ADAPTIVE ALGORITHMS FOR QUANTIZATION ERROR NORMALIZATION OF DIGITAL ENCODER-BASED TACHOMETERS

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Abstract. The authors' analysis of the instantaneous and average values digital tachometer quantization error assessment in the dynamic measurements of angular velocity with an encoder allowed for the first time to obtain a mathematical model for calculating the critical speed numerical value for an exponential mathematical model that adequately describes the transient process of the electric machine's operation. It was found that the value of the critical speed depends on the resolution z of the encoder, the quantization frequency, the duration of the sample time interval, which variation allows to measure the angular velocity with a predetermined normalized value of the quantization error during the transient process of the electric machine from the lower to the upper measurement limit.

Keywords: Electric Machine, Transient Characteristic, Encoder, Transfer Function, Quantization Error Equation, Critical Speed, Adaptive Algorithm, Microcontroller Tachometer, Normalized Value of Quantization Error.

Introduction. Currently, to intensify the testing of electric machines (EM), most of the research is focused on the acceleration of the tests carried out in the "no load" experiment. The main one here is the transient characteristic (variable angular velocity over time n(t)), which is obtained in the dynamic mode of measuring object operation (electric machine) with practically zero moment of resistance on its shaft (MC≅0) [1-5]. A feature of the experimental studies of this characteristic is the determination with high accuracy in real time of the available dips, sudden emissions, synchronous dips, which significantly affect the vibroacoustic characteristics of electric machines. This scientific and applied problem is solved by providing the maximum number of measurement results during the electric machine transient process, the quantization error of which during the measurement experiment should not exceed the normalized value.

The purpose of the work is to develop a criteria and embedded tools for implementing an adaptive algorithm for real time measuring angular velocity, which quantization error will not exceed a predetermined normalized value.

Formulation of the problem. Analysis of the dynamic measurements allows us to state the following: during the EM transient process, when the angular velocity increases from zero to the maximum value, the quantization error is a variable value.

Solving the problem. Based on the comparative characteristics of quantization errors of instantaneous and average values, a tachometer adaptive to changes in angular velocity is proposed, which provides its dynamic measurements in a wide range with a quantization error that does not exceed the normalized value.

To implement such an approach, it is first necessary to synthesize an algorithm for software support of hardware for the microcontroller (MCU).

If we equate the quantization errors of the instantaneous and average values of the tachometers considered above

$$\frac{60}{n \cdot z \cdot t_0}\,100\% = \frac{n \cdot z}{60 \cdot f_0}\,100\%, \tag{1}$$

then we will get a dependence for estimating the value of the critical speed n_c

$$n_c = \frac{60}{z}\sqrt{\frac{f_0}{t_0}}. \tag{2}$$

For $t_0 = 5 \cdot 10^{-2}\ s$, $f_0 = 5 \cdot 10^6\ Hz$ and $z = 1500$, the intersection point of the quantization errors δ_{qi} and δ_{qa} dependencies are shown in Fig. 1.

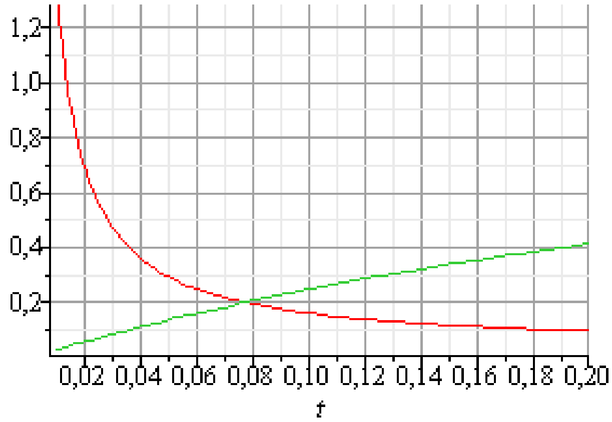

Fig. 1. To the question of determining the critical speed.

Based on (2) and Fig. 1, the following algorithm adaptive to changes in angular velocity is proposed:

If the measured current value of the angular speed is less than the value of the critical speed ($n \leq n_c$), then two microcontroller timers implement the algorithm of instantaneous values tachometer in "adjacent" intervals.

Under the condition $n > n_c$, the third timer of the microcontroller is programmed to the tachometer algorithm of average values.

Analysis (7) shows that f_0 and z for a specific schematic implementation are constant values. It is possible to vary only $t_0 \rightarrow var$, which allows you to set the required value of the critical speed n_c.

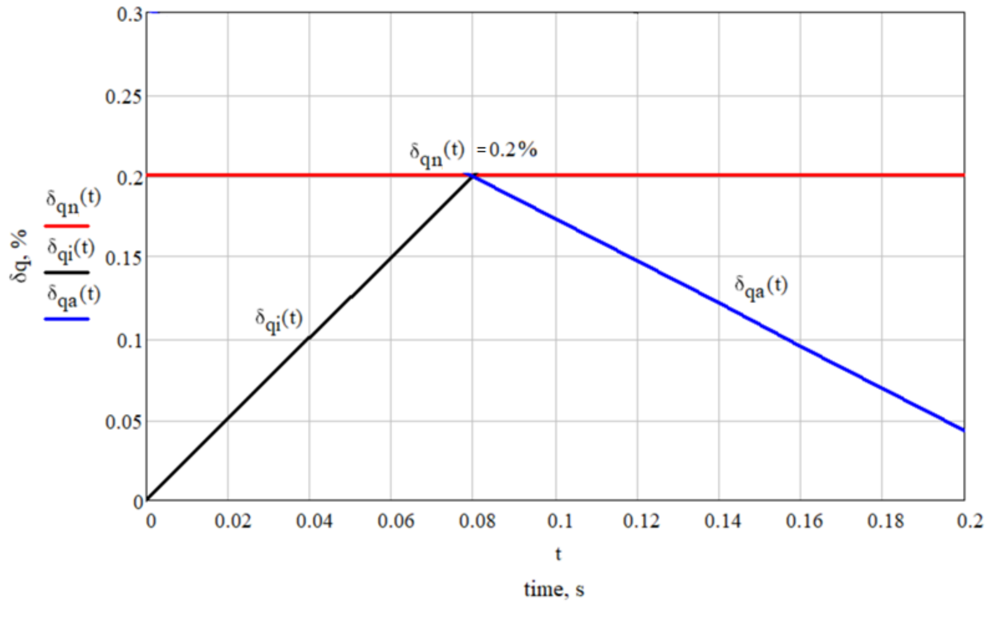

Fig. 2. Characteristics of the change in the normalized values of quantization errors

Conclusion. The analysis of the main metrological characteristics of instantaneous and average values digital tachometers made it possible to propose criterion, the hardware and software implementation of which provided the synthesis of an adaptive (for the changes in angular velocity inherent the EM transients) algorithm of quantization error normalization.

Formulated requirements for hardware and software implementation of a microcontroller tachometer, adaptive to the change in angular velocity during the EM transient, which are shown in its structural diagram.

The essential differences of the synthesized adaptive algorithm are as follows: the first stage – the measurement of the angular velocity is carried out in real time during the transient EM process; the second stage is the processing of the obtained results after the end of the measurement process (transient process).

The usage of the advantages of instantaneous and average values tachometers in one tool ensures the implementation of dynamic measurements with a predetermined normalized value of the quantization error (see Fig. 2). Such adaptive microcontroller tachometers are advisable to use in cases where at the beginning of the transient characteristic of EM, the angular velocity changes significantly over time.

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