Management of the digital transformation of the electricity sector

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Abstract. The presented study analyzes the existing methods of non-destructive testing of elements of the electric power system, which are currently used in the electric power industry. It was proved in the work that the developed methods for assessing the monitoring of the state of electric power infrastructure facilities should be applied taking into account modern technologies. The work revealed that digital technologies, namely unmanned aerial vehicles, are used in everyday life and industry. In this regard, the study suggested the need to use this method in the electric power industry. Unmanned aerial vehicles must be equipped with video cameras and thermal imagers, so that it will be possible to carry out optical and thermal monitoring of the state of the elements of the electric power system.

1. Introduction
The development of electric power systems and networks began in the Soviet period, when the main potential of the electric power complex was formed. In the same period, the main methods and methods were developed that ensure reliable and uninterrupted operation of the electric power industry. The process of creating and manufacturing equipment in the electric power industry has been observed in recent years, when it was in the first stage, so that all the main backgrounds were built and were built in the Soviet period [1-3]. In addition, in the energy sector there is obsolescence of equipment, that is, equipment aging due to the fact that a newer and more advanced equipment has appeared. In the electric power industry, although new technologies for the production and transmission of electric energy, control and monitoring of the state of equipment have been created, they have been used for decades and have lost their effectiveness. The created devices are functioning to the present, but they no longer bring the planned effect and require a large operational cost from the industry associated with maintaining and maintaining this equipment in working condition [4-6].

Today, all over the world, such technologies are being improved and modernized, which requires the Russian electric power complex to comply with international trends in order to maintain the electric power industry in an operable and safe state. So, for example, the trend of today is the transition to innovative and digital technologies, thanks to which the decision-making process is
accelerated, operating costs are reduced, the efficiency of individual processes and the entire technological chain is increased [7-8].

In modern times, the process of transition to innovative technologies requires significant capital and operating costs, which should be aimed at creating an innovative or digital product, the development of which should be carried out by specialized research institutions or energy enterprises. However, it must be borne in mind that today in the energy sector the necessary scientific capacities are often lacking, on the basis of which it is possible to create an innovative and digital product. First of all, this is due to the lack of the necessary personnel, digital infrastructure, laboratory potential and other elements in the energy sector that ensure the creation of an innovative and digital product [9-11].

In this regard, we consider it necessary to study the existing methods of non-destructive testing of elements of the electric power system and networks, to propose methods for monitoring the state of networks and systems with digital technologies.

2. Materials and methods
The purpose of the study is to study the existing methods of non-destructive testing, as well as to develop proposals for the use of digital technologies in the electricity industry in order to monitor and control the state of electricity facilities. The following tasks were formed:

- To study the existing methods of non-destructive testing of the elements of the electric power system;
- Develop recommendations on the use of control methods for electric power equipment, taking into account modern digital technologies.

The study was built based on a study of existing non-destructive testing methods for electric power facilities and digital technologies used in industry.

3. Results
Monitoring and control over the state of electric power facilities is the most important task for the electric power complex. Such events in the energy sector are held around the clock and every year, since any violation in the power supply to consumers can cause significant problems for the state apparatus, industrial complex, organizations that ensure human life. Of course, such monitoring and control should be carried out using modern technologies, including using remote and remote technologies. In addition, it should be noted that it is not always possible to monitor the state of equipment by stopping the operation and analysis of equipment, which is why measures related to the use of non-destructive testing of elements of electric power systems are common in the electric power industry.

Currently, there are many non-destructive testing methods for elements of electric power systems that were created decades ago, some methods work when the equipment is turned on, but some can only be used in the off state. Such methods make it possible to carry out operational monitoring of electric power equipment and increase the effectiveness of repair measures. Among the main methods of non-destructive testing, the following methods can be distinguished [12]:

- Acoustic methods, which consist in assessing the elastic vibrations created in the studied object. A similar method allows you to identify internal and surface defects in equipment;
- Magnetic (electromagnetic) methods include recording magnetic fields of the equipment under test. This method is used to detect surface defects in nodes and various parts;
- Optical methods consist in the interaction of light radiation and the analyzed object. They are mainly used to detect external defects, and the methods used include visual inspection and the endoscopic method;
- The method for detecting defects by penetrating substances is divided into capillary methods based on the capillary penetration of liquids into the analyzed object, and the leak detection method, which consists in the penetration of liquids and gases into the through slits of the analyzed objects;
- The radiation method, based on the creation of ionizing radiation, consists in the penetration of ionizing cure into a registered and controlled object;
• Radio wave methods are registration of electromagnetic waves of the radio range, committed within the analyzed object;
• Chromatographic method is based on the identification of gases characterizing the level of aging in oil-filled power equipment;
• Electrical methods are based on the analysis of the electric field of the analyzed object;
• Thermal methods are based on the analysis of temperature changes in the analyzed objects. A similar method is used for all types of materials and surfaces. This method is the most common, since at a remote distance with the help of heat-visual imagers you can determine the defects of objects and the type of defect. An example of this type of non-destructive testing is presented in the figure 1.

![Figure 1. Heat-visual image of a high-voltage support.](image)

Thus, today all the presented methods for monitoring the state of the elements of the electric power system are used, which helps prevent equipment malfunctions and form the most effective plan for the repair campaign. However, all these non-destructive testing methods are carried out with the full participation of the operational and repair personnel, who perform the whole range of work related to the assessment of the condition of equipment.

In our opinion, during the period of digitalization and the transition to new digital technologies of industrial production, it is necessary to reduce human participation in such activities and implement digital devices to carry out this kind of work [13-15].

4. Discussion
Modern time there is a process of transformation of various areas of industrial activity on innovative and digital technologies. One of the industries that should make the transition to new technologies should be electricity. As part of the energy infrastructure, a large number of network and switching equipment are involved; this requires daily monitoring and control of the technical safety of individual
elements of the entire electric power system. Today, the Russian electric power industry uses outdated work technologies and principles for monitoring the state of the energy infrastructure, which, of course, reduces the quality of work, increases the number of equipment failures, and reduces the level of reliability, stability and uninterrupted operation of the entire energy system.

Today, the use of digital and remote devices permeate all spheres of human activity and production, which allow us to ensure the necessary quality level of equipment operation, which, of course, helps to reduce adverse effects. One way could be to use unmanned aerial vehicles.

So, for example, unmanned aerial vehicles are used in such fields of activity as [16-18]:

- Zone surveying, that is, surveying in various spectra of electromagnetic waves, which help agriculture monitor soils and analyze their changes;
- Aerial photography is the process of photographing the area, thanks to which it is possible to determine the location of various objects on the territory and analyze the volume of forest plantations and agricultural land;
- Observation of the animal world, due to which it is possible to determine animal populations, their habitat and concentration;
- Video surveillance of oil and gas facilities is one of the most popular types of remote monitoring of fuel and energy facilities, which allows to identify a number of problems - man-made and commercial damage;
- Aerial and space imagery of the area, due to which it is possible to identify various adverse climatic consequences, as well as provide constant monitoring of the activities of enterprises that affect the environment;
- Aerial photography and geodesy allows for cadastral registration, control during emergencies and adverse weather conditions, as well as for various objects owned by the state and to monitor the condition of agricultural land;
- Monitoring of forest resources, allows you to determine the number of forest stands, to protect and control them;
- Monitoring and control of construction work, which allows offline monitoring of public and private facilities under construction;
- Unmanned security and assistance, due to which the state of the state borders is monitored, various objects are protected, assistance is provided in emergencies, etc.

Thus, unmanned aerial vehicles are used in all spheres of human activity and industrial production, in this regard, we consider it necessary to use a similar type of monitoring, which will ensure control over the state of overhead power lines, switching equipment and other elements of the electric power system. The most optimal non-destructive testing methods when using unmanned aerial vehicles are optical and thermal methods.

In the electric power industry, unmanned aerial vehicles should be used to solve the following problems:

- Monitoring the state of the electric power infrastructure;
- Rapid detection of accidents and breaks in power lines;
- Control and prevention of accidents and short circuits;
- Identification of problematic and dangerous sections of the electric power system;
- Operational monitoring of repair work at the facilities of the electric power system;
- Operational control of unauthorized connections to the electric network;
- Remote monitoring of wear and technical condition of electrical circuit elements;
- Identification of areas of disconnection and damage to the electrical circuit.

Unmanned aerial vehicles should be equipped with photo and video cameras, which will provide optical control over the electricity infrastructure. The cameras will be used for visual monitoring of the elements of the electric power system. In addition, a thermal imaging camera must be installed on the unmanned device, thanks to which it will be possible to identify damaged elements of the electrical network, as well as conduct shooting at night.
Thus, modern digital technologies, which are currently actively used in industry and everyday life, are expeditiously used in the electric power industry, which will allow for more efficient monitoring of the state of electric power facilities and increase the level of reliability, stability and uninterrupted operation of the entire electric power system.

5. Conclusion
As part of the study, existing methods of non-destructive testing of electric power equipment were analyzed, among which we distinguished acoustic, optical, electromagnetic, thermal, radio wave, chromatographic and other methods. Based on the analysis, it was concluded that it is possible to use separate methods using digital technologies. The study proposed the use of unmanned aerial vehicles used in everyday life and industry, which are advisable to use in the electric power industry for the purpose of remote monitoring and control over the elements of the electric power system.

In addition, the study showed that to date, a lot of technologies have been developed in the electric power industry that allow monitoring the state of electric power systems and networks, both directly on equipment, that is, using special tools and devices, and remotely, that is, using modern technologies. Of course, modern electric power industry should switch to new technologies, namely, management, assessment and monitoring of the state of electric power systems and networks remotely, that is, using modern technologies, which, in fact, will reduce the work of maintenance and repair personnel and allow predicting the state of the system in the long term. At the same time, it should be noted that the electric power industry today, although it is controlled mainly remotely, is related to global issues, and not private ones, such as monitoring networks, predicting equipment failure, remotely switching consumers during a power outage, etc [19-22].

Thus, we can draw a general conclusion that the Russian energy sector today has the necessary technical potential for assessing, monitoring and controlling the state of electric power systems and networks. At the same time, the indicated potential is already obsolete and today there are new ways to assess the state of electric power equipment. Undoubtedly, the modern Russian energy sector needs to ensure the search and development of new technologies that will ensure a high-quality transition of monitoring and control over the state of electric power systems and networks. It should also be noted that in the light of the recent transformations in the Russian electric power industry, many independent companies have been formed that provide for the production, transmission, distribution and marketing of electric energy, which have the necessary scientific potential and have the necessary sites for providing research and development activities. Combining the existing potential, including educational and scientific organizations, will solve the problems associated with the creation of digital technologies, which will allow us to move to a qualitative stage in matters of assessment, monitoring and control over the state of electric power systems and networks. Issues related to the creation of such associations carrying out joint activities in the field of R&D may be the subjects of further research on this topic.

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