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On the Relevancy of Taking into Account the Consumers Importance Score in Reliability Management of Power Supply

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ABSTRACT
In modern realities, ensuring a reliable power supply is an economic challenge. The problem of deterioration of the power grid infrastructure is acute in the Russian Federation. It is proposed to take into account the importance score of electricity consumers when planning repair and modernization activities, for addressing to solve this and a number of other problems in conditions of electric power organizations limited resources. The importance score of the consumer should depend on the possible consequences of a power supply outage.

Keywords: *Power supply reliability management, Sustainable development, Electric power industry, Power grid complex.*

1. INTRODUCTION

In the context of the development of market relations in the electric power industry, the concept of "reliability of power supply" can be attributed not only to the technical category, but also to a greater extent to the economic category. Accordingly, ensuring the optimal level of reliability of power supply becomes an important economic task [1]. The need to improve the reliability of power supply to consumers is noted in various official public documents, including the Energy Strategy of Russia. [2].

Despite the fact that at the end of 2019 the Ministry of Energy of the Russian Federation assessed the conditions of Russia's power grids as "very good", the problem of the power grid complex is quite acute. The fact is that the statistics of the Ministry of Energy assesses the technical condition of only a part of the objects of the power grid complex. So, the Ministry of Energy estimates deterioration only for power transformers 110 kV and above and power lines 35 kV and above. Other substation equipment and transformers below 110 kV, as well as power lines below 35 kV are not evaluated [3].

As at 01.01.2020, the deterioration of the backbone networks of the largest industrial complex of Rosseti PJSC FGC UES is more than 50 %. At the current low rates of infrastructure renewal, the average deterioration of the power grid infrastructure of the largest industry holding will exceed 60 % by 2025. The probability of such an outcome is quite high and is constantly increasing considering the economic crisis amid the pandemic. In some regions, things are much worse than the average in Russia. For example, the proportion of the standard service life expired equipment in the Smolensk branch of Rosseti Centre IDGC PJSC in the Smolensk region reached 79.81 %, and in the Tver Region reached 77.58 % [4].

For the end consumer, the quality of electric power transmission services is assessed, among other things, by the duration and frequency of emergency and scheduled outages. Accordingly, the electric power equipment that has fulfilled its standard service life requires more frequent and longer repairs. That can lead both to dissatisfaction with the service quality and to large-scale avalanche-like power outages.

Solving the problem of deterioration reducing and obsolescence of the power grid infrastructure, we are engaged in increasing the satisfying of the end users requirements for high quality and reliable power supply service.

2. MAIN PART

In market conditions, and at the existing social restrictions on the growth of tariffs at the same time, electric power companies face the difficult task of determining the list of priority measures for reconstruction and current and capital repairs. Since repairs of electric power equipment require significant investments by attracting own or leveraged financing, their simultaneous implementation does not always turn out possible. This leads to increase in failures and accidents in the power supply system. The consequences of failures in the power supply system may be different. For example, a short-term interruption in the supply of electricity to a residential building can cause only minor inconveniences to apartment owners by the inability to make a meal or watch TV. However, a power outage for a large enterprise can lead to the loss of raw materials prepared, semi-products and finished products, damage to multi-million technological equipment, serious environmental consequences both at the local level and for the entire region, as well as endanger the health and lives of employees and people living nearby the enterprise. This is the key factor in the sustainability of the enterprise.

A large number of technical and organizational measures have been developed by now to provide the consumer with the required level of reliability of power supply. At the same time, the matter of method development for decision-making on these activities implementation order is not practically worked out. This leads to the unjustified and uncontrolled implementation of these measures, which reduces their effectiveness significantly and does not produce the expected result.

One of the problems of effective implementation of technical and organizational solutions is the fact that calculating the technical and economic effect of such an implementation is a rather labour intensive and time-consuming process. Accordingly, it is necessary to range the repair activities order of priority in sequence based on some cost criterion. From the above it follows that it is necessary to take into account the information: the reliability of power supply to which consumers this particular work (repair or reconstruction) may have an impact, as well as the importance score of each consumer. By the importance score of the consumer is understood the priority of ensuring reliable power supply to this consumer by a certain power grid company. The specified criterion for determining the importance score of the consumer may be potential damage (direct or indirect), which is likely to be caused by a power outage of a particular consumer. Moreover, damage should be understood as not only economic damage associated with product damage and equipment failure, but also possible damage from the implementation of environmental and social risks that unreliable power supply carries.

These risks can be considered within the framework of the concept of sustainable development. This concept combines three areas:

- Economic – the preservation and exaggeration of various types of capital that provide economic production (including natural, social capital);
- Environmental – stability of natural and ecological systems, neglect of which leads to environmental degradation and endangers the existence of mankind;
- Social – maintaining cultural and social stability.

Sustainable development standards in the field of environmental, social issues and corporate governance (or ESG) affect not only business relations with government bodies and people.

They also affect the business financial performance, not only because they require obvious additional costs, but also because they help reduce some costs, affect the value of the business (including the value of the company's shares) and provide additional opportunities or limit its strategic development [5].

Disruption of power supply to various groups of consumers can lead to socio-environmental consequences of various kinds. As part of its sustainable development strategy, the power grid company must ensure that its internal priorities are linked to those in the field of environmental protection, social advancement and corporate governance.

External stakeholders include:

- Consumers of the power grid company;
- Network organizations;
- State and municipal government bodies;
- Investors;
- Partners;
- The public.

Internal stakeholders:

- Shareholders of the company;
- Employees of the company;
- The company management.

The map of the mutual influence of the company's stakeholders is presented in Figure 1.

Based on the factors analysed when determining the company's compliance with the criteria for sustainable development, it is possible to identify social and environmental risks that should be taken into account when determining the importance score of the consumer. [6].

- "Environment"
  - Atmospheric air pollution;
  - Pollution of water resources; Pollution and destruction of land resources;
  - Negative impact on biodiversity;
- "Relationship with society"
  - Violation of labor protection and industrial safety;
  - Negative impact on regional development;
- "Corporate Governance"
  - Lack of interaction with stakeholders.

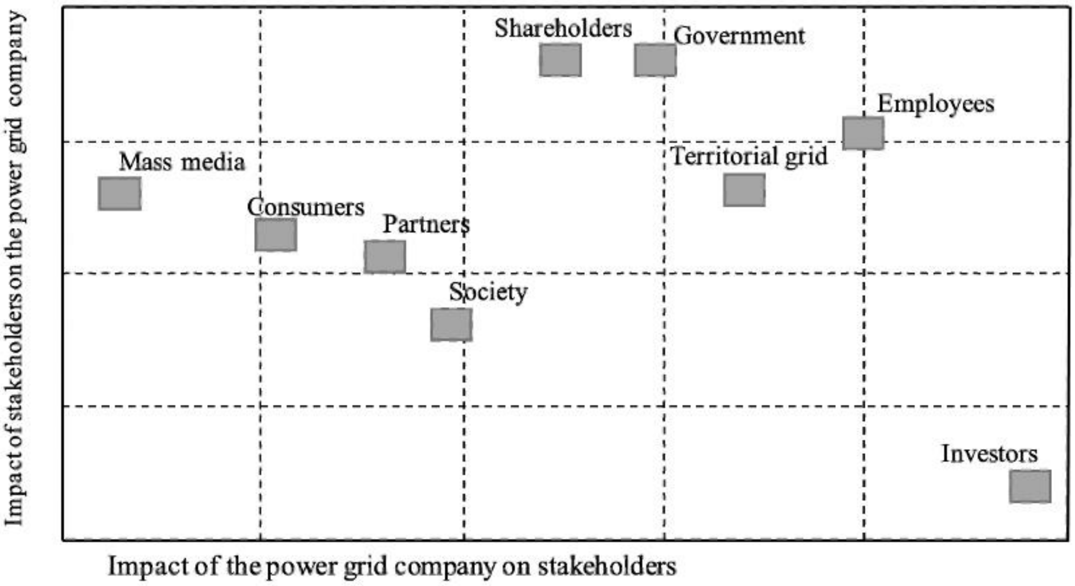

Figure 1. Map of the mutual influence of stakeholders of the electric power grid company

In order to improve the reliability of power supply, it is necessary to develop a mechanism for taking into account the importance score of consumers, which will allow electric power companies to allocate available resources most efficiently to maintain and modernize the electric grid complex. The importance score of the consumer should be determined by the possible consequences that a power outage can lead to, and in addition to economic damage, it is also necessary to consider and build on the model the risks identified in accordance with the ESG approach.

The technological process of the consumer has the greatest influence on the amount of the expected damage. Besides that, for a number of technological processes, the peculiarities of the climatic region in which the consumer operates are important. Accordingly, consumers should be divided into groups based on the main technological process. Also, for a number of technological processes, it is necessary to identify groups with the consideration of the climatic specifics of the region. The groups should be distinguished so that the expected consequences of a power supply disruption to all consumers of the same group can be described according to the same rules.

In general terms, the real economic damage P_{RED} that the electric grid company must compensate for the consumer can be expressed by the equation:

$$P_{RED}=P_{FA}+P_{IG}+P_{DPT}+P_{loc}\,, \quad (1)$$

where P_{FA} – the loss of fixed assets, rubles; P_{IG} – loss of inventory and goods, rubles; P_{DPT} – losses from the destruction of property of third parties, rubles; P_{loc} – costs of localization and elimination of accidents, rubles.

However, the complexity of assessing the possible consequences of a power outage is mainly in the data incompleteness for an accurate calculation of economic damage, as well as the labour intensity of this process. From the point of view of social and environmental damage, the difficulty is its "digitization", correlation with economic consequences.

It is important to note that due to the insufficient amount of available data, it does not seem correct using the machinery of probability theory in this case. In the course of the study, the author developed and analysed two approaches to importance score assessing:

Algorithm for assessing the importance score of consumers using the theory of generalized fuzzy numbers (GFN). This algorithm was obtained by modifying the algorithm for assessing the risks of investment projects [7].

Application of GFN theory is an innovative approach to risk analysis. Within the framework of this concept, the expert can vary the degree of confidence in different judgments. The algorithm can be represented as follows:

- Division of consumers into several categories;
- Setting variables in linguistic form;
- Conducting a modified qualitative risk analysis;
- Assignment of the degree of confidence of each expert in the probability of implementation of each factor;
- Calculation of the importance score indicator based on the probability of implementation for each factor;
- Calculation of the measure of similarity of the risk variable with each of the terms;
- Calculation of the exact value of the risk.

An integrative algorithm for assessing the importance score of consumers. This algorithm is based on a scenario approach for calculating the possible consequences of a power failure [8]. The highest accuracy of this algorithm is achieved when using expert assessments in conjunction with statistical data on the outages that have occurred. The operation of this algorithm can be represented as follows:

- Division of consumers into several categories;
- Identification of the main scenarios for the development of the accident;
- Calculation of the economic and socio-ecological components of the grade point assessment;
- Calculation of the score for each category;
- Formation of the existing list of consumers;
- Determination of the importance score for each consumer.

The described algorithms were tested on a real sample of consumers of the power grid company. As a result of approbation, it was concluded that the most preferable is applying of an integrative algorithm. However, if it is impossible to obtain the necessary data on consumers, the use of an algorithm based on GFN is justified.

The disadvantages of the GFN-based algorithm in comparison with the integrative algorithm include a small “spread” of the obtained values of importance score, a rather significant number of consumers with the same importance score values. This, in turn, leads to a probable error when choosing the optimal set of specific measures for the repair and reconstruction of power supply facilities for the evaluated consumers.

3. CONCLUSION

To improve the reliability of power supply, the program of repair measures should be drawn up taking into account the importance score of consumers who are affected by this measure action. The assessment of the importance score of consumers must be carried out in accordance with the possible consequences that unreliable power supply can lead to. In addition to the economic component, the consequences of a power outage include social and environmental factors.

Calculating the real economic damage for each specific consumer is a rather difficult task. On the other hand, to determine the importance score of consumers, it is enough to find out the relative values. The author has developed and tested algorithms for calculating the importance score of consumers, which can be used when planning repair activities in power grid companies.

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