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Operating Manual for

POWER TRANSDUCER PA 144

Complete version 2.0

The complete and most actual version of this manual is available online at http://www.KMB.cz/

Contents

1 General Description

The PA 144 is specially designed for monitoring of energy and power quality in advanced power systems and smart grids. It is intended to be used mostly for DIN rail mounting. This display-less design with multiple communication options is suitable for a wide spectrum of automation tasks in modern buildings, distributed power generation, remote supervision of the infrastructure and also remote load management. Absence of local panel controls (display and keyboard) limits possibilities for hostile user interaction. For advanced protection, the configuration of PA 144 can be also locked by a pin.

It is equipped with four voltage inputs and four current inputs for external through-hole or clamp-on current sensors for direct measuring up to 2400 A nominal current. It uses standard RS485 serial communication. Additional peripherals such as digital inputs and outputs, secondary communication interface, WiFi, USB or Ethernet modules can be optionally assembled. There are three LED diodes for device status indication and programmable alarm monitoring.

1.1 Version 2.0 improvements

- advanced calibration and higher precision
- optional six-quadrant meter - differentiates reactive energy through the direction of active power flow.
- improved, more precise and continuous measurement of harmonic phasors (amplitude, phase)
- advanced time synchronization options: NMEA, PPS, PPM, power frequency lock
- special rugged current inputs X/100 mA
-
- optional expansion modules USB, WiFi and ZigBee possible
- modular firmware - Power Quality, ModBus Master, Ethernet-Serial (only for instruments, which have booth interfaces) and General Oscillogram modules
- *PQ module*: power quality analysis according to EN 50160 ed. 3.
  - voltage and current measurement class S according to IEC 61000-4-30 ed. 3
  - inter-harmonics (IEC 61000-4-30 ed. 3, 61000-4-7 ed. 2)
  - flicker severity indices (P_{inst}, P_{st} a P_{lt} class F3 as defined in IEC 61000-4-15 ed. 2)
  - voltage interruptions, dips and swells
- *RCS module*: measurement, analysis and recording of the mains signaling voltage signals

1.2 Characteristic features

Connection and Measurement

- up to four measuring voltage inputs (L_1, L_2, L_3, L_4) towards input N
- up to four inputs current sensors (I_1, I_2, I_3, I_4)

- current input options
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  - special wire-through (Pxxx) or split-core (Sxxx) current probes for direct measurement - defined by actual type for $I_{nom} = 5\,A\,..\,600\,A$ (table 1).
  - option X/100mA for indirect measurement with special curerent transformers (nominal secondary current up to 100 mA)
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  - option NOCT measures only voltages, does not have any current inputs. It is possible to use it as a smart transducer and relay, to analyse frequency, voltage, harmonics, unbalance and voltage quality (with PQ module).
- two digital inputs (option D)
- single relay or impulse output (option R or I)
- features can be upgraded via external I/O modules (with ModBus Master module)
- power supply:
  - option U: $75 \div 510\,V_{AC}$ or $85 \div 350\,V_{DC}$
  - option L: $24 \div 48\,V_{AC}$ or $20 \div 75\,V_{DC}$
  - option S: $12 \div 24\,V_{AC}$ or $9 \div 36\,V_{DC}$
- 128 samples per period, voltage and current inputs are read continuously without any gaps
- 63 voltage and current harmonics
- evaluation of all usual three-phase and single-phase quantities such as powers (active, reactive, apparent, distortion, fundamental), power factors, harmonics and THD of voltages and currents etc.

Transfer and Evaluation of Data

- ENVIS software suite available free of charge for configuration and data analysis
- system service ENVIS.Online for live data recording.
- primary RS-485 interface for data transmission, device configuration and firmware upgrade
- can be equipped with Ethernet (option E), secondary RS-485 (option B), M-Bus (option M), USB (option U, W, Z), WiFi or ZigBee (option Z).

1.3 Types and accessories

The PA 144 is available in several configurations according to the customer requirements[1]. See the ordering scheme on figure 1.

[1]Complete and most up to date list of optional and other accessories are available on request from the device vendor.

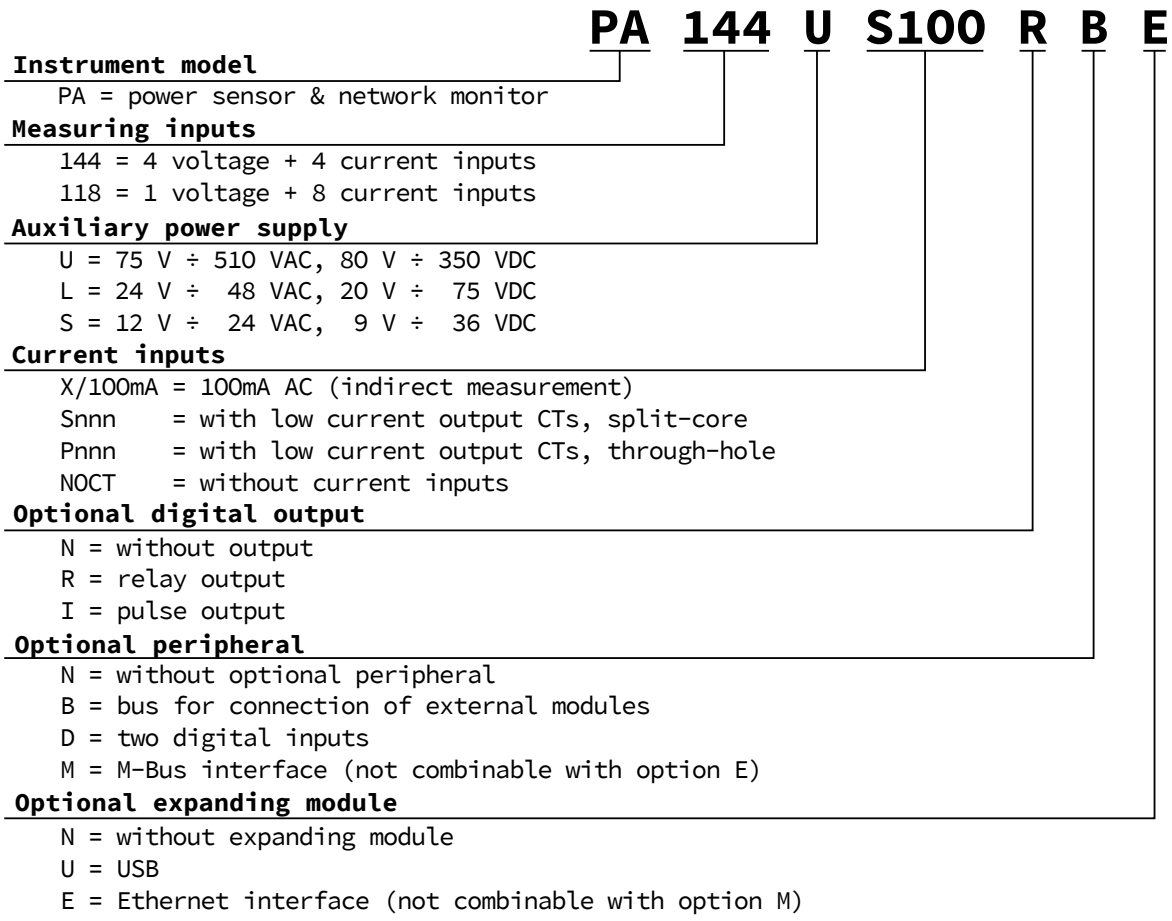

Figure 1: Schematics of the PA 144 ordering options and variants. It includes special codes for proper current and voltage rating options.

In table 1 there are dimensions and weights of Sxxx and Pxxx current sensors for special current input variants. Parameter d is inner diameter for a measured conductor. Parameters x, y, z are external dimensions and g is weight of a sensor.

Table 1: Physical dimensions of special, supplied current sensors for **devices with Sxxx** options. See chapter 2.2.3.

Option	Model	Inom [A]	d [mm]	Connection	Dimmension [mm]
S005	JC10F	5A	10mm	Terminal	50×23×26
S015	JC10F	15A	10mm	Terminal	50×23×26
S025	JC10F	25A	10mm	Terminal	50×23×26
S035	JC10F	35A	10mm	Terminal	50×23×26
S050	JC10F	50A	10mm	Terminal	50×23×26
S075	JC16F	75A	16mm	Terminal	55×30×31
S100	JC16F	100A	16mm	Terminal	55×30×31
S150	JC24F	150A	24mm	Terminal	75×45×34
S200	JC24F	200A	24mm	Terminal	75×45×34
S250	JC24F	250A	24mm	Terminal	75×45×34
S300	JC36S-3	300A	36mm	Terminal	91×57×41
S400	JC36S-3	400A	36mm	Terminal	91×57×41
S500	JC36S-3	500A	36mm	Terminal	91×57×41
S600	JC36S-3	600A	36mm	Terminal	91×57×41

Table 2: Physical dimensions of special, supplied current sensors for **devices with Pxxx** options. See chapter 2.2.3.

Option	Model	Inom [A]	d [mm]	Connection	Dimmension [mm]
P005	JP3W	5A	7	Wire	27×24×11
P015	JP3W	15A	7	Wire	27×24×11
P025	JP5W	25A	13	Wire	41×37×14
P035	JP5W	35A	13	Wire	41×37×14
P050	JP5W	50A	13	Wire	41×37×14
P075	JP5W	75A	13	Wire	41×37×14
P100	JP5W	100A	13	Wire	41×37×14
P150	JP5W	150A	13	Wire	41×37×14
P200	JP6W	200A	19	Wire	51×49×20
P250	JP6W	250A	19	Wire	51×49×20
P300	JP6W	300A	19	Wire	51×49×20

Table 3: Selected parameters for **option X/100mA** for indirect measurement with special types of supplied 100mA CTs. See chapter 2.2.3.

Split-Core Model	Inom [A]	d [mm]	Connection	Dimmension [mm]	Overvoltage Category
JS17F – Inom/100mA	050, 100 125, 150	17	Terminal	64×33×34	600V CAT III
JS17S – Inom/100mA	200	17	Terminal	64×33×34	600V CAT III
JS24F – Inom/100mA	200	24	Terminal	75×45×34	600V CAT III
JS24S – Inom/100mA	250, 300	24	Terminal	75×45×34	600V CAT III
JS36S – Inom/100mA	300, 400 500, 600	36	Terminal	91×57×40	600V CAT III
JSC-01 – Inom/100mA	250, 400	38×32	Wire	93×92×39	600V CAT III
JSC-02 – Inom/100mA	400, 600, 800 1000, 1200	73×62	Wire	128×124×39	600V CAT III
JSC-03 – Inom/100mA	800, 1000, 1200 1600, 2000, 2400	141×62	Wire	196×124×39	600V CAT III

2 Operating the Meter

2.1 Safety requirements when using PA 144

Warning !: When working with the instrument it is necessary to perform all necessary measures for the protection of persons and property against injury and electric shock.

- The device must be operated by a person with all required qualifications for such work and this person must know in detail the operation principles of the equipment listed in this description!
- When the device is being connected to the parts which are under dangerous voltage it is necessary to comply with all the necessary measures to protect users and equipment against injury with electrical shock.
- Person, performing the installation or maintenance of the instrument must be equipped with and must use personal protective clothing and tools.
- If the analyzer is used in a manner not specified by the manufacturer, the protection provided by the analyzer may be impaired.
- If the analyzer or its accessories appear to be impaired or not functioning properly, do not use it and send it in for repair.

2.2 Installation of the instrument

Natural air circulation should be provided inside the distribution board cabinet, and in the instrument's neighborhood, especially underneath the instrument, no other instrumentation that is source of heat should be installed or the temperature value measured may be false. A connection wire's maximum cross section area is $2.5\,mm^2$ in case of all screw terminals.

The PA 144 is primarily intended for DIN-rail mounting. Dimensions of the instrument are on figure 2. There are also positions marked with dash dot lines of holes for wall-mounting with three screws.

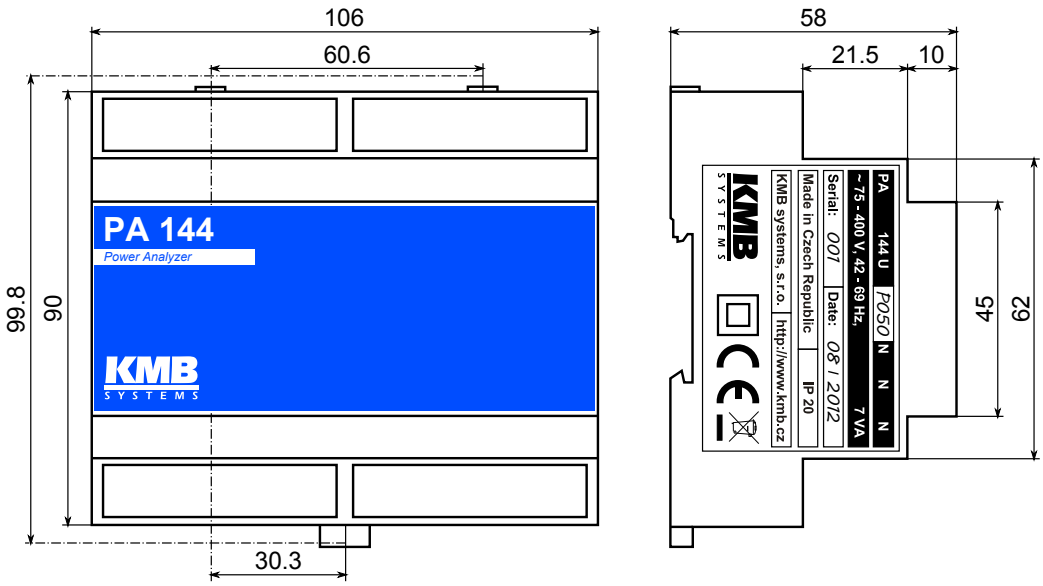

Figure 2: Dimensions of the PA 144 .

2.2.1 Supply voltage

Power supply voltage (options in ch. 5) must be connected to the terminals X1 and X2 via a circuit breaking device (power switch – see installation diagram on figure 3). It has to be located left to the instrument and reachable by the operator. The circuit breaking device must be identified as the equipment power disconnection switch. A circuit breaker of the nominal value $1\,A$ is a convenient circuit breaking device, its function and position has to be clearly identified (symbols '0' and 'I' acc. to IEC EN 61010-1). Internal power supply is galvanically isolated from internal circuits.

2.2.2 Measured voltage

The measured voltages are connected to the terminals L1, L2, L3 and L4. The common terminal to connect the neutral wire to being identified as N - with delta or Aaron connections it remains unused. Terminal L4 can be optionally used to measure potential of one line voltage or the PE against N terminal. All voltage measurement inputs are connected with internal circuits over high impedance.

It is suitable to protect the voltage lines measured for example with 1A fuses of the required rating. Measured voltages can also be connected via instrument voltage transformers. A connection cable maximum cross section area is $2.5\,mm^2$.

2.2.3 Measured currents

For proper current measuring the current sensors must be installed with correct orientation and polarity. Figure 3 illustrates such connection of through-hole current transformers in LV network. Intended direction of power flow is from left (source) to right (load). It is highly recommended to verify correctness of wiring and polarity of currents with phasor diagram in Actual Data window ot the ENVIS.Daq application.

The current inputs are directly connected with internal circuits. Inputs *l1*, *l2*, *l3* and *l4* are interconnected inside the instrument. Inputs l_i and k_i are connected through shunt resistors.

Warning !: Current inputs can not be used for dirrect current measurement. Connection of unsupported type of current transformer such as the common type with 5A or 1A secondary to an instrument is strictly forbidden! The instrument can be seriously damaged!

Warning !: Do not connect the current input signals with neither ground nor other potential! Otherwise, measurement accuracy can be affected or the instrument can be damaged!

Always use only correctly rated measurement current transformers which were originally supplied with the actual instrument. A connection cable maximum cross section area is $1.5\,mm^2$.

2.2.4 Communication peripherals

All peripherals stated below are galvanically isolated from the rest of the instrument and from each other.

Ethernet interface (optional) 10Base-T Ethernet interface with RJ-45 connector described *ETH* is situated on a top panel of the device. Ethernet interface can be used as substitution for the primary RS-485 for connection of the device to LAN and for easy connection of remote control PC.

RS-485 Serial Line serves usually as a remote communication for reading of actual data and device configuration. Serial RS-485 line uses terminals *A*, *B* with shielding at terminal *G* of *COM1* block (fig. 6). The final points of the communication line must be properly terminated with resistance.

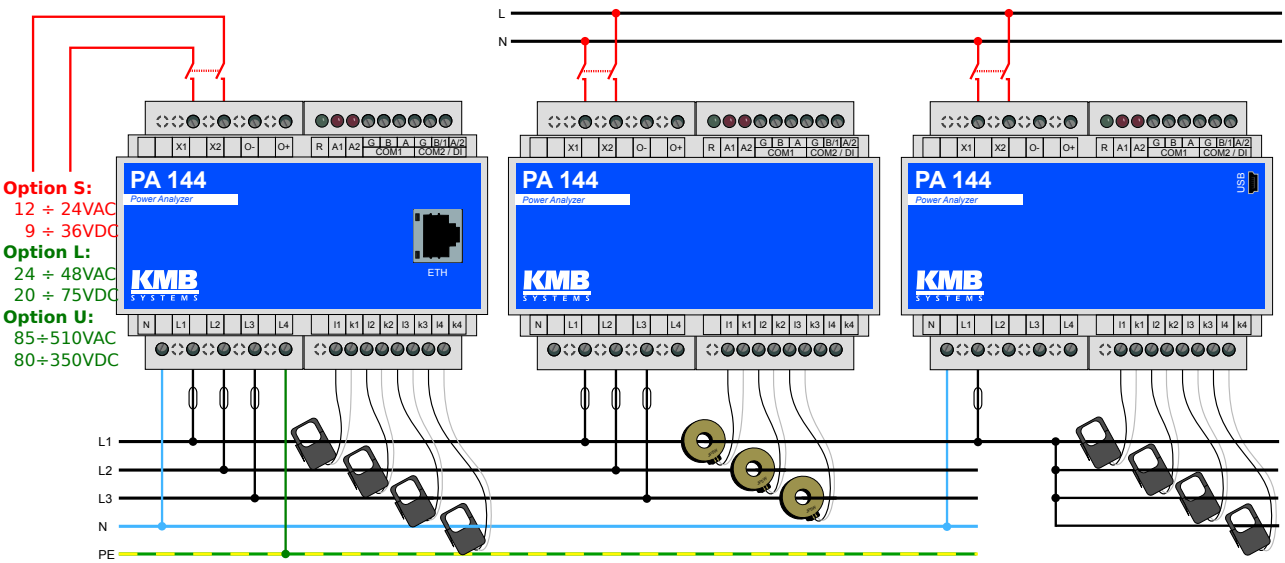

Figure 3: An example of typical installation of PA 144 instrument in a low voltage network — left to right: with low voltage supply voltage (possible DC, AC including battery backed UPS setups); with supply from measured network. Typical connection options for voltage measurements: star, delta and four single phase feeders. Option E for Ethernet port remote communication, option U for local USB communication port (all instruments provide RS485 serial line).

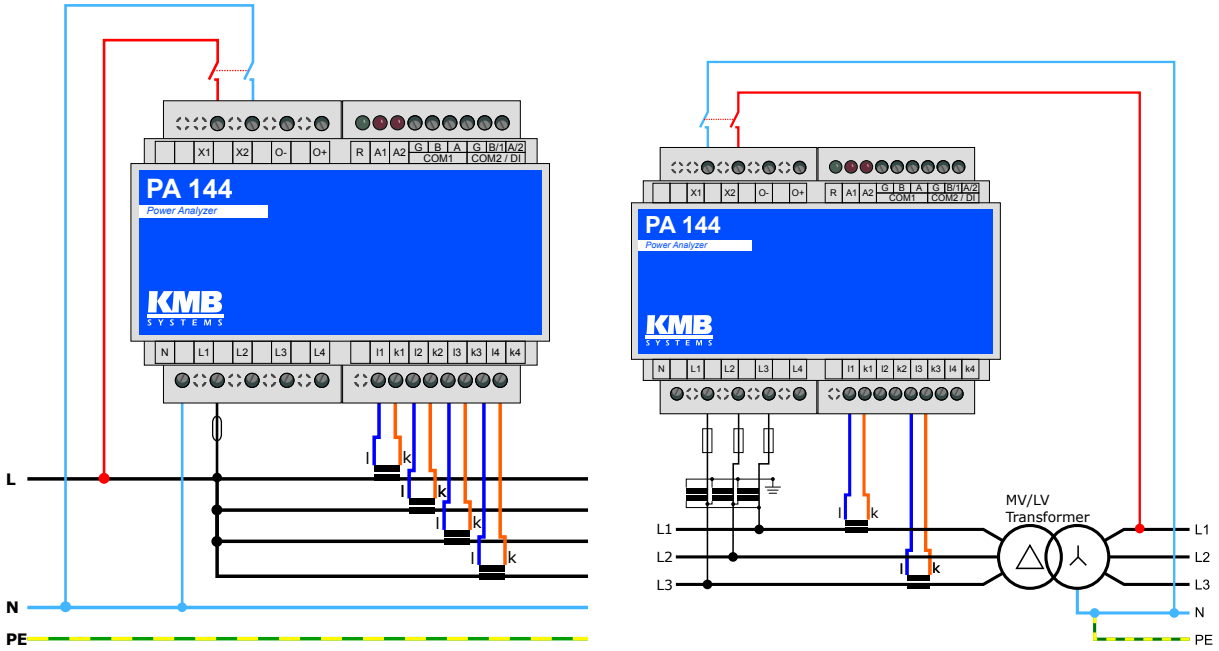

Figure 4: Special cases of connection for PA 144 instrument: single phase three wire connection in LV network and Aron connection. .

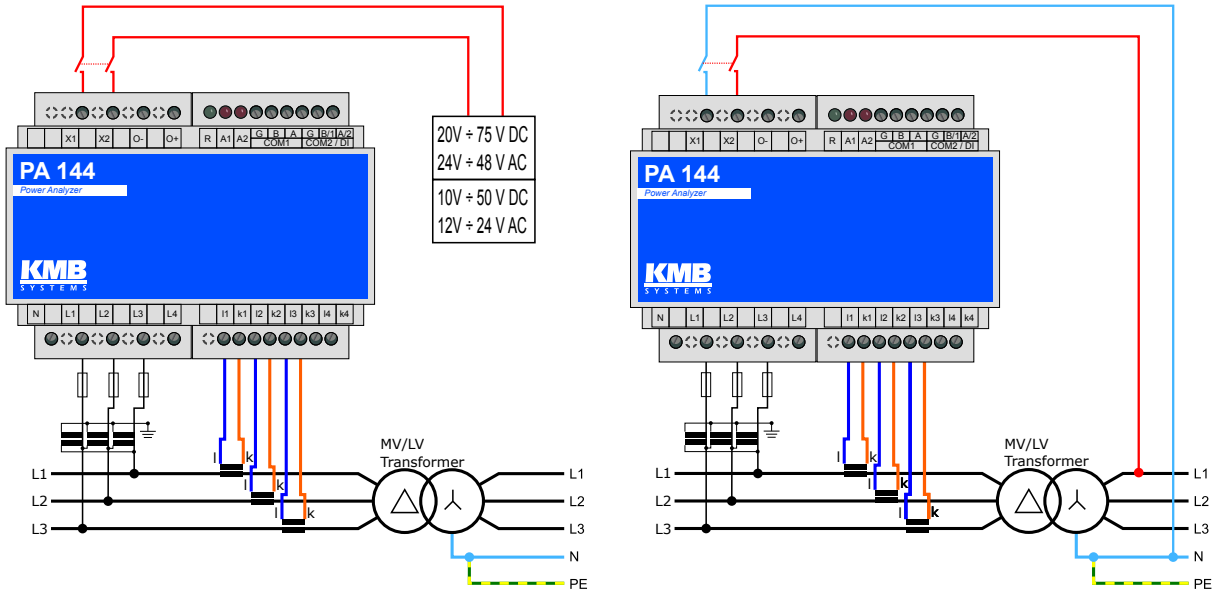

Figure 5: Example of typical connection of PA 144 with indirect measurement via voltage transformers. Option L on left side is supplied from a backup power supply. Option U on the right side is supplied from L1 of the LV network.

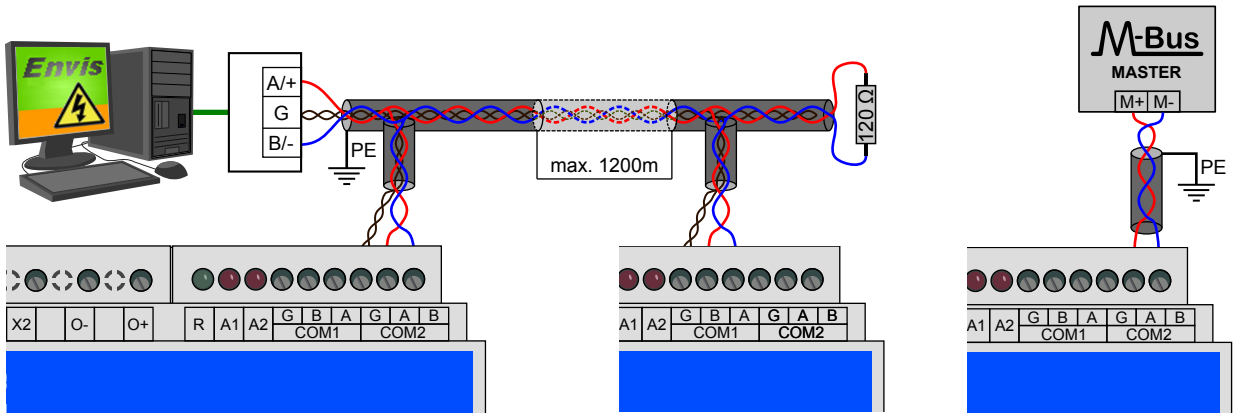

Figure 6: Typical wiring of the RS-485 communication line terminals in PA 144 or optional M-Bus (right).

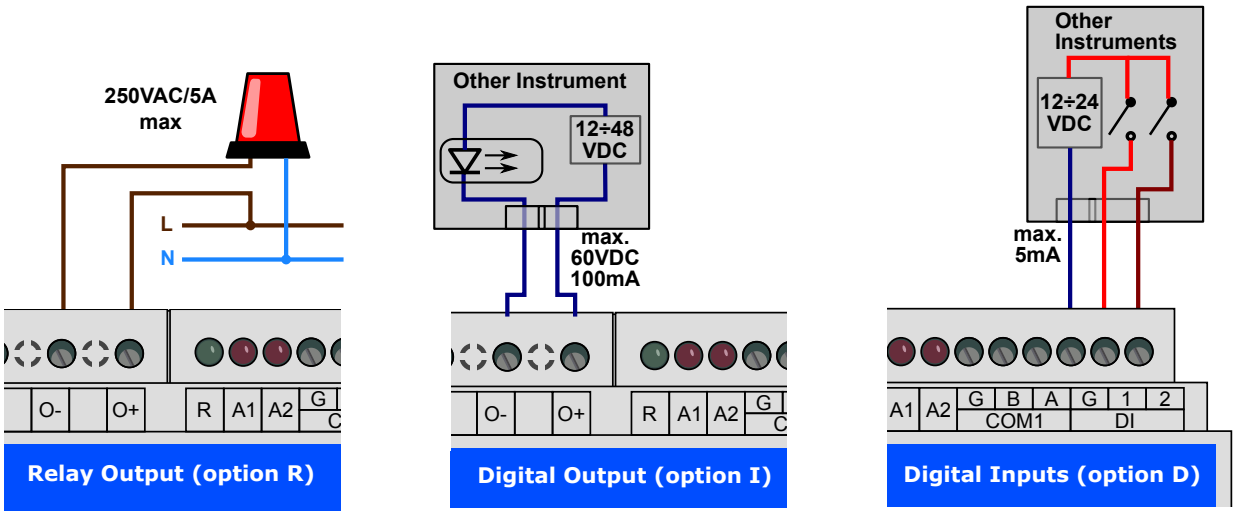

Figure 7: An example of wiring connection for inputs and outputs in PA 144 .

Secondary RS-485 (optional) communication line serves for connection of external I/O modules or remote display unit. Secondary RS-485 line uses terminals *A/2*, *B/1* with shielding at terminal *G* of *COM2/DI* block (fig. 6). The final points of the communication line have to be fitted with terminating resistance.

M-Bus interface (optional) is intended for remote reading of gas or electricity meters. M-Bus interface uses terminals *A/2* and *B/1* of *COM2/DI* block on fig. 6 (right). Polarity of the connection is free.

2.2.5 Outputs and inputs

Digital Inputs (optional) DI1 and DI2, sensitive to voltage, are using three terminals in *COM2/DI* block — *G* is common terminal, *B/1* is first and *A/2* is second digital input. Voltage lower than 3 V applied between *G* and digital input *B/1* or *A/2* is evaluated as inactive state, voltage greater than 10 V is evaluated as active state. On fig. 7 right there is a sample schema for connection of two external switches in series with voltage source of 24 V_{DC}.

Digital Output (optional) RO1 or DO1 is connected through terminals *O+* and *O-*. There must be an external voltage source in series (24 V_{DC} is recommended). In case of solid state based DO outputs an external voltage supply polarity must comply with terminal poles (see fig. 7). In case of relay output the polarity can be freely chosen. Loads of maximum power of 750 VA/90 W or 3 A can be controlled directly in 230 V_{AC} network.

2.3 Detailed configuration of PA 144 on a PC

To begin a measurement it is recommended to configure the PA 144 instrument appropriately. This setting is done by PC with an ENVIS.Daq[2] application.

Warning !: This setting will erase all previously archived data in memory of the instrument. Before writing new configuration to the device make sure to backup the last measured archive.

[2]The ENVIS.Daq application is used for configuration of the instrument. This software is available for download form WWW.KMB.CZ as a part of ENVIS installation package or as a standalone application. Detailed description can be found in The ENVIS User Guide.

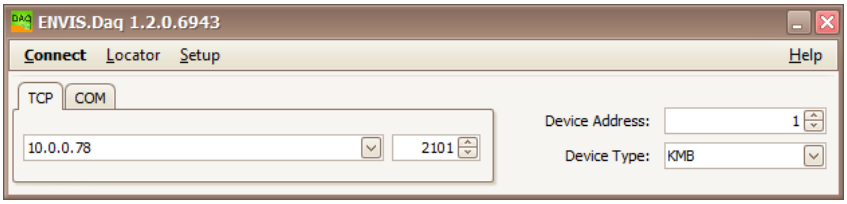

Figure 8: Main window of the ENVIS.Daq application - enter communication type, choose its parameters and click *Connect* to continue.

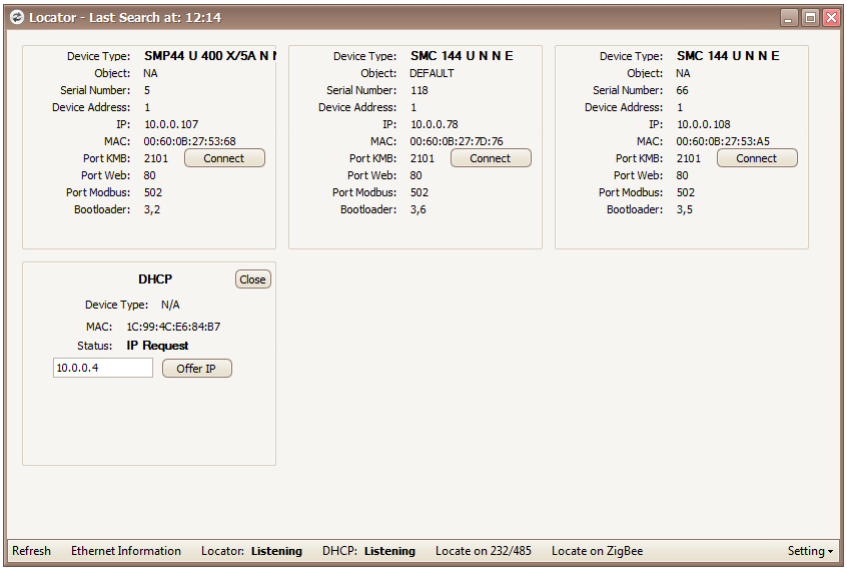

Figure 9: Window of *Locator* tool - provides automatic discovery of the supported instruments in a local network.

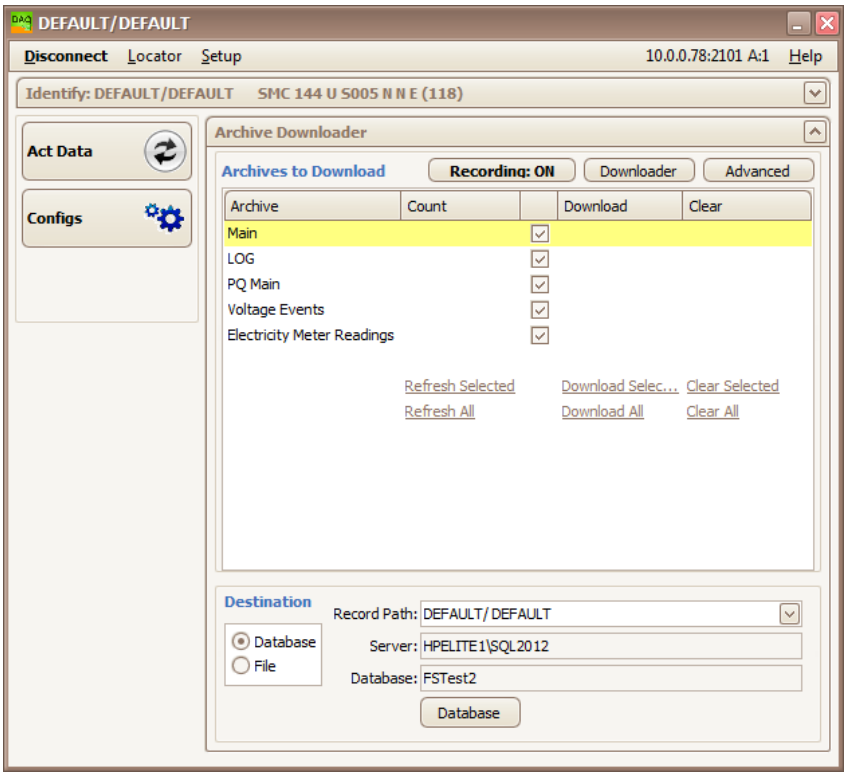

Figure 10: ENVIS.Daq application connected to the instrument.

1. Turn on the instrument. Supply voltage will be indicated by the blinking green LED (PWR).
2. Connect the PA 144 to a computer via USB[3], RS-485 or Ethernet interface. Now the unit is ready to be configured.
3. Run ENVIS.Daq application and pick the appropriate tab for the given communication line.
4. Fill in communication line parameters. A connection form with typical parameters is shown in figure 8.
   (a) USB: choose the correct virtual communication port from the list
   (b) RS485: Immediatelly after power up the green LED is fast blinking (once per 400 ms). For the first 10 seconds after power-up, device can always communicate with fixed baud rate 9600 bps and is listening on address 250. If PA 144 does not receive any command until the interval expires, its communication port is reconfigured to the user defined parameters. During start the PA 144 is also listening on its own address — if same baud rate as default is set, it is possible to connect to the device immediately after power-up. Otherwise, user has to wait 10 seconds before connecting with his own baud rate. End of start interval is indicated by slowly blinking green LED (once per 2 s). Select the correct serial port from a list and set up communication line baud rate.
   (c) Ethernet: enter correct IP address and port (default: 2101). If you do not know the right values you can use *Locator*[4] (fig. 9).

[3]If a USB instrument is connected to the PC for the first time it is necessary to install its driver in Windows. You can find the actual driver for our instruments online on the the WWW.KMB.CZ website. It is also located in the driver folder of ENVIS software installation folder, for example in: *'C:\Program Files (x86)\KMB systems\ENVIS 1.2\driver'*

[4]Locator is a tool for automatic look-up of the instruments in a local network or on a serial line. Caution: it contains special

(d) Edit an address of the instrument (Default: 1)

(e) Enter the device type: KMB

5. Press the *Connect* button or the *ENTER* key. application will attempt to connect to the instrument. In case of successful connection it reads the configuration from the instrument and displays new window with summary information (figure 10).

6. Press the *Settings* button in left column. New window with actual instrument settings will be opened.

Category *Instrument Settings* includes sub-categories, sorted and grouped in various tabs. Changes in configuration are only performed in the windows application. To the instrument they are sent with a *Send* button. With button *Receive* user can re-read the stored configuration from a device. This will effectively cancel all the local modification in the application. Unwritten changes in configuration on each tab is signalized by an exclamation sign. Buttons *Save* and *Load* provide a possibility to archive the actual settings to a file.

For correct operation an appropriate configuration of at least *Installation* and *Time and Date* tab is crucial.

2.3.1 Installation (fig.11)

- *Nominal Frequency* - defines the nominal network frequency measured at 50 or 60 Hz. It also influences, how power quality indice are evaluated.

- *Connection Mode* - the way of connection of the instrument to the measured voltage — either direct voltage measurement or via voltage transformers (usually in a HV network).

- *Connection Type* - type of measured network according to the actual connection - three-phase star, three-phase delta or Aron connection. Supported connections schema are in fig. 11b, 11c and 11d for illustration.

- U_{NOM}, P_{NOM} (rated voltage and power) — correct configuration of these values influences relative values used on display and in condition evaluation (alarms, PQ evaluation, IO, ENVIS data processing).

  - U_{NOM} is a nominal (primary) voltage of the measured network
  - P_{NOM} is a nominal power given by the system transformer or used protection device.

- *VT Ratio, VTN Ratio* - sets the conversion ratio of voltage inputs for *Connection Mode: via VT* measurement. Must be set accordingly to the primary and secondary rating of the measuring voltage transformer (transfer ratio). 'VTN' designates the optional fourth voltage input, available with some *Connection Types*.

  - nominal primary voltage: default value for 'via VT' option is 22 000 V.
  - nominal secondary voltage: default value is 100 V (other common values are 110, 120, 230V)

- *CT Ratio, CTN Ratio* - sets the conversion ratio of current input. 'CTN' designates the fourth input, usually a neutral wire.

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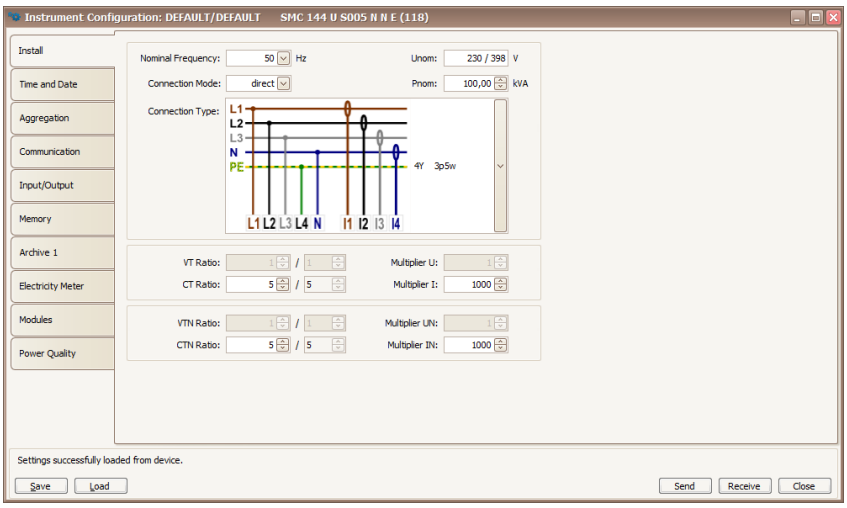
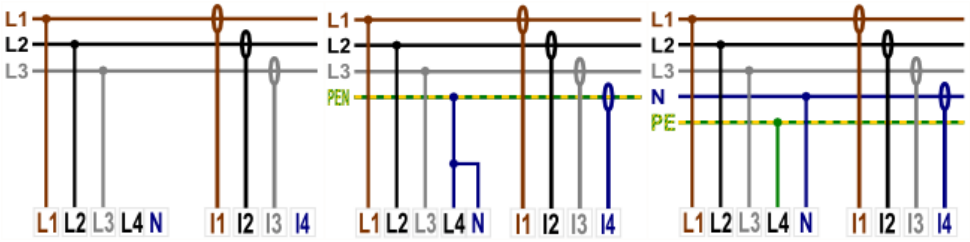
  - For PA 144 options X/100mA and X/20mA a nominal primary and nominal secondary current of the supplied transformer is used. Default value is 100 A/100 mA resp. 20 mA.

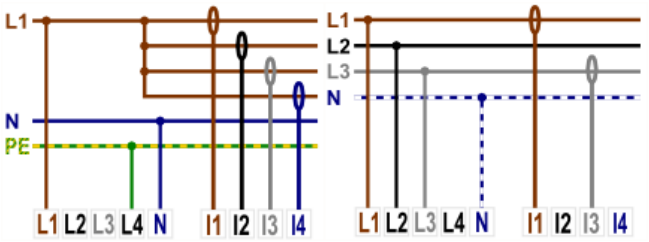
functions such as an embedded DHCP server, which can severely interfere with the normal operation of Ethernet network. It also might need a customization of your PC firewall to work correctly.



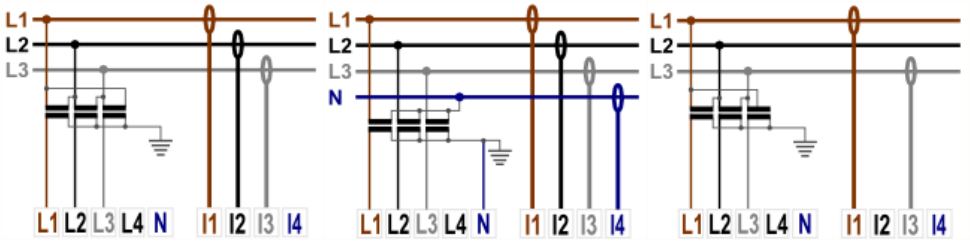
(a) Configuration of basic installation parameters in ENVIS.Daq.



(b) Typical instrument connection types for direct measurement (in LV networks).



(c) Special instrument connection types for direct measurement (in LV networks).



(d) Instrument connection types for indirect measurement — to be connected via VT (in HV networks).

Figure 11: ENVIS.Daq - configuration of the device installation.

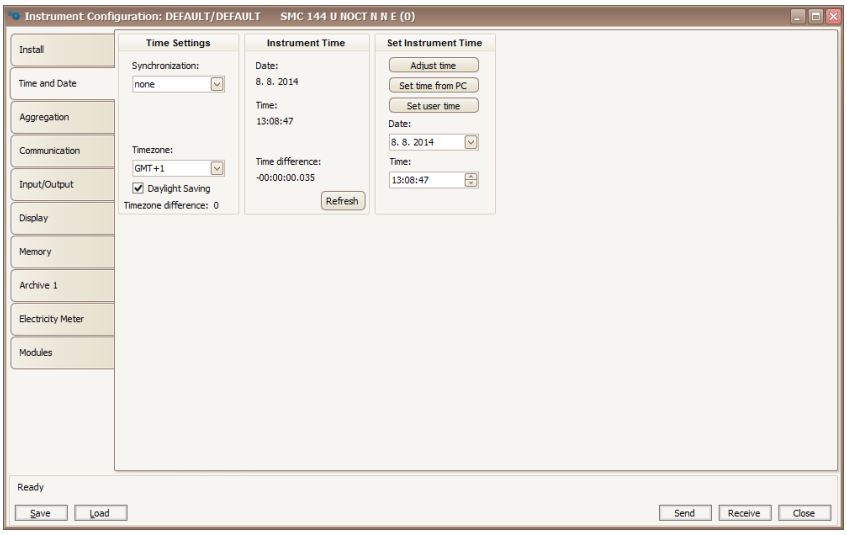


Figure 12: ENVIS.Daq - configuration of date and time options.

  - For PA 144 options Sxxx and Pxxx **the factory default value corresponds to range of specific current input variant stated after slash** (for example *Range I: 50 / 50* for S050 or P050 option) and shouldn't be changed under normal conditions!

- *Multiplier U*: this parameter is usually not necessary. Default value is 1. In special cases it can be used to correct the ratio of measured voltage.

- *Multiplier I* - this parameter is usually not nescessry. Default value is 1.

  - in case of direct current measurement (fig. 3) leave the *Multiplier I* in its default value:1.

  - in case of indirect current measurements with nonstandard conversion ratio (multiple loops of measured wire through the measuring transformer etc) specify the new ratio as a fraction[5] to which you need to multiply the original conversion ratio to get the real measured value of current.

2.3.2 Date and time (fig. 12)

This tab contains configurations related to the instrument internal time and date settings.

Warning !: manipulation with the time configuration erases all instrument archives and related registers.

Instrument Time panel displays actual time and date in the instrument and an absolute difference to the actual time in PC. When this tab is opened for the first time the instrument time is immediately read and is periodically actualized. Button *Refresh* rereads the instrument time again.

Time Setup panel provides controls for actual modification of the time in instrument.

- *Set Time from PC* — sets the instrument time according to the clock in PC

- *Set user Time* — sets the instrument time to the manually given value

[5] If, for example, primary CT with ratio 100/5 is used, set multiplier to $\frac{100}{5} = 20$. Another example, when *Multiplier I* can be used, is winding more than one loop of measured conductor through current transformer for sensitivity extension (and range reduction). For example for 4 loops *Multiplier I* should be set to $\frac{1}{4} = 0.25$.

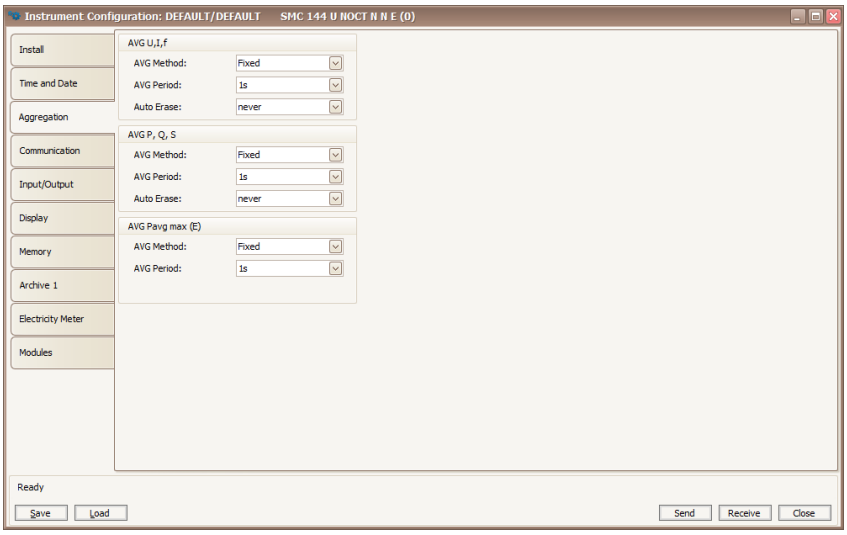


Figure 13: ENVIS.Daq - aggregation configuration defines how instrument evaluates average, minimum and maximum actual values for display and communication.

- *Adjust Time* — aligns the instrument time to the PC time without erasing instrument memory. Adjustment to the desired value is achieved in a way that:
  - to move time forwards it skips required number of archives
  - to move time backwards it waits with the creation of next archive until the instrument reaches the time given in setup.

Calendar Configuration defines ways of interpretation and display of time tags in instrument and in its archives:

- *Synchronization* — defines how each instrument synchronizes its time. Methods supported include:
  - pulse per second and pulse per minute (PPS, PPM) on a digital input,
  - NMEA protocol on a communication line - the comm port must be configured,
  - NTP protocol over Ethernet - IP address of the time server must be filled
  - and a network frequency lock.
  - It is also possible to disable this function.
- *Time Zone* — must be set according to the local requirements. The configuration is important for correct interpretation of the local time for tariff, for remote communication etc.
- *Summer Time* — if set the calendar automatically adjusts itself to the change of the local time according to the season.

2.3.3 Aggregation (averaging, fig. 13)

This configuration influences algorithms used for calculation of special ModBus registers of the aggregated values. In instruments with graphical display it also influences how aggregated (AVG) values are displayed. Parameters are defined separately for primary quantities - voltages, currents and frequency, for derived quantities and specially for PavgMax. Correctly configured aggregation in an istrument allows in connection with ENVIS software to evaluate quarter-hour or hour maximal demand (power).

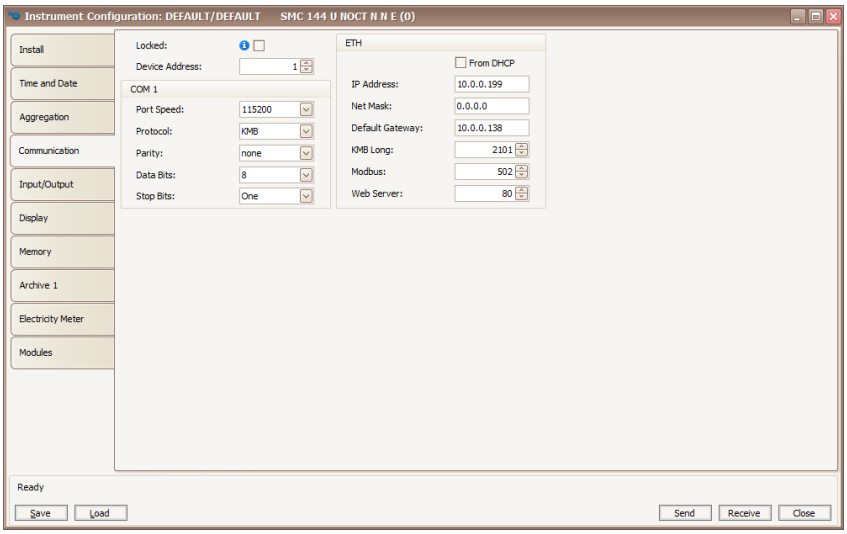


Figure 14: ENVIS.Daq - setting up communication line options.

2.3.4 Communication (fig. 14)

Device is always equipped with at least one RS 485 port (COM1) for parametrization and data acquisition. Optionally it can be equipped with secondary RS485 port (COM2) or with Ethernet (ETH) interface.

- *Instrument Address* - assign unique address to each instrument on the same serial line.

COM1, COM2

- *Communication Speed* — speed (baud rate) of the communication line. Default value is 9600 bps.
- *Communication Protocol* — to be chosen between KMB protocol and ModBus RTU.
- *Parity* — odd, even or none. Defines behavior of the parity bit control settings.
- *Data bits* — defines number of data bits.
- *Stop bits* — defines number of re-synchronization bits after each sent character.

ETH

- *IP address* — to be specified by user or assigned via the local DHCP server.
- *Network Mask* — setting of the network mask.
- *Gateway* — setting of network gateway.
- TCP Ports — each port can be individually assigned a special TCP port. Default values are:
  - *KMB Long protocol:* 2101,
  - *ModBus TCP protocol:* 502,
  - *Web server:* 80.

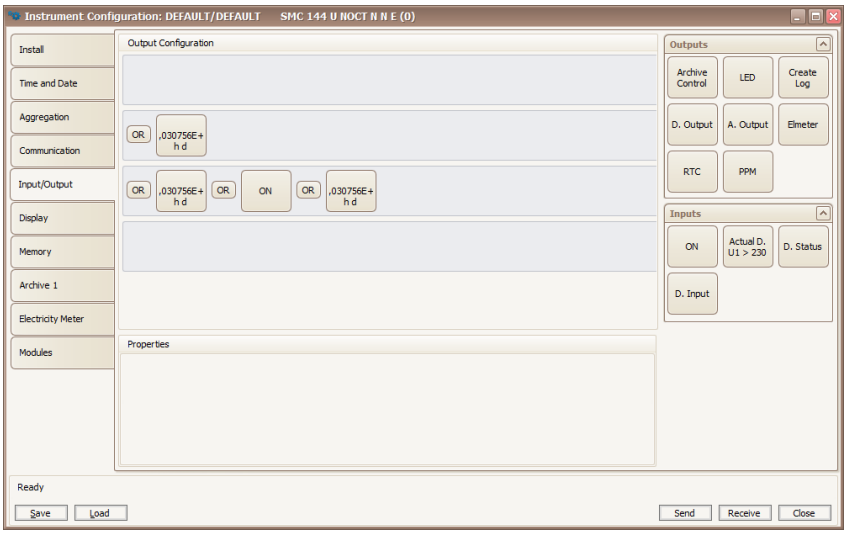


Figure 15: ENVIS.Daq - nastavení chování programovatelných vstupů a výstupů.

2.3.5 Inputs & Outputs (fig. 15)

PA 144 is assembled with two alarm leds A1 and A2 and optionally (options R, I) with one relay or SSR output O1.

- output controll logic can be programmed into the instrument
- any output can be configured to provide meter pulse output. In such cases the control quantity can be either active or reactive energy in each quadrant. It is nescessary to correctly configure number of pulses per kWh or kvarh.

Firmware Modules (fig. 16) This tabs allows the user to activate or deactivate optional firmware modules by providing a valid activation code. State of each supported module is indicated.

2.4 Energy meter readings

PA 144 has an embedded three phase, four-quadrant energy meter with automatic meter reading functions and tariff (Time-of-Use, TOU). The instrument registers active and reactive energy separately (EP+, EP-). For reactive energy it measures — capacitive EQC and inductive EQL for four-quadrant meter resp. reactive EQC+, EQC- and EQL+, EQL- separately for active power demanded and supplied for six-quadrant meter.

Meter data readings can be downloaded and analyzed in ENVIS or via the standard ModBus protool in any other system.

2.5 Embedded Webserver

All of instruments with Ethernet communication option are equipped with a native embedded webserver. Over this feature all important actual main measurements, registers and instrument setting can be viewed with a standard web browser with support for HTML5. It requires to set properly the instrument remote communication parameters and to connect it to the network. Then in the web browser enter an appropriate IP address of the instrument and information from the instrument appears.

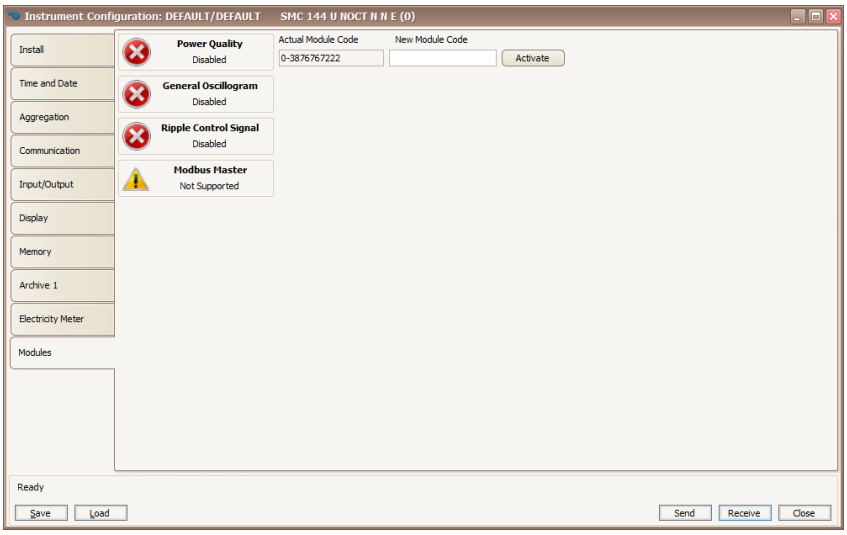


Figure 16: ENVIS.Daq - activation and deactivation of the supported special firmware options.

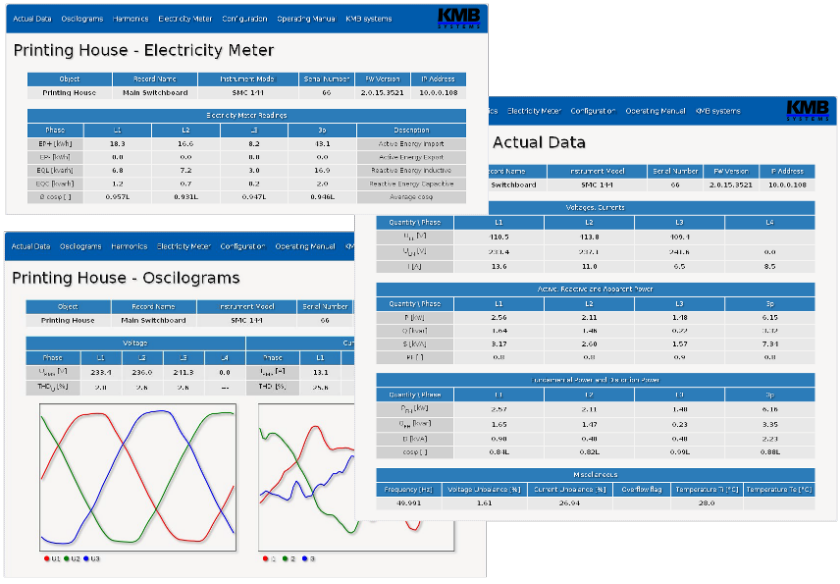


Figure 17: Sample pages of the embedded web server - actual data, electricity meter, oscilograms.

3 Functional description

3.1 Instrument construction

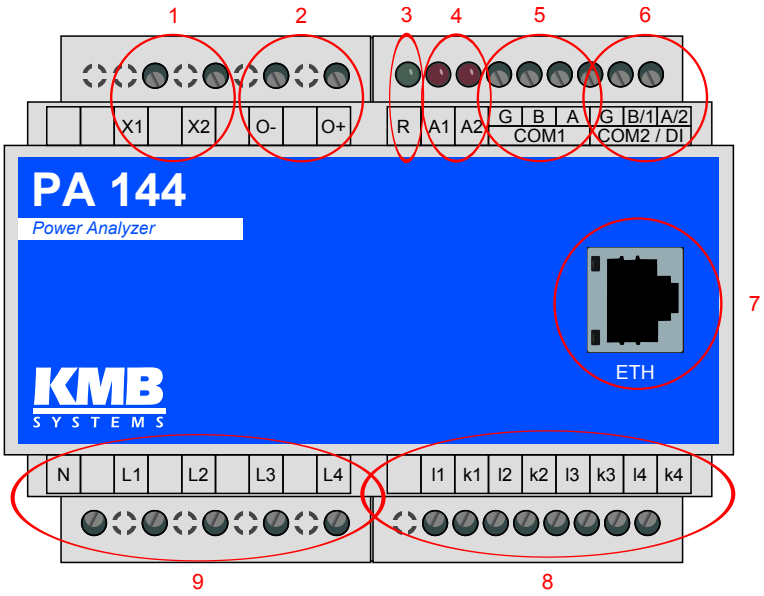


Figure 18: Description of the PA 144 instrument.

1. Input connector for auxiliary power supply voltage
2. Galvanically isolated digital relay or impulse output (optional)
3. Green instrument status LED
4. Two red configurable alarm LED
5. Primary communication RS-485 interface
6. Secondary RS-485 of M-Bus interface (optional) or two digital inputs (optional)
7. RJ-45 Ethernet connector (optional)
8. Current inputs for externally connected current sensors
9. Voltage inputs for four measured voltages

3.2 Control

PA 144 device has no control buttons. It simply works while connected to proper auxiliary voltage (see Technical specifications). Communication using ENVIS software on your PC, which is the only way, how to control PA 144 device, was described in chapter 2.

3.2.1 Machine status

PA 144 can be in one of three basic states indicated by green LED. Function of green LED in conjunction with 10 seconds power-up interval and fixed baud rate communication was previously described in 2.3.

3.2.2 LED codes

LED "PWR" (green) - device status:

-  (off) power supply voltage is not present, measurement is stopped
-  (slow blinking once per 2 s) normal operation, ready for connection
-  (fast blinking once per 400 ms) device is awaiting commands in fixed baud rate (see 2.3)

LED "A1" and "A2" (red) - configurable/alarm LEDs:

-  (off) configurable (e.g. alarm off)
-  (on) configurable (e.g. alarm on)
-  (blinking) configurable (e.g. electricity meter pulse output)

"PWR", "A1" and "A2" LEDs while firmware upgrade is in progress:

-  erasing main program memory
-  receiving new firmware

4 The Method of Measurement and Evaluation of Individual Variables

Measurement includes three continuously performed processes: frequency evaluation, sampling voltage and current signals and evaluation of these sampled data.

Frequency of the fundamental harmonic voltage component is continuously measured and evaluated every 10 seconds. The measured signal is a line voltage of first phase signal modified with a low pass filter. Frequency is assessed as a percentage of the number of full cycles of the network established within each 10 seconds and the cumulative duration of full cycles.

Voltages and currents are evaluated continuously without gaps. Basic evaluation interval is 10/12 cycles of the network ($\sim 200\,ms$ for both $50\,Hz$ or $60\,Hz$ network). All channels are sampled at the frequency of 128 samples per network cycle. Sampling is controlled by the measured frequency in channel U_1. If the value of the frequency is in measurable range it also controls the sampling — sampling is automatically adjusted to the frequency change. Otherwise, the sampling runs according to the preset nominal frequency ($50\,Hz$ or $60\,Hz$). RMS voltage and currents are evaluated from the sampled values for the measuring cycle according to equations:

4.1 Basic quantities (RMS)

Line-to-Neutral and Line-to-Line voltages, currents:

$$U_1 = \sqrt{\frac{1}{n}\sum_{i=1}^{n} U_{1i}^2},\ U_{12} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (U_{1i} - U_{2i})^2},\ I_1 = \sqrt{\frac{1}{n}\sum_{i=1}^{n} I_{1i}^2}$$

where: i..... sample index
n..... number of samples per cycle of measurement (128)
$U_{1,i}$, $U_{2,i}$, $I_{1,i}$ ..... individual samples of voltage and current

4.2 Powers and power factor (PF)

Active and reactive power (single phase, three phase)[6]:

$$P_1 = \frac{1}{n}\sum_{i=1}^{n} U_{1i} \times I_{1i},\ 3P = P_1 + P_2 + P_3$$

$$Q_1 = \sum_{k=1}^{N} U_{1,k} \times I_{1,k} \times \sin \triangle\varphi_{1,k},\ 3Q = Q_1 + Q_2 + Q_3$$

[6]The equations are valid for a three phase star connection.

where: k ..... index of the order of each harmonic
N ..... highest harmonic (63)
$U_{1,k}$, $I_{1,k}$ ..... k-th harmonic of voltage and current (1^{st} phase)
$\Delta\varphi_{1,k}$ ..... angle between $U_{1,k}$, $I_{1,k}$ (1^{st} phase)

Apparent and Distortion power (per phase, three phase):

$$S_1 = U_1 \times I_1,\ 3S = S_1 + S_2 + S_3$$

$$D_1 = \sqrt{S_1^2 - P_1^2 - Q_1^2},\ 3D = \sqrt{3S^2 - 3P^2 - 3Q^2}$$

Power factor (per phase, three phase):

$$PF_1 = \frac{|P_1|}{S_1},\ 3PF = \frac{|3P|}{3S}$$

4.3 Harmonic distortion of voltages and currents

is continuously evaluated by FFT up to 63rd harmonic. The calculation is performed by using a rectangular window of each measurement cycle. Following parameters are evaluated from the harmonic analysis:

Fundamental (1^{st}) harmonic of voltage and current:

$$Ufh_1,\ Ifh_1$$

The absolute angle of the fundamental harmonic voltage and current phasors:

$$\varphi U_1,\ \varphi I_1$$

The angle between the corresponding phasors of the fundamental harmonic components of voltage and current:

$$\triangle\varphi_1$$

The angle between a voltage and the corresponding current phasors of the i-th order:

$$\triangle\varphi_i$$

Total harmonic distortion of voltage and current (as defined in 61000-4-30):

$$THDU = \frac{\sqrt{\sum_{i=2}^{40} Uh_i^2}}{Uh_1} \times 100,\ \ THD\text{–}R_U = \frac{\sqrt{\sum_{i=2}^{max} Uh_i^2}}{U} \times 100\,[\%]$$

$$THDI = \frac{\sqrt{\sum_{i=2}^{40} Ih_i^2}}{Ih_1} \times 100,\ \ THD\text{–}R_I = \frac{\sqrt{\sum_{i=2}^{max} Ih_i^2}}{I} \times 100\,[\%]$$

where: U ..... voltage TRMS (line-to-neutral or line-to-line)
I ..... current TRMS
i ..... order of the respective harmonic component
Uh_i, Ih_i ..... i-th harmonic of voltage and current

Power factor (of the fundamental harmonic components):

$$\cos \triangle\varphi_1$$

$$3cos\triangle\varphi = cos\left(\arctan\left(\frac{3Qfh}{3Pfh}\right)\right)$$

Reactive and reactive power of the fundamental harmonic component:

$$Pfh_1 = Ufh_1 \times Ifh_1 \times cos\triangle\varphi_1,\ 3Pfh = Pfh_1 + Pfh_2 + Pfh_3$$

$$Qfh_1 = Ufh_1 \times Ifh_1 \times sin\triangle\varphi_1,\ 3Qfh = Qfh_1 + Qfh_2 + Qfh_3$$

4.4 Symmetrical components

Voltage, current unbalance and negative sequence current is evaluated as a decomposition to the positive and negative sequence of fundamental harmonic:

$$unb_U = \frac{negative\_sequence\_component}{positive\_sequence\_component} \times 100\%$$

$$unb_I = \frac{negative\_sequence\_component}{positive\_sequence\_component} \times 100\%$$

$$\varphi nsl$$

5 Technical Specifications

5.1 Basic Parameters

Auxiliary Voltage			
	model „U“	**model „L“**	**model „S“**
AC aux. voltage range, f=40÷450 Hz	85 ÷ 275 VAC	20 ÷ 50 VAC	10 ÷ 26 VAC
DC aux. voltage range	80 ÷ 350 VDC	20 ÷ 75 VDC	9 ÷ 36 VDC
power supply	3 VA / 3 W		
overvoltage category	III		
pollution degree	2		
connection	isolated, polarity free		

Other Specifications	
operational temperature	- 20 to 60°C
storage temperature	- 40 to 80°C
operational and storage humidity	< 95 % - non-condensable environment
EMC – immunity	EN 61000 – 4 - 2 (4kV / 8kV) EN 61000 – 4 - 3 (10 V/m up to 1 GHz) EN 61000 – 4 - 4 (2 kV) EN 61000 – 4 - 5 (2 kV) EN 61000 – 4 - 6 (3 V) EN 61000 – 4 - 11 (5 periods)
EMC – emissions	EN 55011, class A EN 55022, class A (not for home use)
communication ports	RS-485, optional USB, Ethernet, ZB, WiFi, Mbus
communication protocols	KMB, Modbus RTU and TCP, web server, DHCP
accuracy of RTC	+/- 2 seconds per day
capacity of RTC backup battery	> 5 years (without supply voltage applied)
protection class front panel whole instrument	 IP 40 IP 20
dimensions front panel whole instrument	 106 x 45 mm 106 x 90 x 58 mm
weight	max. 0.25 kg

5.2 Measured Quantities

Measured Quantities – Voltage	
Frequency	
f_{NOM}– nominal frequency	50 / 60 Hz
measuring range	42 ÷ 57 / 51 ÷ 70 Hz
uncertainty	± 20 mHz
Voltage	
voltage input option	**standard variant („230“)**
U_{NOM} (U_{DIN})– rated voltage	180 ÷ 250 V_{AC}
measuring range line-to-line	6 ÷ 300 V_{AC}
measuring range line-to-neutral	11 ÷ 520 V_{AC}
intrinsic uncertainty (t_A=23±2°C)	+/- 0.05 % of rdg ± +/- 0.02 % of rng
temperature drift	+/- 0.03 % of rdg ± +/- 0.01 % of rng / 10 °C
measurement category	300V CAT III
permanent overload	1300 V_{AC} (UL–N)
peak overload, 1 second	1950 V_{AC} (UL–N)
burden power (impedance)	< 0.03 VA (Ri = 2.7 MΩ)
Voltrage Unbalance	
measuring range	0 ÷ 10 %
measuring uncertainty	± 0.3% of rdg or ± 0.3
THDU	
measuring range	0 ÷ 20 %
measuring uncertainty	± 0.5
Harmonics (up to 50th order)	
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

Mains Signalling Voltage (with optional firmware module „RCS“ only)	
measuring range	0 ÷ 20 % U_{NOM}
measuring uncertainty	twice the levels of class II acc. to IEC 61000–4-7 ed.2

Measured Quantities – Current, Temperature			
Current			
current input option	**„Pxxx“**	**„Sxxx“**	**„X/100mA“**
I_{NOM} (I_B) – rated (basic) current	xxx AAC	xxx AAC	0.1 AAC
measuring range	0.0025 ÷ 1.2 xxx AAC	0.0025 ÷ 1.2 xxx AAC	0.0025 ÷ 0.12 AAC
intrinsic uncertainty (t_A=23 ±2 ºC)	+/- 0.05 % of rdg ± +/- 0.02 % of rng		
temperature drift	+/- 0.03 % of rdg ± +/- 0.01 % of rng / 10 ºC		
measurement category	150V CAT III	600V CAT III	600V CAT III
permanent overload	2 x INOM	2 x INOM	0.2 AAC
peak overload 1 second, maximum repetition frequency > 5 minutes	I_{NOM}<35A: 20xI_{NOM} I_{NOM}=35÷100A:10xI_{NOM} I_{NOM}>100 A: 5xI_{NOM}	I_{NOM}<35A: 20xI_{NOM} I_{NOM}=35÷100A:10xI_{NOM} I_{NOM}>100 A: 5xI_{NOM}	1 AAC
burden power (impedance)	<0.05 VA (Ri=0.7÷91 Ω)	<0.05 VA (Ri=0.7÷91 Ω)	< 0.005 VA (Ri < 0.5 Ω)
Current Unbalance			
measuring range	0 ÷ 100 %		
measuring uncertainty	± 1 % of rdg or ± 0.5		
Harmonics & Interharmonics (up to 50th order)			
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	Ih <= 10% INOM : ± 1% INOM		
	Ih > 10% INOM : ± 1% of rdg		
THDI			
measuring range	0 ÷ 200 %		
measuring uncertainty	THDI <= 100% : ± 0.6		
	THDI > 100% : ± 0.6 % of rdg		
Temperature (internal sensor, measured value affected by the instrument power dissipation)			
measuring range	- 40 ÷ 80°C		
measuring uncertainty	± 2 ºC		

Measured Quantities – Power, Power Factor, Energy	
Active / Reactive Power, Power Factor (PF), cos φ (P_{NOM} = U_{NOM} x I_{NOM})	
reference conditions “A” : ambient temperature (t_A) U, I for active power, PF, cos φ for reactive power	 23 ±2 ºC U = 80 ÷ 120 % U_{NOM}, I = 1 ÷ 120 % I_{NOM} PF = 1.00 PF = 0.00
act. / react. power uncertainty	± 0.5 % of rdg ± 0.005 % P_{NOM}
PF & cos φ uncertainty	+/- 0.005
“reference conditions ”B” : ambient temperature (t_A) U, I for active power, PF, cos φ for reactive power	 23 ±2 ºC U = 80 ÷ 120 % U_{NOM}, I = 2 ÷ 120 % I_{NOM} PF >= 0.5 PF <= 0.87
act. / react. power uncertainty	± 1 % of rdg ± 0.01 % P_{NOM}
PF & cos φ uncertainty	+/- 0.005
temperature drift of powers	+/- 0.05 % od rdg ± +/- 0.02 % P_{NOM} / 10 ºC
Energy	
measuring range	6 „quadrants“, corresponds to U & I measuring ranges
active energy uncertainty	class 1 acc. to EN 62053 – 21
reactive energy uncertainty	class 2 acc. to EN 62053 – 23

5.3 Inputs and Outputs

Digital Outputs & Digital Input	
„R“-type (relay)	
type	N.O. contact
load rating	250 V_{AC} / 30 V_{DC}, 3 A
„I“-type (solid state, opto-MOS)	
type	Opto-MOS, unipolar
load rating	100 V_{DC}, 300 mA
Two Digital Inputs „I“	
type	optoisolated, unipolar
maximum voltage	30 V_{DC}
voltage for “logical 1“	> 10 V_{DC}
voltage for “logical 0“	< 3 V_{DC}
input current	3 mA @ 10V / 8 mA @ 24V

5.4 IEC 61557-12: Classification of the power monitoring instrument

Instrument characteristics according to IEC 61557-12	
power quality assessment function	PQI-S
classification according to par. 4.3 direct voltage connection voltage connection via VT	 SD SS
temperature according to par. 4.5.2.2	K55
humidity + altitude according to par. 4.5.2.3	< 95 % - noncondensation conditions < 3000 m
active power/energy function performance class	1

Function characteristics according to IEC 61557-12 Model **„P005“** or **„S005“**, I_{NOM} = 5 A, U_{NOM} = 230 V				
Symbol	Function	Class	Measuring range	Notes
P	total effective power	1	0 ÷ 5400 W	
Q_A, Q_V	total reactive power	2	0 ÷ 5400 var	
S_A, S_V	total apparent power	1	0 ÷ 5400 VA	
E_a	total active energy	1	0 ÷ 5400 Wh	
E_{rA}, E_{rV}	total reactive energy	2	0 ÷ 5400 varh	
E_{apA}, E_{apV}	total apparent energy	1	0 ÷ 5400 Vah	
f	frequency	0.05	42 ÷ 70 Hz	
I	phase current	0.2	0.025 ÷ 6 A_{AC}	
I_N	neutral current measured	0.2	0.025 ÷ 6 A_{AC}	
I_{Nc}	neutral current calculated	–	–	
U_{LN}	line-to-neutral voltage	0.1	40 ÷ 280 V_{AC}	
U_{LL}	line-to-line voltage	0.1	70 ÷ 480 V_{AC}	
PF_A, PF_V	power factor	0.5	0 ÷ 1	
P_{st}, P_{lt}	flicker	5	0.4 ÷ 10	2)
U_{dip}	voltage dips	0.5	10 ÷ 230 V_{AC}	2)
U_{swl}	voltage swells	0.5	230 ÷ 280 V_{AC}	2)
U_{tr}	transients overvoltage	–	–	
U_{int}	voltage interruption	1	0 ÷ 10 V_{AC}	2)
U_{nba}	voltage unbalance (amp.)	0.5	0 ÷ 10 %	4)
U_{nb}	voltage unbalance (ph.&amp.)	0.5	0 ÷ 10 %	
U_h	voltage harmonics	2	up to 50th order	1)
THD_u	voltage total harmonic distortion (rel. to fund.)	2	0 ÷ 20 %	1)
$THD\text{-}R_u$	voltage total harmonic distortion (rel. to RMS)	2	0 ÷ 20 %	1, 4)
I_h	current harmonics	2	up to 50th order	1)
THD_i	current total harmonic distortion (rel. to fund.)	2	0 ÷ 20 %	1)
$THD\text{-}R_i$	voltage total harmonic distortion (rel. to RMS)	2	0 ÷ 20 %	1, 4)
M_{SV}	mains signalling voltage	2	0 ÷ 46 V_{AC}	1,3)

1) … according to IEC 61000-4-7

2) … with optional firmware module „PQ S“

3) … with optional firmware module „RCS“

4) … value available in the ENVIS program only

6 Maintenance, Service, Warranty

Maintenance: the PA 144 power analyzer does not require any maintenance during its 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.

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

KMB Systems, s. r. o.
Tř. dr. M. Horákové 559
460 05 Liberec 7
Czech Republic
Tel. 485 130 314, Fax 482 739 957
E-mail: kmb@kmb.cz, Web: `www.kmb.cz`

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:	PA 144	Serial number:	.....
Date of dispatch:	.....	Final quality inspection:	.....
		Manufacturer's seal:	.....
Date of purchase:	.....	Supplier's seal:	.....