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EVALUATION OF ACCURACY IN MEASURING NON-SINUSOIDAL VALUE BY DEVICE OF MAGNETIC AND ELECTRIC SYSTEM

The paper considers the problem of measuring currents and voltages of non sinusoidal forms. There had been set and solved mathematical model of the device of magnetic and electrical system during measuring signals of complicated form. It had also been shown that during measuring of non sinusoidal currents and voltages there appears the considerable error of measuring.

Key words: *sinusoidal currents and voltages, mathematical model, error of measuring, measuring device, measuring values.*

Introduction. Recently much attention has been paid to the issue of measuring of non sinusoidal values. Such tasks appear during measurements in devices of power transformation equipment which, following their characteristics are non linear elements, therefore voltages and currents of complicated non-harmonica form flow through them. Means of measurement, which are used during measurements of such values, which are the constituent element of the industrial samples of power transformers do not satisfy the requirements as for the accuracy of measuring such values.

Such problem is met during measurements of directed currents and voltages, controlled and no controlled rectifier. These devices are built so, that the above values are of pulsing character and have non sinusoidal form, and their harmonica content depend on different modes of operation of rectifier and its loading. Such values are mostly measured by electrical and mechanical devices of magnetic and electric system which measures the average value. [1] The researches, however, conducted in [2-4] showed that during measuring of constant values with the considerable variable component the above devices do not ensure the necessary accuracy in measurement. The error in measuring depend on the form of measuring value and increases with the increase if the variable of non sinusoidal component is up to 10 – 15 %.

That is, with the availability of variable component of the measured value the arrow of the device deviates by the angle less then the angle which answers the average value of this value. This is due to the mechanical peculiarities of the device itself, which does not consider the equation of device transformation. That is why there appears a task of creation of the mathematical model of the device of the given system, which should not take into consideration the mechanical properties of the device during measuring the direct pulsing currents and error estimation of measuring the above values with its help.

The objective of the suggested work is the evaluation of the accuracy of measuring currents and voltages of standard forms (rectangular, triangular, trapezoid etc.) as well as real forms which take place in devices of transforming equipment

Material and results of the researches.

With the objective to estimate the error of measuring of the above values there had been created the mathematical model of the device of this system, which considers its mechanical peculiarities. This mathematical model is a differential equation of the second order, in the right part of which there is the dependence of currents on time:

$$J \cdot \frac{d^2\alpha}{dt^2} + P \cdot \frac{d\alpha}{dt} + W \cdot \alpha = BS\omega \cdot i(t)\,, \tag{1}$$

where J – moment of inertia in the movable part, P – coefficient of frame soothing W – specific counteracted moment of spring , B – magnetic induction, created by the constant magnet in the chink, S – square of the frame, ω – number of windings in the coil , i(t) – current which flows in the coil.

The solution to this equation is the dependence of the device’s arrow deviation angle change in time during the flow of the currents of different form through the coil of the device. Comparing them with the value of the angle of arrow deviation during the flow of the direct current equal by its value to the average meaning of pulsing current of the corresponding form, we receive the error which appears during the measuring of currents of such form.

This work uses the ammeter M330 for the researches. It has such mechanical characteristics(1), that the equation will look like:

$$0{,}87\cdot 10^{-7}\cdot\frac{d^2\alpha}{dt^2}+9{,}835\cdot 10^{-7}\cdot\frac{d\alpha}{dt}+185{,}5\cdot 10^{-9}\cdot\alpha=455{,}36\cdot 10^{-6}\cdot i(t) \qquad (2)$$

Let's analyze the behavior of the arrow during flowing of ideal direct current through the frame of the device, and , for example, trapezoid signal, analytical writing of which is represented by harmonical series:

$$i_2(t)=30\cdot 10^{-3}+\frac{12\cdot 30\cdot 10^{-3}}{\pi^2}(\sin(\frac{\pi}{3})\sin(\omega t)+\frac{1}{3^2}\sin(\frac{2\pi}{3})\sin(3\omega t)+\frac{1}{5^2}\sin(\frac{5\pi}{3})\sin(5\omega t)+...) \qquad (3)$$

The researched currents are represented graphically on fig.1, which shows that the average value of the function of non sinusoidal current equals on the value to the ideal direct current and makes up 30 мА.

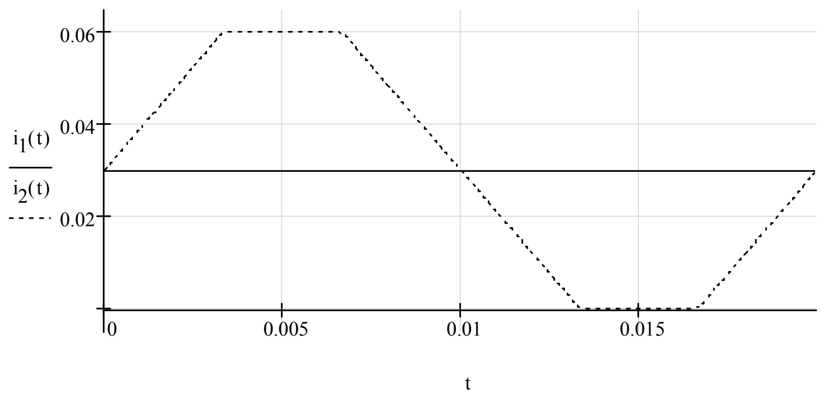


Fig. 1 – Form of the researched signals

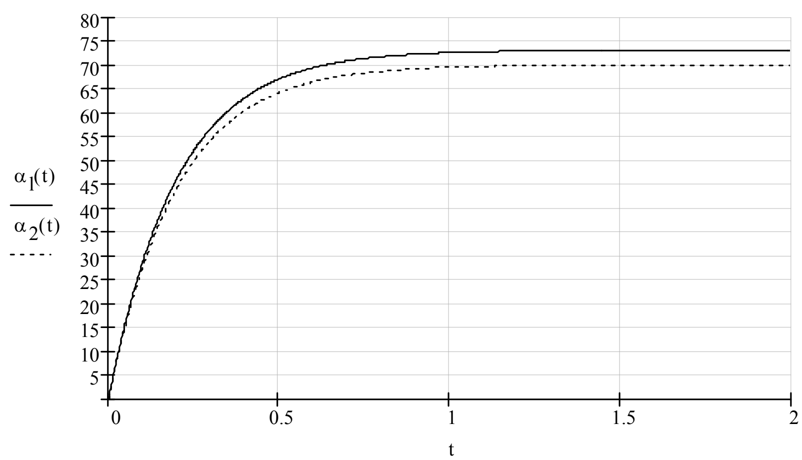


Fig. 2 – Graphs of changes of arrow deviation angle in time

Fig. 2 presents the graphic solution of the mathematical model for the two above forms of the measured signals. As is seen from the obtained dependences, the final arrow deviation angle is different for the signals of different forms, though their average value is equal. Deviation angle with the influence of the direct current makes up 73° and it may be considered as the angle which answers the average value, and the second dependence simulates the arrow behavior during the complicated form current flow through the coils of the device, which, in the result, deviated by the angle of $69{,}9^{\circ}$. Therefore these dependences allow to find relative error of measuring of trapezoid signal:

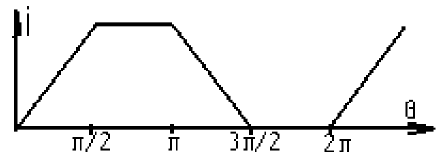
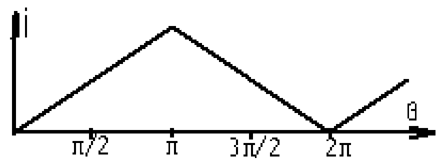
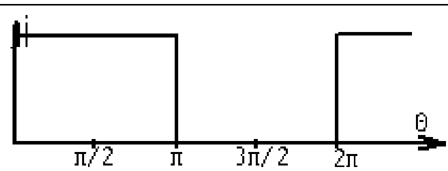
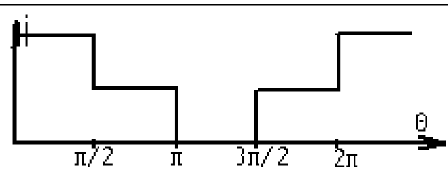
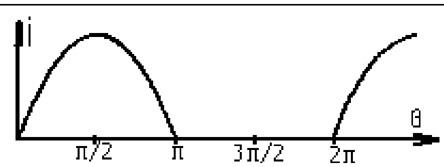
$$\delta = (73 – 69,9) * 100~\% / 73 = 4,2~\%.$$

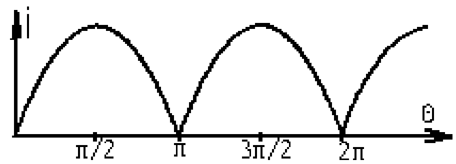
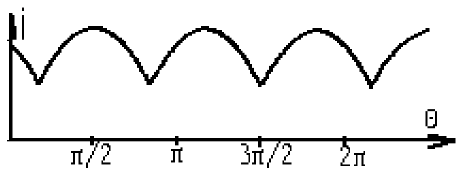
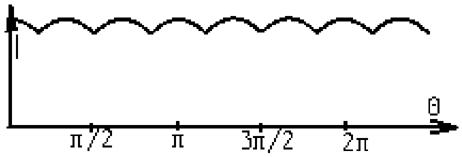
Let us conduct the analogical calculations for the signals of the regular shape. Table 1 presents graphical presentation of signals, analytical writing in the kind of trigonometric series as well as the results of simulation with the evaluation of the relative error, which appear during measuring current of the corresponding form.

The obtained results show that measuring of nonsinusoidal current and voltage is accompanied by significant deviations which go up to 10 %, which greatly exceeds the accuracy class of the device under research and depend on the form of the measuring signal. These errors are conditioned by mechanical peculiarities of the device and coincide with the results of experimental researches conducted in [2-4].

Table 1

Calculation results of errors of measuring currents of different forms.

№	Current form and its analytical representation	Arrow deviation		Error %
		Direct current	Current of the set form	
1	 $i(t)=30\cdot10^{-3}+\frac{12\cdot30\cdot10^{-3}}{\pi^2}(\sin\frac{\pi}{3}\cdot\sin\omega t+\frac{1}{9}\sin\pi\cdot\sin3\omega t+\frac{1}{25}\sin\frac{5\pi}{3}\cdot\sin5\omega t+...)$	73	69,9	4,2
2	 $i(t)=30\cdot10^{-3}+\frac{8\cdot30\cdot10^{-3}}{\pi^2}(\sin314t-\frac{1}{9}\sin3\cdot314t+\frac{1}{25}\sin5\cdot314t-...)$	73	68,5	6,1
3	 $i(t)=30\cdot10^{-3}+\frac{4\cdot30\cdot10^{-3}}{\pi}(\sin\omega t+\frac{1}{3}\sin3\omega t+\frac{1}{5}\sin5\omega t+...)$	73	66,3	9,2
4	 $i(t)=30\cdot10^{-3}+\frac{4\cdot30\cdot10^{-3}}{\pi}(\sin\frac{\pi}{3}\cdot\cos\omega t+\frac{1}{3}\sin3\cdot\frac{\pi}{3}\cdot\cos3\omega t+\frac{1}{5}\sin5\cdot\frac{\pi}{3}\cdot\cos5\omega t+...)$	73	66,7	8,4
5	 $i(t)=60\cdot10^{-3}(\frac{1}{2}+\frac{\pi}{4}\cdot\cos\omega t+\frac{1}{1\cdot3}\cos2\omega t-...)$	73	63,4	13,2

6	 $i(t) = 60 \cdot 10^{-3}(\frac{1}{2} + \frac{1}{1 \cdot 3}\cos 2\omega t - \frac{1}{3 \cdot 5}\cos 4\omega t + ...)$	73	70,4	3,5
7	 $i(t) = 60 \cdot 10^{-3}(\frac{1}{2} + \frac{1}{2 \cdot 4}\cos 3\omega t - \frac{1}{5 \cdot 7}\cos 6\omega t + ...)$	73	72,1	1,3
8	 $i(t) = 30 \cdot 10^{-3}(1 + \frac{2\cos 6\omega t}{5 \cdot 7} - \frac{2\cos 12\omega t}{11 \cdot 13} + ...)$	73	72,7	0,37

Conclusions

During the research there had been created the mathematical model of the device of magnetic and electrical system for measuring nonsinusoidal current and voltage. Its solution for the serial device showed that during measuring signals of complicated form there appears the considerable error exceeding the accuracy rating for this device. The created model substantiates mathematically the experimental data received on previous stages of the research. The results, obtained with its help may be used for evaluation and correction of measuring errors of nonsinusoidal current and voltage by magnetic and electrical measuring devices. In particular the results, received in researches № 5 – 8 may be used for the evaluation of measuring accuracy in devices of power transforming devices with current and voltage of the above forms.

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