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THERMONOISE METHOD OF RESISTANCE MEASUREMENT OF HIGHOHMIC OBJECTS

The paper presents the thermonoise anemeter of highresistance objects, in which the influence of temperature of the underresearch object, that can vary within the wide limits is excluded. It also excludes the influence of instability of frequencies of noise voltage's bar as well as theinfluence of instability of noise voltage's increasing, that provides the increasing of measuring accuracy of highresistance objects by the level of thermal noises.

Keywords: *highresistance object, thermonoise anemeter, thermal noise, noise voltage, noise current.*

It is known that the thermonoise or thermal fluctuation level in the physical bodies and environments depends on the object temperature and the electric resistance. It can be quantified with Nickvist formula [1]:

$$\overline{U^2} = 4kT\Delta fR ,$$

where $\overline{U^2}$ – average square (dispersion) of thermal noise;

k – Boltsman constant;

T – thermodinamical temperature;

Δf – noise tension frequency band;

R – resistance of the object under research.

Consequently, the own thermal noises can be used as a measuring informational souse for thermonoise resistance measurement of highohmic objects, especially when the application of outer voltage is impossible.

The analysis of the latest researches and publications

There has been made the analysis of the existent resistance measuring devices of highohmic objects.

It is not possible to measure punctually the resistance as its own thermal booster noises collide on the thermal noise of the under research object in the resistance measuring device of highohmic objects [2]. The measuring device operations allow to separate the object noises and the own noises of the booster as well as to eliminate the influence the own noises of the booster on the measuring result.

There is eliminated the influence the own noises of the booster on the thermal noises measuring result of the object presented as a constant voltage in the resistance measuring device of highohmic objects [3]. But this voltage value determines the thermal noise of the investigated object as well as its temperature which can change in the wide range. Besides the measuring constant voltage depends on the noise tension frequency measuring band, this constant voltage is hardly stabilized being influenced by the destabilizing factors. Big amplification, necessary for the measuring of the noise voltage, is also not stable and introduces the big error into the resistance to be measured, which does not provide for accuracy in measurement

Task Setting

The objective of the research is to ensure the accuracy improvement in measuring the resistance of the high-resistance objects eliminating the influence of the temperature of the underresearch object, nonstability of the frequency band and amplification of the noise voltage on the measuring results.

Results and their discussions

The suggested method may be used for the estimation of the electric resistance of the high-resistance objects on the level of their thermal noise, such as insulation of electric devices, gas and plasma environments, fields of electric losses, polymer materials, sensors of low – conducting environments etc.

The picture presents the analogue-digital diagram, which allows to realize the suggested method.

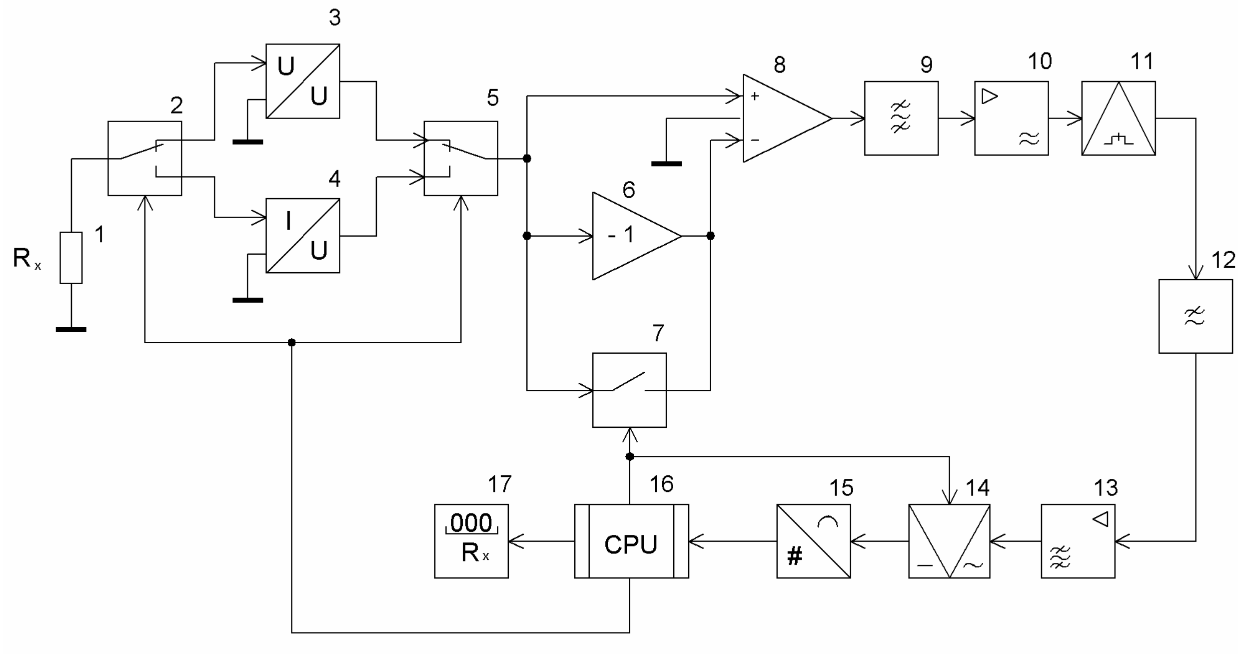

Fig. Structural diagram of the thermal noise resistance measuring instrument of high-resistance objects

High-resistance object 1 through the switcher 2 is switched to the high-resistance commutator 3 “voltage – voltage” or to the low-resistance commutator 4 “current – voltage”. the switcher 5 switches the inverter 6, shunt by the key 7, and the differential amplifier 8 to the output of commutator 3 and 4. To the output of the differential amplifier 8 there had been switched in series the band-pass filter 9, amplifier 10 of high frequency, quadratic detector 11, filter 12 of low frequency, selecting amplifier 13 of low frequency, synchronous detector 14, integrating analoque – digital commutator (ADC)15, electronic computer (EC) 16. The output of EC are connected to the controlling inputs of the switchers 2, 5 and the key 7. The digital indicator 17 is switched to the EC 16.

The method is executed as follows.

With the indicated state of the switchers, the noise voltage is taken from the under research object *UX1(t)*, which branches out for two equal voltages $U_1(t)=U_2(t)=U_{X1}(t)$. One of the voltages *U1(t)* changes its polarity with the nverting element, which is shunted periodically with the key. Periodically inverted voltage *U1(t)* influences the direct input of the differentiating amplifier 8, on the inverse input of which is influenced by the inverted voltage *U2(t)*.

If the noisy voltage *UX1(t)* shall be introduced in the complex kind $\dot{U}_{X1}$, the periodically inverted voltage *U1(t)* can be introduced as the temporary succession of complexes $+\dot{U}_1$ и $-\dot{U}_1$, and the non inverted voltage *U2(t)* as $+\dot{U}_2$. When the key is open, the brunched voltages, one of which is inverted, are not deducted, but added on the output of the differential amplifier. With the consideration of the own noises of the differential amplifier on the amplifier output we get the total voltage:

$$\dot{U}_3 = 2k_1\dot{U}_{X1} + \dot{U}_H + \dot{U}_B, \qquad (1)$$

where k_1 – amplifying factor of the differentiating amplifier;

$\dot{U}_H$ and $\dot{U}_B$ – voltages of low frequency and high frequency noises on the output of the differentiating amplifier.

In the thermo noise method of the resistance determination of the high ohm object, the information noise of the underresearch object after the amplifying ($2k_1\dot{U}_X$) of the same order with the own noises on the output of the amplifier ($2k_1\dot{U}_{X1} \approx \dot{U}_B$). Therefore they cannot be neglected.

With the closed key, the inverting of one of noise voltages is absent – difference voltage, on the output of the differential amplifier is determined by own noises:

$$\dot{U}_4 = \dot{U}_H + \dot{U}_B . \tag{2}$$

Automated key is controlled by the low frequency rectangular voltage, which is formed by the EC. In the result of periodical key closing-opening on the output of the differential amplifier the noise voltage changes from the total value (1) to the difference value (2), that is, the noise voltage, modulated on amplitude is formed. The modulated voltage is filtered in the frequency band of heat fluctuations by the band filter. The voltage, filtered from the low frequency components shall be amplified by the high frequency amplifier.

High frequency components of the amplified modulated voltage can be introduced as follows:

$$\dot{U}_5 = k_2(2k_1\dot{U}_{X1} + \dot{U}_B), \tag{3}$$

$$\dot{U}_6 = k_2\dot{U}_B , \tag{4}$$

where k_2 – amplification factor of the high frequency amplifier.

The components of the modulated voltage (3) and (4) shall be quadratically detected in the quadratic detector and averaged by the low frequency filter. In the result of averaging of the quadratically converted noises, there had been formed the sequence of impulses with the amplitudes:

$$U_7 = k_3 S_1 \left[k_2 \left(\overline{2k_1\dot{U}_{X1} + \dot{U}_B} \right) \right]^2 , \tag{5}$$

$$U_8 = k_3 S_1 \left[\overline{k_2\dot{U}_B} \right]^2 , \tag{6}$$

where S_1 – steep slope of the quadratic detecting;

k_3 – factor of transferring of low frequency filter.

In the succession of the averaged voltages (5) and (6) with the non equal amplitudes there had been singled out the low envelope frequency of square impulses:

$$U_9 = \frac{U_7 - U_8}{2} sign \sin 2\pi Ft + U_H(t), \tag{7}$$

wher F – the frequency of periodical inverting of noise voltage;

$sign \sin 2\pi Ft$ – low frequency of square form;

$U_H(t)$ – low frequency noises of quadratic detector.

The first harmonica of voltage is amplified by the sampling amplifier, tuned on the frequency F, the first voltage harmonica is amplified (7). The voltage of the first harmonica with the consideration of the impulses amplitudes (5) and (6):

$$U_{10} = \frac{8}{\pi} k_4 k_3 k_2^2 k_1 S_1 \left(\overline{\dot{U}_B \dot{U}_{X1}} + k_1 \overline{\dot{U}_{X1}^2} \right) + \Delta\dot{U}_H , \tag{8}$$

where k_4 – factor of amplification of the sampling amplifier of low frequency;

$\Delta\dot{U}_H$ – part of the voltage of low frequency noises which enter the band of pass band of the sampling amplifier of the low frequency.

The expression (8) comprises the product of the voltages of the own high frequency noises of differentiating amplifier and thermal noises of the object. But it is necessary to account for the fact, that these noises are non correlated between themselves. Therefore their averaged product equals zero:

$$\overline{\dot{U}_B \dot{U}_{X1}} = 0 . \tag{9}$$

The second member of the expression – mean-square voltage of thermal noises, that is the dispersion of the thermal fluctuations. Following the Nyquiet formula:

$$\overline{U_{X1}^2} = 4kT\Delta f R_X , \tag{10}$$

where k – Boltzmann constant;

T– thermodynamic object's formula;

Δf – frequency band, determined by the band filter;

R_X – resistance of the underresearch object.

Considering the above, the low frequency voltage is in proportion to the dispersion of the thermal noises only:

$$U_{11} = \frac{8}{\pi} k_1^2 k_2^2 k_3 k_4 S_1 \overline{U_{X1}^2} \sin 2\pi F t + \Delta U_H(t). \tag{11}$$

The low frequency voltage is synchronically detected by the synchronic detector and is averaged in the ADC. The digital code on the ADC output is determined by the constant component of the detected voltage only:

$$N_1 = \frac{8}{\pi} \frac{k_1^2 k_2^2 k_3 k_4 S_1 S_2}{q} \overline{U_{X1}^2} , \tag{12}$$

where S_2 – steep loop of the transformation of the synchronous detector;

q – unit of the subordinate grade of the ADC, ($q = \frac{U_{on}}{2^n}$, where U_{on} – reference voltage of ADC, n – digit capacity of ADC).

The digital code N_1 is remembered by the EC. Then, following the command of the EC, the switchers are transferred to the low position. And the commutator "current-voltage" with the low-resistance input is switched to the under research object. there had been formed the voltage on the output of the commutator, in proportion to the noise current of the object:

$$U_{X2} = S_i i_X(t), \tag{13}$$

where S_i – steep loop of the current transformation into voltage.

The second noise current after the branching and inverting, enters the inputs of the differential amplifier. After the analogical to the above transformation, we get the digital code:

$$N_2 = \frac{8}{\pi} \frac{k_1^2 k_2^2 k_3 k_4 S_1 S_2}{q} \overline{U_{X2}^2} . \tag{14}$$

Dispersion of the second noise current is determined by the dispersion of the noise current: $\overline{U_{X2}^2} = S_2^2 \overline{i_X^2}$, where the dispersion of the current noises in the regime of short circuit of the object is inversely proportional to its resistance:

$$\overline{i_X^2} = \frac{4kT\Delta f}{R_X} . \tag{15}$$

Digital code N_2 is also remembered by the EC. In the EC processor the first digital code is divided by the second digital code. We get the quotient from the division of two codes, which is proportional to the dispersion of the first and the second noise voltages:

$$\frac{N_1}{N_2} = \frac{\overline{U_{X1}^2}}{\overline{U_{X2}^2}}, \; \frac{N_1}{N_2} = \frac{4kT\Delta f R_X}{S_i^2 \overline{i_X^2}} . \tag{16}$$

Considering (15) we get:

$$\frac{N_1}{N_2} = \frac{R_X^2}{S_i^2} . \tag{17}$$

The square root is extracted from the relations of digital, and with the help of the obtained value of the digital code the value of the measured resistance is determined, which is shown on the digital screen:

$$R_X = S_i \sqrt{\frac{N_1}{N_2}} . \tag{18}$$

Conclusions

The obtained expression shows that the value of the measured resistance R_X does not depend on the temperature of the under research object T, frequency bands, in which the dispersions of the noise voltage and current are measured, parameters of the amplifying – transforming section (k_1, k_2, k_3, k_4 и S_1, S_2) and the level of the own noises of this section (U_H и U_B). Elimination of the influence of the indicated factors allows to achieve the high accuracy of measurements, and to reduce the final error to the value less ±0,2% measuring the resistance within the range of 0,5 – 500 megohm.

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