Tests of the stabilizer model have shown that variations of the supply current I_n from 25 to 45 ma altered the stabilizer output current I_{st} by less than 0.4% (Fig.2). With variations in I_n amounting to ±15% the value of I_{st} remained constant with an accuracy of 0.1%. A variation in the amplifier gain by a factor of 3 (from 70 000 to 200 000) and of the load resistance from 3 to 40 ohm produced changes in the current I_{st} not exceeding 0.4%.

ERRORS IN THE BEAT METHOD

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GOST (All-Union State Standard) 1845-59 [1] specifies the beat method in testing electrical measuring instruments for the effect of external magnetic fields [2] and for the effect of distortions on current and voltage waveforms. In the second instance it was assumed that if an instrument measuring the effective (actual) voltage or current of any waveform (electrostatic voltmeters or thermal and thermoelectric ammeters operating over a wide frequency range) is fed with a variable represented by equation

$$a = A_{1m}\left[\sin\omega t + \alpha \sin(n\omega t + \Delta\omega t)\right], \tag{1}$$

the readings of this instrument will correspond at any instant to the effective value

$$A = \frac{A_{1m}}{\sqrt{2}}\sqrt{1+\alpha^2}, \tag{2}$$

where A_{1m} is the amplitude of the voltage or current first harmonic; α is the ratio of the n-th harmonic amplitude to that of the first harmonic; ω is the angular frequency of the first harmonic; $\Delta\omega$ is the beat frequency.

However, tests of electrostatic voltmeters by the beat method have not confirmed the above assumptions, namely in measuring a voltage represented by (1) readings of electrostatic voltmeters periodically varied at the beat frequency $\Delta\omega$.

Let us show that this phenomenon has a sound theoretical explanation and is the result of an inherent error in applying the beat method for determining the effect of the waveform on the tested instruments.

It is known [1,2] that for these tests a low beat frequency is used, and since during time $T_B = 2\pi/\Delta\omega$ the effective value of the measured current or voltage varies from period to period for period T of the fundamental frequency, the moving part of the instrument is able to follow these variations owing to the low beat frequency $\Delta\omega$, i.e., the instrument readings vary periodically.

Let us now find for time interval $kT-(k+1)T$, where $k \geq 0$ and $(k+1) \leq T_B/T$, the effective value of the voltage or current represented by (1) for period T:

$$A(k) = \sqrt{\frac{1}{T}\int\limits_{kT}^{(k+1)T}\left\{A_{1m}\left[\sin\omega t + \alpha\sin(n\omega t + \Delta\omega t)\right]\right\}^2 dt} = A_{1m}\sqrt{\frac{1+\alpha^2}{2} - \frac{\left[\sin 2\Delta\omega(k+1)T - \sin 2\Delta\omega kT\right]\alpha^2}{4(n\omega+\Delta\omega)T(1+\alpha^2)}}. \tag{3}$$

Thus the effective value of A(k) is not constant over time interval T_B, and differs from the effective value of A (2), which the instrument should indicate in the presence of a harmonic with a relative amplitude α, by the amount of

$$A(k) - A = -\frac{A_{1m}}{\sqrt{2}}\sqrt{1+\alpha^2} \times \frac{\left[\sin 2\Delta\omega(k+1)T - \sin 2\Delta\omega kT\right]\alpha^2}{4(n\omega+\Delta\omega)T(1+\alpha^2)}. \tag{4}$$

This determines the relative error of the beat method

$$\delta_B = \frac{A(k)-A}{A} = \frac{\sin 2\Delta\omega kT - \sin 2\Delta\omega (k+1)\,T}{4\,(n\omega+\Delta\omega)\,T\left(1+\frac{1}{\alpha^2}\right)}, \tag{5}$$

which has a maximum for k = 0 (or, which is the same thing, for $(k+1)\,T = T_B$), i.e.

$$|\delta B\max| = \frac{\sin 2\Delta\omega\,T}{4\,(n\omega+\Delta\omega)\,T\left(1+\frac{1}{\alpha^2}\right)}. \tag{6}$$

A computation by means of (6) shows that in the presence of 30% third harmonic, a beat frequency of 0.5 cps and a fundamental of 50 cps, the beat method error amounts ot 0.15%, which can be neglected when testing instruments of grade 0.5 or lower. This error cannot be neglected, however, when testing instruments of the 0.1 or 0.2 grades. Thus, in testing instruments of grades 0.1 or 0.2 for the effect of the waveform of the measured current or voltage with relatively large values of α the beat method cannot be applied. However, in the overwhelming majority of cases encountered in practice the beat method error is negligibly small.

Let us note that in testing instruments for the effect of external magnetic fields [2] the beat method also introduces an inherent error; however, it is an error within an error, since it only introduces fluctuations in the effective field strength, and the beat method in this instance can therefore always be used.

LITERATURE CITED

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DETERMINING THE PHASE ERROR AND MUTUAL INDUCTANCE OF AIR-CORED TRANSFORMERS AT HIGH FREQUENCIES

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The VNIIK (All-Union Scientific Research Institute of the Committee of Standards, Measures, and Measuring Instruments) has developed a method for measuring phase errors and mutual inductance of air-cored transformers at high frequencies.

The phase errors and mutual inductance of air transformers are measured in this method by means of a box of reference capacitances with a known small loss angle, a reference resistance box and a reference current transformer [1].

The schematic measuring circuit is shown in Fig.1.

At balance the following relation holds between the parameters of circuit elements:

$$j\omega M\dot{I}_1\,E^{-j\varphi} - j\,\frac{\dot{I}_1}{\omega C}\,E^{j\alpha} - \frac{\dot{I}_1}{k}\,r\,(1+\lambda)=0, \tag{a}$$

where M is the measured mutual inductance of the air-cored transformer; $\dot{I}_1$ is the current in the primary winding of the air-cored transformer; ω is the angular frequency of the current; C is the capacitance of the reference box; r is the value of the reference resistance; φ is the phase error of the air-cored transformer; α is the loss angle of the reference capacitance box; k is the ratio of the reference current transformer; $\lambda = f + j\delta$ is the complex error of the refer-