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RESEARCH OF THE OPERATING MODES OF A DC MOTOR USING SIMULATION AND COMPUTER MODELING

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Keywords: DC motor, independent excitation, operating modes, current, rotational speed, torque, simulation, MatLab.
Abstract. The modes of operation of a DC motor with independent excitation were analyzed during the development of a simulation model using a laboratory bench and a computer model implemented in the MatLab software package. The transitional modes of operation from the point of view of the dynamics of the electric drive, namely starting and braking the engine, were subject to consideration. The electrical wiring diagram of the motor windings is shown, and the list of laboratory equipment units used in the work is given. A computer model has been developed and tested, and the simulation results are shown. It is concluded that the error in modeling does not exceed 10%, which is acceptable for computer models of complex electrical devices.

ИССЛЕДОВАНИЕ РЕЖИМОВ РАБОТЫ ДВИГАТЕЛЯ ПОСТОЯННОГО ТОКА ПРИ ПОМОЩИ ИМИТАЦИОННОГО И КОМПЬЮТЕРНОГО МОДЕЛИРОВАНИЯ

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Ключевые слова: двигатель постоянного тока, независимое возбуждение, режимы работы, ток, частота вращения, момент, моделирование, MatLab.
Аннотация. В работе были проанализированы режимы работы двигателя постоянного тока с независимым возбуждением в ходе разработки имитационной модели при помощи лабораторного стенда и на компьютерной модели, реализованной в пакете программ MatLab. Рассмотрению подлежали переходные режимы работы с точки зрения динамики электропривода, а именно запуск и торможение двигателя. Показана электрическая схема соединений обмоток двигателя, приведён перечень блоков лабораторной установки, используемых в работе. Разработана и апробирована компьютерная модель, показаны результаты моделирования. Сделаны выводы, что погрешность при моделировании не превышает 10%, что является допустимым для компьютерных моделей сложных электротехнических устройств.

Introduction. Industrial production in our country consumes about 65% of the total generated electric energy [1]. The main consumers at enterprises are electric drive systems of complex technological installations [2]. Individual mining enterprises, for example, are very energy-intensive, where the total installed capacity of consumers can reach 50 MW, and the capacity of single electric drive systems can reach 5 MW [3]. Therefore, the development and design of such electric power systems is difficult without the use of simulation and computer modeling programs [4]. When developing such computer models, it will be possible to safely substitute various parameters of electric motors or other devices to select the best technological process [5].

DC motors are widely used in mining enterprises in electric drive systems of various lifting installations [6]. In this regard, consideration of their operating modes is an important task for the correct execution of the technological process [7]. DC motors are divided according to the type of excitation winding. We will study a DC motor with an independent excitation winding, which have become most widespread due to the wider control capabilities [8].

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Simulation model. To begin with, we will evaluate the starting and braking modes of the DC motor on a specialized laboratory installation that we assembled while working on a design task in the laboratory of Electric Drive and Electric Machines at the Department of Electric Power Engineering and Industrial Automation of the Mirny Polytechnic Institute (branch) Ammosov North-Eastern Federal University.

Figure 1 shows the electrical wiring diagram of the power unit, which uses the following units: rectifier, three-pole switches, starting rheostat, DC motor excitation rheostat, current and voltage sensor unit, three-phase power supply, power supply DC motor, adjustable autotransformer, AC motor, angular displacement converter, single-phase power supply (not shown in the diagram), DC machine, speed indicator.

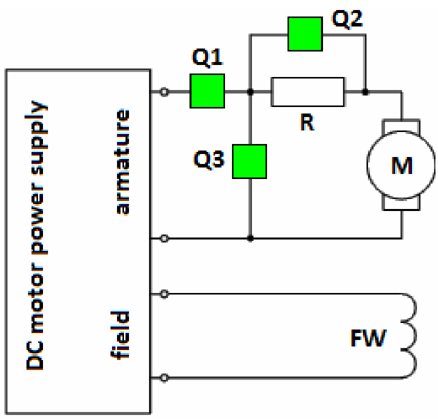

Fig. 1. Electrical circuit diagram of the power unit of the laboratory installation

The simulation results are shown on the oscilloscope below (Fig. 2), where the simulation time is displayed along the abscissa axis, and the corresponding parameter is displayed along the ordinate axis: voltage, rotation speed, and motor current. Figure 3 shows the mechanical characteristics of a DC motor, where the transients of rheostatic startling and natural braking are visible.

The graph (Fig. 2) shows that the launch is carried out stepwise due to the use of a starting rheostat, and by about 4.5 seconds the rotation speed reaches its nominal value. Then, after 5 seconds, the natural braking of the motor is simulated, that is, its windings are simply disconnected from the mains, and the motor stops by about 16 seconds. It can be seen that the parameters obtained during the simulation do not exceed the nominal values of the passport by more than 10%.

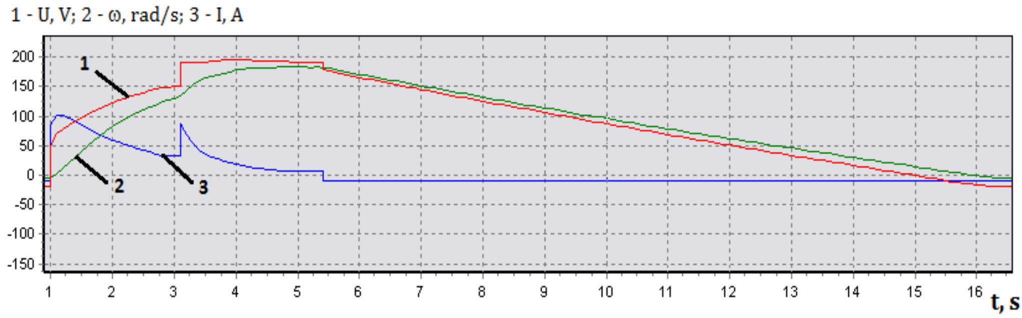

Fig. 2. Simulation results: voltage, rotation speed and motor current

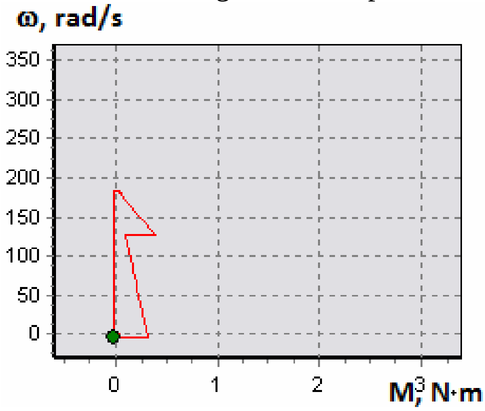

Fig. 3. Mechanical characteristics of a DC motor

Computer model. The MatLab software package contains the Simulink block library, which, in turn, includes the additional SimPowerSystems library [9]. A large number of scientific papers have been devoted to the development of computer models in MatLab/Simulink. In one of these [10], computer models of typical technological installations of an underground diamond mine are considered and the undoubted advantages of SimPowerSystems are noted, consisting in a combination of simulation and structural modeling methods for complex electrical systems.

The computer model (Fig. 4) is an analog of a basic electrical circuit consisting of constant voltage sources, a rheostatic starter unit, a DC motor, a unit for measuring the main parameters of the motor, and an oscilloscope for measuring current, torque, and speed.

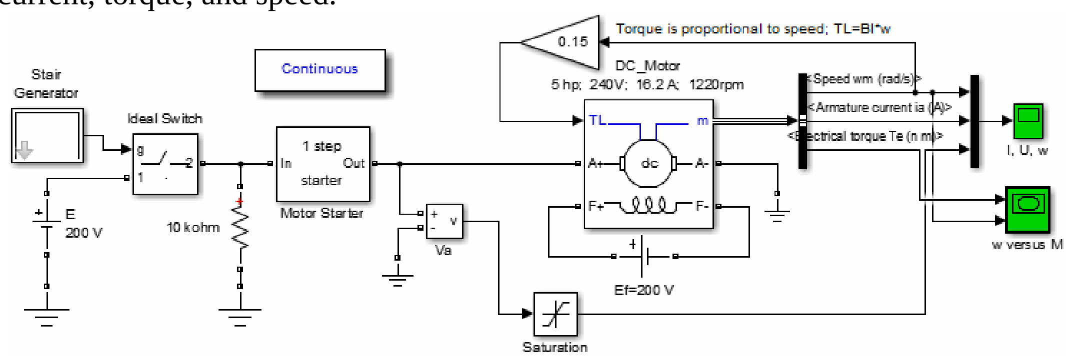

Fig. 4. A model of a DC motor with independent excitation in MatLab

We insert the engine's passport data into the “DC_Motor” block by opening the parameters window by double-clicking the left mouse button. We also individually set the voltage in the armature circuit and the excitation winding circuit. We configure the “Motor Starter” block in the same way as the data from the simulation model.

On the oscilloscope (Fig. 5) we obtain the results of modeling the angular velocity, current and torque of the motor. Figure 6 shows the mechanical characteristics of the engine.

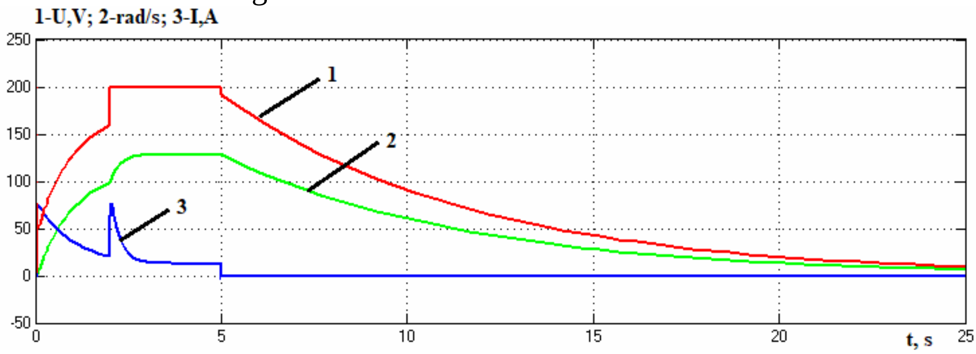

Fig. 5. The results of modeling rheostatic start-up and natural braking of DC motor in MatLab; the numbers indicate the following parameters: 1 – voltage, 2 – rotation speed, 3 – motor current

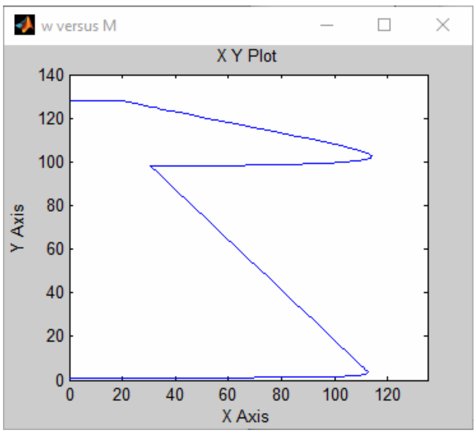

Fig. 6. Mechanical characteristics of a DC motor

According to the simulation results, it can be seen that the start-up, as well as for simulation, is carried out stepwise, while the starting current and torque are limited. The braking process lasts a little longer than in simulation. This is because the lowest-power engine in the MatLab software package is more powerful than in our laboratory setup. Here, too, the error of the simulation results does not exceed 10% in relation to the parameters and calculated values.

Conclusion. In conclusion, it is worth noting that in the framework of this work, we have investigated the starting and braking modes of operation of a DC motor with independent excitation. Simulation and computer models have been developed that have confirmed the good applicability of computer modeling to electrical engineering problems with an error of no more than 10%.

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