EVALUATION OF UNCERTAINTY OF THE RESULTS OF DYNAMIC MEASUREMENTS, CONDITIONED THE LIMITED PROPERTIES USED THE MEASURING INSTRUMENT

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Abstract. Proposed the spectral of method to assessing the dynamic uncertainty of measurement devices which allows to investigate the accuracy of changes in the dynamic operation conditions in the frequency domain, estimate the amplitude dynamic uncertainty based on frequency characteristic and the spectral function of the input signal.

Keywords: dynamic uncertainty of measurement devices, quality assurance of dynamic measurements, spectral function, frequency characteristic.

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 signalX(t) has the equation [1]:

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

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]:

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

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

Therefore it follows that [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, 3]:

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

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:

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

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

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

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

where ω_0 – circular frequency of input signal.

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

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

References

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