ABSTRACT

of the dissertation for the degree of Doctor of Philosophy (PhD)
in the educational program 8D07103 – «Electrotechnical complexes and systems»
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«THE CREATION OF CONTROL SYSTEMS ADJUSTABLE SPEED ELECTRIC DRIVE IN THE MODES OF THE GENERATOR BRAKING»

The dissertation work is devoted to the issues of improving the reliability of machines and mechanisms of mining enterprises.

The relevance of the work.

Improving the safety of operation, technical and economic indicators and reliability of newly designed, mass-produced machines and mechanisms is an important scientific and technical task. One of the ways to solve this problem is the use of an adjustable electric drive, which provides continuous control, both in motor and braking modes. In the works of Denki Kabushiki Kaisha, (Japan) Horald S. Ogden (USA), E. G. Kraus, I.V. Breido (Kazakhstan), etc. some theoretical and practical problems related to the research of electric drives, including electric drives of mining machines, in the modes of generator controlled braking are investigated. However, the existing developments do not sufficiently take into account the dynamic properties and features of the regulated electric drive in generator modes, the dynamic characteristics of the electric drive in emergency situations associated with a sudden power outage, the probability of which is quite high in mining enterprises, are insufficiently investigated. Improving the reliability and compliance with safety standards for the operation of machines and mechanisms by means of a regulated electric drive in generator operating modes is difficult for the following reasons:

1. Mathematical models have not been developed that adequately describe the physical processes occurring in the electric drive in the controlled braking mode.

2. Algorithms for optimal control of the braking process have not been established.

3. There are no technical solutions to implement controlled modes of generator braking.

These issues indicate the relevance of the scientific task being solved in the dissertation, and the development and implementation of a set of technical solutions for the implementation of controlled braking systems will significantly improve the operational characteristics of mining machines and mechanisms.

Dissertation work on specialty D099 -- "Power engineering and electrical engineering" on the study of static and dynamic characteristics of regulated electric drives in generator modes of operation of direct and alternating current of mining machines and mechanisms.

The purpose of the work is to develop methods for designing control systems for AC and DC electric drives in generator braking modes and means of their technical implementation in order to improve the operational safety and reliability of mining machines and mechanisms.

The idea of the study is to develop optimal control laws taking into account the static and dynamic characteristics of the unchanged part of the electric drive in the generator mode of operation based on a set of scientific and technical solutions that provide current control of the output coordinates of the electric drive.

The object of the study is an adjustable DC and AC electric drive in the generator mode of operation.

The tasks of the work to be solved to achieve this goal:

- analysis of the requirements for braking modes of machines and mechanisms of the mining, metallurgical and metalworking industries;

- development of criteria for optimal control of an adjustable electric drive in the generator mode of operation;

- development of mathematical and simulation models of the fixed part of the regulated electric drive in the generator mode of operation;

theoretical studies of static and dynamic characteristics of an adjustable DC and AC electric drive in generator operating modes;

- technical implementation of the electric drive control system in the generator mode of operation;

experimental studies of the electric drive control system in the generator mode of operation.

Scientific novelty:

–mathematical and simulation models of an adjustable electric drive in controlled braking modes have been developed, taking into account the specifics of the power part of the electric drive;

– optimal control laws for the minimum braking distance have been synthesized, taking into account the limitation of the maximum permissible parameters for various ranges of the angular velocity of the electric drive;

– parametric optimization of the system for limiting the parameters of the electric drive has been carried out.

The main scientific provisions and research results submitted for protection:

- optimal control laws of a regulated electric drive in generator mode, taking into account the maximum permissible parameters of the unchanged part;

- method of determining the maximum permissible parameters of the unchangeable part of the regulated electric drive in the generator mode;

- algorithms for controlling an adjustable DC electric drive with a sequential and independent excitation motor;

- algorithms for controlling an adjustable electric drive with a frequency converter in dynamic braking mode.

Research methods.

The scientific and practical results of the dissertation work were obtained using the methods of the theory of electrical circuits and electrical engineering, the theoretical foundations of an automated electric drive, the theory of automatic control, the formulation and planning of the experiment. Simulation studies, as well as simulation results, were performed in the MATLAB software environment. The analysis and processing of experimental data was carried out in the Microsoft Excel program.

The practical significance of the results obtained lies in the development of:

–a controlled mode of dynamic braking of a DC electric drive with sequential and independent excitation;

– technical solutions for controlled braking of an adjustable electric drive with an asynchronous electric motor and a frequency converter.

Justification and reliability of the results and conclusions.

The substantiated and reliable results and conclusions of the dissertation are based on the use of proven methods of the theory of electrical circuits, the theoretical foundations of electrical engineering, the theoretical foundations of automated electric drive, the theory of automatic control, simulation modeling. Scientific statements, research results and conclusions are confirmed by evaluating the adequacy of computer modeling materials and experimental studies.

Scope and structure of the dissertation: the dissertation consists of a list of abbreviations, an introduction, the main part of four sections, and a conclusion. The volume of the dissertation is 123 pages of typewritten text, contains 55 figures, 12 tables, a list of sources used, including 109 titles, 1 appendix.

The content of the work. The introduction substantiates the relevance of the topic, the scientific novelty of the work and its practical significance; the purpose of the work, the main objectives of the study and the provisions submitted for defense are formulated.the dissertation consists of a list of abbreviations, an introduction, the main part of four sections, and a conclusion. The volume of the

dissertation is 123 pages of typewritten text, contains 55 figures, 12 tables, a list of sources used, including 109 titles, 1 appendix.

In the first chapter, the state of the issue is outlined and a review of literature sources devoted to the analysis of requirements for braking modes is carried out. This chapter discusses the existing braking devices used in electric drives of mining machines and characterized by low reliability and insufficient compliance with the requirements of safety standards regulating the amount of braking distance. Based on the analysis of studies of the technical solutions used for braking methods and safety standards, it is concluded that it is advisable to use controlled braking.

In the second chapter, theoretical studies of the invariable part of the regulated AC and DC electric drives in the generator mode are carried out.

As a result of simulation experiments with a sequential excitation motor in the mode of controlled dynamic braking, an assessment of the stability of the electric drive is given and a schematic solution of the power part is proposed that provides stable braking over the entire range of braking torque control.

In the third chapter, a generalized functional scheme of the simulation model is developed to study the static characteristics of an adjustable electric drive in the dynamic braking mode. As a result of theoretical research, an optimal circuit design has been developed that provides stable braking in the operating speed range.

In the fourth chapter, the development of a method for linearization of an adjustable electric drive via a control channel using a MATLAB application software package is carried out.

Linear transfer functions of an adjustable electric drive are obtained:

- with a DC electric motor in dynamic braking mode with a pulse converter;
- with an asynchronous electric motor with a frequency converter with a DC link.

Studies of the current limiting system in an asynchronous electric drive in dynamic braking mode with a frequency converter have been carried out.

The fifth chapter presents the results of experimental studies and industrial tests of an adjustable electric drive in braking modes, which confirm the main results of theoretical research.

The developed adjustable braking system ensures maximum braking intensity (with current and braking torque limitation) at the level of the maximum permissible values.

In the course of experimental studies and industrial tests, it was found that the adjustable braking system provides effective braking in the operating range of the angular velocity of the analyzed machines and mechanisms.

During bench tests, it was found that the mathematical model reflects the processes occurring in an adjustable DC and AC electric drive in the dynamic braking mode.

It follows from the results of industrial tests that the use of an adjustable braking system ensures compliance with safety requirements.

The main results of the performed studies are as follows:

1. The analysis was carried out and the requirements for the generator modes of operation of the electric drive of mining and other machines and mechanisms were formulated, and the minimum braking distance and braking time were proposed as optimality criteria.

2. Mathematical and simulation models of DC AC electric drives in dynamic braking modes have been developed.

3. Algorithms have been developed for controlling an adjustable DC electric drive in dynamic braking modes with a minimum braking distance, taking into account the limitations of the maximum permissible values of the armature current and braking torque. Practically realizable quasi-optimal control algorithms are obtained.

4. An electric drive control system has been developed in the modes of sudden power outage, the principle of operation of which is based on the use of electromagnetic energy stored in the reactive components of the electric motor and the capacitance of the filter capacitor of the DC power supply source in the power part of the converter.

5. Experimental studies and factory tests have been carried out;

6. The operability of dynamic braking control systems designed and manufactured on the basis of the proposed principles has been confirmed.

The conducted scientific research and implemented technical solutions can be recommended for use in electric drives of lifting mechanisms of other industries.

The personal contribution of the dissertation consists in solving research problems, developing and substantiating the provisions that make up the scientific novelty and practical significance of the work, developing and manufacturing an experimental installation and a mock-up of the proposed technical solution, analyzing and processing experimental data.

The main scientific results of the doctoral dissertation have been published in 7 scientific papers, including 3 publications in publications recommended by KKSON of the Ministry of Education and Science of the Republic of Kazakhstan, 1 publication included in the information base of Scopus companies, 3 publication in international scientific and practical conferences.