"Chelenergopribor"

Limited Liability Company

Voltamperemeter and phase meter VFM-3

Operational manual

Passport

Chelyabinsk
2017

Contents

ATTENTION!

Don't start using this device without reading this document carefully.
Due to the fact that constant upgrades are made, some changes can be brought to the device not influencing its technical characteristics and not discussed in this document.

This operational manual is designated to instruct the user about the technical characteristics, components, principles and the rules of operation of Voltamperemeter and phase meter "VFM-3".

1 Regulatory references

GOST 12.3.019-80 Electrical tests and measurements. General safety requirements.
GOST 22261-94 Means for measuring electrical and magnetic quantities. General specifications.
GOST 26104-89 Electronic measuring means. Technical requirements for safety. Test methods.

2 Definitions, symbols and abbreviations

This operational manual has the following definitions, symbols and abbreviations:

- Device – voltamperemeter and phase meter "VFM-3", technical specifications 4221-015-71693739-2014;
- Voltage measuring pliers – clamp meter;
- LSD – low-order digit;
- PC – personal computer.

3 Safety requirements

3.1 Concerning electric shock hazard protection, the device belongs to class II according to GOST 26104.
3.2 Degree of the protection, provided by the device enclosure according to GOST 14254-80 (IEC-529) is IP40.
3.3 Only the personnel who got safety requirements training and studied this operational manual can be allowed to operate this device.
3.4 It is prohibited to connect input circuit of the device with switched on power if there is some voltage in the circuits under test.
3.5 When connecting to the circuits under test, use one hand only.

4 Description of the device and the modes of its operation

4.1 Intended use

4.1.1 The device is intended to measure effective value of three phase and three-port voltage and effective value of the strength of three alternating currents with simultaneous calculation of active, reactive, full power and energy in the three circuits, measurement of frequency and phase-shift angle between current and voltage.

4.1.2 The device is manufactured in compliance with the requirements of GOST 22261 and operating standards of State System for Ensuring Uniform Measurement.

4.2 Operation conditions

4.2.1 Normal operation conditions of the device according to GOST 22261:

- Ambient temperature 20 ±5 ºC;
- Relative air humidity (30 – 80) %;
- Atmospheric pressure (84 – 106,7) kPa.

4.2.2 Operation conditions in terms of mechanical impact in compliance with the group 4 requirements according to GOST 22261.

4.2.3 Operation conditions in terms of the impact of environmental climatic factors:

- Ambient temperature (–20 – +55) ºC;
- Relative air humidity is 90% at 30 ºC;
- Atmospheric pressure (84 – 106,7) kPa.

4.3 Power supply and consumption requirements

The device is powered from four replaceable Ni-MH batteries of AA size with total voltage of 4,8 V.
Four batteries of AA size with the voltage of 1,5 V can also be used as power supply for the device. In case the batteries are used it is prohibited to connect the device to the charger.
Maximum power consumption is not more than 1,5 W.
Four batteries, connected successively and totally producing less than 4 volt are considered unsuitable for use. In that case the device is switched off automatically.

4.4 Dielectric strength and insulation resistance

4.4.1 Dielectric strength and insulation resistance comply with the requirements of GOST 26104.

4.4.2 Insulation resistance is not less than 20 mega ohm between the voltage measurement inputs of the device on one side and other circuits, available for connecting from the outside on the other side.

4.4.3 Electrical insulation between the voltage measurement inputs of the device and its case, as well as the case of voltage measuring pliers can withstand dielectric test voltage with effective value of 2 kV and frequency of 50 Hz without damage for 1 minute.

4.5 Requirements to the device operation under voltage overload conditions

4.5.1 The device withstands voltage overload of $1,2*U_k$, where U_k is a finite value of voltage range being measured, within 5 seconds.

4.5.2 The device withstands current overload of $2*I_k$, where I_k is a finite value of the current range being measured, within 5 seconds.

4.6 Specifications

4.6.1 Measurement range of:

- effective value of volts alternating current, V .... 0 – 460
- effective value of alternating current, A .... 0 – 30
- phase-shift angle between voltage and voltage, between voltage and current, degree………………………………………………………………………….. –180 – +180
- active (reactive, full) power, W (reactive volt ampere, VA) .... 0 – 13800
- frequency of voltage and alternating current, Hz .... 45 – 65

4.6.2 The limits of permissible relative error of measurement of:

- effective value of volts alternating current, % ……………..…… $\pm\left[0.2 + 0.01\left(\frac{Umax}{U} - 1\right)\right]$
- effective value of alternating current, % .... $\pm\left[1 + 0.005\left(\frac{I\max}{I} - 1\right)\right]$
- frequency of voltage alternating current, % .... ±0.1

4.6.3 The limits of permissible relative error of measurement of phase-shift angle between voltage and current (when voltage is more than 30 V and current is more than 100 milliampere), degree .... ±1

4.6.4 The device determines sequential order of phases in three-phase system.

4.6.5 Response time for the device, sec, not more than 15

4.6.6 Input impedance of voltage channels, mega ohm, not less than 1

4.6.7 Opening of magnetic circuit of the clamp meter, mm .... 8±0,5

4.6.8 Weight without accessories, kg, not more than 0,3

4.6.9 Dimensions, mm, not more than 150x94x34

4.6.10 Average service life, years, not less than 10

4.6.11 Average time between failures, years, not less than 3000

Note:

1. U – voltage measured value, U_{max} – voltage measurement limit, I – current measured value, I_{max} – current measurement limit.

2. Basic errors in measurement (clauses 4.6.2, 4.6.3) are the characteristics, which determine the failure.

4.7 Device structure and physical operation

4.7.1 Structure

The device appearance is shown in Fig. 1. The device is put into an isolated case made of high impact plastic. The case consists of: an upper cover (1) and a bottom plate, fixed by 4 screws. On the upper cover there is (1) a power on button (2) and a button for switching to the measurement mode (3), LCD screen (4).On the side surface of the case there is a yellow socket (5) for connecting phase A voltage signal, a green socket (6) for connecting phase B voltage signal, a red socket (7) for connecting phase C voltage signal, a black socket (8) for connecting to zero. Sockets (9, 10, 11) on the side surface of the device are used for connecting clamp meters to phases A, B and C respectively. Socket (12) is intended for plugging in the charger supplied with the device.

Fig. 1. General view of the device.

4.7.2 The device layout and operation

The device block scheme is shown on Fig. 2. The device consists of three input resistance dividers, a multi-channel analog-to-digital converter (ADC) for digitizing input signals, digital signal processor (DSP) for signal processing, a microcontroller (MC) for controlling the peripherals and batteries charging, LCD screen for showing measurement data, USB interface for connecting to PC, constant-voltage regulator (CVR) and accumulator batteries (AB).

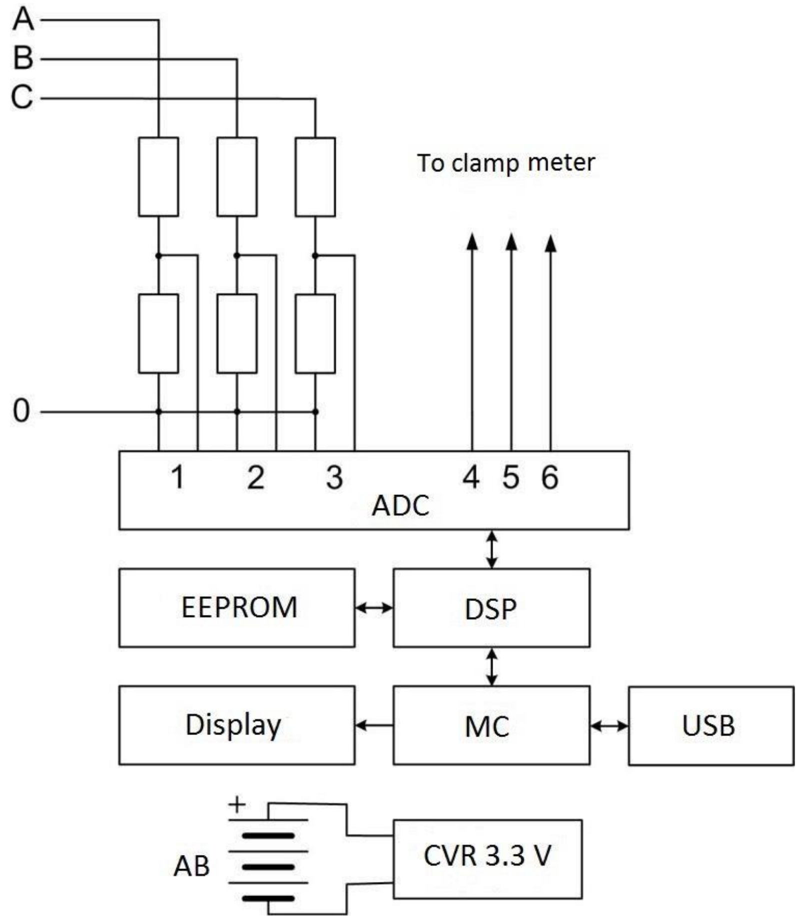

Fig. 2. The device block scheme.

The analog-to-digital converter registers with the frequency of 8 kHz instantaneous value of voltage, applied to its inputs within 1 second. As the result of the measurements, arrays $\{U_{An}\},\{U_{Bn}\},\{U_{Cn}\},\{I_{An}\},\{I_{An}\},\{I_{Bn}\},\{I_{Cn}\}$ each consisting of 8000 points are obtained.

To determine the signal frequency we find out the numbers of all points X_n, in which condition (1) is fulfilled. As a result, array $\{n_m\}$, consisting of M points, is obtained. After creating this array, the signal frequency can be calculated by the formula (2).

$$\begin{cases} X_n \geq 0 \\ X_{n+1} < 0 \end{cases} \tag{1}$$

$$f = f_{sampling} \frac{M-1}{n_M - n_1} \text{ Hz} \tag{2}$$

To calculate effective values of signals X_e, we square their sample values (X_n), then we take the square root of constant component of the obtained signal:

$$X_e = K_x \sqrt{\frac{1}{N} \sum_{n=1}^{N} X_n^2} \,,$$

where K_x is a gauge coefficient.

To calculate active power we use formula:

$$P = K_u K_i \sum \frac{U_k}{U_{FS}} \times \frac{I_k}{I_{FS}} \times \cos(\varphi_k - \gamma_k) \times PMAX \times \frac{1}{2^4} \text{ W,}$$

where K_u and K_i are gauge coefficients of voltage and current respectively.

We calculate reactive power by formula:

$$Q = K_u K_i \sum \frac{U_k}{U_{FS}} \times \frac{I_k}{I_{FS}} \times \sin(\varphi_k - \gamma_k) \times PMAX \times \frac{1}{2^4} \text{ var.}$$

Phase-to-phase voltage is calculated by formula:

$$U_{ab} = \sqrt{U_a^2 + U_b^2 - 2K_{U_a}K_{U_b}\cos(\Psi_{ab})} \text{ V.}$$

Full power is calculated by formula:

$$S = K_u K_i \frac{U}{U_{FS}} \times \frac{I}{I_{FS}} \times PMAX \times \frac{1}{2^4} \text{ VA.}$$

Power is calculated by formula:

$$W = \frac{1}{f_{sampling}} \sum_{k=1}^{N} P_k \text{ kW*h.}$$

To calculate phase shifts between signals X_1 and X_2 we find out the numbers of points (n and k) $X_{1,n}$ and $X_{2,k}$, in which the condition (3) is fulfilled. The phase shits between the first signal (1st phase voltage) and the second signal (1st phase current or 2nd phase voltage) are calculated by formula (4):

$$\begin{cases} x_{1,n} \geq 0 \\ x_{1,n+1} < 0 \\ x_{1,k} \geq 0 \\ x_{1,k+1} < 0 \end{cases} \tag{3}$$

$$\varphi = N \times \frac{360° \times f}{f_{sampling}} \tag{4}$$

where N = n - k.

Low currents (less than 50 milliampere) are measured by synchronously detecting current with the signal, formed from the voltage applied between inputs **A** and **N**, of not less than 100 V and of the same frequency as the current.

5 Completeness

VFM-3 includes:

- Measuring device .... 1 pcs.
- Clamp meter with a wire .... 3 pcs.
- Test probes with wires to measure voltage .... 4 pcs.
- Charger .... 1 pcs.
- Carrying bag .... 1 pcs.
- Operational manual and passport .... 1 pcs.
- Test procedure description.. 1 pcs.

6 Operation of the device

6.1 Power supply of the device

6.1.1 The device is powered from four Ni-MH batteries AA size with total voltage of 4.8 V.
It is accessible to use batteries of arbitrary capacity. To install batteries, unscrew bolts on the back cover of the device and put 4 batteries in accordance with polarity marking on the battery case.

6.1.2 The device continues operating till battery discharges to the total voltage of 4 V, after that the device switches off.

6.1.3 Batteries charge is indicated by the sign in the left upper corner (). If the sign is red, the batteries are low and they need charging.

6.1.4 To charge batteries, an external battery charger, supplied with the device, should be connected to the appropriate socket. Full charge takes not less than 24 hours.

6.1.5 Quick discharge of the batteries means their failure. In this case the batteries should be changed. All the batteries should be changed simultaneously. Batteries should be of the same type and of equal capacity.

6.1.6 Instead of an accumulator battery it is accessible to use voltaic cells of AA size and with 1.5 V voltage for each cell without connecting to the charger. In case of using non-chargeable voltaic cells, it is prohibited to connect the device to the charger.

6.1.7 Don’t store the device with deeply discharged batteries as it can lead to battery electrolyte leakage and damage the device.

6.2 Measurement procedure

6.2.1 Switch on power.

6.2.2 To measure alternating voltage, a measuring probe should be connected to sockets **A**, **B**, **C**, **N** (yellow, green, red and black respectively). Then, connect the probes to the corresponding phases of the circuit being measured and to the zero and take the readings in Volts.

6.2.2 To measure alternating current, you should grip a current-carrying conductor with a clamp meter. After that you should take the readings in ampere.
To obtain more precise readings, the clam meter should be placed so that the current-carrying conductor is situated at the minimal distance from the opening of the clamp meter.
When measuring low currents (less than 50 milliampere) to improve the accuracy of measurements you should apply the voltage of the same frequency as the current with the value of not less than 100 V to sockets **A**, **B**, **C** and **N**.

Fig. 3 displays the measured values in the mode of reading value, which is set by default after the device is switched on. In this mode, the vector diagram of the circuit being measured is displayed without observing graphical scales.
The frequency of the voltage is displayed in Hz in the last line.
The frequency is measured by phase A.

6.2.3 To measure power and phase shifts the connections similar to those made for voltage and current measurements are performed. Active, reactive and full power and energy are read from the screen as it shown on Fig. 4, in watts, Var and volt-ampere respectively. To determine the sequential order of the phases in a three-wire circuit, you should switch to the 1st mode on the device to display vector diagrams.
Capacity coefficient, actual power sum, cosine of shift in each phase are displayed on the screen (fig. 4).

If the obtained values of active power or capacity coefficient are negative, the clamp meter should be flipped through 180° towards current carrying wire.

Capacity coefficient is calculated as:

$$\lambda = \frac{\sum P_i}{\sum W_i},$$

where P_i (W) - active power of phase i, and W_i – full power of phase i.

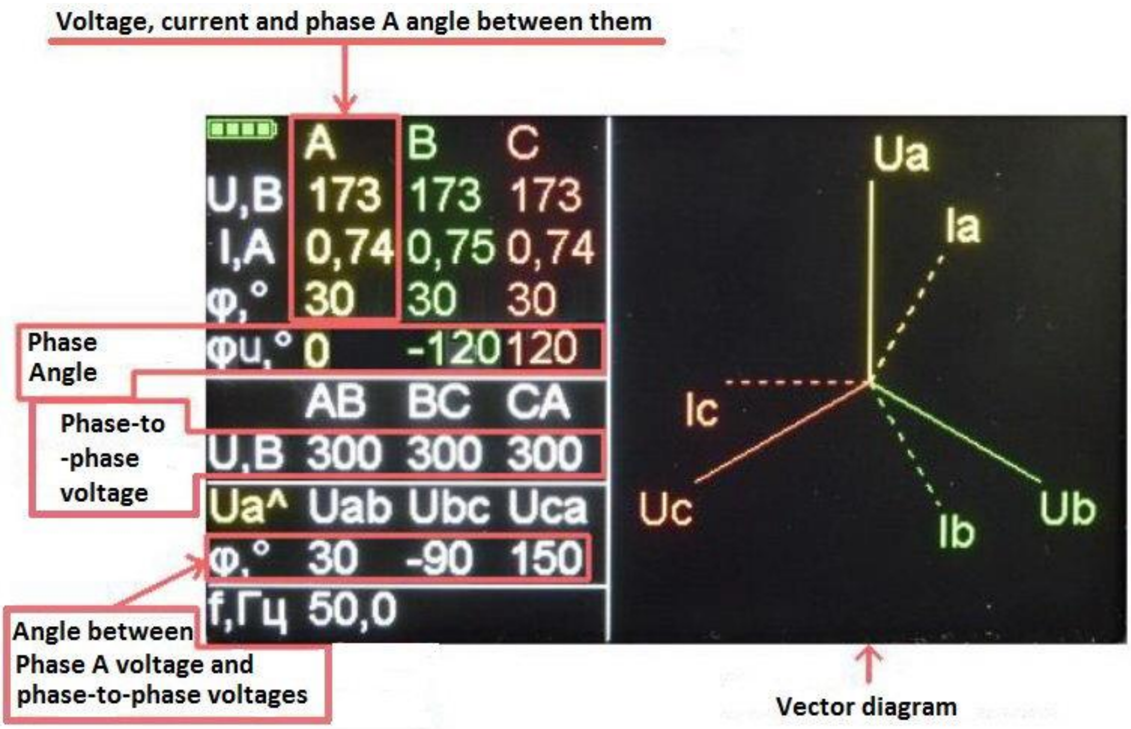

Fig. 3. Indication of the 1st mode on the LCD of the device.

When the sign of phases is displayed, a zero vector is considered to be the first vector in indication. Example is shown on fig. 3.

- When measuring a phase shift between the current and the voltage of one phase, a voltage vector is taken for the initial vector. The number on the screen is read as: Ua outruns vector Ia by 30 degrees.
- When measuring the angle between phase voltages, initial phase Ua is taken for zero one. Initial phases Ub and Uc are displayed as related to initial phase Ua.

6.2.4 If it is necessary to measure a phase shift between phase-to-phase voltage, Uab for example, and phase current, the following should be done:

- connect «zero» (black wire), to phase B;
- connect phase A (yellow wire) to phase A;
- connect the clamp meter of phase A to the phase current being measured.

The angle, which is displayed as the shift angle of phase A (fig.3, highlighted column), will correspond with the phase shift of the current being measured as related to phase-to-phase voltage AB.

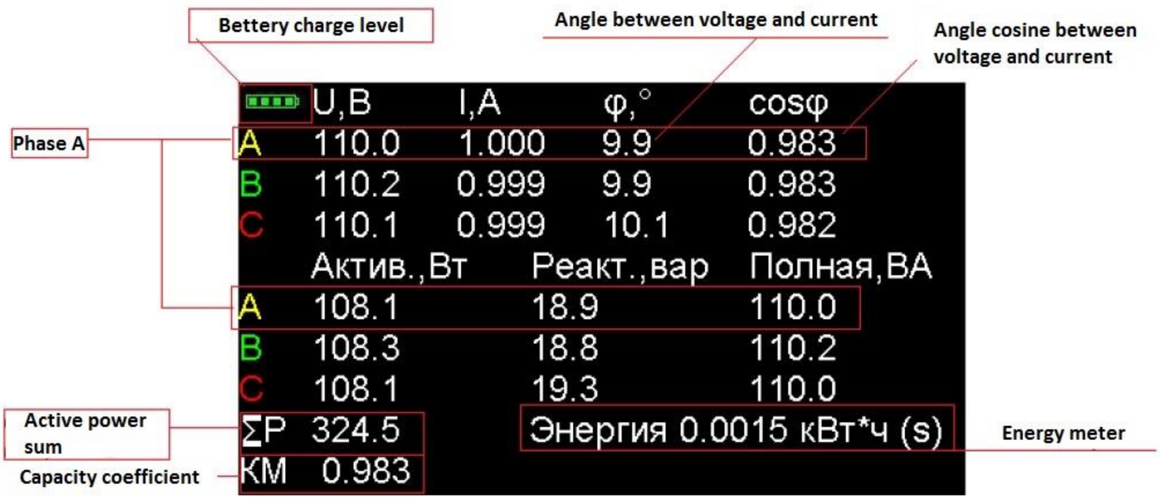

Fig. 4. Indication of the 2nd mode on the LCD of the device.

6.2.5 Switch between the modes by pushing the button «Режим» (Mode) shortly.

6.2.6 To start the power meter, you should:

- Switch to the second mode;
- Shortly push the button «Включение» (Turn on).

The meter is started by letter «s» in brackets («Энергия 0,0000 кВт*ч (s)»(Energy 0,0000 kWh).

6.2.7 To stop the power meter, you should push the button «Включение» (Turn on) shortly. The meter is stopped by letter «p» in brackets («Энергия 0,0000 кВт*ч (p)»)»(Energy 0,0000 kWh).

6.3 Saving the results of the measurement

The device allows saving the results of 100 measurements. The results are presented as screenshots of the two modes, both in text and graphics format.

To save the results of the measurements while the measurements are being taken, push the button «Режим» (Mode) and hold it till the inscription «Сохранение…» (Recording) appears. After this message appears the button can be released. On the screen you will see the names of the files in which the screenshots of the two modes have been saved. After the results are saved, the device will automatically return to the measurement mode.

The files, which names are not underlined, show the screen in the first mode.

The files, which names are underlined, show the screen in the second mode.

If the maximum possible amount of measurements is saved in the device at the moment, the files will be recorded over the previous ones starting with the earliest one. If there isn't enough memory for saving the results of the measurements in the device due to the user's saving personal data or incomplete deleting of the files, containing the measurements, the device will produce the message «Недостаточно места» (memory is full). In this case the user should delete the data manually. All 4 files of each measurements should be deleted.

It is not recommended to save personal files in the device memory and to save manually after the message «Недостаточно места» (memory is full) appears on the screen.

6.4 Connecting the device to PC

To connect the device to PC, the user should use a cable mini-USB – USB-A. The device should be turned on before connecting the cable. After connecting the device, a new appliance «Съемный диск» (removable disk) will appear.

Then these data files, saved in the device memory, can be used as regular files on a removable disk. Graphic data are saved in GIF format and text ones are saved in HTML format in files. It is convenient to look through these files on PC and use them for drawing up protocols and reports with the help of commonly used office applications.

When connected to PC, the device is powered from the computer,

ATTENTION! DON'T CONNECT THE DEVICE TO PC WHILE MEASUREMENTS ARE BEING TAKEN.

7 Adjustment of the device

The device is adjusted by the manufacturer.

8 Verification of the device

Verification of VFM-3 is conducted once every 24 months in compliance with the document « State System for Ensuring Uniform Measurement. Voltamperemeter and phase meter VFM-3. Test procedure 25-262-2014», is approved by Federal State Unitary Enterprise «UNIIM».

9 Labeling, packaging and sealing

9.1 The device is labelled with: the name, the type, the trademark of the manufacturing enterprise, the national conformity mark, the serial number, the year of manufacture, symbols for input and output circuits, warning labels in compliance with GOST 26104.

9.2 Packaging, concerning the impact of environmental and climate factors in compliance with GOST 22261, group 4.
9.3 Packaging, concerning the impact of mechanical factors according to GOST 22261, group 4.

Dimensions in package 240×240×155 mm.
Gross weight is not more than 3 kg.
The device is sealed with the sealing mark which breaks when open. **Don’t break the seal!**

10 Transportation and storage

Terms and conditions of transportation and storage should comply with GOST 22261.

PASSPORT

Voltamperemeter and phase meter VFM-3

1 Intended use

Voltamperemeter and phase meter VFM-3 is intended to measure the effective value of three phase and three-port voltages and the effective value of strength of three alternating currents with simultaneous calculation of active and reactive power in the circuit, as well as to measure frequency and phase-shift angle between current and voltage as well as to determine sequential order of the phases in a three-wire circuit.

The device can be used in complex tests of generator protection, lines, in CT and VT circuits, adjustment of phase-sensitive relay protection schemes and other.

2 Operation conditions:

2.1 Normal conditions of use of the device according to GOST 22261.

- Ambient temperature 20±5°C;
- Relative air humidity is 30…80 %.
- Atmospheric pressure is 84 – 106 kPa.

2.2 Operation conditions in terms of mechanical impact in compliance with the group 4 requirements according to GOST 22261.

2.3 Operation conditions in terms of the impact of environmental climatic factors:
ambient temperature is from −20 to +55 °C;
relative air humidity is 90% at 30 °C;.
atmospheric pressure is from 84 to 106 kPa.

3 Power supply and consumption requirements

The device is powered from four replaceable Ni-MH batteries of AA size.
Maximum power consumption is not more than 1,5 W.
Four batteries, connected successively and totally producing less than 4 volt are considered unsuitable for use. In that case the device is switched off automatically.

4 Specifications

4.1 Measurement range of:

- effective value of volts alternating current, V .... 0 – 460
- effective value of alternating current, A .... 0 – 30
- phase-shift angle between voltage and voltage, between voltage and current, degree... –180 – +180
- active (reactive, full) power, W (reactive volt ampere, VA) …………………....... 0 – 13800
- frequency of voltage and alternating current, Hz .... 45 – 65

4.2 The limits of permissible basic relative error of measurements:

- effective value of alternating current voltage, ……... $\pm\left[0.2+0.01\left(\frac{U_{max}}{U}-1\right)\right]\% \pm LOD$
- effective value of alternating current, ……………….. $\pm\left[1+0.005\left(\frac{I_{max}}{I}-1\right)\right]\% \pm 1\ LOD$
- frequencies of alternating current voltage, %.. ±1

4.3 The limits of permissible relative error of measurement:

- of phase-shift angle between voltage and current (when voltage is more than 30 V and current is more than 100 milliampere), degree.. ±1

4.4 The device determines sequential order of phases in three-phase system.
4.5 Response time for the device, sec, not more than 5
4.6 Input impedance of voltage channels, mega ohm, not less than .... ±1
4.7 Opening of magnetic circuit of the clamp meter, mm .... 8±0.5
4.8 Weight without accessories, kg, not more than 0,3
4.9 Dimensions, mm, not more than 150x94x34
4.10 Average service life, years, not less than.. 10
4.11 Average time between failures, years, not less than 3000

Note: Basic errors in measurements (clauses 4.2, 4.3) are the characteristics, which determine the failure.

5 Completeness

VFM-3 includes:

- Measuring device .... 1 pcs.
- Clamp meter with a wire .... 3 pcs.
- Test probes with wires to measure voltage .... 4 pcs.
- Charger .... 1 pcs.
- Carrying bag .... 1 pcs.
- Operational manual and passport .... 1 pcs.
- Test procedure description... 1 pcs.

6 Long storage

Table 1. Long storage of VFM-3

Date	Name of operation	Service life, years	Position , surname and signature

7 Packing certificate

Voltamperemeter and phase meter VFM-3 serial № ……………..…..……are packed in compliance with the requirements, specified by the technical documents in force.

____________________	____________________	____________________
(position)	(personal signature)	(clarification of signature)

____

(year, month, date)

8 Acceptance certificate

Voltamperemeter and phase meter VFM-3 serial № ……………...……… complies with the requirements of technical specifications 4221-015-71693739-2014 and is approved for operation.

Stamp Quality control chief

____________________	____________________	____________________
(year, month, date)	(personal signature)	(clarification of signature)

8.2. Voltamperemeter and phase meter VFM-3 serial № ………………… initial verification was conducted under the conditions provided by the manufacturer in compliance with Test procedure 25-262-2014 « Voltamperemeter and phase meter VFM-3. Test procedure» and was declared suitable for operation.

____

(test date)

Verification officer:

____________________	____________________
(personal signature)	(clarification of signature)

9 Warranty liabilities

9.1 The manufacturer guarantees compliance of the manufactured devices VFM-3 with controlled technical requirements if the user observes operation, storage and transportation regulations, specified in «Operational manual».

9.2 The warranty is valid for 18 months, calculated from the date of delivery to the user.

9.3 Within the warranty period the manufacturer eliminates all the discovered defects free of charge.

9.4 Warranty liabilities don’t cover devices with substantial mechanical defects and batteries replacement.
9.5 The manufacturer is entitled to countercheck customer complaints to evaluate reasonability of claims.
9.6 Current and post-warranty repairs are carried out by the manufacturing enterprise.

10 Transfer of the device while in service

Table 2. Transfer of VFM-3 while in service

Installation date	Place of installation	Date of removal	Service hours		Reason for removal	Signature of the person, who conducted installation (or removal)
			From the start of operation	After the last repair		

11 Transportation and storage

11.1 Device VFM-3 allows for short-term storage in the manufacturer's packaging at ambient air temperature of +5 to +40°C and relative humidity up to 80% and at temperature of 25°C for up to 6 months. There should be no dust, corrosive gases and other harmful mixtures, which cause corrosion in the storage rooms.

11.2 The methods of transportation of VFM-3 should comply with GOST 22261-94.

11.3 Climatic effects on VFM-3 in utmost conditions of transportation should comply with the storage conditions 3 or 5 according to GOST 15150-69.

12 Disposal

The measures for preparing and sending VFM-3 to disposal are conducted in accordance with consumer enterprise requirements and instructions. The battery disposal is conducted in accordance with the requirements and instructions of the battery manufacturer.

The address of the development engineer-manufacturer: 454902, 1b, Severnaya str, Shirshny, Chelyabinsk, LLC «Chelenergopribor». Tel./fax: (351) 211-54-01.

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