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NON-STATISTICAL APPROACH TO ESTIMATING THE UNCERTAINTY OF DYNAMIC MEASUREMENTS

When reporting on the results of dynamic measurements, it is necessary to provide a quantitative assessment of the quality of the experiment in order that its reliability may be correctly appraised [1-7]. Without such a reference value, the results of dynamic measurement can neither be compared with other equivalent studies, nor with standard reference values. It is therefore necessary to develop a uniform and understandable assessment methodology of the quality characteristics of dynamic measurements.

If the equation of the measuring transmitter is:

$$Y = K_C X, \tag{1}$$

where X – a physical quantity to be measured (input signal); K_C – transformation coefficient of the measuring device; Y – measurement result (output signal).

Then mathematical expectation of the input signal equals to M[X], and mathematical expectation of the output signal will equal:

$$M[Y] = K_C M[X], \tag{2}$$

where M[Y] and M[X] – mathematical expectations of the output and input signals of measuring device correspondingly.

Spectral density of the input signal X(t) has the equation [1, 2]:

$$H_X(\omega) = \lim \frac{1}{2T}\left|X(j\omega)\right|^2 \text{ when } T \to \infty, \tag{3}$$

where X(jω) – Fourier image, received by substitution of the meanings onjω in the operator image X(s); T – observation time; ω = 2πf.

Similarly the equation for spectral density of output signal can be represented as:

$$H_Y(\omega) = \lim \frac{1}{2T}\left|Y(j\omega)\right|^2 \text{ when } T \to \infty. \tag{4}$$

Images ratio of output and input meanings results in the equation of measuring device transfer function [2, 3]:

$$K_C(s) = \frac{Y(s)}{X(s)} = \frac{\sum_{k=0}^{m} B_k s^k}{\sum_{q=0}^{n} A_q s^q}, \tag{5}$$

where Y(s), X(s) – operators images of output Y(t) and input X(t) signals correspondingly; k, q – derivative or derfrom Y и X correspondingly; A_q, B_k – coefficients of differential equation.

Therefore it follows that [1, 3]

$$H_Y(\omega) = \left|K_C(j\omega)\right|^2 H_X(\omega), \tag{6}$$

where $K_C(j\omega)$ – frequency characteristics of measuring transformer.

We can determine the uncertainty of output signal on dynamic measurements as a square root from integral of output signal spectral density according to all available frequencies [1, 5]:

$$u_D = \frac{1}{\sqrt{2\pi}}\sqrt{\int_{-\infty}^{\infty}\left|K_C(j\omega)\right|^2 H_X(\omega)d\omega} = \frac{1}{\sqrt{2\pi}}\sqrt{\frac{1}{2T}\int_{-\infty}^{\infty}\left|K_C(j\omega)\right|^2\left|X(j\omega)\right|^2 d\omega}, \tag{7}$$

where $\left|K_C(j\omega)\right|$ – modulus of measuring device frequency characteristics being used for dynamic measurement.

Modulus of measuring device frequency characteristic is determined by the formula:

$$\left|K_C(j\omega)\right| = \sqrt{a^2(\omega) + b^2(\omega)}, \tag{8}$$

where $a(\omega)$, $b(\omega)$ – real and imaginary parts of frequency characteristic correspondingly $K_C(j\omega)$.

Spectral function of the input signal X(jω) is linked to its time function X(t) by Laplace equation:

$$X(j\omega) = \int_0^{\infty} X(t) e^{-j\omega_0 t} dt \,, \tag{9}$$

where ω_0 – circular frequency of input signal.

Infinity sign can be substituted by summary observation time T when time interval is final.

Thus, under dynamic measurement uncertainty is defined as a factor of measurement uncertainty, which is caused by a response by the measurement means to the frequency (speed) of the measurement of the input variable, which itself depends on the dynamic properties of the measurement means and the frequency spectrum of the input signal.

So the uncertainty introduced by the limited capacity of the measuring device on dynamic measurements can be evaluated on the basis of the model equation of input signal spectral function and frequency characteristics of the used device by the formula (7).

Conclusions. For the first time offered to a non-statistical approach to estimating the uncertainty of dynamic measurements, which complies with international standards for assessing the quality of measurements.

References

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