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Reliability control of failure-free operation of power supply system of railroad and its components by methods of intellectualization and informatization

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Abstract
We conducted the fundamental, applied and experimental studies to solve a complex problem of the innovative transformation of traction electrical networks of railways and their management system. It is achieved by creating a single model of deep integration of the distributed computer environment architecture and topology of the railway power supply network by the introduction of modern computer energy-saving technologies for optimization of power supply for traction.
Such organization of power supply networks has fundamentally new architectural and functional properties, such as reconfiguration of the structure with self-organization elements. It allows real-time implementation of all-mode continuous monitoring of a set of parameters of traction networks and power equipment of traction substations and creating new intelligent technologies for power supply control. These technologies are oriented to accumulate new knowledge in the field of anomalous and regular operation modes of traction networks using advanced management concepts, optimization of power supply, organizing energy-saving technologies for power consumption, technical condition assessing, emergencies forecasting, increasing the reliability of electrical systems and improving the level of accident-free transportations.
Key words: COMPUTER INTELLECTUALIZATION, NETWORK TECHNOLOGIES, COMPUTER SYSTEMS, MONITORING, CONTROL SYSTEM, DISTRIBUTED SYSTEMS, INTELLIGENT TECHNOLOGIES

Problem statement

Despite the deep researches in the field of electric power control at the present stage, which is characterized by a large increase in the amount of information formed during computer monitoring and control of the parameters of technological processes in electric power facilities and networks for the formation of managerial decisions, currently the mathematical models for a formalized description of their functioning are insufficiently developed, as well as methods for solving a set of tasks for managing power consumption modes from general system positions are

poorly developed and issues on the coordination of the solution of these problems are not considered [2, 4]. Existing methods of forecasting electric loads of consumers impose strict conditions on the primary information received, the behavior of electric power management objects and can not always satisfy the accuracy of modeling for operational management [3]. Modern dispatching and commercial accounting systems are focused on performing control functions and not on solving optimization problems, only in some cases, they have the ability to simulate the dynamics of regular and abnormal modes or use them as simulators for maintenance staff. This is characterized by the fact that, as a rule, the developers of computer systems and networks pay the main attention to technical support and software, rather than to setting and solving mathematical problems of system analysis of generation processes, power consumption and the quality of electrical networks. Modern computer systems and network technologies do not fully solve the tasks of continuous monitoring and maintenance of the schedule of preventive maintenance of electrical equipment, quality control of electric power, optimization of the modes taking place in electrical systems, maintaining the balance of the received and consumed electricity, calculating individual parameters of power consumption, automatic data archiving on the modes of the power system. Namely, this complex of tasks is the decisive factor in the intellectualization of traction electrical networks and, as a result, power consumption optimizing and electricity saving.

Research objectives

Investigation of ways, means and methods to ensure the efficiency of the use of intelligent power supply systems, which will allow obtaining a higher quality of electricity supply services, by forming an integrated multi-level control system with increasing automation volume and a significant increase in the reliability of the system of power supply, energy saving, optimization of power consumption and, correspondingly, improving the safety of railway traffic and a new strategy for the development of the electric power industry, directly by computerization and the intellectualization of technological processes for managing the traction networks of the railways of Ukraine.

Main research material

In recent years, automation of electrical facilities and monitoring of their operation have received a new impulse due to the widespread introduction of modern and promising computer technologies, as well as various microprocessor-based programmable controllers. The rapid development of microprocessor technology and, in particular, the technology of centralized information processing, initiated the transition to decentralized management, which provided the opportunity to automate the management of geographically distributed objects including the railway. All this became the basis for the creation of integrated systems for the commercial management of electrical networks, which automation management requires solving of a wide range of tasks of economic, dispatching, technological and operational management at different levels of the hierarchy. In this connection, the formation of a set of principles and methods for the synthesis of integrated computer monitoring systems, diagnostics and determination of the technical state of power electrical equipment for railways on the application of a unified environment for the primary measurement of electrical parameters from a single information position became relevant.

Ensuring the reliable and efficient operation of electric power systems is directly related to the level of informatization and intellectualization of their monitoring and management systems.

Informatization is the most promising and least expensive way to increase the reliability and efficiency of electric power production, which, in comparison with others, does not require significant investment [5].

The intellectualization of electric traction networks of railways opens the possibility to implement the deep integration of infrastructures of the power supply network and computer control systems and, thereby, makes it capable of solving the whole range of tasks related to the management of electric power production.

This approach can be implemented by organizing a multi-level distributed computerized environment adequately reflecting the topology of the traction network infrastructure and be oriented to solving a complex of tasks of increased intellectual complexity and dimension and the presentation of various information to all levels of management, the main source of which are technological processes and events directly occurring in power supply networks and facilities [7]. When creating a distributed computer environment for solving these problems, we will be guided by the bottom-up information strategy due to the sources of primary information and the elements of the system that support the implementation of control actions are at the object level. To ensure the observability of the system at all levels of the hierarchy is an indispensable condition for the effective functioning of intelligent traction networks and reliable management of

their modes. This requires, at a minimum, the completeness of information, and in some cases, certain redundancy in the corresponding segments of the network management hierarchy, if taking into account the level of operational reliability of means of the information collection and transmission system. First of all, this concerns primary information received from monitoring systems as discrete signals, for example, indication of the position of all switching devices to the level of outgoing lines from low-voltage buses of substations, and changes in the state of start-up and output means of all relay protection devices, and in the form of analog signals of current measurements of the modes parameters at different points in the power supply network. If these conditions are met, a multi-level hierarchical distributed at each level of hierarchy computer architecture of the control system for traction power supply networks and objects with the possibility of constant development can be synthesized. It provides an effective solution, primarily for the tasks of technological and operational dispatch control, as well as a number of other tasks related to production and technical processes including the tasks of control and organizational economic management. Depending on the level of the hierarchy of management of the intellectual traction network, the fragments of the computer environment can be distinguished by electronic components, characteristics and the composition of tasks on the results of solving, on which the management functions are based. The main thing is not to violate the basic principles of construction and use of the computing environment [1]. It should be noted that the distributed computer information and software environment for the management of electrical objects and networks will significantly affect the changes in the technology of management organization, bringing more and more management functions to the automatic mode of execution, which is implemented by providing the possibility of automatical solution of the corresponding problems. Due to the introduction of modern intelligent technologies in the electric power industry of railway transport, more and more time of the operational dispatch personnel is being released to perform its main functions in the automated control system such as analyzing situations, making optimal decisions and managing their implementation [5].

The management of operating modes at all levels of the hierarchy of the Ukrainian railways' electric networks should ensure the stage-by-stage implementation without disrupting the current technological process of dispatch control, the exchange of telemetric information with existing and prospective software and hardware complexes of the controlled points of power facilities; long-term storage, processing and provision of the necessary telemetric information to all levels of the management hierarchy, sites of the telemechanic network; automatic control of redundant communication channels, reservation of telemetric information of the main communication channels; adjustment and maintenance of software and hardware with the help of an integrated set of service programs; protection against unauthorized interference.

In addition to the above, the open architecture of the power supply networks management systems should provide the opportunity for the development of functionality by setting up additional programs: the introduction of a single database of normative and reference information; maintenance of operative electronic journals with electronic signature for automation of dispatching personnel and other servi- ces involved in the management processes of the operating modes of power supply networks; integration with the geoinformation system; WEB-access to data via the Internet; On-line retransmission of operational information into SQL compatible databases; dispatch of SMS notifications about emergency events in the system from sites of the telemechanical network to the operational personnel of line services.

The power supply networks management system at all levels of the hierarchy is a centralized, hierarchically distributed, multi-level automated dispatch control system for operating modes of the Ukrainian railways' electric networks, which has its own structure that corresponds to the organizational one and consists of four levels Fig. 1.

This system opens the possibility to improve the reliability of dispatching control of the operating modes of the electric networks of Ukraine's railways, the quality of management in the context of the elimination of failures, violations of the mode and the consequences of natural disasters; to improve the safety of personnel and failure-free operation of equipment. And also to ensure the correspondence of the automation of operational and technological and production-technical business processes, the possibility of using the information of the topological model of the power supply network, the conformity of functionality, reliability, architecture, synchronization of operational data to international electricity standards, and the ability to exchange information at all levels of the hierarchy [5].

With the introduction and development of modern communication channels, telecontrol systems, technical condition monitoring, automatic diagnostics and

monitoring of process equipment, relay protection and emergency automatics systems, power quality measurement systems, the increase of telemechanized substations and the number of controlled parameters, the control system of electric networks should increase the following characteristics: the quality and efficiency of the analysis of the flow of the technological process; reliability and economy of transportation and distribution of electric energy; stability and trouble-free operation, efficient operation of power supply networks [7].

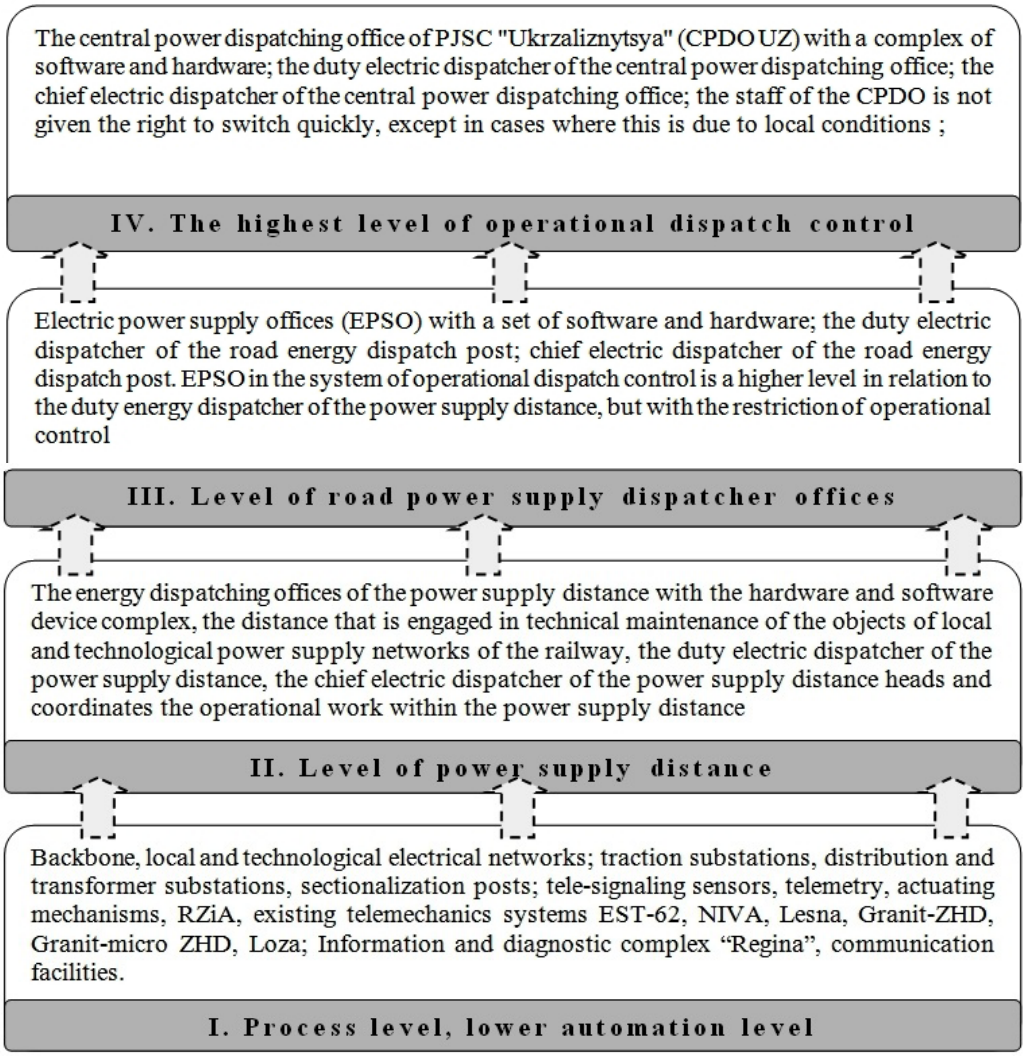

Figure1. Organizational structure of the levels of the power supply network management system

Traction electrical networks of railways as management objects differ from power supply networks in other sectors of the economy by a number of features such as power supply scheme, generation of higher harmonics (first of all, the third one), etc. Such features require the use of fundamentally different mathematical models, information structures and algorithms for performing the necessary calculations in the operational control mode. In this regard, the corporate integrated system for monitoring and managing contact electric networks of railways belongs to the class of complex multi-position control systems for geographically distributed objects with moving loads.

The only analog of such a system can be integrated control system for general distribution electrical networks, although in such systems, there is no need to take into account the "mobility effect" of electrical loads on the hauls between traction substations.

Taking into account the above and technical characteristics and functional capabilities of microprocessor systems, which are present in the market of facilities and services, the implementation of this integrated system for the registration of emergency modes of traction substations of all six railways, the continuous diagnosis of electrical equipment and the prediction of its technical condition have been carried out using IDC "Regina".

The IDC of the "Regina" family registers analog (mode parameters) and discrete signals (signals from protection and automation systems, equipment operation modes), providing, among other things, the

possibility of solving operational and technological problems [3].

With the help of the IDC "Regina", information is obtained on the basis of which the tasks of the analysis of modes and operational management are solved. The tasks connected with the analysis are solved in off-line mode on the basis of the received synchronized information on the events occurred. Due to the time tagging of the input discrete signals of relay protection automation (RPA) and switching devices, it is possible to analyze the sequence of events, causes and consequences of technological violations and accidents. Based on the results of such an analysis, it is possible to establish the correct functioning (and, accordingly, adjustment) of the equipment of electric power facilities (EPF) including RPA devices. In order to minimize the negative impact of the human factor on the reliability of the results of the analysis of the functioning of the electric power system (EPS), and also to enhance the functionality of the monitoring systems, "Regina" complexes implement the functionality elements of the operational staff support systems in decision-making (SSOSDM), and also interact with additional SSOSDM. Thus, for example, the tasks of determining the short-circuit on a power line are solved both directly by the IDC "Regina" and "in parallel" applying hybrid SSOSDM using artificial intelligence [2,3].

With the help of additional SSOSDM that use the information obtained by the IDC "Regina" facilities on the basis of the EPS computer model, it is possible to diagnose complex system emergency states and improve the quality of EPF management.

Tasks that are directly related to operational management are performed on-line, they are also divided into monitoring tasks and assessment tasks (diagnosis) of current modes. Such a choice, as the existing experience of operation of the created corporate system has fully justified itself, since the technical and functional capabilities of the IDC "Regina" fully meet the requirements.

The high level of complexity of electrical objects and networks, the variety of components and the possibility of their functioning in a wide range of frequencies, as well as changes in states, have contributed to the emergence of a large number of approaches, methods, techniques, technical means, and later computer components and network technologies to solve a set of tasks of electric power control.

Conclusions

1. The analysis of the control system of power supply networks was conducted, the ways of researches were outlined and conceptual bases of the organization of an intellectual traction electric network were shown.

2. The complex of issues related to the reliability of effective power supply for traction is closely intertwined with real-time monitoring of a set of parameter values reflecting the mode of operation of the power supply system.

3. Approaches and methods of computer intellectualization of the modes of operation of traction networks of railways were considered on the basis of research of general properties of mathematical models, methods, algorithms and architectures computing.

4. The organizational structure of levels of a control system of electric networks was presented, which was implemented by integration of power supply network and computer information infrastructures.

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