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THE INVESTIGATION OF THE INTERNET OF THINGS (IoT) IN ELECTRIC POWER SYSTEMS

Abstract. In recent years, with the continued growth of energy demand, intelligent energy systems have become a common choice for the world's energy to meet the challenges of the future. Currently, the rapid development of the Internet of Things leads to the use of new, advanced solutions in various fields. One of the target markets for IoT is electric power systems. This article presents the current state of electric power systems based on IoT. The architecture of the Internet of Things and its components, as well as its importance in electric power systems, have been studied. The methodology and structure of the application of the Internet of Things in the electric power industry are shown.

Keywords: Internet of Energy (IoE), The Internet of Things (IoT), electric power systems, power systems control.

Introduction. Currently, experts are already talking about concepts such as the Internet of Energy [1] and the Internet of Things [2]. One example of the implementation of these concepts is the so-called Smart Grid which assesses the need for electricity and redirects it to the place where the need for electricity is maximum at the moment. The Internet of things (IoT) is considered to be the third digital revolution after the computer and the Internet, and it offers significant benefits of an intelligent network. Predicting and preventing natural disasters of power lines is one of the most difficult problems for power transmission companies. Advanced IoT detection and communication technologies can effectively prevent or reduce disaster damage to power lines and, consequently, increase the reliability and stability of power transmission [3].

Internet of Energy (IoE) is a network of energy producers and consumers integrated into the common infrastructure and exchanging its surpluses. The implementation of this methodology also implies the introduction of the Internet of Things (IoT) concept, which involves the creation of a computer network of physical objects that have the ability to interact with each other and with the external environment.

The Internet of Things (IoT) provides the ability to build multi-agent, machine-based interaction and coordinated work, power system control, which is aimed at the formation and regulation of the transmission of electricity and its parameters, as well as the economic optimization of the power system and its power equipment pools.

At power plants, IoT systems also provide real-time information on the operation of equipment and timely decisions on its repair. This technology helps to optimize the stopping time of generating equipment and minimize the risk of accidents. Taking into account the existing regulatory framework, the equipment will be repaired according to the regulations in the foreseeable future. However, the IOT in the electric power industry makes it possible to understand not the routine, but the real condition of the equipment, the parameters of its operation after the planned repair (and they should ideally correspond to the factory ones) [4, 5].

The Internet of Things (IoT) system in electric power industry. The purpose of the IoT system, the architecture of which is shown in figure 1, is to provide machine-to-machine interaction between power equipment control systems, including various power conversion devices, by means of which power equipment of users is integrated into electrical networks, as well as load control systems [6].

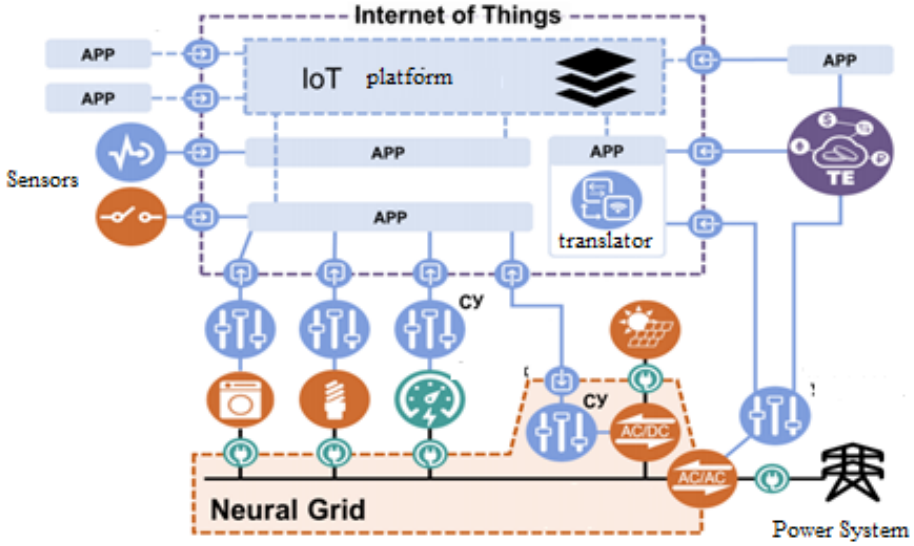

Figure 1 – Functional diagram of the Internet of Things (IoT) in Power Systems

As a result of machine-to-machine interaction between these control systems of various power equipment occurring in the IoT system, an environment for multi-agent control of distributed power equipment pools is created [7, 8]. Interaction in the IoT system makes it possible to make the operation of this equipment consistent and thus, firstly, to form the mode of transmission of electricity, controlling its generation, accumulation and consumption, and secondly, to carry out various functions of operational control associated with the secondary and tertiary power balance control and ensuring the specified quality of electricity from users [9].

Components of the IoT system are [10-12]:

- digital interfaces with control systems of various power equipment - power converting devices through which generation and storage are integrated into electrical networks, as well as controlled load;
- digital interfaces with measurement tools required to obtain current data on mode parameters;
- various sensors required to obtain information that is not data on the parameters of the power transmission mode, but necessary for the economic and technical management of power equipment pools;
- various actuators required to support the management of power equipment pools, but are not control systems of this equipment;
- proprietary system applications that ensure the efficiency and reliability of the system, including embedded and implemented in the logic of IoT energy management systems (EMS);
- information interfaces with custom applications;
- IoT platform is a digital environment for interaction of applications, equipment control systems, sensors and actuators with each other.

The IoT system enables user applications to build a multi-agent, based on machine-to-machine interaction and coordinated work, power system control, which is aimed at the formation and regulation of the power transmission mode and its parameters, as well as the economic optimization of the power system and its energy equipment pools. The IoT system allows to build economic self-organization, mutual adjustment and economic optimization of such pools.

The key areas in all elements of the power industry that will be affected by the introduction of IoT are:

technologies, including their reliability will be increased;

efficiency, including costs will be reduced;

the emergence of new markets, the creation of new properties and businesses.

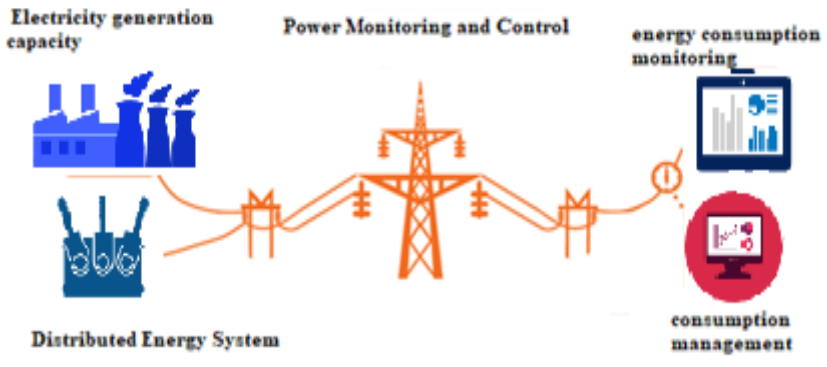

Figure 2 – Applications of IoT in electric power industry

Architecture of energy internet and its components. Internet energy is such a decentralized power system in which intelligent distributed control is implemented, carried out at the expense of energy transactions between its users. The architecture of energy Internet should provide, on the one hand, the ability to implement energy transactions, on the other - the ability to control energy cells through machine-to-machine interaction and, finally, to provide the possibility of such distributed mode control in real time, which allows to maintain the power balance in the power system and its static and dynamic stability [13, 14].

Energy Internet is a system of systems (SoS), the architecture of which is based on a special combination of three systems, the boundaries and interactions of which are shown in figure 3 [6]:

- Systems of formation, control of execution and payment of smart contracts of Transactive energy (TE);
- System of machine-to-machine interaction and exchange of control actions between energy cells and energy equipment of the Internet of Things (IoT);
- System of regime control, maintaining the power balance and ensuring the static and dynamic stability of the Neural Grid power system (NG).

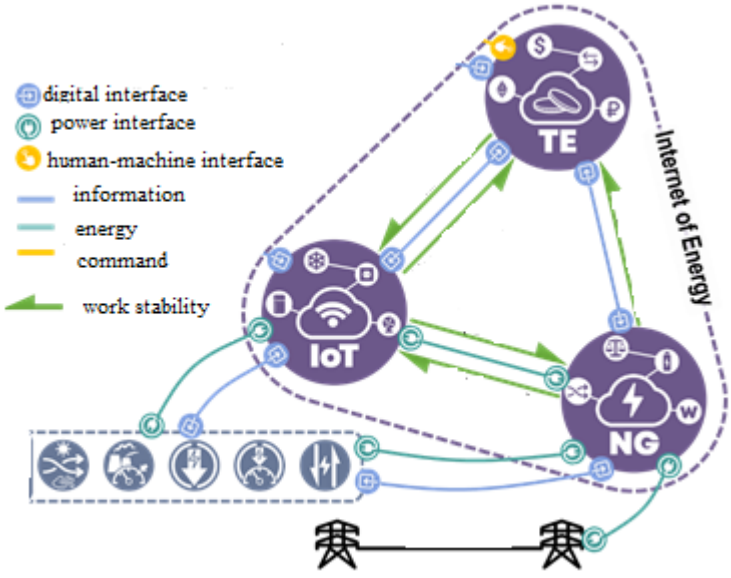

Figure 3 – The architecture of the Internet energy as systems of systems

Each of these systems can be deployed independently and perform its function independently of other systems, but only a set of interconnected and interacting by special protocols TE, IoT and NG systems forms the Internet of energy.

The interconnection and interaction between the systems is ensured during the implementation of energy transactions between users and the corresponding energy cells. The smart contract of energy

transaction is formed in the TE system, the information on obligations under the smart contract is transmitted to the IoT system, and this smart contract is implemented in the form of coordination of the work of energy cells (setting power flow parameters) due to their machine-to-machine interaction. At the same time, the NG system receives the parameters of the regime formed due to the implementation of a set of energy transactions, i.e. due to the operation of energy cells, and ensures its stability, maintaining the balance of power both at the level of energy cells and at the level of power flows between them. Control the execution of the smart contract and payment are carried out in the TE system. In case the NG system cannot ensure the maintenance of the power balance within any boundaries, where it is necessary, on its own (only with the help of the NG system components), it requests the power reserve through the TE system, i.e. initiates the energy transaction necessary to ensure the reserve of the regulating power [1].

Energy Internet users interact with the TE system, participating, if necessary, in defining the parameters of smart contracts and in transactions with financial assets through appropriate human-machine interfaces.

The main thing for Internet energy users is interaction with user applications (Application, App), which provide the formation and conduct of energy transactions (relevant smart contracts in the TE system and control actions on energy cells and energy equipment through the IoT system). Therefore, user applications (App) on information channels interact with these two systems.

Interaction of users and energy cells with external to the Internet energy information and control systems of traditional, centralized power system or local control systems, standing in power supply systems, such as SCADA, DMS, EMS, OMS, is also carried out through user applications (App) of energy in digital.

Reduction of energy consumption by the end user at certain economic signals of the electricity market with the receipt of revenue for the implementation of such a reduction in consumption.

Lifecycle management of power equipment condition. Grid companies use the Internet of Things technology through RFID, GPS and other sensors to monitor and collect all aspects of power equipment information (including the environment, conditions, accounting, testing, defects, a reasonable choice of statistical methods), analyze the current state of equipment, the law on the future development and the main influencing factors to form a method for assessing the risk of equipment based on the Internet of Things technology, this system can dynamically update added, distributed, serving, inactive, unnecessary, and other historical data. In this system, equipment status information and asset management information are effectively integrated, supervision management is unified [15]. Lifecycle management of power equipment condition.The IOT-based energy equipment lifecycle management system is shown in figure 4.

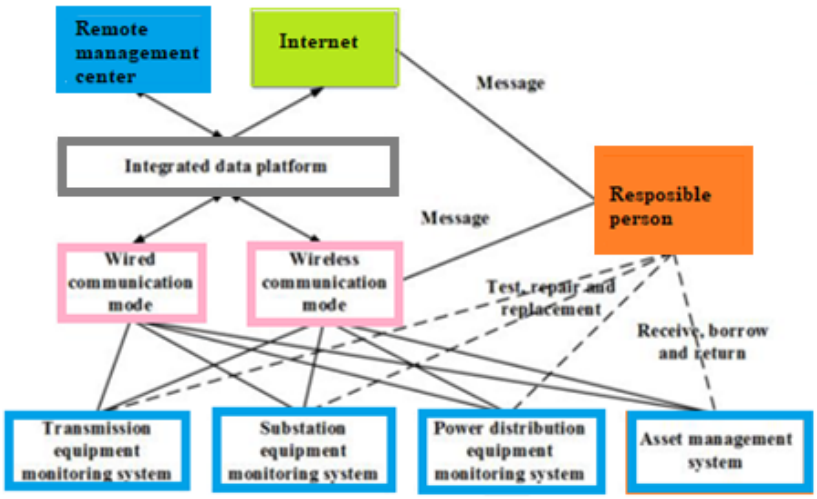

Figure 4 – Power equipment lifecycle management system based on the Internet of things [16]

To check the effectiveness of the system, a simulation test will be conducted on the performance of power equipment [17]. The system can real-time detect the operating status of power equipment in order to increase management efficiency and realize intelligent and digital control of the energy industry figure 5.

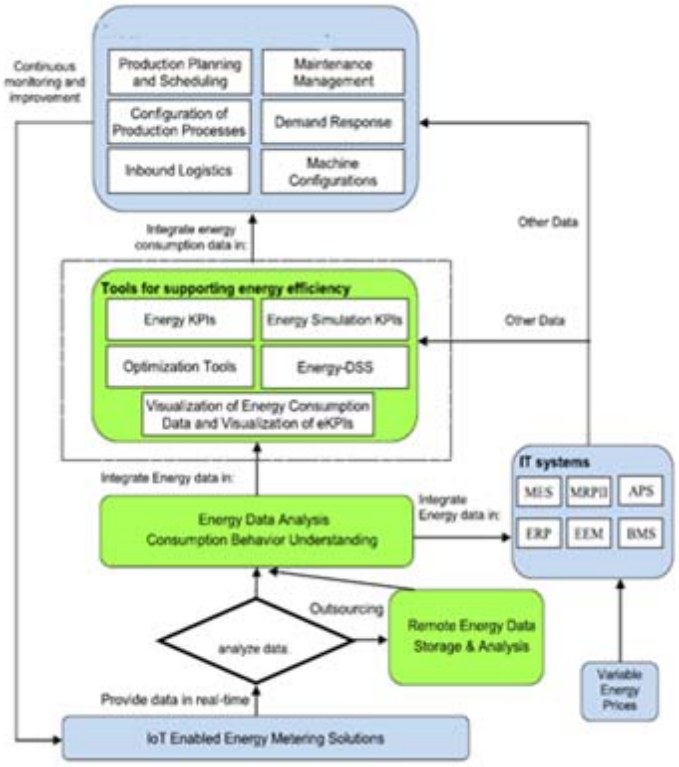

Figure 5 – The structure of energy data integration based on the Internet of Things in industrial control solutions

The Internet of things has been an integral part of the transformation towards smart grids. Examples of IoT technologies that are currently used in intelligent electric power systems include Advanced Metering Infrastructure and Supervisory control and data acquisition (SCADA)[18]. There are several advantages to deploying IoT into intelligent electrical systems:

- Increased reliability, fault tolerance, adaptability and energy efficiency;
- Reduced number of communication protocols;
- Networking and extended work with information scope;
- Improved control over household appliances;
- Enable on-demand access and end-to-end provision of services;
- Improved sensory capabilities;
- Improved scalability and compatibility;
- Disaster Damage Reduction;
- Decreased physical attacks (for example breaking into substation).

Conclusion. As an inseparable technology to support an intelligent system, the Internet of Things technology has become a center of research in the field of energy.

To achieve a high degree of integration of the intelligent system and the Internet of things, this article proposes a system of energy equipment management throughout the lifecycle, based on the Internet of things. Based on the study of the functional characteristics of the Internet of things and the state of its application in the power system, the basis for managing the entire life cycle of power equipment is created. This system provides a research base for improving the application of Internet of things technology in power systems and achieving a high degree of integration of intelligent networks and network technologies. The intelligent system further optimizes network management at all levels, provides panoramic information about the power system through a combination of centralization and decentralization, and integrates various types of production and processing information to provide comprehensive and complete reference information for decision-making for operation and management.

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ЭЛЕКТРОЭНЕРГЕТИКАЛЫҚ ЖҮЙЕЛЕРДЕ ИНТЕРНЕТ ЗАТТАР (IoT) ТЕХНОЛОГИЯСЫН ЗЕРТТЕУ

Аннотация. Соңғы жылдары энергияны тұтыну сұранысы жоғарлағандықтын, жалпы әлемдік энергетика үшін интеллектуалдық энергетикалық жүйені таңдау болашақ мәселесі болды. Қазіргі таңда Интернет заттардың (IoT) дамуы алуан түрлі аймақтарда алдығы қатарлы шешімдерді қолдануға мүмкіндік береді. Электроэнергетикалық жүйе үшінде IoT қолдану қарқындады. Мақалада IoT негізіндегі электроэнергетикалық жүйелердің қазіргі жағдайы көрсетілген. Интернет заттар архитектурасы мен оның құрамдасбөліктері, электроэнергетикалық жүйелердегі мәні зерттелген. Интернет заттардың - электроэнергетикадағы қолдану құрылымы мен әдістемесі қарастырылған.

Түйін сөздер: Интернет Энергия (IoE), Интернет заттар(IoT), Электроэнергетикалық жүйелер, Энергожүйені басқару.

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ИССЛЕДОВАНИЕ ТЕХНОЛОГИИ ИНТЕРНЕТА ВЕЩЕЙ (IoT) В ЭЛЕКТРОЭНЕРГЕТИЧЕСКИХ СИСТЕМАХ

Аннотация. В последние годы, в условиях продолжающегося роста спроса на энергию, интеллектуальные энергосистемы стали общим выбором для мировой энергетики для решения задач будущего. В настоящее время бурное развитие Интернета вещей (IoT) приводит к использованию новых передовых решений в различных областях. Одним из целевых рынков для IoT являются электроэнергетические системы. В статье представлено современное состояние электроэнергетических систем на основе IoT. Исследована архитектура Интернета вещей и ее компоненты, а также ее значимость в электроэнергетических системах. Показана методология и структура применения Интернета вещей в электроэнергетике.

Ключевые слова: Интернет Энергии (IoE), Интернет вещей (IoT), электроэнергетические системы, управление энергосистемами.

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