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Simulation model of Permanent Magnet Synchronous Motor in phase loss operation mode

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Abstract

There is a need to prevent technological accidents and minimize irreparable economic losses at important critical technologies and hazardous production facilities (HEP). The requirements for operational safety which could limit the risks of undesirable modes during the operation of nuclear, chemical, construction, metallurgical and other facilities are determining factors in the survivability criteria of the main technological equipment. Thus, in the production of defense products, there are rigorous conditions for the implementation of technological processes when creating products: "a particularly responsible technological process, as a technological process, a violation of which can lead to the failure of defense products or to a change (loss) in its functional properties".

Keywords: Electric motor, permanent magnet synchronous motor (PMSM), mathematical model;

1. Introduction

A large number of production facilities incorporate equipment with DC electric drives which failures lead to the impossibility of fulfilling the working functions of maintenance-free mechanisms in processes with a long or non-stop processing cycle. Currently, special attention is paid to the survivability of a permanent magnet synchronous motor in hoisting-and-transport complexes for moving potentially dangerous goods, oil and gas products, and rocket and aviation systems [1].

In modern hoisting-and-transport complexes, digital electric drives of rotational or translational motion are widely used, where valve motors of various designs are used as actuating motors. To solve the problems of ensuring the operational survivability of such complexes, the role of methods and algorithms for fault-tolerant control of power pulse converters and executive motors, as the main elements of an electromechanical system, significantly increases.

In this paper, we consider a method for restoring PMSM when the supply phase is disconnected. In order to be able to conduct experiments to restore the efficiency of the electric motor, it is first necessary to assemble the PMSM model. The electric motor mathematical model is built in the Matlab Simulink software package. Using this model, it is necessary to conduct experiments in the event of an emergency and restore the operability of the electric motor by changing the angle of the supply current.

2. PMSM model

The development of a mathematical model of a PMSM for a connection circuit with isolated phases (with separate flow of phase currents) was carried out in two stages.

At the first stage, on the basis of a static model for calculating the total active and reactive power of the PMSM, the parameters determining the maximum moment of the PMSM in the emergency two-phase operation mode were determined. At the second stage, a system of equations of a mathematical model was developed for describing transients in an in-phase emergency operation mode of a three-phase PMSM for a connection circuit with isolated phases.

To develop a mathematical model, the following assumptions are made: the magnetic circuit of the motor is assumed to be unsaturated; steel losses and mechanical losses are negligible; the distribution of MDS and induction is sinusoidal; there are no higher harmonics, the air gap is uniform.

In the three-phase PMSM mode, the electromagnetic moment is maximum at the maximum active power for load angles $\theta = \theta_A = \theta_B = \theta_C = \pi/2$.

For the two-phase PMSM mode, the angles θ_A and θ_C are not equal (phase B failure), since the phase voltage vectors U_A $\overrightarrow{U_C}$ and the phase shifts of the angles φ_A and φ_C have different signs with respect to current vectors. Therefore, it is impractical to control the PMSM in an out-of-phase mode based on the angles θ_A и θ_C as parameters determining the maximum moment [2].

Figure 1 shows the mathematical model of PMSM. This model was built using the standard library blocks of Matlab Simulink. A comparison is also made of the constructed mathematical motor model with the standard Matlab PMSM block. The output signals of both blocks are combined into one scope block.

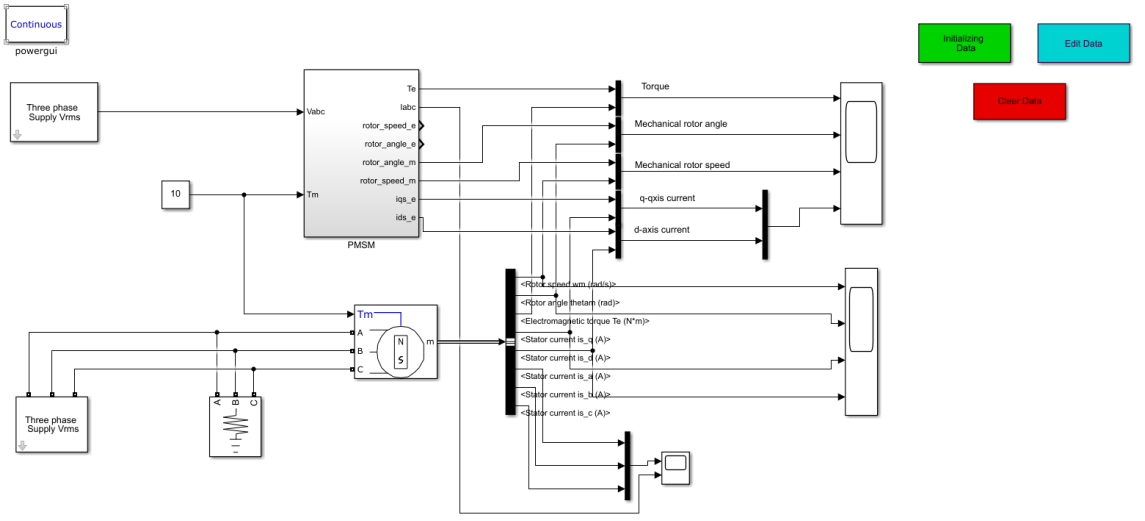

Fig. 1. PMSM model

Figure 2 shows the composition of the PMSM block. It consists of electrical and dynamic systems. The electrical system, in turn, consists of an input voltage converter from the ABC system to the dq system. A dynamic system is necessary to obtain graphs of changes in the motor torque and other parameters [3].

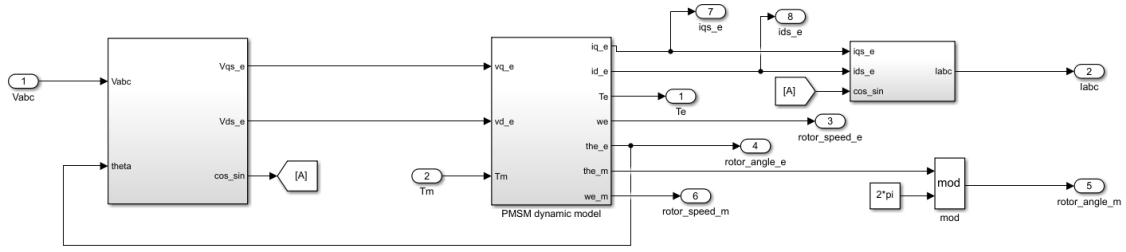

Fig. 2. PMSM block

Figure 3 shows graphs of the electromagnetic torque Te, rotor angle, and rotor speed and stator currents. According to the obtained results, it follows that the constructed PMSM model completely coincides with the standard model. Using the constructed model, it is possible to make experiments on the occurrence of a phase loss operation mode, for example, a break in one or two phases, as well as restore the operability of the electric motor using a control system.

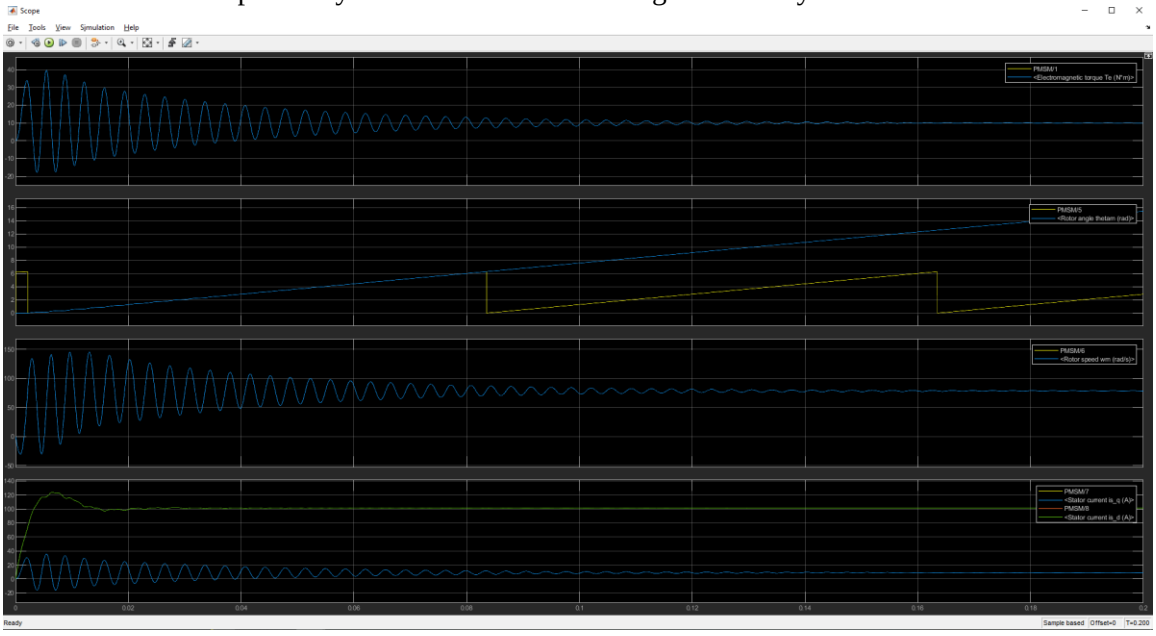

Fig. 3. Results of simulation

3. Conclusion

This paper describes the mathematical model of PMSM and its simulation model. A comparison of the graphical results of the constructed motor model with the standard block of the Matlab Simulink software package is presented. These graphs completely coincide which indicates the correctness of the constructed model. With the help of this model, it became possible to conduct experiments to create phase loss operating modes of the motor and restore its efficiency.

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