# Dual-channel Voltage Comparator
# MarsComp K-1000

Version 17

User Manual

NFTSR.411113.006 UM

2022

# CONTENTS

# INTRODUCTION

This document describes the Dual-Channel Voltage Comparator MarsComp K-1000 (the Comparator below).

The Comparator is manufactured in compliance with Technical Specifications NFTSR.411113.006 TS.

The set of documents as part of the scope of supply of the Comparator includes:

| | |
|---|---|
| User Manual | NFTSR.411113.006 UM |
| Equipment Certificate | NFTSR.411113.006 EC |

# 1 DESCRIPTION AND OPERATION

## *1.1 Description*

### 1.1.1 Modifications

In terms of design, functionality, rated frequency and accessory equipment, the Comparator comes in various options.

The legend (shown below) contains information about the options as specified in the purchase order:

MarsComp K-1000 X-X-X-X
1 2 3 4

1 – Design version:

- "S" – stationary (19’’ rack mount enclosure)
- "P" – portable (in a plastic case with a handle)

2 – Nominal AC frequency ($f_{NOM}$):

- "50" – $f_{NOM}$ = 50 Hz (operating frequency range: 42.5 to 67.5 Hz)
- "50/400" – $f_{NOM}$ = 50 and 400 Hz (operating frequency range: 42.5 to 67.5 Hz and 396 to 404 Hz)

3 – Presence of the Burden Box (BB) in the delivery package:

- "B" – the Burden Box providing the possibility to change the impedance (input resistance and capacitance components) of the measuring channels of the Comparator rated at 10 V (or less) as required for testing low-power instrument transformers (LPITs) or sensors is included in the delivery package
- "xM/yP" – the Burden Box is not present in the delivery package. The impedance of the built-in burden of the measuring channels rated at 10 V (or less) includes a resistance component of x MOhm and a capacitance component of y pF

4 – Possibility to measure distorted voltage signals:

- "H" – The option is active
- No symbol – The option is inactive

Here is an example of the model name:

MarsComp K-1000 S-50/400-2M/50P-H

### 1.1.2 Functions

The comparator does the following:

- Measures ratio error and phase displacement of voltage-scaling converters, such as low-power instrument transformers (LPITs), conventional transformers, sensors, or voltage dividers

- Measures ratio error and phase displacement of current-scaling converters, such as low-power instrument current transformers (LPITs), or current sensors

- Measures accuracy characteristics of voltage-scaling converters, such as low-power instrument transformers (LPITs), conventional transformers, sensors, or voltage dividers for distorted high-voltage waveforms

- Performs high-precision AC current, voltage, frequency and voltage harmonic measurements

### 1.1.3 Normal and operating conditions

| | |
|---|---|
| Ambient temperature, | +10 to +35 °C |
| Relative humidity | 80% (or less) at 25 °C |
| Atmospheric pressure | 70 to 106.7 kPa |

## *1.2 Specifications*

### 1.2.1 Accuracy specifications

Rated values of current ($I_{NOM}$): 0.1, 0.5, 1, 5, 10 A (RMS).

Rated values of voltage ($U_{NOM}$): 840, 420, 120, 60 V and 8400, 4200, 1000, 500, 100, 50, 10, 5 mV (RMS).

Basic accuracy specifications are given in Tables 1.1- 1.2.

Table 1.1 – Measuring ranges and limits of permissible measurement errors

| Parameter or range | Value |
|---|---|
| AC frequency measuring range | 16 to 2500 Hz (inclusive) |
| Limits of permissible intrinsic error (related to the reading) | ±0.02% |
| Range of measurements of AC voltage U (RMS) and fundamental harmonic of AC voltage $U_{(1)}$ (RMS) at a frequency of the 1st harmonic of current $f_1$ from 45 to 65 Hz | $0.1 \cdot U_{NOM}$ to $1.2 \cdot U_{NOM}$ V |
| Limits of permissible intrinsic error in measurements of AC voltage signal U (RMS) at a frequency of the 1st harmonic of current $f_1$: from 45 to 65 Hz | |
| $0.5 < U \leq 10$ mV (related to the range) | ±0.25% |
| $10 < U \leq 100$ mV (related to the reading) | $\pm[0.03+0.005 \cdot (U_{NOM}/U-1)]$% |
| $0.1 < U \leq 420$ V (related to the reading) | $\pm[0.01+0.005 \cdot (U_{NOM}/U-1)]$% |
| $420 < U \leq 1000$ V (related to the reading) | $\pm[0.03+0.005 \cdot (U_{NOM}/U-1)]$% |

| Parameter or range | Value |
|---|---|
| Limits of permissible intrinsic error in measurements of fundamental harmonic of AC voltage $U_{(1)}$ (RMS) at a frequency of the 1st harmonic of current $f_1$: from 45 to 65 Hz | |
| $0.5 < U \leq 10$ mV | $\pm[0.03+0.005\cdot( U_{NOM}/U-1)]$% |
| $0.1 < U \leq 420$ V | $\pm[0.01+0.005\cdot( U_{NOM}/U-1)]$% |
| $420 < U \leq 1000$ V | $\pm[0.03+0.005\cdot( U_{NOM}/U-1)]$% |
| Range of measurements of AC voltage U (RMS) and fundamental harmonic of AC voltage $U_{(1)}$ (RMS) at a frequency of the 1st harmonic of current $f_1$: from 396 to 404 Hz[2)] | 0.001 to 240 V (inclusive) |
| Limits of permissible intrinsic error in measurements of fundamental harmonic of AC voltage $U_{(1)}$ (RMS) at a frequency of the 1st harmonic of current $f_1$: 396 to 404 Hz[2)] | |
| $1 < U \leq 100$ mV | $\pm[0.1+0.01\cdot(U_{NOM}/U-1)]$% |
| $0.1 < U \leq 240$ V | $\pm[0.05+0.01\cdot(U_{NOM}/U-1)]$% |
| Range of measurements of AC current I (RMS) and fundamental harmonic of AC current $I_{(1)}$ (RMS) at a frequency of the 1st harmonic of current $f_1$: 45 to 65 Hz | $0.1\cdot I_{NOM}$ to $1.2\cdot I_{NOM}$ A |
| Limits of permissible intrinsic error in measurements of AC current I (RMS) and fundamental harmonic of AC current $I_{(1)}$ (RMS) at a frequency of the 1st harmonic of current $f_1$: 45 to 65 Hz | $\pm[0.015+0.002\cdot(I_{NOM}/I-1)]$% |
| Range of measurements of AC current I (RMS) and fundamental harmonic of AC current $I_{(1)}$ (RMS) at a frequency of the 1st harmonic of current $f_1$: 396 to 404 Hz[2)] | $0.1\cdot I_{NOM}$ to $1.2\cdot I_{NOM}$ A |
| Limits of permissible intrinsic error in measurements of AC current I (RMS) and fundamental harmonic of AC current $I_{(1)}$ (RMS) at a frequency of the 1st harmonic of current $f_1$: 396 to 404 Hz[2)] | $\pm[0.05+0.01\cdot(I_{NOM}/I-1)]$% |
| Range of measurements of AC voltage (RMS) at a frequency f, where f is within: 16 Hz to 45 Hz and 65 Hz to 2500 Hz[1)] | 8.4 to 400 V (inclusive) |
| Limits of permissible intrinsic error in measurements of AC voltage (RMS) at a frequency f, where f is within: 16 to 45 Hz and 65 to 2500 Hz[1)] | $\pm[0.04+0.005\cdot(U_{NOM}/U-1) +0.0004\cdot f ]$% |
| Range of measurements of Total Harmonic Distortion of voltage ($THD_U$), where U is within $0.2U_{NOM} < U < 1.2U_{NOM}$, U> 50 mV | 0 to 49.9% |
| Type and limits of permissible intrinsic error in measurements of Total Harmonic Distortion of voltage ($THD_U$), U>50 mV: | |
| $THD_U < 1.0$ | Absolute ±0.03% |
| $THD_U \geq 1.0$ | Relative ±0.3% |
| Range of measurements of phase shift ($\Delta\varphi$ ) between two voltages of the same frequency f taken from two different channels, $U_{NOM} > 500$ mV[1)] | -90 to 90 degrees (inclusive) |

| Parameter or range | Value |
|---|---|
| Limits of permissible intrinsic error (absolute) in measurements of phase shift ($\Delta\varphi$ ) between two voltages of the same frequency f, where f is within 16 to 400[1) 2)] Hz taken from two different channels, $U_{NOM}$ > 500 mV | ± 0.00033·f degrees |
| Range of measurements of AC voltage harmonic components of order h at a frequency of the 1st harmonic of voltage $f_1$, where $f_1$ is within 45 to 65 Hz[1)], $U_{NOM}$ > 500 mV, where h lies in the range: | |
| - $0.3 \leq h \leq 0.9$ in increments of 0.1 | 0.1 to 15% |
| - $2 \leq h \leq 50$ in increments of 1 | 0.1 to 25% |
| Limits of permissible intrinsic error in measurements of AC voltage harmonic components of order h at a frequency of the 1st harmonic of voltage $f_1$, where $f_1$ is within 45 to 65 Hz[1)], $U_{NOM}$ > 500 mV, where h lies in the range: | |
| - $0.3 \leq h \leq 0.9$ in increments of 0.1 | $\pm[0.2+0.02\cdot(U_{NOM}/U-1) +0.02\cdot\lvert h-1\rvert]\%$ |
| - $2 \leq h \leq 50$ in increments of 1 | $\pm[0.08+0.02\cdot(U_{NOM}/U-1) +0.02\cdot\lvert h-1\rvert]\%$ |
| Limits of permissible intrinsic error in measurements of AC current harmonic components of order h at a frequency of the 1st harmonic of voltage $f_1$, where $f_1$ is within 45 to 65 Hz[1)], $I_{NOM}$ > 500 mV, where h lies in the range: | |
| - $0.3 \leq h \leq 0.9$ in increments of 0.1 | $\pm[0.2+0.02\cdot(I_{NOM}/I-1) +0.02\cdot\lvert h-1\rvert]\%$ |
| - $2 \leq h \leq 50$ in increments of 1 | $\pm[0.08+0.02\cdot(I_{NOM}/I-1) +0.02\cdot\lvert h-1\rvert]\%$ |
| Notes<br>[1)] – Available for the modification of MarsComp K-1000 X-X/X-xM/yP-H<br>[2)] – As declared for the modification<br>U – voltage reading<br>I – current reading | |

Table 1.2 – Measuring ranges and limits of permissible measurement errors as regards to testing (verification) of conventional voltage instrument transformers (VTs), low-power voltage instrument transformers (LPVTs) and low-power current instrument transformers (LPCTs)

| Parameter or range | Value |
|---|---|
| Range of measurements of transformer's voltage ratio error (related to the reading) | –19.99 to +19.99 % [1)] |
| Limits of permissible error (absolute) in measurements of transformer's ratio error of voltage (related to the reading) [$\varepsilon_U$] ($\delta_{Ku(TR)}$) | $\pm(0.02+0.03\cdot X)\%$ [2) 3)] |
| | $\pm(0.2+0.03\cdot X)\%$ [4)] |
| | $\pm(2+0.05\cdot X)\%$ [5)] |
| Range of measurements of transformer's phase displacement | -3600 to +3600 min |
| Limits of permissible error (absolute) in measurements of transformer's phase displacement [$\Delta\varphi_{VT}$] ($\Delta\varphi_{u(TR)}$) and [$\Delta\varphi_{CT}$] ($\Delta\delta$) | $\pm0.006\cdot f$ [1) 6)] |
| | ±5.0 min [7)] |
| Range of measurements of transformer's current ratio error (related to the reading) | –19.99 to +19.99 % [8)] |

| Parameter or range | Value |
|---|---|
| Limits of permissible error (absolute) in measurements of transformer's ratio error of current (related to the reading) [$\varepsilon_I$] ($\delta_f$) | ±(0.02+0.03·X)% [2) 3)] |
| | ±(0.2+0.03·X)% [4)] |
| | ±(2+0.05·X)% [5)] |
| Range of measurements of transformer's composite error | –19.99 to +19.99 % [8)] |
| Limits of permissible error (absolute) in measurements of transformer's composite error [$\varepsilon_C$] | ±0.05 % |

Notes

[1)] Provided that $U_1$ is within $0.1 \cdot U_{NOM}$ to $1.2 \cdot U_{NOM}$, $U_{NOM} \geq 10$ mV, f = ($f_{NOM}$ ± 1) Hz
$U_{NOM}$, $U_{iNOM}$ – nominal (rated) value of the actual voltage measurement range
$f_{NOM}$ – nominal (rated) frequency of the transformer under test (50, 60 or 400 Hz)

[2)] X – reading of the transformer's error (%)

[3)] Range of the reading X ±0.5 %

[4)] Range of the reading X ±2.0 %

[5)] Range of the reading X ±20.0 %

[6)] Range of the reading of the transformer's error ±60 min

[7)] Range of the reading of the transformer's error ±3600 min

[8)] Provided that $I_1$ is within $0.01 \cdot I_{NOM}$ to $1.2 \cdot I_{NOM}$, the voltage value of a signal of current Ui lies within $0.1 \cdot Ui_{NOM}$ to $Ui_{NOM}$; $Ui_{NOM} \geq 10$ mV
f = ($f_{NOM}$ ± 1) Hz
$f_{NOM}$ – nominal (rated) frequency of the transformer under test (50, 60 or 400 Hz)

### 1.2.2 General specifications

General specifications are represented in Table 1.3.

Table 1.3 – Reference technical specifications

| **Parameter** | **Value** |
|---|---|
| Power supply:<br>- AC voltage<br>- AC frequency | <br>200 to 260 V<br>50±5 Hz |
| Total power consumed by the Comparator | 100 VA, or less |
| Overall dimensions:<br>For MarsComp K-1000 S (stationary)<br>- height<br>- width<br>- depth<br>For MarsComp K-1000 P (portable)<br>- height<br>- width<br>- depth | <br><br><br>266 mm, or less<br>483 mm, or less<br>430 mm, or less<br><br><br>155 mm, or less<br>335 mm, or less<br>289 mm, or less |
| Weight:<br>For MarsComp K-1000 S (stationary)<br>For MarsComp K-1000 S (stationary) | <br>6 kg, or less<br>5 kg, or less |
| Time of establishing stable operation | 15 min, or less |
| Degree of protection of the enclosures (IEC 60529) | IP20 |
| Mean time to failure | 20000 hours |

The input resistance and input capacitance components of the measuring channels of the Comparator (except the model with the harmonic measurement function marked with the letter H) should be as follows:

- For inputs 6 and 7: 2 MOhm or more; 50 pF or less (differential)
- For inputs 1, 2, 4, and 5: 1 MOhm or more; 1 pF (non-differential).

NOTE! *The differential inputs (6 and 7) can be rearranged to non-differential ones by connecting the corresponding "minus" and "common" input conductors (from the side of the signal source).*

For the Comparator complete with the Burden Box, the values of the input resistance for inputs 6 and 7 should be within the range 0.002 to 2.0 MOhm and should vary from their nominal values by no more than ±4 %. The nominal values are specified in the Equipment Certificate (section 7).

For the Comparator complete with the Burden Box, the values of input capacitance for inputs 6 and 7 should be within the range from 0.033 to 10 nF and should vary from their nominal values by no more than ±4 %. The nominal values are specified in the Equipment Certificate (section 7).

Input connectors are selected to provide compatibility with the devices to be tested.

## *1.3 Design of components*

### 1.3.1 Stationary and portable versions

The stationary version of MarsComp (K-1000-S) is designed as a 19" rack mount unit (see Fig. 1.1 and 1.2).

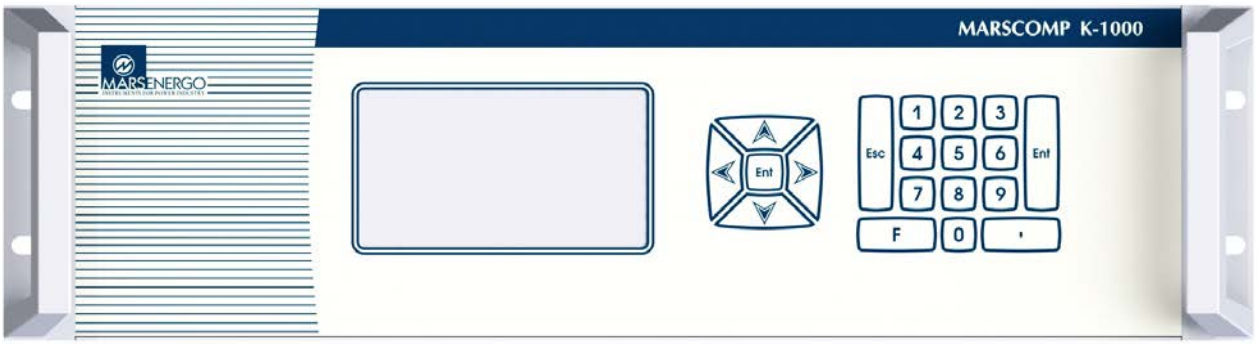
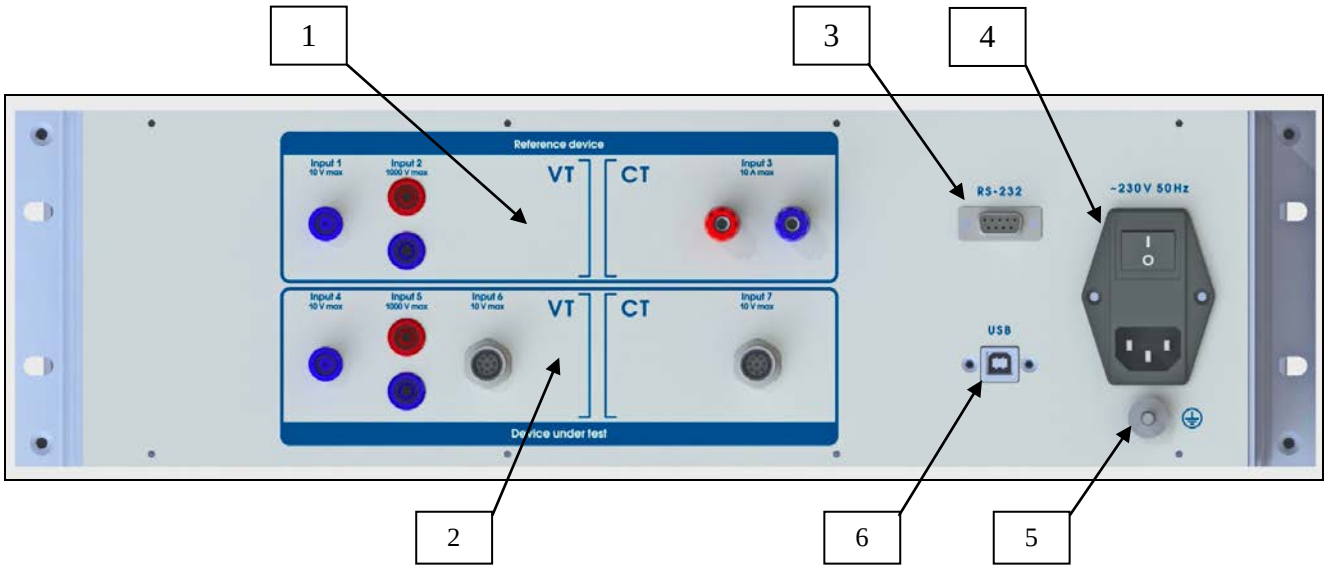


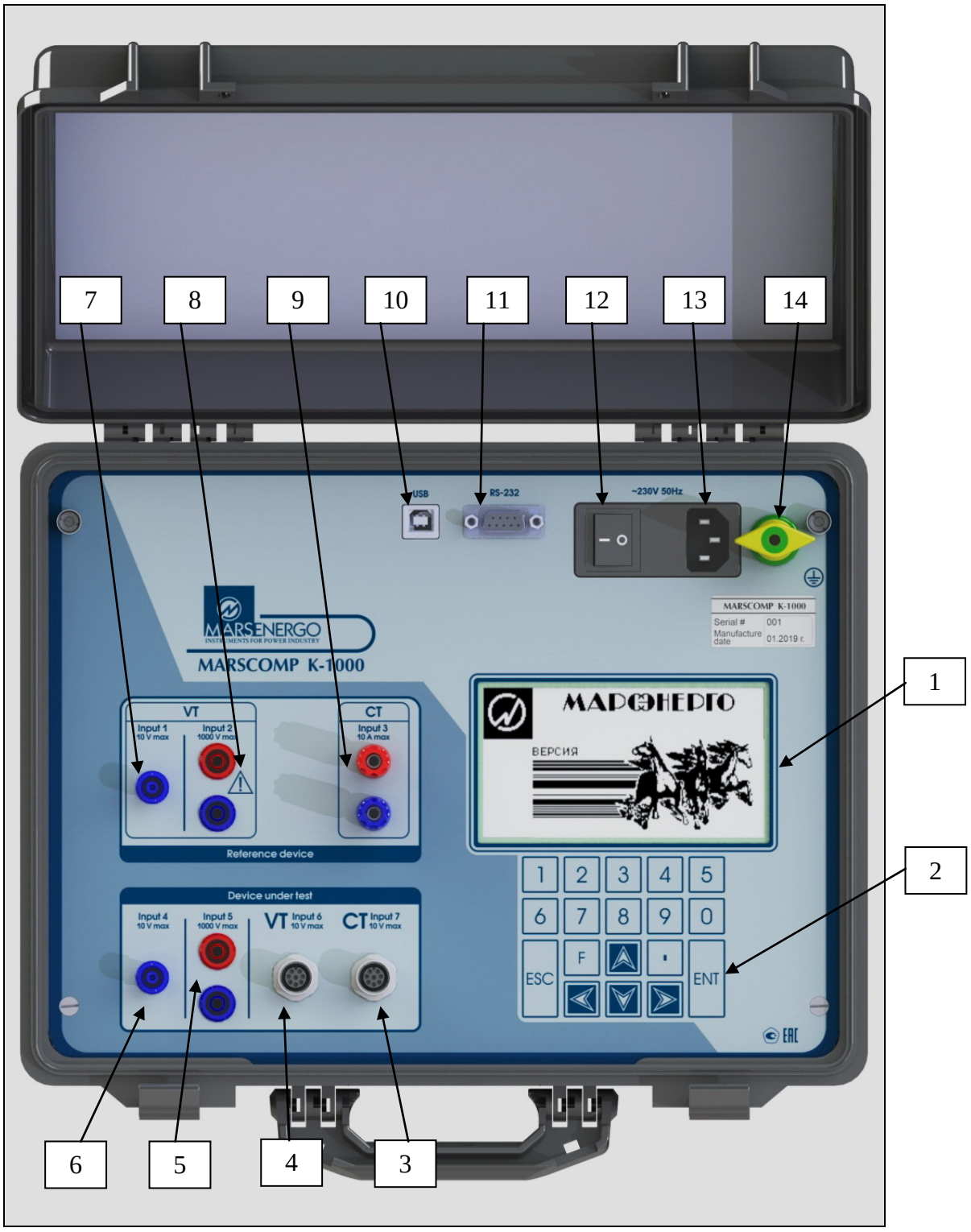

Fig. 1.1 MarsComp K-1000S (front panel)




1 – Connectors of the “Reference” channel
2 – Connectors of the “Device under test” channel
3 – RS-232 connector for connection to a PC
4 – Power supply connector, power supply switch and protection fuses
5 – Grounding terminal
6 – USB connector for connection to a PC

Fig. 1.2 MarsComp K-1000S (rear panel)

The portable version of MarsComp (K-1000-P) comes in a plastic case with a handle (see Fig. 1.3).




1 – Display, 2 – Keypad, 3 –Connector (M12) that accepts output voltage signals (up to 10 V) from current-scaling converters under test, 4 –Connector (M12) that accepts output voltage signals (up to 10 V) from voltage-scaling converters under test, 5 – Connector (banana jack 4 mm) that accepts voltage signals up to 1000 V from the device under test, 6 – Connector (BNC) that accepts voltage signals up to 10 V from the device under test, 7 – Connector (BNC) that accepts voltage signals up to 10 V from the reference device, 8 – Connector (banana jack 4 mm) that accepts voltage signals up to 1000 V from the reference device, 9 – Connectors (binding post) that accept current signals up to 10 A from the reference device, 10 – Port RS-232, 11 – Port USB, 12 – Power supply switch and protection fuses, 13 – Power supply connector, 14 – Grounding terminal

Fig. 1.3 MarsComp K-1000-P

The display (LCD) and membrane keypad are mounted on the front panel. Using the keypad, it is possible to manage displayed data, make configuration settings etc.

Types of connectors in use:

- Inputs 1 and 4 – BNC
- Inputs 2 and 5 – banana sockets 4 mm
- Input 3 – binding posts
- Inputs 6 and 7 – M12 circular connectors (differential, connected in parallel)

### 1.3.2 Rated Burden

The value of rated burden for testing LPITs consisting of a resistance in parallel with a capacitance is defined in relevant standards. In the Comparator, the values of the resistance and capacitance (to be integrated into the circuits of Inputs 6 and 7) can be specified according to the customer's requirements on placing the purchase order.

A set of rated burdens (optional) can also be provided on order as an accessory device (the Burden Box).

For MarsComp K-1000, the standard values of rated burden (as per IEC 61869-6) are:

Resistance: 2 MOhm

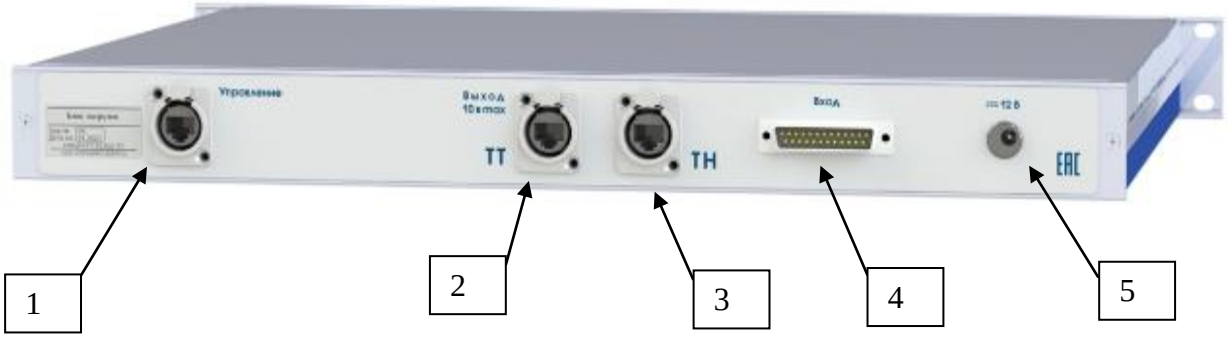
Capacitance: 50 pF.

### 1.3.3 Burden Box

The Burden Box (Fig. 1.4 or Fig. 1.5) can be optionally included in the scope of supply of the model MarsComp K-1000 X-XX-B.

Front panel


Rear panel




1 – Connector RJ-45 for connection to a PC
2 – Connector RJ-45 for applying secondary voltage of the LPCT to the Comparator
3 – Connector RJ-45for applying secondary voltage of the LPVT to the Comparator
4 – Connector for accepting signals from a low-power transformer (its type is selected by the user)
5 – Power supply connector (12 V)

Fig. 1.4 Burden Box for MarsComp K-1000 S-XX-H (stationary)


Fig. 1.5 Burden Box for MarsComp K-1000 P-XX-H (portable)

The Burden Box is manufactured on order either for voltage or current signals. It contains 2 burden sets with fixed values of input resistance and capacitance to be connected to the inputs 6 or 7 (for testing LPVTs or LPCTs respectively). Following the commands from the controlling software, the burden sets (1 and 2) are connected to the inputs (to phases L1, L2, and L3 in turn). The Burden Box has indicators 1 and 2 (named “Burden”) showing which set is enabled.

To provide connection with LPVTs and LPCTs of the required type, the construction of the connector “Input” is selected by the customer on placing the purchase order.

The Burden Box is connected to a PC with an Ethernet cable (via the “Control” connector).

The Burden Box is connected to the Comparator with measuring cables (via the connectors “CT Input” and “VT Input”).

The Burden Box is powered via the measuring cables connected to the input 6 or input 7. The “Power” indicator is on in this case.

Alternatively, to power the Burden Box, a power adapter 230 VAC / 12 VDC (optional) can be connected via the “12 V” connector.

## *1.4 Operation*

### 1.4.1 Measurement methods

The Comparator utilizes sampling and analogue-to-digital conversion methods.

Instantaneous values of input voltages and currents are converted into digital codes and directed to the Central Processor board, where the arrays of sampled instantaneous values of voltage are created. After calculations over the arrays, the calculated values of measured parameters are saved in the internal memory of the Comparator, displayed on its LCD and sent to the external PC. The calculation method means that processing of the arrays does not require frequency synchronization between sampling process and measured waveforms.

To plot ratio-frequency or phase-frequency responses of the VT or voltage-scaling converter under test, the Comparator makes the comparison of voltage harmonic signals coming from the secondary winding of the VT under test and from the output of the reference voltage-scaling converter to the inputs of the $1^{st}$ and $2^{nd}$ measuring channels of the Comparator respectively.

The voltage signals at the inputs of the Comparator are proportional to the high-voltage signals simultaneously applied to the primary winding of the VT under test and to the input of the reference voltage-scaling converter. Signals of the following types can be measured:

- "Distorted" – contains a fundamental frequency component $f_1$ with an added harmonic of order h, where h lies in the range:
  - $0.3 \leq h \leq 0.9$ in increments of 0.1
  - $1 \leq h \leq 50$ in increments of 1
- "Sine"– contains just a component of frequency f.

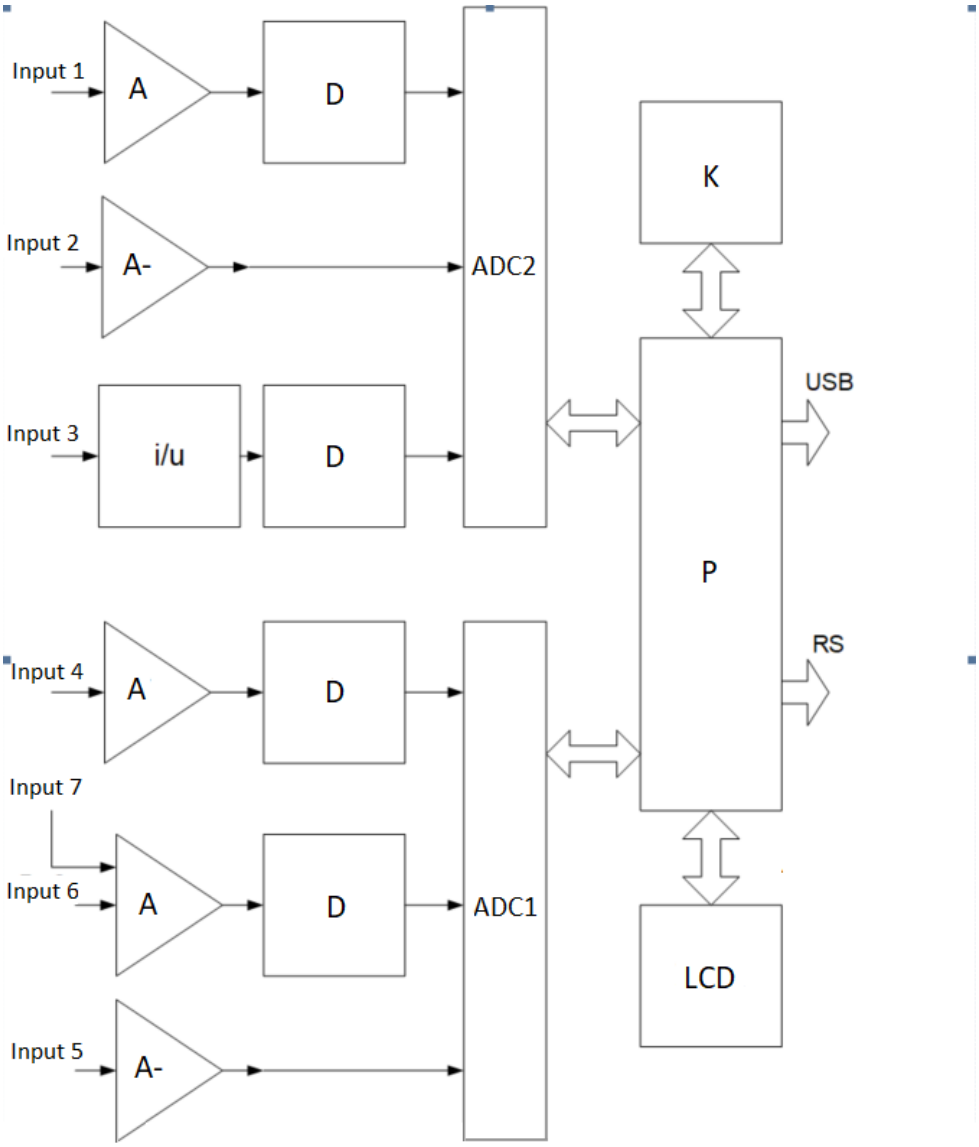
The ratio error of voltage-scaling converters (low-power and conventional transformers, voltage sensors and dividers) and current-scaling converters (low-power and conventional transformers, current sensors) is calculated by a PC software using the method of comparison of RMS values of the first voltage harmonics measured by the firmware of the Comparator in 2 measuring channels.

The phase displacement of scaling converters is calculated by the firmware of the Comparator using the method of comparison of phase shifts of the first voltage harmonics measured by the firmware in 2 measuring channels.

The composite error of current-scaling converters (low-power transformers or sensors) is calculated by the firmware of the Comparator using the RMS value of the difference between the currents in 2 measuring channels derived from 2 arrays of instantaneous values according to IEC 61869-10.

### 1.4.2 Relationship between components

The block diagram of the Comparator is shown in Fig. 1.5.




A – Programmable amplifier
A- – Programmable inverting amplifier
D – ADC driver
i/u – Current-to-voltage converter
K – Keypad
LCD – Display
P – Processor board

Fig. 1.5 – Block diagram of the Comparator

The Comparator has two channels where analogue signals are converted into digital ones. Signals from the outputs of devices under test come to the inputs of the Channel 1 (Inputs 4…7),

whereas output signals from reference devices are applied to the inputs of the Channel 2 (Inputs 1…3).

The inputs are designed to accept:

- Input 1 – output voltage signals in the range from 0.2 mV to 8.4 V (from reference electronic voltage transformers or voltage dividers)
- Input 2 – output voltage signals in the range from 8 V to 840 V (from reference instrument voltage transformers or voltage dividers)
- Input 3 – output current signals in the range from 1 mA to 10 A (from reference instrument current transformers)
- Input 4 – output voltage signals in the range from 0.2 mV to 8.4 V (from devices under test)
- Input 5 – output voltage signals in the range of 8 V to 840 V (from conventional voltage transformers under test etc.)
- Input 6 – output voltage signals in the range from 0.5 mV to 8.4 V (from low-power voltage transformers under test with output voltage signal)
- Input 7 – output voltage signals in the range from 0.5 mV to 8.4 V (from low-power current transformers under test with output voltage signal).

The Channels 1 and 2 are measuring converters in which input signals are converted to voltage signals with peak values of up to 12 V and up to 6 V (which are maximum values for ADC inputs).

In terms of design, the inputs 1, 4, 7 and 6 are measuring converters built on the basis of programmable measuring amplifiers (with gain factors of 1, 10, 100, and 1000) and ADC drivers (gain factors are 1 and 10) connected to the outputs of the amplifiers.

The input measuring converters for the inputs 2 and 5 are programmable inverting amplifiers (with gain factors 0.01 and 0.05).

To convert signals from reference CTs within 1mA to 10 A range (Input 3), the scheme utilizes a 3-range current-to-voltage converter built on the basis of a precision current transformer ($I_{NOM}$ = 10A, 1A, 0.1A). The voltage developed across the shunt connected to the output of the transformer is applied to an ADC driver with a gain of 20.

Output signals from the measuring converters of the Channels 1 and 2 come to the ADC 1 and ADC 2. The ADCs are provided with bipolar inputs with selectable input ranges (±6 V and ±12 V). They perform complete 16-bit AD conversion of the signals without missing codes and generate successive digital codes on request of the Processor.

Gain factors of the measuring converters and ADC ranges are set by commands from the Processor.

The Processor board provides full control over the Comparator, and is responsible for its performance as a whole. In particular, it performs calculations over the arrays of samples, saves the results in flash memory, tracks time and provides time stamps, communicates with external devices (PCs), accepts commands and data from the keypad, displays the results etc. The Processor board is based on a signal processor and field-programmable gate array (FPGA).

Analogue-to-digital conversion of input waveforms is carried out at a sampling rate of 25.6 kHz. Further processing depends on actual signal characteristics.

The Power Supply Unit generates power supply voltages for the Processor board and Measuring board.

The Burden Box is manufactured on order. The model of the Comparator is MarsComp K-1000 X-XX-B in this case. The Burden Box includes 2 burden sets separately designed for accepting voltage and current signals, where each set contains a combination of rated resistance and capacitance and is provided with the inputs switchable among 3 phases. The Burden Box is connected to the inputs 4, 6, or 7 of the Comparator with measuring cables. The serial numbers of the Burden Box and Comparator must be identical.

After applying power the Comparator performs self-testing and initialization procedures. Under normal and operating conditions the characteristics declared for the Comparator are provided after a lapse of 15 minutes.

The Comparator is designed for continuous operation.

The interval over which measured values of current and voltage are averaged can be set to 1.25 s, 2.5 s, 5 s, 10 s, 1 min, 15 min, and 30 min.

The Comparator is controlled by firmware (FW) and application software (SW). The FW installed by the manufacturer and kept in the flash memory of the Comparator, controls operating modes, processing algorithms and representation of measurement data.

Structurally the FW consists of metrologically significant (affecting the accuracy) and metrologically insignificant components. Each component is protected by a CRC32-IEEE 802.3 checksum, and the checksums are monitored by the Diagnostics module.

To provide a better accuracy of measurements, the differences in characteristics of measuring channels and correction factors determined in the course of adjustment procedures are recorded into the flash memory of the Comparator and applied to further measurements. These correction values and factors are protected by checksums which are monitored by the Diagnostics module.

The firmware as a whole as well as the arrays of correction factors and correction values are protected from changes or removal. Accuracy characteristics of the Comparator are specified with regard to the effect of the firmware on measurement results.

The SW has no effect on measurement accuracy. The application makes it possible to select

operating modes, parameters to be measured, and measurement ranges as well as to upload measurement results from the flash memory.

The Comparator is protected from unauthorized access to the firmware and measurement data. The protection level of the Comparator from intentional or unintentional changes to the firmware is “high” according to the Russian “Guidelines for metrology” R 50.2.077-2014.

The identification data of the firmware are shown in Table 1.4.

Table 1.4 – Identification data of the firmware

| Identification data (type) | Value |
|---|---|
| Identification name | MarsComp K-1000 |
| Firmware version (identification number) | 1.03, or higher |

## *1.5 Marking and sealing*

### 1.5.1 Marking

The front panel of the Comparator bears:

- Model name
- Manufacturer’s trade mark
- Power supply type and nominal power supply voltage
- Designations of input and output connectors.

The nameplate on the case of the Comparator bears:

- Model name and modification
- Serial number
- Manufacturer’s trade mark
- Manufacturer’s name
- Serial number
- Date of manufacture (month and year).

The nameplate on the case of the Burden Box bears:

- Name and modification of the Comparator and name of the Burden Box
- Manufacturer’s name
- Serial number of the Burden Box (identical to the one of the Comparator)
- Nominal values of burden components in reference to the positions of the switch
- Data of manufacture (month and year).

### 1.5.2 Marking of transportation box

Side and face walls of the transportation box bear handling symbols “Fragile”, “Keep dry” and “Top”.

1.5.3 Sealing

The seal is installed:

- For stationary modifications (“S”) – in the hole of a fastening screw on the rear panel
- For portable modifications (“P”) – in the hole of a fastening screw on the front panel.

When the Comparator was opened for repair, the seal should be reinstalled by an authorized service company.

# 2 PUTTING INTO OPERATION

## *2.1 Notes on operating conditions*

**Caution!** If the Comparator has been moved from a cold environment (with ambient temperature below -20$^{o}$ C) into a warm one, it shall be left to stand for at least 4 hours at room temperature before applying power, to make sure that no condensation remains inside.

**Warning!** The Device shall not be used under the ingress of moisture inside its body.

## *2.2 Preparing for operation*

### 2.2.1 Safety requirements

The Comparator is included in the product range of instruments compliant with the requirements of “Interbranch Rules for Labor Safety When Operating Electrical Systems”

With respect to electric shock protection, the instrument relates to class I equipment as stated in IEC 61140:2009 (“Protection against electric shock. Common aspects for installation and equipment”).

The instrument is compliant with the safety requirements of IEC 61010-1:2001 (“Safety requirements for electrical equipment for measurement, control and laboratory use”):

- Insulation category: basic
- Measurement category: III
- Degree of protection against pollution: 1

Protection provided by the enclosure: IP20 (according to IEC 60259).

**Warning!** The Comparator must not be energized until its grounding clamp has been connected to an external grounding system.

### 2.2.2 Unpacking

Check that the delivery package contains all parts specified in Table 4.1 of the Equipment Certificate. Check to see if the manufacturer's seals are intact. Should anything in the package be found damaged, contact the supplier immediately.

### 2.2.3 Turning on

**Warning!** It is strongly recommended to connect (disconnect) the Comparator to the measured circuits following local safety regulations in force. It is necessary to make sure that all joints are made properly to avoid overheating and excessively high resistance.

Turn on the Comparator in the following order:

- Connect the Comparator to:
  - External protection grounding system
  - Mains
  - Device under test
  - Reference device
- Connect the Burden Box (if applicable) to the Comparator
- Power up device under test
- Power up the Comparator and Burden Box (if applicable) by setting the power supply switch to the "ON" position.

As it is powered up, the Comparator turns on the display backlight and performs self-test and initialization procedures that should be completed in 30 s (these procedures are performed at each power up). At the conclusion, the welcome screen (Fig. 2.1) containing manufacturer's name and logo, device name, and firmware version appears.

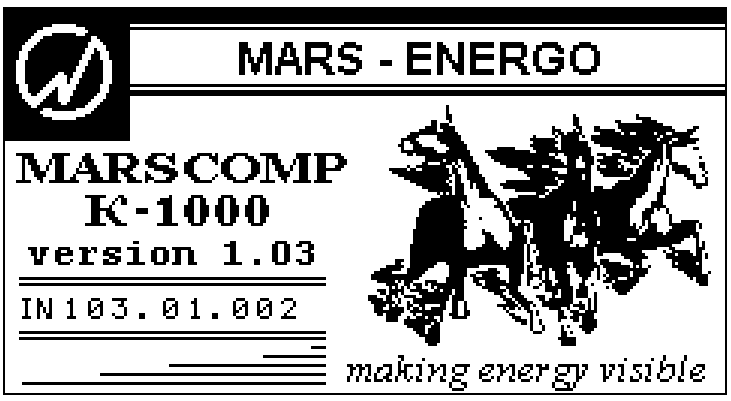



Fig. 2.1

The Comparator is considered set for stable operation in 15 min after applying power. Its specifications are as declared from this point.

## *2.3 Operation*

### 2.3.1 PC controlled operation

To control the Comparator from a PC, you must install E-TransformerTest software (the Program below) on your PC, and then connect the Comparator to the PC via the USB-4RS232 adapter provided in the delivery package.

The Program runs on MS Windows 7 (32 and 64 bit), or higher.

Section 2.3.2.4 contains the description of the “INPUT MODE” option of the “EXTRA SETTINGS” menu (Fig. 3.25), where you can select the first screen to appear when you turn on the Comparator. It can be the “Main menu” screen or “Connection via RS232” screen. In the latter case, the Comparator establishes connection to the PC without human intervention. The setting remains intact at next start-ups.

With the start-up procedures completed, the Comparator goes to the password entry mode. Press the ENT key on the Comparator to go to the main menu. The password is needed just for service engineers to reprogram the firmware.

To enable the PC controlled mode in the Comparator, in the “Connection with PC” screen of the Comparator’s main menu select “Connection via RS-232” or “Connection via USB” (Fig. 2.2) and launch E-TransformerTest software on your PC.

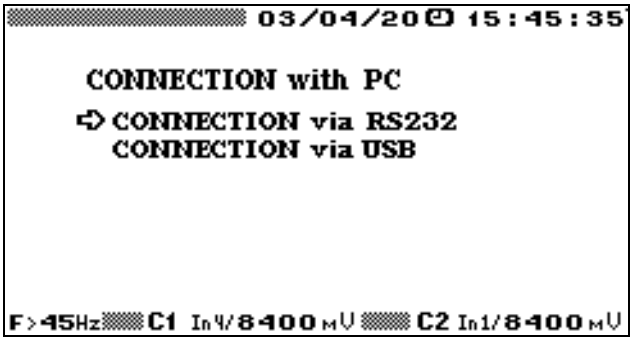



Fig. 2.2 – “Connection with PC” screen

Press the ESC key on the keypad to go back to the main menu.

#### 2.3.1.1 Installation of E-TransformerTest

Insert the software installation flash drive into your computer.

Close all running Windows applications.

Launch the file “Install_ E-TransformerTest.exe”.

As soon as the installation window appears, click on “Next”.

Accept the license agreement and click on “Next”.

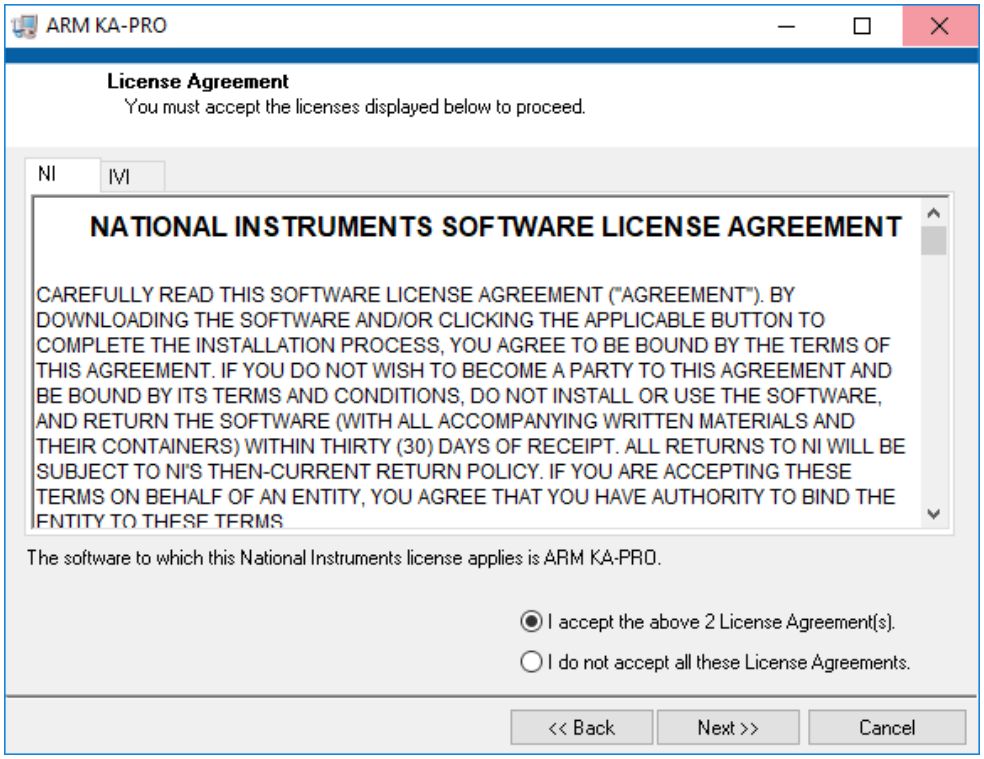
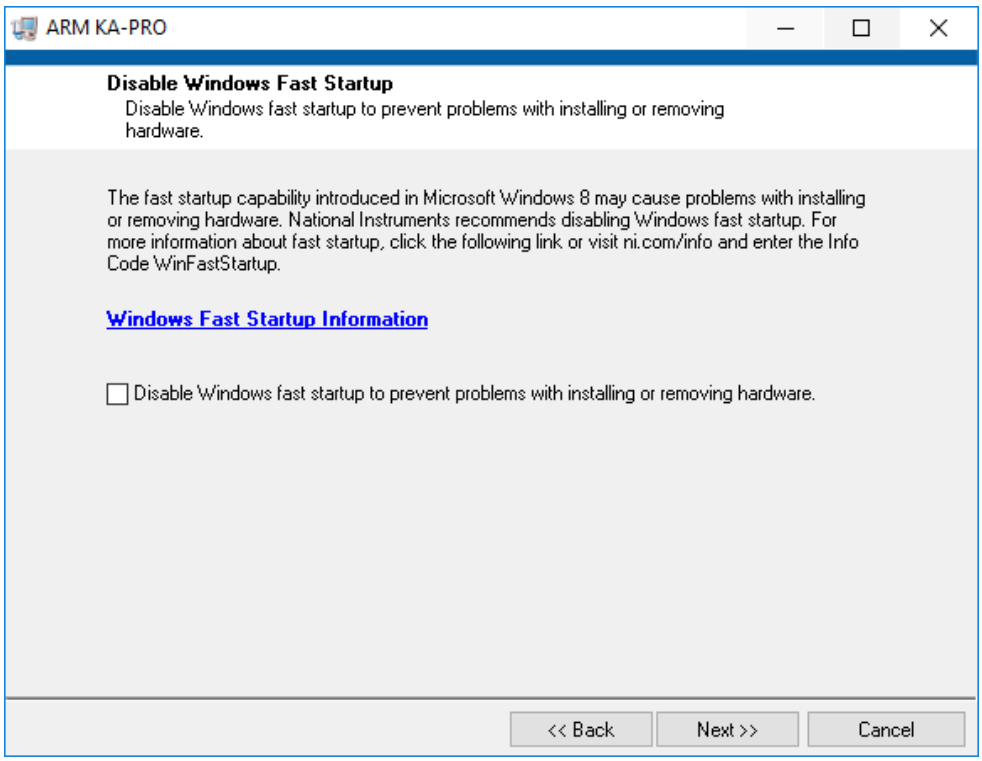
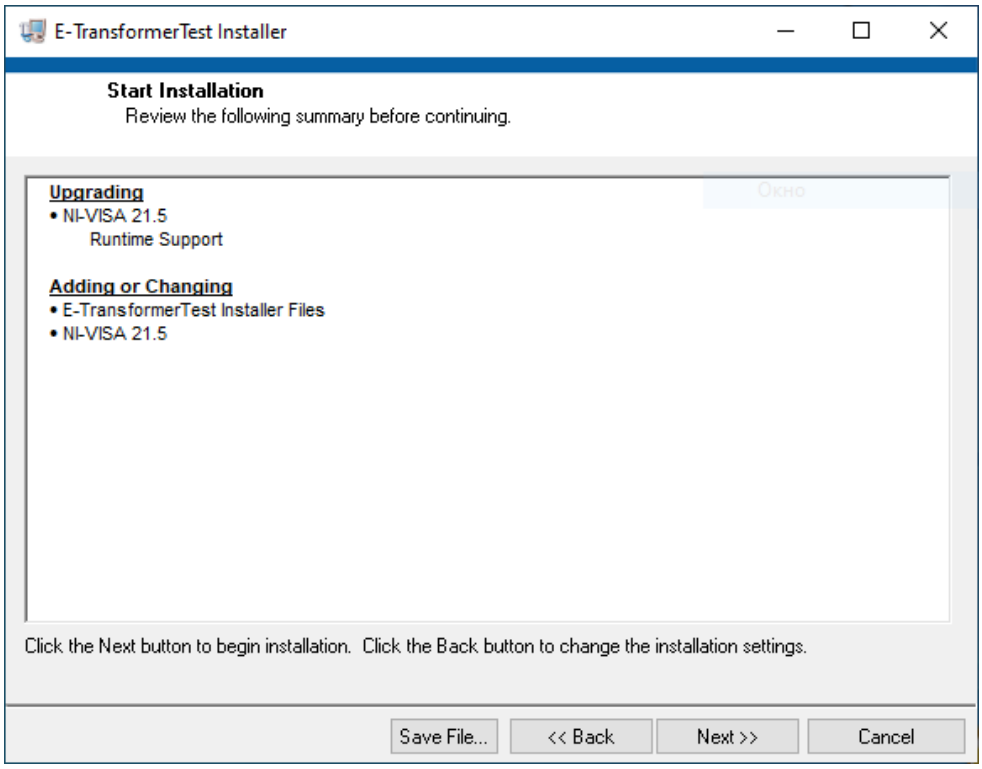



Fig. 2.4

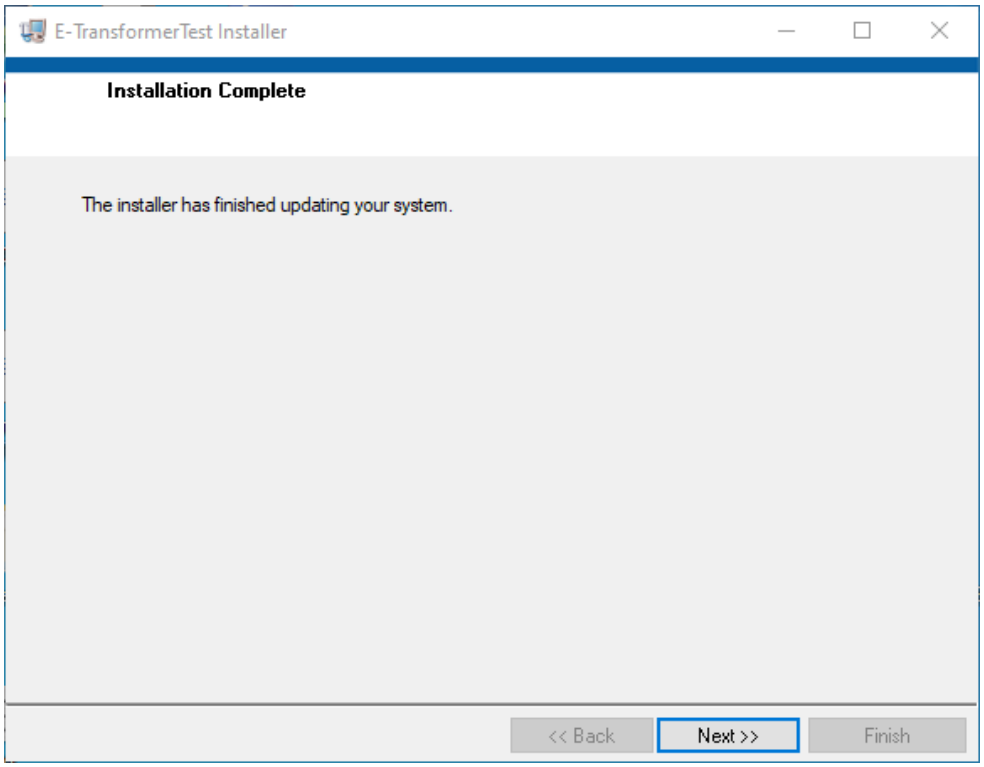



In the dialog box below, uncheck the "**Disable Windows fast startup…"** checkbox and click on "Next".

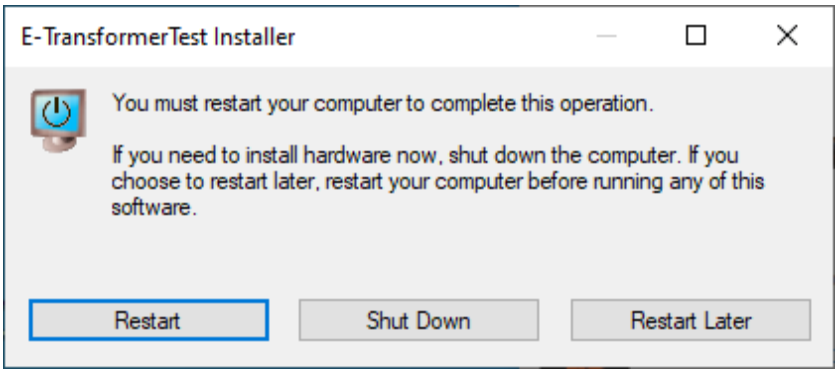
Fig. 2.5




In the dialog box with the list of components to be installed, click on "Next".



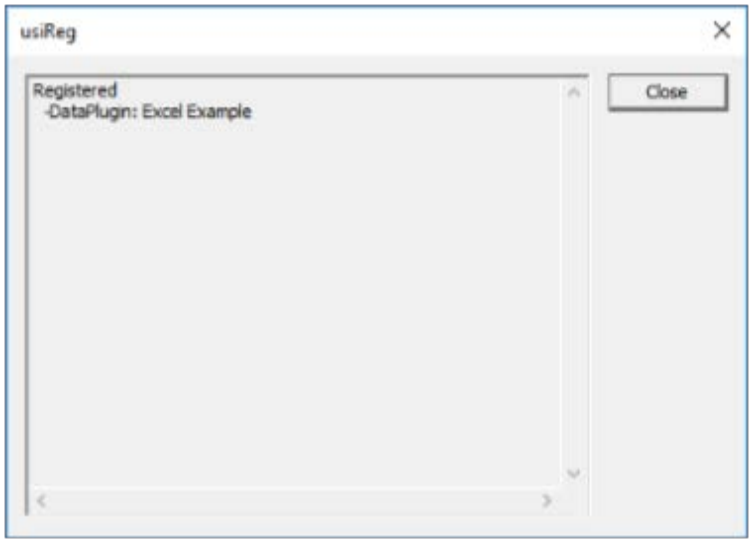

Wait for the installation to complete and click on “Next”.




In the next dialog box, click “Restart Later”.

The program icon will be placed on your desktop.

For correct operation of the Program together with Microsoft Office Components it is necessary to install a special plug-in. The plug-in and the drivers for the 4RS232-USB adapter will be installed automatically on completion of the program installation. In case of re-installation or when the automatic installation failed, the tools can be installed manually. To do this, go to the program folder and launch the file Install_addon.bat from the “data” sub-folder. The default location of the file is: C:\Program Files (x86)\MarsEnergo\E-TransformerTest\data\ Install_addon.bat.




The program E-TransformerTest can be launched in 3 ways:

1. Run E-TransformerTest.exe file from the directory where the program was installed C:\Program Files\ E-TransformerTest is the default path.
2. Double-click on the icon E-TransformerTest on the desktop.
3. Select MarsEnergo\ E-TransformerTest from the Start menu.

NOTE! *To manage test report files (*.rtf) and tables with measurement results (*.xlsx), use appropriate office applications.*

#### 2.3.1.2 De-installation

To remove the program, open the Windows “Control Panel”, select “Add/Remove Programs”, choose “E-TransformerTest” and click on the “Remove” button.

#### 2.3.1.3 Commands and measured parameters

The Comparator sends information via serial port upon commands from a PC.

The supported commands enable the Comparator to:

1. Set required measuring modes
2. Perform measurements and transfer results to the PC
3. Set required measurement ranges.

Measured values are sent to the PC in the following order:

- 51 harmonics (harmonic components $HR_{(U)}$ with respect to the fundamental) for both channels
- 7 interharmonics (interharmonic components) for both channels
- THD for both channels

- RMS values of voltage and current
- RMS values of the 1st harmonic of voltage and current
- RMS values of voltage harmonics of order h ($U_h$)
- Phase angle between 1st harmonics of voltage
- Phase angles between voltage harmonics of order h
- Frequency of the circuit under review
- Actual voltage/current measurement range
- RMS value of difference between signals
- Voltage ratio error (for VTs and LPVTs)
- Current ratio error (for LPCTs)
- Phase displacement
- Composite error (for LPCTs).

#### 2.3.1.4 Parameters calculated by the Comparator

For VTs and LPVTs:

- Primary (high) voltage of input signal / input signal harmonic specified as the voltage measured at the input of the channel C1 multiplied by the rated transformation ratio ($K_{r(Ref)U}$) of the reference voltage-scaling converter (voltage transformer).
- K is the ratio between the rated transformation ratios of the reference voltage-scaling converter (voltage transformer) and the tested one.

  $K= K_{r(Ref)U} /K_{r(DUT)U}$ where

  $K_{r(Ref)U}$ and $K_{r(DUT)U}$ can be expressed as $1000000/K_{VS}$

  $K_{VS}$ (mV/kV) is the “voltage sensor factor”.
- $\varepsilon_u$ is the voltage ratio error of the DUT (expressed in %) obtained at a frequency of the harmonic of order h (in the course of verification/calibration of voltage transformers h=1 according to IEC 61869-3-2012 and IEC 61869-6-2021) which is defined by the formula:

$$\varepsilon_u = \frac{U_{1\,meas} - U_{2\,meas} * K}{U_{2\,meas} * K} * 100\%, \text{ where}$$

$U_{2\,meas}$ is the secondary voltage of the harmonic h measured by the Comparator (obtained from the reference voltage transformer or other reference voltage-scaling instrument)

$U_{1\,meas}$ is the secondary voltage of the harmonic h measured by the Comparator (obtained from the VT under test).

- $\Delta\varphi_h$ is the phase error (phase displacement) of the DUT (expressed in minutes) obtained for a harmonic of order h (in the course of verification/calibration of transformers h=1) on condition that the rated phase offset $\varphi_{OR}$ and the rated delay time $t_{dr}$ equal zero.

For LPCTs:

- Primary current specified as the secondary current of the reference CT measured at the input of the channel C1 multiplied by the rated transformation ratio ($K_{r(Ref)I}$) of the reference CT.
- K is the ratio between the rated transformation ratios of the reference CT and the tested one.
  K= $K_{r(Ref)I}$ /$K_{r(DUT)Ui}$ where
  $K_{r(Ref)I}$ and $K_{r\ (DUT)Ui}$ can be expressed as 1/$K_{CS}$
  $K_{CS}$ (A/mV) is the "current sensor factor".
- $\varepsilon_i$ is the current ratio error of the DUT (expressed in %) obtained at a frequency of the harmonic of order h (h=1) which is defined by the formula:

$$\varepsilon_i = \frac{I_{1\,meas} - I_{2\,meas} * K}{I_{2\,meas} * K} * 100\%, \text{ where}$$

$I_{2\ meas}$ is the 1st harmonic of secondary current measured by the Comparator (obtained from the reference current transformer or other reference current-scaling instrument)
$I_{1\ meas}$ is the 1st harmonic of secondary voltage ($U_{i1}$) measured by the Comparator (obtained from the LPCT under test).

- $\Delta\varphi_h$ is the phase error (phase displacement) of the DUT (expressed in minutes) obtained for a harmonic of order h (in the course of verification/calibration of transformers h=1) on condition that the rated phase offset $\varphi_{OR}$ and the rated delay time $t_{dr}$ equal zero.
- $\varepsilon_c$ is the composite error of the LPCT (in %) specified according to IEC 61869-6-2021.
- $\varepsilon_{c1}$ is the composite error of the LPCT (in %) calculated from the transformer errors $\varepsilon_i$ and $\Delta\varphi_h$ at a frequency of the 1st (fundamental) harmonic.

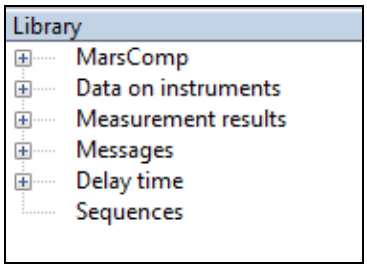
When the number of measurements n for a parameter is set from 2 to 100, the Program calculates the arithmetic mean of the parameter together with its standard deviation, namely the standard (root mean square) deviation of the measured or calculated parameter obtained for n measurements.

### 2.3.1.5 Main menu

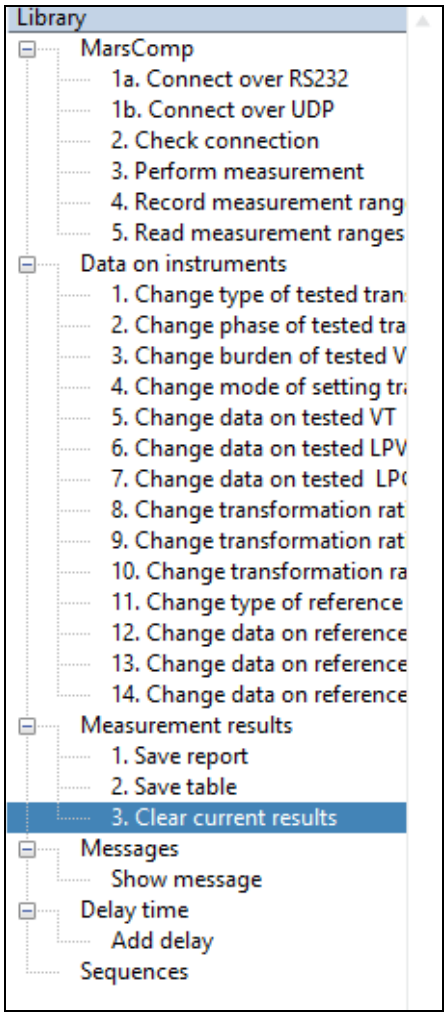
The main window is divided into 3 areas conventionally named “Library”, “Instruments and Operations”, and “Configuration and Indication”.

These areas are described below.

*1. “Library” (of instruments and functions)*: MarsComp, Data on Instruments, Measurement results, Messages, Delay time, and Sequences.

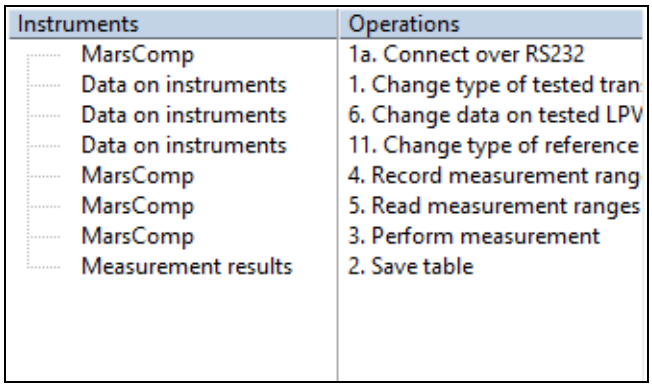



Each option of the “Library” area contains sequences of actions available (shown below).



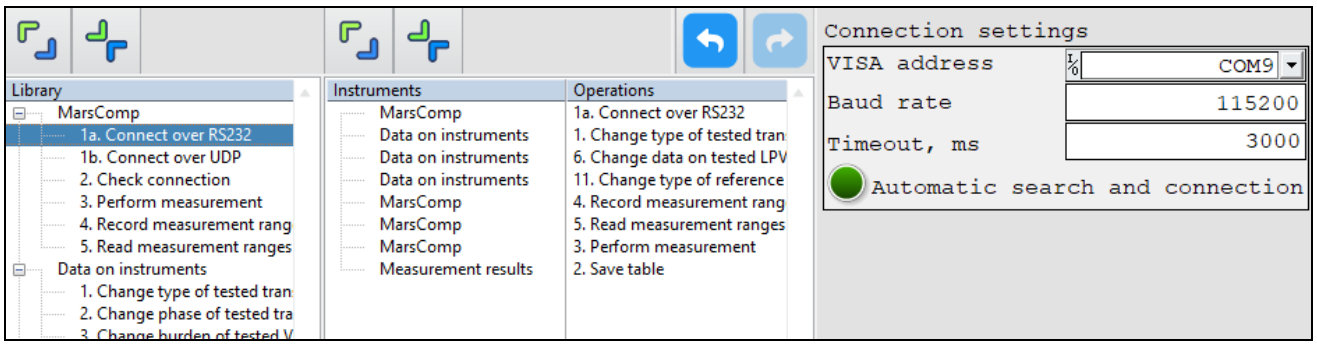
*2. “Instruments and operations” area*

Here you can create an actual sequence of operations necessary to achieve your test purposes.




3 *“Configuration and Indication” area*

The area occupies the right-most part of the main window. Its contents depend on the option selected from the Library.




### 2.3.1.6 Operation in the manual mode

In the manual mode, the Comparator and test procedures are controlled through three folders of the “Library” area: “MarsComp”, “Data on instruments”, and “Measurement results”.

**“Data on instruments” folder**

Clicking on this folder calls up the panel with 3 tabs: “Data on instruments”, “Verification data” and “Calculations”.

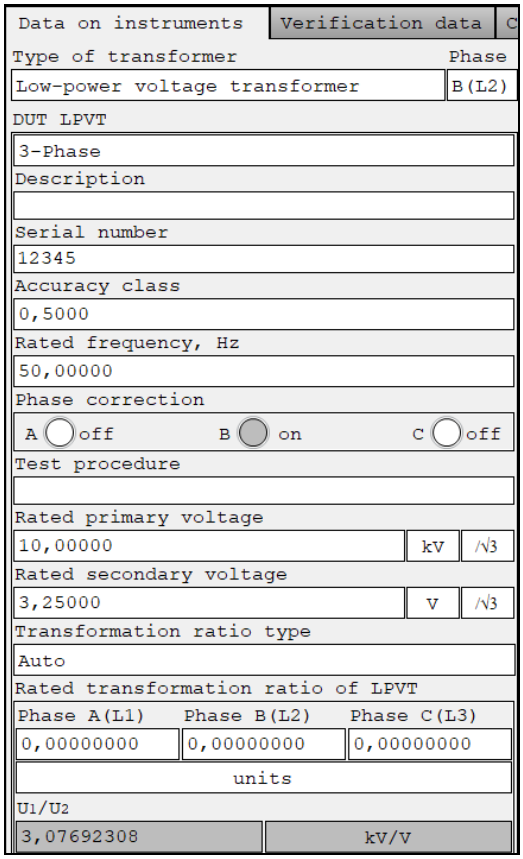

**“Data on instruments” tab**

The tab is conventionally divided into three areas devoted respectively to the device under test (DUT), comparator, and reference instrument.

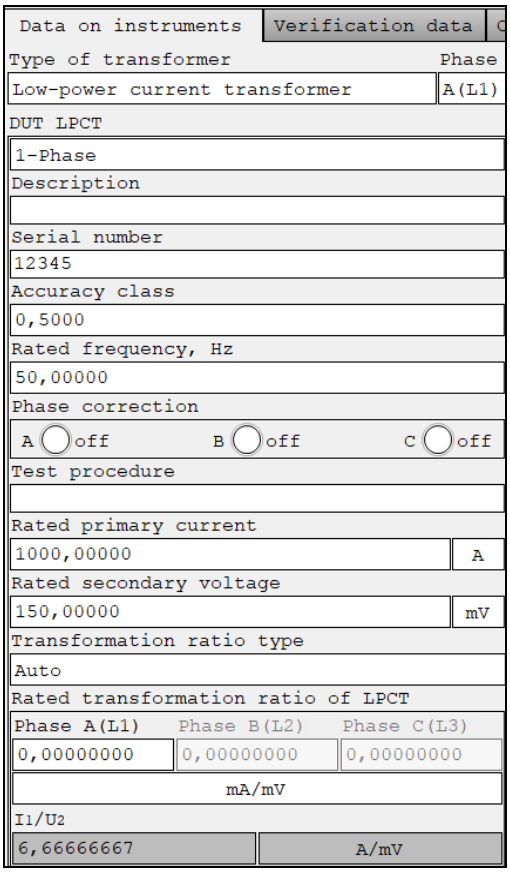
The values specified in the fields will be represented in the test report and/or used for calculations.

The fields related to the DUT are shown below.

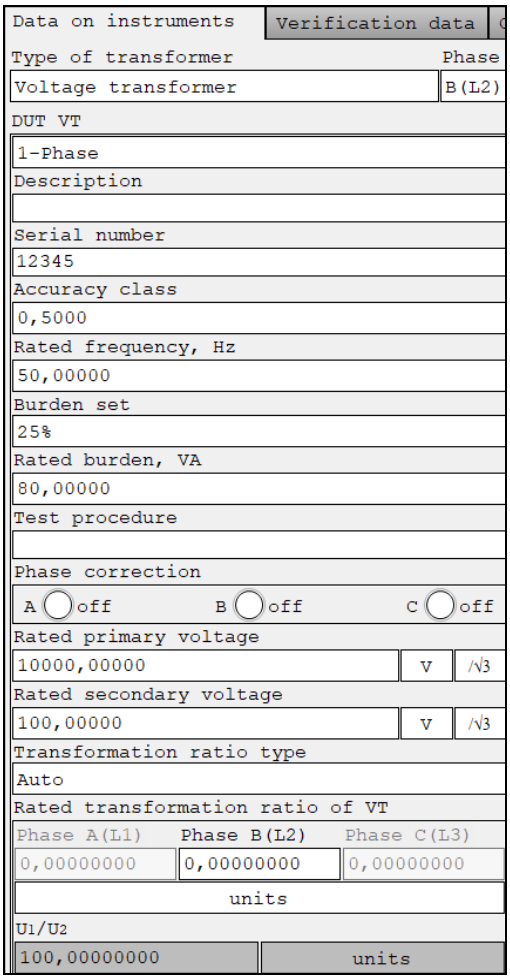
For LPVTs:



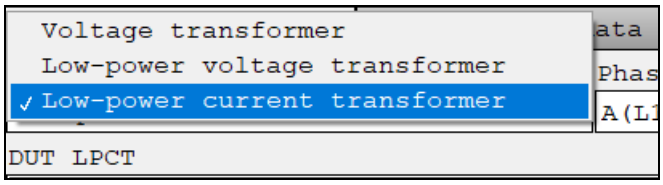

For LPCTs:



For VTs:



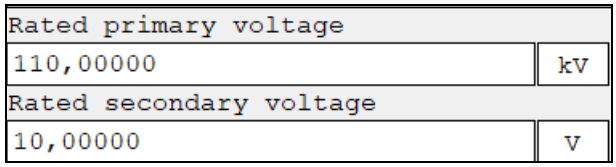

- Type of transformer – you can select a type of the device under test: voltage transformer, low-power voltage transformer, or low-power current transformer




- DUT VT (LPVT, LPCT) – classification of the DUT with respect to the electrical network type (single-phase or three-phase)
- Description – you can specify the identification data to be added to the test report (e.g., designation of the type or model name)
- Serial number
- Accuracy class – accuracy class of the DUT (used in calculations)
- Rated frequency

- Burden set – this field (related just to VTs under test) is used to select an active burden set (in % of rated burden)
- Rated burden – Rated burden of the DUT
- Test procedure – designation of the test procedure in use
- Phase correction – when the switch is ON, phase error is calculated considering correction by 180°
- Rated primary voltage (VTs, LPVTs) or current (LPCTs)
- Rated secondary voltage
- Transformation ratio type – "Auto" means that the transformation ratio $Kr_U$ (or $Kr_{Ui}$) of the transformer under review is calculated by the Program on the basis of the rated primary and secondary signals entered by the user; "Manual" means that the Program uses $Kr_U$ or $Kr_{Ui}$ specified by the user in the "Rated transformation ratio" field
- Rated transformation ratio – this field is used to set the value of $Kr_U$ or $Kr_{Ui}$ manually per each phase (which is taken from the Equipment Certificate or from the nameplate of the tested transformer)
- U1/U2 or I1/U2 – the transformation ratio calculated from the values specified in the "Rated primary voltage (current)" and "Rated secondary voltage" fields.

For conventional and low-power voltage transformers, the "Rated primary voltage" and "Rated secondary voltage" fields shown in the figure below should contain the values of line (phase-to-phase) voltage.




The multipliers "/√3", "·√3", and "·1" are used to bring this value of line voltage value to the "phase" one.

For example:

- If the rated primary voltage of a VT under test is indicated as 110/√3 kV, the corresponding field should contain "110" (kV) or "110000" (V), and the multiplier "/√3" should be selected.
- If the rated primary voltage of a VT under test is indicated as 35 kV, the corresponding field should contain "35" (kV) or "35000" (V), and the multiplier "·1" should be selected.
- If the rated primary voltage of a LPVT under test is indicated as 3.25/√3 V, the field

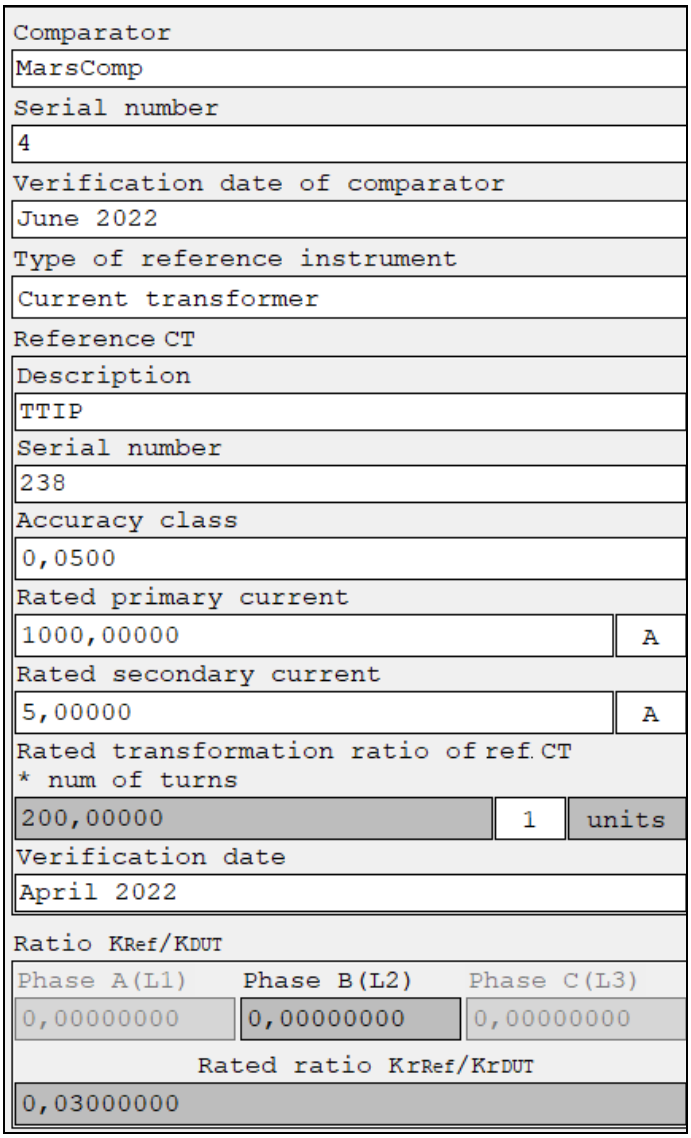
should contain “3.250” (V) or “3250” (mV) and the multiplier “/√3” should be selected.

The fields of the Comparator area should contain basic information on the Comparator.

The area devoted to the reference instrument includes the following fields:

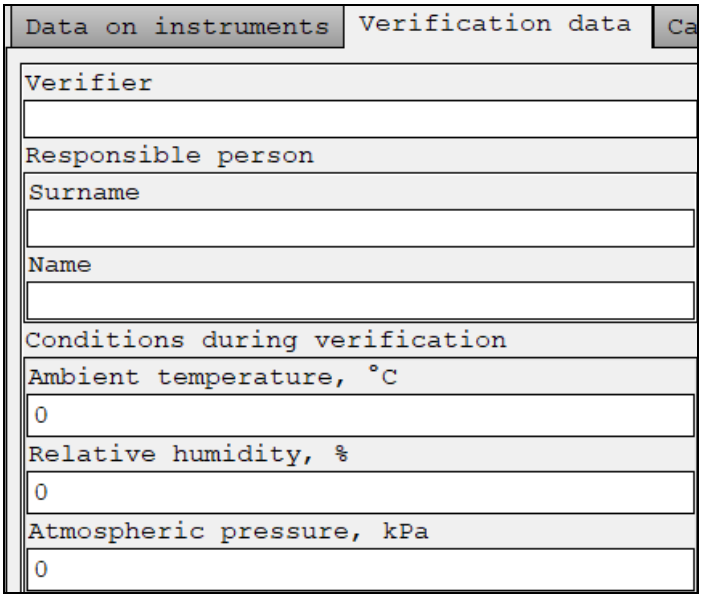
- Type – selection among the supported types of reference instruments
- Description – identification data on the reference instrument to be added to the test report
- Serial number
- Accuracy class
- Rated primary voltage (for a reference VT/voltage divider or LPVT) or current (for a reference CT)
- Rated secondary voltage (current) – rated secondary voltage (current) of the reference instrument
- Rated transformation ratio – the rated transformation ratio of the reference transformer or divider calculated as a ratio between the rated primary and secondary signals
- Verification date – the date of the latest verification of the reference instrument
- Rated ratio $K_{rRef}/_{KrDUT}$ – the ratio between the rated transformation ratios of the reference and tested instruments.

The areas devoted to the Comparator and reference instrument are shown below:



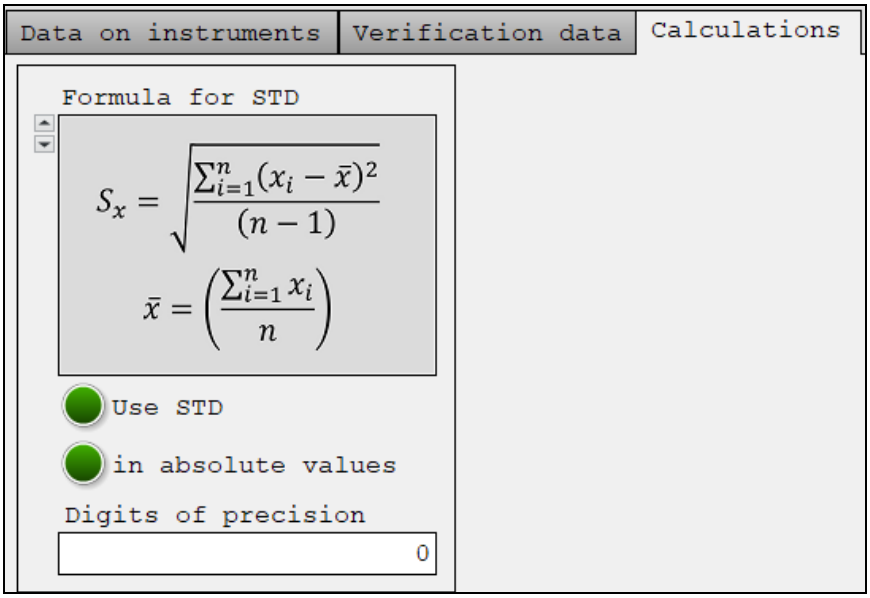

**“Verification data” tab**

The information specified here will be represented in the test report.



**“Calculations” tab**

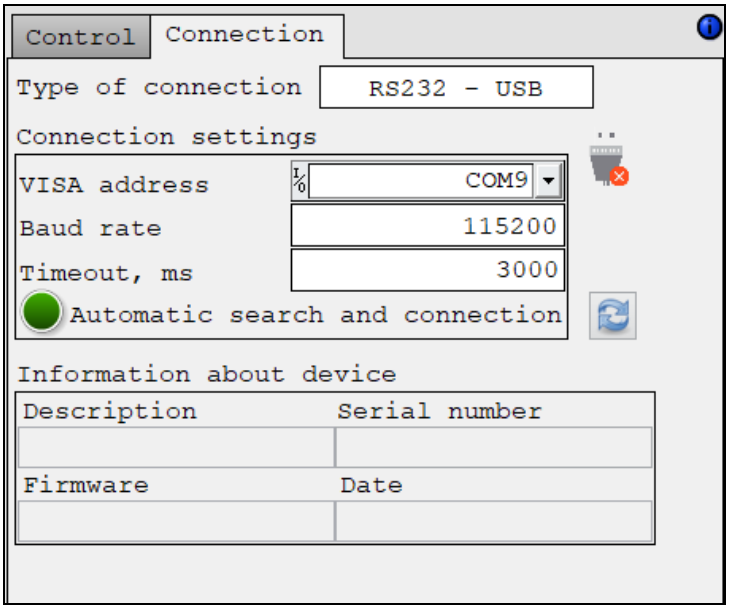
This is for setting the formula according to which a standard (root-mean-square) deviation will be calculated.




**“MarsComp” folder**

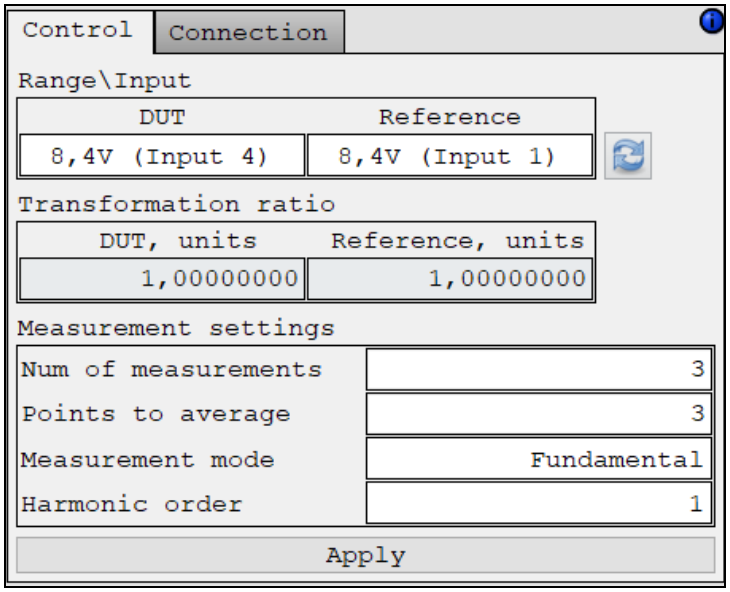
From this folder it is possible to:

- Select communications settings between the Comparator and PC on the “Connection” tab




- Select active inputs of the Comparator and specify rated values for these inputs

**NOTE!** The rated values for the inputs of the Comparator should be selected so that they are fully consistent with the expected values of input signals and test circuitry.




- Specify the number of points (“Points to average” over which the arithmetic mean and standard deviation (STD) of the parameter will be calculated) as well as the number of measurements to be performed after clicking the “Start” button.

**“Measurement results” folder**

In this area you can view measurement results and create records of the tests.

The area is divided into 3 parts.

The upper right panel provides control over the primary signal. It contains the following fields:

– % of rated value – the relative value of the primary voltage $U_1$ or current $I_1$ of the reference instrument (with respect to its rated value)

– Primary $U_1$, V ($I_1$, A) – the measured value of the secondary voltage (current) of the reference instrument multiplied by its rated transformation ratio

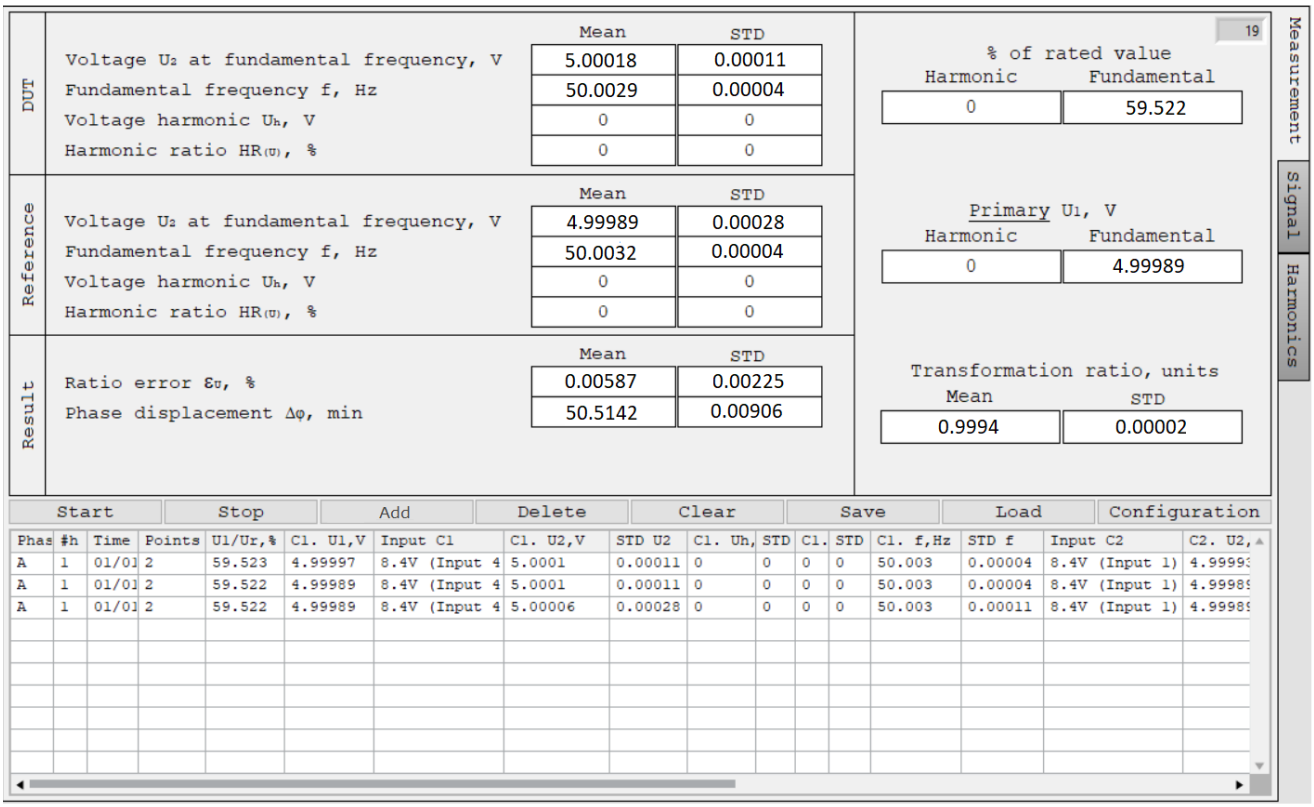
– Transformation ratio – the measured value of the transformation ratio of the transformer under test.

The upper left panel shows the result of an actual measurement that can be saved to the “Measurements” table as a new measurement record. It contains:

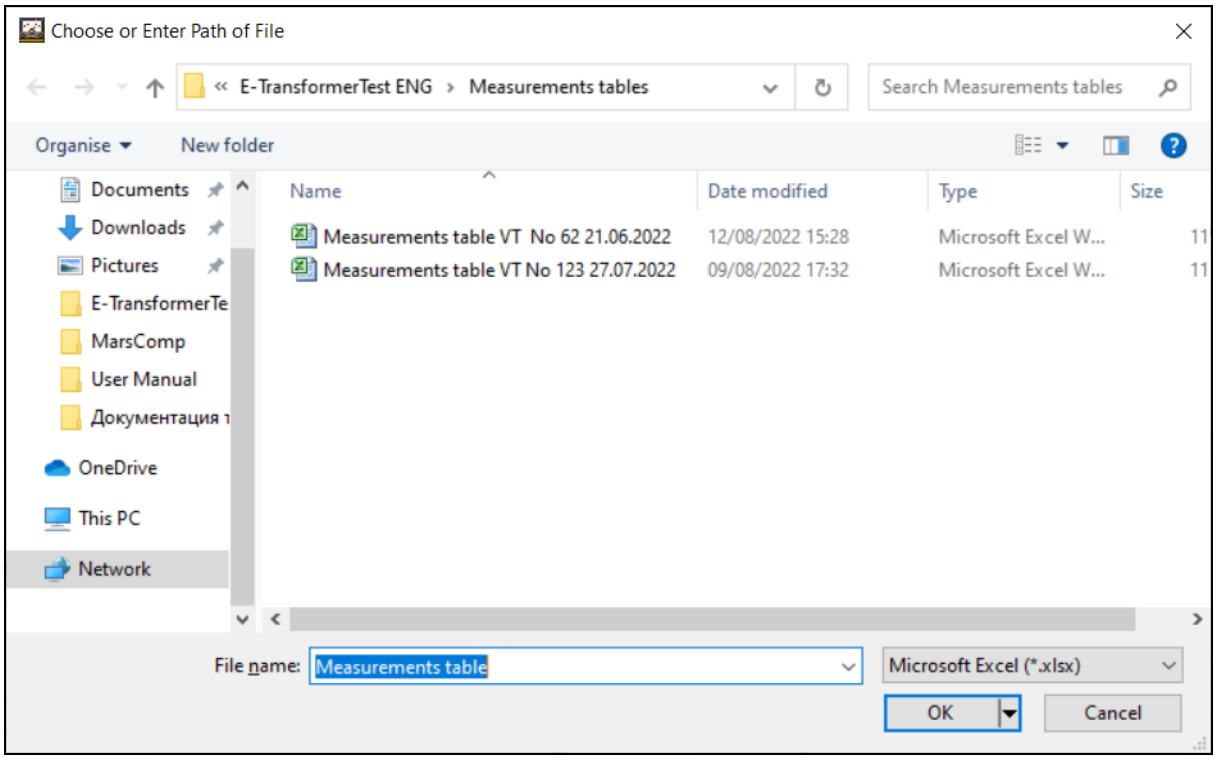
– Readings of the reference and tested signals taken by the Comparator from active inputs

– Calculated values of the ratio error and phase displacement of the transformer under test.

The lower part of the area is occupied by the “Measurements” table. The buttons used to control the process of measurements and measurement records are located over it.




The table filled with measurement records can be saved to a file in the form of a table or verification report. On clicking the “Save” button and selecting the file type, you will see a standard “Save as” dialog box.




By default the file is saved to the Program directory either to the “Verification reports” or to the “Measurements tables” folder. A recorded file can be loaded for viewing in the Program by clicking on the “Load” button. The types of verification reports available in the Program are shown in Appendices A.1, A.2, and A.3.

The default name of a verification report file is: [Verification report DUT type DUT serial number Verification date.rtf] where the fields “DUT type” and “DUT serial number” are filled with actual data pre-specified in the “Data on instruments” folder, and the “Verification date“ is a current system date on the PC.

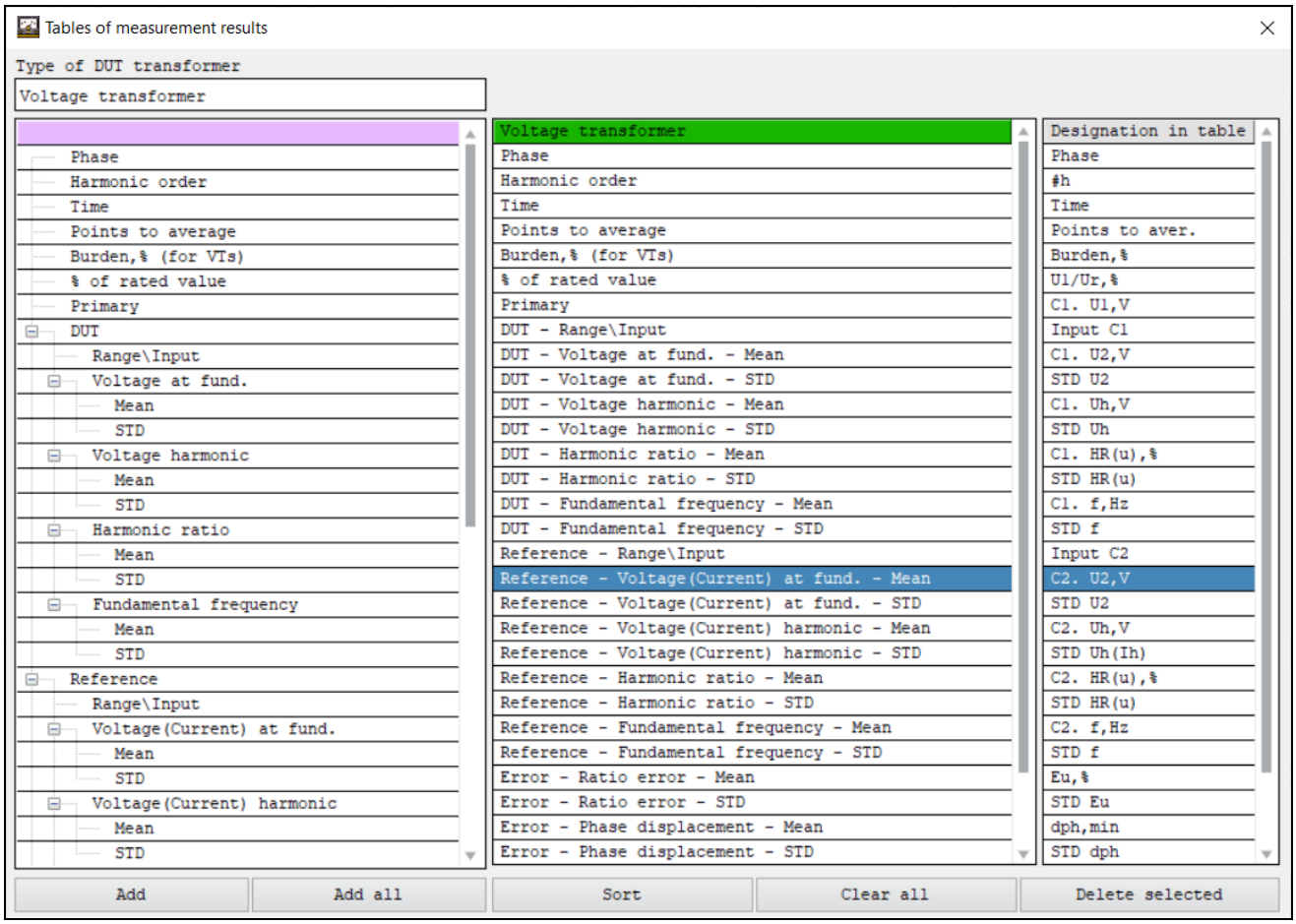
The default name of a file containing a table with measurement results is: [Measurements table DUT type DUT serial number Verification date. xlsx] where the fields “DUT type” and “DUT serial number” are filled with actual data pre-specified in the “Data on instruments” folder, and the “Verification date” is a current system date on the PC.

The functions of the control buttons located over the table are described below:

- Add – adds an actual measurement to the table
- Delete – deletes a highlighted record from the table
- Clear – deletes all records from the table
- Save – creates verification reports (rtf) or tables with measurement results (xlsx)
- Load – loads data from a file previously saved in the program.
- Start – launches measurements
- Stop – stops measurements

- Configuration – used to select the parameters to be displayed in the “Measurements” table.

A complete list of the parameters that can be displayed in the “Measurements” table appears when you click on the “Configuration” button. To select a parameter, make it appear on the right panel by double-clicking on it.




On starting measurements by clicking the “Start” button, the readings taken from the Comparator appear on the “Measurement results” panel once in 2 seconds provided that the number of measurements was set to 1. If the number of measurements was set to other value, the update period will be longer.

The composite error $\varepsilon_c$ (%) for a low-power current transformer is calculated according to IEC 61869–10. In addition, the composite error (designated as $\varepsilon_{c1}$) is calculated from the ratio and phase errors obtained for the first signal harmonic. In case of a distorted waveform, the values of these errors may differ considerably.

### 2.3.1.7 Operation in the automatic mode

In the automatic mode the Comparator can be configured and controlled automatically. An automatic test procedure is created as a sequence of operations. The operations are selected from the list on the Library panel. When complete, the sequence can be recorded to a file for further use.

The toolbar for creating test procedures contains the following buttons (from left to right):

- Add a line (an operation)
- Add a folder name for the folder with operations
- Change a folder name
- Delete a selected operation
- Save to a file (it can be accessed from the folder “Sequences”)
- Delete all operations
- Launch a selected operation
- Launch a sequence
- Clear the warning dialog box from error messages

**Available operations**

**MarsComp – the options for controlling the Comparator**

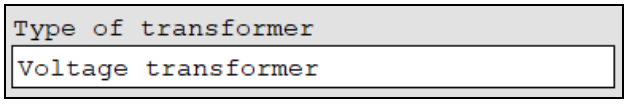
| Connection settings | |
|---|---|
| VISA address | COM9 |
| Baud rate | 115200 |
| Timeout, ms | 3000 |
| Automatic search and connection | |

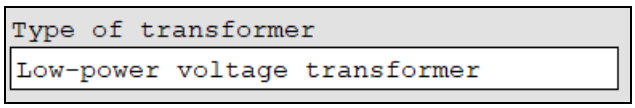
| Measurement settings | |
|---|---|
| Num of measurements | 1 |
| Points to average | 3 |
| Measurement mode | Fundamental |
| Harmonic order | 1 |

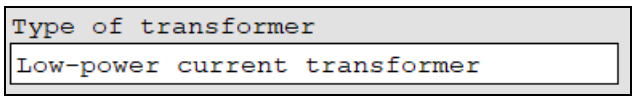
| Range\Input | |
|---|---|
| DUT | Reference |
| 60V (Input 5) | 420V (Input 2) |

**<u>Data on instruments</u> – the fields for specifying data on the transformer under test, namely**

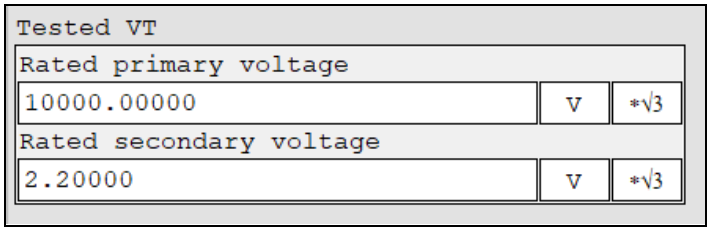
For selecting the type of the transformer under test:

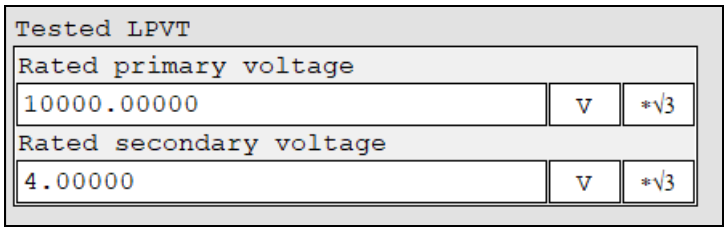


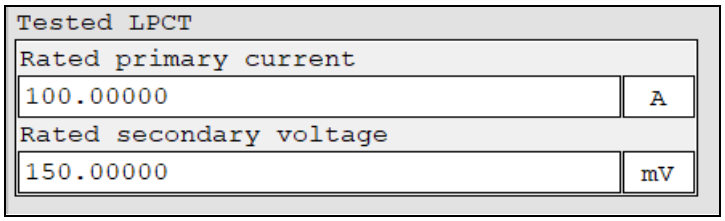




For specifying nameplate data on the transformer under test:

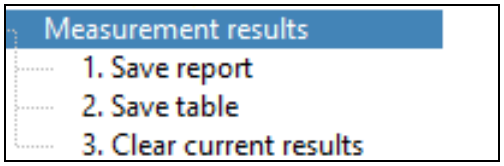



**<u>Measurement results</u> – the fields for managing test results and creating test reports**

The operations available:



### 2.3.2 Off-Line mode (control from keypad)

NOTE! *When the Comparator is controlled from the keypad, the set of measurements can be performed only in part.*

#### 2.3.2.1 Operator interface

In the off-line mode the Comparator is controlled from the menu. The keys "ENT", "ESC", ⇓, ⇑, ⇐, ⇒ are used to navigate through the screens or menu items.

Functions of the keys are described in the table below.

| Key | Function |
|---|---|
| 0...9 | For entering numeric values |
| ⇓⇑ | For moving the cursor up and down and for specifying numeric values |
| ⇐⇒ | For moving the cursor left and right and for specifying numeric values |
| `ENT` | Used to open screens, save values to the memory, or enable modes |
| `ESC` | Used to exit modes, or leave some current menu item for an upper level menu |
| `F` | It's a "hot key" used to go to the measuring range selection screen |

Regardless of an active screen, the current date and time are shown on the top of the display, while its bottom line always shows active measurement ranges. Depending on an active input, there may be various combinations of measurement ranges selected for the Channel 1 (C1) and Channel 2 (C2). The measurement ranges can be changed via the "Settings" menu, or with the "hot key" F.

The arrow keys ⇓ and ⇑ are used to move the cursor through menu options, and the "ENT" key is used to call up the selected option.

NOTE! *The operator interface may be modified with respect to the order of displaying data. These changes do not affect the accuracy and technical characteristics of the Comparator*.

The options of the main menu (Fig. 3.2) allow you to make all configuration settings for the Comparator, or, alternatively, to go to the "Measurements" mode to start measurements.

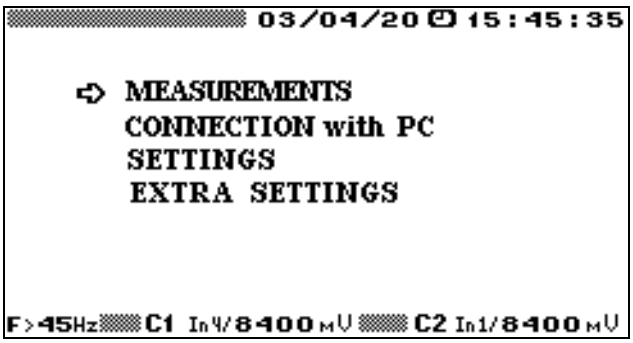



Fig. 3.2 – Main menu

### 2.3.2.2 “Settings” menu

The “Settings” menu is shown in Fig. 3.3.

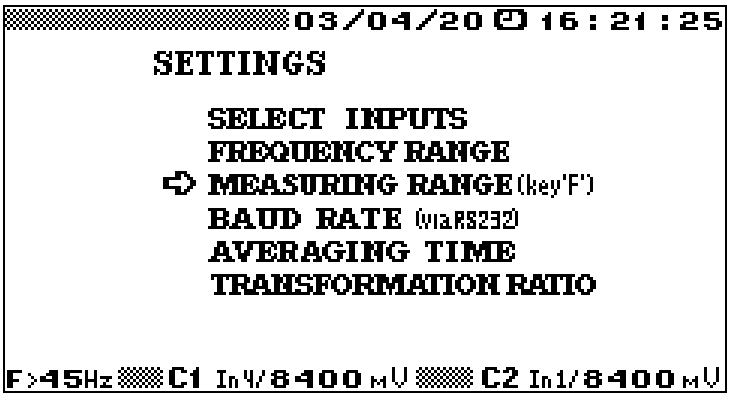



Fig. 3.3 – “Settings” menu

The options of the “Settings” menu are described below.

**“Select Inputs”**

The Comparator has seven inputs, three of which (1 to 3) are connected to the measurement channel “C2” (the “reference” channel for reference instruments), and four of which (4 to 7) are connected to the measurement channel “C1” (the channel for devices under test). The “Select Inputs” screen gives you the possibility to choose an active combination of the inputs for the channels C1 and C2 (see Fig. 3.4).

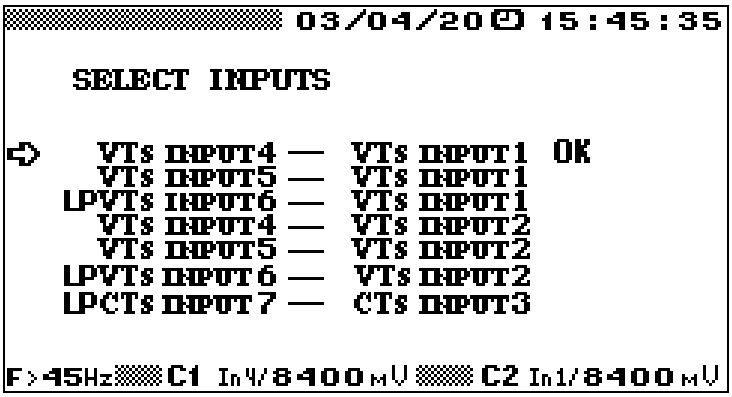



Fig. 3.4 – Screen for choosing active inputs for measurement channels

When the desired combination of the inputs has been selected with arrow keys, the “OK” confirmation message appears next to it. Pressing the ESC key reverts back to the “Settings menu”.

**Measuring range**

The mode in which the desired measuring ranges can be activated for each channel is called up either by selecting its name in the “Settings” menu, or by pressing the hot key “F”. Select the desired channel on the first screen (shown in Fig. 3.5), and then select the desired measurement range for the selected channel (Figures 3.6 and 3.7).

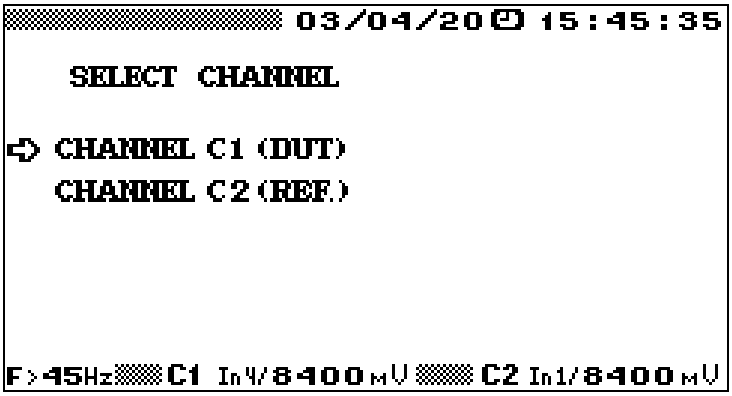



Fig. 3.5 – Choosing channel for measurement range selection

At power up the Comparator sets the highest possible measuring range for all inputs.

The following measuring ranges can be set depending on the selected input (for each of the inputs individually):

- Inputs 2 and 7 – 840, 420, 120 and 60 V (RMS)
- Inputs 1, 4, 6, 7 – 8400, 4200, 1000, 500, 100, 50, 10, 5 mV (RMS)
- Input 3 – 0.1, 0.5, 1, 5, 10A.

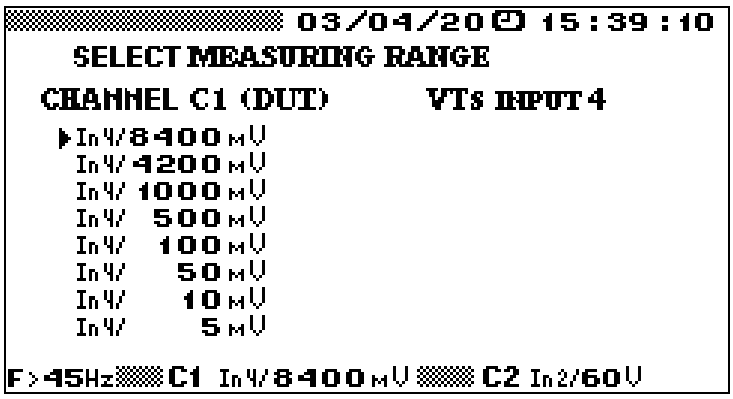



Fig. 3.6 – Screen for choosing measurement range for the Channel C1

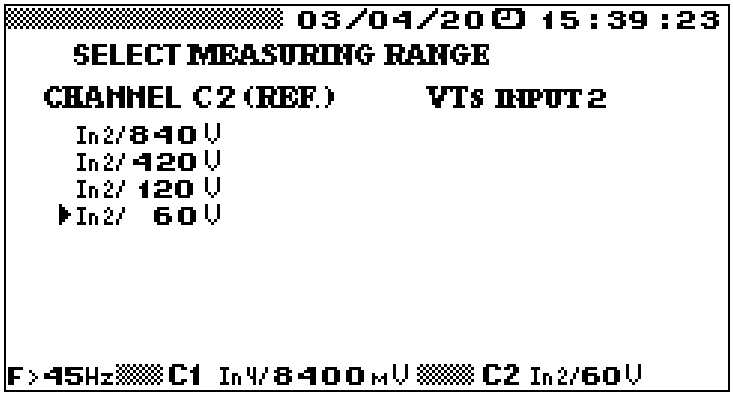



Fig. 3.7 – Screen for choosing measurement range for the Channel C2

Actual measuring ranges are always represented on the status (bottom) line of the display.

If the voltage input signal exceeds the limit of a currently active measuring range, the Comparator automatically swaps to the highest voltage range. Conversely, when the voltage input signal decreases, the Comparator does not swap to a lower range.

### Averaging time

In this mode you can specify a period over which sampled values of measured parameters will be averaged.

The averaging time is set for all modes from the “Measurements” menu (excluding the “Waveforms”), and the options are as follows: 1.25 s, 2.5 s, 5 s, and 10 s.

When the desired value has been selected with arrow keys, the “OK” confirmation message appears next to it. Pressing the ESC key reverts back to the “Settings menu”.

The default value is 1.25 s.

### Frequency range

The “Frequency range” screen is shown in Fig. 3.8. Thus, the Comparator works in 2 frequency ranges: (45 to 2500 Hz) or (15 to 800 Hz).

The 15…800 Hz range is used just to measure subharmonics.

The 45…2500 Hz range is used for testing transformers rated at 50 (60 or 100 Hz), for measuring signals at frequencies over 45 Hz, and for measuring harmonics of orders from 1 to 50.

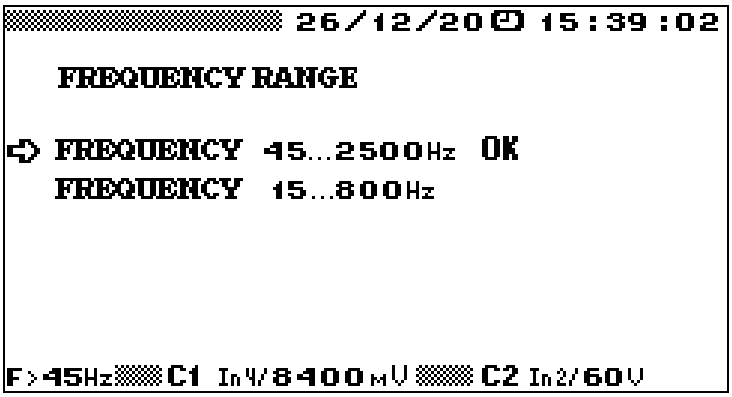



Fig. 3.8 – Screen for choosing frequency range

### Baud rate via RS-232

The Comparator supports data transfer to/from a PC via RS-232 at a rate of:

- 115200 bit/s
- 38400 bit/s
- 19200 bit/s
- 9600 bit/s.

When the desired value has been selected with arrow keys, the “OK” confirmation message appears next to it. Pressing the ESC key reverts back to the “Settings” menu.

The default value is 19200 bit/s.

### Setting transformation ratios for CTs (LPCTs) or VTs (LPVTs)

The screen shown in Fig. 3.8 is used to specify the value of rated transformation ratio for the transformers connected to each of the two measuring channels. The ratios specified for the reference device (that may be a CT or VT) and device under test (that may be a VT, LPCT, or LPVT) are then used to calculate the error of the tested transformer.

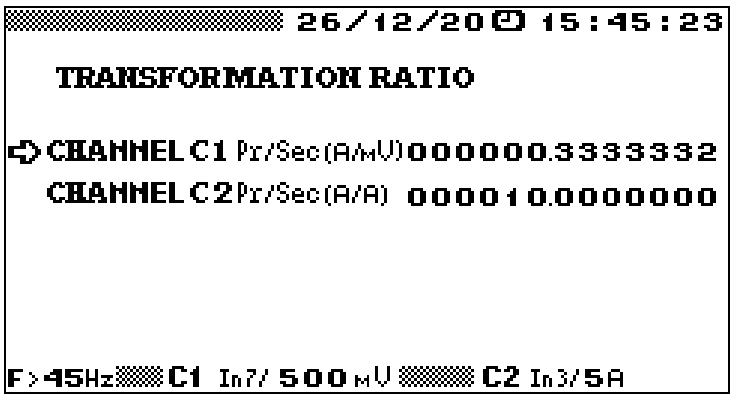



Fig. 3.8 – Screen for entering rated transformation ratios

### 2.3.2.3 “Measurements” menu

The options available in the “Measurements” menu depend on which frequency range has been selected. The range (15 to 800 Hz) corresponds to the options shown in Fig. 3.9.

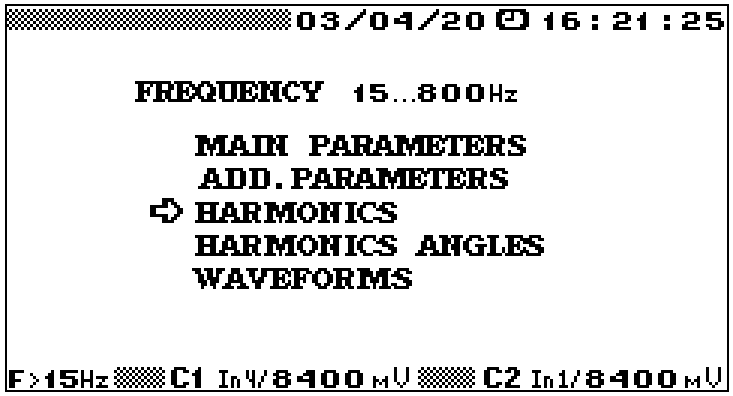



Fig. 3.9 – “Measurements” menu for the range (15 to 800 Hz)

The options available for the “45...2500 Hz” range are shown in Fig. 3.10.

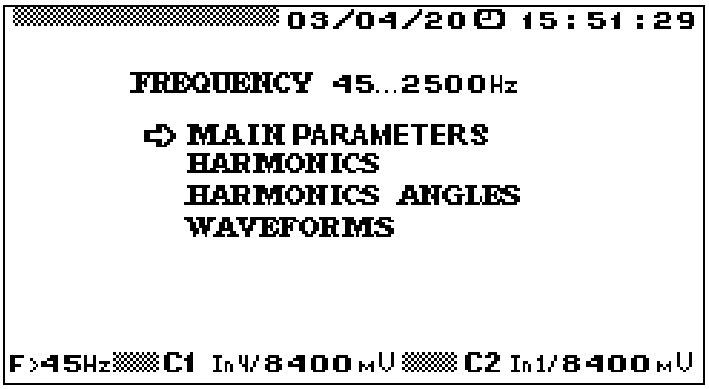



Fig. 3.10 – “Measurements” menu for the range (45 to 2500 Hz)

All measurement modes listed on the above screens show actual values of measured parameters calculated in real time (except for “Waveforms”, see section 3).

When measurements are in progress, a progress bar reflecting the elapsed time of each averaging cycle is displayed at the left top part of the screen (unless the averaging time is set to the 1.25 s default value).

### "Main parameters" mode

In this mode the Comparator measures sinusoidal signals in each measuring channel.

The mode contains one screen (Fig. 3.11) that displays RMS voltage (or current) values together with values of frequency and phase difference between the fundamental harmonics of two signals in the channels C1 and C2. The RMS values of the 1st (fundamental) harmonics of these signals are shown in order to evaluate the degree of distortion of sine waves.

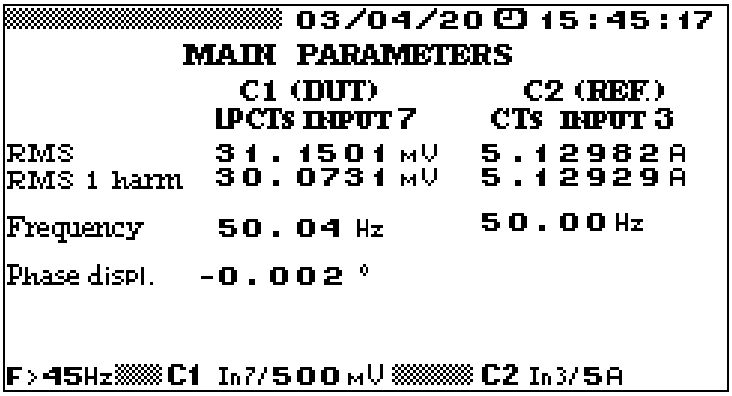



Fig. 3.11– "Main parameters" screen

### "Harmonics" mode

The Comparator works in 2 frequency ranges: (45 to 2500 Hz) or (15 to 800 Hz).

When the frequency range is set to (45 to 2500 Hz), in the "Harmonics" mode the Comparator displays values of harmonic parameters (Fig. 3.12) obtained from composite voltage waveforms in the channels C1 and C2. The parameters are as follows:

- RMS value of the 1st voltage harmonic $RMS1_{(1)}$ (for the channel C1) or $RMS2_{(1)}$ (for the channel C2) within the (45 to 55 Hz) frequency range
- Frequency of the 1st (fundamental) harmonic within the (45 to 55 Hz) frequency range
- Total harmonic distortion of voltage $THD_{U1}$ (for the channel C1) or $THD_{U2}$ (for the channel C2)
- Harmonic components (ratios) in % of the 1st harmonic, from the 1st to 50th.

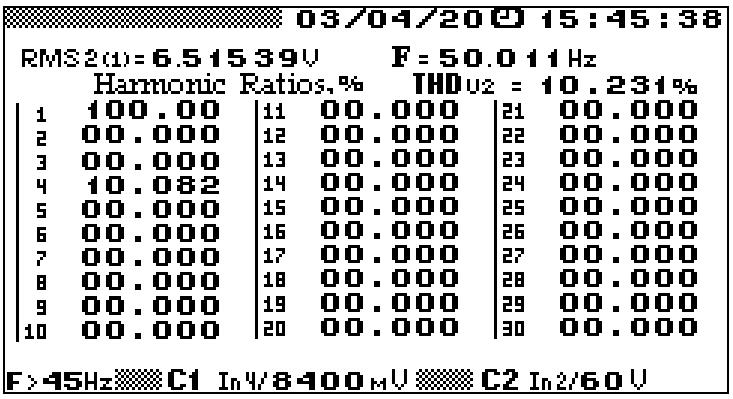



Fig. 3.12 – “Harmonics” screen for channel C2 (with a range of 45 to 2500 Hz enabled)

There are the first 30 harmonics on the screen. To view the harmonics of order from 31 to 50, use the up and down arrow keys (⇓⇑).

To switch between the “Harmonics” screens related to the channel C1 and C2, use the left and right arrow keys (⇐, ⇒).

NOTE! *In the “Harmonics” mode, if an RMS value of input voltage appears to be less than 1% of the nominal value of the currently active measuring range, the parameters are not calculated (the fields contain zeros instead of measurements).*

When the frequency range is set to (15 to 800 Hz), in the “Harmonics” mode the Comparator displays values of harmonic parameters (Fig. 3.13) obtained from composite voltage waveforms in the channels C1 and C2. The parameters are as follows:

- RMS value of the 1st voltage harmonic $RMS1_{(1)}$ (for the channel C1) or $RMS2_{(1)}$ (for the channel C2) within the (45 to 55 Hz) frequency range
- Frequency of the 1st (fundamental) harmonic within the (45 to 55 Hz) frequency range
- Total harmonic distortion of voltage $THD_{U1}$ (for the channel C1) or $THD_{U2}$ (for the channel C2)
- Harmonic components (ratios) in % of the 1st harmonic: from the 0.3th to 15th.

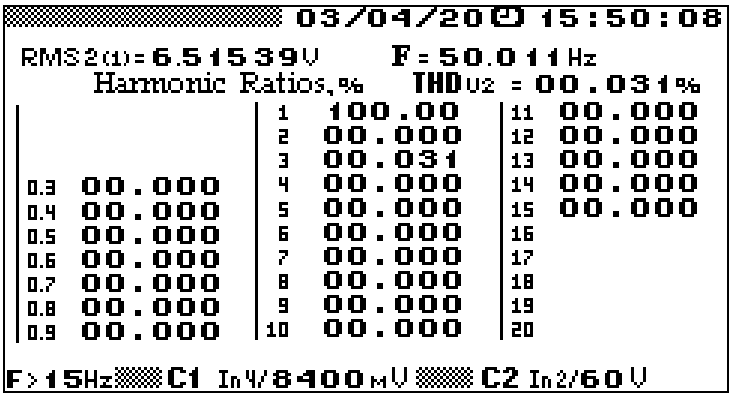



Fig. 3.13 “Harmonics” screen for channel C2 (with a range of 15 to 800 Hz enabled)

NOTE! *In the "Harmonics" mode, if an RMS value of input voltage appears to be less than 1% of the nominal value of the currently active measuring range, the parameters are not calculated (the fields contain zeros instead of measurements).*

### "Harmonics angles" mode

When the frequency range is set to (45 to 2500 Hz), the "Harmonics angles" mode is available just for signals with the 1st harmonic within (45 to 55 Hz) range.

The display shows phase shifts (in degrees) between pairs of the same order harmonic components (from the 1st to the 50th) obtained from composite voltage waveforms in the channels C1 and C2 (Fig. 3.14).

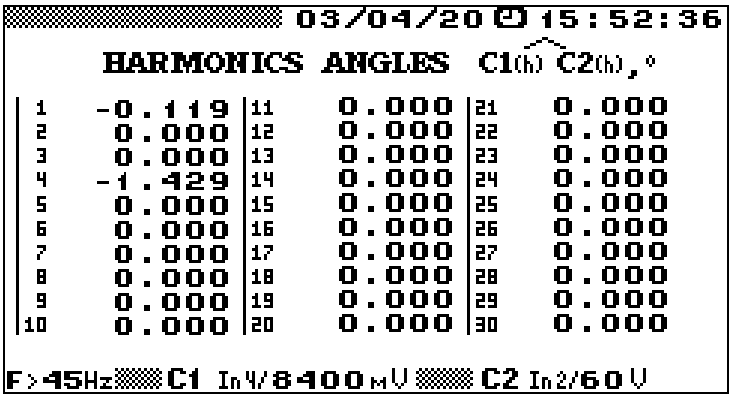



Fig. 3.14 Phase shifts between pairs of harmonics in channels C1 and C2 (45 to 2500 Hz range)

The screen with harmonics of order from 31 to 50 is called up with the keys ⇓⇑.

When the frequency range is set to (15 to 800 Hz), in the "Harmonics angles" mode the display shows phase shifts (in degrees) between pairs of the same order harmonic components (from the 0.3th to 15th) obtained from composite voltage waveforms in the channels C1 and C2 (Fig. 3.15).

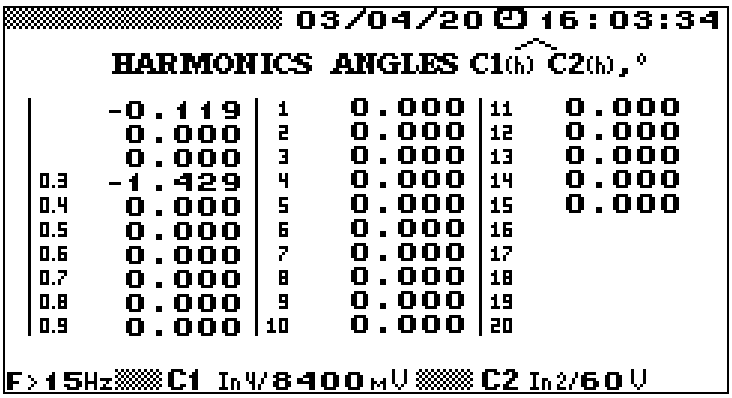



Fig. 3.15 Phase shifts between pairs of harmonics in channels C1 and C2 (15 to 800 Hz range)

### "Waveform" mode

The Comparator plots waveforms in the channels C1 and C2 (Fig. 3.16). In addition to the plots, RMS values of the displayed signals are shown in the upper right part of the screen.

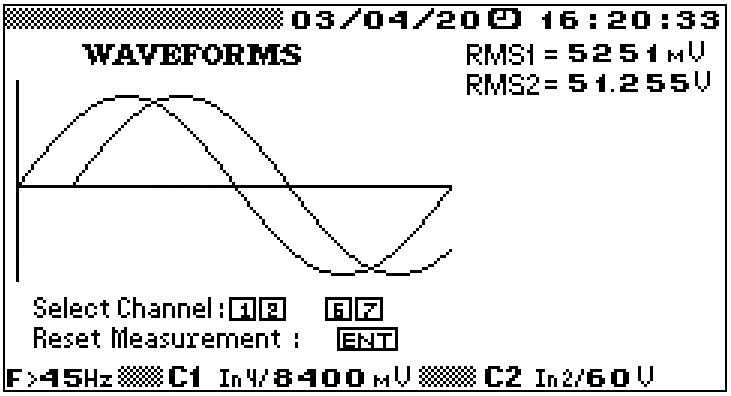



Fig. 3.16 "Waveforms" mode

By pressing the numeric keys "1" and "2" you can make visible (or hide) the waveforms and their RMS values.

Each displayed waveform/RMS value reflects the moment of entering the mode. Press "ENT" to refresh the screen.

### "Additional parameters" mode

The screen shows the following parameters specified earlier or obtained in the course of testing transformers:

- Fundamental frequency signals (RMS) coming to the measuring inputs
- Phase error of the transformer defined as "phase displacement" (IEC 61869-6)
- Ratio (voltage or current) error: relative, in %
- For the inputs 3 and 7: composite error of the LPCT under test (%) and the RMS value of the difference between the secondary currents in the channels C1 and C2 derived from two arrays of instantaneous values as stated in IEC 61869 –10 (designated as Δ).
- Transformation ratios of the reference transformer and transformer under test applied to calculation of errors (pre-configured in the E-TransformerTest program or from the menu of the Comparator).

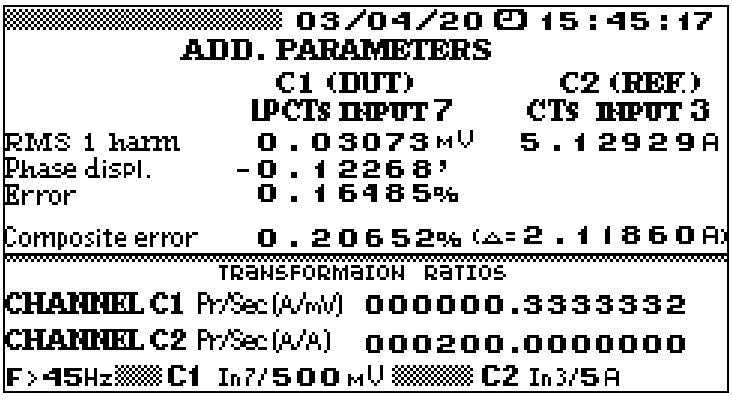



Fig. 3.17 “Additional parameters” screen when testing a low-power current transformer

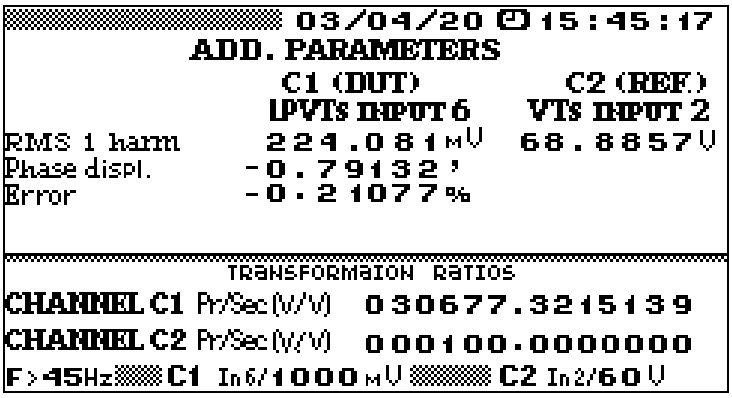



Fig. 3.18 “Additional parameters” screen when testing a low-power voltage transformer

### 2.3.2.4 Extra Settings

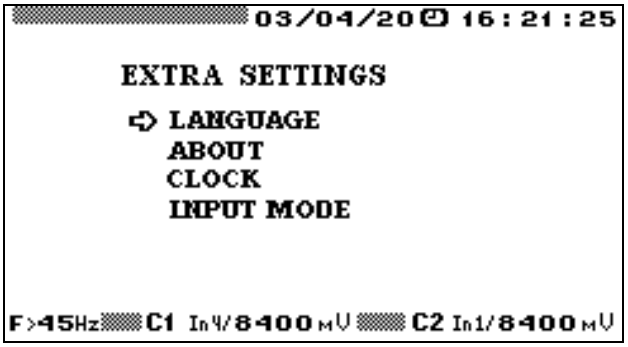



Fig. 3.19 – “Extra Settings” screen

The “Extra settings” menu has 4 options described below.

The “Language” option (Fig. 3.20) is used to set the user interface language. The “OK” message is set next to the selected language. Pressing the ESC key reverts back to the “Settings menu”.

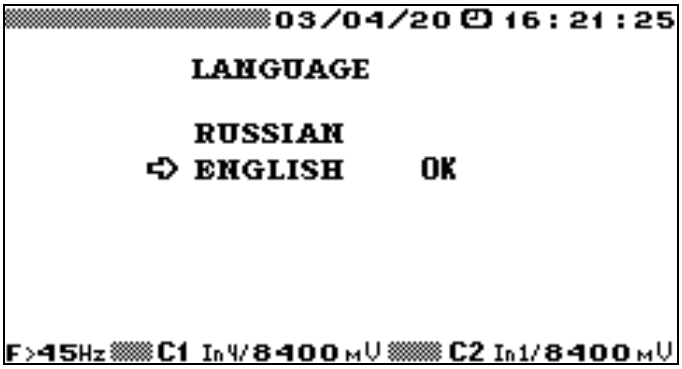



Fig. 3.20 “Language” screen

The screen “About” (Fig. 3.21) is used for product identification and for calibration of the Comparator.

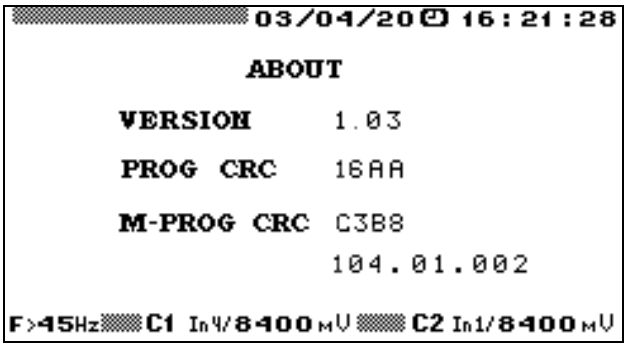



Fig. 3.21 “About” screen

The screen contains the following fields:

- **VERSION** – firmware version number
- **PROG CRC** – Cyclic Redundancy Checksum of the firmware module
- **M-PROG CRC** – Cyclic Redundancy Checksum of the metrologically significant firmware component of the firmware module
- Identification number of the Comparator.

The “Clock” screen (Fig. 3.22) has 2 options: “Clock setting” and “Clock Calibration”.

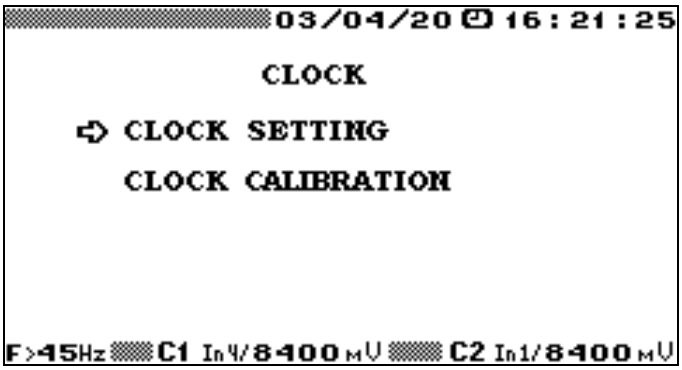



Fig. 3.22 “Clock” menu

The “Clock setting” screen (Fig. 3.23) allows you to modify the date and time currently kept by the internal clock. To do this, specify new values with the numeric keys on the keypad and press “ENT” to confirm. The Comparator will return to the “Extra Settings” menu with the new date and time on the top line of the display.

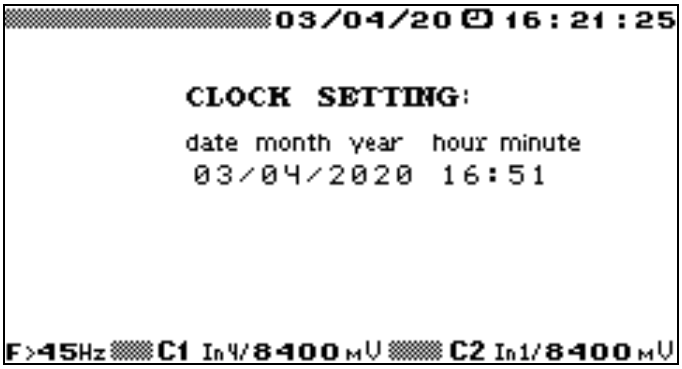



Fig. 3.23 “Clock setting” screen

The mode “Clock calibration” is used in the course of calibration of the Comparator. In this mode, the display shows current values of date and time (Fig. 3.24) while the Comparator produces pulses with a period of 1s at its frequency output.

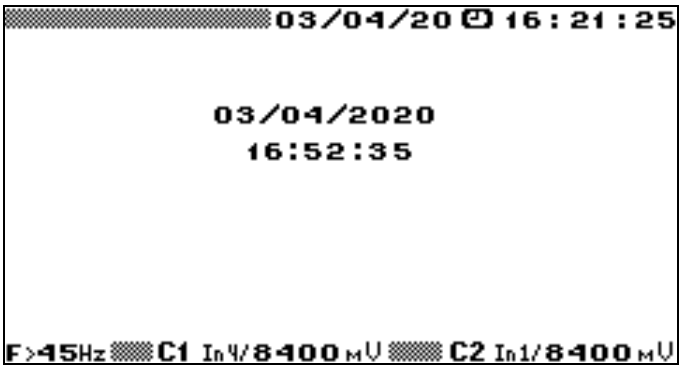



Fig. 3.24 “Clock calibration” screen

In the “Input mode” screen (Fig. 3.25) you can select the screen to appear when the Comparator is turned on.

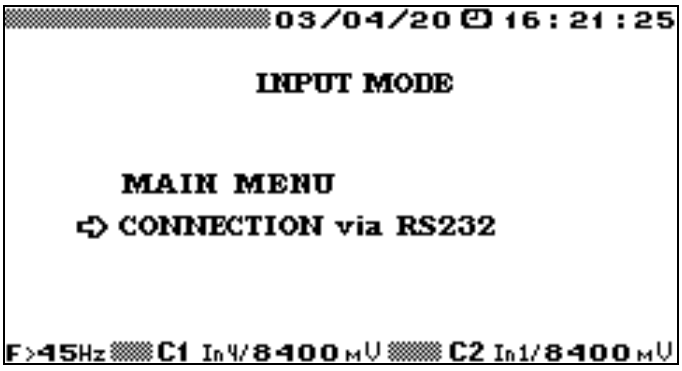



Fig. 3.25 “Input” mode screen

It can be the “Main menu” screen or “Connection via RS232” screen. In the latter case, the Comparator establishes connection to the PC without human intervention. The setting remains intact at next start-ups.

# 3 MAINTENANCE

## *3.1 General*

Maintenance is the care and servicing that the user provides for keeping the equipment operational over its life cycle.

## *3.2 Safety requirements*

Every maintenance operation must meet the safety requirements described in Section 2 of this Manual.

## *3.3 Maintenance procedures*

Routine maintenance includes the following procedures:

- Cleaning the display and keypad with a damp cloth
- Cleaning the oxidized contacts and checking the reliability of their fixing.

## *3.4 Troubleshooting*

| Problem | How to solve it |
|---|---|
| The comparator does not start up on applying power. | Check that the power supply cable is reliably connected.<br>Replace fuses. |
| There is no connection between the Comparator and PC. | Make sure that the correct COM port has been selected for the PC. If not, check the COM port setting.<br>Check the connection cable. |
| An error message appears on the display. | Contact the manufacturer. |

Manufacturer's address:
**Mars-Energo**
V.O. 13 Line, 6 - 8, office 41H, St. Petersburg, Russia
Tel/Fax: (812) 327-21-11, (812) 331-87-35 (812) 334-72-41
E-mail: mars@mars-energo.com
Web-site: www.mars-energo.com

# 4 STORAGE

Storage conditions should comply with National Standard GOST 15150-69.

The Comparator should be stored in a heated storeroom in the manufacturer's package.

Storage conditions in the manufacturer's package:

- Ambient temperature: 0 to 40 °C
- Relative humidity: 80 % at 35 °C

Storage conditions without the package:

- Ambient temperature: 10 to 35 °C
- Relative humidity: 80 % at 25 °C

The storeroom should be free from corrosive dust, acid or alkali fumes and other aggressive substances. Concentration of corrosive components in the air must not exceed the values stated in Russian national standard GOST 15150-69 (the atmosphere of type 1), namely

Concentration limits of corrosive components in the air:

Sulfur dioxide gas – maximum 20 mg / ($m^2$ · day) (maximum 0.025 mg/m3)

Chlorides – 0.3 mg / ($m^2$ · day).

# 5 TRANSPORTATION

The Comparator should only be transported packed in the manufacturer's box in an enclosed vehicle or train wagon protected from atmospheric precipitation, or by air in an air-tight heated cargo compartment.

Transportation conditions:

Ambient temperature: from –50 to 50 °C

Relative humidity: 95% at 25 °C

The parameters of transportation bounce (regulated by Russian state standard GOST 22261, group 2) are as follows:

Maximum number of strikes per minute: 80…120

Maximum acceleration ($m/s^2$): 30

Duration of exposure (h): 1

# *Appendix A.1*

**VERIFICATION REPORT**
For the instrument voltage transformer

Performed by _____
Company

Tested transformer
Name _____
Type _____
Serial No _____
Accuracy class ____%
Rated primary voltage _____
Rated secondary voltage _____
Rated frequency ____ Hz
Rated power ____ VA
Test procedure _____

Reference instruments in use

Reference transformer/divider
Name _____
Type _____
Serial No _____
Date of latest verification _____

Comparator
Name _____
Type _____
Serial No _____
Date of latest verification _____

Verification conditions
Ambient temperature ___ °C
Relative humidity ___%
Atmospheric pressure ___ kPa

1. During visual inspection no defects are found _____
Yes, no

2. The terminals are marked correctly _____
Yes, no

3. Electrical strength and resistance of insulation comply with the requirements
_____
Yes, no

4. Measurement results

| Phase | Burden, % | $U_1$, V | $U_1/U_r$, % | $\varepsilon_u$, % | $\Delta\varphi$, min |
|---|---|---|---|---|---|
| | | | | | |

More measurement results are available in Appendix A to this report (File Path)

Summary _____
Ready (Not ready) for operation

Verification performed by _____ _____ _____
Signature Name, surname Date

# *Appendix A.2*

**VERIFICATION REPORT**
For the instrument low-power voltage transformer

Performed by _____
Company

Tested transformer
Name _____
Type _____
Serial No _____
Accuracy class ____%
Rated primary voltage _____
Rated secondary voltage _____
Rated frequency ____ Hz
Test procedure _____

Reference instruments in use

Reference transformer/divider
Name _____
Type _____
Serial No _____
Date of latest verification _____

Comparator
Name _____
Type _____
Serial No _____
Date of latest verification _____

Verification conditions
Ambient temperature ___ °C
Relative humidity ___%
Atmospheric pressure ___ kPa

1. During visual inspection no defects are found _____
Yes, no

2. The terminals are marked correctly _____
Yes, no

3. Electrical strength and resistance of insulation comply with the requirements
_____
Yes, no

4. Measurement results

| Phase | $U_1$, V | $U_1/U_r$, % | $\varepsilon_u$, % | $\Delta\varphi$, min |
|---|---|---|---|---|
| | | | | |

More measurement results are available in Appendix A to this report (File Path)

Summary _____
Ready (Not ready) for operation

Verification performed by _____ _____ _____
Signature Name, surname Date

# *Appendix A.3*

**VERIFICATION REPORT**
For the instrument low-power current transformer

Performed by _____
Company

Tested transformer
Name _____
Type _____
Serial No _____
Accuracy class ____%
Rated primary current _____
Rated secondary voltage _____
Rated frequency____ Hz
Test procedure _____

Reference instruments in use

Reference transformer
Name _____
Type _____
Serial No _____
Date of latest verification _____

Comparator
Name _____
Type _____
Serial No _____
Date of latest verification _____

Verification conditions
Ambient temperature ___ °C
Relative humidity ___%
Atmospheric pressure ___ kPa

1. During visual inspection no defects are found _____
Yes, no

2. The terminals are marked correctly _____
Yes, no

3. Electrical strength and resistance of insulation comply with the requirements
_____
Yes, no

4. Measurement results

| Phase | $I_1$, A | $I_1 / I_r$, % | $\varepsilon_i$, % | $\varepsilon_c$, % | $\Delta\varphi$, min |
|---|---|---|---|---|---|
| | | | | | |

More measurement results are available in Appendix A to this report (File Path)

Summary _____
Ready (Not ready) for operation

Verification performed by _____ _____ _____
Signature Name, surname Date