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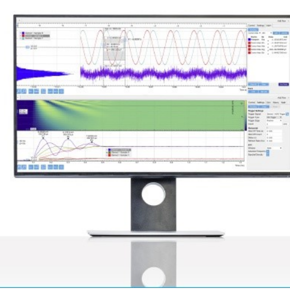

Indirect Torque Monitoring of Synchronous Electric Motors of Thermal Power Objects

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Abstract. This paper presents the results of the method developed by the authors for effective torque monitoring of synchronous electric motor, which does not require additional measuring devices and provides the required quality of measurements indirectly. Simulation model and programs for investigation of static and dynamic indices of indirect torque monitoring of implicitly synchronous electric motor were developed. The simulation experiment results are shown. The recommendations on application of the method of indirect torque monitoring are given.

INTRODUCTION

The automation level of technological processes of heat power engineering objects, in particular heat generation, predetermines to a large extent their reliable and efficient operation [1-5]. Obtaining the necessary technological information requires the appropriate measuring systems and devices usage that monitor the state of the main as well as auxiliary equipment of heat generation systems. Particularly there are electrical equipment of mechanisms for own needs such as circulation electric motors, feed and other electric pumps, electric motors of smoke pumps, fans of hot and cold blow with the use of synchronous electric motors of medium and large unit capacity.

One of the important indicators of the operating mode of electric motors is the torque. There are known developments of methods and devices for torque monitoring [6-12], which relate to direct monitoring methods and require the use of additional devices in the mechanical part of the equipment.

It is developed a method [13] and a device [14] of indirect torque monitoring of three-phase implicitly synchronous electric motor. The necessary information on torque of three-phase implicitly synchronous motor was obtained on the basis of analysis and conversion of known power-angle curve equation [15, 16].

Known motor passport data are used for indirect torque monitoring and frequency of main voltage harmonic and instantaneous values of phase voltage and phase current are measured then conversion, multiplication, integration and division operations are performed [17].

RESEARCH METHOD AND RESULT ANALYSIS

Simulation methods with application MATLAB [18-20] system was used to study static and dynamic properties of indirect torque monitoring of implicitly pole synchronous electric motor.

The developed simulation model shown in Figure 1 includes standard elements of the system's instrumental librariesas well as additionally developed subsystems of phase transformation of coordinates (a,b,c → d,q;

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d,q → a,b,c) and implicit pole synchronous motor taking into account the mutual influence of the excitation winding and damper winding spatially belonging to one coordinate (Fig. 2).

The developed program performs the required processing of measurement results and transformation of variables as well as computation of torque and indirect monitoring error. The simulation was calculated based on the Dormand-Prince numerical method with a fixed integration step of 0.001 s which is 1/20 T at 50 Hz supply voltage frequency.

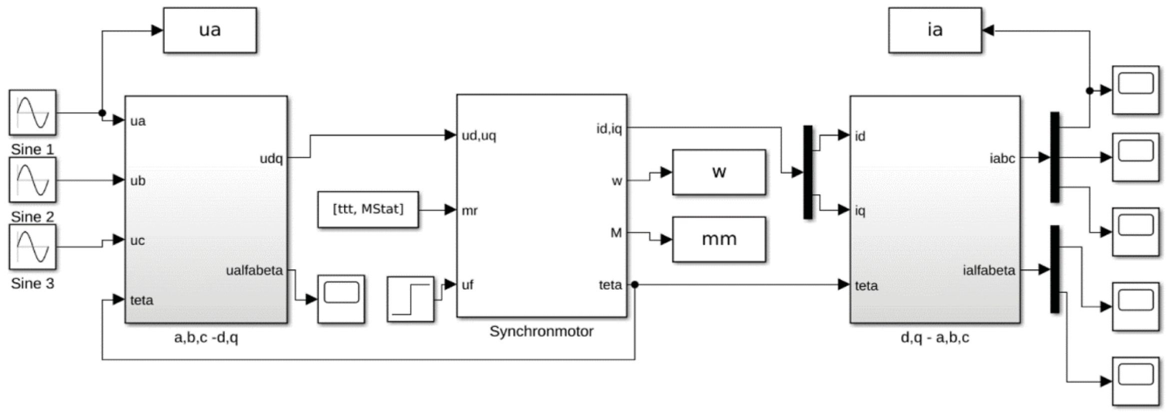


FIGURE 1. Simulation study model

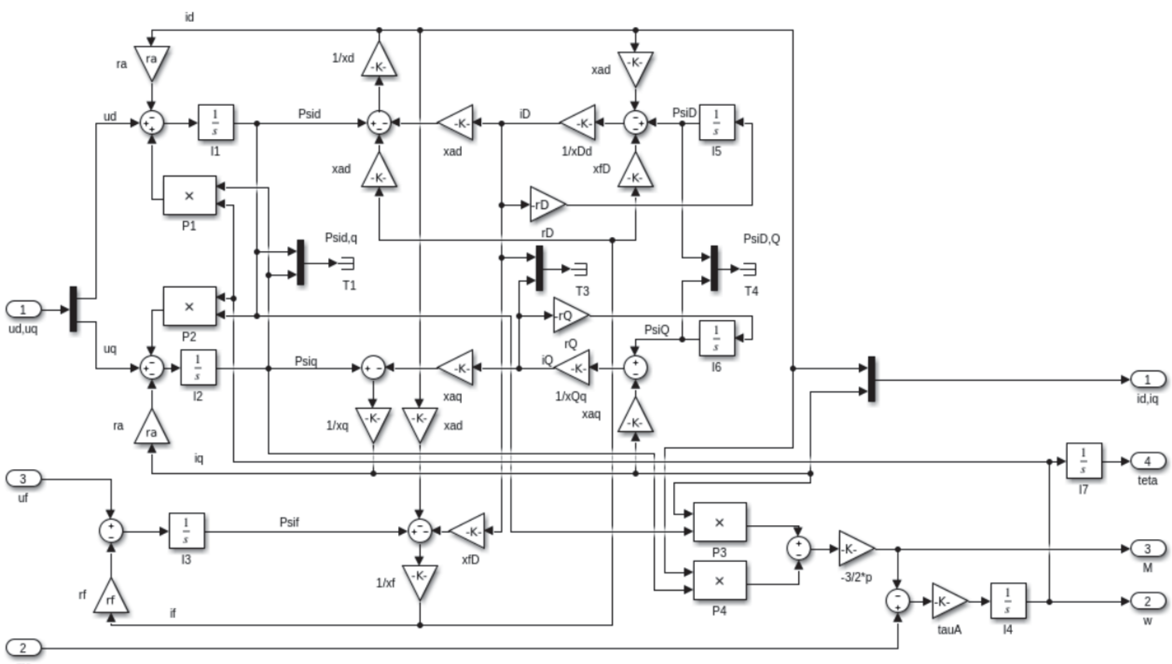


FIGURE 2. Implicit synchronous motor

Studies were carried out for the implicitly pole synchronous motor with capacity of 3.5 kW with damping windings located on axes d and q [21]. The simulation results are presented at Figures 3 and 4. Several experiments were performed by changing the given load in the range from 0.3 M_N to 1.5 M_N. Also, experiments were conducted at frequency control of speed of the synchronous electric motor at constant load equal to M_N. Supply voltage frequency was changed within the range from 15 to 50 Hz.

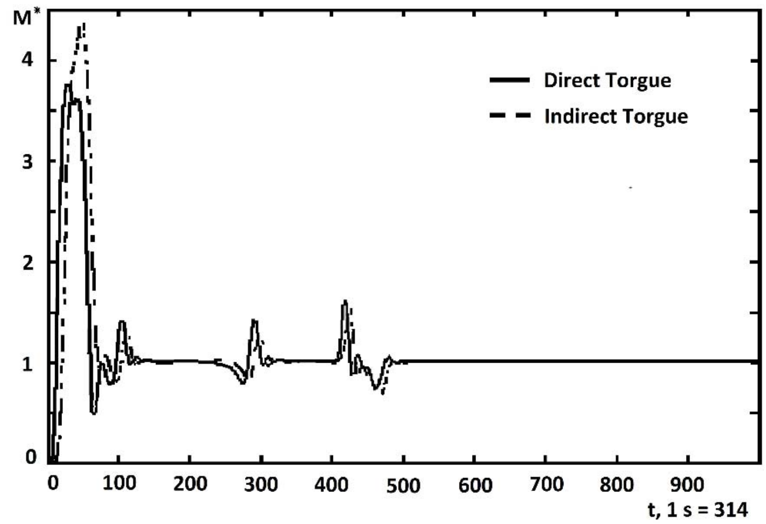
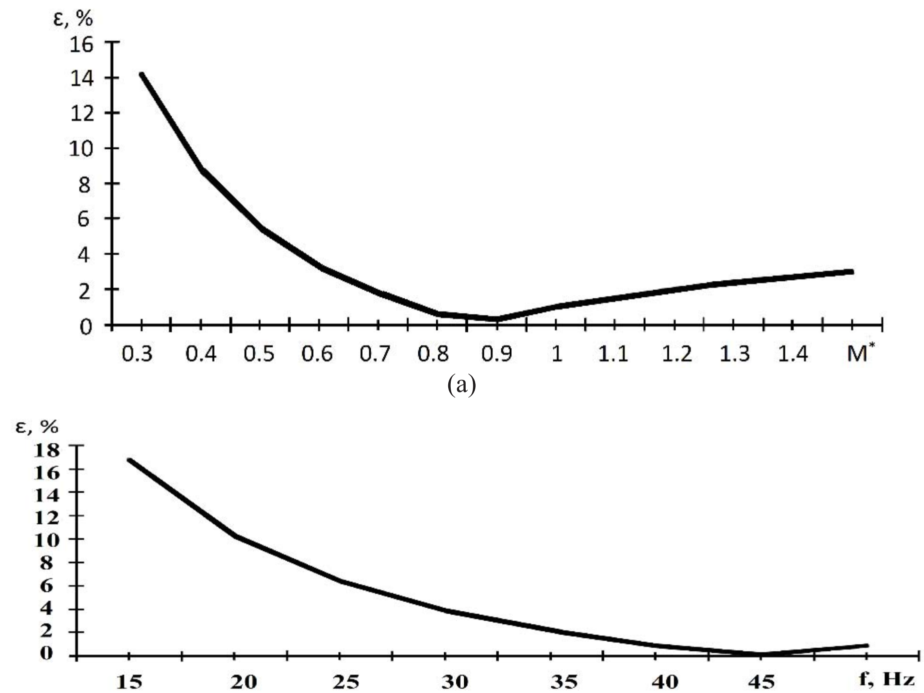


FIGURE 3. Dynamic motor torque characteristics



(b)

FIGURE 4. Error dependence of indirect torque monitoring on load (a) and frequency (b) of supply voltage

The dynamic characteristics analysis shows that the torque determined by the indirect method is delayed relative to the actual value. The delay time is within the range of 0.02 s to 0.04 s which corresponds to one and two periods of the main harmonic supply voltage respectively.

The analysis of the results in the steady state operation shows that the accuracy of the indirect torque monitoring method depends on the motor shaft load. In the area of small loads, the error has its maximum values and cannot be accepted as permissible. In the zone of loads from 0.6 M_N to 1.5 M_N the error of the indirect torque monitoring method reaches 3.3%.

With frequency control of the synchronous motor speed the indirect torque monitoring error also has a nonlinear dependence. In the frequency range from 50 to 30 Hz the measurement error reaches 4%.

CONCLUSIONS

The method of indirect torque monitoring of implicitly pole synchronous electric motor is most expedient to apply in electric drives with quasi-stationary mode of operation, which, as a rule, is typical for synchronous electric motors of medium and large capacity and nominal loads. At small loads on the motor shaft as well as at frequency regulation it is necessary to apply special algorithms of additional correction of torque monitoring.

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