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Article

Development of an innovative model for the inter-integration of the architecture of the intelligent computer environment of critical infrastructure facilities of the railway

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DEVELOPMENT OF AN INNOVATIVE MODEL FOR THE INTER-INTEGRATION OF THE ARCHITECTURE OF THE INTELLIGENT COMPUTER ENVIRONMENT OF CRITICAL INFRASTRUCTURE FACILITIES OF THE RAILWAY

The object of research is the processes of intelligent management of the computer environment of data objects of the critical infrastructure of railway transport. When developing an innovative model of deep mutual integration of the architecture of an intelligent computer environment for the management of objects in the power supply system of railway transport, the only urgent task is to solve the problems of efficient and reliable power supply of electricity for train traction to ensure the transportation process. The approaches, mathematical models and methods that became the basis for the creation of an innovative model and a new structure of the management system, the integration of the architecture of the computer environment of data of critical objects of the infrastructure of railway transport, meet the requirements of modernity and the strategy of sustainable development of the transport infrastructure.

Management of an intelligent computer environment in the context of the railway power supply system is a complex process that includes the use of various technologies and strategies to optimize the functioning of systems, increase reliability, ensure efficient use of electricity, and ensure the transportation process. The basis of the creation of an intelligent computer environment is the principle of a single informational and synchronous space for the formation of primary information, which is an important concept in the development of intelligent control systems for the power supply system of railway transport. This principle requires that all parameters and data that are collected from different systems of power supply facilities should be combined in a single information space and be available for analysis and management in real time. This principle creates the basis for innovative solutions in the field of railway power supply system management, and the use of the Internet of Things, artificial intelligence, machine learning and deep learning allows the development of systems that meet modern requirements for the efficiency and reliability of energy systems.

The use of the approach of deep mutual integration of the architecture of the computer environment is key in the possibility of automating the processes of data collection and analysis, as well as in improving the interaction between the components of the systems of power supply facilities of railway transport, the reliability and efficiency of the system, which makes it more flexible and adaptive to changes in load and working conditions.

The research presented in the work can be used in practice in organizations, structural units and at the levels of the management system of critical infrastructure objects in railway transport, transport sector enterprises, which will allow a quick response to an emergency situation and switch to backup modes, ensuring reliability and availability of power supply in conditions of challenges.

Keywords: *computer environment, facilities management, power supply system, innovative model, critical infrastructure of railway transport.*

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1. Introduction

The power supply system of railway transport is a complex set of engineering solutions that provides the supply of electrical energy to locomotives and electric trains for their movement. In the conditions of martial law, the objects of the power supply system become critical infrastructure objects for the safety, efficiency and stability of the country, and the further proper operation of the power supply system is necessary to ensure the support and safety of the transportation of passengers, military equipment, cargo of various kinds of importance, which currently has an important socio-economic character of the international level.

Management of the power supply system of railway transport requires innovative and improved solutions to ensure reliability, safety and efficiency in the conditions of military conflict.

Therefore, the application of the intelligent management of the computer environment of the power supply system objects has several key advantages and can be decisive for the efficiency and reliability of the system, which will allow to ensure more efficient, reliable and energy-efficient operation of the electrical network of railway transport.

The computer architecture of the power supply system, focused on the research and management of the power supply of railways, includes a variety of technological components that contribute to the collection, analysis and optimization of data, as well as the management of the power network. The key elements of the computer architecture of the power supply system are:

- data collection and monitoring systems, which include sensors, measuring devices and other equipment for collecting data on the state of the power grid, including voltage, current, frequency, temperature, etc.;
- data storage systems are databases and data warehouses where all collected data is stored. They can use database technologies such as SQL or NoSQL to provide reliable and fast data access;
- analytics and forecasting systems that use machine learning algorithms and other data analysis methods to identify dependencies, build models and predict events in power supply systems;
- resource management systems, including resource allocation management software, including electrical power and backup power system charging;
- energy efficiency management systems that help reduce electricity consumption and optimize the operation of systems, ensuring maximum performance with the least resources;
- systems for managing emergency situations and recovery, which automate the processes of detecting emergency situations, managing backup power and restoring systems after emergency situations;
- query and reporting management systems that enable users to create queries to the database, as well as generate reports and analytical data for decision-making;
- communication technologies, which include communication protocols for data transmission between efficient system components, such as Wi-Fi, Ethernet, LoRaWAN, etc.

These components interact with each other to ensure the reliability, efficiency and safety of the railway power supply system. This allows research, analysis and management of railway power supply at a high level of accuracy and productivity.

An analytical review of works on the application of intelligent management of power supply system objects is given in works [1–6]. Namely, in work [1] the question of the organization of the architecture of intelligent management of the power supply system was considered, but the construction of the system itself was investigated, not taking into account the distributed exchange of information between the levels of the system hierarchy. Work [2] investigates the methodology of building classification systems and methods of identifying emergency modes of power supply system objects. Data processing was carried out from territorially distributed energy facilities, but not in the formed single information space. The works [3, 4] present the ways of computer intellectualization of traction network operation modes that take place in the structure of an intelligent electric network, and it is proposed to use the generalized structure of an intelligent electric network formed as a result of the mutual integration of the architecture of the traction network of power supply and the computer information architecture of control. In order to increase the efficiency of management of technical means of power supply system objects, works [5, 6] suggested using a multilevel intelligent control system. In works [7, 8], the main technologies of intelligent electric energy, modern trends in the development of electricity transmission are considered.

The aim of research is to develop an innovative model that will reflect the mutual integration of architecture and intelligent control of the computer environment of the parameters of the objects of the power supply system of railway transport. The innovative model includes a number of energy technologies, mathematical models and methods for increasing the efficiency, reliability and safety of electricity supply for train traction.

2. Materials and Methods

The object of research is the processes of intellectual management of the computer environment of the parameters of the objects of the critical infrastructure of railway transport.

The paper presents the prospects and possibilities of using the intelligent management of the computer environment of the parameters of the objects of the critical infrastructure of railway transport. The main components of the computer architecture of the power supply system and the principles of operation of each component are considered.

The possibilities of applying the approach of deep mutual integration of the architecture of the computer environment are revealed. Deep integration allows the use of machine and deep learning algorithms for automatic analysis of large volumes of data. Systems can detect patterns, identify anomalies, and predict the future state of the system based on this data. Deep mutual integration allows various components of the system to continuously interact with each other. This means that data can be transferred between components in real-time without delays or interruptions, allowing to react to changes and past events.

It was determined that the concepts of the Internet of Things (IoT) and artificial intelligence (AI) can be used to reveal an innovative model of deep mutual integration of the architecture of an intelligent computer environment, as well as focus on developments in the field of computing, capable learning (machine learning) and deep learning (deep learning) [9].

Internet of Things: IoT allows connecting a variety of devices and sensors to the Internet, which provides the collection of a large amount of data about the state of power supply systems, equipment and loads. This allows for the creation of a distributed network of sensors that send data for further analysis and management.

Artificial Intelligence: AI can be used to analyze large amounts of data collected from sensors and other sources

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and make automated decisions. For example, AI systems can detect anomalies, predict changes in load and identify some risks.

Machine learning and deep learning: These technologies allow to build models that can learn and understand complex relationships in data. They can be used for forecasting, optimization and detection of anomalies in power supply systems.

Automation and decision management: an intelligent system can automatically respond to changes in system parameters and make decisions regarding regulation of voltage [10], power and other parameters. This allows to optimize the operation of the system and increase its reliability.

Security and cyber defense: IoT and AI also play an important role in providing cyber defense systems. They can detect current threats and security measures to protect against cyber-attacks.

Thanks to these technologies and approaches, it is possible to develop an intelligent system that is able not only to monitor the state of the power supply system, but also to predict the possibility of problems and automatically respond to them. This will make it possible to provide effective and reliable management of the power supply of railway transport in real time.

3. Results and Discussion

Let's note that the innovative model will reflect the mutual integration of architecture and intelligent control of the computer environment of the parameters of the objects of the railway power supply system. It also includes a number of energy technologies, mathematical models and methods for improving the efficiency, reliability and safety of power supply for train traction. These definitions and principles of the content of the model became the basis for the organization of its computer architecture. The architecture of the model is focused on research and intelligent management of the power supply system of railway transport.

The architecture of intelligent management is organized on the basis of a hierarchical structure, which allows to manage the system at different levels of complexity and ensures optimal organization and coordination of various functions of the system.

An innovative model of deep mutual integration of the architecture of an intelligent computer environment allows solving a complex of problems of diagnosis and control of control and monitoring systems, forecasting and management, ensuring an uninterrupted supply of electricity and increasing the overall productivity and traffic safety.

The computer environment for the parameters of the power supply system is based on the principle of a single information and synchronous space for the formation of primary information, which is an important concept in the development of intelligent control systems for the power supply system of railway transport. This principle requires that all parameters and data that are collected from different systems of power supply facilities be combined in a single information space, which will avoid duplication and mismatch of data and be available for analysis and management in real-time modes. Data is collected and processed in real time, which allows the system to respond to changes in the power supply system instantly. This is especially important for real-time management. A unified information system ensures the availability of only one set of data that is true and up-to-date [1]. This is ensuring the unity of information in all parts of the systems. If the data resides in a single information system, centralized security strategies including encryption and authentication can be used. Data in a single informational and synchronous space can be easily monitored and managed. Automated systems can detect anomalies in a timely manner and take the necessary measures.

The use of a single information and synchronous space is key to optimizing management and ensuring the reliability of railway power supply systems [3].

Deep mutual integration allows to automate the processes of data collection and analysis, as well as for various components of the system to interact with each other without interruptions and communication failures. Thanks to continuous interaction between system components and automated data analysis, the system can quickly respond to any changes reflected in the power supply system. Deep mutual integration allows to create systems that can automatically switch to backup sources, detect and eliminate faults, which should ensure the stability and reliability of the system, even in the event of problems.

The innovative model is simulated using specialized BP win software.

The main window of the context diagram of the program for displaying the main components of the innovation model, namely initial data, resources, mechanisms, and reporting information is shown in Fig. 1.

The first level of the hierarchical structure (Fig. 2) reflects a set of structural subdivisions and objects, namely traction substations: transit, support and dead-end. At this level, a complex of tasks of management and organization of continuous monitoring of the modes of operation of electric networks is implemented. Identification and determination of the accident site is also carried out [3]. Equipment diagnostics are provided: sensors, microprocessor devices, etc., including a forecast of the technical condition of traction substation equipment, intelligent electricity accounting, etc.

At the next level (Fig. 3), a single information-synchronous space of primary information and a database is formed, as well as express files and complete emergency and commercial information with its sequential transfer to all levels of management for analysis and management decision-making.

The second level of the hierarchy (Fig. 4) reflects the operational management of objects of the power supply system of railway transport. At this level, a number of procedures related to the collection, processing, analysis, and archiving of secondary data coming from lower-level power supply system facilities are performed. Blocks of processed data are formed and transferred to the next management level in the appropriate format.

At the level of the railway transport management office of JSC «Ukrzaliznytsia» (Fig. 5), the strategy and coordination of the development and management of critical infrastructure facilities is developed. Modern relations with the market in the field of electricity purchase and sale services are also being formed [11]. At the same level, the generation of reporting documents in the form of statistical reporting is implemented for other management bodies of objects of critical infrastructure of railway transport [12]. All these operations and procedures are performed thanks to the processing and analysis of data received from all regional branches of Ukrzaliznytsia.

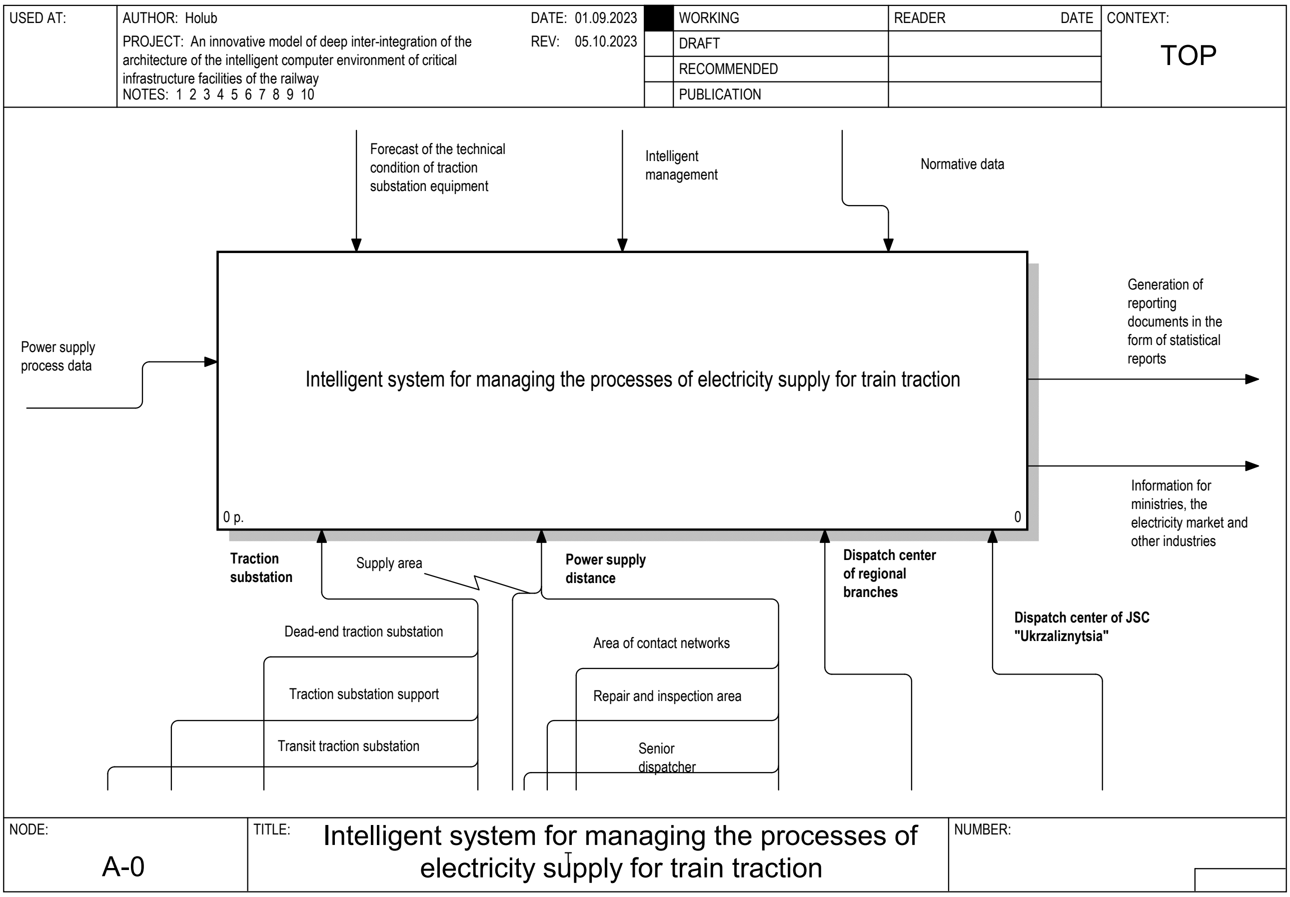

Fig. 1. General appearance of the model

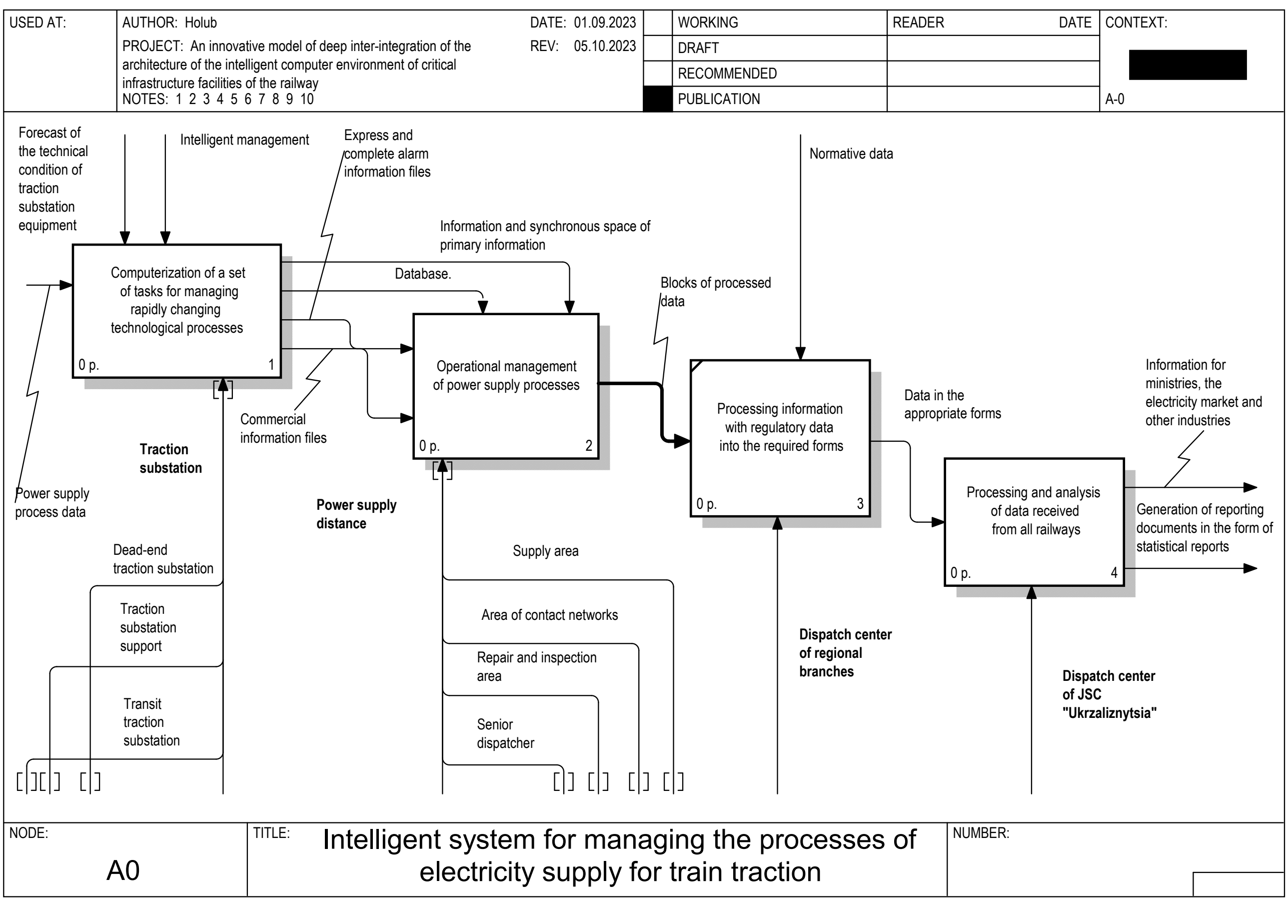

Fig. 2. Decomposition diagram of the set of management and monitoring tasks

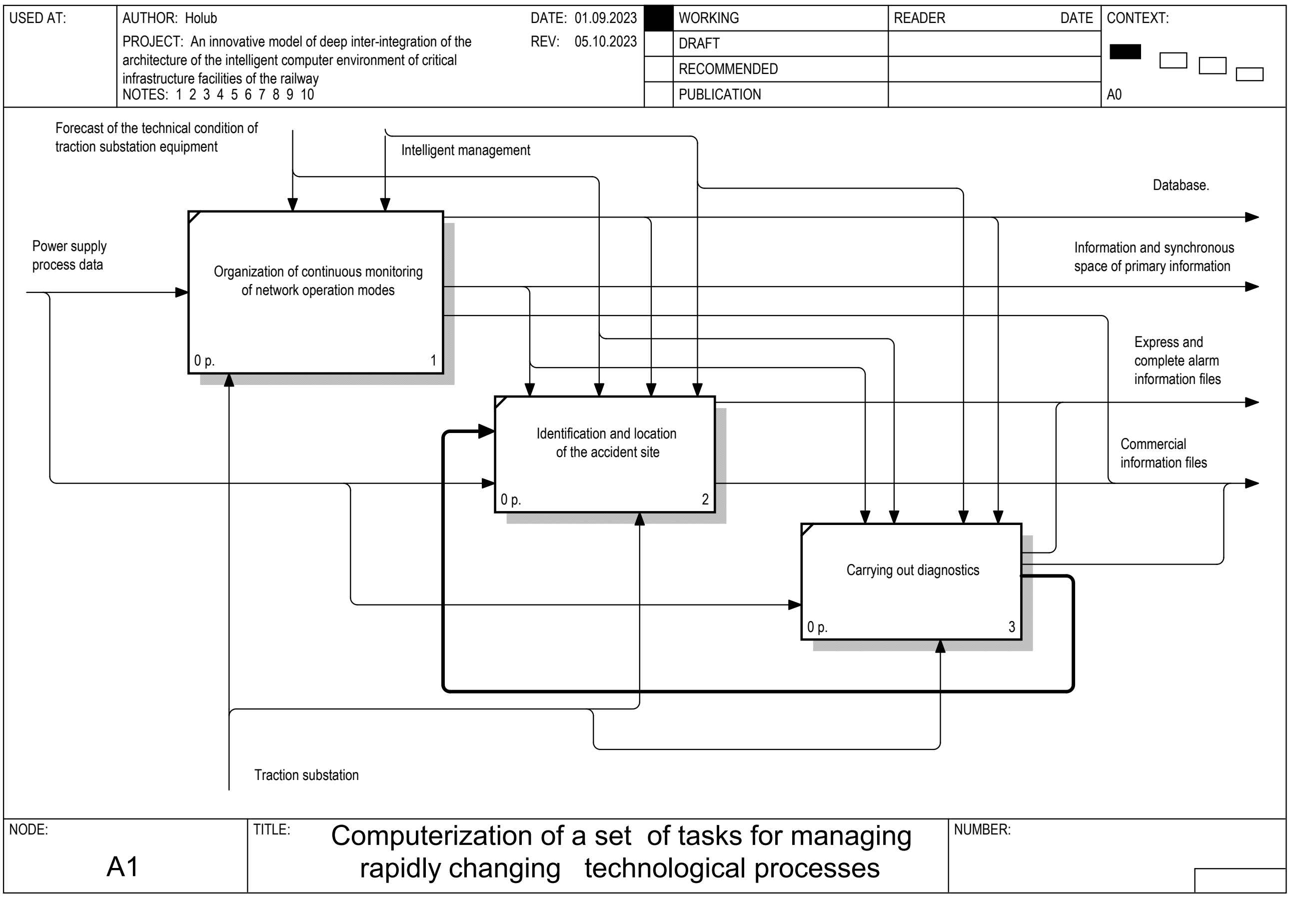

Fig. 3. Diagram of the model of a single information space formation

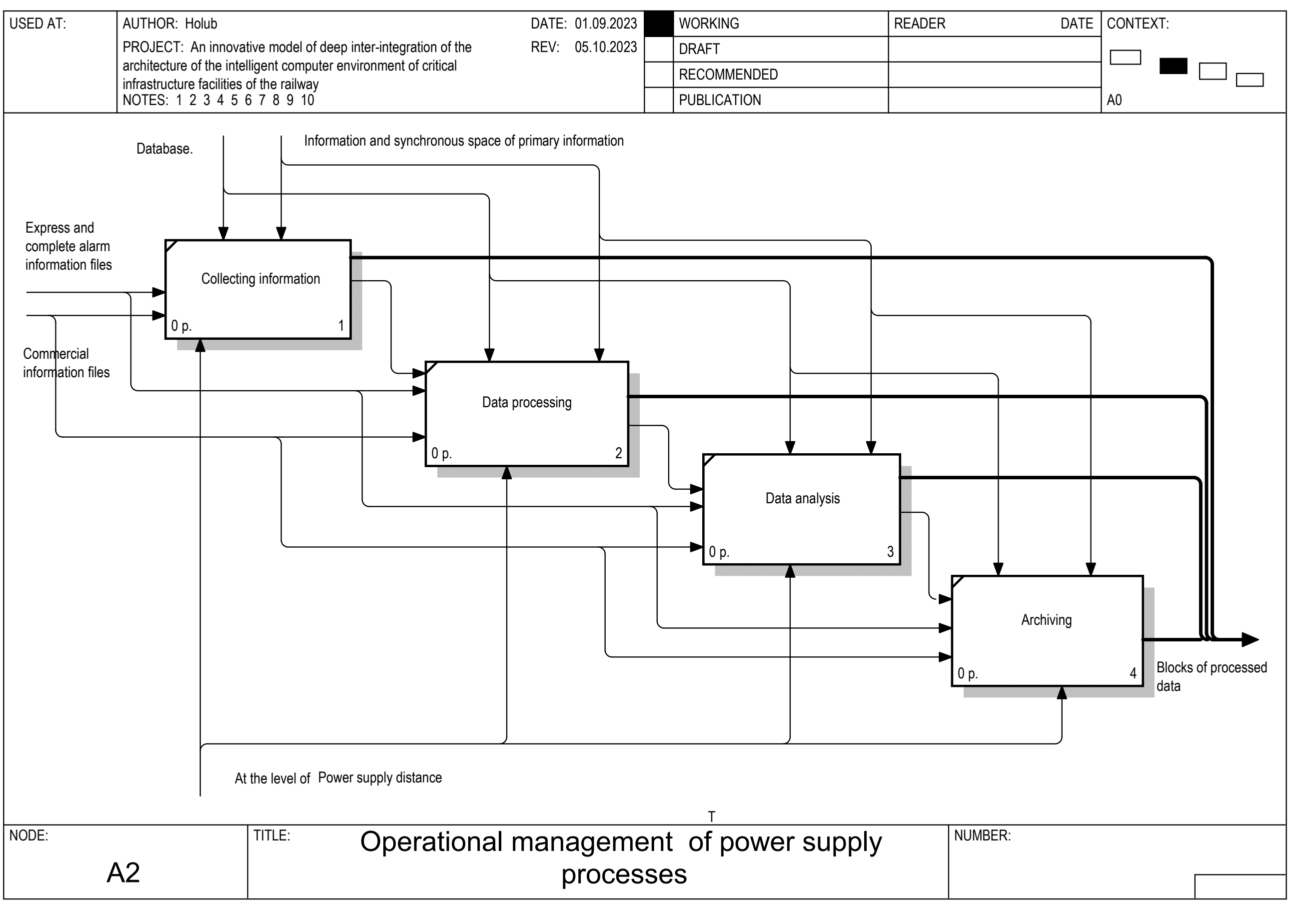

Fig. 4. Functional diagram of operational management of the railway power supply system objects

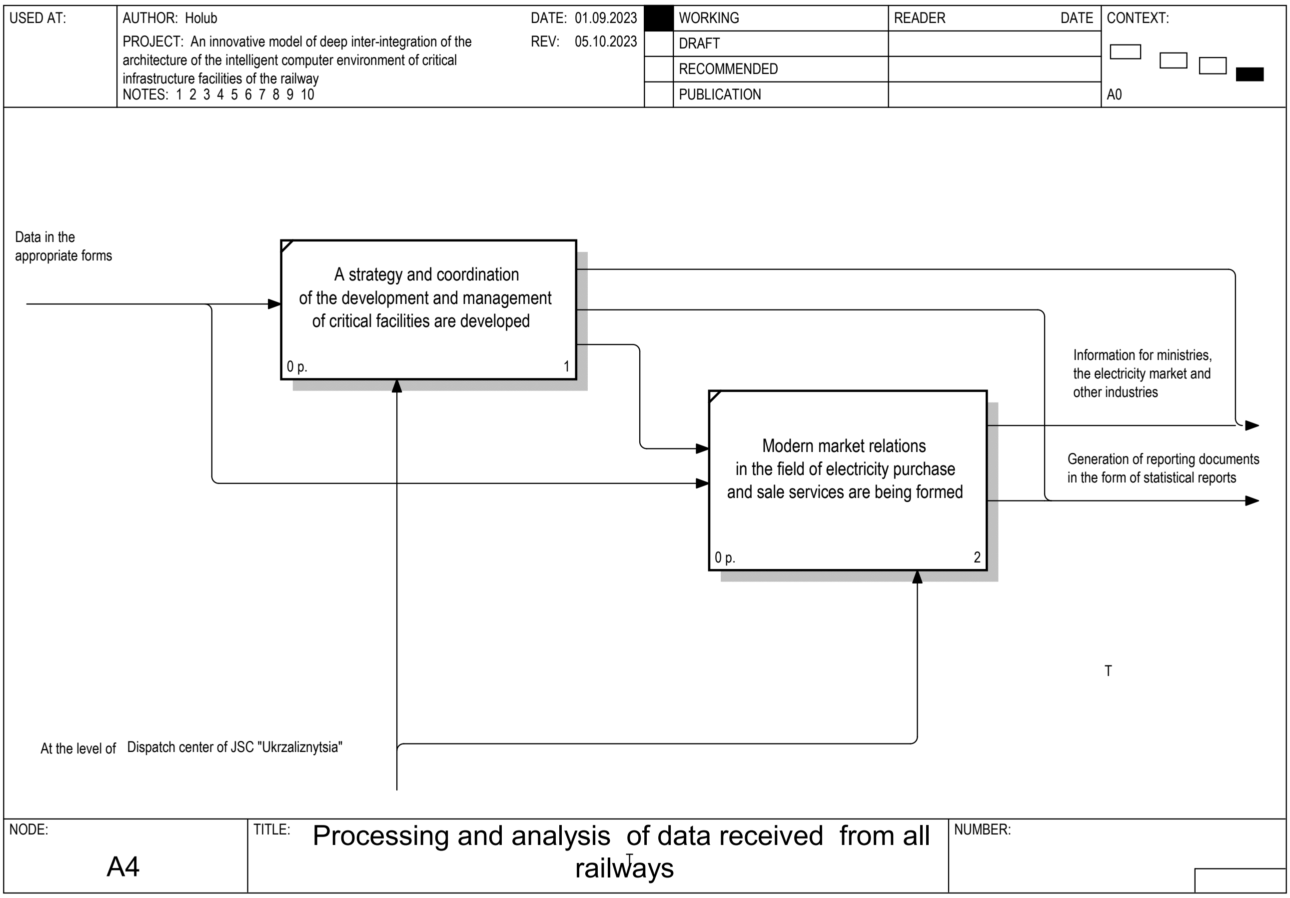

Fig. 5. Functional diagram of the office management of Ukrzaliznytsia

As a result of modeling the model, let's obtain a node tree diagram (Fig. 6), which reflects the visualization of the structure of the innovative model of deep mutual integration of the architecture of the intelligent computer environment for managing the power supply system of railway transport. This diagram is composed of nodes that represent the various components and subsystems of the control system. The diagram includes operational collection of synchronously registered primary data, on the basis of which a single information space is formed. There is also distributed real-time data processing, automation of decisions and actions at workplaces.

With such mutual integration of the architecture of the intelligent computer environment of the data objects of the power supply system, the possibility opens up:

- real-time data collection, which allows for automatic detection of anomalies and emergency situations, allowing operators to react quickly and avoid serious problems;
- data analysis that will help optimize the use of resources, such as energy, reducing costs and increasing productivity;
- predict loading, helping to avoid reloads and improve scheduling support;
- through a real-time monitoring system, it is possible to find points of energy loss and optimize their operation to reduce losses;
- integration with intelligent systems allows to implement automatic management and remote control over objects of power supply systems;
- intelligent systems can detect and prevent cyber-attacks, ensuring data security and integrity [13].

With the use of data, malfunctions can be predicted and maintenance can be carried out in a timely manner, which allows to prevent serious problems from occurring and reduce downtime for repairs.

The conditions of military operations in Ukraine create serious problems for critical infrastructure, such as railway transport, and the electricity supply system in terms of ensuring stability and functioning.

The importance of research, development and implementation of new models, approaches of mutual integration and methods of management of objects of critical infrastructure of railway transport is extremely great for several reasons.

The conditions of military operations can create risks for infrastructure. The development of new models and methods will ensure the stability of the power supply system and other key systems in emergency situations. New approaches will make it possible to quickly respond to changes in the situation and quickly take measures to prevent possible threats. In the context of military operations, resources such as electricity can be limited. The use of new methods can help optimize the use of resources and ensure their effective use in the most important areas. It is important to have means of communication and communications that remain reliable even during military conflicts. New technologies can improve communication capabilities. Military conflicts often involve cyber-attacks. Ensuring the cyber security of the railway transport system is important to prevent information leakage and unauthorized interference. New management methods can ensure the mobility and flexibility of the railway power supply system, which is important for quick response to changes in the situation. New technologies can make it easier for operators and other workers in emergency situations, helping them focus on core tasks.

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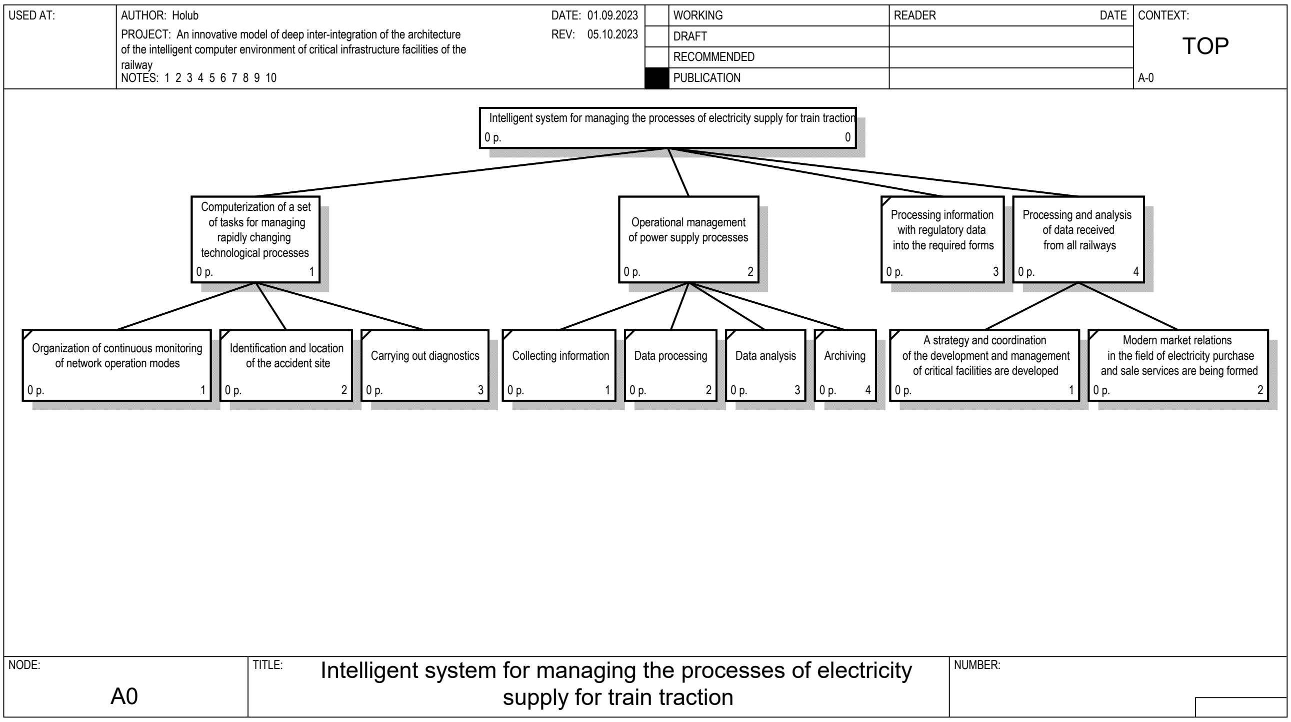

Fig. 6. Diagram of a tree of visualization nodes of an innovative model structure of deep mutual integration of an intelligent computer environment architecture

The use of research results in the field of model development, approaches to the mutual integration of the architecture of an intelligent computer environment, and methods of managing objects of critical infrastructure of railway transport faces *several limitations* that must be taken into account. The large amounts of data and the complexity of the algorithms can lead to significant computational and hardware costs. It is important to ensure system efficiency and optimize costs. Some new technologies may require specialized equipment or infrastructure that may not be cost-effective or difficult to implement. Systems must be able to interact with existing infrastructure, technical solutions and devices already in use.

Prospects for further research on new models, approaches to the mutual integration of the architecture of an intelligent computer environment and methods of managing objects of critical infrastructure of railway transport are extremely important in the context of ensuring the safety, efficiency and stability of transport systems. Research can be directed to the development of integrated management systems that combine data in the form of a single information space. As well as management methods for data analysis, Internet of Things technology and big data systems to optimize work, safety of railway transport systems. The use of big data analysis to forecast costs, service needs and resource allocation can ensure optimal management of objects of railway infrastructure systems. Data analysis can also detect anomalies and predict failures, allowing timely response and prevention of potential problems. The integration of intelligent computer systems with the power supply system opens the way to optimize and improve various aspects of railway operation, ensuring a more efficient, safe and sustainable operation of the power supply system.

4. Conclusions

In the work, the prospects for the application of intelligent management of the computer environment of data objects of the critical infrastructure of railway transport have been given.

The importance of forming a single intelligent computer environment for the objects of the power supply system has been analyzed.

On the basis of models, methods, approaches, an innovative model of deep mutual integration of the architecture of the intelligent computer environment of the railway critical infrastructure objects has been simulated, which will significantly improve all aspects of the operation of the power supply system of railway transport, ensuring greater reliability, efficiency and safety.

It has been determined that it is the mutual integration of the architecture of the intelligent computer environment for data management of power supply system objects that can ensure the mobility and flexibility of the railway power supply system. These properties of the system are important for rapid response to changes in situations at each level of the hierarchical structure of the management system. All these changes can be ensured thanks to the use of new management methods and technologies.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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