ANNOTATION

dissertations for the degree of Doctor of Philosophy (PhD)
in the specialty 8D07103 – «Electrotechnical complexes and systems»

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DEVELOPMENT OF THE METHODS AND MEANS FOR IMPROVING EFFICIENCY OF THE POWER SUPPLY SYSTEMS IN MINING FACILITIES

The dissertation is dedicated to improving the efficiency of the power supply systems of mining enterprises.

Relevance of the study.

The modern mining industry faces several challenges related to efficiency and safety. The intensification of production processes leads to an increase in mining operations and higher demands for their quality and speed of execution. In this context, the implementation of efficient and safe practices, such as the use of the latest mining and equipment monitoring technologies, becomes an important factor in improving the efficiency and safety of mining operations. The efficiency of the power supply system is determined by its ability to meet electricity demand with minimal transmission and distribution costs. To achieve system efficiency, factors such as reliability, stability, flexibility, economic efficiency, and others must be considered.

The efficiency of the power supply system depends directly on the reliability and safety of electrical networks, including networks up to 1000 V, which are an integral part of power supply and whose reliable operation is necessary for the sustainable development of the power industry. Regular maintenance of three-phase electrical networks and adherence to high safety standards guarantee an increase in the level of electrical safety and reliability of electrical networks, thereby improving the efficiency of the power supply system. Insufficient maintenance of electrical networks can lead to accidents, downtime, and other problems, which, in turn, can reduce the efficiency of the power supply system. Equipment downtime can significantly reduce the efficiency of mineral and other resource extraction and lead to additional costs for repairing or replacing faulty equipment. As a result, the company may incur losses and limit its ability to further develop.

Based on the above, research on the development of methods for determining insulation parameters, evaluating insulation and protection device conditions are important aspects of electrical network operation, especially in the context of improving their efficiency and reliability. Continuous monitoring and analysis of insulation conditions can help prevent accidents and ensure uninterrupted operation of electrical networks, thereby increasing the level of electrical safety and efficiency of the power supply system as a whole.

The connection of the dissertation topic with state programs and the university's work plan. The work was carried out at the Kazakh Agrotechnical University named after S. Seifullin in accordance with budget program 217 «Scientific and/or scientific-technical activities», subprogram 102 «Grant funding for

scientific research» on the topic AR05132692 «Development of innovative technologies to improve the efficiency of power supply for mountain enterprises».

The object of the research is three-phase electrical networks with an isolated neutral at voltages up to and above 1000 V.

The subject of the research is the determination of insulation parameters, single-phase earth fault current, leakage current, and touch voltage in electrical networks with an isolated neutral.

The aim of the work is to improve the efficiency of power supply for mountain enterprises by developing methods for determining insulation parameters, single-phase earth fault current, leakage current, and touch voltage in electrical networks with an isolated neutral.

The idea of the work is to increase the efficiency of power supply for mountain enterprises by developing methods for determining insulation parameters, single-phase earth fault current, leakage current, and touch voltage in electrical networks with an isolated neutral based on the application of the laws of voltage change with artificial neutral displacement.

To achieve the goal, the following scientific tasks were set:

– to develop mathematical dependencies for determining insulation parameters in an asymmetrical electrical network with an isolated neutral;

– to develop methods for determining insulation parameters, leakage currents, single-phase earth fault currents, and touch voltages in an asymmetrical electrical network with an isolated neutral;

– to conduct a numerical experimental study of the proposed method for determining insulation parameters in order to perform a comparative analysis of the results;

– to conduct a numerical experimental study of the developed methods for determining insulation parameters, single-phase earth fault currents, leakage currents, and touch voltages in existing electrical networks with an isolated neutral at mountain enterprises;

– to develop means of improving the efficiency of the power supply system at mountain enterprises.

Scientific novelty:

– establishment of mathematical dependencies for determining insulation parameters, one-phase earth fault currents, leakage currents, and touch voltages in a three-phase electrical network based on measurements of the magnitudes of zero sequence voltage, phase voltage with respect to earth, and their vector angles, the difference of which is the consideration of unsymmetrical phase voltages and their symmetrical components;

– development of methods for determining insulation parameters, one-phase earth fault currents, leakage currents, and touch voltages in a three-phase electrical network, which allow determining the insulation parameters of mining enterprise networks with an accuracy of not more than 10%;

– the first numerical values of insulation parameters in an electrical network with a voltage up to 1000 V on the rotary excavator SRC(K)-2000 were obtained using the developed methods.

Practical significance:

– development of effective methods for determining insulation parameters, one-phase earth fault currents, leakage currents, and touch voltages in a three-phase electrical network with an isolated neutral;

– the proposed methods can be applied in the operation of electrical networks with an isolated neutral under working voltage by regularly monitoring and analyzing the state of insulation, which increases the level of electrical safety and the efficiency of the power supply system as a whole;

– the analytical dependencies of phase voltages and insulation parameters obtained in the study have a universal character and can be applied in electrical networks with an isolated neutral in other industrial sectors.

Methodology of the research: In developing methods for determining insulation parameters, single-phase earth fault current, and touch voltage in three-phase electrical networks with isolated neutral, the following were used: methods of symmetrical components; theory of errors; theoretical foundations of electrical engineering; mathematical statistics and probability theory; Maple software, and the Python programming language with libraries such as Numpy, Scipy, and Matplotlib.

The main scientific principles and research results presented for defense are as follows:

1. mathematical description of the determination of insulation parameters in a three-phase asymmetric electrical network with an isolated neutral based on the application of voltage variation patterns during artificial neutral shifting;
2. methods for determining insulation parameters, single-phase earth fault currents, leakage currents, and touch voltages in a three-phase electrical network based on measurements of the magnitudes of zero-sequence voltages, phase voltages, and their vector angles before and after connecting additional capacitance between the electrical network phase and earth, taking into account the asymmetric phase voltages and their symmetrical components;
3. assessment of electrical safety at mining enterprises based on new experimental data of insulation parameters in electrical networks with an isolated neutral using the developed methods;
4. means of improving the effectiveness of the power supply system by increasing the sensitivity of protective shutdown devices, based on a comprehensive analysis of the results of experimental research conducted under real operating conditions of the mining enterprise's power supply system.

The validity and reliability of scientific principles, conclusions, and recommendations are confirmed by considering important processes, adopting adequate levels of assumptions for mathematical modeling phenomena, basing initial assumptions on fundamental laws of natural sciences and the principles of electrical circuit theory, comparing qualitative parameters of theoretical research results with experimental data obtained in operating networks, as well as having a sufficient volume and results of experimental research.

The implementation of the research results in the industry. The methodology for determining insulation parameters in an electrical network with an isolated neutral, based on measuring the magnitudes of zero-sequence voltage modules, phase voltages relative to earth, and their vector angles after connecting capacitive additional conductivity between the phase of the electrical network and the earth, has been implemented in the scientific and educational process of the Navoi State Mining and Technological University, as well as in the technological process of the mining enterprise «Bogatyr Coal» LLP.

The dissertation consists of an introduction, a main part consisting of four sections, a conclusion. The volume of the dissertation is 94 pages of typewritten text, including 7 tables, 32 figures, a list of references, which includes 64 items, and 2 appendices.

The content of the work.

The introduction justifies the relevance of the scientific problem addressed in the research and formulates the aim and idea of the work, presents the main defended scientific positions, scientific novelty, and practical value of the obtained results, provides information on the implementation of the research results, their testing, and the number of publications.

In the first chapter, the state of the art and a literature review are presented, focusing on the research into the state of isolation in electrical networks with an isolated neutral. The review and analysis of existing insulation control methods and protective devices are provided, and the goals and objectives of the research are formulated. Based on the research and analysis of publications both in the country and abroad, it was identified that the development of new methods for determining the parameters of network insulation is an important task, as it contributes to increasing the level of electrical safety and ensuring the continuity of power supply to enterprises.

In the second chapter, methods for determining the parameters of insulation in an asymmetric network with an isolated neutral with a voltage of 1000 V or higher are developed using newly derived mathematical dependencies. The proposed method for determining the parameters of insulation in a three-phase asymmetric network with an isolated neutral, with a voltage of 1000 V or higher, is based on measuring the module values of the zero-sequence voltage, the phase voltage with respect to the earth, and their vector angles, before and after connecting additional capacitive conductivity between phase A of the electrical network and the earth. The parameters of the network insulation are calculated, taking into account the value of the introduced additional capacitive conductivity. The proposed method allows for the determination of insulation parameters in an asymmetric three-phase network with an isolated neutral with sufficient accuracy and simplicity.

Numerical experimental studies of the developed method were carried out, and comparative analysis of the results was conducted, where the relative error did not exceed 10%. The analysis of the error showed that the developed method has sufficiently high accuracy and also has advantages in conducting measurements.

The third chapter explores and develops methods for determining leakage current, single-phase earth fault current, and touch voltage in an asymmetric electrical

network with an isolated neutral. An analysis of the error in indirect measurement of phase voltage, zero sequence voltage, and their vector angles before and after connecting additional conductivity was conducted, which showed satisfactory accuracy.

In the fourth chapter, the developed methods were applied to operating excavators, and the results of the measurements were analyzed. Testing the developed methods on operating electrical installations enabled obtaining numerical indicators of insulation parameters and single-phase earth fault current in an asymmetric three-phase electrical network with an isolated neutral with a voltage of up to 1000 V on the EKG-5 excavator and the SRs (K) - 2000 rotary excavator of «Bogatyr Coal» LLP. The analysis of the results revealed a deficiency in the functioning of the protective disconnection devices of the UAKI-380 and RU-127/220 type, which prompted the development of means to increase their effectiveness.

The conclusion presents the research results.

Validation of the work. The main materials and results of the dissertation were presented and discussed at the international conference on electrical, computer, and energy technologies ICECET-2022.

The main scientific results of the dissertation were published in 2 scientific papers, including 1 publication that is included in the Scopus database (percentile - 83) and 2 publications in transactions recommended by the CQAFSHE MSHE RK. The Eurasian patent for the invention №041128 dated 16.09.2022 and the patent of the Republic of Kazakhstan for the invention №35922 dated 21.10.2022 were obtained.