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Leading prospects for the development of production asset management systems of Russian thermal power plants

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Abstract At present, solving the problems of improving the reliability of the assets of thermal power plants (TTP) in Russian Federation is possible only as a result of the transition of equipment management systems to a fundamentally new paradigm for diagnosing operating equipment. Nevertheless, this problem constitutes one of the leading prospects the TPP industry.
This paper considers the problem of the transition from asset management systems that currently exist to an innovative system – i.e. the diagnostics and information management of operating equipment parameters based on measuring the parameters of its actual state. It becomes apparent that the introduction of the fifth-generation asset management system can lead to a significant reduction in the cost of repairs, the exclusion of unreasonable repairs on a case-law basis and to the minimization of the cost of the life cycle of ownership of assets of thermal power plants.

1 Introduction

Nowadays, the installed capacity of thermal power plants (TPP) in the structure of energy production in Russia ranges at 68% (Rosstat 2018; Rosstat 2016). At the same time, the wear of the main generating equipment of TPPs reaches 74%, which leads to an increase in the volume of maintenance and repairs, the risk of failures and accidents, and, accordingly, a decrease in safety and reliability of power plants (Rosstat 2016; Energy Strategy 2014). The issues of managing the operation of the main power equipment of thermal power plants are of particular relevance (Strielkowski et al. 2017; or Tronchin et al. 2018). The organization of energy supply in Russia has two stable trends (Energy Strategy 2014; Lisin et al. 2016a; Lisin et al. 2016b; Lisin et al. 2018):

- growth in the power consumption of the Russian economy and an increase in the fleet of equipment operated by power plants with a constant increase in requirements for equipment durability;
- aging of the TPP equipment fleet, which has a life cycle duration of 40–50 years and is currently operating for 15 years or more.

According to the Ministry of Energy of the Russian Federation, the average age of the generating equipment is currently 32.4 years. By the end of 2020, this value will increase to 34.1 years (Minenergo 2018; Energy Strategy 2014).

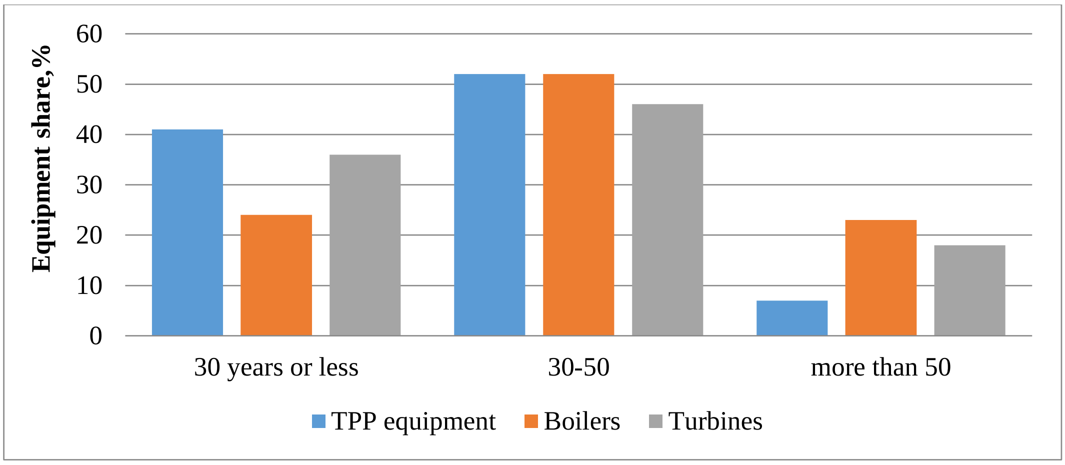

Fig. 1. Statistical analysis of the age of equipment TPPs
Source: Own results based on Minenergo (2018) and Energy Strategy (2014)

Figure 1 above presents the data of the average age of all equipment of TPPs and in its division by power generation units. Of all the equipment of TPPs, the statistics of age over 50 years is mainly determined by boiler and turbine units.

Thus, in the territory of Russia in modern conditions, a situation has arisen whereby the share of aging equipment in the total capacity of power plants is steadily increasing. The situation is gradually moving to a dangerous point, when the age of equipment of thermal power plants is approaching the natural term of its life cycle. This leads to a decrease in the reliability of TPP equipment and the occurrence of emergencies and even man-made disasters. At the same time, at the state level, there are requirements to reduce production costs, including to curb the growth of tariffs for electricity and heat.

In 2014, international standards and ISO 55000 series “Asset Management Systems” were published. They expanded the set of management standards applied by industry to ensure quality and reliability of production, such as (Hodkiewicz 2015; Alsyouf et al. 2018):

- ISO series 9000 “Quality Management Systems”;
- ISO series 14000 “Environmental Management Systems”;
- OHSAS series 18000 “Personnel Security Systems”;
- ISO series 50001 “Energy Management Systems”.

Thus, it becomes necessary to consider the evolution of TPP asset management systems and their development prospects, as well as to identify possible contradictions in the management of the reliability of thermal power plants brought about by the introduction of various management standards.

2 The evolution of production asset management systems of thermal power plants

It is conditionally possible to distinguish 4 generations of asset management in accordance with the evolution of the asset management system of power industry enterprises (Table 1).

Table 1. The evolution of approaches to the management of production assets of energy companies

Generation	Years	Description of management approach
I	1930 – 1955	Repair after a breakdown
II	1955 – 1980	Preventive work
III	1980 – 2000	Condition and reliability planning
IV	2001 – 2015	Asset reliability and cost of ownership management
V	2015 - nowadays	Information and diagnostic management of working equipment (“smart energy”)

Source: Own results

The first generation (from 1930 to 1955) defined the period of asset management in the form of a paradigm for organizing repairs of power equipment upon its failure. It is characterized by low costs for training technical staff, but also associated with the arisen long downtime of power equipment at TPPs (De Souza 2012; Krishnasamy et al. 2005).

The second generation (from 1955 to 1980) of asset management systems is characterized by the development of planned preventive effects on the power equipment of a power plant (Shahidehpour et al. 2005; Sabouhi et al. 2016). This led to a reduction in equipment downtime, reduced the risk of failures, but also caused unreasonable equipment maintenance (“over-servicing”), which caused an increase in costs and cost of ownership of assets of energy companies.

The third generation (from 1980 to 2000) of asset management systems can be defined as the organization of planning on the state of reliability. There is a reduction in the risks of costs and costs of “over-servicing”, but the share of costs of the expert component increases when making decisions on the state of assets and in assessing the condition of equipment (De Souza 2012; Sabouhi et al. 2016).

The fourth generation (from 2000 to 2015) is characterized by a qualitative leap in the development of asset management systems, which can be described as an organization that manages the reliability and cost of ownership of energy assets of the enterprise. The advantages of this type of management include: making decisions on the status of assets, improving the accuracy of forecasts of equipment and equipment failures, managing risks, revenues, costs throughout the asset life cycle, which allows you to make effective investment decisions in the long term (Trappey et al. 2015; Lisin et al. 2015). However, such management requires large investments in the development of technical personnel and information systems.

The fifth generation of development of control systems is associated with the evolution of information systems and the emergence of technologies of "smart energy" that allows for innovative diagnostics based on the processing of information coming from operating power equipment (Lisin et al. 2015; Lisin et al. 2019). Their distribution largely determines the development of ISO "Asset management systems".

The application of ISO standards in the field of asset management for energy companies has a number of limitations and contradictions, which does not allow to fully manage the cost of ownership of production assets on the basis of managing their reliability.

For the equipment of the power plant, statistics on failures and changes in the state parameters for the period of operation of single equipment cannot be obtained, since the statistics presupposes the presence of a certain array of the same type equipment that is in the same conditions. The isolation of power plants limits the use of statistical methods of the theory of reliability for single power plant equipment. This state of the control can be positioned as an indirect case-management of production funds and assets. In this case, decisions on the operating modes of the power plant equipment are made according to the statistics of the operation of the same type equipment at other power plants operating in other conditions and operating modes.

Improving the accuracy of predicting residual equipment life can be achieved by using expert-statistical method for predicting residual equipment life. In accordance with this method, experts assess the condition of the unit, node and the entire equipment, and predict the residual resource using various statistical methods. With such management structure the limit of possibilities of the direct operation of the equipment is reached. Therefore, further development of the methodology for managing the production assets of the power industry based on lifecycle management is possible by introducing a methodology for diagnosing the resource of each equipment at a specific power plant, based on innovative methods for measuring internal and external equipment parameters. For this, a complex of modern methods for constructing technological information systems is used.

3 Innovative generation of production asset life cycle management systems

The current structure of the management of the life cycle of electric power industry equipment has a proven system of alternation of operating and maintenance periods with repair work, which has been verified by production experience, from the moment of equipment installation to its dismantling (Figure 2).

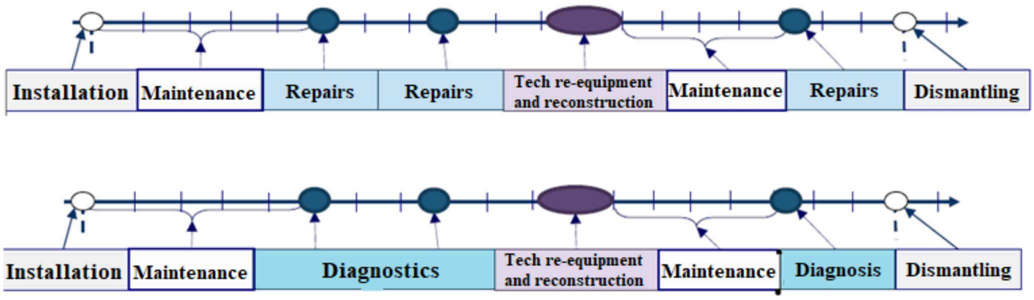

Fig. 2. The structure of the life cycle management of electric power equipment
Source: Own results

In the fifth, innovative generation of management, this structure will be accompanied by diagnostic measurements and control, according to which the information system will decide on the validity and types of repairs. Objective information about the condition of the equipment can reduce the number of unreasonable repairs and change their quality. In addition, diagnostic measurements of monitored parameters will make it possible to measure the quality of repairs by quantitative indicators of the equipment's entry into serviceable condition areas.

In the fifth innovative generation of equipment lifecycle management, a symbiosis of economic problems and management problems arises with physical problems that are responsible for the reliability of individual components and equipment in general. Solving physical problems formats the technology, which in turn determines the methods for managing the reliability of equipment and the economic efficiency of its work.

Developed four levels of definition of the life cycle of technical and technological management:

- temperature method of equipment resource,
- on the resource of insulating materials,
- by mechanical resource of construction materials,
- on the resource of electromagnetic and mechanical vibrations of equipment.

Electromechanical transformations cause the loss of energy of the equipment, which increases its temperature to the temperature of the limiting state and the end of the life cycle. A method for calculating the life cycle of equipment on the basis of measuring its temperature during its operation is proposed.

Insulating materials have a lifetime associated with the decomposition of the chemical composition of dielectrics under the influence of temperature. The resource of heat resistance of insulating materials and the resource of aging are determined depending on the degree of polymerization.

The lifetime of the structural units of the equipment is determined by mechanical stresses and mechanical strength of the limiting state of spontaneous growth of microcracks. The conditions of mechanical strength of the equipment are revealed due to thermomechanical interactions.

Vibrations of electric power equipment caused by electromagnetic forces in magnetic materials and windings are the main source of failures and emergency conditions. The mechanism of such failures is revealed. If the frequency of oscillations of the magnetic circuit coincides with the frequencies of mechanical oscillations of the structural elements of electrical equipment, there is a violation of mechanical contacts, which causes sparks, discharges and overheating of the equipment. By measuring the vibrations of a magnetic circuit with spectrum analyzers and vibration analyzers, information is obtained about the equipment resource.

All these measures can lead to a significant reduction in the cost of repairs, the elimination of unreasonable repairs on a case-by-case basis and minimization of the cost of the life cycle of asset ownership.

4 Conclusions and implications

Overall, one can conclude that the evolution of the production asset management systems of thermal power plants has led to the formation of the fifth generation of systems, which can be characterized as innovations in diagnostics of operating equipment. This is an innovative transition in the operation of equipment and increase its reliability, as well as the qualitative development of the expert-statistical method for managing the life cycle of a production asset, where the expert component is complemented by the analysis of information on physical measurements of equipment parameters (Smaliukienė and Monni 2019; Petrenko et al. 2019).

The results of this paper show that the asset management system of thermal power plants is based on minimizing the life cycle cost of an asset. At the same time, to create a unified management system for the whole complex of assets, functioning at all levels and ensuring effective decision-making throughout the entire life cycle of tangible assets, an organization of management is required in accordance with the following management structure:

- production complex (generation systems (generating equipment), transmission and distribution systems (electrical and heat networks), process control systems, protection systems),
- technological complex (repair complex, project complex, construction and installation complex, research and development complex, information and technological complex).

All in all, it becomes apparent that in addition to tangible assets, a separate management space, dually linked to the tangible asset space, should be financial assets, human resources assets, corporate personnel, and corporate legal services as well as security.

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