KMB systems, s.r.o.
Dr. M. Horákové 559, 460 06 Liberec 7, Czech Republic
tel. +420 485 130 314, fax +420 482 736 896
email : kmb@kmb.cz, internet : www.kmb.cz

SML 133

Multifunctional Meter

Operating Manual

Firmware 2.0.12.3491

The instrument measures line and phase voltages, currents, active, reactive and apparent powers, power factors, THD and harmonics of voltages and currents, as well as frequency in single-phase and three-phase low, medium and high voltage power systems.

Built-in electricity meter measures electric energy in four or six quadrants, as well maximum active power demand.

The instrument further allows informative measurement of temperatures within a switchboard cabinet using an inbuilt temperature sensor.

Besides actual values, average values during preset time window are evaluated too. Maximum and minimum values of them are registered.

The instrument feature three voltage and three fully isolated current measuring inputs.

Nominal range of the voltage inputs can be in range from 57.7/100 up to 400/690 V_{AC},optionally.

The current inputs are designed for indirect measurement only - they must be connected via external current transformers. The models with current-type inputs are available as either the „X/5A“, i.e. with 5 A_{AC} nominal range (for standard CTs), or the „X/100mA“ with nominal range of 0.1 A_{AC}. The „X/333mV“ models are determined either for CTs with output nominal voltage of 333 millivolts or for flexible current sensors (Rogowski coils) with embedded integrator and appropriate output voltage. Such models are equipped with auxiliary power supply of 5V for the sensors.

The instrument can be optionally equipped with two relays with programmable function or solid-state outputs that can be used as electricity meter impulse outputs and one digital input for general state monitoring.

Power supply of standard instrument models has universal range 85 ÷ 275 V_{AC} or 80 ÷ 350 $V_{DC.}$
Optional power supply range is 12 ÷ 48 $V_{DC.}$

The instruments can be equipped with an RS 485 or Ethernet communication interface. Then the ENVIS software allows remotely viewing data measured. For custom design systems, the Modbus communication protocol can be used too.

4 / 2015

1. Putting in Operation

1.1 Instrument Connection

1.1.1 Physical

The SML 133 instrument is built in a plastic box to be installed in a distribution board panel. The instrument's position must be fixed with locks.

Natural air circulation should be provided inside the distribution board cabinet, and in the instrument's neighbourhood, especially underneath the instrument, no other instrumentation that is source of heat should be installed or the temperature value measured may be false.

1.1.2 Power Supply

The supply voltage (in range according technical specifications) connects to terminals AV1 (No. 9) and AV2 (10) via a disconnecting device (switch – see wiring diagram). It must be located at the instrument's proximity and easily accessible by the operator. The disconnecting device must be marked as such. A circuit breaker for nominal current of 1 amp makes a suitable disconnecting device, its function and working positions, however, must be clearly marked.

1.1.3 Measured Voltages

The phase voltages measured are connected to terminals L1 (12), L2 (13), L3 (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). It is suitable to protect the voltage lines measured for example with 1A fuses. Measured voltages can also be connected via instrument voltage transformers.

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

SML 133 U 400 X/5A Instrument Rear Panel

1.1.4 Measured Currents

The instruments are designed for indirect current measurement via external CTs only. Proper current signal polarity (K & L 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).

In the P.01 parameter (see below), set the CT-ratio.

The I2k, I2l 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 (P.01 parameter). 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.

1.1.4.1 Current Type Current Inputs Instruments (Models „X/5A“, „X/100mA“)

The current signals from 5A or 1A (or 0.1A for the „X/100mA“ models) instrument current transformers must be connected to the terminal pairs I1k, I1l, I2k, I2l, I3k, I3l (No. 1 ÷ 6).

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

1.1.4.2 Voltage Type Current Inputs Instruments (Models „X/333mV“)

The instruments are equipped with separate connectors for particular measuring current input. Each connector has three terminals. Function of the terminals is described in following table :

“X/333mV“ Models Current Inputs Connection

terminal No.	signal
62	SI1 … signal corresponding to I1 current (in phase L1), terminal “k”
65	SI2 … I2k (phase L2)
68	SI3 … I3k (phase L3)
63, 66, 69	SG …common pole of the I1 ÷I3 signals (terminals “l”) and negative pole of the 5V built-in auxiliary power supply for current sensors (the terminals are interconnected)
61, 64, 67	SP... positive pole of the 5V built-in auxiliary power supply for current sensors (the terminals are interconnected)

The instruments are designed for cooperation with current transformers with output nominal voltage of 333 millivolts. They can be also used with flexible current sensors (Rogowski coils) with embedded integrator of appropriate voltage output signal.

The CTs must be connected with two-wire twisted cable of 1.5 mm^2 maximum cross section area. Again, proper current signal polarity (k & l terminals) must be observed.

Maximum length of the cable is 3 metres !

The flexible current sensors with embedded integrator usually require a power supply. For such purpose the instruments are equipped with auxiliary power supply 5V. Maximum load of each sensor connected is 20 mA.

Connection of standard CTs with 5A or 1A nominal output current to the „X/333mV“ instruments s ***forbidden*** *!!! Otherwise the instrument can be damaged !!!*

1.2 Basic Operation

On connecting power supply the display shows all of the segments, then gradually screens with the instrument type and setting of basic parameters :

1. line 1 : **133** - instrument type number

   line 2 : **5A** - current input type

   line 3 : **r1** - digital output type : relay (**r**), pulse (**1**), or none (**n**)
2. when connection of voltage via voltage transformers set (otherwise the screen is skipped) :

   line 1 : **Ut** - voltage transformer connected identification
   line 2 : nominal primary voltage [kV]

line 3 : 0. 1 - nominal secondary voltage [kV]

3. line 1 : Ct - current transformer/range specification
   line 2 : nominal primary current [A]
   line 3 : nominal secondary current [A]
4. line 1 : F U - nominal frequency and voltage
   line 2 : nominal frequency
   line 3 : nominal voltage

Then the instrument starts display actual measured values. Simultaneously, if the instrument has a communication line, it can be set and its measured values read via the communication link using a PC.

1.2.1 Setup

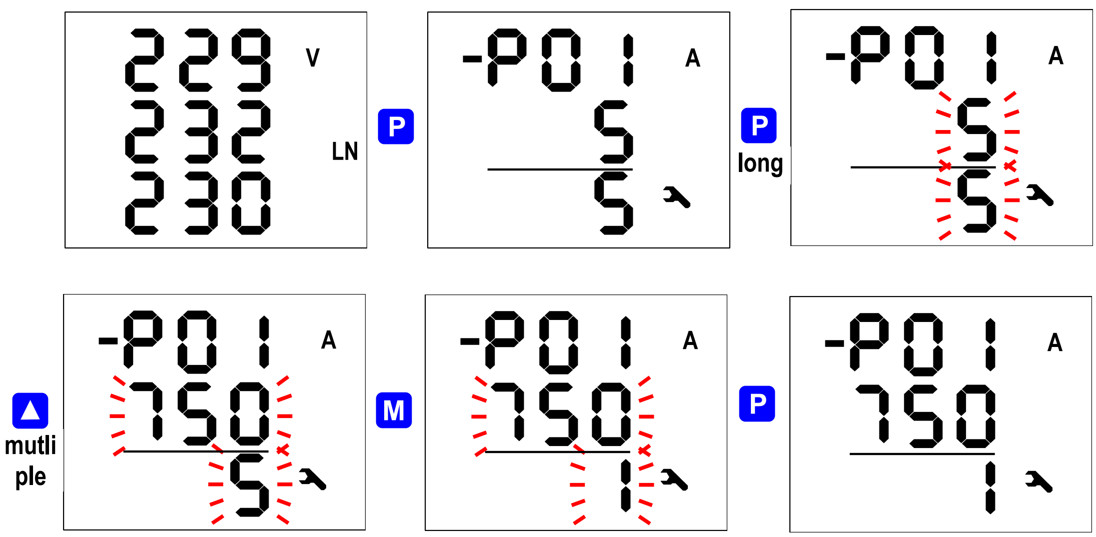
At this moment it is necessary to set *instrument parameters* that are essential for proper instrument measurement :

- CT ratio – parameter 01 (or multiplier)
- type of connection – parameter 02 (wye, delta, Aron)
- mode of connection – parameter 04 (direct or via VT connection, VT ratio)
- nominal frequency **f**$_{NOM}$ and nominal voltage **U**$_{NOM}$ – double parameter 05

Usually, it is only necessary to adjust the CT ratio. Next example shows how to do it :

Assuming that the ratio of used CTs is 750/1 A. First off all, it is necessary to switch display from measured data branch (the ULN screen on the example below) to *the parameter branch* with the **P** button. The branch is indicated with the 🔧 symbol . Parameter 01 appears – this parameter is the CT ratio and its default value is 5/5 A.

CT Ratio Change Procedure Example



Now enter editing mode by pressing and holding the **P** until the value gets flashing.

As soon as the value flashes, release the **P**. Now you can change it. Increase primary value by pressing of the **▲**. If you keep it pressed two-speed autorepeat helps to reach target value quickly. Then use multiple pressing of **▲** and **▼** for fine setup.

To change the secondary value, simply press the **M**. The button serves as toggle switch between 5 and 1.

Target CT value is prepared now and we can leave the edit mode with (short) pressing the **P**. The value is stored into the instrument memory and the flashing stops.

Now you can scroll to other parameters with ▲ and ▼ and edit them in a similar way or you can return to the measured data branch with the M.

The summary of all instrument parameters is stated in the table below. Their description is stated in following chapters.

1.2.2 Measured Data

The instrument starts display actual measured values on power-up. The screen that was selected before the last powerdown is displayed. You can navigate through all of measured and evaluated values with ▲, ▼ and M buttons as shown on *the Measured Data Navigation Chart* below.

If phase values displayed, individual L1 / L2 / L3 - phase value is shown in the line 1 / 2 / 3. If a three-phase value is displayed, it is shown in the line 2 and the Σ symbol appears.

The quantities' meaning and evaluation formulas can be found in the appropriate chapter further below.

Most of data are arranged in four columns :

- Actual …. actual values, refreshed each 3 measurement cycles (30/36 mains cycles)
- Avg .... average values per appropriate averaging period (see below)
- AvgMax ... maximum of the avg-value reached since the last clearing
- AvgMin …. minimum of the avg-value reached since the last clearing

You can scroll inside a column down and up with the ▲ and ▼ keys and move horizontally from a column to the next right one cyclically with the M key.

Exception : Only actual values of harmonics and electrical energy are available. These values are arranged in different way – see further below.

1.2.2.1 Average Values

Average values are processed according set averaging method and length of averaging window (individually for “U/I”-group and “P/Q/S”-group of quantities). Maximum and minimum values of them are registered into the instrument's memory. The maximums are displayed in the “AvgMax” column and they are identified with the ▲ symbol in the front of the value. Analogically, the minimums in the “AvgMin” column are identified with the ▼ symbol.

Neither maximum nor minimum of cosφ values are evaluated due to special character of the quantity. Similarly, these extreme values are not evaluated at harmonics.

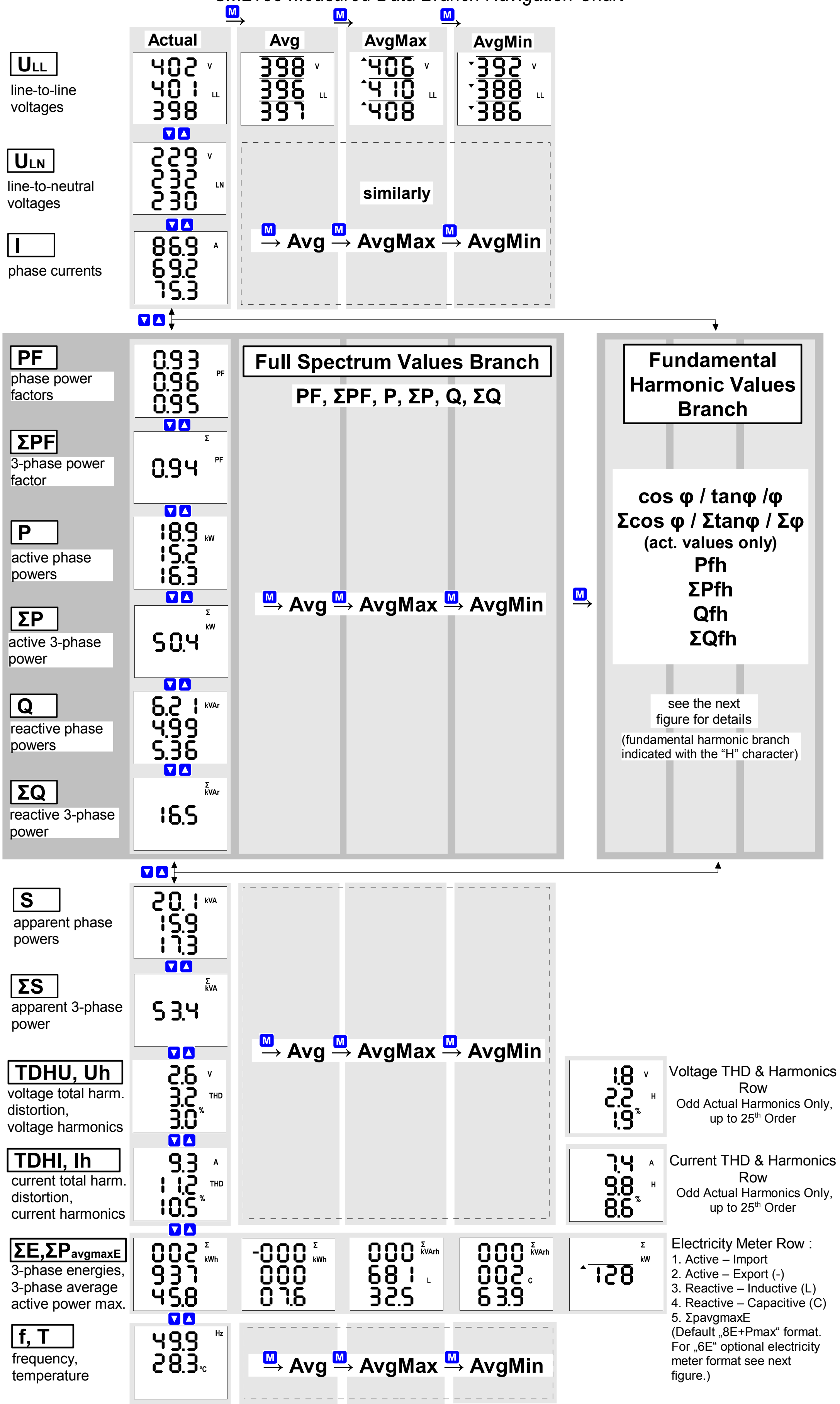
You can clear the “AvgMax”/“AvgMin” values. All of the maximums/minimums of appropriate quantity group are cleared simultaneously. To do it, follow next :

- navigate on corresponding AvgMax or AvgMin value
- press the M key until the value starts flashing
- with the ▲ or ▼ key, choose the CLr option
- then confirm by pressing the M

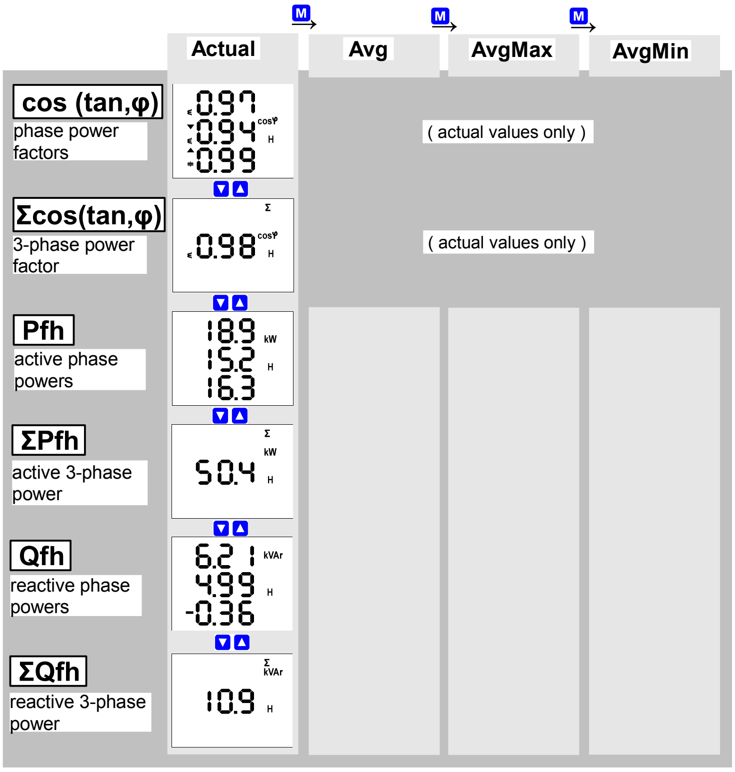
The appropriate group (U/I or P/Q/S) of average maxs/mins is affected by single clearing only ! Each group must be cleared individually.

If the instrument is locked, the clearing is not possible.

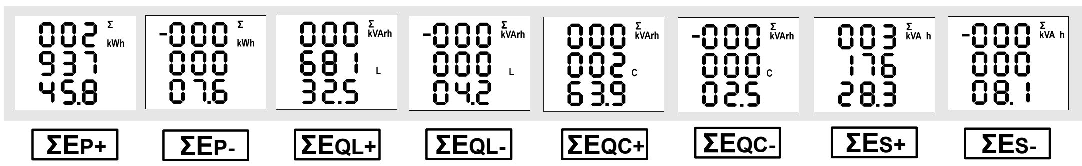
SML133 Measured Data Branch Navigation Chart



SML133 Fundamental Harmonic Values Branch



Optional "8E" Electricity Meter Display Format



1.2.2.2 Full Spectrum Values P/Q/PF & Fundamental Harmonic Values Pfh/Qfh/cos φ

As standard, active and reactive powers (and therefore power factor) are evaluated from full spectrum of harmonic components of both voltage and current.
Sometimes (for example for power factor compensation system checking), it is useful to know fundamental harmonic part of these quantities too. Such quantities are marked Pfh, Qfh, cos φ.
As you can see on the navigation chart you can navigate from *the full spectrum values branch* with the **M** key further right into *the fundamental harmonic values branch* and vice versa. To distinguish actual displayed branch, the **H** symbol is displayed for the fundamental harmonic branch.

Exception : Actual values only of fundamental harmonic power factor – *the cos φ* – are evaluated (no average values available). Next, this fundamental harmonic power factor can be expressed not only as *cos φ*, but as *tan φ* or *φ* too, depending on setting of parameter 09.

1.2.2.3 Fundamental Harmonic Power Factor Formats cosφ/tanφ/φ

The fundamental harmonic power factor can be expressed not only as cos φ, but as tan φ or φ too, depending on setting of parameter 09.
For outright specification of the quadrant, the power factor of the fundamental harmonic component is accompanied with two attributes :

- a sign (**+** or **-**), which indicates polarity of appropriate active power
- a symbol or , which indicates the power factor character

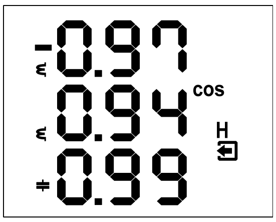
For detailed information see chapter *Power, Power Factor and Unbalance Evaluation Method* below.

At the following figures there are examples of three-phase fundamental power factor presentations :

Fundamental Harmonic Power Factor Formats

- the left figure : **Σcos φ** = 0.98 inductive (choke symbol displayed). Furthermore, active three phase power is being negative, therefore the leading "minus"-sign (and the symbol displayed)
- the middle figure : **Σtan φ** = 0.20 inductive. Active three phase power is positive.
- the right figure : **Σφ** = 8 degrees inductive. Active three phase power is positive.

Fundamental Harmonic Power Factor Sign & Character



On the figure on the left, there is phase cos φ values example :

- cos φ1 = 0.97 inductive. L1-phase active power is currently negative (because of leading "minus"-sign)
- cos φ2 = 0.94 inductive (L2-phase active power currently positive)
- cos φ3 = 0.99 capacitive (L3-phase active power currently positive)

1.2.2.4 THDs and Harmonic Components

You can check actual values of both voltage and current THDs and harmonic components in appropriate rows (see *the Measured Data Navigation Chart*).
When you scroll to one of this rows, THD values of all measured phases are displayed as default. Symbols **THD - V - LN** or **THD - A** indicate phase voltage or current THD values, respectively.
With the M key you can switch to harmonic components. The symbol **H** appears, indicating harmonic components (of voltage or current). Symbol **%** means that the values are expressed in percent of fundamental harmonic component. Order of harmonics just displayed flashes periodically in the display middle line – for example, string **H03** means 3rd harmonics.
By repetitive pressing of the M key you can check other harmonics. Although the instrument evaluates all of the harmonic components up to 50th order internally, only odd components to 25th order can be viewed of its display (full spectrum od the harmonics is available via communication interface only).

1.2.2.5 Electricity Meter

Electricity meter comprises three-phase energy data and maximum tree-phase active power demand value. The values are situated in particular row.

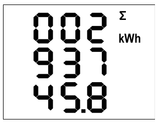
Depending on the parameter 08 setup, two electricity meter display modes can be chosen :

- "4E+Pmax" mode (default)
- "8E" mode

1.2.2.5.1 "4E+Pmax" Display Mode

In this mode, first four windows contain three-phase energies of four-quadrants :

- **ΣE_{P+}** … three-phase imported active energy, indicated with **Σ - kWh** (or **MWh** or **kMWh** = GWh)
- **ΣE_{P-}** … three-phase exported active energy, indicated with **Σ - kWh** and preceeding **—** sign
- **ΣE_{QL}** … three-phase inductive reactive energy, indicated with **Σ - kVArh – L**
- **ΣE_{QC}** … three-phase capacitive reactive energy, indicated with **Σ - kVArh - C**



Each value occupies all of three display lines, 8 digits before the decimal point and one after it. For the exaple at left, ΣE_{P+} = 293745.8 kWh.

The values are registered since the last clearing. To clear the energies, display any of them and then follow the same procedure as for max/min average values. All of the energies are cleared simultaneously ant start to count from zero again.

In the 5th window there is

- **$\Sigma P_{avgmaxE}$** … maximum of three-phase average active power (power demand), indicated with **Σ - kW - ▲** and bar over the value

The value contains maximum of three-phase average active power since the last clearing. Averaging method and averaging period for this value can be set regardless of the method of standard average values, described above. The quantity is marked with the "E" letter to distinguish from the standard maximum average quantities.

Similarly as the energies, the value can be cleared independently.

If the instrument is locked, clearing is not possible.

If the instrument is equipped with a communication interface, the values can be cleared remotely.

1.2.2.5.2 "8E" Display Mode

In this mode, reactive energies registered separately depending on actual three-phase active power (ΣP) sign are displayed ("six-quadrant " mode; such format can be convenient for renewable sources monitoring, for example) :

- **ΣE_{P+}** … three-phase imported active energy, indicated with **Σ - kWh** (or **MWh** or **kMWh** = GWh)
- **ΣE_{P-}** … three-phase exported active energy, indicated with **Σ - kWh** and preceeding **—** sign
- **ΣE_{QL+}** … three-phase inductive reactive energy registered during the ΣE_P value was positive (import); indicated with **Σ - kVArh – L**
- **ΣE_{QL-}** … three-phase inductive reactive energy registered during the ΣE_P value was negative (export); indicated with **Σ - kVArh – L** and preceeding **—** sign
- **ΣE_{QC+}** … three-phase capacitive reactive energy registered during the ΣE_P value was positive; indicated with **Σ - kVArh – C**

- **ΣEQC-** … three-phase capacitive reactive energy registered during the ΣEP value was negative; indicated with **Σ - kVArh – C** and preceeding **—** sign

Furthermore, energies in VAh are available too :

- **ΣEs+** … three-phase apparent energy registered during the ΣEP value was positive; indicated with **Σ - kVAh**
- **ΣEs-** … three-phase apparent energy registered during the ΣEP value was negative; indicated with **Σ - kVAh** and preceeding **—** sign

The three-phase active power demand **ΣP**$_{avgmaxE}$ is not displayed in this mode.

1.2.3 Instrument State Symbols

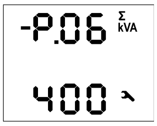
Except of measured data, the instrument indicates following states with dedicated symbols :

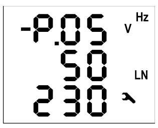
- .... Export of three-phase active power. Displayed when the **ΣP** value is negative.
- ○ / ● … A1(top) and A2 (bottom) alarm lights off / on. See output setup below.
- .... DI1 digital input state is active.
- .... Instrument parameters are displayed.

1.2.4 Instrument Parameters

For proper operation in particular conditions, the instrument must be set. The instrument setup is determined using parameters, for example the current transformer [CT] conversion, type of measured voltage connection (direct connection or via a voltage transformer [VT] and its ratio), and connection configuration (wye / delta / Aron). Overview of all the parameters is listed in the table below.

To check or edit the parameters, press the **P** key. As default, parameter group 01 is displayed and symbol (wrench) indicates, that setup data are displayed now.





The parameters are arranged in groups, numbered from 00 up. The number of group is displayed in the first line in format **- P. n n** (with preceding dash). You can browse through the parameter groups with the **▲** or **▼** keys.

If one parameter only in the group, its value is in the bottom line as shown at the example (nominal power 400 kVA).

If two parameters in the group, usually the first of them is displayed in the 2nd line and the second in the 3rd line (nominal frequency 50 Hz and nominal voltage 230 V).

To edit a particular parameter, scroll to its group. Then press and hold the **P** until the value gets flashing. Now release the key and set target value with the **▲** or **▼**, or the **M** key for some of parameters. You can use autorepeat function by keeping one of the arrow keys pressed too. Finally, press the **P** and the value is stored into the memory.

If more parameters in the group, the first one is chosen when entering editing mode for the first time. If you want to modify the second parameter only, simply cancel editing of the first parameter without any change and reenter the editing again – now the second parameter is chosen.

To return back to measured values display, simply press the **M** key.

SML 133 Instrument Parameters

#	parameter group	range	default	comment
00	lock	LOC / OPN	OPN	see Instrument Setup Locking / Unlocking
01	CT – ratio row 2 : nominal primary current row 3 : nominal secondary current (for models “X/100mA”,“X/333mV” fixed)	 primary : 1A ÷ 10 kA sec. : 5A / 1A (0.1A) (0.1 A, 0.333 V)	5 / 5 A	secondary current selection with the **M** key
02	connection type	3Y / 3D / 3A	3Y	
04	connection mode: direct (- - -) or VT–ratio: row 2 : primary U [kV] row 3 : secondary U (0.1 kV fixed)	primary: 0.1kV÷1MV	direct (- - -)	
05	f_{NOM}, U_{NOM} row 2 : f_{NOM} [Hz] row 3 : U_{NOM} [V / kV]	 50 / 60 Hz 50 V ÷ 1MV	 50 230	U_{NOM} specification depending on connection mode : - direct : line-to-neutral - via VT : line-to-line
06	ΣP_{NOM} [kVA / MVA]	1 kVA ÷ 999 MVA	-	
07	averaging period row 2 : for U/I group row 3 : for P/Q/S group	0.01 ÷ 60 (1 sec÷ 60 mins)	 1 min 15 min	floating window type averaging method applied as default; thermal method indicated with symbol ▲
08	avg period for $\Sigma P_{avgmaxE}$, El-meter d. mode line 2 : averaging period for $\Sigma P_{avgmaxE}$, line 3 : Electricity meter display mode	0.01 ÷ 60 (1 sec÷ 60 mins) “4E+Pmax” / “8E”	15 min “4E+ Pmax”	floating window type averaging method applied
09	fund. harmonic PF display format	cos / tan / fi	cos	
10	backlight	AUT / ON	ON	AUT-mode : the backlight is switched off automatically after approx. 5 minutes if no key is pressed to decrease power dissipation.
11	output setup row 2 : output DO1 row 3 : output DO2 standard type : “-O-” impulse type : pulses / kWh(kvarh) control energy symbol : • none … ΣEP+ • - … ΣEP- • ɛ … ΣEQL • ╪ … ΣEQC	“ - - -” = off “-O-” = standard output 0.001 ÷ 999 = impulse output	- - - (off)	control energy selection with the **M** key Standard type output can be set via communication line only, not from instrument panel. Symbol ▲ indicates different setup of the alarm light A1 from the DO1 and the A2 from the DO2 If impulse type output set from instrument panel, the A1 and the A2 alarm lights are set identically as the DO1 and the DO2, respectively.
15	communication for RS-485 : row 2 : address row 3 : rate [kBd] for Ethernet: row 2 : DHCP row 3 : IP-address (scrolls)	 1 ÷ 255 4.8 ÷ 115 ON / OFF (read only)	 1 9.6 OFF 10.0.0.1	
16	communication : nunber of data bits and parity	 8 / 9-n / 9-E / 9-0	 8	KMB / Modbus protocol automatic detection; for the KMB protocol set to “8”
19	instrument status (read only) row 2 : failure specification row 3 : serial no. & instr. version (scroll)	 0 ÷ 255 -	 0 -	row 2 : 0 = failure-free row 3 : S...serial no. F... firmware version b...bootloader version H...hardware version

1.2.5 Instrument Setup Locking / Unlocking

When shipped, parameter editing is unlocked, that means :

- all of the parameters can be edited
- standard average maximums / minimums, electricity meter energies ΣEP+, ΣEP-, etc., and electricity meter maximum power demand $\Sigma P_{avgmaxE}$ can be cleared

After being put in operation, such operations can be locked (=disabled) to protect the instrument against unauthorized changes. Then operator can only check measured values and parameters, but cannot change anything, excluding special parameter No. 00, that serves as the instrument lock. It has one of two values :

LOC .... instrument is locked

OPn .... instrument is unlocked (open)

If the instrument is locked, you can unlock it using the following procedure, which is similar to editing of other parameters:

1. Press the P key and scroll to parameter group 00 with arrow keys – value LOC is displayed.
2. Press the P and hold it down until the value is replaced with flashing number between 000 and 999. As an example, you can imagine flashing 345 is displayed.
3. Press the following sequence: ▼, ▲, ▲, ▼. The value changes gradually to 344, 345, 346, 345, so the same value is shown at the end as at the beginning.
4. Press the P. The flashing number is replaced with OPn, indicating unlocked state.

The digit shown while entering the unlocking keypress sequence is random and it is not important for correct unlocking (it is there only to confuse). Only the sequence of keys pressed is important and must be followed exactly.

The instrument can be locked in a way analogous to unlocking but it is necessary to press any keypress sequence that is different from the unlocking sequence noted above.

2. Detailed Operation Description

2.1 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.

2.1.1 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 symbol **Hz**.

2.1.2 Voltage and Current Measurement Method

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

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

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

Phase voltage (effective value) : $$U_1 = \sqrt{\frac{1}{n}\sum_{i=1}^{n} Ui_1^2}$$

Line voltage (effective value) : $$U_{12} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (Ui_1 - Ui_2)^2}$$

Current (effective value) : $$I_1 = \sqrt{\frac{1}{n}\sum_{i=1}^{n} Ii_1^2}$$

where : i .... sample index

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

Ui_1, Ii_1 … sampled values of voltage and current

The data for the longer measurements are aggregated from these measurement cycles.

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

Three current signals - I_1, I_2, I_3 - are measured. Another current is calculated from samples of directly measured ones as negative vector sum of all measured current vectors (Kirchhoff rule). The calculated current is referenced as $\mathbf{I_{PEN}}$. The $\mathbf{I_{PEN}}$ value is not displayed, it is available on a PC via communication with ENVIS program only.

2.1.3 Harmonics and THD Evaluation Method

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

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

Absolute angle of voltage harmonic component phasor : φUih_1

Current harmonic component phasor angle relative to phasor Ufh_1 : φIih_1

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

Total harmonic distortion of voltage : $$THD_{U1} = \frac{1}{U1h_1}\sqrt{\sum_{i=2}^{40} {Uih_1}^2} \times 100\%$$

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

2.1.4 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).

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

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

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

Apparent power : $S_1 = U_1 \times I_1$

Power factor : $PF_1 = |P_1| / S_1$

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

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

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

Three-phase power factor : $\Sigma PF = |\Sigma P| / \Sigma S$

Fundamental harmonic component quantities :

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

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

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

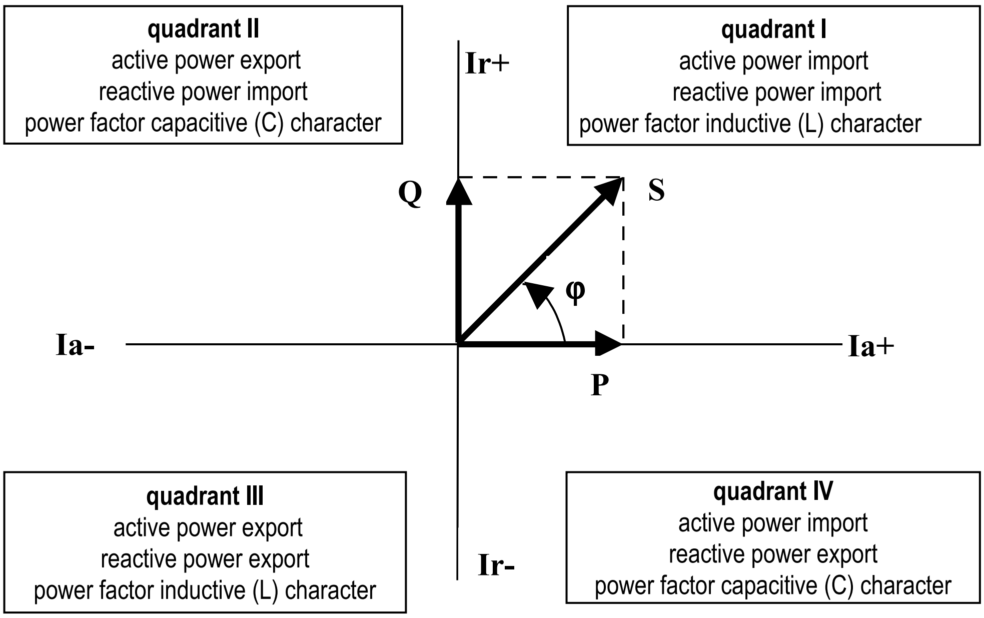
Fundamental harmonic three-phase active power : $\Sigma\, Pfh = Pfh_1 + Pfh_2 + Pfh_3$

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

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

Powers and power factors of the fundamental harmonic component (cos φ) are evaluated in 4 quadrants in compliance with the standard specifications, see figure below.

Identification of consumption- supply and the character of reactive power according to phase difference



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

- *a sign* (**+** or **-**), which indicates polarity of active power
- *a character* (or), 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 : $unb_U = \frac{voltage\_negative\_sequence}{voltage\_positive\_sequence} \times 100\%$

Current unbalance : $unb_I = \frac{current\_negative\_sequence}{current\_positive\_sequence} \times 100\%$

Current negative sequence angle : φnsI

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

2.1.5 Temperature

The temperature is measured with built in sensor and updated each approx. 10 seconds.

2.2 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.

2.2.1 Actual Values Evaluation and Aggregation

Actual (instantaneous) values of measured quantities, that can be viewed on instrument's display, are evaluated each *display refresh cycl*e as average of integral number of measurement cycle values. The display refresh cycle is preset to 3 measurement cycles , corresponding approx. to 0.6 sec display refresh cycle duration.

Exceptions :

- frequency – the value is refreshed each frequency measurement cycle (see above)
- voltage and current harmonic components – the last measurement cycle values are displayed (no averaging). Only odd harmonic components to 25th order are displayed. Higher components are available via communication link only.
- 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.

2.2.2 Average Values Evaluation

From measurement cycle values, average values of all basic quantities are calculated. The averaging period in range from 1 second to 1 hour can be used.

As default, *the floating window* averaging method is applied. An internal cyclic buffer is used to store auxiliary partial averages. The buffer has depth of 60 values. If preset average period is 1 minute or shorter, partial averages of a quantity are buffered each second and new average values are updated from the preset averaging period each second. If the preset average period is longer than 1 minute, partial averages for longer duration are buffered and the average values are updated less frequently (for example, if the preset average period is 15 minutes, partial averages are buffered each 15 seconds and average values are updated with this frequency).

At instruments equipped with communication link, *the thermal* averaging method sen be set too. An exponential function simulation is used to get the thermal dependence. Unit step time response depends on the preset averaging period – during this period, an average value reaches about 90 % of unit step amplitude.

The averaging period can be set in parameter group No. 07 independently for two groups of quantities : so called **U/I** -group and **P/Q/S** -group. Following table lists processed quantities of both groups.

Average Values Groups

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

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

2.2.3 Embedded Electricity Meter

For the electric energy measurement, a stand-alone functional unit - an electricity meter - is implemented inside instruments. Except of electric energy, maximum active power demands are registered in the unit.

2.2.3.1 Electric Energy Processing

Measured values of electrical energy are recorded separately in six “quadrants” :

- active energy consumed (E_{P+}, import), active energy supplied (E_{P-}, export)
- reactive energy registered at the three-phase active energy being consumed (imported) : inductive (E_{QL+}) and capacitive (E_{QC+}) energy
- reactive energy registered at the three-phase active energy being supplied (exported) : inductive (E_{QL-}) and capacitive (E_{QC-}) energy

Both single-phase and three-phase energies are processed. But on the instrument display, only three-phase (Σ) values can be viewed. Desired presentation format can be set with parameter 08.

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 99999999.9 kWh/kvarh, instrument's display format automatically switches to MWh/Mvarh, then to GWh/Gvarh.

2.2.3.2 Maximum Active Power Demand Registration

From the instantaneous measured values of all active powers the instrument evaluates their average values per preset period using preset averaging method – active power demands. Note that the active power demand, which is evaluated in the electricity meter unit (ΣP_{AVGE}), is processed individually and its averaging period is presetable independently on standard average values. Its current value is not available on the display - only its registered three-phase maximum $\Sigma P_{avgmaxE}$ is.

The averaging method if fixed – the floating window type. The averaging period can be set in range from 1 to 60 minutes.

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

2.3 Display Contrast

Although the display contrast is temperature compensated, there can be sometimes necessary to tune it slightly. To do it, press keys ▲ and ▼ simultaneously and keep pressed.

Then message COn appears in the first line and the contrast value in the second one.

Now, if the display too light, keep the ▼ pressed and increase with repetitive pressing of the ▲ key.

Likewise, if too dark, keep the ▲ and adjust with the ▼ key.

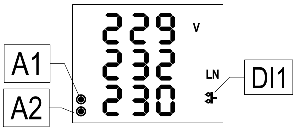
Finally, release the keys and new contrast is set.

3. Digital Outputs & Input

Instruments can be optionally equipped with a combination of outputs and inputs. A summary of possible variations and connection examples at the end of this manual.

Following inputs & outputs are available :

- two digital outputs – *relay* (electromechanical, **R**) or *impulse* (solid-state, **I**)
- one digital input



Furthermore, all of instrument models feature two “alarm ” lights **A1** and **A2** for indication of various states, that can be considered as other special digital outputs. Function of these lights can be set in the same way as at standard digital outputs.

The behaviour of digital outputs can be programmed according to requirements as :

- *transmitting electricity meter impulse output mode*
- *standard output mode* , e.g. as a simple two-position controller or a defined status indicator
- *remote controlled output mode* (by an external application via a communication link)

The digital input **DI1** state is indicated with the symbol and can be used for state monitoring via a communication link only.

3.1 Ouputs & Input Connection

Digital inputs & outputs are connected to terminals on a rear panel of an instrument according to the following table. A connection cable maximum cross section area is 2.5 mm^2.

Connection of Digital Outputs & Input

pin No.	signal
15, 16	DO1A, DO1B … digital output DO1
17, 18	DO2A, DO2B … digital output DO2
19, 20	DI1A, DI1B ….... digital input DI1

All of digital outputs and input are *isolated not only from instrument internal circuits but mutually too*.

3.1.1 Relay Output Connection

A SPST-NO (single-pole, single-throw, normally open) relay type is used. Maximum allowable voltage and load current according technical specifications must be observed.

3.1.1.1 Impulse Output Connection

Impulse outputs are accomplished by a semiconductor switching device. It is assumed that the input optocouplers of the external recording or controlling system will be connected to these outputs via current–limiting resistors. The signal polarity is free.

3.1.1.2 Digital Input Connection

The input supposes a voltage signal of appropriate magnitude is connected to the the **DI1** terminals (see technical specifications). The signal polarity is free.

If the voltage exceeds declared level, the input is activated and the symbol is displayed.

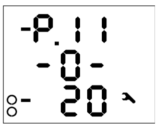
Usual 12 or 24 V DC/AC signals can be connected directly. If you need to connect a voltage signal of magnitude exceeding maximum digital input voltage, external limiting resistor of appropriate rating must be used.

3.2 Outputs Setup

Digital outputs (including alarm lights) function can be set either as *standard output* or as electricity meter *impulse output*.
The DO1 / DO2 output function can be checked in parameter group 11. Possible setup options are :

- - - - ... the output DO1/2 is disabled
- -0- ... the output DO1/2 is set to standard output mode (detailed setup available using the ENVIS program via a communication line only)
- nnn ... the output DO1/2 is set to impulse output mode with nnn pulses per kWh; the control quantity is ΣE_{P+} (no symbol shown). Other control quantities options according accompanying symbol :
  - - … ΣE_{P-}
  - ⊰ … ΣE_{QL}
  - ⊣⊢ … ΣE_{QC}

Example :



Output DO1 : set to standard output mode (details via communication link only)
Output DO2 : set to pulse mode, 20 pulses/kWh of energy ΣE_{P-}

The alarm lights A1, A2 setup is not displayed, it is available via a communication line only. You can only check if the setup is the same as corresponding DO1/DO2 setup – see below.

The impulse output function can be set from the instrument panel using parameter group 11.

The standard output function can be used at instruments equipped with communication link only – it can be adjusted only via connected PC using ENVIS program (see ENVIS program manual).

If any of signal lights A1, A2 is set, the outlines of both lights appear on the display. They stay hidden when function of both lights is disabled.

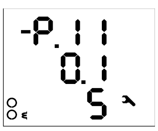
3.2.1 Impulse Output Mode

Any of digital outputs or alarm lights can be set as transmitting electricity meter. The frequency of generated impulses can be set depending on values of measured electric energy by the embedded electricity meter unit.

*You can set to impulse output mode not only the **I**-type (solid-state) outputs, but the **R**-type (electromechanical relay) outputs too. But note lifetime of electromechanical relays, they have limited number of switchings.*

The outputs DO1/2 can be set to impulse output mode both manually from the instrument panel and remotely via a communication line. The manual setup is available in parameter group 11. After entering editation, set edited parameter (range 0.001÷999) with arrow keys and select desired energy with the M key.

Example :



Output DO1 : 0.1 pulses/kWh = 1 pulse / 10 kWh, energy ΣE_{P+} (no additional symbol)
Output DO2 : 5 pulses/kvarh , energy ΣE_{QL} (due to symbol ⊰)

By setting any of the DO1/02 outputs from the instrument panel, corresponding alarm light A1/A2 is set in the same way automatically too. Then the DO1/DO2 activity can be checked by the A1/A2 lights on the instrument display. Separate setup of the lights is available using the ENVIS program via a communication line only. If any of lights is set different from corresponding DO1/DO2 output the symbol ▲ preceeding appropriate setup appears.

Even if an instrument is equipped with neither any digital output nor any communication line, you can set impulse function of alarm lights A1, A2 by setting the DO1/DO2 outputs.

After the impulse function mode is set, every 200 milliseconds the instrument executes evaluation of the measured electric energy. If the increment of recorded electric power is higher or equal to the quantity of power per one impulse, the instrument will transmit one or two impulses. The mentioned description shows that the fluency of impulse transmission is +/- 200 ms.

The impulse duty cycle is 50/50 ms (compliant with so-called SO-output definition), maximum frequency is 10 impulses per second.

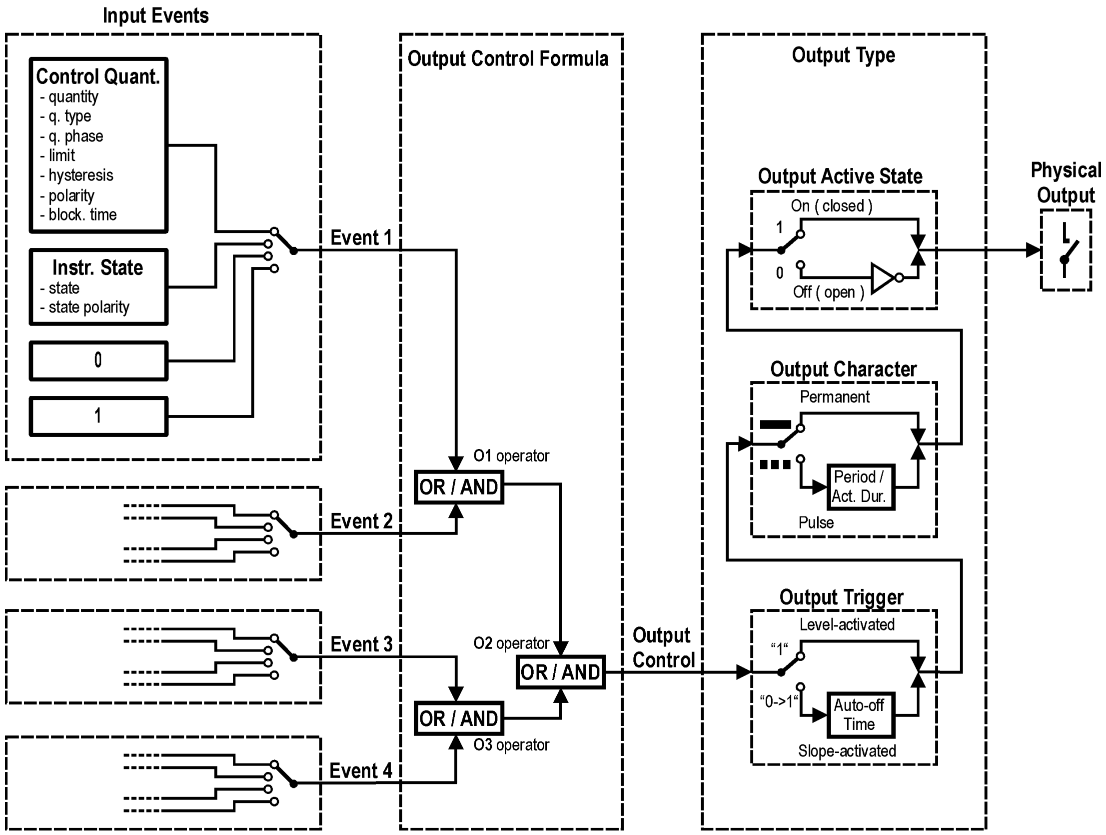
3.2.2 Standard Output Mode

For the standard output mode setup you need to use the ENVIS program, therefore it can be used at instruments equipped with a communication line only.

The figure below describes standard digital output operation. For complete output setup, following functions need to be set :

- *input events*
- *output control formula*
- *output type*

Standard digital output setup



3.2.2.1 Input Events

Each of four *input events* can be preset independently. An event type can be preset as :

- control quantity size
- instrument state
- *permanently inactive* (0, false)
- *permanently active* (1, true)

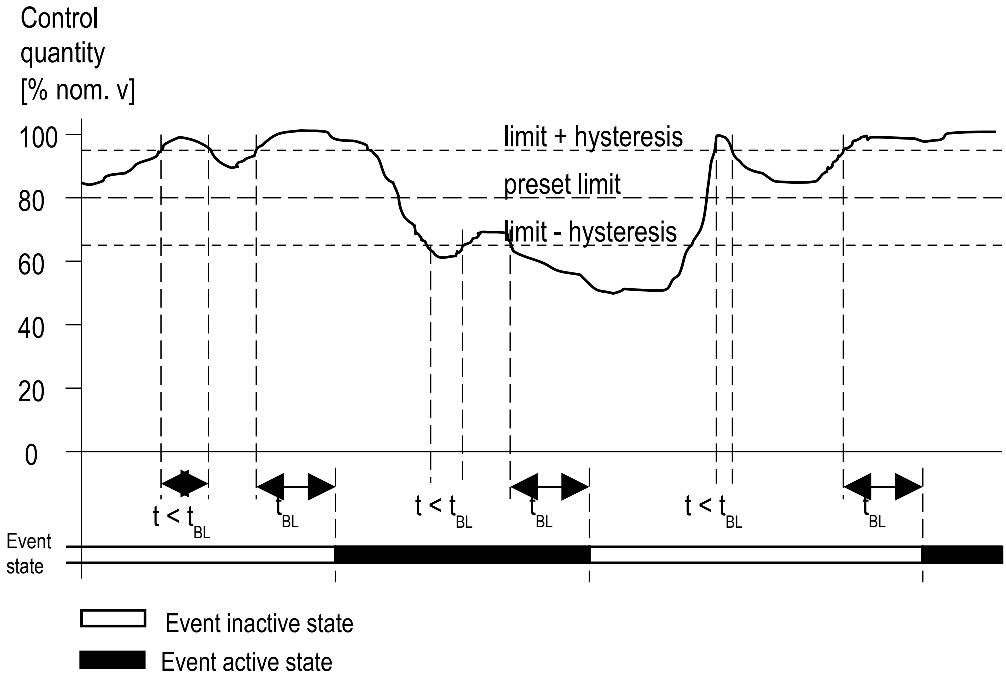
3.2.2.2 Control Quantity Size Event

At *control quantity size event,* the quantity size is compared with preset limit which results in the event state. For this, the following parameters must be preset :

- *control quantity* … one of measured quantities
- *control quantity type* … specifies if an actual or an average value of control quantity is used
- *control quantity phase* … desired phase(s) values or 3-phase value can be selected (applicable for phase character quantities only)
- *limit* size … limit value of the control quantity at which the event state changes
- *limit hysteresis* … defines the insensibility range of the event state
- *control quantity deviation polarity* … if the event state gets active over the limit or below the limit
- event state change *blocking time* … defines minimum time for the even state change

The function is shown below. The quantity that controls the event state (*control quantity*), can be chosen according to the following table. Furthermore, it is necessary to define, how to control the event status by the chosen control quantity. Thereby the other parameters are used.

Control quantity size event function



Limit and hysteresis specification

control quantity	***limit size*** and ***limit hysteresis*** specification
U_{LL}, U_{LN}	in percent, $\mathbf{U_{NOM}}$ ~ 100 %
I	in A
PF	in percent, 1,00 ~ 100 %
φ	in angle degrees
P, Q, S	in percent, $\mathbf{P_{NOM} / 3}$ ~ 100 %
3P, 3Q, 3S	in percent, $\mathbf{P_{NOM}}$ ~ 100 %
THDU, THDI, unb_U	in percent
f	in Hz
T	in °C
phase order	in percent, forward ~ 100% (reverse ~ 0 %)

The control quantity type can be selected from the list, which generally includes individual phase values, their logical disjunction and logical conjunction and three - phase value, if appropriate:

- L1
- L2
- L3
- N
- At least one of L1, L2, L3
- All L1, L2, L3
- 3-p

The control quantity deviation polarity for the event active state can be set either *over* the limit or *under* the limit.

The limit size and *the limit hysteresis* can be entered either in percentages of the preset nominal value or directly in the control quantity units. Specification of the values is mentioned in the table. For the correct operation in case of the values percentage expression, the nominal voltage $\mathbf{U_{NOM}}$ and the nominal power $\mathbf{P_{NOM}}$ must be adjusted properly in the instrument.

Depending on *the control quantity* character *the limit size* can be entered including the sign. Quantities that can be negative (active (P) and reactive (Q) powers, fundamental harmonic U to I phasor angle (φ) and temperature (T)) are compared with the limit including their signs.

The same proportion as *control quantity* also applies to *hysteresis*, which can adjust the event status insensitivity. If the controlling quantity varies in the zone of values [(*limit - hysteresis*), (*limit + hysteresis*)], the event status does not change.

Furthermore, the event status insensitivity to quick changes of *the control quantity* can also be set by so - called *blocking time*. Subsequently, the event changes its status only ,if the value of *the control quantity* stays continuously above or under the defined limit(including hysteresis) at least for the adjusted *blocking time*.

3.2.2.3 Instrument State Event

With *the instrument state event,* output behaviour can be controlled by the instrument state, various single-shot events or digital input status.

Following instrument states are supported :

- *digital input closed …* This state has value 1 (active) if the instrument digital input is closed. If open its value is 0 (inactive).
- *instrument initialization …* This state gets value 1 (active) as soon as the instrument is restarted, usually when powered on (or restarted by operator command or by a remote PC).

After the first *output control formula* evaluation (explanation follows below) it gets back to 0 (inactive).

- *instrument error* … This state is controlled by the instrument *error code* . It gets value 1 (active) when non-zero error code value. If the error code equals to zero value, the state value is 0 (inactive).
- *instrument setup change* … This state gets value 1 (active) as soon as the instrument setup is changed, either manually by operator or by local or remote link command. Immediately after the next *output control formula* evaluation it gets back to 0 (inactive).
- *instrument electricity meter clear* … This state gets value 1 (active) as soon as the instrument electricity meter state is cleared, either manually by an operator or by a local or remote link command. Immediately after the next *output control formula* evaluation it gets back to 0 (inactive).

When desired instrument state selected, its *polarity* can be set too (direct or negated).

Note : The instrument states assortment is subject to the upgrade and change in further firmware versions.

3.2.2.4 Permanent State Event

For all unused events their values can be set either as permanently inactive or permanently active.

3.2.2.5 Output Control Formula

Actual states of all preset events described above are processed each measurement cycle (= 10/12 mains cycles, i.e. 200 ms at 50 Hz) and so called *output control formula* is evaluated :

output control *= (**event1 O1 event2**) **O2** (**event3 O3 event4**)*

where :

output control ...logic result of the output control formula

event1 ÷ event4 … actual logic state of input events 1 ÷ 4

O1 ÷ O3 … logic operators, presetable to either **OR** or **AND**

A physical output state is driven by *the output control* status according to a preset *output type* (see below).

3.2.2.6 Output Type

Actual value of *the output control* status and preset *output type* specifies physical output behaviour. Following *output type* parameters can be set :

- *output active state* … Defines output state polarity when the *output control* status value is 1 (active). Can be set either to *on* (output switch is closed) or *off* (open).
- *output character* … Can be set either as *permanent* or *pulse*. If set to *pulse* , the pulse signal parameters must be set :
  - *pulse signal period* … period (in ten/twelve mains cycles resolution)
  - *pulse active state duration* … duration of the active state (defined with *the output active state* parameter) part of the pulse signal (duty of the signal). The preset value must be lower than *the pulse signal period .*
- *output trigger* … If set to *level-activated* , the output is continuously controlled by actual *output control* value. On the contrary, if set to *slope-activated* , the output gets to preset active state when the value of *the output control* status changes from inactive (0) to active (1) state only. In such case another parameter should be set :

- *active state auto-off time* … duration of the active state after being triggered. Time from one second up to one week can be set. When preset time expires the output reverts back to inactive state. If this parameter is set to *never* , the output after being triggered stays in active state continually. The only two ways to switch it off are either the output setup change or the manual output clear.

3.2.3 Remote Controlled Output Mode

When set in this way, the output state can be controlled by an external application (program) via the communication interface (for example by a web browser). Detailed information can be found at the remote communication link protocol manual.

4. Computer Controlled Operation

Monitoring the currently measured values and the instrument setup can using a remote computer connected to the instrument via a communication link. Such operation allows you to use all the setup options of the instrument, which it is not possible from the panel of the instrument.

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

4.1 Communication Interface

4.1.1 RS-485 Interface

The link is isolated from other circuits of the instrument. Use terminals **A** (No. 28), **B** (29) and **GND** (30).

4.1.1.1 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 **GND** signal.

4.1.1.2 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 330 Ohm.

4.1.2 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 10/100 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. But it is not possible to set the IP-address from the instrument panel; you have to use the ENVIS-DAQ program. The setup procedure description can be found in application handbook *ES01 Embedded Ethernet to Serial Link Converter* that is available on www.kmbsystems.eu .

From the instrument panel you can set the DHCP function only (parameter 15, row 2) for dynamic IP-address allocation. Actual IP-address can be checked in row 3 (its value scrolls).

4.2 Communication Protocols

Instruments support both proprietary KMB protocol and Modbus protocol. Protocol detection is automatic; for proper link operation, the communication address, baudrate, number of data bits and, optionally, the parity too(parameter groups 15 and 16) must be set.

4.2.1 KMB Communications Protocol

This manufacturer proprietary protocol is used for communication with the ENVIS-DAQ or the ENVIS-Online program. Number of data bits (parameter No. 16) must be set to 8.

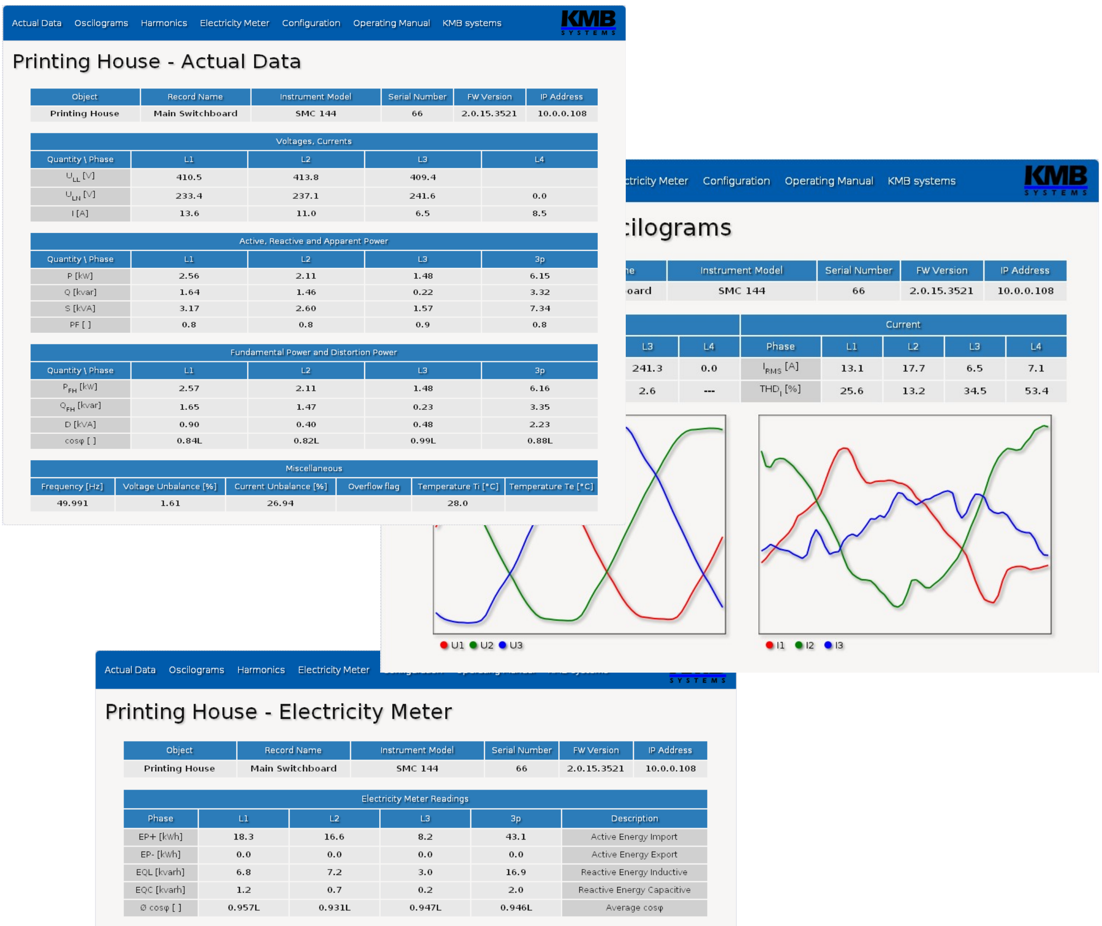
4.2.2 Modbus Communications Protocol

For the chance of easier integration of the instrument to the user's program, the instrument is also equipped with the Modbus–RTU / Modbus–TCP communications protocol. A detailed description can be found in the *SML 133 Multifunctional Panel Meter Protocol description for Modbus TCP and Modbus RTU Protocol* manual available on www.kmbsystems.eu .

4.2.3 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.

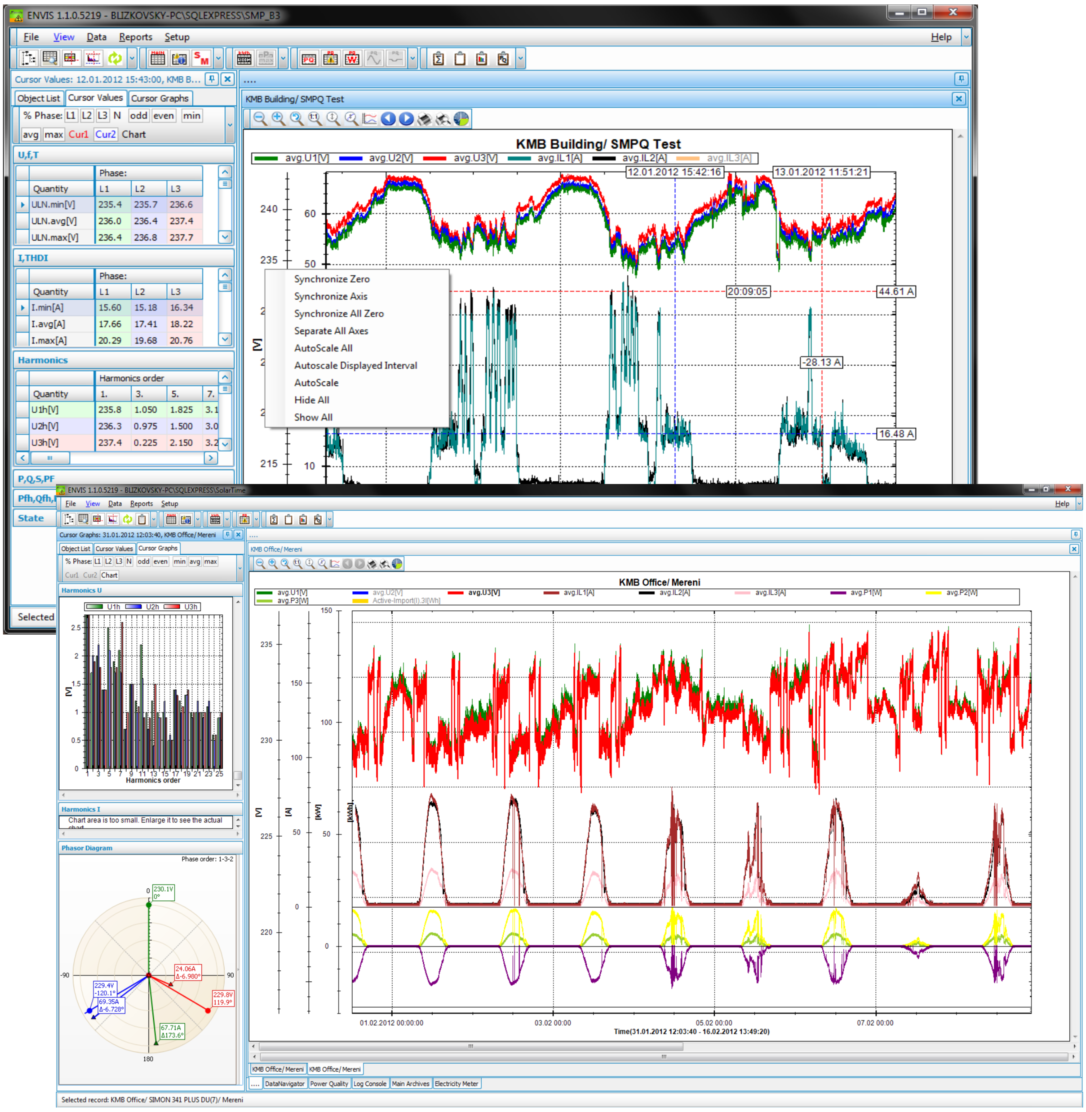
Webserver



4.3 The ENVIS Program

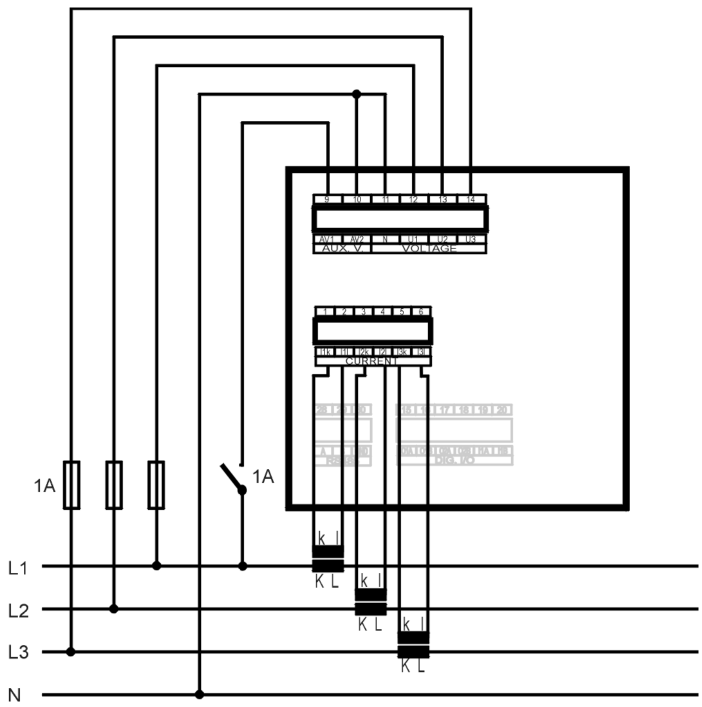
The ENVIS set of programs is used to set up the instruments, downloading actual measured data and to data visualization and archiving on a supervising PC. Detailed operation description can be found in manuals of the programs (www.kmbsystems.eu).

Measured Data Visualization Examples

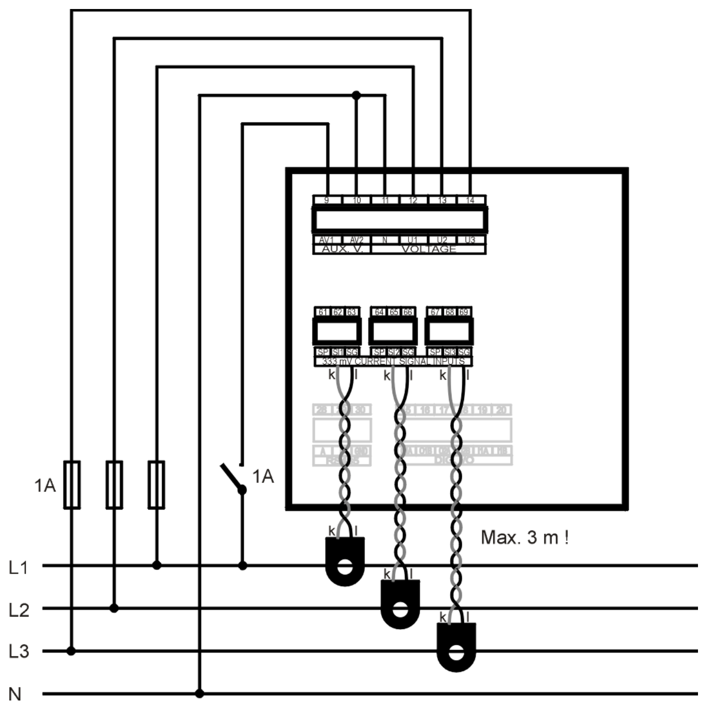


5. Examples of Connections

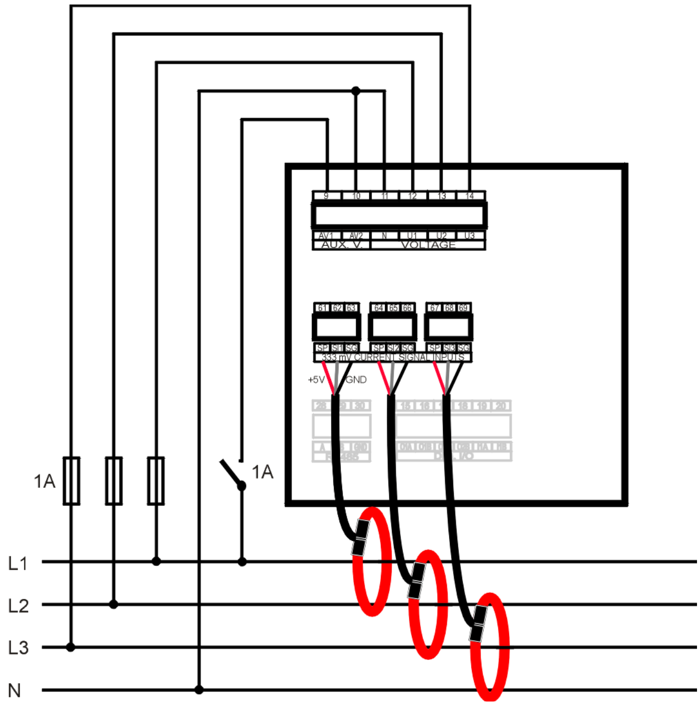
SML133 U 230 X/5A – Connection with 5A Nominal Output CTs
TN-Network, Direct Star ("3Y") Connection



SML133 U 230 X/333mV – Connection with 333 mV Nominal Output CTs



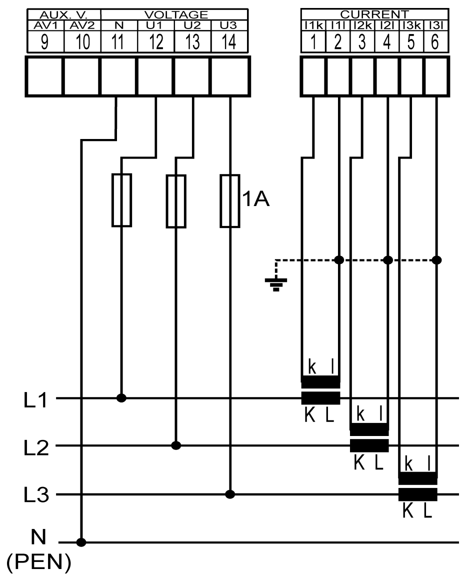
SML133 U 230 X/333mV – Connection with 333 mV Nominal Output Rogowski Current Sensors Equipped with Embedded Integrators



SML133 ... X/5A – Measured Signal Connection Examples

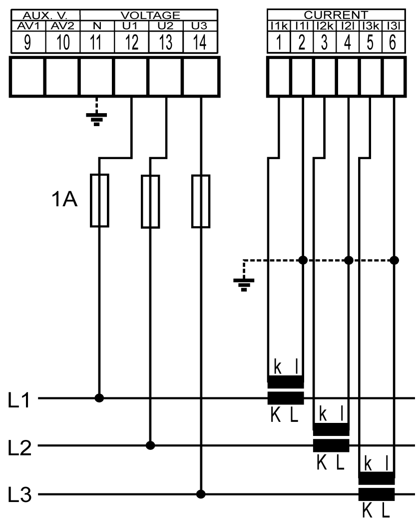
TN Network

Direct Star ("3Y") Connection

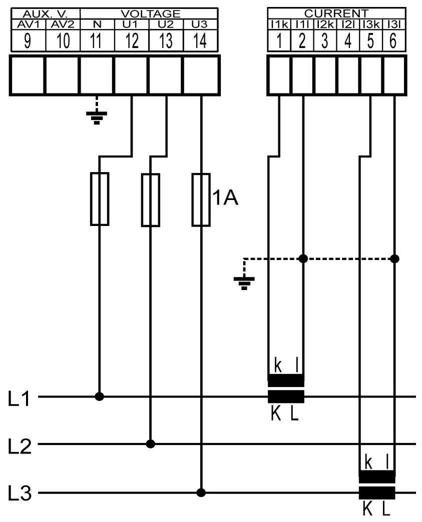


IT Network

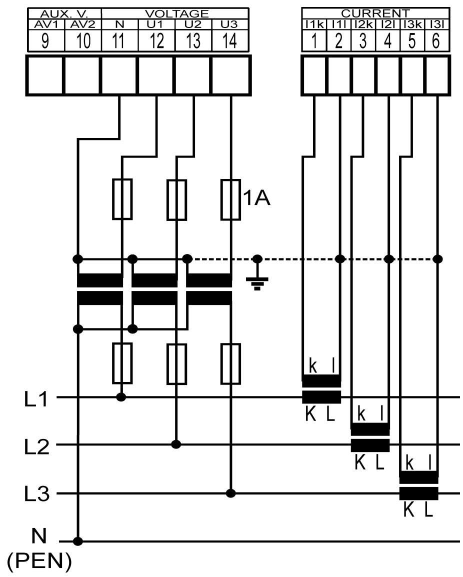
Direct Delta ("3D") Connection



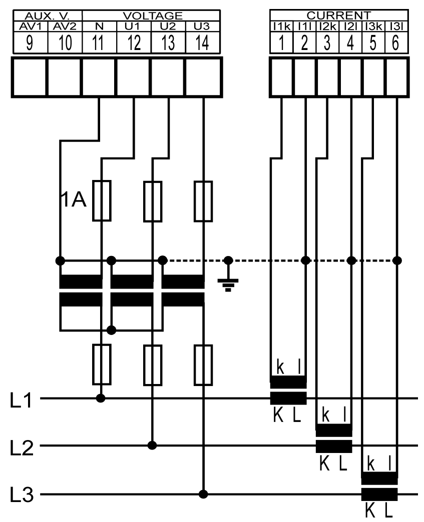
IT Network
Direct Aron ("3A") Connection



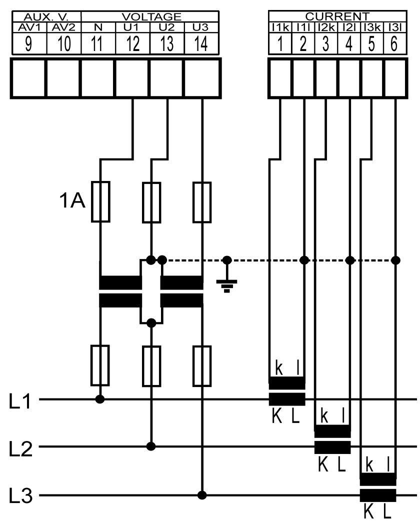
TN Network
Star ("3Y") Connection via VT



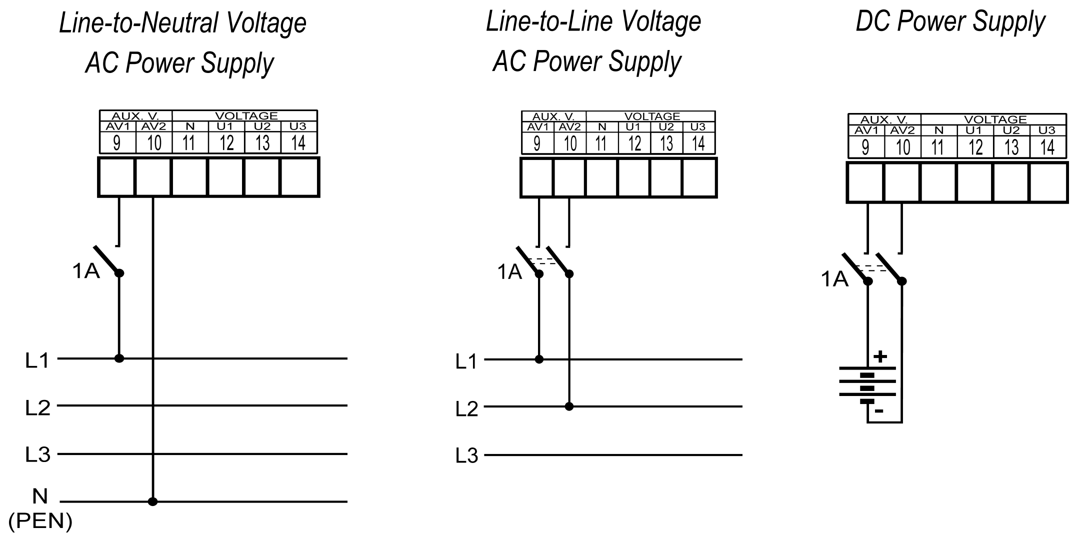
IT Network
Delta ("3D") Connection via VT
(VT to Line-to-Neutral Primary Voltage)



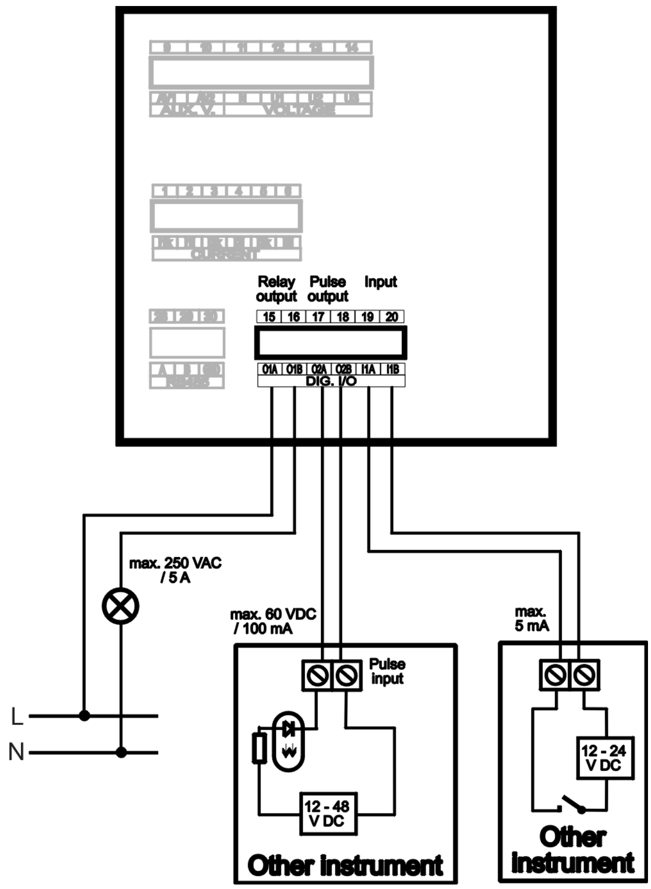
IT Network
Delta ("3D") Connection via VT
(VT to Line-to-Line Primary Voltage)



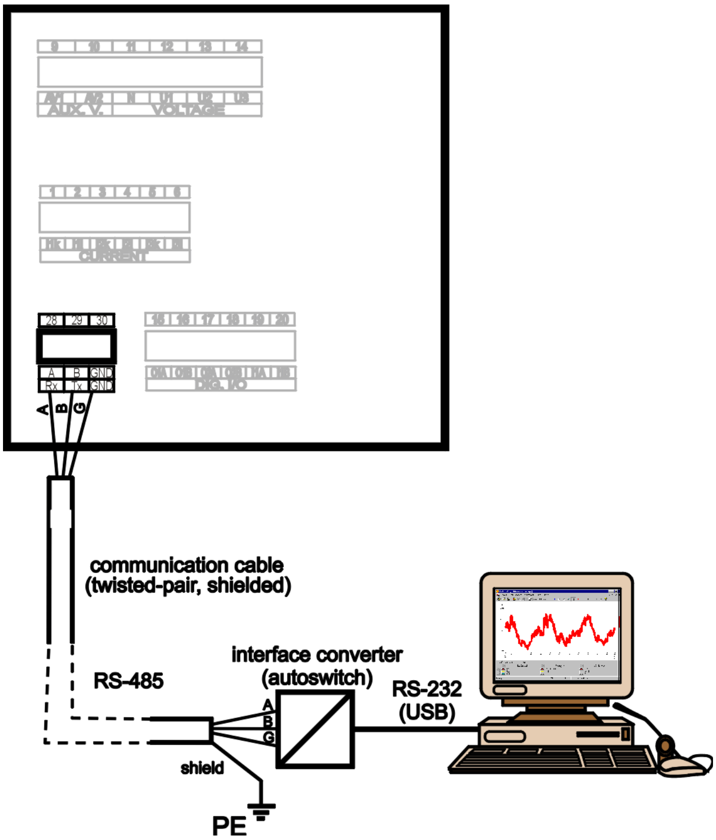
SML133 ... – Power Supply Options



SML133 ... RI Digital I/O Connection Example



SML133 ... 4 RS-485 Communication Link Connection



Numbering of Terminals

signál	svorka č.	signál	svorka č.
AV1	9	DO1A	15
AV2	10	DO1B	16
L1	12	DO2A	17
L2	13	DO2B	18
L3	14	DI1A	19
N	11	DI1B	20
I1k (SI1*)	1 (62*)	A (RS485)	28
I1l (SG*)	2 (63*)	B (RS485)	29
I2k (SI2*)	3 (65*)	G (RS485)	30
I2l (SG*)	4 (66*)	positive pole of 5V aux. supply for current sensors *)	61, 64, 67 *)
I3k (SI3*)	5 (68*)		
I3l (SG*)	6 (69*)		

**) … valid for „X/333mV" models*

6. Manufactured Models and Marking

SML 133 U 230 X/5A RR E

Instrument Model

SML 133 = Three-phase multimeter, 3U, 3I

Auxiliary Power Supply

U = 75 V ÷ 275 VAC, 75 V ÷ 350 VDC
S = 10 V ÷ 26 VAC, 10 V ÷ 36 VDC
L = 20 V ÷ 50 VAC, 20 V ÷ 75 VDC

Nominal Measuring Voltage

230 = 230V/400V
100 = 57,7V/100V
400 = 400V/690V

Current Inputs

X/5A = 5A AC (standard indirect measurement)
X/1A = 1A AC (standard indirect measurement)
X/100mA = 100mA AC (indirect measurement)
333mV = input for sensors with 333mV output

Digital I/O

N = without I/O
RR = 2× relay output + 1× logical input 24V
RI = 1× relay output + 1× pulse output + 1× logical input 24V
II = 2× pulse output + 1× logical input 24V

Dálkové komunikační rozhraní

N = no remote comm. link
4 = RS-485
E = Ethernet 10BaseT

7. Technical Specifications

Function Characteristics according to IEC 61557-12
Model **„230 X/5A“**, U_{NOM} = 230 V, I_{NOM} = 5 A

Symbol	Function	Class	Measuring range	Notes
P	total effective power	0.5	0 ÷ 5400 W	
Q_A, Q_V	total reactive power	1	0 ÷ 5400 var	
S_A, S_V	total apparent power	0.5	0 ÷ 5400 VA	
E_a	total active energy	0.5	0 ÷ 5400 Wh	
E_{rA}, E_{rV}	total reactive energy	2	0 ÷ 5400 varh	
E_{apA}, E_{apV}	total apparent energy	0.5	0 ÷ 5400 VAh	
f	frequency	0.05	40 ÷ 70 Hz	
I	phase current	0.2	0.005 ÷ 6 A_{AC}	
I_N	neutral current measured	–	–	
I_{Nc}	neutral current calculated	0.2	0.005 ÷ 18 A_{AC}	2)
U_{LN}	line-to-neutral voltage	0.2	40 ÷ 280 V_{AC}	
U_{LL}	line-to-line voltage	0.2	70 ÷ 480 V_{AC}	
PF_A, PF_V	power factor	0.5	0 ÷ 1	
P_{st}, P_{lt}	flicker	–	–	
U_{dip}	voltage dips	–	–	
U_{swl}	voltage swells	–	–	
U_{tr}	transients overvoltage	–	–	
U_{int}	voltage interruption	–	–	
U_{nba}	voltage unbalance (amp.)	0.5	0 ÷ 10 %	2)
U_{nb}	voltage unbalance (ph.&amp.)	0.5	0 ÷ 10 %	2)
U_h	voltage harmonics	2	up to 50th order	1)
THD_u	voltage total harm. distortion (rel. to fund.)	2	0 ÷ 20 %	1)
$THD\text{-}R_u$	voltage total harm. distortion (rel. to RMS)	2	0 ÷ 20 %	1, 2)
I_h	current harmonics	2	up to 50th order	1)
THD_i	current total harm. distortion (rel. to fund.)	2	0 ÷ 200 %	1)
$THD\text{-}R_i$	voltage total harm. distortion (rel. to RMS)	2	0 ÷ 200 %	1)
M_{SV}	mains signalling voltage	–	–	1, 2)

Notes : 1) …according to IEC 61000-4-7 ed.2
2) … value available via communication link only, not displayed

Function Characteristics according to IEC 61557-12
U_{NOM} = 100 / 230 / 400 V for model “100” / “230” / “400”
Model **„X/5A“**, I_{NOM} = 5 A

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

Notes : 1) …according to IEC 61000-4-7 ed.2
2) … value available via communication link only, not displayed

Function Characteristics according to IEC 61557-12 U_{NOM} = 100 / 230 / 400 V for model "100" / "230" / "400" Model **„X/100mA"**, I_{NOM} = 0.1 A				
Symbol	Function	Class	Measuring range	Notes
P	total effective power	0.5	0 ÷ (0.43 * U_{NOM}) W	
Q_A, Q_V	total reactive power	1	0 ÷ (0.43 * U_{NOM}) var	
S_A, S_V	total apparent power	0.5	0 ÷ (0.43 * U_{NOM}) VA	
E_a	total active energy	0.5	0 ÷ (0.43 * U_{NOM}) Wh	
E_{rA}, E_{rV}	total reactive energy	2	0 ÷ (0.43 * U_{NOM}) varh	
E_{apA}, E_{apV}	total apparent energy	0.5	0 ÷ (0.43 * U_{NOM}) VAh	
f	frequency	0.05	40 ÷ 70 Hz	
I	phase current	0.2	0.001 ÷ 0.12 A_{AC}	
I_N	neutral current measured	–	–	
I_{Nc}	neutral current calculated	0.2	0.001 ÷ 0.36 A_{AC}	2)
U_{LN}	line-to-neutral voltage	0.2	0.2 ÷ 1.2 * U_{NOM}	
U_{LL}	line-to-line voltage	0.2	0.2 ÷ 1.2 * U_{NOM} * v3	
PF_A, PF_V	power factor	0.5	0 ÷ 1	
P_{st}, P_{lt}	flicker	–	–	
U_{dip}	voltage dips	–	–	
U_{swl}	voltage swells	–	–	
U_{tr}	transients overvoltage	–	–	
U_{int}	voltage interruption	–	–	
U_{nba}	voltage unbalance (amp.)	0.5	0 ÷ 10 %	2)
U_{nb}	voltage unbalance (ph.&amp.)	0.5	0 ÷ 10 %	2)
U_h	voltage harmonics	2	up to 50^{th} order	1)
THD_u	voltage total harm. distortion (rel. to fund.)	2	0 ÷ 20 %	1)
$THD\text{-}R_u$	voltage total harm. distortion (rel. to RMS)	2	0 ÷ 20 %	1, 2)
I_h	current harmonics	2	up to 50^{th} order	1)
THD_i	current total harm. distortion (rel. to fund.)	2	0 ÷ 200 %	1)
$THD\text{-}R_i$	voltage total harm. distortion (rel. to RMS)	2	0 ÷ 200 %	1)
M_{SV}	mains signalling voltage	–	–	1, 2)

Notes : 1) …according to IEC 61000-4-7 ed.2
2)… value available via communication link only, not displayed

Measured Quantities - Voltage			
Frequency			
f_{NOM}– nominal frequency	50 / 60 Hz		
measuring range	40 ÷ 57 / 51 ÷ 70 Hz		
measuring uncertainty	± 20 mHz		
Voltage			
model	**„100“**	**„230“**	**„400“**
U_{NOM} (U_{DIN}) – rated voltage (phase-to-neutral, U_{L-N})	57.7 ÷ 125 VAC	180 ÷ 250 VAC	300 ÷ 415 VAC
measuring range U_{L-N}	3 ÷ 150 VAC	6 ÷ 300 VAC	10 ÷ 500 VAC
measuring range U_{L-L}	5 ÷ 260 VAC	8 ÷ 520 VAC	20 ÷ 865 VAC
measuring uncertainty (t_A=23±2°C)	+/- 0.05 % of rdg +/- 0.02 % of rng		
temperature drift	+/- 0.03 % of rdg +/- 0.01 % of rng / 10 °C		
measurement category	150V CAT IV	300V CAT III	300V CAT III 600V CATII
permanent overload	300 VAC	600 VAC	1000 VAC
peak overload ($U_{L–N}$ / 1 sec.)	600 VAC	1200 VAC	2000 VAC
burden power, impedance	< 0.013 VA Ri = 1.8 MΩ	< 0.025 VA Ri = 3.6 MΩ	< 0.05 VA Ri = 6 MΩ
Voltage Unbalance			
measuring range	0 ÷ 10 %		
measuring uncertainty	± 0.3		
Harmonics & Interharmonics (up to 50thorder)			
reference conditions	other harmonics up to 200 % of class 3 acc. to IEC 61000–2-4 ed.2		
measuring range	10 ÷ 100 % of class 3 acc. to IEC 61000–2-4 ed.2		
measuring uncertainty	twice the levels of class II acc. to IEC 61000–4-7 ed.2		
THDU			
measuring range	0 ÷ 20 %		
measuring uncertainty	± 0.5		

Measured Quantities – Temperature (internal sensor, measured value affected by the instrument power dissipation)	
measuring range	- 40 ÷ 80°C
measurement uncertainty	± 2 °C

Measured Quantities – Current			
model	**„X/5A“**	**„X/100mA“**	**„X/333mV“**
I_{NOM} (I_B) – rated current	1 / 5 A_{AC}	0.1 A_{AC}	I @ 333mV
measuring range	0.005 ÷ 7 A_{AC}	0.001 ÷ 0.39 A_{AC}	0.002 ÷ 0.5 V_{AC}
meas. uncertainty (t_A=23±2°C)	+/- 0.05 % of rdg +/- 0.02 % of rng		
temperature drift	+/- 0.03 % of rdg +/- 0.01 % of rng / 10 °C		
measurement category	150V CAT III	150V CAT III	undefined
permanent overload	7.5 A_{AC}	1 A_{AC}	15 V_{AC}
peak overload - for 1 second, max. repetition frequency > 5 minutes	70 A_{AC}	10 A_{AC}	15 V_{AC}
burden power (impedance)	< 0.5 VA (Ri < 10 mΩ)	< 0.01 VA (Ri < 40 mΩ)	< 3 uVA (Ri>100kΩ)
Current Unbalance			
measuring range	0 ÷ 100 %		
measuring uncertainty	± 1 % of rdg or ± 0.5		
Harmonics & Interharmonics (up to 50^{th}order)			
reference conditions	other harm. up to 1000 % of class 3 acc. to IEC 61000–2-4 ed.2		
measuring range	500 % of class 3 acc. to IEC 61000–2-4 ed.2		
measuring uncertainty	Ih <= 10% I_{NOM} : ± 1% I_{NOM} Ih > 10% I_{NOM} : ± 1% of rdg		
THDI			
measuring range	0 ÷ 200 %		
measuring uncertainty	THDI <= 100% : ± 0.6 THDI > 100% : ± 0.6 % of rdg		

Measured Quantities – Power, Power Factor, Energy	
Active / Reactive Power, Power Factor (PF), cos φ ($P_{NOM} = U_{NOM} \times I_{NOM}$)	
reference conditions “A” : ambient temperature (t_A) U, I for active power, PF, cos φ for reactive power	 23 ± 2 °C U = 80 ÷ 120 % U_{NOM}, I = 1 ÷ 120 % I_{NOM} PF = 1.00 PF = 0.00
act. / react. power uncertainty	± 0.5 % of rdg ± 0.005 % P_{NOM}
PF & cos φ uncertainty	± 0.005
reference conditions “B” : ambient temperature (t_A) U, I for active power, PF, cos φ for reactive powe	 23 ± 2 °C U = 80 ÷ 120 % U_{NOM}, I = 1 ÷ 120 % I_{NOM} PF <= 0.87 PF <= 0.87
act. / react. power uncertainty	± 1 % of rdg ± 0.01 % P_{NOM}
PF & cos φ uncertainty	± 0.005
temperature drift of powers	+/- 0.05 % od rgd +/- 0.02 % P_{NOM} / 10 °C
Energy	
measuring range	6 „quadrants“, corresponds to U & I measuring ranges
active energy uncertainty	class 0.5S acc. to EN 62053 – 22
reactive energy uncertainty	class 2 acc. to EN 62053 – 23

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

Instrument Auxiliary Power Supply Voltage			
model	**„U“**	**„L“**	**„S“**
aux. voltage range AC: f=40÷450 Hz; DC reference conditions “1” : - +5V aux. power load : 0 mA (for models "333mV") reference conditions “2” : - +5V aux. power load : 60 mA (for models "333mV")	85 ÷ 275 V_{AC} 80 ÷ 350 V_{DC} 90 ÷ 275 V_{AC} 85 ÷ 350 V_{DC}	20 ÷ 50 V_{AC} 20 ÷ 75 V_{DC}	10 ÷ 26 V_{AC} 10 ÷ 36 V_{DC}
power	3 VA / 3 W		
overvoltage cat.	III		
pollution degree	2		
connection	isolated, polarity free		

„X/333mV“ Instrument Model Auxiliary Voltage for Current Sensors	
connection	non-isolated (connected with the instrument internal circuitry)
output voltage	+5 VDC ± 5 %
maximum permanent load	60 mADC
short-circuit current, max. duration	approx. 100 mADC, 5 seconds

Digital Outputs & Digital Input	
„R“-type (relay)	
type	N.O. contact
load rating	250 VAC / 30 VDC, 4 A
„I“-type (solid state, opto-MOS)	
type	Opto-MOS, bipolar
load rating	60 VAC / 100 VDC, 100 mA
Digital Input	
type	optoisolated, bipolar
maximum voltage	100 VDC / / 60 VAC
voltage for “logical 1“	> 10 VDC
voltage for “logical 0“	< 3 VDC
input current	1 mA @ 10V / 5 mA @ 24V / 10 mA @ 48V

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)
remote communication port (option)	RS-485 / protocols KMB, Modbus-RTU or Ethernet 10/100 Base-T / DHCP, webserver, Modbus-TCP
display	Segment LCD FSTN with backlight
protection class front panel back panel	 IP 40 (IP 54 with cover sheet) IP 20
dimensions front panel built-in depth installation cutout	 96 x 96 mm 80 mm 92^{+1} x 92^{+1} mm
mass	max. 0.3 kg

8. Maintenance, Service

The SML 133 instruments do not require any maintenance in their operation. For reliable operation it is only necessary to meet operating conditions specified and not expose the instrument to violent handling and activity of water or chemicals which could cause mechanical damage.

If the product has a breakdown, you need to complain to the supplier at their address:

Supplier:

Manufacturer : KMB systems, s.r.o.
Dr. M. Horákové 559
460 06 LIBEREC 7
Czech Republic
telephone: +420 485 130 314
fax: +420 482 736 896
e–mail : kmb@kmb.cz
website : www.kmbsystems.eu

The product must be in proper package to prevent damage in transit. 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 must enclose an order for the repair.

Warranty Certificate

Warranty period of 24 months from the date of purchase is provided for the instrument. 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 got damaged in out-of-specs falls or by improper handling or if it has been operated in contradiction with the technical specifications presented.

type of product: **SML 133** ....

serial number ....

final quality inspection: ....

date of dispatch: ....

manufacturer's seal:

date of purchase: ....

supplier's seal: