

Dynamic Invariance of the Electric Power System

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Abstract – Questions on the problems of stability and invariance of various systems acquire relevance in the period of changes and dynamic movement of the system itself or the object under study. The article is devoted to the problems of studying the invariance of the electric power system and the formation of mechanisms for its conservation in a dynamic state. The methods of theoretical research used are based on analysis and synthesis, deduction and induction, mental modeling, comparison and generalization. The paper found that the invariance of the electric power system is affected by many determinants, among them the wear, reliability and efficiency of power equipment are the main ones. At the end of the article, recommendations were formulated to ensure a dynamic equilibrium of the electric power system.

Keywords – invariance; Sustainability; dynamic equilibrium; electric power system.

I. INTRODUCTION

Questions of stability and invariance of the system are gaining increasing interest in recent decades; this is due to the emergence of new factors affecting the objects of research. The invariance of the electric power system of the Russian Federation acquires a special meaning in the period of the ongoing changes in the electric power industry, connected with the fall of reliability and technical and technological stability of power equipment, wear, permanent accidents and equipment failure. The determinants adversely affect the electric power system, both in the static and in the dynamic state. It is expedient to base the dynamic equilibrium of a complex multifunctional system on a number of interrelated elements capable of changing the qualitative and quantitative characteristics of the entire electric power complex, at the same time, it is expedient to consider them not only in the context of technical or economic science but within the framework of an interdisciplinary approach.

II. FORMULATION OF THE TASK

A. Theoretically justify that the system is subject to constant changes and fluctuations

Conduct a theoretical study of factors that affect the dynamic invariance of different systems. Determine the features of the theoretical representation of the invariance and stability of the electric power system and the determinants that form its dynamic equilibrium.

B. Create mechanisms for ensuring the dynamic invariance of the electric power system

Based on the theoretical and empirical studies present mechanisms for ensuring the invariance of the electric power system, including the interconnection of the mathematical, technical, economic and management sciences.

III. THEORY

The development of the system cannot be imagined without the constant impact on it of the positive and negative determinants that ensure its movement and disrupt the dynamic equilibrium of the object which is under study. Problems of stability and invariance of systems were studied by domestic and foreign scientists, Lagrange, Poincaré, Lyapunova and others were considered to be the founders of mathematical stability. They investigated the motion of the system and the factors that affect its stability. The terms "stability" [6] and "invariance" were understood as the possibility of maintaining the state of the system within the framework of physical impacts on the object, but in recent years this theory has undergone transformation and it has been used at an interdisciplinary level, thereby penetrating into all spheres of activity.

The term "invariance" is understood as the process of the system to keep the given parameters under the influence of various factors that can affect the dynamic equilibrium of the system. The desire to return to the original state of equilibrium

or invariance has mechanical systems, and equilibrium can only be achieved by balancing the forces acting on the system, while the object itself must have the ability to reject negative factors and the property of self-healing. At the same time, A.M. Lyapunov supplemented the theory of stability, in which he pointed out that there exist permissible perturbations and deviations of the system from the given parameters, in this case, the object is not threatened by the loss of invariance (Fig. 1) [8; 18].

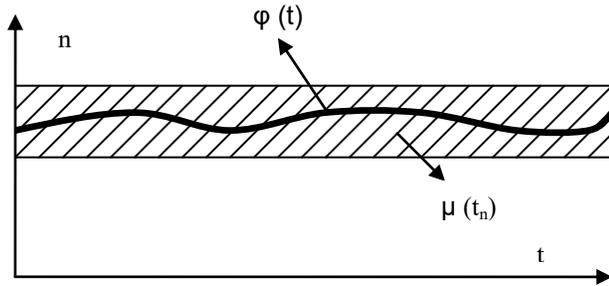


Figure 1. Preservation of stability of the system in mechanics

Thus, a function $\varphi(t)$ must be in the region $\mu(t_n)$ to preserve the invariance and stability of the system:

$$\varphi(t) \leq \mu(t_n) \quad (1)$$

In modern economic science, more attention is paid to the issues of ensuring the stability of the economic system during the instability of the national economy, the lack of innovative and investment resources, integration processes in the external and internal national environment and the economic blockade of the Russian Federation [1; 12]. Invariance of the economic system is the property of the system to be in an unchanged state and its ability to maintain equilibrium under the influence of positive and negative determinants. Determinants are external and internal disturbances that can give stability or weakness to the system [2].

In the electric power industry, invariance and stability are considered from the point of view of reliability of power equipment [11]. The property of reliability is understood as preserving the operational properties of a technical facility and providing electricity to consumers. Reliability in the electric power industry is presented in the Rules for the installation of electrical installations [14] and is characterized by a combination of the following elements - readiness, reliability, durability, maintainability and maintainability [3]. The readiness property is characterized by the ability to operate the equipment with the set parameters to perform the assigned tasks. Reliability is the property of the equipment to remain operational for a certain period of time. Durability consists in the ability of the equipment to produce the assigned resource before the onset of the limiting state. Repairability is the ability of equipment to be subject to maintenance and repair. Retentivity lies in the ability of the object to work with the specified parameters and perform the assigned functions [7; 17].

In the electric power industry, the reliability of the functioning of the system's objects acquires an archival

significance, since an equipment failure can result in not only a violation of human vital activity, but also technogenic catastrophes. In this regard, consumers are supplied with electricity through various electrical schemes, and reliability is divided into three categories [9; 10]:

- The first category of reliability includes electric receivers, a break in electricity supply which can lead to technogenic catastrophes, cause a danger of life and a threat to national security, entail massive material damage to production. The design of power supply schemes is carried out using backup power lines or a power source.
- The second category of reliability implies the possibility of an interruption in power supply in the mode of automatic redundancy, most of the times, a break in electricity supply can lead to a mass simple workman, a violation of the normal functioning and output of farms, a shortage or defect of products and others.
- The third category of reliability includes electric receivers which are not included in the first and second category, mostly, the break in electricity can be up to 24 hours.

Thus, the property of invariance and stability is used in mathematical, technical and economic sciences, and for each field of activity there are features in its interpretation and content.

IV. RESULTS OF THE EXPERIMENT

As an analysis of indicators of the invariance of the electricity industry lets focus on a few factors:

1. Specific consumption of conventional fuel. Units of fossil fuels are the unit of accounting for fossil fuels used to compare the efficiency of various fuels and their total inventory:

$$B_v = \frac{Q_H^P}{7000} \cdot B_H \quad (2)$$

where B_v – amount of conventional fuel, grams of c.f./kW*h;

B_H – amount of natural fuel, tons

Q_H^P – the calorific value, according to the chemical laboratory, of solid and liquid or gaseous fuels, kcal / kg (MJ / kg) and kcal / m³, respectively.

The normative value of this indicator should not exceed 250 grams c.f./kW*h [4; 5].

Let's consider specific consumption of conditional fuel at the basic generating companies of electric power industry (figure 2).

The graph shows that the normative value of the specific consumption of conventional fuel which is only retained by Mosenergo. Increased indicators of GFP not only increase fuel consumption, but also require greater efficiency of energy equipment, and cause an increase in emissions of pollutants into the atmosphere.

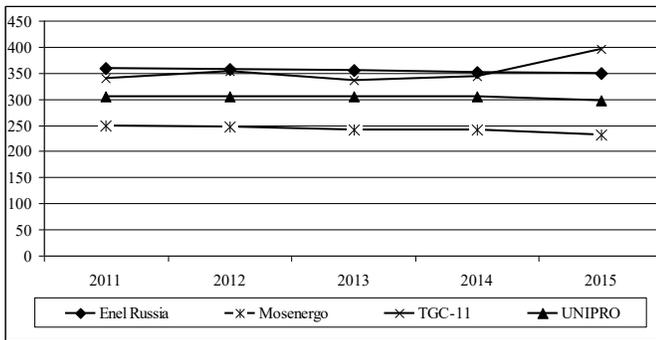


Figure 2. Specific consumption of conventional fuel, grams of c.f./kW*h

Next, consider the indicator of the park resource of power equipment (Figure 3), which characterizes the service life of the equipment.

The figure shows that most of the generating equipment is operated outside the park resource.

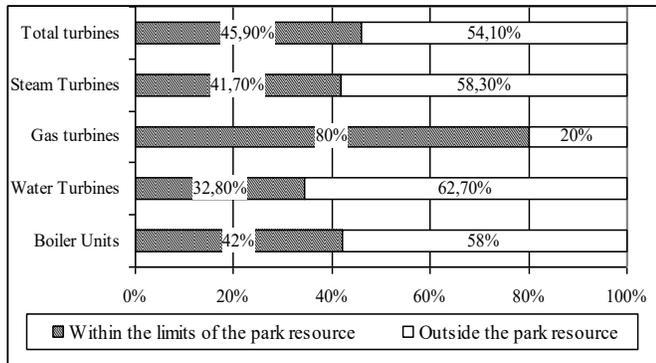


Figure 3. The share of the main generating equipment, operated within / outside the park resource, from the quantity of the corresponding type

In the end, consider the accident rates at the generation facilities and the power grid complex (Figure 4).

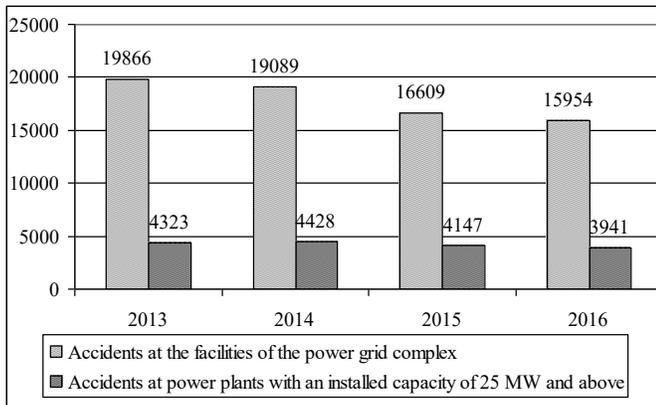


Figure 4. Accidents at the facilities of the electric power complex of the Russian Federation

From the figure it can be seen that the number of accidents at the sites of the network and generating complex is decreasing, however, in general, they are at a sufficiently high level. Unconditionally, accidents affect the invariance of the entire electric power system, as a result of which the

technological process is disrupted, equipment is stopped and consumer power is discontinued.

Thus, as a result of the study, we found that the invariance of the electric power system is affected by the interconnection of determinants, which not only disrupts the technological process of a particular system object, but also jeopardizes the invariance of the electric power system as a whole.

V. DISCUSSION OF THE RESULTS

The analyzed data indicate that the invariance of the electric power system is mainly influenced by technical and technological factors. In order to increase the dynamic stability, it is necessary to develop mechanisms aimed at preserving the reliability and safety of electric power facilities [13; 15; 16, 19].

Formation of the mechanisms of dynamic stability is expedient to be based on two components: internal and external determinants, interconnected with the system and affecting it both from the outside and from within. The electric power system can not have a significant effect on the macro determinants, which makes the process of their rejection difficult, however, the electric power industry has the property of influencing other elements of the system, as a result of which the energy system has the advantage of interacting with other systems and preserving the dynamic invariance.

Microdeterminants are formed in intrasystemic objects and more violate the dynamic invariance of the electric power system. In order to minimize them, the following mechanisms should be used:

- Reducing the use of equipment outside the park resource, which affects not only the invariance of the entire system, but also the stability of a single object in the electric power system;
- Improving the quality of the output of fuel and energy resources used in the production process;
- Improvement of planned preventive maintenance in the electric power system;
- Carrying out of measures for technical re-equipment and modernization of production facilities.

Thus, the formulated mechanisms will allow not only to increase the energy efficiency of industrial objects, but also to ensure the dynamic invariance of the electric power system.

VI. FINDINGS AND CONCLUSIONS

In the presented work, it was justified that the system is in constant motion, as a result of which external and internal disturbances influence it. Ensuring dynamic invariance of the electric power system must be based mainly on technical and management mechanisms, at the same time, the issues of system stability can not be considered exclusively in the plane of one science, in recent years, it acquires an interdisciplinary character.

As part of further research, it is advisable to consider issues related to the reduction of accidents at generation facilities and the power grid complex, the development of new technologies aimed at increasing the efficiency of technological processes and producing electric power.

REFERENCES

- [1] T. Alferova, E. Shilova, E. Tretiakova, «Methodical approaches to sustainable development of industrial enterprises». *European Research Studies Journal*, 2015, No 3, pp. 115-128.
- [2] A.A. Gibadullin, "The formation of a system of determinants that affect the stability of the economic system during the integration processes of the Russian economy." *Collection of articles of the V All-Russian Scientific Conference "Lviv Readings - 2017"*. Moscow: The Publishing House of the State University of Management, pp. 62-64.
- [3] A.A. Gibadullin, "Development of a Reliability System in the Electric Power Industry". *Materials of the All-Russian Scientific and Practical Conference of Young Scientists, Post-Graduate Students and Students with the International Participation "Actual Problems of Modern Science: A View of Young Scientists"*. Makhachkala: ALEF, 2017, pp. 492-494.
- [4] Gibadullin, V.N. Pulyaeva, "Modern mechanisms of innovative development of Russian industry". Moscow: State University of Management, 2016, 159 p.
- [5] A.A. Gibadullin, «Formation of the mechanism for sustainable development of electricity production facilities; abstract of dissertation for the Candidate of Economics degree: 08.00.05». Moscow, 2013, 26 p.
- [6] A.A. Gibadullin, «Mechanisms of stable industry development». *The international scientific journal*, 2012, No 4, pp. 23-27.
- [7] GOST R 27.002-2009 "Reliability in engineering". Moscow, Standartinform, 2011, 32 p.
- [8] B.P. Demidovich, "Lectures on the mathematical theory of stability: Proc. allowance ", 2 nd ed. Moscow, Publishing House of Moscow University, 1998, 480 p.
- [9] M.S. Ershov, A.V. Egorov, A.A. Trifonov, E.I. Rudin, "Some Problems of the Stability of Industrial Electrical Systems with Generators for Their Own Needs". *Industrial Energy*, 2006, No 8, pp. 21-25.
- [10] M.S. Ershov, A.V. Egorov, N.V. Valov, A.N. Komkov, "Accounting for supply voltage asymmetry in protection systems against loss of stability of industrial electrical systems". *Industrial Energy*, 2011, No 9, pp. 22-24.
- [11] I.V. Zhezhenko, I.V. Fedorov, V.S. Shamray, M.V. Fedorova, "Chaos and instability in electrical systems". *Dynamics of systems, mechanisms and machines*, 2012, No 1, pp. 130-133.
- [12] E.L. Loginov, A.N. Raikov, «Network information attacks on the control systems of power facilities belonging to the critical infrastructure». *Thermal Engineering*, 2015, No 4, pp. 233-239.
- [13] E.L. Loginov, S.I. Bortalevich, "System-dynamic approaches to increasing sustainability and reducing risks in the energy supply of large urban agglomerations." *Problems of security and emergency situations*, 2016, No 4, pp. 56-63.
- [14] Rules for the stability of electrical installations: the seventh edition. Moscow, 2015, 222 p.
- [15] Yu.V. Repin, A.A. Trifonov, "Quantitative assessment of the stability of industrial electrical systems". *Territory of Neftegaz*, 2009, No 4, pp. 64-67.
- [16] V.N. Kharitonova, "Formation of the corporate knowledge management system as a factor in the sustainable development of the organization". *Scientific and technical statements SPbSPU. Economic Sciences*, 2011, No 4 (127), pp. 165-169.
- [17] I.Kh. Hakho, "On the analysis of stability and reliability of electrical equipment, control systems and technological protection". *Reliability*, 2004, No 3 (22), pp. 65-69.
- [18] S.V. Chuprov, "Monitoring the sustainability of production systems." Irkutsk, Publishing house BGUEP, 2005, 221 p.
- [19] Denis B. Solovev Instrument current transducer for measurements in asymmetrical conditions in three-phase circuits with upper harmonics / Denis B. Solovev, Alexander S. Shadrin // *International Journal of Electrical Power and Energy Systems*, Vol. 84, pp. 195-201, 2017. [Online]. Available: <http://dx.doi.org/10.1016/j.ijepes.2016.05.012>