

ABSTRACT

of the Thesis for the Doctor of Philosophy Degree
in specialty 6D071800 – “Electric Power Engineering”

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DEVELOPMENT OF REMOTE MONITORING PRINCIPLES FOR THE OPERATING MODES OF MINING ELECTRICAL EQUIPMENT

The thesis is devoted to the development of principles and systems for remote monitoring of mining electrical equipment operating modes with the purpose to improve the energy efficiency of such equipment.

Research Rationale. Surface mining of mineral deposits is characterized by such process features as distribution of high capacity single unit equipment across long distances and its remoteness from power sources. Mining operations stability is also greatly affected by severe operating conditions of the equipment including extreme seasonal variations in temperature, various types of precipitation throughout a year, vibration, dustiness and etc. In this regard, active research and pilot studies are currently in progress to work out various remote monitoring systems that allow monitoring of power consumption data and operating conditions of electrical equipment for surface and underground mining, including start-control devices, generators, electric motors, their emergency protection and control systems.

The research and the development of remote monitoring systems are a focus point of scientific works by many scientists: I.V. Breido, L.A. Avdeev, V.N. Kostyukov, S.N. Boichenko, A.V. Kostyukov, Yu.L. Zhukovskiy, A.E. Kozyaruk, A.A. Korzheva, A.V. Krivenko, P.A. Budko, A.I. Litvinov, as well as by the specialists of foreign enterprises, such as JANITZA GbmH and Rittal (Germany).

The analysis of publications shows that there is a demand for the development of remote monitoring systems for mining electrical equipment operating modes stemming from the specific needs, such as:

- the need to have continuous remote monitoring of territorially distributed mining equipment, including excavators, drill rigs, mine face equipment, and other;
- the need to reduce power consumption through the continuous monitoring of excavator working modes and the elimination of idle conditions. Based on the field operation it was identified that the average idle power consumption amounts to no less than 10-15% of the total power consumption;
- the need to reduce downtime through the timely detection of failures of the electrical equipment that is territorially distributed.

The Object of the Research is the electrical equipment of the mining industry that requires remote monitoring.

The Purpose of the Research is to improve automated control efficiency, to reduce lost time and downtime in case of electrical equipment failures, as well as to enhance energy use efficiency of the remote electrical equipment in the mining industry.

The Idea of the Research presents the use of monitoring systems to improve automated control efficiency, to reduce lost time and downtime in case of electrical equipment failures, as well as to enhance energy use efficiency of the remote electrical equipment in the mining industry.

Scientific Novelty of the Research comprises the following aspects:

- the development of anti-interference algorithms for information acquisition and transmission taking into account switching interference;
- the development of technical solutions that ensure automatic selection of possible data transmission channels in remote monitoring systems under dynamic real-life conditions of mining equipment operation;
- the development of prediction and planning methods to identify nominal power consumption by excavators based on the analysis of the accumulated data in the remote monitoring system.

The Objectives of the Research:

- to analyze research studies and technical solutions for the monitoring of electrical equipment operating modes in the mining industry;
- to analyze remote electrical equipment operating modes in surface mining operation under noise conditions;
- to develop simulation models depicting the influence of the operating modes of multi-engined mining electrical machinery (excavators) on the interference immunity, validity, and reliability of monitoring systems;
- to develop anti-interference algorithms for information acquisition and transmission taking into account switching interference;
- to develop technical solutions that ensure automatic selection of possible data transmission channels in remote monitoring systems under dynamic real-life conditions of mining equipment operation;
- to conduct testing and pilot operation of remote monitoring systems for high-voltage substations and excavator electrical equipment.

Main Scientific Concepts and Research Results to be defended:

- principles and methods to ensure interference resistance when transmitting technical data in remote monitoring systems for territorially distributed mining equipment taking into account its electrical equipment operating modes;
- prediction and planning methods to identify nominal power consumption by excavators based on the analysis of the accumulated data in remote monitoring system;
- the aggregate of technical solutions to develop remote monitoring systems for traveling machinery and fixed equipment with the automatic selection of possible telemetric data transmission channels depending on dynamic conditions of mining operation;

Research Methods: scientific and application results of the thesis were obtained through the use of information theory, electrical engineering, and probability theory methods. Mathematical models for predicting power consumption and electrical parameters were developed based on the established distribution laws and regression analysis with the help of application suite “STATISTICA”. Simulation, as well as

simulation results, were obtained using application suite MATLAB/SIMULINK and SimPowerSystems.

Practical Importance of the Obtained Results is as follows:

- the development of the aggregate of technical solutions for remote monitoring of mining electrical equipment operating modes;
- the performance of tests and pilot operation of remote monitoring systems for high-voltage substations and excavator electrical equipment;
- the industrial introduction of remote monitoring of mining electrical equipment operating modes.

Justification and Validity of the Results and Conclusions. Justified and valid results and thesis conclusions are based on the use of proven methods of electrical engineering theory, simulation modeling, with the aid of application program packages MATLAB/SIMULINK. Scientific concepts, research results, and conclusions are confirmed through the efficacy assessment of computer simulation data and experimental studies of remote monitoring systems at mining enterprises.

Thesis Size and Structure. The thesis consists of an introduction, five chapters, a conclusion, seven appendices. It contains 114 pages of typed text, 55 pictures, 25 tables, reference listing that comprises 135 titles.

Thesis Contents. The introduction chapter shows that the development of the principles for remote monitoring of electrical equipment operating modes in the mining operation is a relevant objective. This chapter gives information on the purpose and the objectives of the thesis, identifies the scientific novelty of the study, presents scientific concepts and research results to be defended, and the practical importance of the results.

The first chapter outlines the current state of the problem and provides the analysis of publications that deal with the process control methods and systems for the monitoring of electrical equipment operating modes in the mining operation. This chapter presents technical solutions for monitoring electrical equipment operating modes for surface and underground mining.

The second chapter is devoted to the analysis and research of amplitude interference that arises during planned and emergency electrical equipment shutdowns in mining operations. The law of switching distribution is determined to develop anti-interference algorithms for information transmission.

The third chapter depicts the developed anti-interference algorithms for data acquisition and transmission in remote monitoring systems for electrical equipment operating modes in mining operations. A block diagram of the monitoring system is presented.

The fourth chapter provides data on the developed remote monitoring system that was put in place at an industrial enterprise of the Republic of Kazakhstan to monitor electrical equipment operating modes of various types of excavators and substations.

The fifth chapter concentrates on the analysis of energy efficiency at AO “Shubarkol Komir” production facility. This analysis is carried out based on the monitoring system field operation results. Energy consumption prediction models are developed.

Key research results are as follows:

- performed the analysis of research studies and technical solutions for remote monitoring of electrical equipment operating modes in the mining industry;
- performed the analysis of remote electrical equipment operating modes in surface mining operation under noise conditions
- developed simulation models depicting the influence of the operating modes of multi-engined mining electrical machinery (excavators) on the interference immunity, validity, and reliability of monitoring systems. Based on the obtained models experimental research was performed, allowing to determine the influence of switching impacts resulting from working under different loads;
- developed anti-interference algorithms for information acquisition, storage, and transmission taking into account switching interference;
- developed monitoring method for measuring, analysis and control devices for electrical substations equipment and mining electrical equipment for open-pit mining;
- developed block diagram of remote monitoring system for mining electrical equipment. This block diagram ensures timely and valid monitoring of electrical equipment operating modes to exclude its switching to emergency modes, as well as to predict possible economic expenditures on the repairment of the existing equipment or the purchase of the new one;
- developed technical solutions that ensure automatic selection of possible data transmission channels in remote monitoring systems under dynamic real-life conditions of mining equipment operation;
- performed testing and pilot operation of remote monitoring systems for high-voltage substations and excavator electrical equipment at AO “Shubarkol Komir” coal pit. Models for predicting power consumption were worked out based on the system operation results;
- described monitoring system application experience for underground mining;
- main scientific concepts of the thesis are reserved by the patent of the Republic of Kazakhstan and by intellectual property licenses.

Areas of Application. Electrical equipment in mining operations distributed across long distances.

Personal Contribution of the Candidate involves: the creation of simulation model of substation functioning in mining operation conditions; the development of anti-interference algorithms for information acquisition and transmission taking into account switching interference; the development of monitoring method for measuring, analysis and control devices for electrical substations equipment and mining electrical equipment for open-pit mining; the development of remote monitoring system for excavators operating modes and substations; the development of the models for predicting power consumption based on data obtained from remote monitoring systems for electrical equipment operating modes in mining operations; as well as preparation of publications on the research subject and obtaining documents of title.

Evaluation of Research and Publication Results. Main concepts of the thesis were delivered, discussed and received approval at

- Karaganda Technical University science and technology seminars
- four international conferences, including one held abroad:

1. Breido I., Sichkarenko A., Kotov Y. Communication channels in systems for remote monitoring of mining electrical equipment operating modes // Proceedings of the 30th DAAAM International Symposium. Vienna, Austria: Published by DAAAM International, 2019. P 298-304;

2. Kotov Y.S., Baskakov P.V. The development of information complex of post-contingency control system for coal mine production units // Third intern. scientific conf. “Integration of science, education and production as the base for Nation Plan” (Saginov Scientific Conference #11). – Karaganda: KarTU, 2019. – Part 5. – p. 83-84;

3. Kotov Y.S., Garbar S.A. Improvement in the effectiveness of mining operations as the result of remote monitoring system application for mining equipment operating modes control // Third intern. scientific conf. “Integration of science, education and production as the base for Nation Plan” (Saginov Scientific Conference #11). – Karaganda: KarTU, 2019. – Part 5. – pp. 81-82;

4. Kotov Y.S., Vyatkin V. The research of switching processes in electrical equipment when entering emergency mode operation // Third intern. scientific conf. “Integration of science, education and production as the base for Nation Plan” (Saginov Scientific Conference #12). – Karaganda: KarSTU, 2020. – Part 1. – pp. 859-860.

There are publications on the main scientific results of the thesis:

- 2 articles that were included in the information databases of Web of Science and Scopus companies with a percentile of 38 (2019):

1. Breido I.V., Sichkarenko A.V., Kotov, E.S. Emergency control of technological environment and electric machinery activity in coal mines // Journal of Mining Science. – Novosibirsk: Pleiades Publishing, Ltd., 2013. – T. 49. – № 2. – pp. 338-342;

2. Breido I.V., Sichkarenko A.V., Kotov E.S. Remote monitoring systems for high-voltage substations and mining machines at open-pit coal mines // Journal of Mining Science. – Novosibirsk: Pleiades Publishing, Ltd., 2016. – T. 52. – № 5. – pp. 919-926.

– 4 articles in journals indicated in the approved list by the Committee for Quality Assurance in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan:

1. Breido I.V., Ivanov V.A., Kotov Y.S. Application of gsm networks for transmitting technological information // Journal for University Proceedings. - Karaganda: KarSTU, 2018. - Issue # 3 (72). - pp. 124-127;

2. Garbar S. A., Kotov Y. S. Research on remote monitoring systems for mining equipment operating modes using various communication channels // Bulletin of KazNITU, - Almaty: KazNITU named after K. I. Satpayev, 2020. - Issue # 2 (138). - pp. 124-130;

3. Breido I. V., Vyatkin V., Kotov Y. S. System of pre-and post-accident control of operation modes of explosion-proof electrical equipment // Bulletin of the Almaty University of Energy and Communications. - Almaty: NAO "Almaty

University of Energy and Communications named after Gumarbek Daukeev", 2020. - Issue # 2 (49). - pp. 114-121;

4. Kotov Y. S., Vyatkin V. Simulation of transient processes on the example of a high-voltage substation at a coal mine // Bulletin of KazNITU, - Almaty: KazNITU named after K. I. Satpayev, 2020. - Issue # 4 (140). - pp. 122-1271;

1. Patent of the Republic of Kazakhstan: Pat. 5132 the Republic of Kazakhstan, IPC G06F 17/40 (2006.01), G05B 13/00 (2006.01), G06F 13/42 (2006.01). Пайдалы қазбаларды ашық өндіру жағдайында тау-кен өндірісінің электр қосалқы станциялардың және электр жабдықтардың өлшеу, талдау және басқару құрылғыларының мониторингін жасау тәсілі Monitoring method for measuring, analysis and control devices for electrical substations equipment and mining electrical equipment for open-pit mining / Kotov Y. S., Breido I. V., Sichkarenko A.V.- No. 2020/0423.2; applied on 02.05.2020; publ. 10.07.2020, Bulletin # 27

– 2 certificates of the state registration of rights to the object of copyright:

1. Kotov Y. S., Sichkarenko A.V., Breido I. V. Operator's Manual to the system of technical accounting of electricity and technological parameters of substations "YUZHNAAYA" and "YUGO-ZAPADNAYA" of AO "Shubarkol Komir" (a work of literature) // Certificate of the state registration of rights to the object of copyright. Entry in the register No. 8594 dated 05.03.2020 – Ministry of Justice of the Republic of Kazakhstan.

2. Kotov Y. S. Program for protection against unauthorized reset of electric power readings: Memory ME96SSR-MB (computer software) / / Certificate of the state registration of rights to the object of copyright. Entry in the register No. 9489 dated 20.04.2020 – Ministry of Justice of the Republic of Kazakhstan.

The results of the research are incorporated into the educational process of Karaganda Technical University, as well as implemented and applied at the coal mine of AO "Shubarkol Komir".