0 %	✗	...

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 **I<** 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.

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; **I** or **A** shown in red means that the appropriate alarm function is currently active

Tab. 4.3 : PFC Alarm Setup – Overview of Parameters

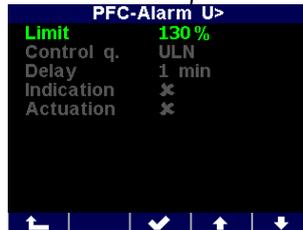
alarm No., mark	alarm event	control quantity / event	limit setting range	activation (/ deact.) delay	default v. Indication, Actuation	notes
<b>U&lt;&lt;</b>	voltage loss	$U_{LN}$ (1 period)	20% of $U_{NOM}$ (fixed)	0.02 sec / 5 sec (fixed)	- <b>I + A</b>	simultaneous disconnection
<b>U&lt;</b>	undervoltage	$U_{LN}$ / $U_{LNAVG}$	20-100% of $U_{NOM}$	1 sec - 20 min	$U_{LN} / 70\%$ / 1 min	
<b>U&gt;</b>	overvoltage	$U_{LN}$ / $U_{LNAVG}$	100-200% of $U_{NOM}$	1 sec - 20 min	$U_{LN} / 130\%$ / 1min	
<b>I&lt;</b>	undercurrent	$I$ / $I_{AVG}$	0-25.0 % of $I_n$ *)	1 sec - 20 min	$I / 0.1\%$ / 5 sec <b>I + A</b>	fixed sections not affected by actuation **)
<b>I&gt;</b>	overcurrent	$I$ / $I_{AVG}$	100-140 % of $I_n$ *)	1 sec - 20 min	$I / 120\%$ / 1 min	indication only
<b>CHL&gt;</b>	CHL limit exceeded	CHL / $CHL_{AVG}$	80-300 %	1 sec - 20 min	CHL/133 % / 1min	
<b>THDU&gt;</b>	THDU limit exceeded	THDU / $THDU_{AVG}$	1-300 %	1 sec - 20 min	THDU /10 % / 1min	
<b>THDI&gt;</b>	THDI limit exceeded	THDI / $THDI_{AVG}$	1-300 %	1 sec - 20 min	THDI / 20 % / 1min	
<b>P&gt;&gt;</b>	P limit exceeded / drop	Pfh / $Pfh_{AVG}$	0-99 %	1 sec - 20 min	0 % / 5 sec	fixed sections not affected by actuation **)
<b>PF&gt;&gt;</b>	PF control failure - PF control deviation out of contr. b'width	$\Delta Qfh$ / $\Delta Qfh_{AVG}$	-	1 sec - 20 min	$\Delta Qfh_{AVG} /$ 5 min <b>I</b>	indication only
<b>NS&gt;</b>	number of switching operations exceeded	number of switching operations	1-9999 thousands	immediat. (0 sec)	100 <b>I</b>	indication only
<b>OE</b>	output error	section failure	0-99 % of reading	3 - 15 consecut. occurrences	20 %; 10 <b>I + A</b>	
<b>T1&gt;&gt;</b> <b>T2&gt;&gt;</b>	temperature exceeded / drop	$T_i$ (internal)	-40 - +60 °C	1 sec - 20 min	>+45 °C / 1 sec >+35 °C / 1 sec	
<b>EXT</b>	external alarm active	digital input state	-	0.02 sec / 5 sec (fixed)	-	simultaneous disconnection
<b>OoC</b>	out of control	PF control process not running	-	1sec - 20min / imm'tely	15 min	indication only
<b>RCF</b>	remote control failure	remote con. process state	-	1sec - 20min / imm'tely	1 min	indication only
<b>PF&gt;</b>	PF control failure - overcompensated	PFfh / $PFfh_{AVG}$	cos : 0.00(C/L) - 1.00	1 sec - 20min	PFfh / 1.00 / 1 min	indication only
<b>PF&lt;</b>	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

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

\*\*) since FW 4.5.4, selected alarm actuation suppressed during ACD, AOR and CT-test processes

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 (  $U_{LN}$ , for the alarm example discussed ) of the quantity or corresponding average value (  $U_{LNAV}$ , 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 actuation gets active, fixed sections stay unaffected. Activation function is ignored during the AOR, ACD and CT-test processes
- **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  $\Delta Q_{fh}$  is checked for the PF control alarm. But there is not any presettable 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 red outline (  ,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

$$10000 / 3 \times 0.2 = 667 \text{ vars}$$

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 Grid Support Setup

See chapter *Grid Support* below.



### 4.3.5 Control / Manual State Indicator and Switch



The icon does not comprise any parameters but it indicates one of two instrument main states – *the 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.



## 4.3.6 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
grid support	off
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 - 3.6 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 )

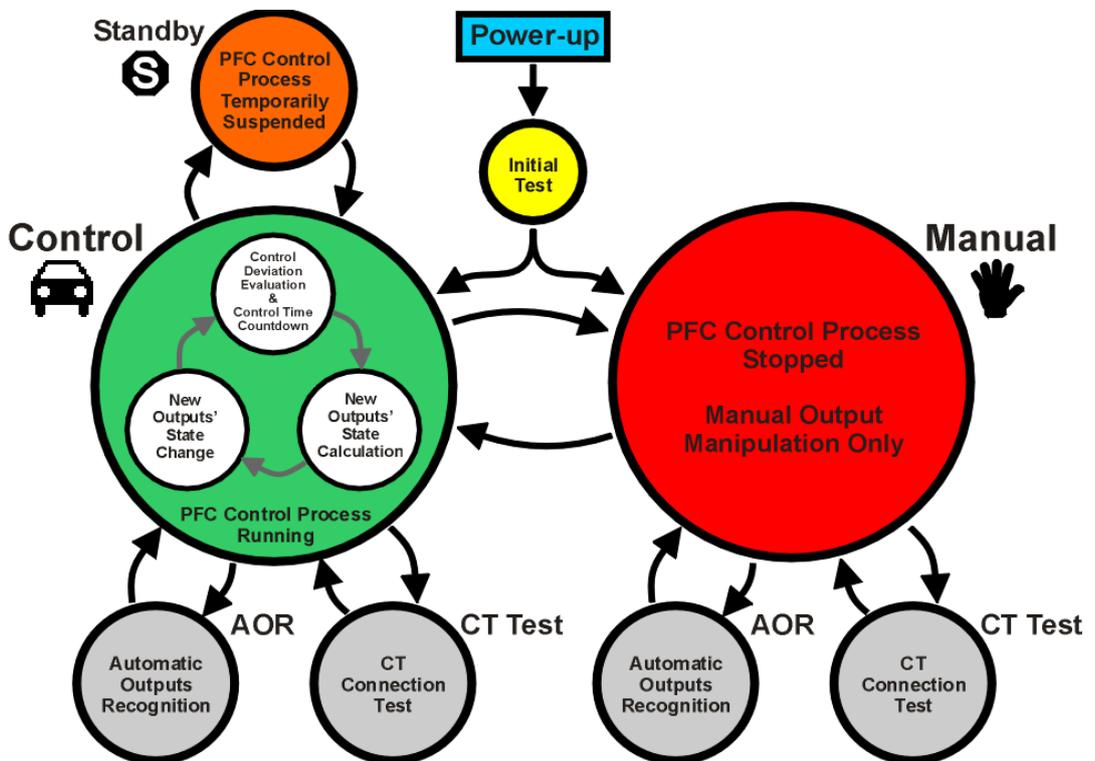
- **Control state** ... The instrument performs power factor control process; if, for some reason, it can not perform it, it gets into the standby state temporarily.
- **Manual state** ... the instrument does not perform power factor control process; manual output manipulation is allowed for testing 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 get temporarily to one of following „substates“ :

- *standby state* (indicated with flashing )
- *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 the controller switches to the manual state and the state icon changes to .

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 , as described 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*.



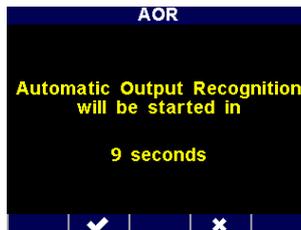
If any chokes are used in the compensation system, the Choke Control parameter must be set first; otherwise, all of chokes (or any inductive character type outputs) will be recognized as zero outputs.



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

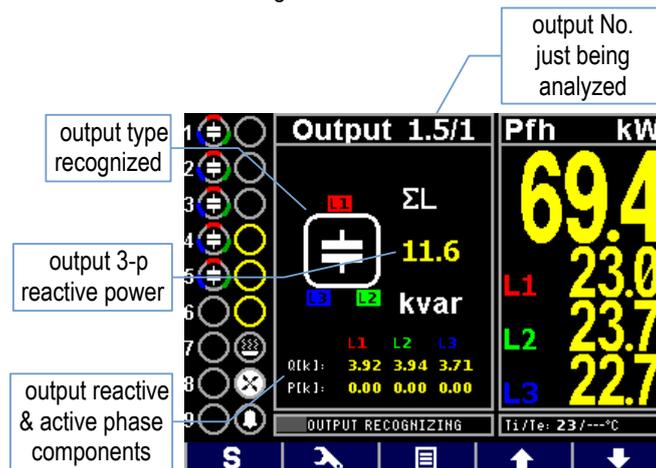


During following 10 seconds, you can either cancel the start command with the  button or to skip the message timeout with the  button to start the AOR process immediately. Or you can simply let the timeout to expire and then the AOR process starts.

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

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. 1.5 that was just measured was recognized as three-phase capacitor with total ( $\Sigma L$ ) reactive (nominal) power of 11.6 kvar
- individual phase powers of the capacitor are 3.92/3.94/3.71 kvar
- up till now, outputs No. 1.1 through 1.5 have been recognized as three-phase capacitors
- outputs No. 1.6 through 2.3 have been recognized as “zero outputs” (with no reactive power response)

- outputs No. 2.4 through 2.6 are set as *fixed-off*, the controller does not use them
- output No. 2.7 is *heating* output, output, currently switched off
- output No. 2.8 is *fan* output, currently switched on
- output No. 2.9 is alarm output; currently switched off



*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 of  or  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.*

#### 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 (terminals S1(k), S2(l)).

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** or **chokes** are connected to **the first four control outputs**. If, for example, two-phase capacitors or 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 report on the upcoming launch of the CT-test appears :

Fig. 4.16 : CT Test Launch Message

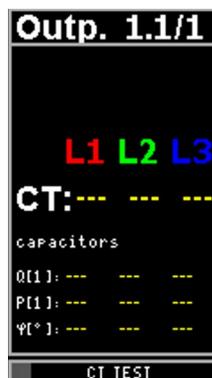


During following 10 seconds, you can either cancel the start command with the  button or to skip the message timeout with the  button to start the CT test immediately. Or you can simply let the timeout to expire and then the CT test starts.

By default, the controller assumes that **capacitors** are connected to the first four control outputs, which is displayed in red. If chokes are connected to them, push the .

Then, the CT test window is shown :

Fig. 4.17 : CT Test Window



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.

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 ).

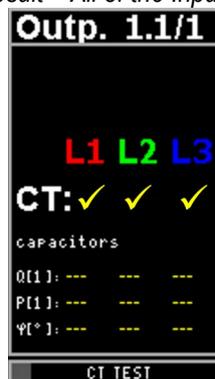
The test can have up to six rounds with four testing steps each. After each step, the measurement results of individual phases are analyzed. If the results of any phase is sufficiently stable, detected current signal connection information is shown in the main line, as can be seen in the picture above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

Tab. 4.18: 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 <b>the next</b> phase current input, keep the polarity
←	wrong phase, correct polarity	move wires to <b>the previous</b> phase current input, keep the polarity
R→	wrong phase, reverse polarity	swap the wires and move them to <b>the next</b> phase current input
R←	wrong phase, reverse polarity	swap the wires and move them to <b>the previous</b> 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 :

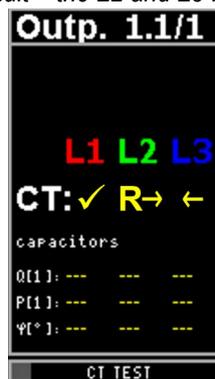
Fig. 4.18 : CT Test Result – All of the Inputs Connected Correctly



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 L1 input 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  or , 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.

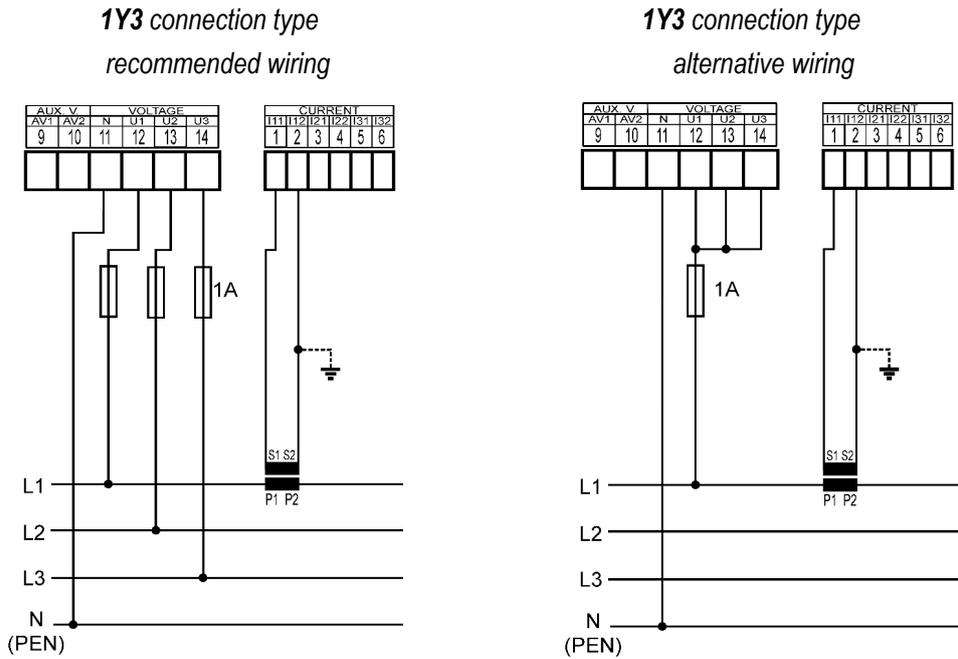
The controller operates in the single-phase mode when the *type of connection* (in the *Installation* group of parameters) is set to **1Y3** or **1D3** .

### 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.

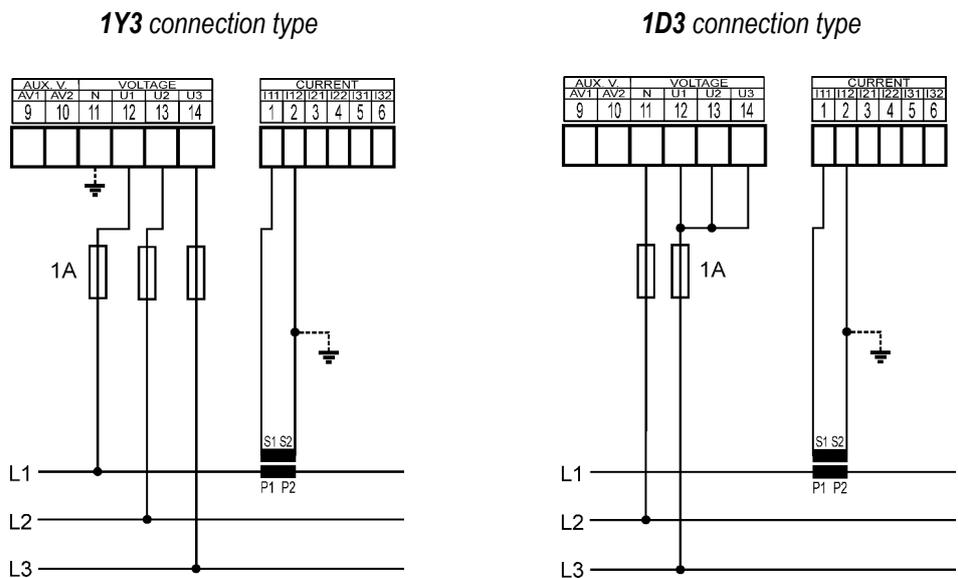
Fig. 4.20 : Single-Phase Connection to Networks with Neutral Wire - Examples



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



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 only detects and sets the U1 angle, but network nominal voltage  $U_{\text{NOM}}$  as well.



For the ACD process usage following condition must be fulfilled : either **three-phase** or **single-phase** compensation **capacitors** or **chokes** 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 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 (---)
- 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 Launch Message



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 ACD starts.

By default, the controller assumes that **capacitors** are connected to the first four control outputs, which is displayed in red. If chokes are connected to them, push the .

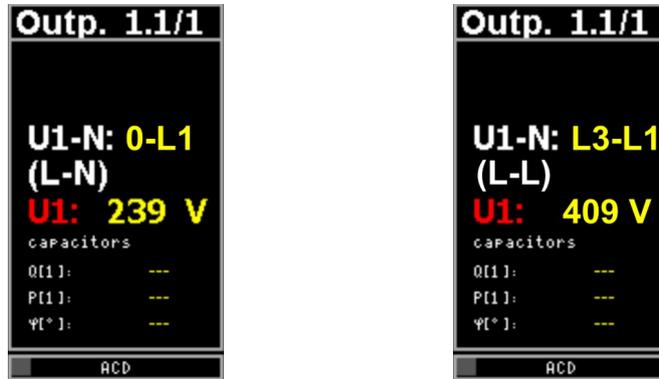
First of all, the first four *control* outputs are disconnected, step by step. Then the instrument waits until discharge time of the outputs just disconnected expires. During this, *Output 1.1* message flashes in the headline, that means that the instrument waits till output No. 1.1 is ready to use.

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)

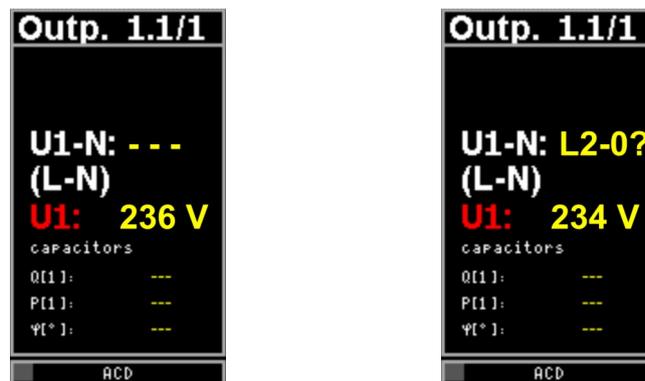
- in the bottom reactive and active powers of the output power found and corresponding angle between voltage and current phasors

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).

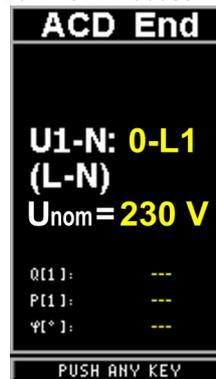


*If unsuccessful steps with the same results and the question mark repeat frequently, the most likely cause is incorrectly set connection type. Check it and try to start the process again.*

Ongoing ACD process can be interrupted at any point either manually by pushing the **S** or , 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  $U_{\text{NOM}}$  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  $U_{\text{NOM}}$  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  $U_{\text{NOM}}$  manually.*

### 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 Accelerated Control

NOVAR 2700 controllers equipped with transistor outputs ("T" type) can be used for so-called *accelerated reactive power compensation* with thyristor switches. The regulation period is 400ms.



*The accelerated control period of 400 ms only applies when a maximum of **18 compensation outputs are connected!** – when multiple outputs are connected, the period is significantly extended (according to the table below) and the control speed is reduced accordingly.*

<i>number of compensation outputs connected</i>	<i>accelerated control period [s]</i>
$\leq 18$	0,4
20	1
22	4
24	15

Full-fledged fast compensation with a control period in the order of tens of ms is not yet supported.

### 4.4.6.1 Accelerated Control Activation

Set, for example, the control time for undercompensation (UC) to the value **0**. This activates the so-called **accelerated control**, which causes:

- the control time for overcompensation (OC) and optionally also the control time for tariff 2 is automatically set to the value 0
- the set **discharge time** (for *parameter set 1 and 2*) is **ignored** and considered zero, so the controller stops taking the discharge state of the capacitors into account when selecting stages
- the calculation of the control intervention is carried out after every second measurement cycle, i.e. every  $2 \times 200 = \mathbf{400\ ms}$  (at a frequency of 50 Hz)
- control action is performed **at once**, i.e. the state of all regulatory outputs will change simultaneously (not one after the other, as with classic control)
- in the Info tab of the PFC main window, "FAST CONTROL" is displayed instead of the immediate status of the control time
- the output error alarm (OE) is not evaluated, cannot be set
- the number of switches and the switching times of the outputs are not updated

### 4.4.6.2 Accelerated Control Deactivation

Accelerated control can be deactivated by setting any of the control times back to a non-zero value.

This will automatically set all control times to the same value (subsequently, each control time must be set individually if desired).

## 4.4.7 Grid Support

With the development of renewable sources and, in general, electricity production plants operated in parallel with the distribution grid, more demanding requirements for reactive power management may arise from the network operator than the simple regulation of the power factor to a set value. In order to stabilize the distribution system, so-called **grid support** may be required (usually depending on the output of the production plant) when supplying energy to the grid: for example, additional reactive power depending on the voltage (**Q(U)** mode) or instead of power factor regulation, direct voltage control (**U/Q** mode). For a more detailed description, see e.g. EN50438 ed.2, EN50549-1, EN50549-2, or the operating instructions of the relevant network distributors.

Grid support is performed only when active power is delivered to the network; if the plant is not currently producing (and usually consuming energy as well), no support is provided. So:

- if the instantaneous value of the three-phase active power  $\Sigma P \geq 0$  (= import, consumption of active energy from the grid), the controller works normally (i.e. it does not support the grid)
- if the instantaneous value of the three-phase active power  $\Sigma P < 0$  (= export, supply of active energy to the grid) and at the same time grid support is enabled (in the *PFC-Control* parameter group), **instead of standard regulation to the set power factor**, the controller will start to **support the grid** in a set way.

As soon as the regulator starts to perform this support, instead of the required power factor, *grid voltage* becomes the decisive quantity for the support control. For this purpose, the regulator evaluates average voltage of three-phase network as **the arithmetic mean of the phase voltages U1, U2, U3**.

According to the instantaneous magnitude of this voltage and the set regulation curve of the support, it maintains either corresponding reactive power or required voltage, in the grid, regardless of the power factor.



*In reality, however, the controller monitors the power factor even when supporting the grid: it supports it only so that the power factor in the network remains in the range of **0.90C–0.90L**. As soon as the support according to the set curve would cause the power factor to deviate from this band, the regulator will limit the support only to such an extent that the power factor does not deviate from the band.*

If grid support is running, then, unlike standard PFC regulation, the regulator reacts differently to the setting of following parameters:

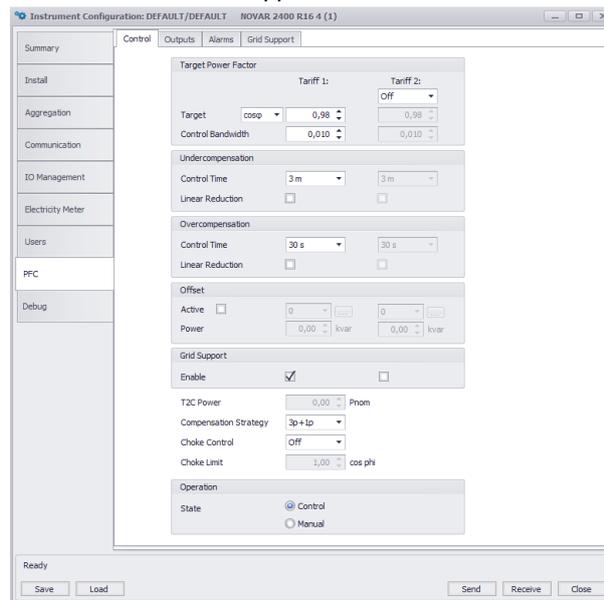
- target power factor : ignored
- control bandwidth : ignored. Regardless of the setting, regulation is performed with a bandwidth of **0.000**
- regulation strategy : ignored. Regardless of the setting, regulation is done with the **3p** strategy
- control with chokes : if it is on, the **non-mixed** mode will be used regardless of the setting
- regulation with offset : ignored. Regardless of the setting, the regulation is carried out **without an offset**
- compensation error alarms PF><, PF>, PF> : ignored. Regardless of the setting, these alarms are **disabled**

### 4.4.7.1 Grid Support Activation

#### 4.4.7.1.1 Settings using the ENVIS-DAQ program

To set up network support, we recommend using the ENVIS-DAQ program (version 2.0.33 or higher). First, you need to turn grid support on by checking the *Enable* option in the *Grid Support* field in the *PFC Settings – Control* tab.

### Grid Support - Activation



#### 4.4.7.1.2 Settings from the instrument panel

To activate support switch the parameter *Grid Support 1* in the *PFC-Control* group to . If the function of the 2nd tariff is enabled, support can be activated separately for tariff 1 and 2.

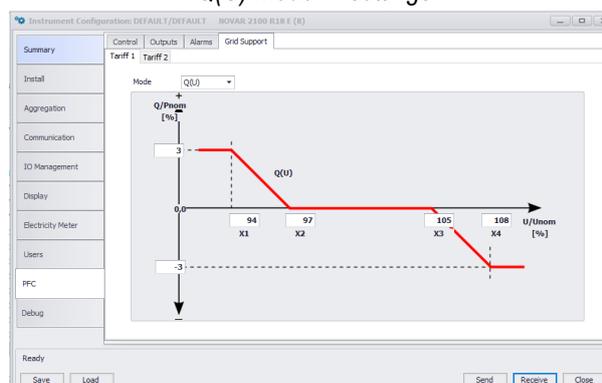
Subsequently, it is necessary to set the support mode and other parameters in the *PFC-Grid Support* group.

#### 4.4.7.2 Grid Support Settings - Q(U) Mode

##### 4.4.7.2.1 Settings using the ENVIS-DAQ program

Once the grid support is enabled, in the *Grid Support* tab, the *Support Mode* must be set to **Q(U)** and the following control curve will appear:

#### Q(U) Mode – settings



Here you need to set the coordinates of the 4 points of the Q(U) kinked curve **X1, X2, X3, X4** (usually prescribed by the network operator):

- enter the coordinates of the horizontal axis in the ratio of the actual voltage to the nominal voltage  $U_{NOM}$  in percent
- for points X1 and X4, also set the coordinates of the vertical axis determining the ratio of the reactive power of the support to the nominal power  $P_{NOM}$  in percent



The  $U_{NOM}$  and  $P_{NOM}$  parameters must be properly set before setting the grid support parameters!



The coordinates of the horizontal axis of points X1 to X4 must be monotonically increasing!

### 4.4.7.2.2 Settings from the instrument panel

Grid Support	
Mode 1	Q(U)
X1 1	94.00
X2 1	97.00
X3 1	105.00
X4 1	108.00
Y1 1	3.00
Y4 1	-3.00

In the *PFC-Grid Support* group, set the Q(U) mode.

Using other parameters, set the coordinates of the control curve points X1-X4 according to the following table.

In the given example, only the parameters for tariff 1 are displayed (the number 1 after the parameter designation). In case of activation of the grid support also for tariff 2, a set of parameters for this tariff (with number 2) will also be displayed.

Q(U) Mode Grid Support Parameters

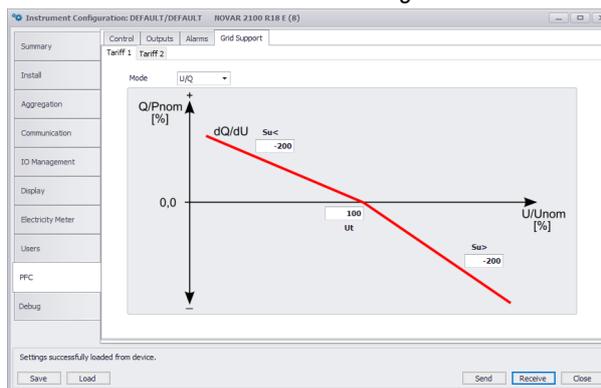
No.	subparameter	range	default v.
1	Q(U) mode	-	-
2	X1 – horizontal coordinate [% $U_{NOM}$ ]	80 - 120	94
3	X2 – horizontal coordinate [% $U_{NOM}$ ]	80 - 120	97
4	X3 – horizontal coordinate [% $U_{NOM}$ ]	80 - 120	105
5	X4 – horizontal coordinate [% $U_{NOM}$ ]	80 - 120	108
6	Y1 – vertical coordinate [% $P_{NOM}$ ]	unlimited	+3
7	Y4 – vertical coordinate [% $P_{NOM}$ ]	unlimited	-3

### 4.4.7.3 Grid Support Settings - U/Q Mode

#### 4.4.7.3.1 Settings using the ENVIS-DAQ program

In the *Grid Support* tab, the *Support Mode* must be set to **U/Q** and the following regulation curve will appear:

### U/Q Mode – settings



Here you need to set:

- target voltage **Ut** in percent of **UNOM**
- slopes of regulation **Su<** and **Su>**. It is the value of the reactive power in percentage of **P<sub>NOM</sub>**, which causes a change in the grid voltage by 1% of **UNOM**. In accordance with the specified control curve, the slopes are always entered as negative.

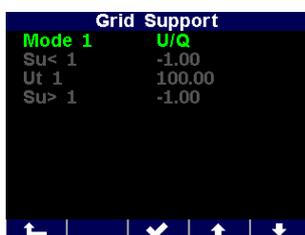


The **UNOM** and **P<sub>NOM</sub>** parameters must be properly set before setting the grid support parameters!



Usually, slopes **Su<** and **Su>** of the same magnitude are entered. In the case of a non-linear dependence of **U** on **Q**, the slope values can be entered differently for the undervoltage area (**Su<**) and for the overvoltage area (**Su>**).

#### 4.4.7.3.2 Settings from the instrument panel



In the *PFC-Grid Support* group, set the U/Q mode.

Furthermore, it is necessary to set the required voltage and steepness according to the following table.

In the given example, only the parameters for tariff 1 are displayed (the number 1 after the parameter designation). In case of activation of the grid support also for tariff 2, a set of parameters for this tariff (with number 2) will also be displayed.

*U/Q Mode Grid Support Parameters*

No.	subparameter	range	default v.
1	U/Q mode	-	-
2	Ut – target voltage [% <b>UNOM</b> ]	80 - 120	100
3	Su< – slope for undervoltage area	0 - -999999	-1
4	Su> – slope for overvoltage area	0 - -999999	-1

### 4.4.7.3.3 Example of slope setting

With U/Q support, the instrument works as a voltage regulator. For this, it needs to know what value of reactive power to connect to the network in order to change the voltage by the desired value. This value needs to be determined experimentally or by calculation.

The following examples explain the entry method:

#### Example #1:

A wind farm with a nominal output of 2MVA is connected to a grid with a nominal voltage of 22kV. The distributor requests support for a voltage of 23.1 kV, i.e. at 105%  $U_{NOM}$ .

Experimentally, it was found that at undervoltage in the network (i.e. at voltage < 23.1 kV), the (line-to-line) voltage increases by 50V if the regulator connects 550 kvar of capacitive reactive power to the grid.

Installation settings:

- $U_{NOM} = 12702/22000$  V (ULN/ULL)
- $P_{NOM} = 2000$  kVA

Network support settings:

- $U_t = 105\%$
- determining the slope of  $Su<$  (for undervoltage): since  $P_{NOM}=2000$  kVA, the value of 550 kvar corresponds to 27.5% of  $P_{NOM}$ . A voltage change of 50V corresponds to 0.23%  $U_{NOM}$ . A voltage change of 1%  $U_{NOM}$  will therefore correspond to  $1/0.23 \times 27.5 = 120$ . We will therefore set the slope  $Su<$  to the value -120
- we set the slope  $Su>$  (for overvoltage) to the same value, i.e. -120

#### Example #2:

The hydropower plant with a nominal output of 3.61MVA is connected to a grid with a nominal voltage of 22kV. The distributor requests support for a voltage of 23 kV, i.e. at 104.5%  $U_{NOM}$ . Experimentally, it was found that during an overvoltage in the network (i.e. at a voltage > 23 kV), the (line-to-line) voltage will decrease by 200V if the regulator connects -700 kvar of reactive power to the network.

Installation settings:

- $U_{NOM} = 12702/22000$  V (ULN/ULL)
- $P_{NOM} = 3610$  kVA

Network support settings:

- $U_t = 104.5\%$
- determining the slope of  $Su>$  (for overvoltage): since  $P_{NOM}= 3610$  kVA, the value of 700 kvar corresponds to 19.4% of  $P_{NOM}$ . A voltage change of 200V corresponds to 0.91%  $U_{NOM}$ . A voltage change of 1%  $U_{NOM}$  will therefore correspond to  $1/0.91 \times 19.4 = 21.3$ . So we set the slope  $Su>$  to -21.3
- we set the slope  $Su<$  (for undervoltage) to the same value, i.e. -21.3

### 4.4.7.4 Grid Support Indication

The fact that the controller works in grid support mode is indicated as follows:

- on the display of the controller in the *Info* folder of the *Data & Status* panel with the **GRID SUPPORT** message and by flashing indicator **GS**
- in the ENVIS-DAQ program in the actual data by the *GRID SUPPORT* message in the *Status* column (see the figure below)

*Indication of running grid support in the ENVIS/DAQ program*



## 4.4.8 Special PFC-Block Related Quantities' Meaning & Method of Evaluation

General quantities' meaning and evaluation formulas can be found in the appropriate chapter. For the PFC-block operation, some additional special quantities are necessary. Description of the quantities follows.

### 4.4.8.1 Values Used for Power Factor Control Evaluation and Aggregation

Powers  $P_{fh}$  and  $Q_{fh}$  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  $\Delta Q_{fh}$  – 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 be compensated with contactor-type outputs.

### 4.4.8.2 $\Delta Q_{fh}$ – 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:

$$Q_{fh_{T1}} = P_{fh_1} * tg\varphi_T$$

where :

$P_{fh_1}$  ... phase L1 fundamental harmonic active power

$\varphi_T$  ... preset target angle between fundamental voltage and current phasors

When target power factor is specified in the  $\cos\varphi$  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 :

$$Q_{fh_{T1}} = P_{fh_1} * tg(\arcsin(\cos\varphi_T))$$

Finally, the control deviation of phase L1 :

$$\Delta Q_{fh_1} = Q_{fh_1} - Q_{fh_{T1}}$$

where :

$Q_{fh_1}$  ... phase L1 fundamental harmonic reactive power

Total three-phase control deviation :

$$\sum \Delta Q_{fh} = \Delta Q_{fh_1} + \Delta Q_{fh_2} + \Delta Q_{fh_3}$$

### 4.4.8.3 Cosφ / Tanφ / φ – Power Fator

The power factor value used in the PFC block can be displayed in different formats: cosφ , tanφ or φ.

The character of the power factor in the PFC block is indicated either by the  icon (=L, inductive) or by the  icon (C, capacitive).

### 4.4.8.4 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

$$I_c = \frac{U}{Z_c} = \frac{U}{\frac{1}{2\pi f C}} = 2\pi f C U \quad [A]$$

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

$$I_c = \sum_{i=1}^n I_i \quad [A]$$

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

$$I_i = 2\pi f_i C U_i = 2\pi (f_f * i) C U_i \quad [A]$$

where :

i.... order of harmonic	[ - ]
li.... current of i <sup>th</sup> harmonic component	[ A ]
Ui... voltage of i <sup>th</sup> harmonic component	[ V ]
fi.... frequency of i <sup>th</sup> harmonic component	[ Hz ]
f <sub>f</sub> ... 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 (U<sub>i</sub> x i) of harmonic. Consequently, the total harmonic distortion, which is defined as

$$THD_U = \frac{1}{U_1} \sqrt{\sum_{i=2}^N U_i^2} * 100 \quad [ \% ]$$

where:

THD <sub>U</sub> ... voltage total harmonic distortion	[ % ]
U <sub>i</sub> ..... voltage of i <sup>th</sup> 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

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

where :

- CHL.... capacitor harmonic load factor [ % ]
- i..... order of harmonic [ - ]
- $U_i$ ..... 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. 4.9: Examples of CHL factor values for selected distributions of voltage harmonic components ( $U_1 = U_{NOM}$ )

No.	voltage harmonic component levels [ % ]									CHL [ % ]
	3 <sup>rd</sup>	5 <sup>th</sup>	7 <sup>th</sup>	9 <sup>th</sup>	11 <sup>th</sup>	13 <sup>th</sup>	15 <sup>th</sup>	17 <sup>th</sup>	19 <sup>th</sup>	
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.

### 4.4.8.5 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 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

$\Delta Q_{fh1}$  ..... 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 in 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 the display to average values (AVG) of the general meter and scroll through the three-phase powers. Press the button  repeatedly to select the 3dQ/3RC/3RL combination – this will display a window with the average values of the three-phase control deviation and compensation reserve powers, including recorded maxima and minima.
4. Reset the maxima&minima in the AVG-Setting window in the P/Q/S values group.
5. 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.

Compensation Reserves - Sufficient



Compensation Reserves - Insufficient Capacitive Reserve



For compensation reactive power capacity assessment, registered minimum values of both reserves are decisive (data with a prefix ↓). On the left example above, registered minimum of three-phase

capacitive reserve is 394.7 kvars, minimum of inductive reserve is 3.78 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 right example shows, reactive power of magnitude that the controller could not compensate appeared sometimes in the network during the testing period. As *the*  $\Sigma RC$  minimum average value is negative, the capacity of compensation capacitors is not sufficient ; 33.0 kvars of capacitors missed. Similarly, as *the*  $\Sigma RL$  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.*

## 5. Meter Block

### 5.1 Basic Functions

The general meter block, which is a universal three-phase measuring system, forms the basis of the entire instrument.

It evaluates 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. 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 or four current signals (for connection of external CTs with either 5 or 1 A<sub>AC</sub> nominal secondary signal) and separate AC/DC power supply input. They can be used in both low and high voltage power grids.

The instruments feature three-rate tariff electricity meter with four-quadrant counters for both active and reactive energies and 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.

The instruments are equipped with battery backedup real-time circuit (RTC) and high capacity „Flash“ type memory for measured data and events recording.

The USB 2.0 communication link can be used for the instrument adjusting and recorded data transfer. For remote access, optional RS-485 or Ethernet communication interface is available. The instruments with Ethernet interface have embedded webserver.

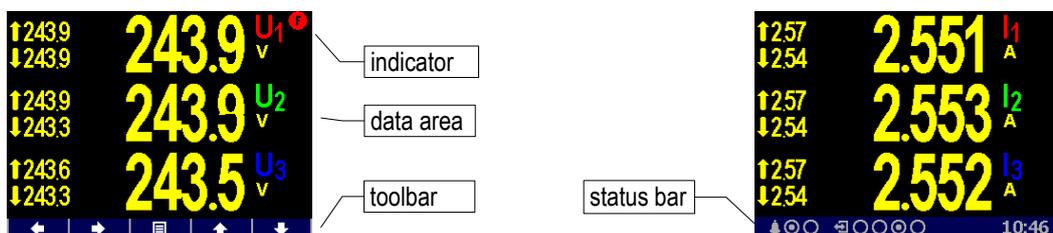
Basic specifications of the instrument can be set up by using the inbuilt keyboard and the display. With the ENVIS program supplied as standard you can, via any of communication link, adjust the instrument and transfer recorded data. In addition to the instrument adjustment, ENVIS program allows you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

### 5.2 Manipulation and Setting

#### 5.2.1 Data Area – Status Bar - Toolbar

The most usual data screen of an instrument consists of two parts : a *data area* and a *status bar / toolbar area*.

Fig. 5.1: Data Area, Data Area, Status Bar, Toolbar



After instrument's startup the status bar appears below data area as default. The status bar contains following information :

-   ... A1 and A2 alarm lights. After the bell icon, two targets represent actual state of the lights; the first one – A1 – is switched on on the example, the A2 is just switched off. This information appears only when either A1 or A2 function is set in the I/O management setup (see below).
-  ... digital I/O state (except outputs for PFC control). The instrument on example is equipped with four bidirectional inputs(DI)/outputs(DO) and either the DI3 input or DO3 output is just active.  
Instruments equipped with unidirectional I/Os uses icon  for inputs and icon  for outputs.
- **10:46** ... local time ( hours : minutes)

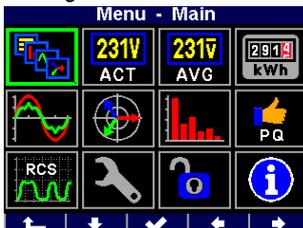
As soon as any button is pressed, a toolbar replaces the status bar. The toolbar determines function of individual buttons and changes dynamically by a context. If no manipulation with buttons for a longer period the toolbar is replaced with *the status bar*.

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
-  ... At least one unconfirmed note is displayed in the *Note* user screen

## 5.2.2 Main Menu

Fig. 5.2: Main Menu



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

All other buttons but the  are context dependent and variable, but the  is accessible from nearly every window which helps to quick orientation.

Next chapters describe individual main menu options.

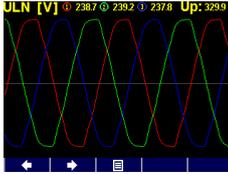
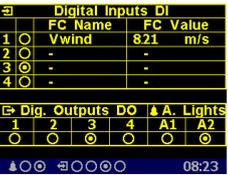


## 5.2.3 Main Data Group

This data group of screens is configurable by user. You can choose data screens you are most interested in and place them in this group for easy access. Use the ENVIS-DAQ program for the setup.

Assortment of available user screens follows :

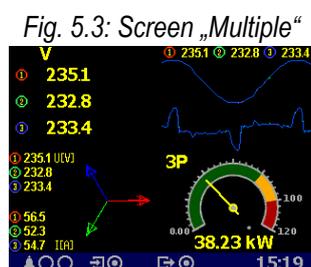
Tab. 5.1: Available User Screens

screen	description
	<p>„3 Rows“</p> <ul style="list-style-type: none"> <li>- up to three arbitrary quantities</li> <li>- single-phase or three-phase</li> <li>- actual, average, percentage values</li> </ul>
	<p>„Summary Table“</p> <ul style="list-style-type: none"> <li>- fixed assortment of basic quantities, no units - only <b>k / M / G</b> multipliers</li> <li>- in the last row voltage unbalance <b>u2 [%]</b> and frequency <b>f [Hz]</b></li> </ul>
	<p>„Waves“</p> <ul style="list-style-type: none"> <li>- waveshapes of voltages and currents</li> <li>- including maximum of their peak values marked as Up/lp.</li> </ul>
	<p>„Phasor Diagram“</p> <ul style="list-style-type: none"> <li>- actual voltage and current fundamental harmonic phasors</li> <li>- phase order (<b>1-2-3</b> or <b>1-3-2</b>)</li> </ul>
	<p>„Harmonics“</p> <ul style="list-style-type: none"> <li>- actual harmonic components of voltages and currents in histogram format</li> <li>- odd components from the 3<sup>rd</sup> to 25<sup>th</sup> only</li> <li>- THD values of individual phases</li> </ul>
	<p>„Multiple“</p> <ul style="list-style-type: none"> <li>- four compressed subscreens, each configurable individually</li> <li>- gauge type available (see details below)</li> </ul>
	<p>„Digital Inputs“, „Analog Inputs“, „Pulse Counters“, „Hour Meter“</p> <ul style="list-style-type: none"> <li>- actual data of digital/analog inputs &amp; outputs</li> <li>- for details see <i>Inputs &amp; Outputs</i> chapter</li> </ul>
	<p>„Electricity Meter“</p> <ul style="list-style-type: none"> <li>- up to three arbitrary energy quantities</li> <li>- see <i>Customizable Energy Screen</i> chapter further below for details</li> </ul>

screen	description																																																		
	<p>„Modbus Master“</p> <ul style="list-style-type: none"> <li>- actual values of quantities of slave units monitored by Modbus master module</li> <li>- see <i>Modbus Master Firmware Module</i> application note for details</li> </ul>																																																		
	<p>„IO Variables“</p> <ul style="list-style-type: none"> <li>- actual values of IO-variables</li> <li>- see <i>Variable Value Monitoring and Manual Change</i> in the <i>Inputs &amp; Outputs</i> chapter for details</li> </ul>																																																		
	<p>„IO Limits“</p> <ul style="list-style-type: none"> <li>- values of meas. quantity condition limits</li> <li>- see <i>Condition Limit Checking and Editing on Instrument Display</i> in the <i>Inputs &amp; Outputs</i> chapter for details</li> </ul>																																																		
	<p>„Notes“</p> <ul style="list-style-type: none"> <li>- see <i>Show Note</i> action description in the <i>Inputs &amp; Outputs</i> chapter for details</li> </ul>																																																		
<table border="1"> <thead> <tr> <th></th> <th>L1</th> <th>L2</th> <th>L3</th> <th>3P</th> </tr> </thead> <tbody> <tr> <td>ULL</td> <td>398.4</td> <td>398.4</td> <td>398.4</td> <td></td> </tr> <tr> <td>ULN</td> <td>230.0</td> <td>230.0</td> <td>230.0</td> <td></td> </tr> <tr> <td>I</td> <td>263.8</td> <td>247.2</td> <td>233.5</td> <td>744.5</td> </tr> <tr> <td>PF</td> <td>0.99</td> <td>0.99</td> <td>0.99</td> <td>0.99</td> </tr> <tr> <td>P</td> <td>60.3</td> <td>56.3</td> <td>53.1</td> <td>169.7</td> </tr> <tr> <td>Q</td> <td>6.87</td> <td>8.01</td> <td>7.75</td> <td>22.63</td> </tr> <tr> <td>S</td> <td>60.7</td> <td>56.9</td> <td>53.7</td> <td>171.2</td> </tr> <tr> <td>THDI</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td></td> </tr> <tr> <td>THDI</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td></td> </tr> </tbody> </table>		L1	L2	L3	3P	ULL	398.4	398.4	398.4		ULN	230.0	230.0	230.0		I	263.8	247.2	233.5	744.5	PF	0.99	0.99	0.99	0.99	P	60.3	56.3	53.1	169.7	Q	6.87	8.01	7.75	22.63	S	60.7	56.9	53.7	171.2	THDI	0.00	0.00	0.00		THDI	0.00	0.00	0.00		<p>„Local Bus“</p> <ul style="list-style-type: none"> <li>- any of Local bus data screen can be added</li> <li>- see <i>Instrument Display</i> description in the <i>Local Bus</i> chapter for details</li> </ul>
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	<p>„Clear“</p> <ul style="list-style-type: none"> <li>- allows clearing of average values, maximum demand values and electricity meter from this single screen</li> <li>- see „Clear“ <i>Screen</i> chapter for details</li> </ul>																																																		

### 5.2.3.1 Gauge Type Subscreen in the „Multiple“ Screen

The screen consists of four compressed subscreens. Each of them can be configured individually.



Type of the subscreens can be chosen from following :

- table
- waves
- phasors
- harmonics
- electricity meter

- gauge

Setup of all of types but the *gauge* is intuitive and needs no closer explanation.

The gauge type has four basic formats according to the control quantity chosen. They differ each from other in arrangement of colour bars of the scale – see below.

Each of gauges is marked with its quantity name in upper left corner of its subscreen. Actual value is displayed in numeric format too below the gauge.

Furthermore, marks of maximum (red) of average value registered since the last clearing and corresponding minimum (blue) value are displayed in most of gauge formats. For details see chapter *Average Values Evaluation* further below.



*If no AVG-max & AVG-min marks displayed, maybe they are not yet available. This occurs always just after appropriate AVG-quantity group is cleared (see chapter Average Values Evaluation further below).*

Tab. 5.2: Gauge Type Subscreen Formats

gauge format	range control parameter
<p style="text-align: center;"><b>Voltage, Current</b></p>	<p><math>U_{NOM} / I_{NOM}</math></p>
<p style="text-align: center;"><b>Power</b></p>	<p><math>P_{NOM}</math> for three-phase powers  <math>P_{NOM} / 3</math> for single-phase powers</p>
<p style="text-align: center;"><b>Frequency</b></p>	<p><math>f_{NOM}</math></p>

gauge format	range control parameter
	fixed arrangement no AVG-max/AVG-min marks (not evaluated for cosφ)

### 5.2.3.2 „Clear“ Screen

This screen allows clearing of various registered values from one point. Moreover, timestamps of the last clearing of quantities' groups can be checked here.

From the screen you can clear these groups :

- registered maxima and minima of average values of U/I-group of quantities (see chapter *Average Values Evaluation* further below)
- registered maxima and minima of average values of P/Q/S-group of quantities
- registered maxima and minima of average values of residual currents (RCM)
- registered maximum demands (MD, see chapter *Maximum Demand Processing*)
- energy counters of electricity meter (see chapter *Embedded Electricity Meter* )

In the ENVIS-DAQ application, add the *Clear* screen and select it. In the right bottom corner you can set the screen properties :

Fig. 5.4: User Screens Setting - „Clear“



Check the quantity groups that you want to allow clearing from the screen – at the example above there are *AVG U/I*, *Maximum Demand* and *Electricity Meter* groups. Now send the setting into the instrument.

Now scroll through the instrument screens in the main data group and find the newly added screen. It should look like the example below.

Fig. 5.5: Screen „Clear“



The *Unlocked* informs that clearing of the quantities is not locked now.

Then list of quantity groups follows. At right of each group you can check timestamp of the last clearing.

With the  and  you can list the quantity group to be cleared. Then push the . After confirmation of the request, the corresponding group is cleared and its timestamp is updated.

The clearing can be locked by a special PIN. The lock operates as follows :

- if an instrument itself is unlocked (see the *Instrument Lock* chapter), the clearing is unlocked too (regardless to the *Clear PIN* setup)
- if the instrument is locked and the *Clear PIN* is set to zero, the clearing is unlocked
- if the instrument is locked and the *Clear PIN* is set to any value different from zero the clearing is locked

To lock the clearing, in the ENVIS-DAQ application set the *Clear PIN* to 1234, for example. Send the setup into the instrument. Then, if the instrument itself in unlocked, lock it – either with the ENVIS-DAQ (check appropriate checkbox in the display setup and send into the instrument) or via the instrument panel.

Now note that the item *Unlocked* has changed to **Locked**. In such case, if you need to clear any of groups you must to unlock the clearing first : list the *Locked* item and push the . At the right, a window with four digits appears. In the window set value to 1234 : with the  you can navigate between individual digits and set their values with the  and . Finally, push the .

If correct PIN set, the item changes to *Unlocked*. Now the clearing is possible.



*The unlocking of clearing is temporary only ! As soon as you leave the screen, the clearing gets locked automatically !*



*To unlock the clearing permanently, in the ENVIS-DAQ application set PIN of the „Clear“ screen to zero and set the setting into the instrument. Optionally, unlock the instrument itself.*

### 5.2.3.3 Default Window

By default, the instrument displays the last selected window (screen) of measured data until an operator switches to another. The instrument remembers the window even in the event of a power failure and displays it after the power is restored.

In the ENVIS-DAQ program, it is possible to force the instrument to automatically switch to the so-called *default window* if no one manipulates the buttons for a certain period of time. *The Default Window* is always the first user screen set in *the main data group* (see description in previous chapters). In the ENVIS-DAQ program, in *the Display* settings tab, place the desired screen first in the list, check *the Default Window* option (see the figure in the previous chapter) and send the settings to the device.

Then the set screen is displayed automatically about 5 minutes after no one manipulates the buttons.



## 5.2.4 Actual & Average Data Groups



Actual / Average values of measured data in numeric form are displayed in the groups. 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.

At the end of the *Actual* data group there is :

- I/O actual data window. For detailed description see chapter *I/O Actual Data Presentation*.
- If a data from slave units are monitored with so called *Modbus Master* feature, another table with actual data measured by the slave units is displayed. For details see *Modbus Master Module* chapter further below.



## 5.2.5 Electricity meter

In this data group you can check active & reactive energies registered in all quadrants. Next, maximum values of average three-phase active power including time stamps – so called maximum demands. For details see the chapter *Embedded Electricity Meter*.



## 5.2.6 Oscillograms

At this group there are actual waveshapes of all measured voltages and currents. With the



you can toggle between voltage and current screen.

They are also displayed effective values of the voltages/currents and maximum of their peak values marked as Up/lp.

Fig. 5.6 : Voltage Waves

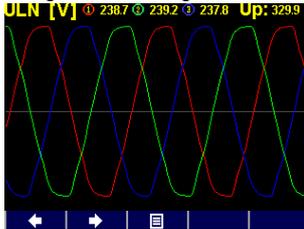


Fig. 5.7 : Current Waves



## 5.2.7 Phasor Diagram

Fig. 5.8 : Phasor Diagram



Diagram of actual voltage and current fundamental harmonic phasors.

Voltage phasor angles  $\varphi$  are absolute, current phasor angles are relative to appropriate voltage phasor ( $\Delta\varphi$ ).

Phase order can be checked here too (indicated as **1-2-3** or **1-3-2**).



## 5.2.8 Harmonics & THDs

Actual harmonic components of all voltage and current signals in graphic ( histogram ) format. They are expressed in per cent of fundamental harmonic component.

Only odd components from the 3<sup>rd</sup> to 25<sup>th</sup> are displayed; for full spectrum of harmonics use ENVIS-DAQ program.

In the upper right corner, there are values of THD of individual phases.

Fig. 5.9 : Voltage Harmonics

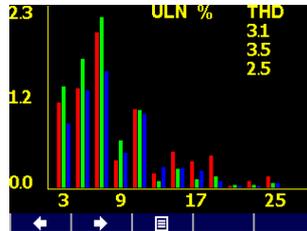
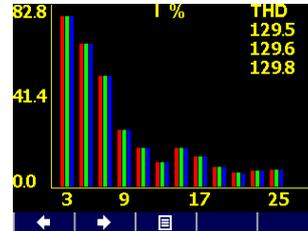


Fig. 5.10 : Current Harmonics



## 5.2.9 Power Quality & Voltage Events

This data group is available when appropriate firmware module is installed only.

On the first screen, there is “calendar” of power quality evaluation according the EN 50160 standard. Each day is marked with either or depending on that if power quality during the day was in compliance with the standard or not.

Next, there is the table of voltage events (VE). The events are sorted according magnitude and duration of each sag/swell/interruption and in the table you can check number of particular events registered since last clear. You can clear the VE-table in the PQ-setup screen.

Fig. 5.11 : Power Quality Calendar



Fig. 5.12 : Voltage Events Table

PQ - Voltage Events					
U<%	0.2	0.5	1	5	60s
90					
80					
70					
40	1				
5			1		
U>%	0.5	5	60s	Clear	
120				30.05.18	
110				15:23:02	

Detailed information of the PQ evaluation and the voltage events can be analyzed after downloaded into the ENVIS program.



## 5.2.10 Ripple Control Signal

This data group is available when appropriate firmware module is installed only.

At the screen you can check live graph of ripple control signal (mains signalling,  $U_{RC}$ ) of chosen frequency. At the example there is starting part of a telegram of frequency 183 Hz on the L1 phase ( $U_{RC1}$ ).

Fig. 5.13 : Ripple Control Signal Graph

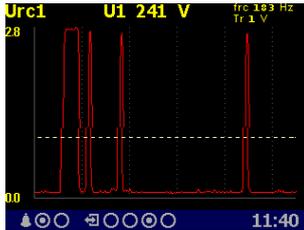


Fig. 5.14 : Ripple Control Signal DataTable

RCS			
Urc [V]	L1	L2	L3
act	3.6	3.6	3.6
avg	0.1	0.1	0.1
Last telegram L1			
avg1	3.7		
max1	3.9		
min1	3.5		
time	15.06.18 07:45:44		
frc=183.3Hz		Trig. Urc=1.0V	

With the and you can pass through all of phases measured. With the and you can toggle into the measured data table. There you can check :

- the upper part : actual and average (3 second floating window) values of the  $U_{RC1}$ ,  $U_{RC2}$ ,  $U_{RC3}$  ripple control signals
- the bottom part : average, maximum and minimum voltage of detected pulses (= when signal exceeds threshold  $U_{RCSTR}$ ) registered during the last telegram.

With the and you can scroll through all measured phases.

The  $f_{RC}$  frequency and the  $U_{RCSTR}$  threshold voltage can be set in the RCS-setup screen.



## 5.2.11 Instrument Settings ( Parameters )

In this group most of presetable parameters can be viewed and edited. Other parameters can be accessed via communication link using the ENVIS-DAQ 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.



### 5.2.11.1 Display Setting

- **Contrast** ... Can be set in range 0 – 100%
- **Brightness** ... The brightness is activated in case of pressing of any button. It will be retained for *the dimming time* after the last press of a button.
- **Dimmed Brightness** ... For the instrument power consumption reduction and the display lifetime extension, it is activated after the set *dimming time* without any button manipulation has elapsed,.
- **Dimming Time** ... Explained above.
- **Default Window** ... Automatic switch to the so-called *default window* after no button manipulation occurs (see the chapter *Default Window* above).
- **Language** ... In addition to the basic English version, other language versions can also be set.
- **Display refresh cycle** ... Actual values refresh period. For details see chapter *Display Actual Values Evaluation and Aggregation*.
- **Display Resolution** ... Actual & average data groups format be set to 3 or 4 significant figures.



### 5.2.11.2 Installation Setting

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



### 5.2.11.3 Remote Communication Setting

Communication parameters for various interface types differ from each other :

**COM (RS-485) interface :**

- **Communication Address**
- **Communication Rate** ...in Bauds (Bd)
- **Data Bits** ... including parity bits! Set to 8 for KMB-protocol; set to 9 when parity bit is used (Modbus-protocol, for example)
- **Parity** ...none/even/odd
- **Stop Bits** ... set to 1 (usually)

**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 (2101 as default)
- **Web-port** ... communication port used for webserver communication (80)
- **Modbus-port** ... communication port used for Modbus protocol communication (502)

Nex information can be found in chapter *Computer Controlled Operation* below.



### 5.2.11.4 Clock Setting

- **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-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. Time synchronization period is adjustable (15 minutes as default).
  - **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** !



### 5.2.11.5 Average Values Processing Setting

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



### 5.2.11.6 Embedded Electricity Meter Setting

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



### 5.2.11.7 Power Quality & Input/Output Setting

There are only overviews of parameters. To edit them, use the ENVIS-DAQ program.



You can only clear the voltage events table in the power quality setup group.



### 5.2.11.8 Ripple Control Signal Setting

- **Method** ... Method of the signal evaluation can be set either to *Filter* or in compliance with the *IEC61000-4-30* standard
- $f_{RC}$  ... frequency of the ripple control signal in Hz
- **$U_{RC}$  unit** ... ripple control voltage unit : either V or percent of  $U_{NOM}$
- **$U_{RC}$  threshold ( $U_{RC(CTR)}$ )** ... minimum signal level to be recognized as „pulse“. Relevant for telegram detection, signal below the threshold is recognized as „gap“.



## 5.2.12 Instrument Lock

To be protected against unauthorized changes or access, an instrument can be locked.

You can lock the instrument in two different ways :

- directly from the instrument panel
- via a communication link with the ENVIS-DAQ program using so called *user management setup* (see below)

The actual lock state is symbolized in *the main* menu by its icon :



- **Unlocked** – anyone with physical access to the instrument panel can freely set-up and configure all parameters in the instrument, clear archives and other persistent data or reset counters.



- **Locked** – a *password* (PIN) is required before any configuration change is requested.



*Exclusion : You can change the display setting group parameters even if the instrument is locked ! These are the only parameters that are free to change always.*

### 5.2.12.1 Locking from the Instrument Panel

To lock the instrument, simply switch in the **Menu-Lock** window the lock from  to . Then escape from the window with the  and confirm saving of changed state.

### 5.2.12.2 Unlocking from the Instrument Panel

To unlock the instrument, switch in **Menu -> Lock** the lock state back from  to  by entering a PIN.

When the instrument was locked from the instrument panel, the value of this PIN 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** .

When the instrument was locked by the user management, you need the PIN defined in the management (see below).

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



*Note, that unlocking **the user management locked state** from the instrument panel is **temporary** and the instrument will switch to the locked state automatically approx. 15 minutes after last pressing of any button. To unlock such instrument permanently, use the user management.*

### 5.2.12.3 Locking/Unlocking by the User Management

*Fig. 5.15 : User Management Locked Instrument*



With the user management you can use more complex and sophisticated access control to the instrument not only from the instrument panel, but from all of communication interfaces.

You can check if the user management lock is used in the **Menu -> Lock** screen – at least one additional parameter *user* is displayed.

In such case, the PIN described in the previous chapter is inapplicable and the PIN defined in the user management is necessary for unlocking. Furthermore, more users with their private PINs can be defined.

So, when you want to change anything from the instrument panel, you must :

1. choose the user (*Peter* in our example)
2. enter the PIN corresponding this user in the user management setup

For details see the application note No. 004 : *Users, passwords and PINs*.



*In case the PIN is lost, ask manufacturer for alternate PIN via manufacturer's website at [www.kmbystems.com](http://www.kmbystems.com) .*



## 5.2.13 Instrument Information

- **Instrument Model & Serial Number** ... Instrument hardware model & serial No.
- **Instrument Hardware, Firmware & Bootloader Versions** ... Instrument hardware & firmware specification.
- **Object** ... Measured node specification ( preset by ENVIS-DAQ 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 created as the sum of binary weights of the errors. The table below provides overview of them and recommended action.
- **Firmware Modules** ... list of installed firmware modules

Tab 5.3 : Instrument Errors

Error No. (weight)	Error	Action
1	RAM memory error	set the instrument (optimally with the ENVIS program, if possible) to the <i>default setting</i> ; if the error appears again send the instrument to a service organization for repair
2	instrument setup error	set the instrument (optimally with the ENVIS program, if possible) to the <i>default setting</i> ; if the error appears again send the instrument to a service organization for repair
4	calibration error	the instrument must be recalibrated – send to a service organization
8	wireless communication module error (Wifi/Zigbee)	send to a service organization
16	RTC error	in <i>the time setup window</i> (or better with the ENVIS program, if possible), set actual date&time; if the error appears again, check built-in backup battery; otherwise send the instrument to a service organization for repair
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
256	FLASH memory error	send to a service organization
512	display error	send to a service organization
1024	ETH-interface error	send to a service organization
2048	SD-card error	if indicated while a card inserted only, replace the card if indicated while the card ejected too, send to a service organization
4096	RTC-backup battery dead	send to a service organization for battery replacement

## 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 at the U1 voltage signal. It is measured continuously and evaluated every 10 seconds.

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  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 288/240 samples per mains cycle. The sampling rate is adjusted according to the frequency measured on voltage input **U1**. 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.

From the sampled signals, following quantities over the measurement cycle are evaluated (examples for phase No. 1) :

DC-component of phase voltage (mean value) :

$$U_{DC1} = \frac{1}{n} \sum_{i=1}^n U1i$$

AC-component of phase voltage (rms value) :

$$U1 = \sqrt{\frac{1}{n} \sum_{i=1}^n (U1i - U_{DC1})^2}$$

Line voltage (rms value of AC-component) :

$$U12 = \sqrt{\frac{1}{n} \sum_{i=1}^n ((U1i - U_{DC1}) - (U2i - U_{DC2}))^2}$$

Current (rms value of AC-component) :

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



*DC-component of the line voltage is not evaluated.*

*The instrument current inputs have an AC-coupling and do not allow the DC-component measurement.*

Meaning of the quantities :  
 i ..... sample index  
 n ..... number of samples per measurement cycle (2880)  
 $U_{i1}$ ,  $I_{i1}$  ... 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**.



*Measuring voltage inputs impedance is in range of units of  $M\Omega$ . 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 !*

At the star (wye, 3Y) connection, 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 current vectors  $I_1$ ,  $I_2$ ,  $I_3$  (Kirchhoff rule). The calculated current is referenced as  $I_{NC}$ .

If an instrument is equipped with four current inputs, the fourth current  $I_4$  is measured too. Then another current, referenced as  $I_{PEC}$ , is calculated as negative vector sum of current vectors  $I_1$ ,  $I_2$ ,  $I_3$ ,  $I_4$ .

At the Aron (3A) connection, the current  $I_2$  is not measured, but it is calculated as negative vector sum of current vectors  $I_1$  and  $I_3$ .

### 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 128<sup>th</sup>/120<sup>th</sup> order :  $U_{ih1}$ ,  $I_{ih1}$   
 ( i .... order of harmonic component )

Absolute angle of voltage harmonic component phasor :  $\varphi_{Uih1}$

Current harmonic component phasor angle relative to phasor  $U_{fh1}$  :  $\varphi_{lih1}$

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

Total harmonic distortion of voltage : 
$$THD_{U1} = \frac{1}{U_{1h1}} \sqrt{\sum_{i=2}^{40} U_{ih1}^2} * 100\%$$

Total harmonic distortion of current : 
$$THD_{I1} = \frac{1}{I_{1h1}} \sqrt{\sum_{i=2}^{40} I_{ih1}^2} * 100\%$$

### 5.3.1.4 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).

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

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

where : k ... harmonic order index, odd components only

N ... order of the highest harmonic component (128)

$U_{k,1}, I_{k,1}$  ... the  $k^{\text{th}}$  harmonic components of voltage and current (of phase 1)

$\Delta \varphi_{k,1}$  ... angle between the  $k^{\text{th}}$  harmonic components  $U_{k,1}, I_{k,1}$  (of phase 1)

(these harmonic components of U and I are evaluated from each measurement cycle)

$$\text{Apparent power : } S_1 = U_1 * I_1$$

$$\text{Distortion power : } D_1 = \sqrt{S_1^2 - P_1^2 - Q_1^2}$$

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

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

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

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

$$\text{Three-phase distortion power : } 3D = \sqrt{3S^2 - 3P^2 - 3Q^2}$$

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

Fundamental harmonic component quantities :

$$\text{Fundamental harmonic power factor : } \cos \Delta \varphi_1 \quad (\text{or } \tan \Delta \varphi_1, \Delta \varphi_1)$$

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

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

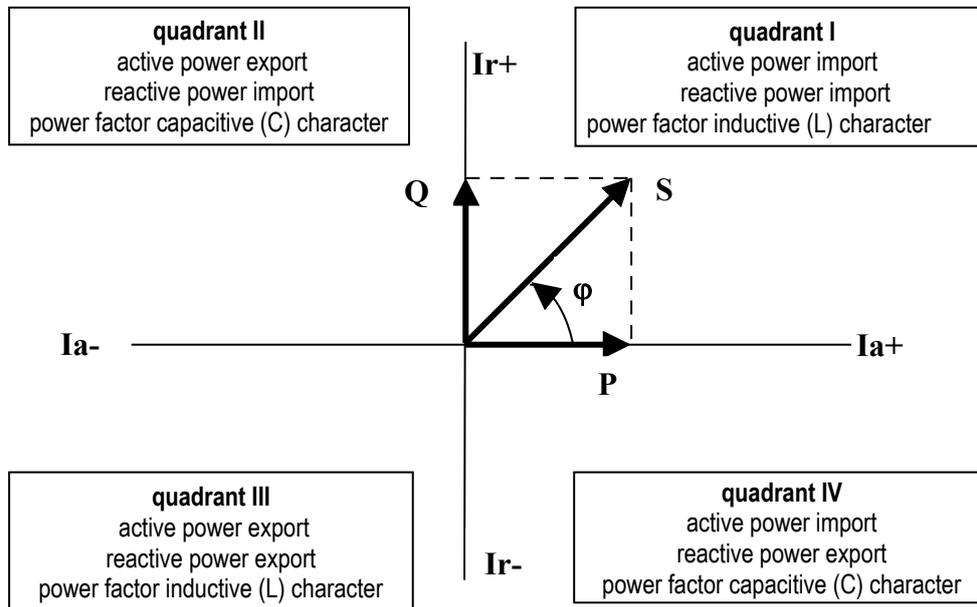
$$\text{Fundamental harmonic three-phase active power : } \sum Pfh = Pfh_1 + Pfh_2 + Pfh_3$$

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

Fundamental harmonic three-phase power factor : 
$$\sum \cos\Delta\varphi = \cos\left(\arctg\left(\frac{\sum Q_{fh}}{\sum P_{fh}}\right)\right)$$

Powers and power factors of the fundamental harmonic component ( $\cos \varphi$ ) are evaluated in 4 quadrants in compliance with the standard IEC 62053 – 23, appendix C :

Fig. 5.20 : 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 –  $\cos \varphi$  – 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 )

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

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

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

Current negative sequence angle :  $\varphi_{nsI}$

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

### 5.3.1.5 Temperature

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

## 5.3.2 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.

### 5.3.2.1 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. 5.21 : Actual Data  
Display Refresh Cycle



Fig. 56.22 : 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  $\cos\phi$  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.*

### 5.3.2.2 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 0.2 second to 1 hour

When **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 **floating window** is set, the exponential moving average is evaluated.

Average values processing can be set independently for so called **U/I** -group, **P/Q/S** -group and optionally for the **RCM**-group of quantities.. Following table lists processed quantities of all of groups.

Tab. 5.5 : Average Values Groups

Average values group	Averaged quantities
“ U / I ”	U <sub>LL</sub> , U <sub>LN</sub> , I, f, T
“ P / Q / S ”	P, Q, S, PF, Pfh, Qfh, cosφ
“ RCM ”	IΔ (residual currents)



After the average parameters set, evaluation of average values starts from beginning. The average values are temporary not available until the first averaging window expires.



Preset averaging parameters noted above are valid for so called standard average values. For the maximum power demand **MD** in the Electricity Meter group, separate parameter is used (see below).

### 5.3.2.2.1 Maximum and Minimum Average Values

Maximum and minimum values of average values are registered into the instrument's memory, including the date & time of their occurrence.

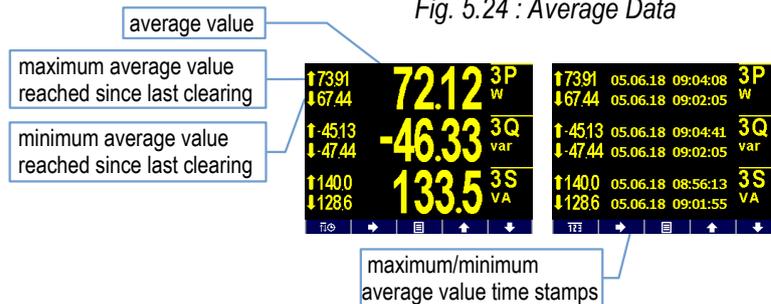
The maximums&minimums are displayed on the left side of average values window - maximum value is identified with the ↑ symbol and minimum value with the ↓ symbol.

To view their time stamps, press the

Fig. 5.23 : Average Data Processing Setting



Fig. 5.24 : Average Data



The maximum and minimum registered values can be cleared either manually or automatic clearing can be set.

To clear the values manually, navigate to appropriate average group setup screen and use **Clear** option. At this screen last clear date can be checked too.

To activate automatic clearing of maximums/minimums of average values, set the automatic clear period.



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



After clearing of registered average maxima/minima, evaluation of appropriate average values starts from beginning. After that, both the average values and their registered maximums/minimums are temporary not available until new averaging window expires.



For manual clearing of registered average maxima/minima so called „Clear“ user screen can be used. See Main Data Group chapter for details.

### 5.3.2.3 Recorded Values Aggregation

All of measured and evaluated data can be optionally archived into the instrument's memory. The record period is presettable in a wide range and aggregated data are archived.

The shortest aggregation interval is 0.2 s while the longest configurable interval is 2 hours. If aggregation interval below 1 minute is selected then evaluation is aggregated according to cycle count at actual frequency. For intervals longer than one minute the aggregation is carried out 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.

## 5.3.3 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.

### 5.3.3.1 Electric Energy Processing

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

In addition, 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.

The 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.



#### 5.3.3.1.1 Standard Energy Presentation

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

As default , so called **2Q** branch is displayed (at the left on the map). The 1<sup>st</sup> screen shows actual three-phase energies registered since last clearing up to now for all tariff zones ( **ΣT** ) :

- **3EP+** ... imported active energy
- **3EP-** ... exported active energy
- **3EQL** ... imported reactive energy ( inductive, **L** )
- **3EQC** ... exported reactive energy ( capacitive, **C** )

Scrolling down, individual phase energies can be checked too.

Navigating to the right you get into the **4Q/T** branch. This presentation brings individual reactive energies registered during active power import and export, that can be useful especially for monitoring of renewable sources. For example :

- **3EQL+** ... registered, when three-phase active power **3P** is positive (+ = import)
- **3EQL-** ... registered, when three-phase active power **3P** is negative (- = export)

Scrolling down you can check these energies registered in individual tariff zones **T1**, **T2** and **T3**.

Finally, at the right branch **4Q/L** you can browse through energies of individual phases **L1**, **L2**, **L3** (for all three tariff zones).

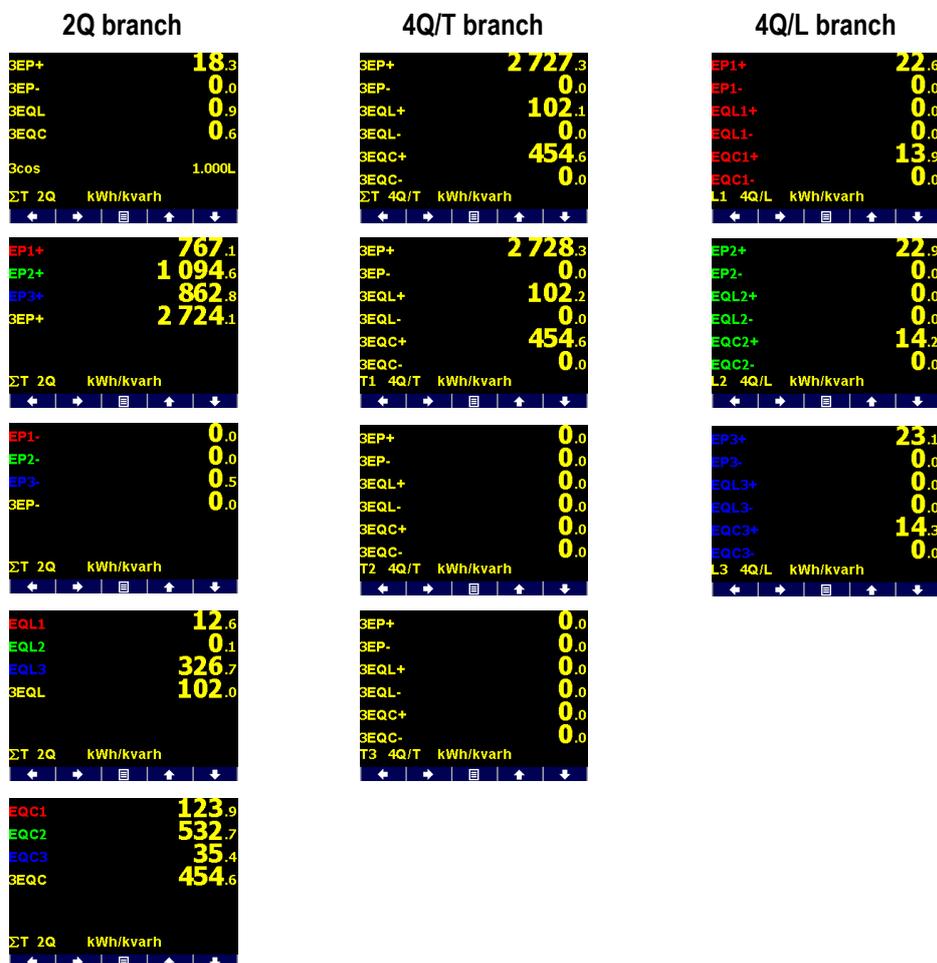
Tariff zones can be set via a communication link using the program ENVIS-DAQ.

Energy counters can be cleared either manually or with a remote PC. Manual clearing can be invoked by the **Clear** option in the electricity meter setup screen. There you can check time & date of the previous clearing too.



For manual clearing of the energy counters, so called „Clear“ user screen can be used. See Main Data Group chapter for details.

Fig. 5.28 : Electricity Meter Screen Map



### 5.3.3.1.2 Customizable Energy Screen

With the ENVIS-DAQ program you can add special user configurable electricity meter screen into the main data group. In the screen you can choose not only energies you are interested in, but processing period too.

The processing period can be selected from :

- **Actual** ... energies registered since the last clearing
- **This Month/Week** ... energies registered during present month/week
- **Last Month/Week** ... energies registered during last month/week
- **Bookmark** ... energies registered since defined date & time (=bookmark)

For example, when you are interested in imported three-phase active energy registered since 11 o'clock of 5<sup>th</sup> June 2018, create such custom screen in the ENVIS-DAQ program, choose evaluation period to *bookmark* and set its date & time. Then desired screen appears in the main data group.

Fig. 5.29 : Electricity Meter Setting

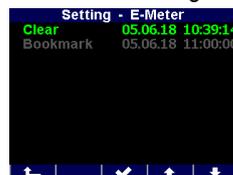
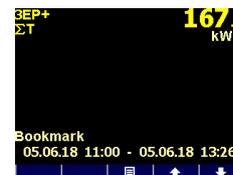


Fig. 5.30 : Custom Electricity Meter Screen with Bookmark



When you set the processing period, note that energies evaluated in this screen are calculated according values stored in the electricity meter archive. If such record is not stored in the archive, the evaluated energies can be false. To get correct values, the electricity meter archive recording must be set appropriately and the archive must be filled with sufficient depth of data. Attention must be paid whenever the electricity meter archive is cleared!

### 5.3.3.1.3 Recorded Values of Energy Aggregation

All of electricity meter readings can be optionally archived into the separate archive. Use the ENVIS-DAQ for the electricity meter archive setup.

You can set *the record period* that defines how often the electricity meter state is stored into the memory. Minimum record period is 1 minute. The electricity meter history can be later downloaded into a PC and analysed.

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

### 5.3.3.2 Maximum Demand Processing

From the instantaneous measured values of all active powers the instrument evaluates their average values per preset period using preset averaging method. Such quantities are called *actual demands* (**AD**). Note that the actual demands are processed individually and their averaging method & period are presettable independently on standard average values ( $P_{AVG}$ ).

Their maximum values reached since the last clearing or during *the MD evaluation interval*, are called *maximum demands* (**MD**).

Fig. 5.31 : Maximum Demand Setting



Parameters determining maximum demand processing can be set in the **Setting – AVG – MD** screen. As default, *the floating window averaging method* is set.

The demand registered since the last clearing is marked simply **MD**. The demands registered during *the MD evaluation interval*, are marked with additional appropriate index X - see below.

The MD evaluation interval can be set in range 1 day up to 1 year.

The maximum demands are stored including their time stamps. They can be cleared independently of standard average maximums & minimums. Time & date of the last clearing can be checked in the MD-

setting screen.



After the MD average parameters set or registered MD values cleared, evaluation of demands starts from beginning. The demand values are temporary not available until the first averaging window expires.

### 5.3.3.2.1 Fixed Window MD Processing, Last Demand and Estimated Demand

If the maximum demand averaging mode is set to the *fixed window* method, evaluation of the **AD** is different from that of floating window. Auxiliary energy buffer is cleared at the beginning of every averaging window and starts to count from zero. So average power that is calculated from energy registered in the buffer divided by averaging window length drops to zero periodically, then raises and reaches true average power at the end of the averaging interval only.

Then other demands can be useful :

- **LD** ... last demand = value of the **AD** (actual demand =average active power) at the end of previous averaging window. The value is displayed including its time stamp, that corresponds to the end of the window
- **ED** ... estimated demand = estimated value of the **AD** (actual demand =average active power) that should be reached at the end of current averaging window



If the maximum demand averaging mode is set to the *floating window* method, the **LD** and **ED** values are irrelevant (contains only copies of the **AD** quantities).

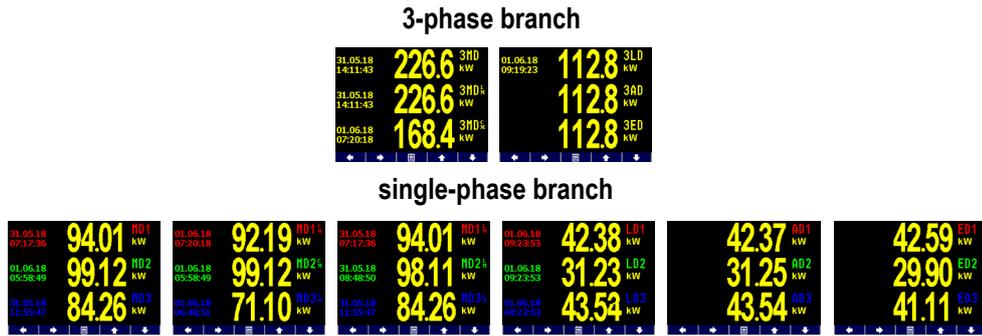
### 5.3.3.2.2 Maximum Demand Presentation

While in the electricity meter energy window you can switch down to the maximum demand windows.

The first branch has two screens only and comprises three-phase values :

- **3MD** ... maximum demand = maximum of **3AD** reached since the last clearing
- **3MD<sub>Lx</sub>**, **3MD<sub>Cx</sub>** ... maximums of the **3AD** reached during the last (**L**) and current (**C**) evaluation interval. The "X"-index depends on *the MD evaluation interval* preset value : D=day, W=week, M=month, Q=quarter, Y=year.
- **3AD**, **3LD**, **3ED** ... actual / last / estimated demand

Fig. 5.32 : Maximum Demand Screen Map



Scrolling down you get into the single-phase branch of the maximum demand values. You can check individual phase demands here.

## 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 software 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 (connectors „A“+„B“).

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.

##### 6.1.2.1 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+** (No. 41), **B-** (42), **G** (43).

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

A USB/485 level converter must be installed on the computer side. For suitable converters see optional accessory list.

### 6.1.2.1.1 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.

Recommended wire type: shielded double twisted pair 2 x 2 x 0.2 mm<sup>2</sup>, for example Belden 9842 or Unitronic Li2YCY (Lappkabel)

Recommended minimum conductor cross-section : 0.2 mm<sup>2</sup>

Maximum conductor cross-section : 2.5 mm<sup>2</sup>

### 6.1.2.1.2 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.

### 6.1.2.2 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.

### 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 the figure.

Fig. 6.1 : Webserver

The screenshot displays the KMB Systems webserver interface. The top navigation bar includes: Actual Data, Oscilograms, Harmonics, Electricity Meter, Configuration, Operating Manual, and KMB systems. The main content is divided into two sections:

### Printing House - Actual Data

Object	Record Name	Instrument Model	Serial Number	FW Version	IP Address
Printing House	Main Switchboard	SMC 144	66	2.0.15.3521	10.0.0.108

Voltages, Currents				
Quantity \ Phase	L1	L2	L3	L4
U <sub>L1</sub> [V]	410.5	413.8	409	
U <sub>L2</sub> [V]	233.4	237.1	241	
I [A]	13.6	11.0	6.2	

Active, Reactive and Apparent Power				
Quantity \ Phase	L1	L2	L3	L4
P [kW]	2.56	2.11	1.4	
Q [kvar]	1.64	1.46	0.2	
S [kVA]	3.17	2.60	1.5	
PF [ ]	0.8	0.8	0.1	

Fundamental Power and Distortion Power				
Quantity \ Phase	L1	L2	L3	L4
P <sub>FM</sub> [kW]	2.57	2.11	1.4	
Q <sub>FM</sub> [kvar]	1.65	1.47	0.2	
D [kVA]	0.90	0.40	0.4	
cosφ [ ]	0.84L	0.82L	0.9	

Miscellaneous			
Frequency [Hz]	Voltage Unbalance [%]	Current Unbalance [%]	Overflow flag
49.991	1.61	26.94	

### PPHU AGG - PFC Status

Object	Record Name	Instrument Model	Serial Number	FW Version	IP Address
PPHU AGG	PPHU AGG	Novar 2618T	365	2.0.23.3739	192.168.147.9

PFC Outputs									
Output Number	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
Type	C1	L1	C1	C1	C2	C2	C2	C2	C2
State	OFF	ON	OFF	OFF	OFF	ON	OFF	ON	OFF
Output Number	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
Type	C2	C3	C3	C3	C3	L1	0	0	0
State	OFF	ON	ON	ON	OFF	ON	OFF	OFF	OFF

Fundamental Power and Power Factor				
Phase	L1	L2	L3	ΣL
P <sub>FM</sub> [kW]	1.07	0.30	1.58	2.95
Q <sub>FM</sub> [var]	78.0	105.3	301.1	484.4
ΔQ <sub>FM</sub> [var]	-139.6	44.0	-19.0	-114.6
cosφ [ ]	1.00L	0.94L	0.98L	0.99L

Alarms			
U<<	I<<	PF>>	NS>

Instrument State	
C.T.: 0s	

### Printing House - Oscilograms

Object	Record Name	Instrument Model
Printing House	Main Switchboard	SMC 144

Voltage				
Phase	L1	L2	L3	L4
U <sub>RMS</sub> [V]	233.4	236.0	241.3	0.0
THD <sub>v</sub> [%]	2.8	2.6	2.6	---

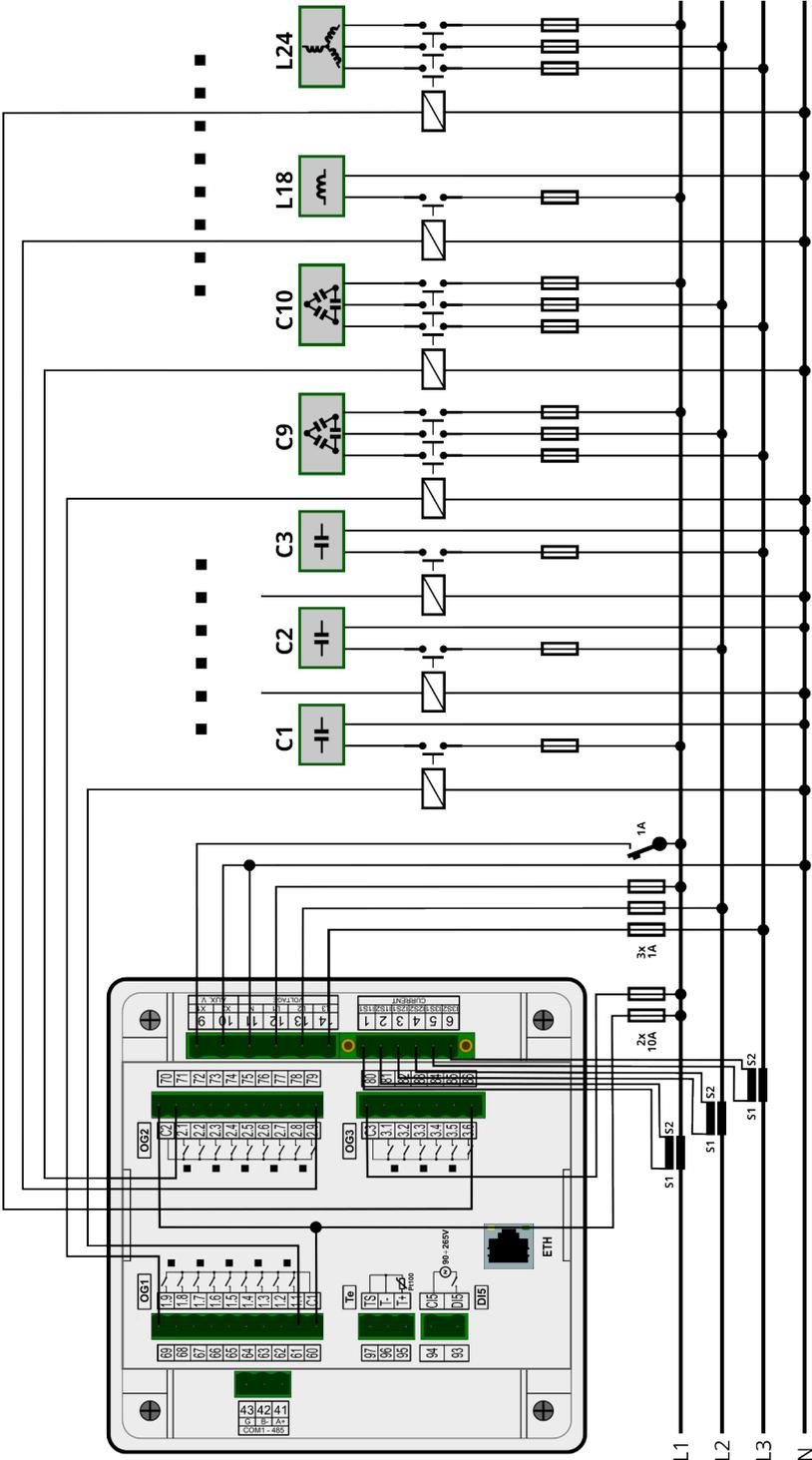
Current				
Phase	L1	L2	L3	L4
I <sub>RMS</sub> [A]				
THD <sub>i</sub> [%]				

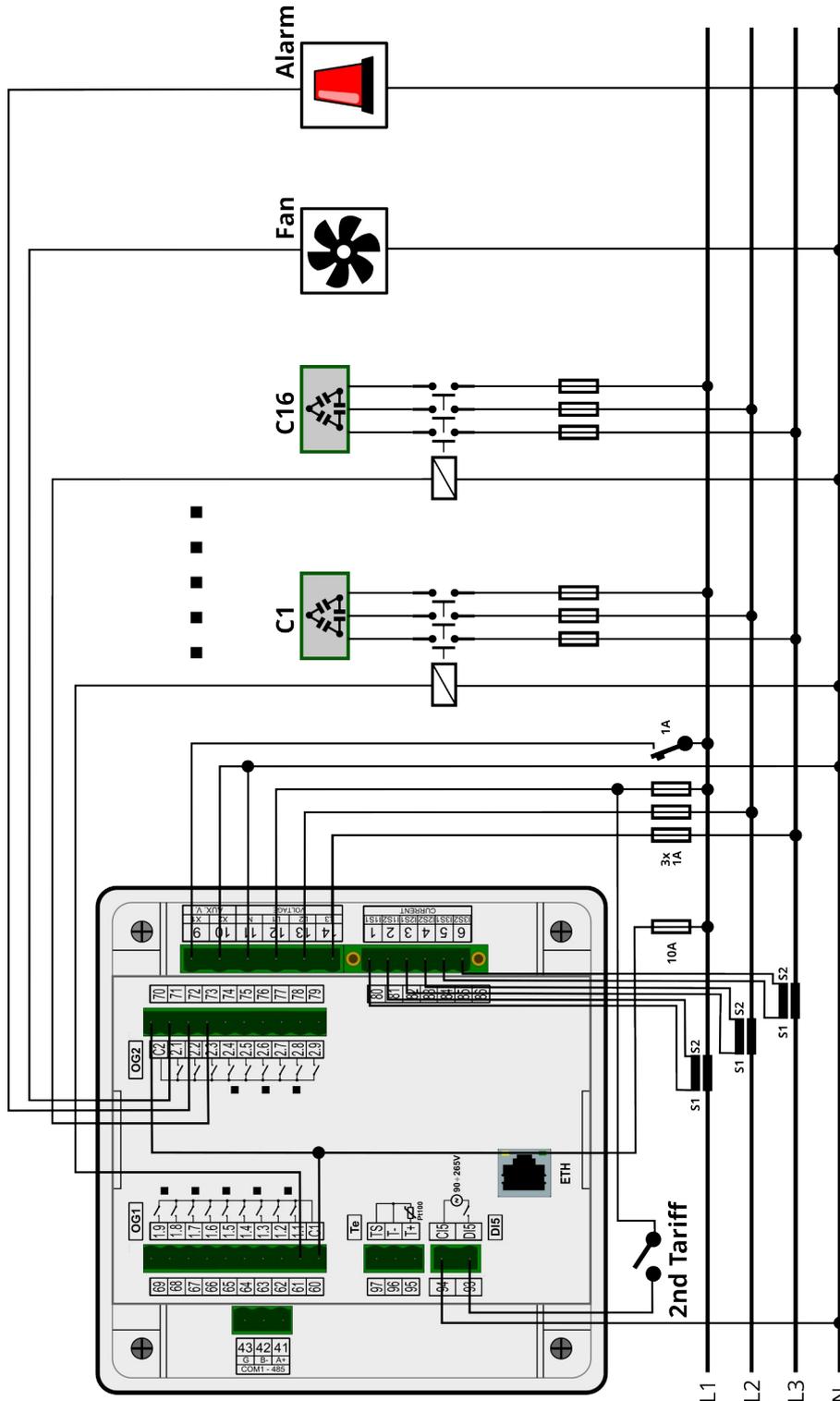
Two oscilogram plots are shown. The left plot displays three-phase voltage waveforms (U1, U2, U3) with a legend below. The right plot displays three-phase current waveforms (I1, I2, I3) with a legend below.

# 7. Examples of Connections

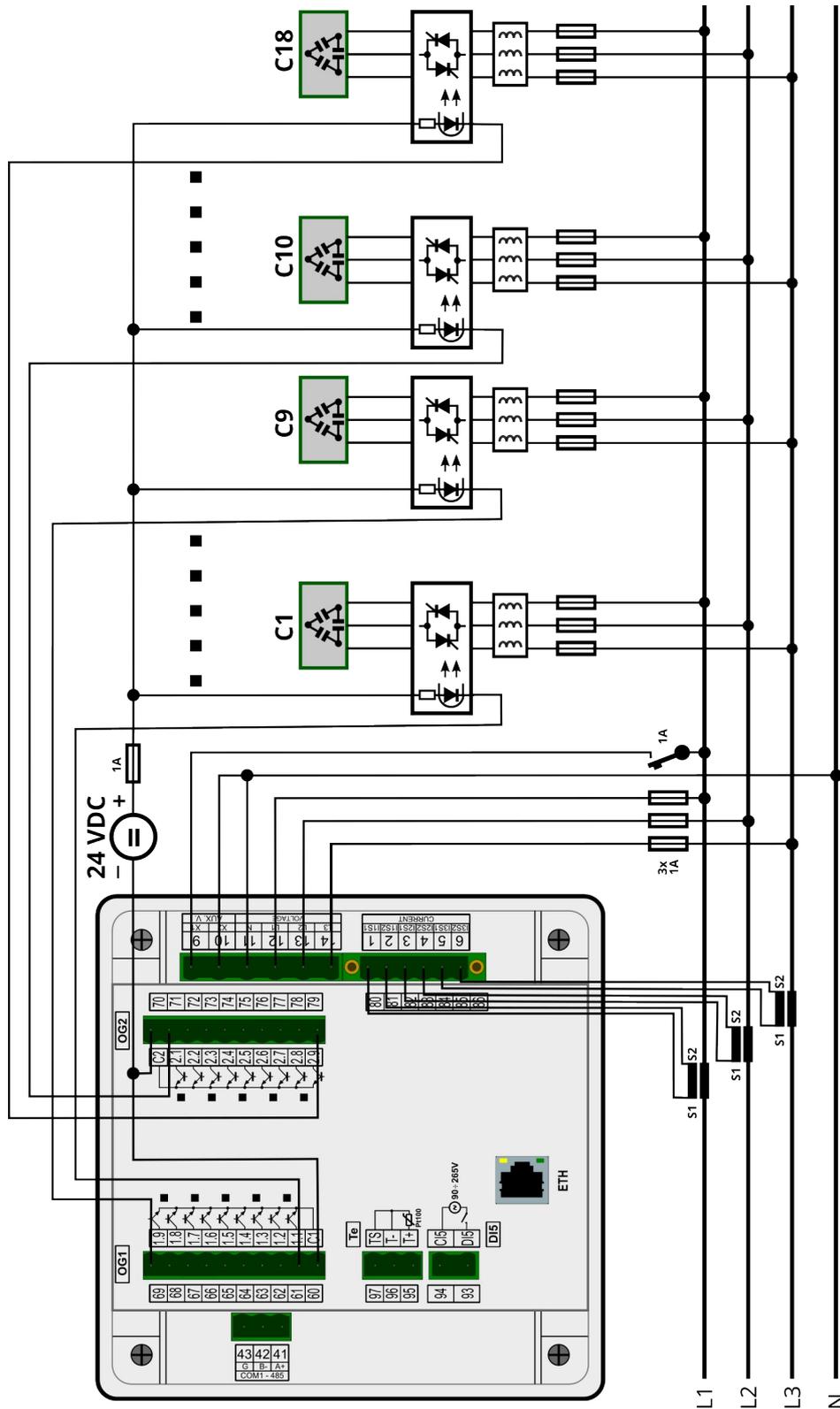
## NOVAR 2700 R24 H T E4 – Typical Installation TN-Network, Direct Star (“3Y”) Connection 24 Contactors



## NOVAR 2700 R18 H T E4 – Installation TN-Network, Direct Star (“3Y”) Connection 16 Contactors, 2<sup>nd</sup> Tariff Control, Fan, Alarm



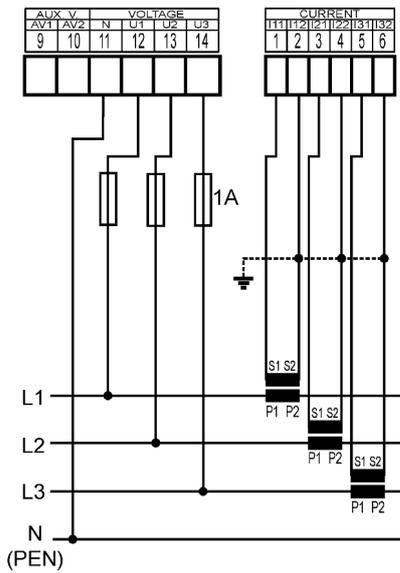
## NOVAR 2700 T18 H T E4 – Installation of Outputs Example 18 Solid State Modules



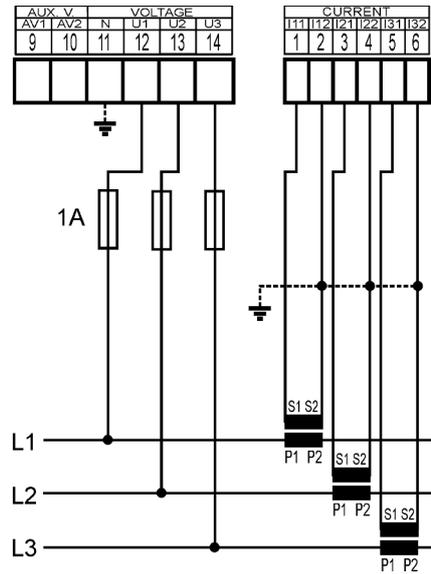
# NOVAR 2700 – Measured Signal Connection Examples

## Three-Phase Connections

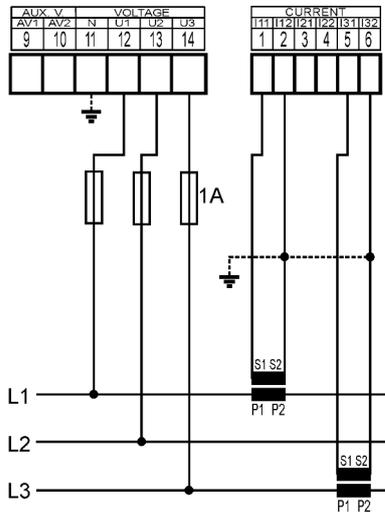
*TN Network  
Direct Star (“3Y”) Connection*



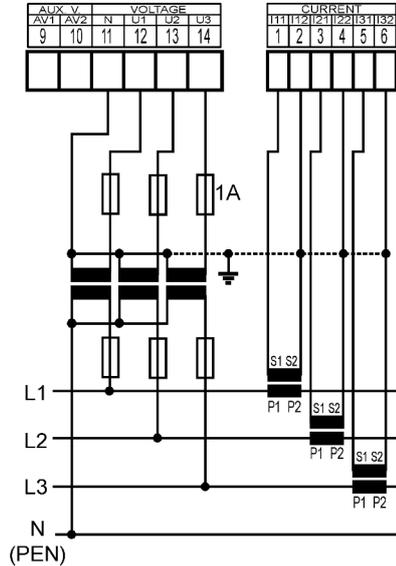
*IT Network  
Direct Delta (“3D”) Connection*



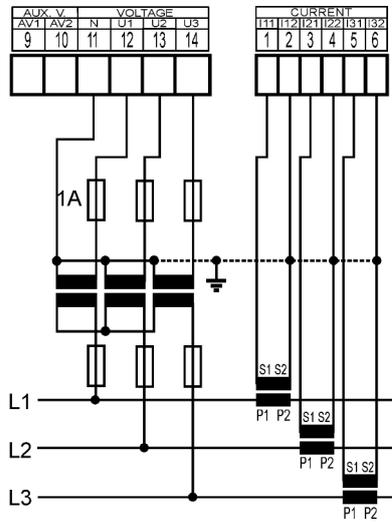
*IT Network  
Direct Aron (“3A”) Connection*



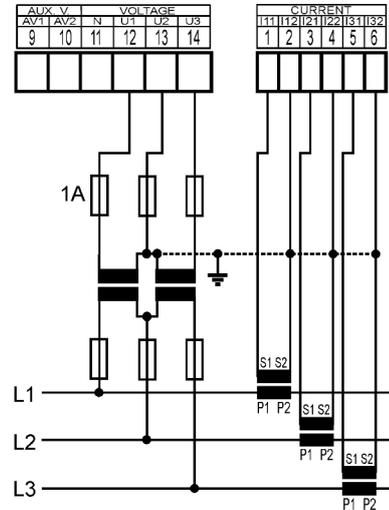
*TN Network  
Star (“3Y”) Connection via VT*



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

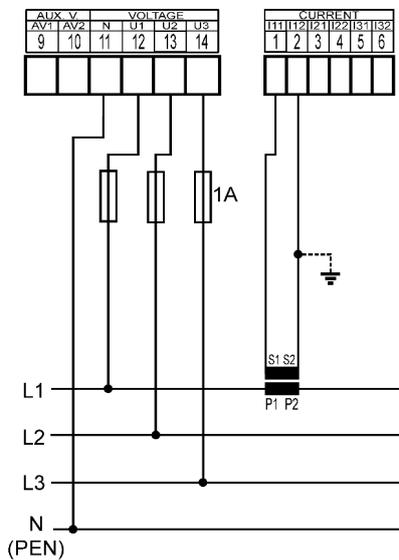


*IT Network  
Delta (“3D”) Connection via VT  
(VT to Line-to-Line Primary Voltage)*

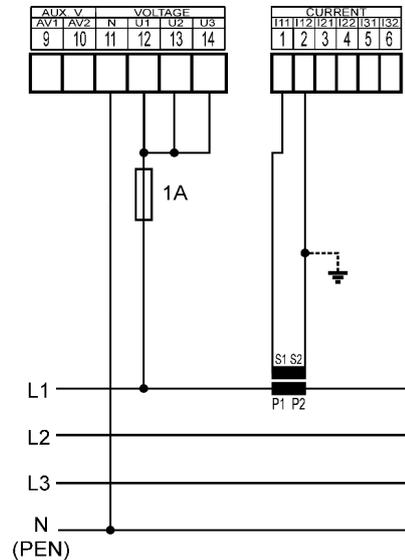


### Single-Phase Connections to Three-Phase Networks

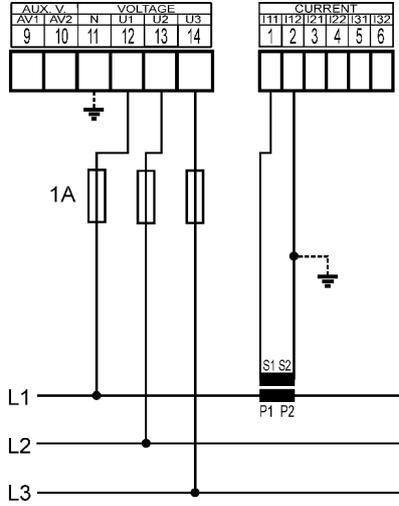
*TN Network  
1Y3 Connection Type  
(recommended wiring)*



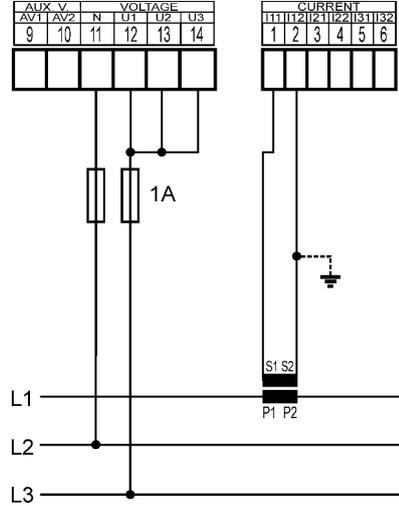
*TN Network  
1Y3 Connection Type*



*IT Network  
1Y3 Connection Type*

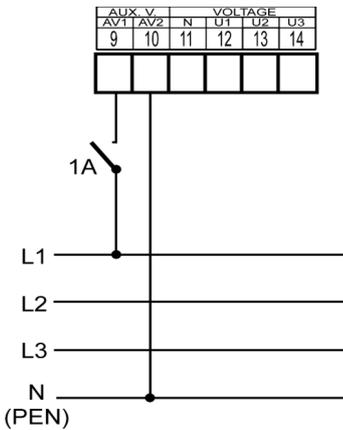


*IT Network  
1D3 Connection Type*

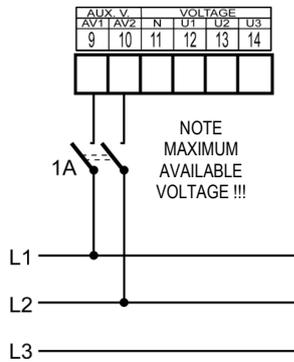


## NOVAR 2700 xxx H – Power Supply Options

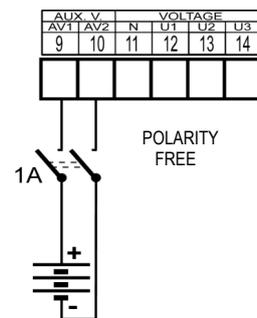
*Line-to-Neutral Voltage  
AC Power Supply*



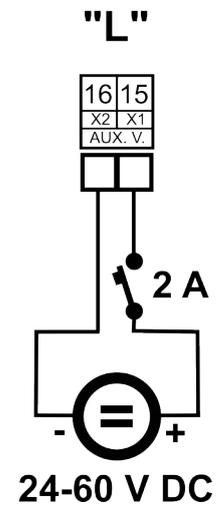
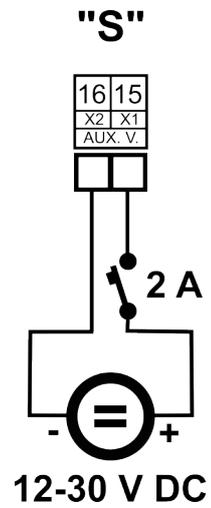
*Line-to-Line Voltage  
AC Power Supply*



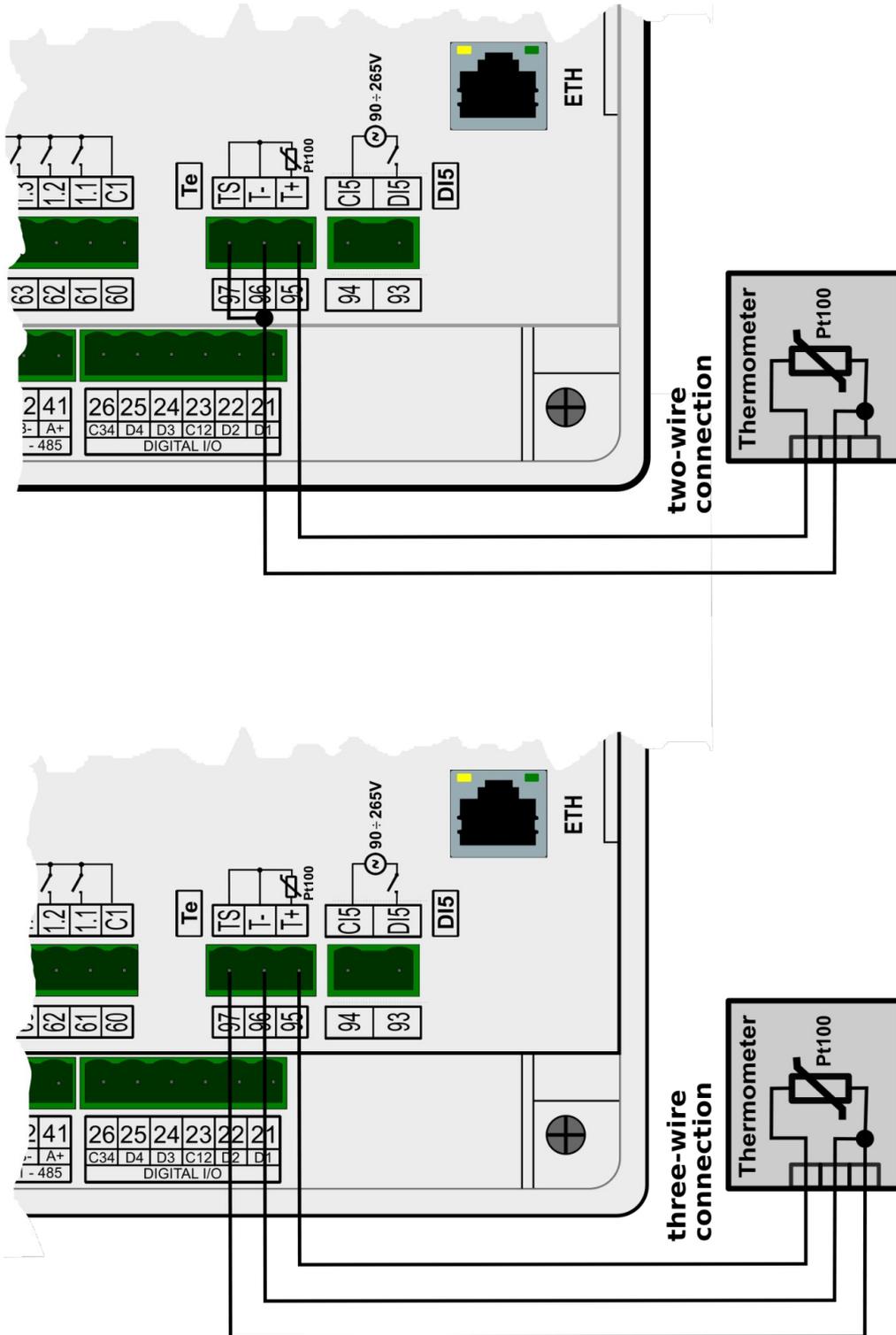
*DC Power Supply*



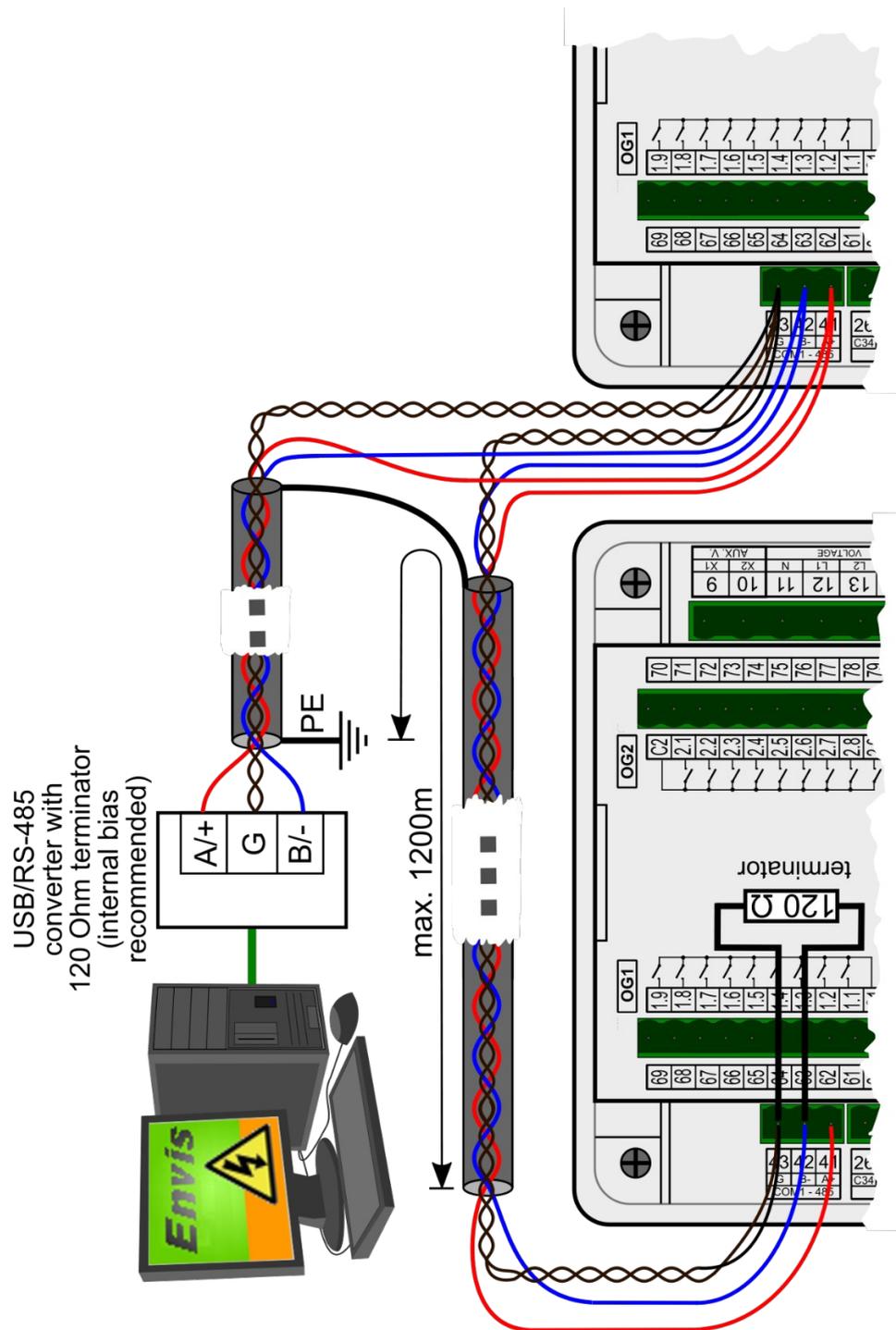
## NOVAR 2700 xxx S/L – Power Supply Connection



# NOVAR 2700 Rxx T – Pt100 Thermometer Connection



## NOVAR 2700 Rxx 4 – RS485 Remote Communication Connection



## 8. Manufactured Models and Marking

	<b>NOVAR 2700</b>	<b>R18</b>	<b>H</b>	<b>T</b>	<b>E4</b>
<b>Instrument class</b>	NOVAR 2700 = 3-ph PF controller, 144x144mm, 512MB memory, LCD				
<b>Outputs</b>	R09 = 9 relay outputs R24 = 24 relay outputs T18 = 9 transistor outputs T24 = 24 transistor outputs				
<b>Auxiliary supply voltage</b>	H = 100 V - 415 VAC, 90 V - 600 VDC S = 12 - 24V DC				
<b>Other peripherals</b>	T = PT100 + digital input				
<b>Remote communication interface + inputs</b>	E4 = USB, Ethernet, RS-485				

## 9. Technical Specifications

Instrument Auxiliary Power Supply Voltage			
model	„H“	„L“	„S“
rated aux. voltage range AC: $f=40\div 100$ Hz; DC	100 – 415 V <sub>AC</sub> 100 – 500 V <sub>DC</sub>	48 V <sub>AC</sub> 24 – 60 V <sub>DC</sub>	24 V <sub>AC</sub> 12 – 30 V <sub>DC</sub>
aux. voltage range AC: $f=40\div 100$ Hz; DC	75 – 500 V <sub>AC</sub> 75 – 600 V <sub>DC</sub>	40 – 53 V <sub>AC</sub> 20 – 75 V <sub>DC</sub>	20 – 27 V <sub>AC</sub> 10 – 36 V <sub>DC</sub>
power supply	20 VA / 8 W		
overvoltage category	300 V CAT III 600 V CAT II	150 V CAT III	
pollution degree	2		
maximum operating altitude	2000 m		
connection	isolated, polarity free		

Voltage characteristics	
<b>Frequency</b>	
$f_{NOM}$ – nominal frequency	50 / 60 Hz
measuring range	40 – 70 Hz
uncertainty	$\pm 10$ mHz
<b>Voltage</b>	
$U_{NOM}$ ( $U_{DIN}$ )– rated voltage	57.7 – 415 V <sub>AC</sub>
crest factor at $U_{NOM}$	2.2
measuring range (line-to-neutral)	2 – 650 V <sub>AC</sub>
measuring range (line-to-line)	3.5 – 1120 V <sub>AC</sub>
measurement category	300 V CAT IV, 600 V CAT III
permanent overload	1200 V <sub>AC</sub> ( $U_{L-N}$ )
peak overload, 1 second	2000 V <sub>AC</sub> ( $U_{L-N}$ )
burden power ( impedance)	$< 0.05$ VA ( $R_i = 6$ M $\Omega$ )
<b>Voltage Unbalance</b>	
measuring range	0 – 10 %
measuring uncertainty	$\pm 1.0$
<b>THDU</b>	
measuring range	0 – 20 %
measuring uncertainty	$\pm 1.0$
<b>Harmonics up to 128th order (120th order @ 60 Hz)</b>	
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

<b>Measured Quantities – Current</b>	
<b>Current</b>	
$I_{NOM}$ ( $I_B$ ) – rated (basic) current	1 – 5 $A_{AC}$
crest factor at $I_{NOM}$ ( $I_B$ )	11.3
measuring range	0.001 – 7.5 $A_{AC}$
measurement category	150 V CAT III
permanent overload	8 $A_{AC}$
peak overload 1 second, maximum repetition frequency > 5 minutes	70 $A_{AC}$
burden power ( impedance)	< 0.5 VA ( $R_i < 10m\Omega$ )
<b>Current Unbalance</b>	
measuring range	0 – 100 %
measuring uncertainty	$\pm 1$ % of rdg or $\pm 0.5$
<b>Harmonics &amp; Interharmonics up to 128th order (120th order @ 60 Hz)</b>	
reference conditions	other harmonics 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	$I_h \leq 10\% I_{NOM} : \pm 1\% I_{NOM}$ $I_h > 10\% I_{NOM} : \pm 1\% \text{ of rdg}$
<b>THDI</b>	
measuring range	0 – 200 %
measuring uncertainty	THDI $\leq 100\% : \pm 0.6$ THDI $> 100\% : \pm 0.6$ % of rdg

<b>Measured Quantities – Temperature</b>	
<b>Temperature – Internal (internal sensor, affected by the instrument power dissipation)</b>	
measuring range	- 40 – 80 °C
measuring uncertainty	$\pm 2$ °C
<b>Temperature - External (external Pt100 temperature sensor input)</b>	
measuring range	- 50 – 150 °C
measuring uncertainty	$\pm 2$ °C (three-wire connection)

<b>Measured Quantities – Power, Power Factor, Energy</b>	
<b>Active / Reactive Power, Power Factor (PF), <math>\cos \varphi</math> ( <math>P_{NOM} = U_{NOM} \times I_{NOM}</math> )</b>	
reference conditions “A” : ambient temperature ( $t_A$ ) U, I for active power, PF, $\cos \varphi$ for reactive power	$23 \pm 2 \text{ }^\circ\text{C}$ $U = 80 - 120 \% U_{NOM}, I = 1 - 120 \% I_{NOM}$ $PF = 1.00$ $PF = 0.00$
act. / react. power uncertainty	$\pm 0.5 \% \text{ of rdg } \pm 0.005 \% P_{NOM}$
PF & $\cos \varphi$ uncertainty	$\pm 0.005$
reference conditions “B” : ambient temperature ( $t_A$ ) U, I for active power, PF, $\cos \varphi$ for reactive power	$23 \pm 2 \text{ }^\circ\text{C}$ $U = 80 - 120 \% U_{NOM}, I = 1 - 120 \% I_{NOM}$ $PF \leq 0.87$ $PF \leq 0.87$
act. / react. power uncertainty	$\pm 1 \% \text{ of rdg } \pm 0.01 \% P_{NOM}$
PF & $\cos \varphi$ uncertainty	$\pm 0.005$
temperature drift of powers	$\pm 0.05 \% \text{ of rdg } \pm 0.02 \% P_{NOM} / 10 \text{ }^\circ\text{C}$
<b>Energy</b>	
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 0.5S acc. to EN 62053 – 24

Function characteristics according to IEC 61557-12 ed.2				
Symbol	Function	Class	Measuring range	Note
$P$	total effective power	0.5	0 – 14625 W	
$Q_A, Q_V$	total reactive power	0.5	0 – 14625 var	
$S_A, S_V$	total apparent power	0.5	0 – 14625 VA	
$E_a$	total active energy	0.5	0 – 14625 Wh	
$E_{rA}, E_{rV}$	total reactive energy	0.5	0 – 14625 varh	
$E_{apA}, E_{apV}$	total apparent energy	0.5	0 – 14625 Vah	
$f$	frequency	0.02	40 – 70 Hz	
$I$	phase current	0.5	0.001 – 7.5 A <sub>AC</sub>	
$I_N$	neutral current measured	0.5	0.001 – 7.5 A <sub>AC</sub>	
$I_{Nc}$	neutral current calculated	0.5	0.001 – 22.5 A <sub>AC</sub>	
$V$	line-to-neutral voltage	0.5	2 – 650 V <sub>AC</sub>	
$U$	line-to-line voltage	0.5	3.5 – 1120 V <sub>AC</sub>	
$PF_A, PF_V$	power factor	0.5	0 – 1	
$P_{stj}, P_{ft}$	flicker	5	0.4 – 10	1, 2)
$V_{dip}$	voltage dips	0.5	2 – 415 V <sub>AC</sub>	2)
$V_{swl}$	voltage swells	0.5	57.7 – 650 V <sub>AC</sub>	2)
$V_{tr}$	transients overvoltage	–	–	
$V_{int}$	voltage interruption	0.5	2 – 22 V <sub>AC</sub>	2)
$V_{nba}$	voltage unbalance (amp.)	1	0 – 10 %	3)
$V_{nb}$	voltage unbalance (ph.&amp;.)	1	0 – 10 %	
$V_h$	voltage harmonics 50 Hz (60 Hz)	2	up to 128th (120th) order	1)
$THD_V$	voltage total harmonic distortion (rel. to fund.)	1	0 – 20 %	1)
$THD-R_V$	voltage total harmonic distortion (rel. to RMS)	1	0 – 20 %	1, 3)
$I_h$	current harmonics 50 Hz (60 Hz)	2	up to 128th (120th) order	1)
$THD_I$	current total harmonic distortion (rel. to fund.)	1	0 – 200 %	1)
$THD-R_I$	current total harmonic distortion (rel. to RMS)	1	0 – 200 %	1, 3)

Notes : 1) ... according to IEC 61000-4-7 ed.2.0, IEC 61000-4-15 ed.2.0

2) ... with optional firmware module „PQ S

3) ... value available in the ENVIS program only

Instrument characteristics according to IEC 61557-12 ed.2	
power quality assessment function	PQI-S
classification according to par. 4.3	
direct voltage connection	SD
voltage connection via VT	SS
temperature according to par. 4.5.2.2	K55
humidity + altitude according to par. 4.5.2.3	< 95 % - noncondensation conditions < 2000 m
active power/energy function performance class	0.5

Digital Outputs & Digital Inputs	
voltage loss & ext. alarm response time (output disconnect.)	$\leq 20$ ms
„R“-type Outputs (relay)	
type	N.O. contact
load rating	250 V <sub>AC</sub> / 30 V <sub>DC</sub> , 4 A
„D“-type Outputs (solid state, opto-MOS)	
type	opto-MOS, bipolar
load rating	60 V <sub>AC</sub> / 100 V <sub>DC</sub> , 100 mA
Input DI5	
type	optoisolated
maximum voltage	265 V <sub>AC</sub> ( 460 V <sub>AC</sub> for overvoltage cat. II )
voltage for “logical 1“	$\geq 90$ V <sub>AC</sub>
voltage for “logical 0“	$\leq 30$ V <sub>AC</sub>
burden power ( impedance )	< 0.4 VA ( Ri = 200 kΩ)
dynamic par. (pulse counter) :	
- pulse/gap duration	$\geq 50 / 50$ ms
- maximum frequency	10 Hz

Note \*) : Limit that correspond to the instrument hardware. Real values depend on the firmware filter adjustment - see the chapter Digital Input Filter.

<b>Other Specifications</b>	
operational temperature	- 25 to 60°C
storage temperature	- 40 to 80°C
operational and storage humidity	< 95 % - non-condensing environment
operational altitude	< 2000 m
protection class	II
EMC – immunity	EN IEC 61326-1 ed.3, EN IEC 61000-6-2 ed.4 EN 61000-4-2 ed.2 (6/8 kV) EN 61000-4-3 ed.3 (10 V/m up to 1 GHz) EN 61000-4-4 ed.3 (1/2 kV) EN 61000-4-5 ed.3 (1/2 kV) EN 61000-4-6 ed.4 (10 V) EN 61000-4-8 ed.2 (100 A/m) EN 61000-4-11 ed.3
EMC – emissions	EN IEC 61000-6-4 ed.3, EN 55011 ed.4 class A (not for home use )
communication ports	USB optional COM1 :RS-485(2400–460800 Bd) / Ethernet 100 Base-T
communication protocols	KMB, Ethernet to RS-485 gateway (optional module), Modbus RTU and TCP, Modbus Master (optional module), WEB server, JSON, DHCP, SMTP, SNTP, SNMP, MQTT, IEC104 (optional module)
display	colour TFT-LCD, 3.5" diagonal, 320 x 240 pixels
sampling frequency	57.6 kHz
RTC :	
accuracy	+/- 2 seconds per day
backup battery capacity	> 5 years ( without supply voltage applied )
protection class	
front panel	IP 40 ( IP 54 with cover sheeting )
back panel	IP 20
dimensions	
front panel	144 x 144 mm
built-in depth	90 mm
installation cutout	138 <sup>+1</sup> x 138 <sup>+1</sup> mm
weight	max. 0.7 kg

# 10. Maintenance, Service

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.

Built-in CR2450 lithium cell backups 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 07 LIBEREC 7 Czech Republic phone: +420 485 130 314 e-mail: <a href="mailto:kmb@kmb.cz">kmb@kmb.cz</a> website: <a href="http://www.kmbsystems.com">www.kmbsystems.com</a>
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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: .....	Serial number.....
Date of dispatch: .....	Final quality inspection: .....

Manufacturer's seal:

Date of purchase: .....	Supplier's seal:
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