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MATHEMATICAL MODEL OF THE ELECTRIC DRIVE SYSTEM OF THE SKIP HOIST INSTALLATION

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Keywords: mathematical modeling, electric drive, technological unit, mining enterprise, MatLab, Simulink.
Abstract. Mathematical modeling of a variable frequency drive system for a skip hoist in an underground mine for the extraction of diamond-bearing rocks in the MatLab/Simulink environment is considered. The model was developed based on the block diagram of the actually used installation using the methodology of Professor Kolganov. The model includes three main transfer functions (frequency converter, electromechanical and mechanical parts of the electric motor), an integrating link and three feedbacks, including full speed feedback. As a result of the simulation, transient processes of the main characteristics of the skip hoist installation were obtained with stepwise and programmable control actions of the speed reference signal.

МАТЕМАТИЧЕСКАЯ МОДЕЛЬ СИСТЕМЫ ЭЛЕКТРОПРИВОДА СКИПОВОЙ ПОДЪЕМНОЙ УСТАНОВКИ

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Ключевые слова: математическое моделирование, электропривод, технологическая установка, горное предприятие, MatLab, Simulink.
Аннотация. Рассмотрено математическое моделирование системы частотно-регулируемого электропривода скиповой подъемной установки подземного рудника по добыче алмазосодержащих пород в среде MatLab/Simulink. Модель разработана на основании структурной схемы реально используемой установки с применением методики профессора Колганова. Модель включает в себя три основные передаточные функции (преобразователя частоты, электромеханической и механической частей электродвигателя), интегрирующее звено и три обратные связи, в том числе полную обратную связь по скорости. В результате моделирования получили переходные процессы основных характеристик скиповой подъемной установки при ступенчатом и программируемом управляющих воздействиях сигнала задания скорости.

Skip hoisting units are designed for issuing the mined mineral to the surface, transporting mining equipment and materials. An electric drive is an electromechanical system consisting of a converter, electric motor, transmission and control devices. The electric drive of lifting installations can consume up to 40% of the total electricity consumed by the mine [1].

The reliability, uninterrupted operation and productivity of the mine hoist directly affects the rhythmic operation of the entire mine, therefore, special requirements are imposed on the electric drive of the mine hoist in terms of reliability and safety [2].

The purpose of the simulation is to build transients of the angular velocity and stator current, acceleration diagrams for the skip movement cycle, as well as diagrams of the speed command control signal [3].

The object of research is a frequency-controlled electric drive (FCED) of a skip hoist. A comprehensive solution to the problem of developing the electric drive of mine hoisting machines in the direction of increasing their efficiency is relevant. Electric drives with frequency converters can significantly increase the service life of mechanical equipment elements and improve the reliability of the system [4].

The relevance of this article lies in modeling the operating modes of an asynchronous electric motor with a phase rotor with a FCED system. Mathematical modeling makes it possible to check the operating modes of the electric drive without interfering with the production technology [5].

The MATLAB software package was chosen as a program for modeling the operating modes of the engine of the skip hoisting unit (SHU). The possibilities of MATLAB are very extensive: it is applicable for calculations in almost any field of science and technology. The basis of computer simulation is a block diagram, based on which the block diagram of the model is implemented (Fig. 1) [6].

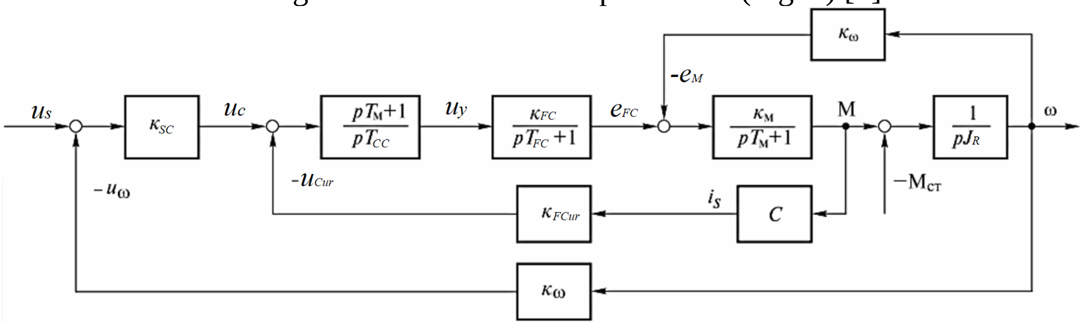

Fig. 1. Structural diagram of a frequency-controlled electric drive of a skip hoist

To simulate the operating modes of the electric drive system, we present the transfer functions of the system. The transfer function of the frequency converter (FC) is:

$$W_{FC}(p) = \frac{K_{FC}}{pT_{FC}+1},$$

where K_{FC} - is the static transmission coefficient of the frequency converter; T_{FC} - time constant of the frequency converter.

The transfer function of the link of the electromagnetic torque of an induction motor has the form of a link of the first order:

$$W_M(p) = \frac{K_M}{pT_M+1},$$

where K_M - is the static transmission coefficient for the electromagnetic torque of the induction motor; T_M - electromagnetic time constant of the frequency-controlled electric drive.

The transfer function of the speed link in the block diagram is represented by an integrating link:

$$W_S(p) = \frac{1}{pJ_R},$$

where J_R - is the reduced moment of inertia of the electromechanical system.

The transfer function of the current controller has the form:

$$W_{CC}(p) = \frac{pT_M + 1}{pT_{CC}},$$

where T_{CC} - is the time constant of the current controller.

The coefficient of proportionality between the stator current and the electromagnetic torque is obtained from the relationship:

$$C = \frac{I_{1nom}}{M_{nom}}.$$

The transfer function of the speed controller has the form:

$$W_{SC} = K_{SC}.$$

Speed feedback coefficient K_{FS}; transfer coefficient of internal feedback on the EMF of the motor K_{ω}; motor current feedback coefficient K_{FCur}.

We set the dependence of the change in accelerations in time for the cycle of movement of the lifting installation, for this we write the Boolean algebra in the block parameters, these parameters have the following form: (u>0)*0.125*(u<12)+(u>12)*0.75*(u<26.9)+(u>26.9)*0*(u<106.9)+(u>106.9)*
(- 1)(u<119.1)+(u>119.1)*0*(u<137.1)+(u>137.1)*(-0.25)*(u<139.7).

Based on the block diagram (Fig. 1), a block diagram of the model of the electric drive system is compiled using the MATLAB software product in the Simulink environment (Fig. 2) [7].

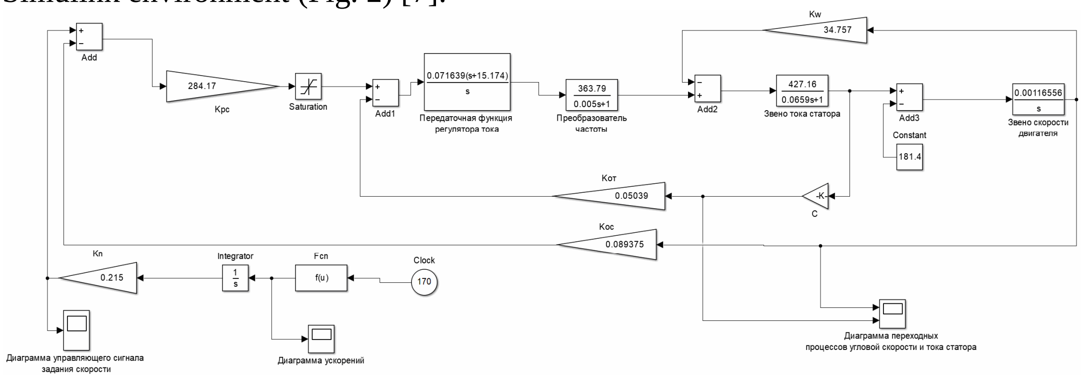

Fig. 2. Block diagram of a FCED model of a skip hoist

The simulation results in the form of dynamic processes for the coordinates of the angular velocity and stator current of the frequency-controlled electric drive are recorded on the transient diagram (Fig. 3).

On Fig. 3 (a) shows the transient processes of the angular velocity and stator current of the frequency-controlled electric drive with a stepwise control action of the speed reference signal (10 V), and in Fig. 3 (b) with a programmable control action of the speed reference signal.

Based on the results of mathematical modeling, it can be concluded that the electric drive system is operational. The error of the calculated and reference data from the simulated values for all parameters does not exceed 5% and is often absent at all, which indicates a qualitatively collected simulation results are presented in the graphs. Evaluation of the results allows us to consider this system as satisfying all goals.

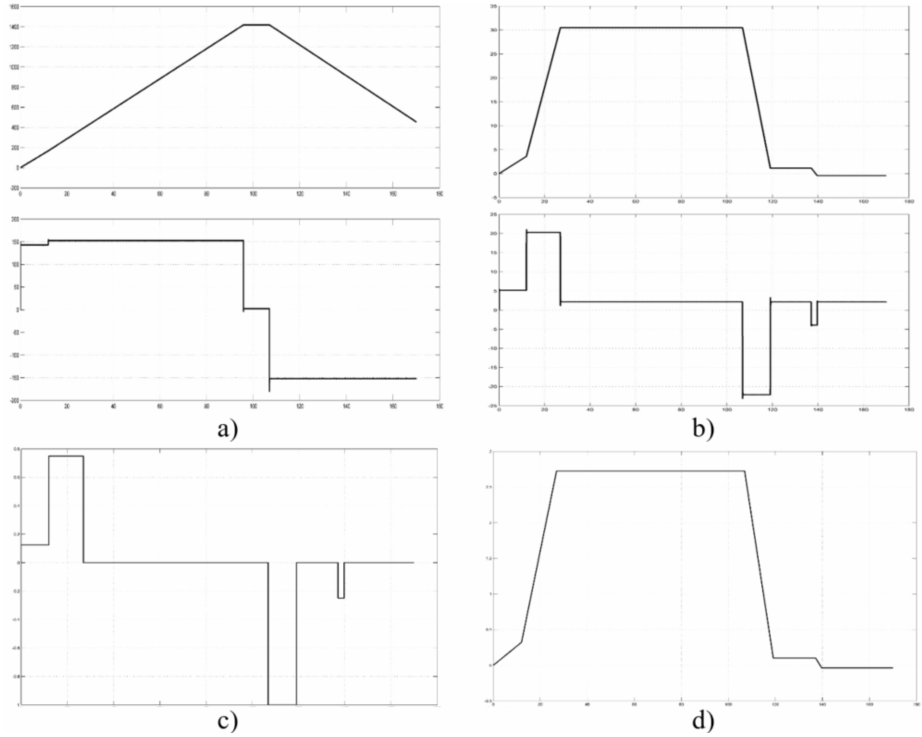

Fig. 3. Graphical results of the simulation of the FCED SHU system: a) transient processes of the angular velocity and stator current with a stepwise control action of the speed reference signal; b) transient processes of the angular velocity and stator current with a programmable control action of the speed reference signal; c) diagram of accelerations for the cycle of movement of the vessels of the skip hoist; d) diagram of the control signal for setting the speed for the cycle of movement of the vessels of the skip hoist

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