

Multi-purpose Test System MTS-MONO-ME

USER MANUAL

NFTSR.411113.005 UM

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INTRODUCTION

This User Manual provides full information on how to use the MTS-MONO-ME multi-purpose test systems (the Test System below).

The Test System is manufactured in compliance with Technical Specifications NFTSR.411113.005 TS.

Documents supplied with the Test System (depending on the scope of supply):

User Manual	NFTSR.411113.005 UM
Equipment Certificate	NFTSR.411113.005 EC
Photoelectric Scanning Head SH+, Equipment Certificate	MC2.000.504 EC
Software EnfCalibrationRig User Manual	Version 2.2.4, or higher
Software Enform-ME User Manual	Version 2.8.6, or higher
Software PTN4 User Manual	Version 3.6.5, or higher

1 DESCRIPTION AND OPERATION

1.1 Sphere of application

1.1.1 The MTS-MONO-ME multi-purpose test system (the Test System below) is designed to measure active, reactive and apparent power/energy, AC frequency, AC current and voltage, phase angles, power factor, and either basic or additional power quality parameters including:

- RMS value of the fundamental voltage harmonic U_{C1}
- RMS value of the voltage harmonic $U_{(h)}$ of order h and frequency $h \cdot f_1$ (h = 2 to 50)
- RMS value of the voltage interharmonic $U_{(m)}$ and frequency $m \cdot f_1$ (m = 0.5 to 50.5) in increments of 1.0
- RMS value of the fundamental current harmonic I_{C1}
- RMS value of the current harmonic $I_{(h)}$ of order h (h = 2 to 50)
- RMS value of the current interharmonic $I_{(m)}$ (with the frequency $m \cdot f_1$, m = 0.5 to 50.5 in increments of 1.0)
- Phase shift between the current and voltage harmonics of order h in the same phase
- Ratio of the voltage harmonic of order h with reference to the fundamental harmonic [$K_U(h)$] (h = 2 to 50)
- Ratio of the current harmonic of order h with reference to the fundamental harmonic [$K_I(h)$] (h = 2 to 50)
- Active power of the fundamental harmonic (P_1)
- Reactive power of the fundamental harmonic (Q_1)
- Power factor (PF) and tangent [tg(φ)]
- Active power of the harmonic of order h [$P_{(h)}$] (h = 2 to 50)
- Total harmonic distortion of voltage (THD_U)
- Total harmonic distortion of current (THD_I)
- Positive sequence voltage of the fundamental harmonic (U_1)
- Zero sequence voltage of the fundamental harmonic (U_0)
- Negative sequence voltage of the fundamental harmonic (U_2)
- Negative sequence voltage ratio (with reference to U_1) [K_{2U}] and zero sequence voltage ratio (with reference to U_1) [K_{0U}]
- Positive sequence current of the fundamental harmonic (I_1)
- Zero sequence current of the fundamental harmonic (I_0)
- Negative sequence current of the fundamental harmonic (I_2)
- Phase shifts between the positive sequence, negative sequence, and zero sequence voltage and current
- Phase shift between the fundamental harmonics of voltage (φ_{UaUb}) or current (φ_{IaIb}) in 2 different phases of a 3-phase system
- Short-term flicker severity
- Duration of a voltage dip (Δt_d)
- Depth of a voltage dip (δU_d)
- Height of a voltage swell ($K_{sw\,U}$)
- Duration of a voltage swell (Δt_{sw})
- Values of DC current and voltage.

The Test System is intended for verification and calibration of instruments used to measure the parameters listed above and for generation of signals with these parameters.

1.1.2 The model name of the MTS-MONO-ME test system describes its characteristics as specified in the purchase order:

MTS-MONO-ME X.X-X-X/X -X -C , where the positions of the symbols in the model name
1 2 3 4 5 6

stand for:

Position 1 provides information on the number of AC voltage/current measurement channels:

- 1 – single-phase
- 3 – three-phase

Position 2 shows the maximum value of AC current of the Test Signal Source (I_{max}, A)

Position 3 shows the maximum value of AC voltage of the Test Signal Source (U_{max}, V)

Position 4 shows the maximum value of phase power on the output of the AC current channel / AC voltage channel (in VA)

Position 5 relates to the design version:

- S – stationary
- P – portable

Position 6 relates to the DC Calibrator function:

- No symbol – the function is absent
- C – the function is available

Examples of model names as may be specified in purchase orders:

MTS-MONO-ME 3.12-300-60/30-P-C is a portable test system intended for verification and calibration of 3-phase measuring instruments including instrument voltage, current and power converters with unified current or voltage DC output (GOST 26.011) and instruments performing DC current and voltage measurements.

MTS-MONO-ME 3.120-576-60/30-S is a stationary test system intended for verification and calibration of 3-phase measuring instruments including instrument voltage, current and power converters with unified current or voltage DC output (GOST 26.011).

MTS-MONO-ME 1.120-300-60/30-P is a portable test system intended for verification and calibration of single-phase measuring instruments.

1.2 Specifications

1.2.1 Accuracy and technical specifications

1.2.1.1 Basic accuracy specifications are listed in Tables 1.1-1.4.

Rated (nominal) values of current I_N for I_{max} = 12 A: 0.1, 0.2, 0.5, 1, 5, and 10 A

Rated (nominal) values of current I_N for I_{max} = 120 A: 0.05, 0.1, 0.25, 0.5, 1, 2.5, 5, 10, 25, 50, and 100 A

Rated (nominal) values of phase voltage U_N for U_{max} = 300 V: 60, 120, and 240 V

Rated (nominal) values of phase voltage U_N for U_{max} = 576 V: 60, 120, 240, and 480 V.

Table 1.1 – Measurement ranges and limits of permissible (relative or absolute) errors in measuring basic parameters

Parameter	Value
Range for measuring RMS values of phase [U] and phase-to-phase [$U\cdot\sqrt{3}$] voltage, where the nominal voltage U_N belongs to the row: 60, 120, 240, 480 V	From $0.1\cdot U_N$ to $1.2\cdot U_N$
Limits of permissible (relative) intrinsic error in measuring RMS values of phase [U) and phase-to-phase [$U\cdot\sqrt{3}$] voltage (%)	$\pm[0.03+0.006\cdot (1.2\cdot U_N/U-1)]$
Range for measuring RMS values of current [I] (A)	From $0.1\cdot I_N$ to $1.2\cdot I_N$

Parameter	Value
Limits of permissible (relative) intrinsic error in measuring RMS values of current [I], where the nominal current I_N belongs to the row: 0.05, 0.1, 0.25, 0.5, 1, 2.5, 5, 10, 25, 50, 100 A (%)	$\pm[0.03+0.006\cdot(1.2\cdot I_N/I-1)]$
Range for measuring active AC power [P] (W)	P from $0.01\cdot P_N$ to $1.44\cdot P_N$ $P_N = U_N\cdot I_N$ U from $0.1\cdot U_N$ to $1.2\cdot U_N$ I from $0.1\cdot I_N$ to $1.2\cdot I_N$
Limits of permissible (relative) intrinsic error in measuring active AC power [P] (%)	$\pm[0.05+0.01\cdot (1.44\cdot P_N/P–1)]$
Range for measuring active or reactive AC energy (kW·h or kVar·h)	From 0.000001 to 10000 over a time interval from 4 to 99996 s
Limits of permissible (relative) intrinsic error in measuring active or reactive AC energy over a time interval of no less than 1000 s (%)	±0.05
Range for measuring reactive AC power [Q] (Var) calculated by: - Cross-connection method - Geometrical method - The method of shifting the voltage signal by ¼ of the fundamental period	From $0.01\cdot Q_N$ to $1.44\cdot Q_N$ $Q_N = U_N\cdot I_N$ U from $0.1\cdot U_N$ to $1.2\cdot U_N$ I from $0.1\cdot I_N$ to $1.2\cdot I_N$
Limits of permissible (relative) intrinsic error in measuring reactive AC power [Q] (%) calculated by: - Cross-connection method - Geometrical method - The method of shifting the voltage signal by ¼ of the fundamental period	$\pm[0.1+0.02\cdot (1.44\cdot Q_N/Q–1)]$
Range for measuring apparent AC power [S] (VA)	From $0.01\cdot S_N$ to $1.44\cdot S_N$ $S_N = U_N\cdot I_N$ U from $0.1\cdot U_N$ to $1.2\cdot U_N$ I from $0.1\cdot I_N$ to $1.2\cdot I_N$
Limits of permissible (relative) intrinsic error in measuring apparent AC power [S] (%)	$\pm[0.06+0.015\cdot(1.2\cdot U_N/U +1.2\cdot I_N/I–2)]$
Range for measuring power factor [PF=P/S]	From 0.1 to 1.0 I from $0.2\cdot I_N$ to $1.2\cdot I_N$ U from $0.2\cdot U_N$ to $1.2\cdot U_N$
Limits of permissible (absolute) intrinsic error in measuring power factor [PF=P/S]	±0.005
Range for measuring AC frequency [f_1] (Hz)	From 40 to 70 U from $0.2\cdot U_N$ to $1.2\cdot U_N$ I from $0.2\cdot I_N$ to $1.2\cdot I_N$
Limits of permissible (absolute) intrinsic error in measuring AC frequency (f_1 = 40 to 70 Hz) (Hz)	±0.002
Range for measuring the phase shift between the fundamental harmonics of input voltages in different phases [1] (degrees)	From 0 to 360
Limits of permissible (absolute) intrinsic error in measuring the phase shift between the fundamental harmonics of input voltages in different phases [1] (degrees)	±0.03
Range for measuring the phase shift between the fundamental harmonics of voltage and current in the same phase [φ_1] (degrees)	From 0 to 360

Parameter	Value
Limits of permissible (absolute) intrinsic error in measuring the phase shift between the fundamental harmonics of voltage and current in the same phase [φ_1] (degrees)	±0.03
Range for measuring RMS values of the fundamental voltage harmonic [U_{C1}] (with the frequency f_1 = from 40 до 70 Hz) (V)	From $0.1 \cdot U_N$ to $1.2 \cdot U_N$
Limits of permissible (relative) intrinsic error in measuring RMS values of the fundamental voltage harmonic [U_{C1}], where the nominal voltage U_N belongs to the row 60, 120, 240, 480 V (%)	$\pm[0.03+0.015 \cdot (1.2 \cdot U_N/U_{C1}-1)]$
Range for measuring RMS values of the voltage harmonic [U_n] of order n (V)	From 0 to $0.6 \cdot U_N$
Limits of permissible (relative) intrinsic error in measuring RMS values of the voltage harmonic [U_n] of order n (%), where n = 2 to 20 n = 21 to 50	 $\pm[0.15+((U_N/U)-2) \cdot 0.001]$ $\pm[0.2+((U_N/U)-2) \cdot 0.01]$
Range for measuring RMS values of the voltage interharmonic [$U_{(m)}$] of order m (V)	From 0 to $0.15 \cdot U_N$
Limits of permissible (absolute, relative) intrinsic error in measuring RMS values of the voltage interharmonic of order m [$U_{(m)}$] (m = 0.5 to 50.5 in increments of 1.0) (V, %) For $U_{(m)}$ below $0.01 \cdot U_N$ For $U_{(m)}$ above $0.01 \cdot U_N$	 Δ: $\pm 0.00015 \cdot U_N$ δ: ±1.5
Range for measuring RMS values of the fundamental current harmonic [I_{C1}] (A)	From $0.1 \cdot I_N$ to $1.2 \cdot I_N$
Limits of permissible (relative) intrinsic error in measuring RMS values of the fundamental current harmonic [I_{C1}] (%)	$\pm[0.03+0.015 \cdot (1.2 \cdot I_N/I_{C1}-1)]$
Range for measuring RMS values of the current harmonic [I_n] of order n (A)	From 0 to $0.6 \cdot I_N$
Limits of permissible (relative) intrinsic error in measuring RMS values of the current harmonic [I_n] of order n (%), where n = 2 to 20 n = 21 to 50	 $\pm[0.15+((I_N/I)-2) \cdot 0.001]$ $\pm[0.2+((I_N/I)-2) \cdot 0.01]$
Range for measuring RMS values of the current interharmonic [$I_{(m)}$] of order m (A)	From 0 to $0.15 \cdot I_N$
Limits of permissible (absolute, relative) intrinsic error in measuring RMS values of the current interharmonic of order m [$I_{(m)}$] (m = 0.5 to 50.5 in increments of 1.0) (A, %) For $I_{(m)}$ below $0.01 \cdot I_N$ For $I_{(m)}$ above $0.01 \cdot I_N$	 Δ: $\pm 0.00015 \cdot I_N$ δ: ±1.5
Range for measuring the phase shift between the current and voltage harmonics of order n in the same phase (degrees)	From 0 to 360
Limits of permissible (absolute) intrinsic error in measuring the phase shift between the current and voltage harmonics of order n in the same phase (degrees) U in the range from $0.2 \cdot U_N$ to $1.2 \cdot U_N$ I in the range from $0.2 \cdot I_N$ to $1.2 \cdot I_N$ $K_I(n)$ and $K_U(n)$ from 2 to 15 % n = 2 to 10 n = 11 to 50	 ±1.0 ±3.0
Range for measuring the ratio of the voltage harmonic of order n with reference to the fundamental harmonic [$K_U(n)$] (V)	From 0 to 49.9

Parameter	Value
Limits of permissible (absolute) intrinsic error in measuring the ratio of the voltage harmonic of order n [$K_U(n)$] with reference to the fundamental harmonic (%) U in the range from $0.2 \cdot U_N$ to $1.2 \cdot U_N$ At $K_U(n)$ below 1.0 n = 2 to 20 n = 21 to 50	 ±0.005 ±0.015
Limits of permissible (relative) intrinsic error in measuring the ratio of the voltage harmonic of order n [$K_U(n)$] with reference to the fundamental harmonic (%) U in the range from $0.2 \cdot U_N$ to $1.2 \cdot U_N$ At $K_U(n)$ above 1.0 n = 2 to 20 n = 21 to 50	 ±0.5 ±1.5
Range for measuring the ratio of the current harmonic of order n [$K_I(n)$] with reference to the fundamental harmonic (A)	From 0 to 49.9
Limits of permissible (absolute) intrinsic error in measuring the ratio of the current harmonic of order n [$K_I(n)$] with reference to the fundamental harmonic (%) n = 2 to 50 I in the range from $0.2 \cdot I_N$ to $1.2 \cdot I_N$ At $K_I(n)$ below 1.0	±0.05
Limits of permissible (relative) intrinsic error in measuring the ratio of the current harmonic of order n [$K_I(n)$] with reference to the fundamental harmonic (%) n = 2 to 50 I in the range from $0.2 \cdot I_N$ to $1.2 \cdot I_N$ At $K_I(n)$ above 1.0	±5
Range for measuring the active AC power of the fundamental harmonic [P_1] (W)	From $0.01 \cdot P_N$ to $1.44 \cdot P_N$ U in the range from $0.1 \cdot U_N$ to $1.2 \cdot U_N$ I in the range from $0.1 \cdot I_N$ to $1.2 \cdot I_N$
Limits of permissible (relative) intrinsic error in measuring the active AC power of the fundamental harmonic [P_1] (%) At $\lvert\cos \varphi\rvert$ in the range from 0.5 to 1.0	$\pm[0.05+0.01 \cdot (1.44 \cdot P_N/P_1-1)]$
Range for measuring the reactive AC power of the fundamental harmonic [Q_1] (Var)	From $0.01 \cdot Q_N$ to $1.44 \cdot Q_N$ U in the range from $0.1 \cdot U_N$ to $1.2 \cdot U_N$ I in the range from $0.1 \cdot I_N$ to $1.2 \cdot I_N$
Limits of permissible (relative) intrinsic error in measuring the reactive AC power of the fundamental harmonic [Q_1] (%)	$\pm[0.1+0.02 \cdot (1.44 \cdot Q_N/Q_1-1)]$
Range for measuring the total harmonic distortion of voltage [THD_U] (%) U in the range from $0.2 \cdot U_N$ to $1.2 \cdot U_N$	From 0 to 49.9
Limits of permissible (absolute) intrinsic error in measuring the total harmonic distortion of voltage [THD_U] (%) $THD_U < 1.0$	±0.05

Parameter	Value
Limits of permissible (relative) intrinsic error in measuring the total harmonic distortion of voltage [THD_U] (%) $THD_U > 1.0$	±5
Range for measuring the total harmonic distortion of current [THD_I] (%) I in the range from $0.2 \cdot I_N$ to $1.2 \cdot I_N$	From 0 to 49.9
Limits of permissible (absolute) intrinsic error in measuring the total harmonic distortion of current [THD_I] (%) $THD_I < 1.0$	±0.05
Limits of permissible (relative) intrinsic error in measuring the total harmonic distortion of current [THD_I] (%) $THD_I > 1.0$	±5
Range for measuring the positive sequence voltage of the fundamental harmonic [U_1] 1) (V)	From 0 to U_N
Limits of permissible (absolute) intrinsic error in measuring the positive sequence voltage of the fundamental harmonic [U_1] (V)	$\pm(0.0006 \cdot U_N \cdot \sqrt{3})$
Range for measuring the zero sequence voltage of the fundamental harmonic [U_0] 1) (V)	From 0 to U_N
Limits of permissible (absolute) intrinsic error in measuring the zero sequence voltage of the fundamental harmonic [U_0] (V) U in the range from $0.5 \cdot U_N$ to $1.2 \cdot U_N$ $K_{0U} < 15$ %	$\pm 0.0015 \cdot U_N$
Range for measuring the negative sequence voltage of the fundamental harmonic [U_2] 1) (V)	From 0 to U_N
Limits of permissible (absolute) intrinsic error in measuring the negative sequence voltage of the fundamental harmonic [U_2] (V) U in the range from $0.5 \cdot U_N$ to $1.2 \cdot U_N$ $K_{2U} < 15$ %	$\pm(0.001 \cdot U_N \cdot \sqrt{3})$
Range for measuring negative sequence voltage ratio [K_{2U}] 1) and zero sequence voltage ratio [K_{0U}] 1)	From 0 to 50
Limits of permissible (absolute) intrinsic error in measuring negative sequence voltage ratio [K_{2U}] and zero sequence voltage ratio [K_{0U}] (%) U in the range from $0.5 \cdot U_N$ to $1.2 \cdot U_N$	±0.2
Range for measuring the positive sequence current of the fundamental harmonic [I_1] 1) (A)	From 0 to I_N
Limits of permissible (absolute) intrinsic error in measuring the positive sequence current of the fundamental harmonic [I_1] (A)	$\pm 0.0006 \cdot I_N$
Range for measuring the zero sequence current of the fundamental harmonic [I_0] 1) (A)	From 0 to I_N
Limits of permissible (absolute) intrinsic error in measuring the zero sequence current of the fundamental harmonic [I_0] (A)	$\pm 0.0015 \cdot I_N$
Range for measuring the negative sequence current of the fundamental harmonic [I_2] 1) (A)	From 0 to I_N
Limits of permissible (absolute) intrinsic error in measuring the negative sequence current of the fundamental harmonic [I_2] (A)	$\pm 0.001 \cdot I_N$
Range for measuring the tangent of the phase shift between voltage and current [tg(φ)]	From 0 to 8

Parameter	Value
Limits of permissible (absolute) error in measuring the tangent of the phase shift between voltage and current From 0 to 2 From 2 to 8	 ±0.003 ±0.035
Notes: 1 The parameters marked with [1)] are only measured by three-phase test systems (modification "3.X"). 2 The frequency of the harmonic of order n and frequency $n \cdot f_1$, should not exceed 2550 Hz. 3 The frequency of the interharmonic of order m and frequency $m \cdot f_1$, should not exceed 2550 Hz. 4 The Test System performs measurements of electrical power/energy parameters provided that the amplitude values of measured signals do not exceed 170% of the rated voltage U_N and current I_N.	

Table 1.2 –Measurement ranges and limits of permissible intrinsic errors in measuring DC current and DC voltage by the Test System with the DC calibrator function (modification "C")

Parameter	Value
Range for measuring DC voltage [U_{IN}] (V)	From -15 to 15
Limits of permissible intrinsic error (in % of range) in measuring DC voltage, where the nominal voltage U_N equals 0.2 V, 5 V, or 10 V	±0.03 %
Range for measuring DC current [I_{IN}] (mA)	From -30 to 30
Limits of permissible intrinsic error (in % of range) in measuring DC current, where the nominal current I_N equals 5 mA or 20 mA	±0.05%
Note: For bipolar signals, the measurement error is given with respect to the full scale.	

Table 1.3 – Ranges and limits of permissible absolute intrinsic error in setting the values of DC voltage, DC current and pulse repetition frequency by the Test System with the DC calibrator function (modification "C")

Parameter	Value
Range for setting generated DC voltage [U_{OUT}] (V)	From -10.5 to +10.5
Increments for setting generated DC voltage (V)	0.001
Limits of permissible absolute intrinsic error in setting generated DC voltage (V)	±0.0021
Range for setting generated DC current [I_{OUT}] (mA)	From -24 to +24
Increments for setting DC current (mA)	0.0001
Limits of permissible absolute intrinsic error in setting generated DC current, mA	±0.0047
Range for setting pulse repetition frequency [F_{OUT}] (Hz)	From 0 to 22500
Increments for setting pulse repetition frequency (Hz)	1
Limits of permissible absolute intrinsic error in setting pulse repetition frequency (Hz)	$\pm 3 \cdot 10^{-5} \cdot F_{OUT}$

Table 1.4 – Ranges and errors in setting AC voltage characteristics

Parameter	Value
Range for setting frequency for the first (fundamental) harmonic of the generated signal [f_1] (Hz)	From 42.5 to 70
Increments for setting frequency for the first (fundamental) harmonic of the generated signal (Hz)	0.01

Parameter	Value
Limits of permissible absolute intrinsic error in setting frequency for the first (fundamental) harmonic of the generated signal (Hz)	±0.01
Ranges for setting RMS values of the fundamental voltage harmonic [U_1] (V)	Over $0.25 \cdot U_N$ to $1.2 \cdot U_N$ From $0.05 \cdot U_N$ to $0.25 \cdot U_N$
Increments for setting RMS values of the fundamental voltage harmonic (V)	0.01
Limits of permissible relative intrinsic error in setting RMS values of the first (fundamental) voltage harmonic (%) For the range over $0.25 \cdot U_N$ to $1.2 \cdot U_N$ For the range from $0.05 \cdot U_N$ to $0.25 \cdot U_N$	 ±1 $\pm[1.0+0.5 \cdot ((U_N/U) - 1)]$
Ranges for setting RMS values of the fundamental current harmonic [I_1] (A)	Over $0.2 \cdot I_N$ to $1.2 \cdot I_N$ From $0.05 \cdot I_N$ to $0.2 \cdot I_N$
Increments for setting RMS values of the fundamental current harmonic (A)	0.0001
Limits of permissible relative intrinsic error in setting RMS values of the fundamental current harmonic (%) For the range over $0.2 \cdot I_N$ to $1.2 \cdot I_N$ For the range from $0.05 \cdot I_N$ to $0.2 \cdot I_N$	 ±1 $\pm[1.0+0.5 \cdot ((I_N / I) - 1)]$
Range for setting the phase shift between the fundamental voltage and current harmonics (degrees)	From –180 to 180
Increments for setting the phase shift between the fundamental voltage and current harmonics (degrees)	0.01
Limits of permissible absolute intrinsic error in setting the phase shift between the fundamental voltage and current harmonics (degrees)	±1
Range for setting voltage dip/swell duration [t] (s)	From 0 to 600
Increments for setting voltage dip/swell duration (s)	0.001
Limits of permissible absolute intrinsic error in setting voltage dip/swell duration (s)	±0.002
Range for setting short term flicker severity under the following conditions: $49 \text{ Hz} < f_1 < 51 \text{ Hz}$ U from 180 to 235 V Square (meander) voltage waveform $\Delta U/U$ from 0.4 % to 10 %	от 0,25 до 10
Limits of permissible relative intrinsic error in setting short term flicker severity	±1.5

1.2.1.2 Specifications of the Test System are given in Tables 1.5-1.6.

Table 1.5 – Specifications for generated sine waveforms

Parameter	Range of setting	In increments of	Notes
1 RMS value of the voltage harmonic of order n, in % of U_1	From 0 to 100	0.01	n = 2 to 19
	From 0 to 50		n = 20 to 50

Parameter	Range of setting	In increments of	Notes
2 RMS value of the current harmonic of order n, in % of I_1	From 0 to 100	0.01	n = 2 to 19
	From 0 to 50		n = 20 to 50
3 RMS value of the voltage interharmonic of order m and frequency m·f1, in % of U_1	From 0 to 15	0.01	m = 0.5 to 50.5 in increments of 1.0
4 RMS value of the current interharmonic of order m and frequency m·f, in % of I_1	From 0 to 15	0.01	
5 Phase shift between the fundamental harmonics of:	от –180 до 180		
Generated voltages, degrees		0.01	U from $0.2 \cdot U_N$ to U_{MAX}, V
Voltage and current in the same phase, degrees		0.01	I from $0.1 \cdot I_N$ to I_{MAX}, A
6 Phase shift between the fundamental voltage harmonic and harmonic of order n, degrees	From –180 to 180	0.01	n = 2 to 50 U from $0.2 \cdot U_N$ to U_{MAX}, V
7 Phase shift between the fundamental voltage harmonic and interharmonic of order m and frequency $m \cdot f_1$, degrees	From –180 to 180	0.01	m = 0.5 to 50.5 in increments of 1.0 U from $0.2 \cdot U_N$ to U_{MAX}, V
8 Phase shift between the fundamental current harmonic and harmonic of order n, degrees	From –180 to 180	0.01	n = 20 to 50 I from $0.1 \cdot I_N$ to I_{MAX}, A
9 Phase shift between the fundamental current harmonic and interharmonic of order m and frequency $m \cdot f_1$, degrees	From –180 to 180	0.01	m = 0.5 to 50.5 in increments of 1.0 I from $0.1 \cdot I_N$ to I_{MAX}, A
10 Number of dips / swells	From 0 to 100 000	1	
11 Residual voltage (during a voltage dip), in % of the declared input voltage	From 10 to 100	0.01	49 Hz < f < 51 Hz
12 Max. voltage (during a voltage swell), in % of the declared input voltage	From 100 to 200	0.5	49 Hz < f < 51 Hz
13 Max. output AC power per current channel, VA	At least 60		As stated for the selected model
14 Max. output AC power per voltage channel,	At least 30		As stated for the

Parameter	Range of setting	In increments of	Notes
VA			selected model
The values of U_{NOM}, U_{MAX}, and I_{MAX} – correspond to those given for the selected model.			

Table 1.6 – Stability and quality of generated voltage and current sine waveforms

Parameter	Range of setting	Permissible value	Notes
Total harmonic distortion of generated voltage waveforms, %	From $0.25 \cdot U_{NOM}$ to $1.2 \cdot U_{NOM}$	1, or less 2, or less	At 10% of the rated load At the rated load
Total harmonic distortion of generated current waveforms, %	From $0.2 \cdot I_{NOM}$ to$1.2 \cdot I_{NOM}$	1 2	At 10% of the rated load At the rated load
Variation in RMS voltage setting	From $0.05 \cdot U_{NOM}$ to $1.2 \cdot U_{NOM}$	±0.02 %/1 min, or less	At a constant load up to 0.8 of maximum output power
Variation in RMS current setting	From $0.01 \cdot I_{NOM}$ to$1.2 \cdot I_{NOM}$	±0.02%/1 min, or less	At a constant load up to 0.8 of maximum output power
Variation in setting of active (reactive) power	From $0.05 \cdot P_{NOM}$ to $1.2 \cdot P_{NOM}$	±0.03, or less	At a constant load up to 0.8 of maximum output power
The values of I_{NOM} and U_{NOM} correspond to those given for the selected model.			

1.2.2 General specifications

1.2.2.1 General specifications of the Test System are listed in Table 1.7.

Table 1.7 – General specifications

Parameter	Value
Power consumption depending on the model • 3.12-300-60/30 • 1.120-300-150/150 • 3.120-576-150/150-P • 3.120-576-150/150-S	250 VA, or less
Power supply: - AC voltage - AC frequency	 230±23 V 50±5 Hz
Maximum repetition rate of pulses on the frequency input "F_{IN}"	22500 Hz
Overall dimensions (model 3.12-300-60/30) - Height - Width - Length	 195 mm, or less 390 mm, or less 478 mm, or less
Overall dimensions (model 3.120-576-150/150-P) - Height - Width - Length	 218 mm, or less 423 mm, or less 546 mm, or less
Overall dimensions (model 3.120-576-150/150-S) - Height - Width - Length	 267 mm, or less 465 mm, or less 483 mm, or less
Overall dimensions (model 1.120-300-150/150) - Height - Width - Length	 170 mm, or less 330 mm, or less 405 mm, or less
Weight (model 3.12-300-60/30)	18 kg, or less
Weight (model 3.120-576-150/150-P)	30 kg, or less
Weight (model 3.120-576-150/150-S)	30 kg, or less
Weight (model 1.120-300-150/150)	12 kg, or less
Time of establishing stable operation	15 min as a minimum
Time of operation at a current of over 100 A	8 hours, or less
Degree of protection of the enclosure (IEC 60529)	IP20
Normal and operating conditions - Ambient temperature - Relative humidity at 25 °C - Atmospheric pressure	 From 10 to 35 °C 80%, or less From 70 to 106.7 kPa
Mean time to failure	20000 hours
Average lifetime	10 years

1.2.2.2 After applying power the Test System performs self-testing and initialization procedures. Under normal and operating conditions the declared characteristics are provided after a lapse of time for establishing stable operation which is specified as no less than 15 minutes.

The Test System is designed for continuous run-time.

1.2.2.3 Pulse input

The Test System is equipped with a pulse input for testing energy meters.

There are 2 connectors that provide connection of external devices to the pulse input of the Test System: the main input connector (named “SH/PF”) for connecting a scanning head (SH) or pulse former (PF) and the second input connector (BNC).

The BNC input connector (named F_{IN}) is used to accept signals from energy meters of electronic type with pulse output. The tested meters and the pulses on their output should have the following specifications:

- Meter constant: from 1 to 999999999 pulses/kW·h
- Pulses with a logic zero level of no more than 0.4 V and logic one level from 4 to 5 V
- Pulse duration of no less than 14 μs.

1.2.2.4 Frequency output

The Test System with the DC calibrator function (modification “C”) is equipped with a frequency output. The frequency of signals generated on this output can be:

- specified in the MTS-Service software
- in proportion to measured DC current or voltage.

The pulse signal generated on the frequency output is a sequence of rectangular voltage pulses with positive polarity, pulse period-to-pulse duration ratio of 2, logic zero level of no more than 0.4 V and logic one level of no less than 4 V at a load resistance of minimum 5 kOhm.

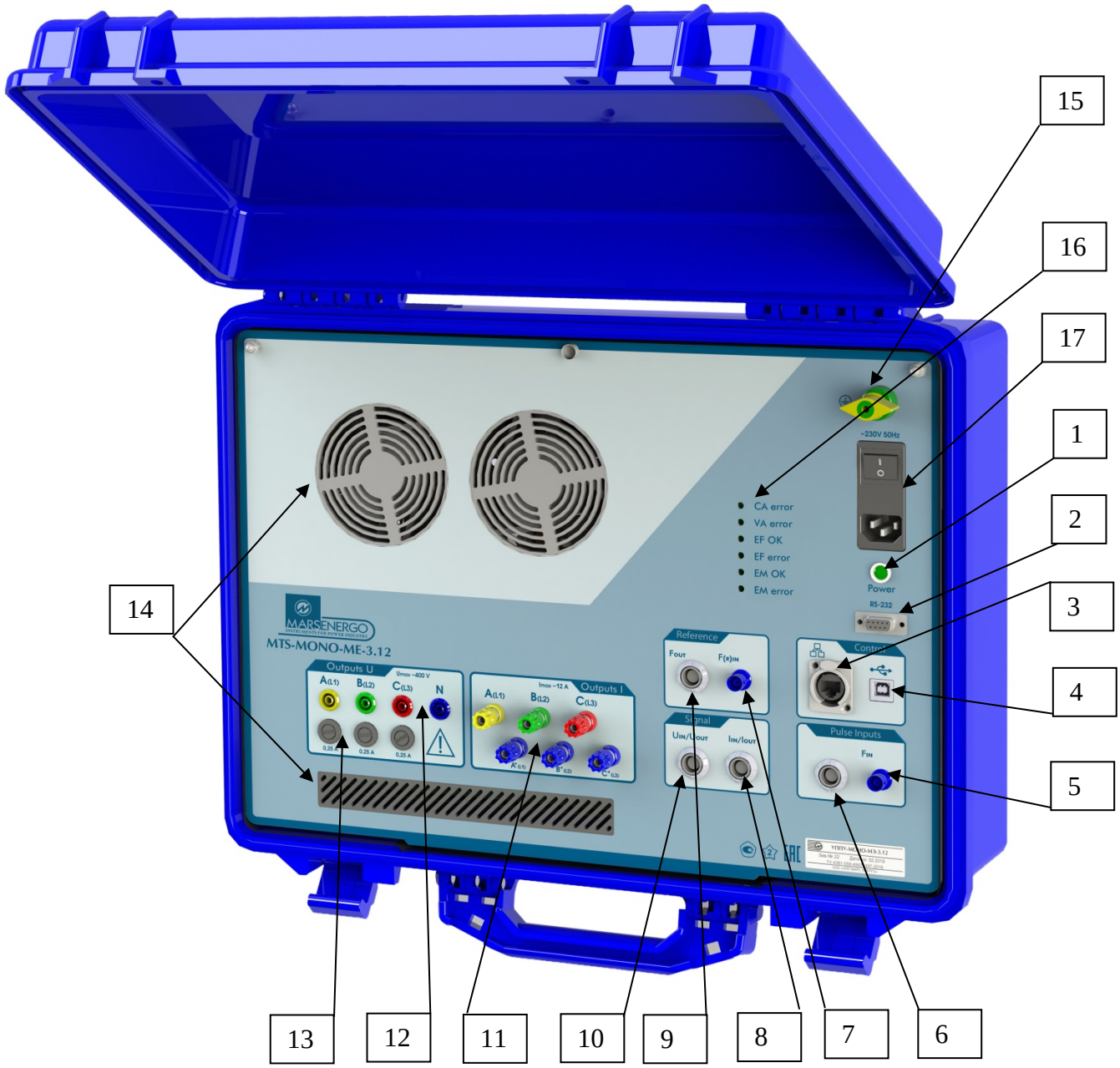
1.3 Overview

1.3.1 Design versions

The portable Test System (modification “P”) is designed as a single device housed in a portable case.

The Test System MTS-MONO-ME 3.12-300-60/30-P is shown in Fig. 1.1 as an example.

All controls and connectors located on the test systems of various modifications are marked identically. The functions of the controls and connectors are listed in Fig. 1.1.



1 – Power Supply LED, 2 – RS-232 port

Set of "Control" connectors:

3 and 4– Ethernet and USB ports (respectively) for connection to PC

Set of "Pulse Inputs" connectors:

5 – Pulse input F_{IN} (BNC) to accept pulses from tested meters with pulse output, 6 – Pulse input SH/PF to accept pulses from a scanning head or Pulse Former

Set of "Reference" connectors:

7 – Reference Input $F(R)_{IN}$ (BNC) to accept reference pulses, 9 – Frequency output F_{OUT} to bring out pulses with preset (or proportional to the measured DC signal) frequency

Set of "Signal" connectors:

8 – Connector I_{IN}/I_{OUT} to accept/bring out DC current signals up to 30 mA, 10 – Connector U_{IN}/U_{OUT} to accept/bring out DC voltage signals up to 10.5 V

Set of connectors "Current outputs":

11 – Connectors used to apply test AC current signals (up to 12 A) to the tested device

Set of connectors "Voltage outputs":

12 – Connectors used to apply test AC voltage signals to the tested device

13 – Phase output fuses, 14 – Fan grilles, 15 – Grounding clamp

16 – Self-test indicators
17 – Power supply connector, switch and fuses.

Fig. 1.1 – Test System MTS-MONO-ME 3.12-300-60/30-P

The stationary Test System (modification “S”) is designed as a single device in a 19’’ enclosure (see Fig. 1.2 and 1.3).



Fig. 1.2 – Test System MTS-MONO-ME 3.120-576-60/30-S (front panel)



Fig. 1.3 – Test System MTS-MONO-ME 3.120-576-60/30-S (rear panel)



Fig. 1.4 – Test System MTS-MONO-ME 1.120-300-60/30-P



Fig. 1.5 – Test System MTS-MONO-ME 3.120-576-150/150-P

Types of connectors (common to all modifications):

- Pulse inputs/outputs – BNC
- Scanning heads, DC voltage and current inputs/outputs –PULL-PUSH (female)
- AC voltage outputs – 4mm banana (female)
- AC current outputs – binding (“universal”) post
- Ethernet – RJ-45.

1.3.2 Design of Scanning Head

The SH-EI is a photoelectric scanning head designed to perform testing, verification, or calibration of electrical energy meters with optical pulse output or induction meters (with rotating disc). The scanning head consists of an adapter and optical sensor. See the corresponding Equipment Certificate (MC2.000.504 EC) for details.

1.4 Operation

1.4.1 Measurement principle

The Test System shares basic principles of analogue-to-digital conversion (ADC) and sampling method. Instantaneous values of voltage and current are converted into digital samples and routed to the central processing unit where the arrays of instantaneous voltage samples are created. Programmatically calculated values of measured parameters are saved in the internal memory and transferred to a PC.

The values of measured parameters are calculated by the program modules from the arrays of samples. Such a method does not require synchronization between the sampling frequency and the frequency of measured signal.

1.4.2 Overview of the Test System and description of its components

1.4.2.1 The Test System is designed as a complete operator's workbench controlled by dedicated software (SW) installed on your PC. Measurement results are viewed on the PC running the software.

The MTS-ME-MONO test systems come in a portable or stationary case. The models also differ in the output ranges of generated test voltage and current, power output of current and voltage channels and presence or absence of the DC calibrator function.

The Test System is supplied as an all-in-one module suitable for hand-carrying (complete with accessories and connection cables).

The components of the Test System are as follows:

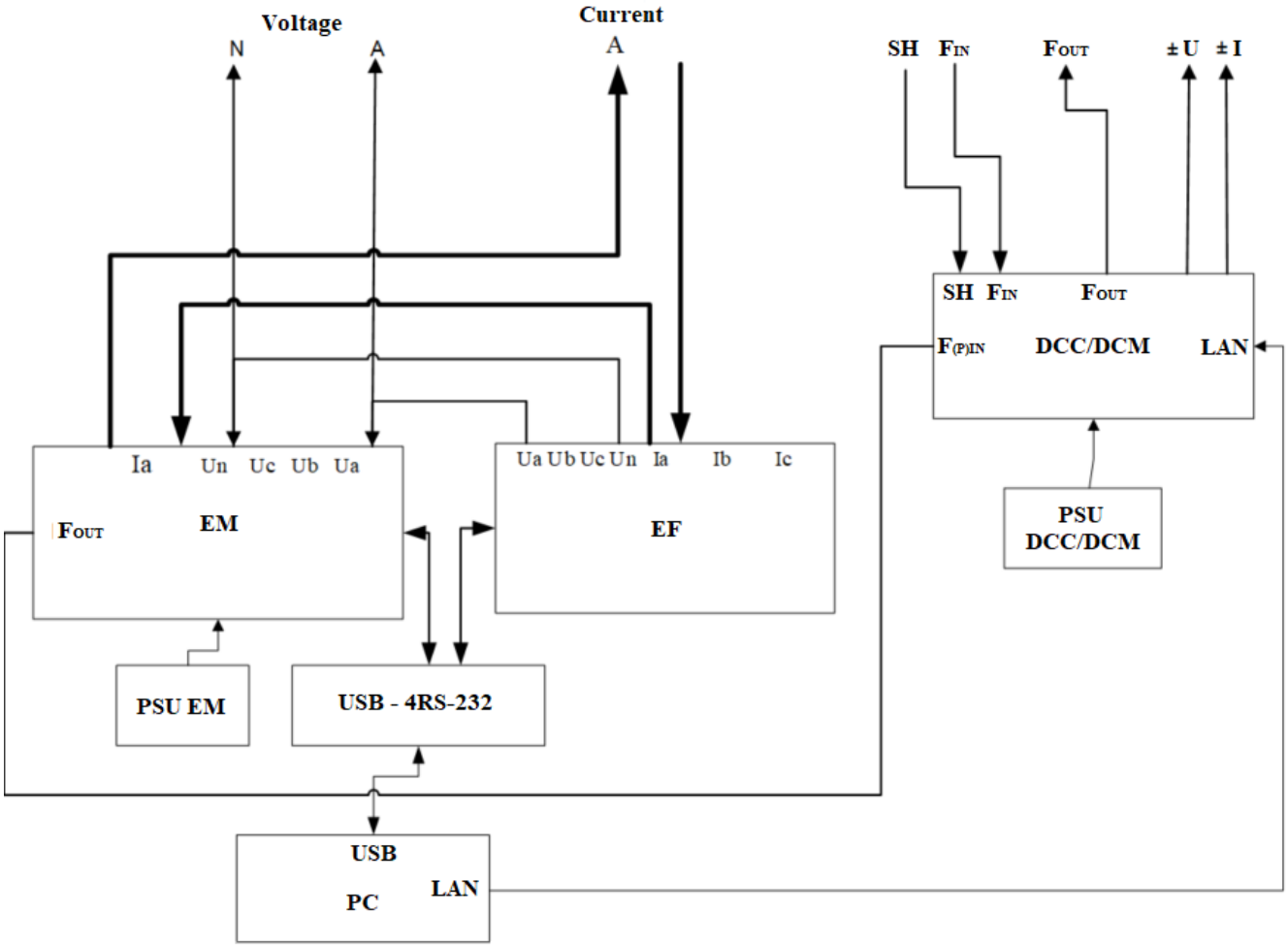
- Reference Meter unit
- Test Signal Source
- DC Calibrator/DC Meter.

The integrated DC Calibrator/DC Meter is responsible for:

- Calculating measurement errors of metering devices with pulse output (energy meters) by comparing pulse repetition rates on the outputs of the reference and tested device
- Measuring DC current and generating the internal pulse signal proportional to the measured current
- Measuring DC voltage and generating the internal pulse signal proportional to the measured voltage

- Generating DC current and DC voltage signals; generating the pulse signal proportional to the DC voltage value (as a calibrator).

The Block diagram of the Test System is shown in Fig. 1.6.



EM – Energomonitor (reference meter), EF – Energoforma (test signal source), DCC/DCM – DC Calibrator/DC Meter, PSU – power supply unit, USB-4RS232 – adapter USB-4RS232, PC – external personal computer with dedicated software

Fig. 1.6 – Block Diagram

Fig. 1.6 illustrates single-phase connections for clarity.

1.4.2.2 The Reference Meter unit (Energomonitor) consists of the following functional components:

- Multi-range input current converters
- Multi-range input voltage converters
- 6-channel ADC board
- Central Processing Unit (based on a signal processor and FPGA)
- Measurement Range Switch
- Power Supply Unit (PSU)

The input current converters based on error compensating CTs convert input currents into proportional voltage signals.

The input voltage converters based on high-precision variable-gain inverting operational amplifiers scale input voltages to match the inputs of the ADC.

The ADC board, which contains 6 ADCs, converts signals coming from the input converters or current transformer calibration switch (CTCS) into 18-bit codes (17 significant and 1 sign bit) at a sampling rate of 25.6 kHz. The ADC board and Central Processing Unit (CPU) are connected via a galvanic isolation scheme.

As part of the Reference Meter, the CPU provides:

- Full control over the Test System
- Calculations over the arrays of samples coming from the ADCs
- Storage of results in the internal flash memory
- Time stamping
- Data exchange with external devices (PCs)
- Results of self-testing using the LED indicators on the front panel.

The CPU is a key element responsible for operation of the Test System as a whole.

The PSU generates power supply voltage.

1.4.2.3 The Test Signal Source (Energoforma) employs 16-bit digital-to-analogue conversion (DAC) technology. The DAC board has 6 identical channels. Operating independently, each converts 16-bit binary input code into analogue form processing 2048 points over a period of 20 ms (2048 samples per period at 50 Hz frequency). The DAC board produces 6 analogue signals: 3 currents and 3 voltages. The current signals are galvanically isolated from each other and from other circuits, and the voltage signals are galvanically isolated from other circuits and linked among each other by a common wire.

The Central Processor Unit of the Test Signal Source incorporates a signal processor, FPGA and flash memory. It exercises full control over the Test Signal Source and ensures:

- Generation of the arrays of samples coming to the DAC board (representing point by point each of the six waveforms)
- Data storage in the internal flash memory of the Source
- Time stamping
- Data exchange with external devices (PCs)
- Results of self-testing using the LED indicators on the front panel.

Dedicated software makes it possible to configure the way of displaying data, enter the parameters of current and voltage waveforms to be generated (wave shape, amplitude, phase shifts etc.), and specify other actions.

The Power Supply Unit generates voltages +5 V, +3.3 V, and +1.6 V to power the Central Processor Unit and +5 V, as an independent power supply, to power the RS-232 port along with the synchronization scheme (which produces meander pulses with (50 x 2048) Hz frequency coming to the CPU board) that keeps output test signals and power supply signals synchronized.

Analogue currents and voltages generated from the samples are taken out of the DAC board and applied to the associated inputs of the current and voltage amplifiers.

The current and voltage amplifiers are respectively built on the basis of:

- Three class D current amplifiers with transformer output
- Three class D voltage amplifiers with transformer output.

Single-phase Test Signal Sources (modification “1.120”) are equipped with one current and one voltage amplifier of class D.

The current amplifiers are protected against circuit overload and disconnection.

The output of each voltage channel is protected against short circuit with a 0.25A fuse.

Each amplifier is powered from an individual AC/DC power source (12 V).

The output ranges of the current and voltage amplifiers are controlled from the CPU via the commands applied to the corresponding relays.

The results of operational testing of the current and voltage amplifiers are indicated on the front panel by means of the “CA error” and “VA error” LEDs.

The dedicated software enables generated current and voltage waveforms to be adjusted in real time depending on the obtained measurement results.

1.4.2.4 The DC Calibrator/DC Meter (DCC/DCM) measures DC voltage and converts it into a series of pulses with the repetition rate proportional to the measured value by applying the input voltage signal to a 24-bit ADC via a scaling converter (resistive divider).

In the DCC/DCM, to measure DC current and to convert it into a pulse signal with the proportional repetition rate, the input current signal comes to an ADC via a current-to-voltage converter (resistive shunt).

The DCC/DCM produces DC signals within 0 to ±24 mA (current) and 0 to ±10.5 V (voltage) ranges using 16-bit DACs.

The DC current signals being generated are measured with use of the current-to-voltage converter (resistive shunt) and ADCs to make real-time adjustments to the signals in response to the measurement results.

The DC voltage signals being generated are measured with use of the scaling converter (resistive divider) and ADCs to make real-time adjustments to the signals in response to the measurement results.

Full control over the DCC/DCM is performed by a microcontroller which carries out measurements and calculations, controls the ADC and DAC, generates pulse sequences on the pulse output and transmits the results to PC via Ethernet.

1.4.2.5 After power up the Test System performs self-test, initialization, and initial setup procedures. It is designed for continuous operation.

The dedicated software of the Test System incorporated firmware (FW) and PC-software (SW) modules. Connection with PC is provided via communication interface ports.

The FW provides data processing, data transmission and control over operation modes of the Test System. The FW is designed and installed by the manufacturer. It is stored in the internal flash memory.

Structurally, with respect to metrology, the firmware is divided into metrologically significant and metrologically insignificant components. Each of the components is protected by a CRC32-IEEE 802.3 checksum controlled by a diagnostic module.

When calculating measurement results, the FW considers the corrections and correction factors, which are determined in the course of adjustment, recorded into the internal flash memory, and protected by checksums controlled by the diagnostic module.

The firmware as a whole along with the corrections and correction factors are protected against modifications and deletions. The accuracy specifications of the Test System are given considering the impact of the FW on measurement results.

The SW has no metrologically significant components. It is used to select operating modes, parameters to be measured and measurement ranges as well as to read measurement results from the internal memory.

The Test System is protected against deliberate or accidental changes to firmware and measurement results. The degree of protection is “high” (R 50.2.077-2014).

Identification information for the FW and SW modules is listed in Table 1.8.

Table 1.8 – Identification information

Identification information (attributes)	Value	
	FW	SW
Name	-	EnForm-ME
Version number (ID number)	-	2.8.0 or higher
Digital ID	-	-
Name	-	EnfCalibrationRig
Version number (ID number)	-	2.2.4 or higher
Digital ID	-	-

Identification information (attributes)	Value	
	FW	SW
Name	EM3.1KM-02	-
Version number (ID number)	8.0.6411 or higher	-
Digital ID	-	-
Name	-	Calmar-DC/PTN4
Version number (ID number)	-	1.0.0 or higher
Digital ID	-	-
Name	-	Energy-ME
Version number (ID number)	-	1.0 or higher
Digital ID	-	-

1.5 Marking and sealing

1.5.1 Marking of the Test System

The following information is stencilled on the case (enclosure):

- Name of the Test System
- Type Approval sign
- Manufacturer's trade mark
- Power supply type and rating
- Marking of input and output connectors.

The manufacturer's nameplate placed on the case bears:

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

1.5.2 Marking of the transportation box

The side and face walls of the transportation box bear handling symbols "Fragile", "Keep dry" and "Top".

1.5.3 Sealing

A seal is installed:

- For stationary systems (modification "S"): in the hole of a fastening screw on the rear panel of the Test System
- For portable systems (modification "P"): in the hole of a fastening screw on the front panel of the Test System.

When the Test System is repaired, the seal should be reinstalled. Only an authorized service company is allowed to reinstall the seal.

2 OPERATION

2.1 Operating restrictions

Caution! If the Test System has been moved from a cold environment (with ambient temperature below minus 20° 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 Test System must not be used under the ingress of moisture inside its body.

Warning! It is forbidden to apply any voltage or current to the Test System from an external source!

2.2 Preparing for operation

2.2.1 Safety requirements

The Test System belongs to the equipment compliant with the requirements of the “Rules for Labour Safety When Operating Electrical Installations”.

As regards the protection against electrical shock, the Test System relates to the equipment of protection class I (IEC 61140).

The Test System meets the requirements of IEC 61010-1 (“Safety requirements for electrical equipment for measurement, control, and laboratory use”). In terms of IEC 61010-1, it is characterized by:

- Category of insulation – basic
- Category of measurements – III
- Pollution grade – 1

Ingress protection code is IP20 (IEC 60529).

Warning! Before the Test System is powered up and before making any connection to it, the Test System’s grounding clamp must be connected to the protective earth ground.

2.2.2 Unpacking

Check that the delivery package contains all parts specified in Table 4.1 of the Equipment Certificate. Inspect the equipment and make sure that manufacturer’s seals are intact. Should anything in the delivery package be found damaged, contact the supplier immediately.

2.2.3 Turning on

Warning! When connecting/disconnecting the Test System to/from tested equipment, the local Safety Requirements for operation of electrical systems must be observed. Before making connections inspect the contacts. Ensure that all of the contacts are made properly and reliably to avoid overheating and excessively high resistance. Ensure that there are no objects placed near the fan grilles that can block the air flow.

Warning! It is forbidden to apply any voltage or current from an external source to the Test System!

Make the connections to the Test System and turn on the components in the following order:

- First connect the Test System to the external protective earth ground, and then in succession to the mains supply and to the tested/reference equipment
- Connect the Test System to a PC
- Switch on the tested device
- Switch on the Test System and PC.

As the Test System is powered up, the PC display is turned on first. Then the Test System performs self-test and initialization procedures. At their conclusion (in 30 s), the “OK” front panel indicators showing the state of the Reference Meter and Test Signal Source should be turned on.

To set the Test System for stable operation, it should be left in the turned on condition for at least 15 minutes.

2.3 Operation

To control the Test System from a PC, it is necessary to install one or more (depending on the model) of the following programs on it:

EnfCalibrationRig
Enform-ME
Energy-ME
PTN4

The Test System is connected to a PC via USB and LAN.

The programs work under MS Windows 7 (32- or 64-bit architecture), or higher.

On completion of initialization, the Test System goes to the PC-controlled mode, and its communications parameters are configured via software.

2.3.1 PTN4 software overview

The Calmar-DC/PTN4 software is designed for use in the Test Systems with the DC calibrator function (modification “C”).

The main window of the program contains 3 tabs: “Generation”, “Measurements”, and “Connection”.

The “**Generation**” tab is used to specify the values of signals to be generated. The three fields labelled U_{OUT}, I_{OUT}, and F_{OUT} serve for this purpose. On clicking the “Start” button, the Test System starts generating a signal with the specified parameter, and the “Start” button is changed to the “Stop” one. A measured value and the absolute error between the programmed and measured values of the parameter are shown in the adjacent fields. As soon as the absolute error falls within its tolerance range, the program displays the “Ready” message. If the generated signal does not achieve the required accuracy in 10 s (e.g., due to a load being over (or above) its limit value), there will be a warning message. The program stops generation on clicking the “Stop” button. At this moment the current screen readings are frozen.

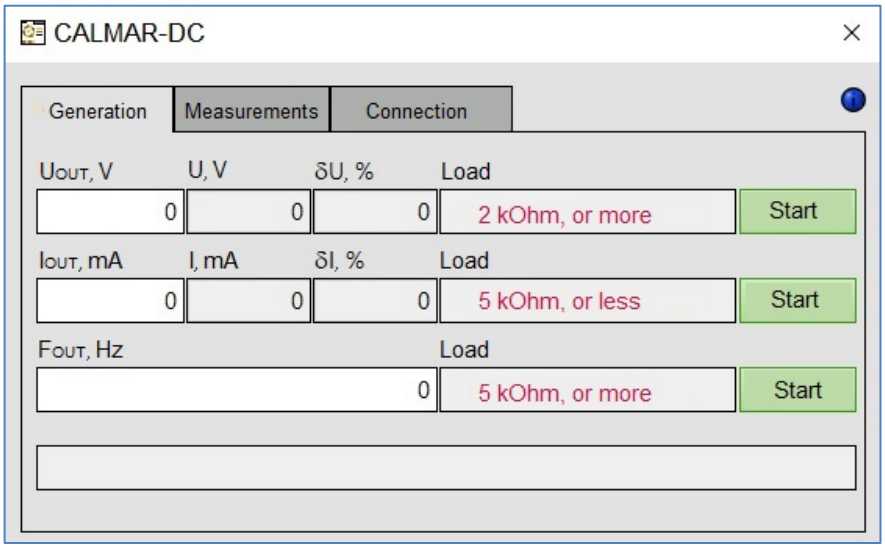


Fig. 2.1 “Generation” tab

The “**Measurements**” tab (Fig. 2.2) contains the fields used to specify rated (nominal) values of voltage (U_{NOM}) and current (I_{NOM}). On clicking the “Start” button, the Test System starts measuring the specified parameters. Measured values are displayed in the U_{IN} and I_{IN} fields, and the “Start” button next to the field is changed to the “Stop” one. Readings are updated once a second. Once the “Stop” button has been clicked, the measurements are stopped, and the current screen readings are frozen.

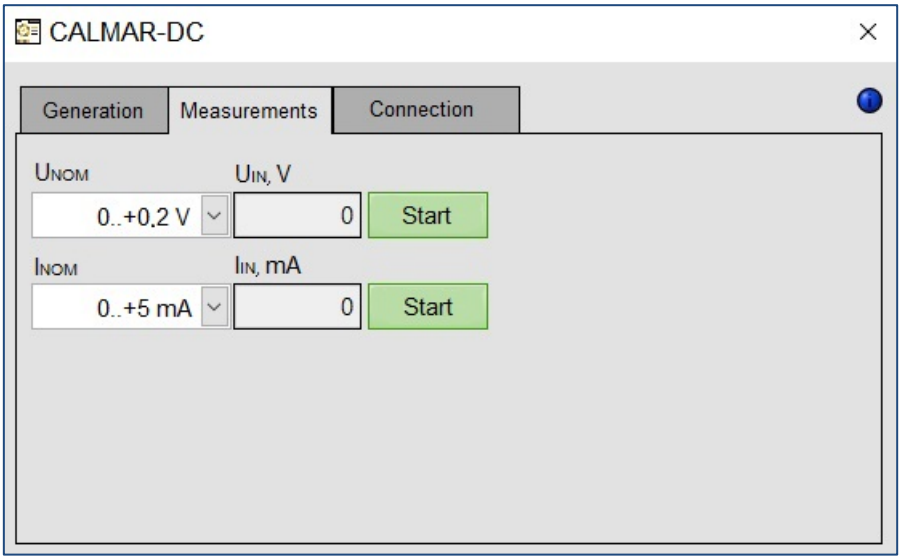


Fig. 2.2 “Measurements” tab

The “**Connection**” tab (Fig. 2.3) is used to provide connection between the Test System and PC. A connection status icon with a red cross is displayed in case of no connection. If an IP address specified is correct, the connection is established automatically, and the red cross is changed to green. The IP address can be reset by clicking on the “Recycle” button.

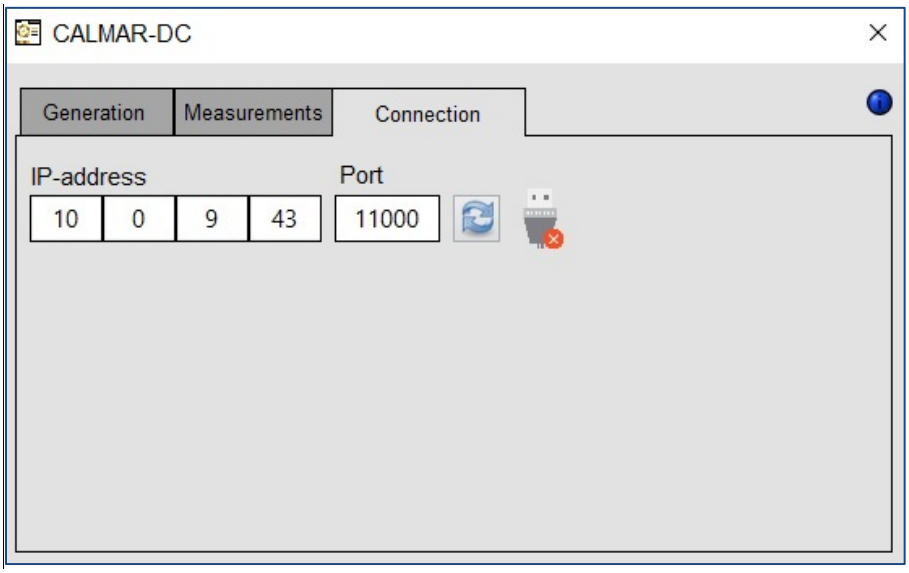
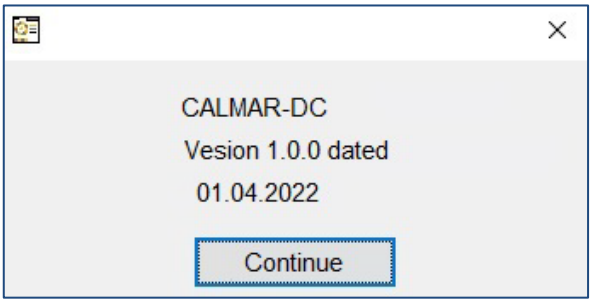


Fig. 2.3 “Connection” tab

The blue button labelled “i” opens a dialog box with the information about the name and version of the software.



2.3.2 Basic software

All of the models of the Test System work with the following software:

Enform-MTS-ME

Enform-ME

Energy-ME

For the information on installation and operation of the software listed above see the corresponding user manuals.

3 USER MAINTENANCE

3.1 General

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

3.2 Safety measures

Every maintenance operation must meet the safety requirements listed in Section 2 of this manual.

3.3 Maintenance operations

Routine maintenance includes self-testing, cleaning panels with a cloth, cleaning oxidized contacts and checking the reliability of their fixing.

3.4 Troubleshooting

Problem	**How to solve it**
The Test System does not start up on applying power.	Check that power supply cables are reliably connected. Replace fuses.
No connection between the Test System and PC	Check COM port settings on the PC. Check the connection cables.
An error message appears on the display.	Contact the manufacturer.

Manufacturer's address:
OOO "NPP Mars-Energo"
V.O. 13 Line, 6 - 8, office 41H, St. Petersburg, Russia, 199034
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

E-mail: mail@mars-energo.ru www. mars-energo.ru

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 / ($m^2 \cdot$ day) (maximum 0.025 mg/m3)

Chlorides – 0.3 mg / ($m^2 \cdot$ 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