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SMC 144

Power Analyzer

Operating Manual

Version 1.1

Contents

1 General Description

The SMC 144 is specially designed for remote monitoring of energy consumption and its quality. The DIN rail display-less design with multiple communication options is suitable for a wide spectrum of automation tasks in modern buildings, 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 SMC 144 can be also locked by a pin.

It is equipped with four voltage inputs and four inputs for external through-hole or clamp-on current sensors for direct measuring up to 600 A nominal current. It uses serial communication and peripherals, such as digital inputs and output, secondary serial communication interface for external I/O modules or ethernet module can be optionally assembled. There are three LEDs for device status indication and alarm monitoring.

1.1 Characteristic Features

Connection and Measurement

- four measuring voltage inputs (L_1, L_2, L_3, L_4) towards neutral input (N)
- four inputs for through-hole (option P) or clamp-on (option S) current sensors with nominal current range from 5 to 600 A (I_1, I_2, I_3, I_4)
- two digital inputs (option D)
- single relay or impulse output (option R or option I)
- features can be upgraded via external I/O modules (with Modbus Master firmware module)
- power supply:
  - auxiliary voltage $75 \div 510\,V_{AC}$ or $80 \div 350\,V_{DC}$ (option N)
  - low auxiliary voltage $24 \div 48\,V_{AC}$ or $20 \div 75\,V_{DC}$ (option L)
- 128 samples per period, voltage and current inputs are read continuously without any gaps
- voltage and current harmonics calculation up to order 63
- evaluation of all usual three-phase and single-phase quantities such as powers, power factors, harmonics and THD of voltages and currents etc.

Registration of Measured Data

- built-in real-time clock with battery backup
- flash memory to record the measured data with a capacity of 512 MB
- aggregation interval from 200 milliseconds to 24 hours
- records voltage outages

Transfer and Evaluation of Recorded Data

- RS-485 communication interface for data transmission, device configuration and firmware upgrade
- device can also be equiped with second RS-485 (option B), M-Bus (option M) or Ethernet (option E) interface
- visualization software ENVIS and configuration program ENVIS.Daq

Supported Firmware Modules

- Modbus Master (MM) — Allows regular data downloads from devices supporting Modbus into its own memory.
- General Oscillograms (GO) — Adds a feature that allows recording of raw signal samples.
- Ripple Control Signals (RCS) — Allows archiving of RCS datagrams and theirs voltage levels.

1.2 Types and Accessories

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

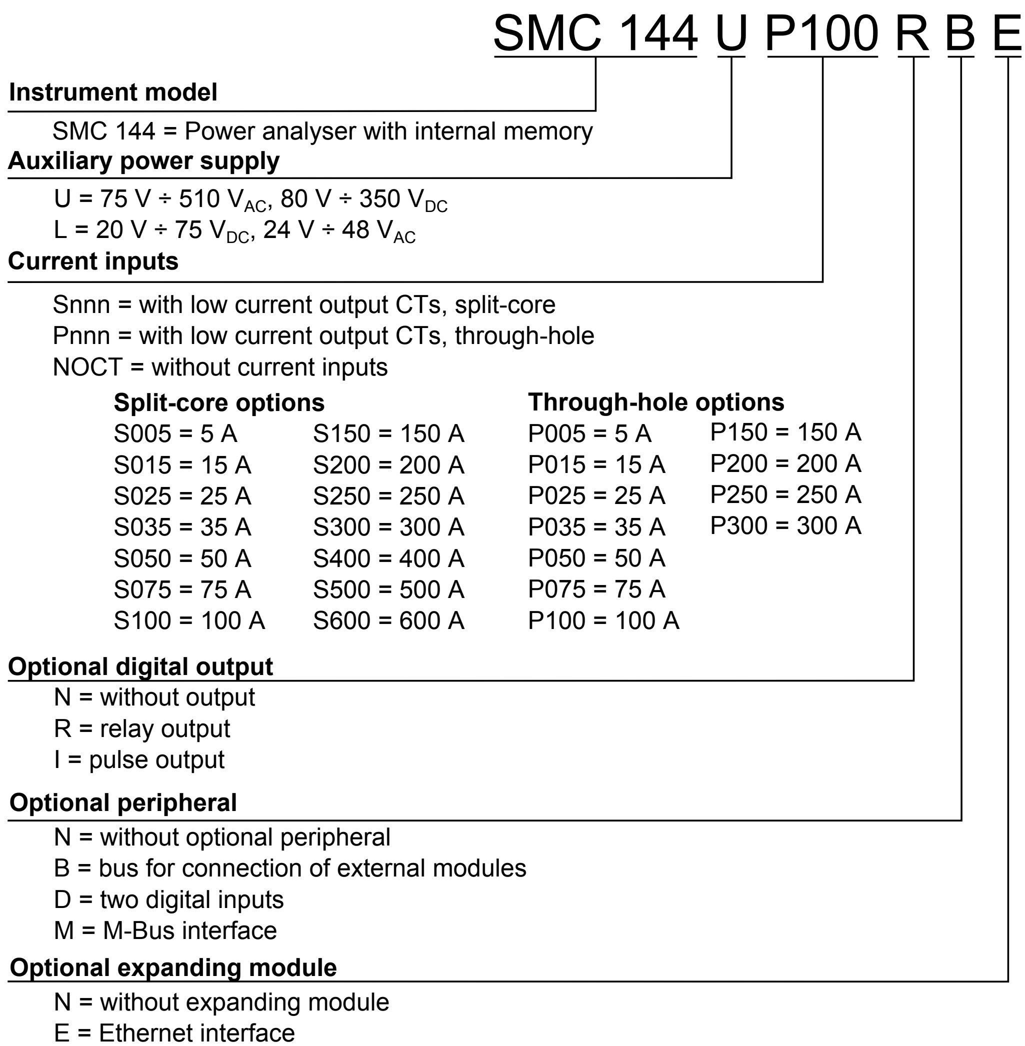


Figure 1: SMC 144 variants and numbering system

In table 1 there are dimensions and weights of current sensors for all 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.

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

Table 1: Physical dimensions of current sensors for individual device variants.

<table>
<tr><th colspan="6">Variant Pxxx</th><th rowspan="2">Range</th><th colspan="6">Variant Sxxx</th></tr>
<tr><th rowspan="2">Type</th><th>d</th><th>x</th><th>y</th><th>z</th><th>m</th><th rowspan="2">Type</th><th>d</th><th>x</th><th>y</th><th>z</th><th>m</th></tr>
<tr><th colspan="4">[mm]</th><th>[g]</th><th>[A]</th><th colspan="4">[mm]</th><th>[g]</th></tr>
<tr><td rowspan="2">JP3W</td><td rowspan="2">7</td><td rowspan="2">24</td><td rowspan="2">27</td><td rowspan="2">11</td><td rowspan="2">11</td><td>005</td><td rowspan="6">JC10F</td><td rowspan="6">10</td><td rowspan="6">23</td><td rowspan="6">50</td><td rowspan="6">26</td><td rowspan="6">45</td></tr>
<tr><td>015</td></tr>
<tr><td rowspan="6">JP5W</td><td rowspan="6">13</td><td rowspan="6">37</td><td rowspan="6">41</td><td rowspan="6">14</td><td rowspan="6">37</td><td>025</td></tr>
<tr><td>035</td></tr>
<tr><td>050</td></tr>
<tr><td>075</td></tr>
<tr><td>100</td><td rowspan="2">JC16F</td><td rowspan="2">16</td><td rowspan="2">30</td><td rowspan="2">55</td><td rowspan="2">31</td><td rowspan="2">75</td></tr>
<tr><td>150</td></tr>
<tr><td rowspan="3">JP6W</td><td rowspan="3">19</td><td rowspan="3">49</td><td rowspan="3">51</td><td rowspan="3">20</td><td rowspan="3">70</td><td>200</td><td rowspan="2">JC24F</td><td rowspan="2">24</td><td rowspan="2">45</td><td rowspan="2">75</td><td rowspan="2">34</td><td rowspan="2">150</td></tr>
<tr><td>250</td></tr>
<tr><td>300</td><td rowspan="4">JC36S-3</td><td rowspan="4">36</td><td rowspan="4">57</td><td rowspan="4">91</td><td rowspan="4">41</td><td rowspan="4">280</td></tr>
<tr><td colspan="6" rowspan="3"></td><td>400</td></tr>
<tr><td>500</td></tr>
<tr><td>600</td></tr>
<tr><td colspan="13">Variant NOCT has not current sensors nor current inputs.</td></tr>
</table>

2 Operating the Meter

2.1 Safety Requirements when Using SMC 144

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. It is recommended to always use protective gloves.

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!

2.2 Preparation Prior to Measurement

Before measurement it is necessary to configure the instrument appropriately. This setting is always done by PC with a standardly supplied program ENVIS.Daq[2].

2.2.1 Configuring SMC 144 on a PC

Connect SMC 144 to a computer via RS-485 to USB converter or Ethernet. Switch on auxiliary voltage powering the SMC 144. Supply voltage will be indicated by the LED PWR blinking green. Than the unit is ready to be adjusted. We can now set-up a desired operation. This setting will erase all previously archived data in internal memory of the instrument. So before writing new configuration to the device make sure to backup the last measured archive.

Run the ENVIS.Daq. First, open the main window. Choose the type of communication interface and its other related parameters. A connection form with typical parameters is shown in figure 2. For 10 seconds after power-up, device can always communicate with fixed baud rate 9600 bps and is listening on address 250. Green LED is fast blinking (once per 400 ms). If SMC 144 do not receive any command until the interval expires, port is reconfigured to parameters previously set by user. SMC 144 is also listening on address set by user — 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).

[2]Before first use the ENVIS must be installed in the PC. Detailed description can be found in The ENVIS User Guide.

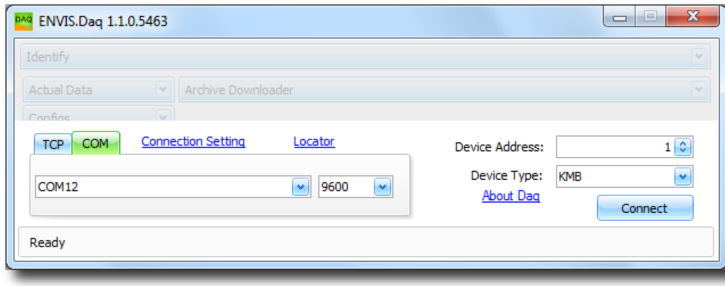


Figure 2: Main window of ENVIS.Daq.

If your device is equipped with the Ethernet module, you can switch to a *TCP* tab and connect with it's IP address and port 2101 or use *Locator* function to find all KMB devices connected to a LAN and simply chose the SMC 144 device you want to connect to.

Press the 'Connect' button. The program reads the settings from the connected device and displays it in the summary window (figure 3).

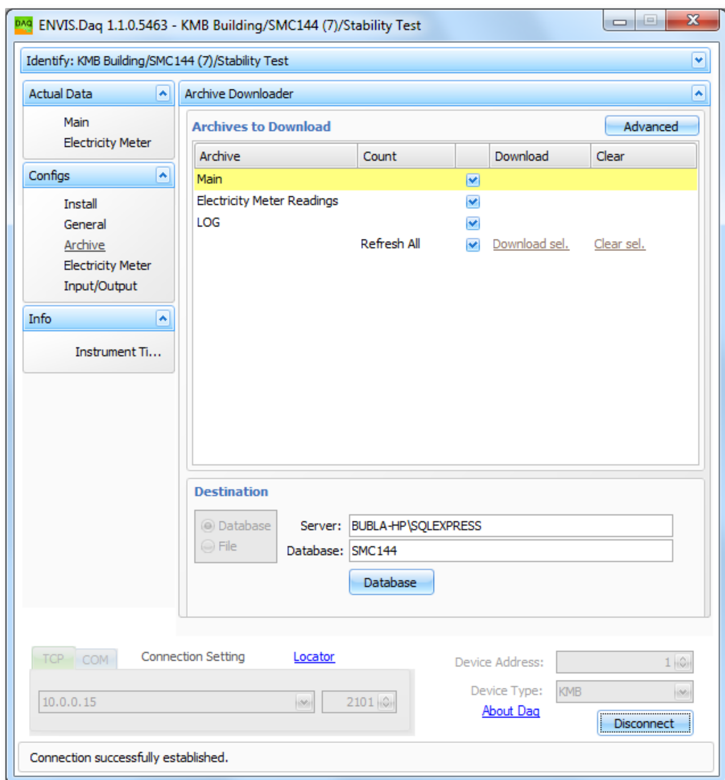


Figure 3: ENVIS.Daq - connected instrument.

Category 'Instrument Settings' includes a number of parameters, which are arranged in tabs according to its relation. User can configure the following in the individual tabs:

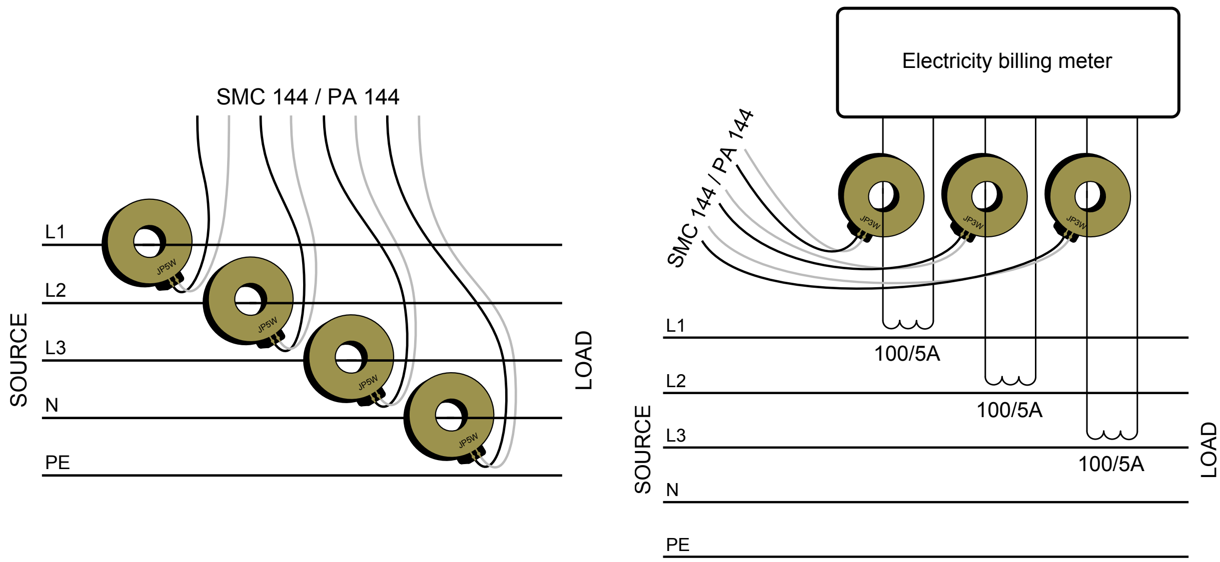
- Identify
  - *Object* - Is a number or name of object (generally a text string), where was performed the measurement. This is a basic identification element, that will organize the measurement archive in a database

record of the ENVIS program. In our case (object name is “DEFAULT”) it was retrieved directly from the instrument. It can later be adjusted manually.

– *Record Name* - The individual records in the measured object can be distinguished by their name (eg. name of the transformer in the building). In that case “DEFAULT”. This is again a text string of maximum length of 32 characters which can be adjusted later.

– Other informative parameters of this tab group indicate the type of connected device (model, serial number, etc.) and they can not be changed.

- Configs
  - *Install (fig. 5a)*
    - *Connection Mode* - Select the type of connection of the instrument — either direct voltage measurement or via voltage transformers.
    - *Connection Type* - Select type of measured network. You can choose from three-phase star, three-phase delta or three-phase star with neutral voltage measurement. Aron connection type can also be selected. Based on this setting, some quantities are calculated differently — for example when three-phase delta is selected, no U_{LN} is measured nor calculated. Proper wiring corresponding to individual selections will be illustrated in chapter 2.3.
    - *Nominal Frequency* - This parameter should be set according to the nominal network frequency measured at 50 or 60 Hz.
    - U_{NOM}, P_{NOM} - Rated voltage and rated power. To be able to view the voltage output as a percentage of nominal value and the detection of voltage events, it is necessary to specify a nominal (primary) voltage U_{NOM} and the nominal three-phase power (power) P_{NOM}. Although the setting for U_{NOM} and P_{NOM} has no effect on the device measuring functionality, we recommend to set at least the P_{NOM} correctly. Proper setting of P_{NOM} is a critical issue as it affects the displayed relative values of power and current and some of the data interpretation functions in ENVIS software. The setting can moreover be adjusted later. If the value of P_{NOM} at the measured point can not be determined, we recommend to set the value according to the nominal power supply of the transformer, or to estimate this value as the maximal expected. U_{NOM} value is displayed in the format as phase/line voltage for convenience.
    - *VT Ratio* - Must be set accordingly to the primary measuring voltage transformer transfer ratio. Available only when *via VT* Connection Mode is selected.
    - *Range I* - This parameter sets the conversion of current range. Factory default value corresponds to range of specific current input variant stated after slash (for example *Range I: 50 / 50*) and usually shouldn't be changed!
    - *Multiplier I* - The SMC 144 device can be used for direct or indirect measurement. In case of direct current measurement (see figure 4a) set the *Multiplier I* to 1. In case of indirect current measurement (as on figure 4b) *Multiplier I* must be set equel to primary current transformer ratio. 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 $\frac{1}{4} = 0.25$.
  - *General (fig. 5b)*
    - *Time Settings*
      - *Timezone* - Time zone must be set according to the local requirements. The setting is important for correct interpretation of local time, which also determines the actual allocation of tariff zones of the meter.
      - *Synchronization* - This parameter determines how the device synchronizes. It is possible to use synchronization over communication line (for example in cooperation with ENVIS.Online), synchronization by one minute period pulses on first digital input (if available) or no synchronization at all.



(a) Direct measurement principle for currents up to range corresponding to device variant.

(b) Example of indirect measurement over primary current transformers with ratio 100/5 A.

Figure 4: Current input connection possibilities.

- · *Daylight Saving* - This parameter can be set to automatically switch of the local time according to the season (e.g. summer or winter time).

∗ *Remote communication* - Device is always equipped with main RS-485 interface. It is optionally available with secondary RS-485 interface, ethernet port or other communication interface. In this part of *General Configuration*, all corresponding parameters of communication interfaces can be set.

- · *Device Address* - Address of the device with RS-485. Assign a unique address to all devices connected to a same bus.
- · *Serial Comm Speed* - RS-485 baud rate. Default is 9600 bps.
- · *IP Address* - IP address of the device with ethernet.
- · *Net Mask* - Net mask of a network.
- · *Default Gateway* - Setting of default network gateway.
- · *Ports* - Setting of ports, on whose the device is listening for communication. Default *KMB Long* message port is 2101, default *Modbus* port is 502 and default *Web server* port is 80. Every port can be changed to whichever is needed, but don't forget to change them appropriately in a remote software.

– *Archive (fig. 5c)* - This settings determines the set of quantities which are being recorded and how:

∗ *Record Name* – Naming the records helps to distinguish different records in the measured object (e.g. using the ID marking of the measured transformer). This is again a text string of maximum length of 32 characters. The records are stored in a database or in a file while using this identifier.

∗ *Record Interval* – This (aggregation) interval of the recording determines the frequency of entry into the archives of readings in the range of 200 ms up to 24 hours.

∗ *Cycle Recording* – With this switch you can determine the behavior of the device when closing the main archive. If this option is not activated, the memory capacity of the archive of the main unit stops recording data in the archive until the instrument is reconfigured. Otherwise, the record continues with the new measured values overwriting the oldest values first (FIFO). The main archive than contains the "latest" data of a total length corresponding to the capacity of the main archive.

  * *Archive Starts at, Immediately* - Determines whether to begin recording immediately after the instrument is powered on or at a preset day and time.
  * *Archived Quantities* - In this section you can choose the set of quantities that you want to record. Column *AVG* tick the required quantity and a record will contain the average values per logging interval. If you want to record the maximum and minimum values of the measuring cycle (see explanation below) during the recording interval, check the appropriate box in column *MIN, MAX*. The powers in column Import/Export can determine whether to store import and export respectively inductive or reactive load sums separately.
  * *Harmonics* - You can choose voltage and/or current harmonics to be recorded. You can select also, if only odd or all harmonics should be recorded and choose maximal harmonic order. Last option enables angles of harmonics to be included in archives.
  * The dialog also shows the estimated capacity of the main archive with the actual configuration (*Estimated Record Time*).

- *Electricity Meter (fig. 5d)* - For settings belonging to measurement of electrical energy. In addition to two tariff, three-phase, four quadrant electric energy, this unit records the maximum and average of active power.
  * *Record Period* - The period of recording of the electricity meter status (automatic meter reading).
  * *Tariff Control* - Set type of tariff control. You can choose from a tariff table or an external digital input for tariff switching.
  * *Tariff Table* - This table can set a daily tariffs for three different prices per hour. The energy will be registered separately for each tariff.
  * *Currency Code* - You can set a local currency code.
  * *Conversion Rate* - You can provide a cost of 1 kWh in different tariffs, so than you are able to optionally see prices of an imported (or exported) energy in a local currency instead of direct energy values.
  * *Window Type, Window Length* - Method of an averaging of the average active power $P_{AVGMAX(E)}$. You can choose a fixed window (Fixed) or a floating window (Floating). In addition, you can set the length of averaging window.

- *Input/Output (fig. 5e)* - The SMC 144 is always equipped with two alarm LEDs (*LED A1*, *LED A2*) and optionally one relay or impulse output (*O1*).
  * You can set a function, that controls each output by selecting the *Standard output* option. Complex conditions can be set by using up to four events/conditions (*E1* through *E4*), which can be in conjunction and/or disjunction. Character of an output can be selected as *Permanent* or *Pulse*. In the latter case, duration of the whole period and the active part of period can be set.
  * Also, you can set any output to behave as a standard electricity meter output by selecting the *Elmeter output* option. In this case, you can select whether you want active or reactive energy output and import or export. Also, number of *pulses/kWh* must be set properly.

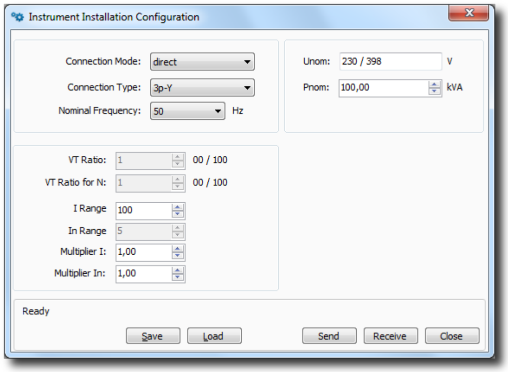
To commit changes in any of the above parameters it is required to send these new values into the instrument using the *Send* button. Settings can also be backed up into the file for later use with the *Save* button.

It is also recommended to check the status of the internal clock in the device. In the *Info* tab open the *Instrument Time* window (figure 5f). The program reads the current time set in your device and displays it. It also displays the difference to the actual PC time (*Time Difference*). If the time in the instrument varies significantly, it can be adjusted by selecting the *Set Time from the PC* option.

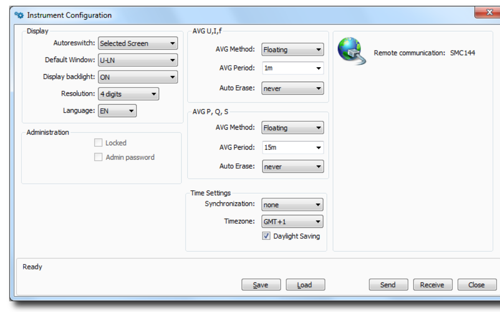
The necessary crucial device settings is than done — disconnect the communication cable and SMC 144 is ready to be connected to the measured network.

2.3 Installation

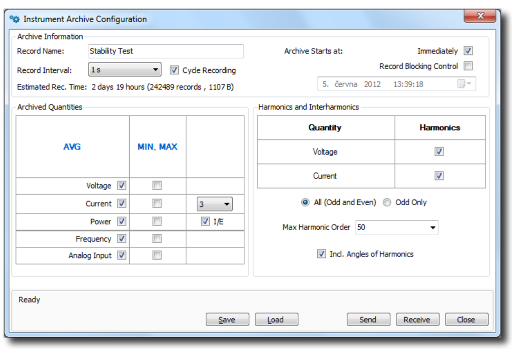
Natural air circulation should be provided inside the distribution board cabinet, and in the instrument's neighborhood, especially underneath the instrument, no other instrumentation that is source of heat should be installed



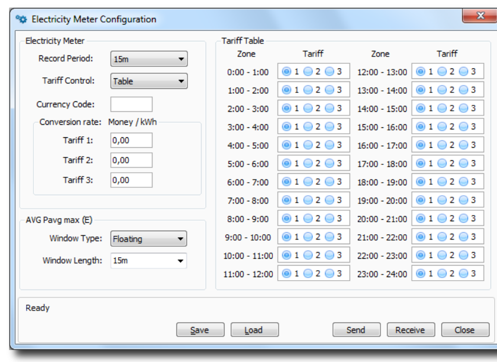
(a) ENVIS.Daq - instrument install configuration



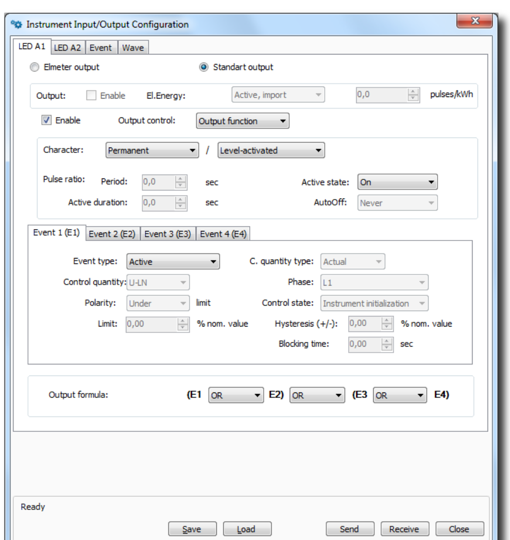
(b) ENVIS.Daq - instrument configuration



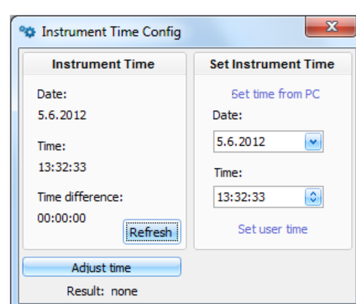
(c) ENVIS.Daq - instrument archive configuration



(d) ENVIS.Daq - instrument electricity meter configuration



(e) ENVIS.Daq - instrument I/O configuration



(f) ENVIS.Daq - instrument time configuration

Figure 5: ENVIS.Daq - SMC 144 configuration forms

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 SMC 144 is primarily intended for DIN-rail mounting. Dimensions of the instrument are on figure 6. There are also positions marked with dash dot lines of holes for wall-mounting with three screws.

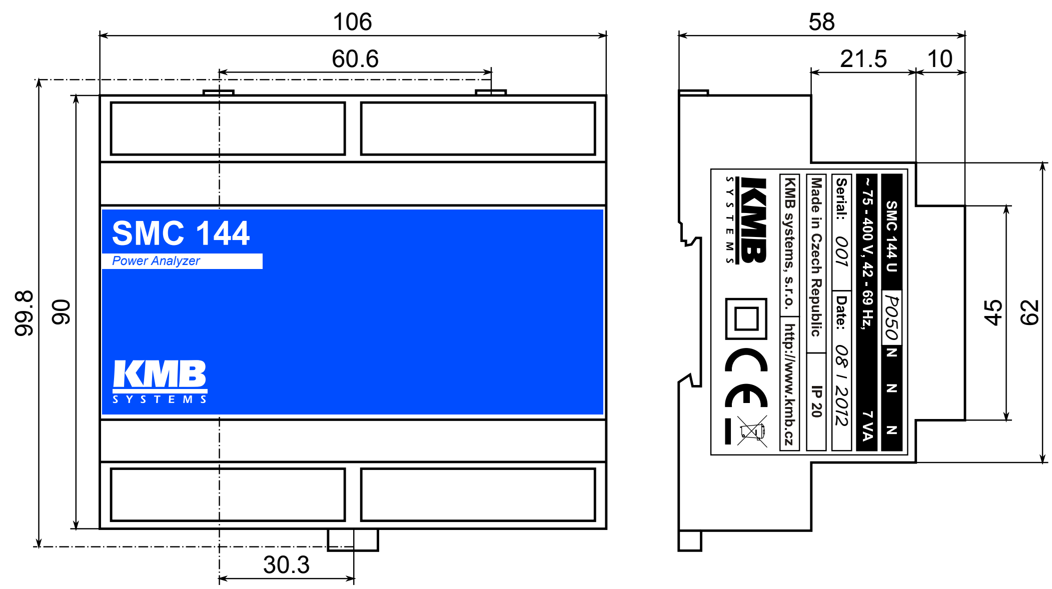


Figure 6: Rozměry přístroje SMC 144.

2.3.1 Voltage

The instrument's power supply voltage (see chapter 4) must be connected to the terminals X1 and X2 via a circuit breaking device (power switch – see installation wiring diagram on figure 7). It has to be located left to the instrument within an easy reach 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 however have to be clearly identified (using the '0' and 'I' symbols, respectively, in accordance with IEC EN 61010-1). Internal power supply is galvanically isolated from internal circuits.

The measured voltages are connected to the terminals L1, L2, L3, L4, the common terminal to connect the neutral wire to being identified as N. It is suitable to protect the measured voltage lines for example with $1\,A$ fuse links. The measured voltages can also be connected via a metering voltage transformers. All voltage measurement inputs are connected with internal circuits over high impedances.

2.3.2 Current

For proper current measuring, external through-hole or clamp-on current sensors must be installed with correct polarity. Figure 7 ilustrates proper connection polarity of precision through-hole current transformers. Intended direction of power flow is from left (source) to right (load). It is highly recommended to verify correct wiring and polarity of currents with phasor diagram in actual data using software ENVIS.Daq.

The current inputs are directly connected with internal cirtuits. Inputs *l1*, *l2*, *l3* and *l4* are internally connected together. Inputs l_i and k_i are connected through shunt resistors. Please note, that CURRENT INPUTS CAN NEVER BE USED FOR DIRECT MEASUREMENT! Always use only recommended supplied current transformers with low-mA output.

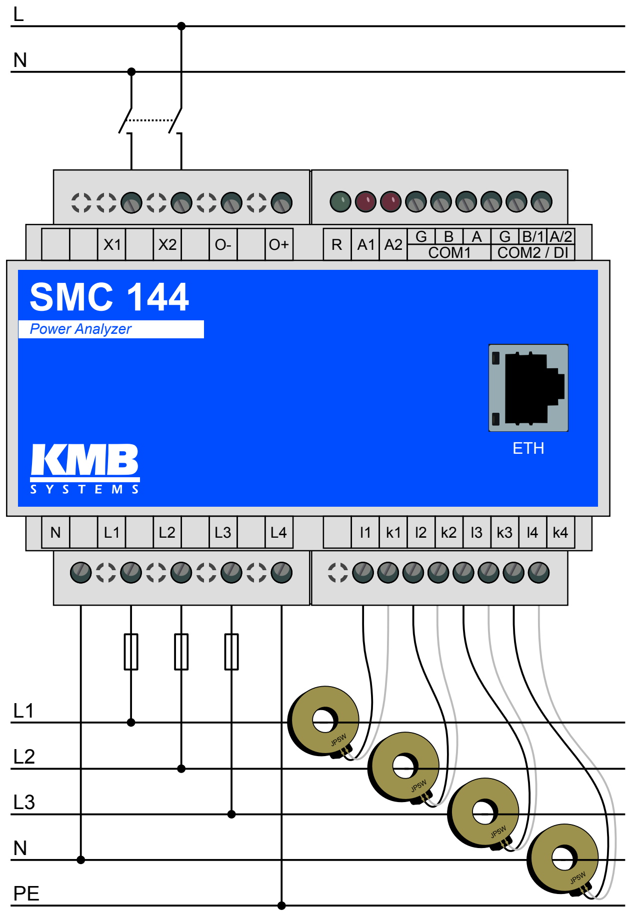


Figure 7: An example of typical installation and wiring diagram for SMC 144.

2.3.3 Peripherals

Function and connection possibilities will be illustrated on an example on figure 8. All peripherals stated below are galvanically isolated from the rest of the instrument and from each other. Digital inputs shares the same inputs with secondary RS-485, so they cannot be assembled both.

Primary RS-485

The primary communication line serves for remote reading of actual data, archive downloading and device configuration. Primary RS-485 line uses terminals *A*, *B* with shielding at terminal *G* of *COM1* block. The final points of the communication line have to be fitted with terminating resistance.

Digital Inputs (optional)

SMC 144 can be optionally equipped with two voltage sensitive digital inputs. It uses 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 the example picture 8 there are two external switches in series with voltage source of 24 V_{DC}.

Secondary RS-485 (optional)

Optional secondary RS-485 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. The

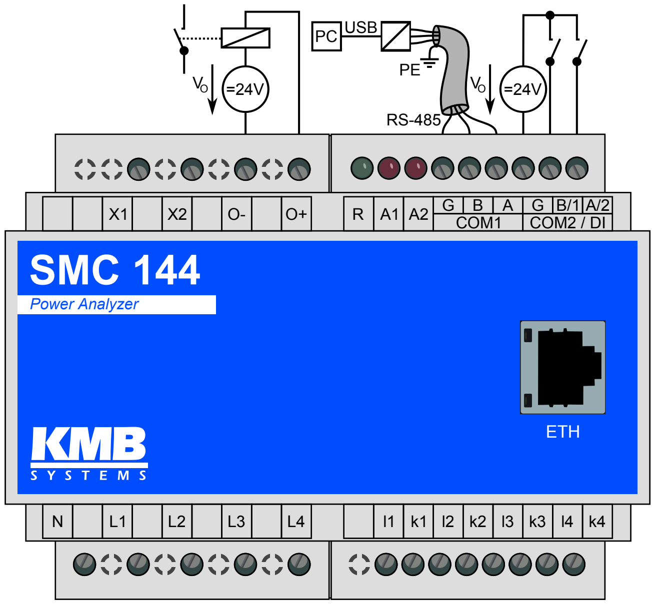


Figure 8: An usage example of digital I/Os.

final points of the communication line have to be fitted with terminating resistance.

M-Bus interface (optional)

M-Bus communication interface is intended for remote reading of gas or electricity meters. M-Bus interface uses terminals *A/2* and *B/1* of *COM2/DI* block. Connection polarity is unimportant.

Digital Output (optional)

Digital outputs are implemented as optional relay switch or impulse output connected through terminals *O+* and *O-*. In case of relay switch, polarity is not important, but when an semiconductor impulse output is used, polarity of external voltage source must comply with terminal labels and example picture. There is an external relay controlled by digital output in picture 8. Again, there must be external voltage source in series. When impulse output is used, direct current voltage source of 24 V is recommended. In case of relay output, nominal voltage of up to 230 V_{AC} can be used.

Ethernet interface (optional)

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 portable computer for archive download.

2.4 Transferring Measured Data to PC

As with setting phase the device should be first connected to the computer where the program ENVIS.Daq runs. Select the appropriate port, baud rate, address and press the *Connect* button. Next, press the button *Refresh All*. This will load and display the actual status of each archive:

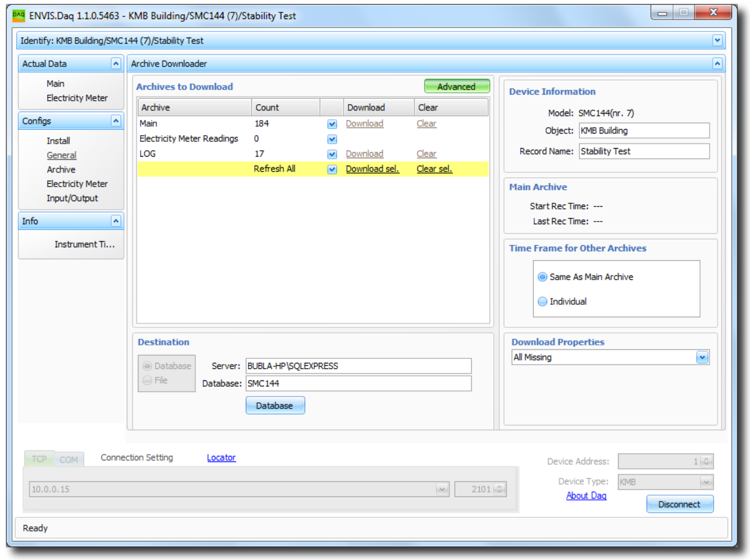


Figure 9: Download records window in program ENVIS.Daq

Device Information section contains editable description and name under which the actual record is stored. *Time Frame for Other Archives* tab allows you to limit the date ranges of all archives by the time interval of the main archive. In the *Destination* section the actual storage can be selected. In the actual version this can be database or file (several formats). The *.CEA* file data can be imported into the database and vice versa. The check boxes in *Archives to Download* determines which specific archive(s) you want to download. The actual download will start by the download button — after confirming the program starts transferring the data. Progress of the data acquisition is displayed in a window as in figure 10. After complete transmission the window will close automatically. Data can be than viewed in the ENVIS Program.

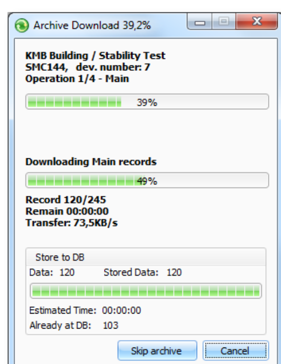


Figure 10: A window providing information about the download progress.

3 Functional Description

3.1 Instrument Construction

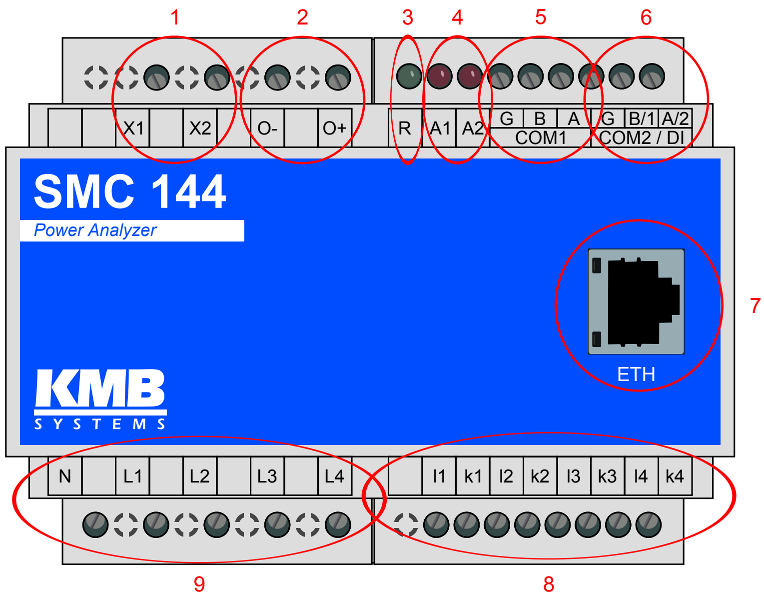


Figure 11: Description of the SMC 144 instrument.

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 LEDs
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

SMC 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 SMC 144 device, was described in chapter 2.

3.2.1 Machine Status

SMC 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 2.2.1.

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 2.2.1)

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

3.3 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.

3.3.1 Measuring the Frequency of the Fundamental Harmonic Voltage Component

Frequency of the fundamental harmonic of voltage signal 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.

3.3.2 Measurement of Voltages and Currents

Voltage and current signals are evaluated continuously without gaps. Basic evaluation interval is ten/twelve cycles of the network (200 ms for both 50 Hz or 60 Hz network). This evaluation forms the basis for all further calculations. All channels are sampled at the frequency of 128 samples per network cycle. Sampling is controlled by the measured frequency at the L_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 or 60 Hz). RMS voltage and currents are evaluated from the sampled values for the measuring cycle according to equations:

Line-to-Neutral voltage (RMS):

$$U_1 = \sqrt{\frac{1}{n}\sum_{i=1}^{n} U_{1i}^2}$$

Line-to-Line voltage (RMS):

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

Current (RMS):

$$I_1 = \sqrt{\frac{1}{n}\sum_{i=1}^{n} I_{1i}^2}$$

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

3.3.3 Evaluation of Powers and Power Factor (PF)

Powers and power factors are evaluated by the following relations. The formulas apply to the star type of connection.

Active power:

$$P_1 = \frac{1}{n}\sum_{i=1}^{n} U_{1i} \times I_{1i}$$

Reactive power:

$$Q_1 = \sum_{k=1}^{N} U_{1,k} \times I_{1,k} \times \sin \triangle\varphi_{1,k}$$

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 power:

$$S_1 = U_1 \times I_1$$

Distortion power:

$$D_1 = \sqrt{S_1^2 - P_1^2 - Q_1^2}$$

Power factor:

$$PF_1 = \frac{|P_1|}{S_1}$$

Three-phase active power:

$$3P = P_1 + P_2 + P_3$$

Three-phase reactive power:

$$3Q = Q_1 + Q_2 + Q_3$$

Three-phase apparent power:

$$3S = S_1 + S_2 + S_3$$

Three-phase distortion power:

$$3D = \sqrt{3S^2 - 3P^2 - 3Q^2}$$

Three-phase power factor:

$$3PF = \frac{|3P|}{3S}$$

3.3.4 Evaluation of Harmonic Distortion

Using Fourier transform the instrument continuously evaluates harmonic distortion of voltages and currents up to order 63. The calculation is performed by using a rectangular window of each measurement cycle (200 ms). Following parameters are evaluated from the harmonic analysis:

Fundamental (= 1^{st}) harmonic phase voltage:

$$Ufh_1$$

Fundamental (= 1^{st}) harmonic current:

$$Ifh_1$$

The absolute angle of the phasors of the fundamental harmonic voltage components:

$$\varphi U_1$$

Phasor shift of the fundamental harmonic current phasors to Ufh_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:

$$THD_{U1} = \frac{1}{U1h_1}\sqrt{\sum_{i=2}^{63} U1h_i^2} \times 100\%$$

Total harmonic distortion of current:

$$THD_{I1} = \frac{1}{I1h_1}\sqrt{\sum_{i=2}^{63} I1h_i^2} \times 100\%$$

Power factor (of the fundamental harmonic components):

$$\cos\triangle\varphi_1$$

Active power of the fundamental harmonic component:

$$Pfh_1 = Ufh_1 \times Ifh_1 \times cos\triangle\varphi_1$$

Reactive power of the fundamental harmonic component:

$$Qfh_1 = Ufh_1 \times Ifh_1 \times sin\triangle\varphi_1$$

Three-phase active power of the fundamental harmonic components:

$$3Pfh = Pfh_1 + Pfh_2 + Pfh_3$$

Three-phase reactive power of fundamental harmonic components:

$$3Qfh = Qfh_1 + Qfh_2 + Qfh_3$$

Three-phase power factor of the fundamental harmonic components:

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

Power and power factors of the fundamental harmonic component ($\cos\varphi$) are evaluated in 4 quadrants in accordance with IEC 60375, see Fig. 12

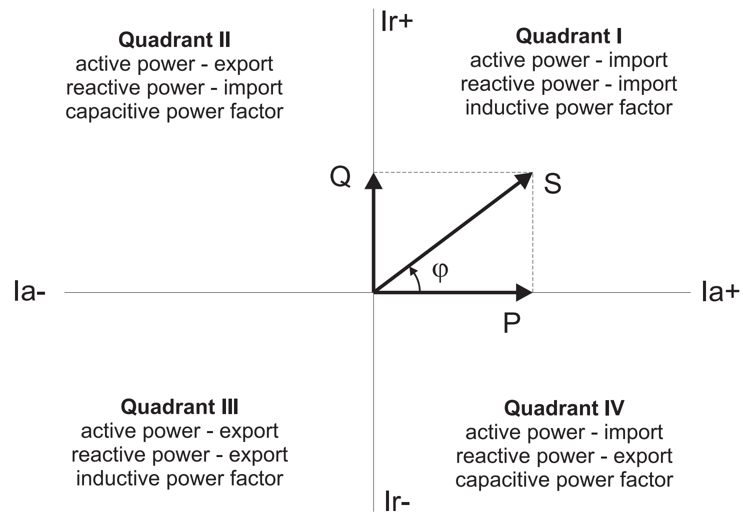


Figure 12: Identification of demand, supply and power factor profile according to the phase angle factor (IEC 60375)

3.3.5 Symmetrical components

Voltage and current unbalances are evaluated on the basis of positive and negative sequence components of fundamental harmonic.

Voltage unbalance:

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

Current unbalance:

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

Negative sequence current:

$$\varphi nsl$$

3.3.6 Aggregation and Recording

Values are aggregated and stored in the archive in instrument memory according to the settings of the recording interval. Aggregated (average) values are recorded by default for all selected parameters. Maximum/minimum values can be separately selected to be recorded. This feature is off by default to save free space.

Aggregation of each interval starts at the beginning of the cycle (determined by RTC tick), following the expiration of the previous time interval as required by the standards. If all the available memory capacity for main archive is used than the archive creation stops or restarts according to the Main Archive configuration. If '*Cyclic Recording*' is not selected, the instrument stops recording until it is reconfigured (and thus erased) by user or software. Otherwise the recording continues with the new measured values overwriting the oldest values in memory (FIFO). The device contains the "latest" set of records, which corresponds to the memory capacity of the actual device and configuration.

4 Technical Specifications

SMC 144	
Power supply	
auxiliary voltage (variant U)	$75 \div 510\,V_{AC}$ or $80 \div 350\,V_{DC}$
auxiliary voltage (variant L)	$24 \div 48\,V_{AC}$ or $20 \div 75\,V_{DC}$
power	$7\,VA/3\,W$
overvoltage category	CAT III / 300 V - in compliance with IEC EN 61010-1
pollution level	2 - in compliance with IEC EN 61010-1
power input	galvanically isolated, polarity insensitive
Voltage	
measuring range ($U_{NOM} = 400/230\,V_{AC}$)	$4 \div 500\,V_{AC}/2.3 \div 285\,V_{AC}$ (line / phase)
uncertainty ($\vartheta = 25^\circ C$)	0.1 % of range
input impedance	$2.7\,M\Omega$ ($L_i \leftrightarrow N$)
connection	wye, delta
permanent overload (IEC 258)	$1300\,V_{RMS}$
surge overload	$1950\,V_{RMS}$ for one second
Current	
measuring range	four CTs $0.02 \div 1.2 \times I_{NOM}$
permanent current overload	$2 \times I_{NOM}$
surge current overload	$10 \times I_{NOM}$ for one second
uncertainty (option P) ($\vartheta = 25^\circ C$)	0.1 % of range + 0.1 % of reading
uncertainty (option S)	0.5 % of range + 0.5 % of reading
max. conductor diameter (option P)	JP3W 6 mm/JP5W 13 mm/JP6W 19.3 mm
max. conductor diameter (option S)	JC10F 10 mm/JC16F 16 mm/JC24F 24 mm
Frequency	
measuring range	$42 \div 69\,Hz$
uncertainty	$\pm 10\,mHz$
Active power ($P_{REF} = 230 \cdot I_{NOM}\,W$)	
measuring range	limited by measurement voltage and current ranges
uncertainty ($PF > 0.5$) (option P)	0.1 % of P_{REF} + 0.2 % of reading
uncertainty ($PF > 0.5$) (option S)	1 % of P_{REF} + 0.2 % of reading
Reactive power	
measuring range	limited by measurement voltage and current ranges
uncertainty (option P)	0.1 % of P_{REF} + 0.2 % of reading
uncertainty (option S)	1 % of P_{REF} + 0.2 % of reading
Energy	
active energy meas. uncertainty	class 1 acc. to EN 62053-21
reactive energy meas. uncertainty	class 1 acc. to EN 62053-23
Harmonics	
measuring uncertainty $U_{H,1} \cdots U_{H,63}$	class 2 acc. to IEC 61557-12 Ed 1.0
measuring uncertainty $I_{H,1} \cdots I_{H,63}$	class 2 acc. to IEC 61557-12 Ed 1.0
measuring uncertainty THD_U	class 1 acc. to IEC 61557-12 Ed 1.0
measuring uncertainty THD_I	class 5 acc. to IEC 61557-12 Ed 1.0
Other quantities	
PF and $\cos\varphi$ measuring uncertainty	0.01

SMC 144	
Instrument temperature (built-in temp. sensor)	
measuring range	$-25 \div 60^{\circ}C$
uncertainty	$\pm 3^{\circ}C$
Digital inputs (optional)	
high-level input voltage	$U_H > 10\,V$
low-level input voltage	$U_L < 3\,V$
maximum input voltage	$U_M = 30\,V$
input current @ input voltage	$3\,mA/12\,V, \quad 8\,mA/24\,V$
Digital relay output (optional)	
switch ratings	$230\,V_{AC}$ or $30\,V_{DC}$ / $3\,A$
Digital impulse output (optional)	
semiconductor ratings	$100\,V_{DC}$ / $300\,mA$
Communication	
interface type	galvanically isolated RS-485
optional interface type	M-Bus
optional interface type	Ethernet 10Base-T
Other specifications	
operating temperature	$-25 \div 60^{\circ}C$
storage temperature	$-40 \div 85^{\circ}C$
operating and storage humidity	$< 95\,\%$ — non condensing environment
EMC — emission	EN 61000 – 4 - 2 (4 kV / 8 kV) 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 — immunity	EN 55011 – class A EN 55022 – class A (not intended for home use)
protection rating	IP 20
dimensions	$w \times h \times d = 105 \times 90 \times 58\,mm$
mass	$0.19\,kg$

5 Maintenance, Service, Warranty

Maintenance

The power analyzer SMC 144 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.

The lithium cell built in the instrument can backup a real time circuit for more than 5 years without power supply, at average temperature $20^\circ C$ and load current in the instrument less than $10\,\mu A$. If the cell is empty, it is necessary to ship the instrument to the manufacturer for battery replacement.

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