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UDC 621

AN APPROXIMATE METHOD OF DETERMINING THE COEFFICIENT OF VOLTAGE HARMONIC DISTORTION

ULADZISLAU BAZEHSKI, ALIAKSANDR VIARSHININ
Polotsk State University, Belarus

This article is devoted to investigations of different methods of determining the coefficient of voltage harmonic distortion. The paper contains approximate expression for the calculation of the coefficient of harmonic distortion of the voltage according to the testimony of voltmeters and tasks for its further metrological studies and checking.

One of the important tasks of modern electric power is to control and maintain the quality of electricity (SCE) in accordance with GOST 13109 - 97[1], as mismatch SCE established requirements leads to a significant economic loss[2].

For an objective quality evaluation of electricity SCE should be measured instrumentally, using the appropriate measuring instruments. SCE measurement is possible in part by a general-purpose instrumentation [3] or using special measuring instruments for measuring the SCE [4].

Of course, special measuring instruments of SCE are favorable because they are universal, measured practically the entire spectrum of the SCE, are complying with the requirements of GOST metrological characteristics, able to record and store information about the measured SCE etc. Meanwhile, this equipment is complex, expensive, often intended for stationary installation and not always mobile. Therefore, if necessary, and in the absence of special instruments for measuring SCE GOST allow the measurement of certain SCE using a general-purpose instruments. [1]

Really, measuring instruments of SCE are devices that actually measure voltage, i.e. to its original purpose are voltmeters. However, not all SCE can be measured with a voltmeter. In addition, measurement of the SCE frequency counters and spectrum analyzers are necessary [4].

Such SCE as steady voltage deviation δU_s , the depth of the voltage dip δU_d , voltage asymmetry on the reverse sequence K2U and zero sequence K0U can be measured with a voltmeter [5] . Information about measuring the coefficient of harmonic distortion using a voltmeter cannot be found in the technical literature.

Harmonic distortion of the voltage according to [1] estimated coefficient voltage harmonic distortion K_{Ui} and coefficient of n-th harmonic voltage component. Of these coefficients using voltmeters can try to determine only the coefficient of voltage harmonic distortion K_{Ui} .

Harmonic distortion coefficient voltage K_{Ui} according to [1] is defined as:

$$K_{Ui} = \frac{\sqrt{\sum_{k=2}^{40} U_k^2}}{U_1} \cdot 100\% \qquad (1)$$

where U_k – active value of the higher harmonics;
U_1 – active value of the first harmonic

For simplification, we introduce a replacement:

$$U_{vg} = \sqrt{\sum_{k=2}^{40} U_k^2} \qquad (2)$$

For the ideal sinusoidal voltage the relation between the amplitude and the current value in the form is typical [6]:

$$\frac{U_{1m}}{U_1} = \sqrt{2} \qquad (3)$$

Estimate of the coefficient of voltage harmonic distortion to build on the default logical expression (3), where:

$$\frac{U_{Dm}}{U_D} \neq \sqrt{2} \quad (4)$$

where U_{Dm} – measured maximum voltage;

U_D – RMS measurement of distorted sine wave.

Rms value of the distorted sine wave can be expressed as [6]:

$$U_D = \sqrt{U_1^2 + \sum_{k=2}^{40} U_k^2} \quad (5)$$

Considering (2):

$$U_D = \sqrt{U_1^2 + {U_{vg}}^2} \quad (6)$$

Distorted voltage amplitude is equal to the algebraic sum of the amplitudes of harmonics with phase shifts, and therefore $U_{Dm} \neq U_{1m}$.

Rms value of the voltage distortion U_D can associate an ideal sinusoidal voltage with an amplitude $U_E = \sqrt{2} \cdot U_D$, and the current value $U_E = U_D$.

Then the difference between the amplitude of the equivalent sinusoidal voltage and voltage distortion will be proportional to the total current value of the higher harmonics U_{vg}:

$$Uvg = \frac{U_{Em} - U_{Dm}}{\sqrt{2}} = U_D - \frac{U_{Dm}}{\sqrt{2}}$$

Then, on the basis of the above mentioned, with (1) may provide an approximation formula rated voltage harmonic distortion factor as:

$$\mathrm{K}_{U_I} = \left|1 - \frac{U_{Dm}}{\sqrt{2} \cdot U_D}\right| \cdot 100\% \quad (7)$$

To determine the suitability of this formula it is necessary first to explore its systematic error in the determination of the coefficient of voltage harmonic distortion, and secondly – in which ranges of values of this coefficient can be used. Furthermore, we should analyze influence of instrumental errors voltmeters accuracy of determination of the desired coefficient.

For these investigations as a test of the distorted sine wave AC voltage should be taken with a known harmonic structure, and known in advance the exact value of coefficient voltage harmonic distortion. According to the research may require correction of the expression (7).

Effect of instrumental errors voltmeters with the rms value of the distorted sinusoidal voltage U_D and U_{Dm} amplitude value can be estimated by standard methods. All research can be done by numerical modeling in any convenient software environment.

For an approximate factor measurement voltage harmonic distortion can be measured with a voltmeter the rms value of the distorted sinusoidal voltage and its amplitude values. Previously an approximate expression for calculating this coefficient has been obtained as:

$$\mathrm{K}_{U_I} = \left|1 - \frac{U_{Dm}}{\sqrt{2} \cdot U_D}\right| \cdot 100\% \quad (8)$$

where U_{Dm} – measured maximum voltage;

U_D – RMS measurement of distorted sine wave.

To estimate the systematic error of expression coefficient of voltage harmonic distortion in the form (8) as a test of the distorted voltage use voltage harmonic composition known in advance, the current value of the voltage, its amplitude value and the known exact value of the coefficient of harmonic distortion. We take as a distorted test trapezoidal alternating voltage with a voltage amplitude U_{Tm} and a changing function of a trapezoidal angle α in the range from 40° to 60°.In favor of this choice is possible to carry that this form is closest to the sinusoidal and has a coefficient of harmonic distortion close to real conditions.

Assessment of systematic error of expression (8) will hold a numerical method in Mathcad software environment and the provision of information in graphical form.

Therefore distorted function alternating voltage is [7]:

$$u = \frac{4 \cdot U_{Tm}}{\pi \cdot \alpha}\left[\sin\alpha \cdot \sin\omega \cdot t + \frac{1}{3^2}(\sin 3\alpha \cdot \sin 3\omega \cdot t) + \frac{1}{5^2}(\sin 5\alpha \cdot \sin 5\omega \cdot t) + \cdots\right] \quad (9)$$

where U_{Tm} - amplitude value of voltage;

α - angle of fracture trapezoidal function.

Rms value of the trapezoidal voltage equal to:

$$U_T = U_{Tm}\sqrt{1 - \frac{4\cdot\alpha}{3\cdot\pi}} \tag{10}$$

First harmonic amplitude trapezoidal voltage is [7]:

$$U_{1m} = \frac{4\cdot U_{Tm}\cdot\sin\alpha}{\pi\cdot\alpha} \tag{11}$$

The total rms value of the higher harmonics find as:

$$U_{v\Sigma} = \sqrt{U_T - U_1} \tag{12}$$

The exact value of the coefficient of distortion of trapezoidal voltage:

$$K_{U_T} = \frac{U_{v\Sigma}}{U_T}\cdot 100\% \tag{13}$$

The approximate value of the coefficient of harmonic distortion trapezoidal voltage according to (8):

$$K_{U_A} = \left|1 - \frac{U_{Tm}}{\sqrt{2}\cdot U_T}\right|\cdot 100\% \tag{14}$$

Let U_{Tm}= 100 V., and α varies from 40° ($\frac{4\pi}{18}$) to 60° ($\frac{\pi}{3}$) with step 1° ($\frac{\pi}{180}$). With the help of Mathcad receive the results of the calculation of exact values of the coefficient (13), and the approximate coefficient (14) in the form of graphs, which are shown on Fig.1.

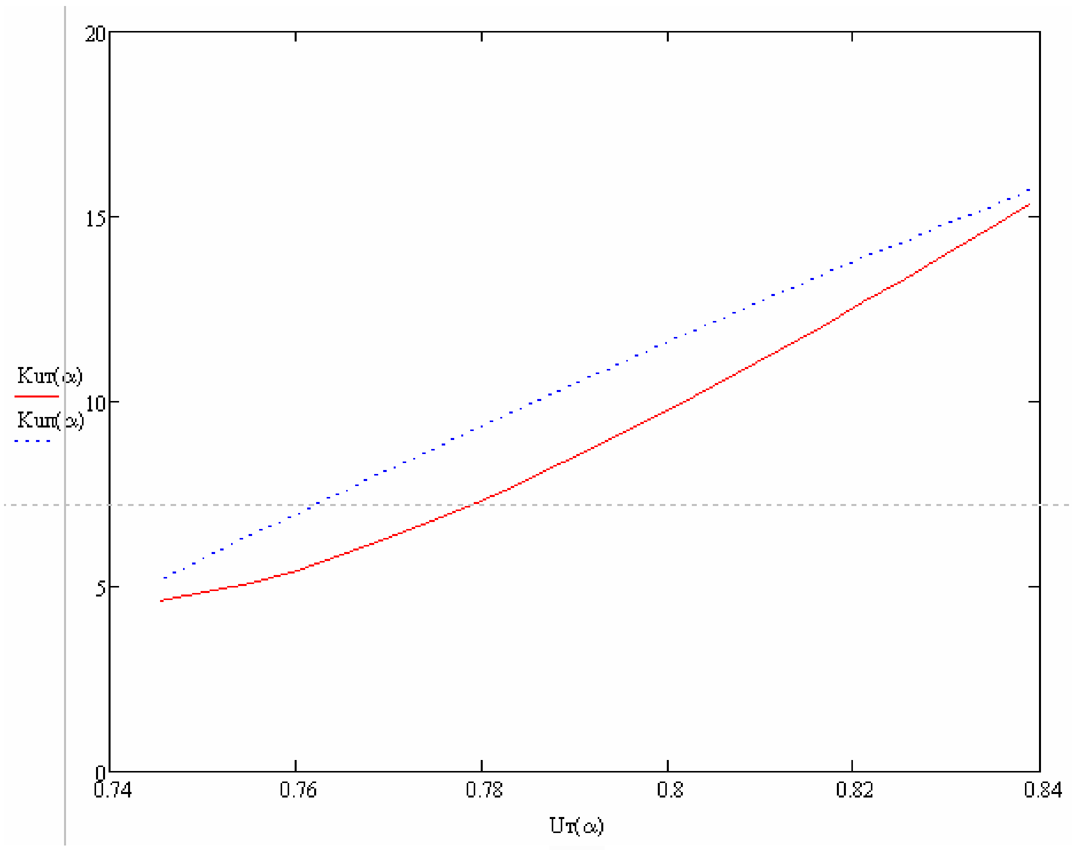

Fig.1

Dependence of the difference of exact and approximate values of the coefficient of harmonic distortion for trapezoidal voltage by changing the angle α in the same range is shown in Figure 2.

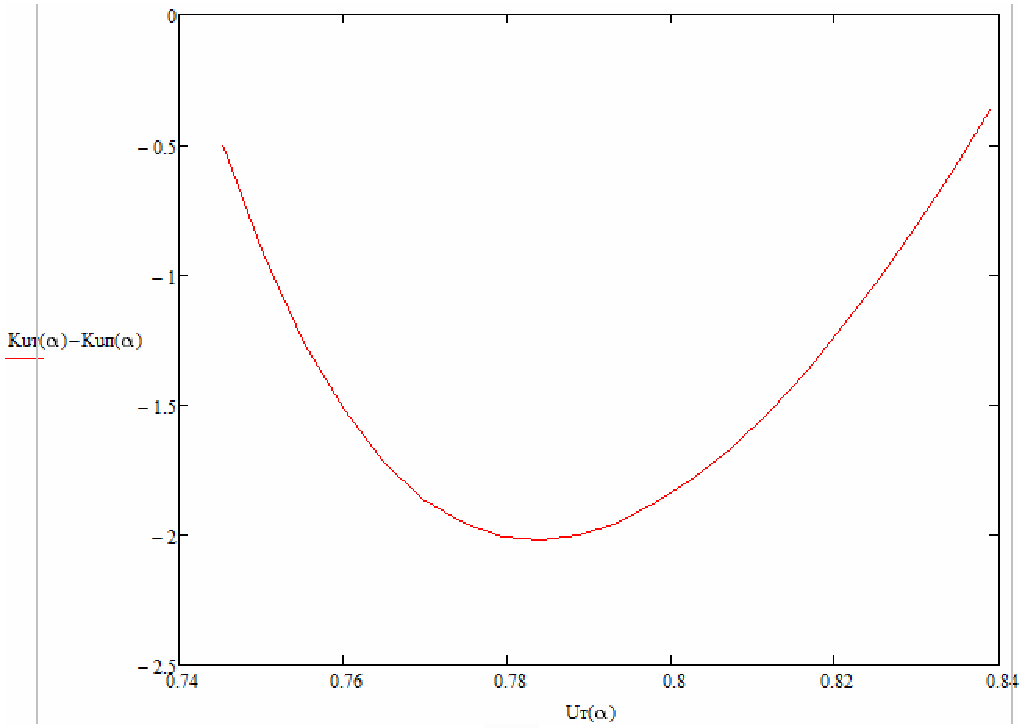

Fig.2

The obtained dependence represents the absolute methodological error of calculation of the required coefficient of harmonic distortion voltage for the expression (8).

To reduce this error in expression (8) it is advisable to introduce the offset and the average magnitude of this error. Then, in accordance with Fig. 2 a revised formula to calculate the coefficient harmonic distortion of the voltage can be represented as:

$$K_{U_i} = \left|1 - \frac{U_{Dm}}{\sqrt{2} \cdot U_D}\right| \cdot 100\% - 1.3 \qquad (15)$$

Dependence of the difference of exact and approximate values of proximate coefficient harmonic distortion (15) for the trapezoidal voltage by changing the angle α in the same limits is shown in Figure 3.

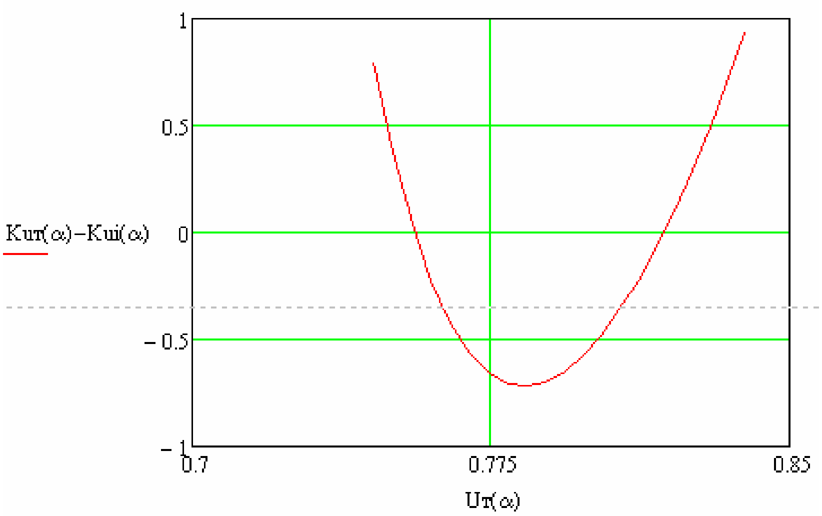

Fig.3

From the analysis of the graph (Figure 3) it should be said that when the angle α trapezoidal functions ranging from 40^0 $(\frac{4\pi}{18})$ to 60^0 $(\frac{\pi}{3})$ with step 1^0 $(\frac{\pi}{180})$ the methodical error of determining the coefficient of harmonic distortion of no more than 1.3%.

Thus, if the sum of simultaneously acting amplitudes of harmonics A3 + A5 + A9 + A7 + A11 is equal to or less than 8% of the amplitude of the first harmonic, the coefficient harmonic distortion of voltage does not exceed 7%, and the absolute error of its determination the formula (15) is not more 1.3%.

With a coefficient of the voltage harmonic distortion up to 7% of the proposed formula for determining the coefficient work and allows us to estimate nonsinusoidal voltage with an absolute error less than 1.3%.

This is verified and the trapezoidal waveform voltage in the range of angle changes from 40 degrees to 60 degrees, and at a voltage in the form of an arbitrary mixture of harmonics up to k = 11 inclusive.

In this article an attempt is made to approximate determination of the coefficient harmonic distortion voltage indications of the voltmeter, measure the rms value of the distorted sinusoidal voltage U_D and peak value U_{Dm} the same voltage.

We received approximate expression (7) for the calculation of the coefficient of harmonic distortion of the voltage according to the testimony of voltmeters.

The formulated tasks for the metrological studies obtained expression to determine the possibility of practical application of the obtained formulas for calculation of the coefficient of the harmonic distortion of the voltage according to the testimony of voltmeters.

The expression (8) can be used for approximate assessment of nonsinusoidal periodic voltage via the measured RMS voltage and of its peak value in a limited range of coefficient for voltage harmonic distortion up to 7% with an absolute error no more than 1,3%.

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DETERMINATION OF THE FINE STRUCTURE INFORMATION SIGNS OF THE SPEECH SIGNAL

IRYNA BURACHONAK, VLADZIMIR ZHELEZNYAK
Polotsk State University, Belarus

The paper presents the research results of methods to assess primary features of the speech signal: the frequency of the mail tone and formants. Deviation of the calculated values of the main tone investigated by means of these methods was ± 1,37%. The most resistant to noise method for estimating the frequency of the man tone is the autocorrelation method. The paper also presents the research results of methods for determining the basic phonemes of Russian formants. According to the research the first phoneme of Russian formant "a" is the most resistant to noise.

The determination of primary features of the speech signal, such as the period (or frequency) of the main tone (MT) F_0 , is a necessary criterion for determining the presence of speech in high level noise. The determination of the formants $F_1, F_2, \ldots, F_n$ is the source of additional, but not less important information, not only about the speech signal, but also about the individual signs of the speaker. The analysis of works by L.R. Rabiner, R.V. Shafer, J. Markel, A.H. Gray, I.O. Arkhipova, V.B. Gitlin, V.G. Mikhailov, L.I. Zlatoustova, A.N. Golubinsky, S.I. Rasskazova [1-6] and others shows that existing methods for determining the frequency of the main tone and formants of speech were tested in normal conditions and practically were not studied in terms of influencing factors. Therefore, the evaluation of primary features of elements of the speech signal such as the frequency of the main tone and formants in terms of influencing factors, is one of the most important tasks of the design and control of communication equipment and systems for the protection of speech information from losses by technical channels [7].