The means of measuring the output coordinates for the three-phase asynchronous electric motor

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***Abstract* - The article considers indirect control methods for the mechanical coordinate's measurement of a three-phase asynchronous electric motor in the dynamic modes, which detects the temperature of the stator winding conductors and the basic frequency of a stator voltage.**

Keywords— asynchronous electric motor, angular speed of rotation, torque, indirect control

I. INTRODUCTION

At present, during elaboration, testing and exploitation of the electric motors it is necessary to measure and register the output parameters such as the rates of rotation and moment on the roller. The elaborated methods and devices for measuring these parameters don't meet the requirements. They are constructed on the bases of supplementary installed or connected with the electric motor micromachines of direct-current or alternating-current supply [3, 5, 8, 9]. These micromachines are very expensive and their design is complicated. Moreover their careful mechanical coupling with rotation parts of the electric motor is required.

Therefore in a number of cases their application is inexpedient due to their design or cost constraints. This leads to the necessity of elaboration, creation and application of other means for control of coordinates of the technological machinery with small content of material and power resources.

Therefore, it is actual to use other means of mechanical coordinates monitoring of general industrial devices, such as indirect control devices, when they are applied, these disadvantages are eliminated [1, 2, 4, 6, 7].

The methods for the measuring the angular velocity of rotation and twisted moment of the three-phase asynchronous electric motor were designed. They are easy to use and provide the required accuracy of the result.

II. PROBLEM STATEMENT

In this regard, the objective of the research is to consider the options for devices of indirect control of coordinates - the angular velocity of rotation and torque of a three-phase squirrel-cage asynchronous motor. Moreover, unlike the existing devices, in the proposed ones the control is simplified, and there is a possibility of accounting for temperature of conductors of a stator winding, the frequency of a fundamental harmonic of the stator voltage, temperature coefficient, which depends on the conductor material, that improves the accuracy of the coordinates of the three-phase asynchronous motor.

III. MATHEMATICAL MODEL

Mathematical model to the angular velocity of rotation $\omega(t)$ of a three-phase squirrel-cage motor describes the equation

$$\omega(t) = \omega_{mes}(t) \cdot \left[1 + \Delta\omega_{\text{int}}(t) + \Delta\omega_{dif}(t)\right],$$

where

$$\omega_{mes}(t) = \sqrt{3} \cdot [u_a(t) - (z + R'_{r\alpha}) \cdot i_a(t)] / \\ /(\int_0^{1/f} (z \cdot [i_a(t) + 2 \cdot i_b(t)] - [u_a(t) + 2 \cdot u_b(t)]) dt - \\ - L_\beta \cdot [i_a(t) + i_b(t)])$$

the measured value of the angular velocity;

$$\Delta\omega_{\text{int}}(t) = \frac{\int_0^{1/f} [u_a(t) - z \cdot i_a(t)] dt}{T_r' \cdot [u_a(t) - (z + R'_{r\alpha}) \cdot i_a(t)]} \text{ -}$$

the dynamic integral component of the relative value of the angular velocity;

$$\Delta\omega_{dif}(t) = \frac{L_\beta \dfrac{di_a(t)}{dt}}{u_a(t) - (z + R'_{r\alpha}) \cdot i_a(t)} \text{ -}$$

the dynamic differential component of the relative value of the angular velocity;

i_a, i_b, u_a, u_b – currents and voltage of correspondently phases A and B of the stator winding;

f – the frequency of a fundamental harmonic of the voltage supply of an asynchronous motor;

$R'_{r\alpha} = R'_r \cdot \alpha$ - active reduced resistance of stator winding taking into account α;

where R'_r - active reduced resistance of a stator;

$\alpha = \frac{L_S}{L'_r}$ - the coefficient equals the ratio of total inductance of the stator winding L_s to reduced total inductance of the stator winding L'_r;

$L_\beta = L_\mu \cdot \beta - L_s$ - the inductance taking into account the coefficient β;

Where L_μ - mutual inductance of stator and rotor windings;

$\beta = \frac{L_\mu}{L'_r}$ - the coefficient is equal to the ratio of mutual inductance L_μ to the reduced total inductance of the rotor winding L'_r;

$T'_r = \frac{L'_r}{R'_r}$ - the rotor time constant.

Active resistance of the stator winding taking into account the temperature coefficient α_t is determined by the following expression:

$$z = R_s \cdot \left[1 + \alpha_t \cdot (t_{con} - 20)\right];$$

where R_s - active resistance of the stator winding;

t_{con} - the temperature of conductors of the stator winding of the asynchronous motor.

Mathematical model to the value of the torque of a three-phase squirrel-cage asynchronous motor describes the equation

$$M(t) = \sqrt{3} \cdot p_n \cdot (i_a(t) \cdot \int_0^{1/f} \left[u_b(t) - z \cdot i_b(t)\right] dt - ,$$
$$- i_b(t) \cdot \int_0^{1/f} \left[u_a(t) - z \cdot i_a(t)\right] dt)$$

where p_n – the number of pairs of motor poles.

IV. EXPERIMENTAL SETUP AND METHODS

Taking into account the known values of the stator and rotor windings resistance the torque and the angular velocity of the asynchronous motor are defined.

To determine the output coordinates it is necessary to measure the instantaneous values of phase currents and voltages, the temperature of the stator winding conductors, the frequency of the fundamental harmonic of stator voltage.

According to the obtained data, the electromagnetic torque and the angular velocity of the asynchronous motor rotation are calculated.

To determine the angular velocity of rotation and torque of a squirrel-cage asynchronous motor a simulation model of a mechanical coordinates measuring device in the software package Matlab has been created.

Moreover, the studies have been carried out for the devices discussed in this article, as well as devices [1,2], which do not take into account the effect of temperature of the stator winding conductors and fundamental frequency of the stator voltage.

V. RESULTS AND DISCUSSION

The comparison of characteristics of the angular velocity of rotation $\omega(t)$ and the torque $M(t)$ obtained by using measuring devices [1, 2], with the characteristics of the angular velocity and the torque of rotation obtained by the proposed device indicates that the accuracy of measurement in the first case is 94-95%, and in second - 96-97%.

The table 1 shows the results of the simulation modeling for a squirrel-cage asynchronous motor 4A50A4 P_2=60 W, $U_{н.ф.}$=220 V, 2p=4, f=50 Hz.

TABLE 1. THE RESULTS OF THE SIMULATION MODELING FOR A SQUIRREL-CAGE ASYNCHRONOUS MOTOR 4A50A4

Title	ω_{max}, rad/s	M_{max}, N · м
The direct measurement of the coordinates	156,8	0,812
Measuring, using the device of indirect control of mechanical coordinates without taking into account the temperature conductors of the stator winding, the fundamental frequency of the stator voltage	148,96	0,763
Measuring, using the device of indirect control of mechanical coordinates taking into account the temperature conductors of the stator winding, the fundamental frequency of the stator voltage.	151,3	0,772

VI. CONCLUSIONS

The conducted research proves that the devices proposed in the paper have the improved accuracy of measurement of mechanical coordinates of a squirrel-cage asynchronous motor in the dynamic working modes of an electric drive and a simpler implementation.

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