Problems of assessing the energy systems reliability in Russia

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Abstract. The paper analyzes the main approaches to assessing the energy systems reliability currently used in Russia. The main terms and requirements for the reliability of energy systems are defined, and gaps in the regulatory framework in this area are indicated. Based on the review and analysis of regulations and scientific research on ensuring the uninterrupted operation of power systems, a universal classification of reliability types is proposed. The expediency of developing a comprehensive approach to assessing system reliability based on the analysis of adequacy and operating reliability is shown, and the directions for improving existing methods for evaluating various types of power systems reliability are determined.

Introduction

One of the most important principles of the state policy in the field of energy security in accordance with the Energy strategy of Russia for the period up to 2030 [1] is to ensure reliable energy supply to consumers, both in normal operation and in the event of a threat of emergency situations. Uninterrupted power supply is the basis for the effective functioning of industrial enterprises and life support systems for the population. In addition, the issues of ensuring the energy systems reliability are inextricably linked to the need to improve the efficiency of the power industry as a whole and reduce the cost of electricity.

The development of measures aimed at ensuring the reliable functioning of energy systems is complicated by the fact that in the Russian Federation there is an economic division of participants in the unified technological process of electricity production and transmission, which entails the division of responsibility areas and the occurrence of legal conflicts [2]. In addition, the regulatory framework for assessing the energy systems reliability in Russia is currently insufficiently developed. The use of foreign experience in improving the reliability of the unified energy system (UES) is complicated by the fact that Russian reliability indicators are not harmonized with similar indicators in other countries, and some of them do not set acceptable regulatory values at all.

The problem of ensuring the energy systems reliability is multi-faceted, since its solution requires both the development of a comprehensive approach to assessing the UES reliability, and the availability of reliability indicators and methods for determining them for various types of reliability, and levels of energy systems (from the UES to energy nodes). Currently, there is no unified approach to assessing reliability in Russia, which makes it difficult to make management decisions on the development of the Russian UES. Therefore, it is particularly relevant to analyze the terminology used in regulatory documents in order to harmonize and unify it, as well as to assess the possibility of using existing methods of reliability assessment to develop a methodology for assessing the reliability of power systems at various levels.
Terminology analysis consistency in the field of ensuring reliable energy systems operation

To ensure the reliability of the Russian UES and its elements, first of all, effective mechanisms are needed to assess the technical condition of energy systems and identify the main risks, for the development of which one of the key aspects is the unity of terminology in this area. Currently, there are different definitions and classifications of reliability in Russia, which complicates the development of a unified concept and universal requirements for ensuring uninterrupted and reliable operation of the power industry in order to meet the demand for electric energy from consumers.

Comparative analysis of the main terms contained in the Russian regulatory framework shows that unity is present only in the definitions of the energy system and electric power facilities. As for the terminology on reliability itself, at the level of Federal legislation [3,4], only the following definition of the energy system reliability is introduced: the ability of energy system to produce, transfer electric energy (capacity) and supply consumers with electric energy in a single technological process and to resume them after violations.

It should be noted that hereinafter the Federal law of 26.03.2003 35-FZ [3] uses the term "system reliability" in the context of "energy system reliability", that allows to consider these two terms synonyms and argued that the concept of system reliability is introduced at the level of Federal legislation.

The Preliminary national standard PNST 304-2018 [5] and the national standard GOST R 58057-2018 [6] also introduce the term "adequacy" - the ability of the energy system to provide the total demand for electric energy and power of consumers, taking into account the capacity of the electric network, as well as planned and likely unplanned outages of energy system elements. This definition shows that adequacy is a part of system reliability, since it characterizes the ability to meet the demand for electric energy - one of the subtasks for ensuring the energy system reliability of the in accordance with GOST R 57114-2016 [7].

Thus, at present, the legal framework for ensuring the reliable operation of the Russian UES contains only the terms "system reliability" and "adequacy" which can be used in determining the parameters, criteria and requirements for reliability.

The terminology analysis in the field of ensuring the Russian UES reliability revealed the need to introduce a classification of reliability types, which will, on the one hand, meet the requirements of the current Russian legislation, and, on the other, harmonize the classifications that currently exist in various scientific and technical sources.

The most common classification of system reliability is its division into adequacy and operating reliability of the energy system. This classification is reflected in the RAO "UES of Russia" standard STO 17330282.27.010.001-2008 [8] and scientific research [2,9,10].

By adequacy, all the above-mentioned scientific and technical sources mean the ability of the energy system to provide the total demand for electric energy and the power of consumers within the set values and restrictions on the energy resources supply. While operating reliability characterizes the energy system ability to maintain acceptable modes of operation under changing conditions and sudden disturbances, that is, it is associated with system violations.

In addition, some sources [8,9] additionally introduce a structural and functional classification of reliability, which assumes the allocation of a structural component of reliability due to the energy system composition, throughput capacity and connections between elements, without taking into account their functions in the system. The design model for structural reliability analysis is determined only by the structure of an energy object, so it is more informative to calculate functional (operating) reliability, for which the design model takes into account the structure of objects, the composition, configuration of its elements connections and their operation modes.

There is also a technological classification of reliability, proposed in the recommended terms collection edited by Voropay N. I.[3], which meets the requirements of modern Russian legislation and includes system reliability and reliability of power supply – the ability to provide uninterrupted power supply to the consumer taking into account its requirements.

Table 1 presents a complete classification of the power systems reliability , according to which system reliability includes three types of reliability: adequacy, operating and structural. The feasibility analysis of evaluating various reliability types to develop solutions for managing the system reliability
of both the Russian UES as a whole and its individual elements has shown that adequacy and operating reliability can be used for this purpose. At the same time, the most informative and enabling reliability assessment of the entire Russian UES is the analysis of adequacy. The analysis results are presented in table 1.

**Table 1.** Assessment of the possibility of applying various reliability analysis types to ensure the reliable operation of the Russian UES.

| Reliability type                        | Availability of evaluation methods | Feasibility of evaluating this reliability type |
|----------------------------------------|-----------------------------------|-----------------------------------------------|
| System reliability (energy systems reliability) |                                   |                                               |
| Adequacy                               | Yes                               | Yes, since there are:                         |
|                                        | GOST R 58730-2019 [11]            | - assessment methodology;                    |
|                                        |                                   | - standard value of the reliability indicator;|
|                                        |                                   | - software that reduces the time and labor costs of conducting an assessment. |
| Operating (mode, functional)           | Yes                               | Yes, since there are:                         |
|                                        | Order Ministry of Energy №630 from 03.08.2018 [12] | - assessment methodology;                    |
|                                        |                                   | - normative value of reliability indicators. |
|                                        |                                   | But conducting this assessment requires high time and labor costs for conducting the assessment. |
|                                        |                                   | The assessment is appropriate for local power systems and power nodes |
| Structural                             | None                              | No, because they are missing:                 |
|                                        |                                   | - assessment methodology;                    |
|                                        |                                   | - normative value of reliability indicators  |

Reliability of energy supply to consumers

- It is possible to conduct an assessment of the reliability of energy supply to consumers, since there is a method for such an assessment.
- But the assessment is complicated by the presence of regulatory indicators not for all categories of consumers

### Analysis of regulatory requirements for ensuring the energy systems reliability

Analysis of the regulatory framework for ensuring the energy systems reliability [3-8,15] shows that the Russian Federation does not have a quantitative criterion that characterizes system reliability. The regulatory documents contain only separate requirements for adequacy, operating reliability and reliability of power supply to consumers.

To determine the estimated power reserves, as a rule, only the adequacy is evaluated, since the operating reliability has a much smaller impact on the system reliability, because the issues of ensuring operating reliability are solved by optimal management and selection of appropriate modes.

In ensuring the adequacy, the main role is played by redundancy and the main task in calculating the adequacy is to determine exactly the amount of the reserve of energy resources, generating capacity and capacity main lines. Since the main lines of energy systems is a probabilistic property, probabilistic indicators are used for its quantitative assessment, which reflect the frequency of occurrence, duration and amount of losses of electric power supplies.
GOST R 58730-2019 [11] sets general requirements for the energy systems adequacy when planning and designing the development of energy systems, as well as when determining the demand for power during the implementation of competitive power selections in the wholesale market of electric energy (capacity). It is established that the main indicator of adequacy is the integral probability of deficit-free operation of the energy system. At the same time the standard level of adequacy in the Russian UES and technologically isolated territorial energy systems is characterized by an integral probability of deficit free operation of the power system not less than 0.996.

The economic feasibility of increasing reliability (the degree of redundancy) in regulatory requirements excess is established by Methodological recommendations [15], which determine that the estimated capacity reserve consists of a repair, compensatory and strategic reserve. At the same time, the value of the compensatory reserve should provide a normalized reliability of load coverage, estimated by the probability of a deficit-free operation of the power system of 0.996.

Within the framework of GOST R 57380-2019 [11], it is proposed to use two more standard indicators of adequacy: the integral exhaustion probability of inter-zone communication capacity (a set of inter-zone communications) and the mathematical expectation of the annual volume of electric energy consumption restriction in the reliability zone and the energysystem as a whole. The standard also allows the use of other adequacy indicators, however, there are no references to documents that may regulate the assessment of these indicators. In addition, the implementation of this methodology for calculating the power systems adequacy is complicated by the lack of recommended software for such calculations. A serious barrier to assessing system reliability is also the lack of standards in the Russian Federation for most reliability indicators. The results of evaluating the availability of regulatory requirements for various types of reliability are shown in tables 2 and 3.

### Table 2. Requirements for reliability of power supply to consumers.

| Power supply category | Number of independent mutually redundant power supplies | Indicator | Normative value |
|-----------------------|--------------------------------------------------------|-----------|----------------|
| PUE 7 ed. [16] + Government Resolution №442 from 04.05.2012 [17]| Order Ministry of Energy №1256 from 29.11.2016 [13]|           |                |
| First                 | 2 for \( t_{\text{disconnect}} \leq t_{\text{autopower}} \) one source | SAIDI, h  |                |
| First (special)       | 3 or 2 (with additional requirements) for \( t_{\text{disconnect}} \leq t_{\text{autopower}} \) one source | SAIFI     |                |
| Second                | 2 for \( t_{\text{disconnect}} \leq t_{\text{backuppower}} \) | Average duration of power transmission interruptions, h | None |
| Third                 | 1 for \( t_{\text{disconnect}} \leq 1 \) day in a row, but no more than 3 days a year | Volume of under-supplied electricity, MW*h |                |

### Conclusion

Thus, at present, the Russian Federation does not have a unified methodology for assessing the system reliability of the unified energy system as a whole or its individual elements. At the same time, there are guidelines in the status of normative legal acts, that is, they are mandatory, according to the calculation:

- reliability of power supply to consumers;
- adequacy;
- operating reliability.

The paper shows the feasibility of developing a comprehensive approach to assessing the energy systems reliability based on the analysis of adequacy and operating reliability. At the same time, the
most informative is the assessment of adequacy, and the methodology for assessing operating reliability requires more detailed study in such matters as:
- harmonization of terminology and introduction of the term "operating reliability" in legal acts;
- determining the requirements for the source data, taking into account the level of the evaluated power system;
- development of software that reduces the time and labor costs of conducting such an assessment.

Table 3. System reliability requirements for energy systems

| Adequacy (GOST 58730-2019 [11]) | Operating reliability (Order Ministry of Energy №630 from 03.08.2018 [12]) | Structural reliability |
|---------------------------------|-------------------------------------------------|------------------------|
| Indicator | Value | Indicator | Mode | Disturbance group | Value | Indicator | Value |
| Integral probability of a power-free operation of energy system | P ≥ 0.996 | Minimum safety factor of static aperiodic stability in active power in controlled sections | Normal | in normal scheme: I, II, III in repair scheme: I, II | Kp ≥ 0,2 | Failure flow |
| Integral probability of interband bandwidth exhaustion | None | Minimum safety factor for static stability at load nodes | Post-accident | Forced | - | Kp ≥ 0,08 | Availability ratio |
| Mathematical expectation of restrictions annual volume on the energy consumption | None | | | | | | |

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