IMPROVEMENT OF MANAGEMENT METHODS FOR THE OPERATIONAL RELIABILITY OF DISTRIBUTED ENERGY FACILITIES

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Abstract

Improving the management of the technical condition of equipment, devices and installations, the service life of which exceeds the standard value, is one of the most important problems of state security. Today, the relative number of such equipment already exceeds 60%. The results of the analysis of literature data on this problem presented, which confirm its relevance and significance. It is important to note that these findings apply to not only electrical power systems, but many other production systems as well. The main difficulties in solving the analyzed problem, first of all, the paucity of statistical data characterizing the reliability of work, their multidimensional and random nature. The authors propose to solve this problem by moving from average annual reliability indicators to average monthly indicators of operational reliability. A brief description of the solution of individual tasks of this problem for overhead power lines is given, which together represent a new methodology for managing the technical condition of distributed type objects. Science-intensive, cumbersome and labor-intensive calculation algorithms determine the expediency of the transition to intelligent systems. At the same time, the management of the electric power system and its individual production enterprises will monthly receive specialized forms indicating recommendations that optimize the increase in the reliability of overhead power transmission lines by restoring wear and tear.

Keywords. Operational reliability, technical condition, automated control, risk-based approach, work efficiency, overhead power transmission lines.

I. Introduction

One of the main problems of electric power systems (hereinafter - EPS) is the improvement of the management of the technical condition of equipment, devices and installations (hereinafter - objects). The system of preventive maintenance (hereinafter - PM) traditionally used for management no longer meets the requirements, or rather, it becomes insufficient. This discrepancy arose, first of all, because the relative number of objects of the same type, the service life of which exceeds the standard value, is systematically increasing in the EPS. So back in 2012, in [1] noted that the EPS of Russia need a serious modernization of fixed assets and the replacement of almost 50% of physically and morally obsolete equipment

In [2], noted that the service life of about two-thirds of nuclear reactors exceeds the standard value, and aging management programs be introduced. The aging of objects is accompanied by an increase in the number and severity of accidents, the consequences of which not only lead to large material costs, but also to environmental violations, injury and death of personnel, and violations of state security.

At the same time, the mandatory replacement of the main facilities, the service life of which exceeds the standard value with a new one, not only creates great economic difficulties, but also inexpedient. And, first of all, because the technical condition (hereinafter - TC) of the main objects in most cases depends not only on the calendar service life, but also on the operating conditions and, above all, on the load.

II. Features of Control Methods for TS of Hazardous Production Facilities

Along with an increase in the relative number of facilities whose service life exceeds the standard value, an increase in the number of unacceptable accidents, the number of publications that form the main comments on the methods of managing the TC of production facilities based on a risk-based approach (hereinafter - RBA). Below are a number of opinions and recommendations on the results of applying these methods for the period from 2011 to 2020, which cannot be disagree. But, first of all, we will agree that by "method" we will understand a "tool" for solving the task, by "approach" - the choice of a certain method, and by methodology - an objective sequence of methods for solving the problem under study. This clarification of terms is formulated on the basis of familiarization with a number of scientific studies on their difference. The most important recommendations, in our opinion, include the following.

In [3], the scientific foundations for ensuring the safety of production facilities considered. It is noted that:

❖ absolute safety of hazardous production facilities (hereinafter - HPF) cannot be ensured in principle;

❖ the risk of HPF TC assessment is a quantitative measure of the risk of unacceptable events occurring in case of HPF failures;

❖ the main task of HPF managers is to maintain the normatively established permissible level of danger (risk);

❖ despite the variety of recommendations on the topic "safety of HPFs", they are of a declarative nature;

❖ the main directions for improving the HPF safety system are:

– creation of an approach to timely (operational) accounting of the impact of HPF TC on safety;

– taking into account the multifactorial impact on the safety of HPFs.

In [4], it is noted that in order to ensure the safety of HIFs of the oil and gas complex, the solution of problems related to the prevention of possible emergencies and the minimization of technological and environmental risks is becoming increasingly important. Currently existing methods for assessing industrial safety risks do not take into account the constantly changing in time non-stationary random nature of risks

In [5], noted that risk analysis is a rapidly developing interdisciplinary scientific direction in which:

❖ the conceptual apparatus of risk analysis has not yet been formulated and differs significantly by industry;

❖ a very large proportion of the quantitative reliability indicators used and the imperfection of the methodology for their use (formation of integral reliability indicators);

❖ imperfection of the existing methodological base. All calculations recommended to be carried out in point setting.

In [6], noted that the disadvantages of existing methods for quantitative risk assessment are:

❖ assessment of the probability of occurrence of an event is carried out on a limited amount of initial statistical data;

❖ despite the cumbersome and science-intensive methods, the calculations are performed manually;

❖ does not take into account the multidimensional nature of the risk.

In [7], noted that quantitative estimates of the frequency of occurrence of failures of the same type of objects differ from each other by two to four orders of magnitude. An analysis of the reasons for this discrepancy shows:

❖ the volume of initial data is insufficient;
❖ when performing calculations, a number of unacceptable assumptions are made;
❖ the presence of significant errors in the calculations of reliability indicators due to insufficient qualifications of performers;
❖ the more indicators that characterize the reliability of HPF, the greater the spread of calculation results.

III. Peculiarities of Normative Methods of Control of TC HPF EPS

The normative methods of managing the TC HPF EPS include, first of all, [8,9]. Unfortunately, the shortcomings of the HPF security methods noted above in [8,9] have not been eliminated. Yes, they not taken into account, despite the fact that the experience of the practical use of these methods discussed at scientific and practical conferences on the topic “Control of the technical condition of the equipment of electric power facilities”, held in 2018 and 2019.

At the same time, noted in [12] that:

❖ the probability of an event occurring in the future is determined based on the frequency of occurrence of this event in the past. This does not take into account the possibility of adjusting actions that transform the flow of events;
❖ there is an insufficient volume and heterogeneity of the sample of statistical data on failures;
❖ indicators such as the number, frequency and average severity of accidents are completely unfounded;
❖ statistics of past years (for 3-5 years) in full accordance with the rules of probability theory and mathematical statistics is unsuitable, as it is non-random and heterogeneous.

In [13] it is noted:

❖ in the foreseeable future, energy companies will have to solve the problem of ensuring reliability in the face of high equipment wear and lack of resources;
❖ along with the systems of preventive maintenance and repair according to the TC, it is advisable to introduce a repair system based on the RBA.
❖ Existing methods for predicting TC HPF based on RBA do not cover power lines and devices with a voltage of 0.4-10 kV. But these transmission lines make up about 90% of the length of networks, belong to the distribution electrical network (hereinafter - DEN) and are sources of 80% of accidents;
❖ methods [8] and [9] are actively used in the EPS of the Russian Federation;
❖ discrete index of technical condition (hereinafter - ITC) serves as the basis for ranking EPS objects (it does not take into account the random nature of the initial data);
❖ for the management of operational repair activities, the calculated ITC is unacceptable.
❖ there are significant gaps in the regulation of RBA

IV. Recommended Approaches to Managing the Technical Condition of Overhead Power Transmission Lines

EPS objects classified into objects of continuous (transformers) and discrete (switches) action, concentrated (power units) and distributed power transmission lines. This difference causes the difference in the number of indicators of their reliability and methods of evaluation. Considering that more than 80% of accidents in EPS are associated with DEN [13], we will consider the solution to this problem for overhead power transmission lines (hereinafter - OPTL).

The foregoing allows us to conclude that the improvement of the management of the TC OPL EPS provides for the possibility of objectively solving a number of tasks, which, first of all, include:
1. Ranking of distribution network enterprises (hereinafter - DNE) according to the degree of aging (hereinafter - DA) of the OPTL and recognition of DNE, the DA of the OPTL of which is the largest;
2. Evaluation of objective indicators of reliability of high OPTL;
2.1. Overcoming the subjectivity of selective survey;
3. Accounting for the random nature of estimates of operational reliability indicators and differences in the degree of technical use of high-voltage transmission lines when:
- comparison of estimates in the settlement and previous months;
- ranking of the DNE;
- recognition of "weak links"

4. Accounting for the random and multidimensional nature of the operational reliability of the OPTL EPS when:
- ranking of the DNE;
- recognition of "weak links"

5. Assessment of the objectivity of recommended methods and algorithms
6. Minimization of the risk of an erroneous decision with the methodological support of the management of the EPS and DNE.

First of all, let's clarify our attitude to the adopted system of designing power supply systems. And, in particular, to ensure the reliability of power supply, taking into account the category of consumers and the requirements of the Electrical Installation Rules.

Many years of experience in the design and operation of power, supply system's indicates that in the vast majority of cases, the commissioned power supply system's meet the requirements. Therefore, there is no reason to doubt the infallibility of design methods. At the same time, the risk of occurrence of unacceptable events exists (recall that absolute safety is excluded [3], although it is insignificant.

Consequently, the meaning of the control of the TC of the power supply system is not at all in assessing the changes in the consequences of a power supply failure. Possible consequences are known from the project documentation. *Not a change in the size of the consequences causes a change in the reliability of objects of power supply systems, but vice versa. Changing the reliability indicators changes the size of the possible consequences.* Thus, when analyzing the TC of power supply facilities, it is sufficient to assess the significance of changes in estimates of the reliability indicators of objects. But the significance of changes in the reliability indicators of specific objects, as a rule, cannot be determined, since there could be no failures, or there are so few of them that quantitative estimates are unreliable. If we also take into account that there are thousands and even tens of thousands of such objects in the EPS, then the cumbersome and laborious calculations also cause a high risk of an erroneous decision and the undoubted advantages of the intuitive approach of specialists.

But you can approach the problem in a slightly different way. Let us summarize some of the results obtained by us and published in 2021, results of solving the problem for OPTL.

In [14], quantitative estimates of DA OPTL are analyzed (see paragraph 1). Shown, that the estimate of the relative number of OPTL, the service life of which exceeds the standard value, used in practice, is unacceptable for comparing and ranking DA OPTL DNE EPS. A method and algorithm for solving this problem developed.

In [15] (see paragraphs 2.1 and 2.2) noted, that it is advisable to evaluate the TC OPTL by operational indicators of the reliability of work. The average monthly values of the probability of automatic emergency shutdowns of the OPTL calculated from the data of operational logs. The results of an objective classification make it possible to identify "weak links" and thereby recognize the OPTL that reduce the efficiency of the EPS to the greatest extent. Reducing the risk of an erroneous decision during the survey of the TC OPTL is achieved by the recommended method of forming a representative sample of the elements of these OPTL to be tested.

In [16] (see paragraph 3), a new method and algorithm for the operational assessment and comparison of the reliability indicators of OPTL is recommended. A distinctive feature of the calculation method is taking into account the degree of technical use of OPTL. The algorithm for estimating operational reliability indicators developed for the specific number of emergency automatic shutdowns of OPTL, for stable failures, the probability of stable failure and the technical utilization factor. Comparison of estimates for two adjacent operational intervals is supposed to be carried out on the basis of the boundary values of fiducial intervals

In [17] (see paragraph 4), a new algorithm for assessing the feasibility of classifying multidimensional data on failures and downtime of OPTL was developed. A method and algorithm for estimating the operational integral indicator of reliability, the physical essence of which is adequate to the wear of the TC, developed. A method and algorithm for comparing integral indicators of operational reliability developed, taking into account errors of the first and second kind. A method and algorithm for ranking indicators of operational reliability has been developed, which makes it possible to identify OPTL that require prompt survey.

In [18] (see paragraph 5), on the example of statistical data on failures of the main 110 and 220 kV OPTL, the results of assessing and comparing operational reliability of operation are given. The purpose of manual analysis is to recognize the varieties of signs for which the specific number of stable failures will exceed this indicator to the greatest extent for the set of OPTL. The identified significant varieties of signs completely coincided with the results of choosing the least reliable OPTL based on an intuitive approach, which confirms the correctness of the recommended method of quantitative analysis.

In [19], a method and algorithm for automated comparative analysis (benchmarking) of the operational reliability of DEN objects is proposed. The transition from an intuitive approach to a quantitative approach to the operational recognition of “weak links” among thousands of objects of the same type made it possible to reduce the risk of an erroneous decision when organizing their maintenance and repair.

For illustrative purposes, Fig. 1 shows an enlarged block diagram of the algorithm, which, based on the methods described in [14-19], allows you to automate the process of generating recommendations to improve the operational reliability of the OPTL EPS.

The results of the monthly automated monitoring of the operational reliability of the operation of the OPTL and recommendations for improving the efficiency of work formalized in the form of special forms and provide information and methodological support for the technical management of the EPS and each ENE. For illustrative purposes, Fig. 2 shows one of the variants of these forms.

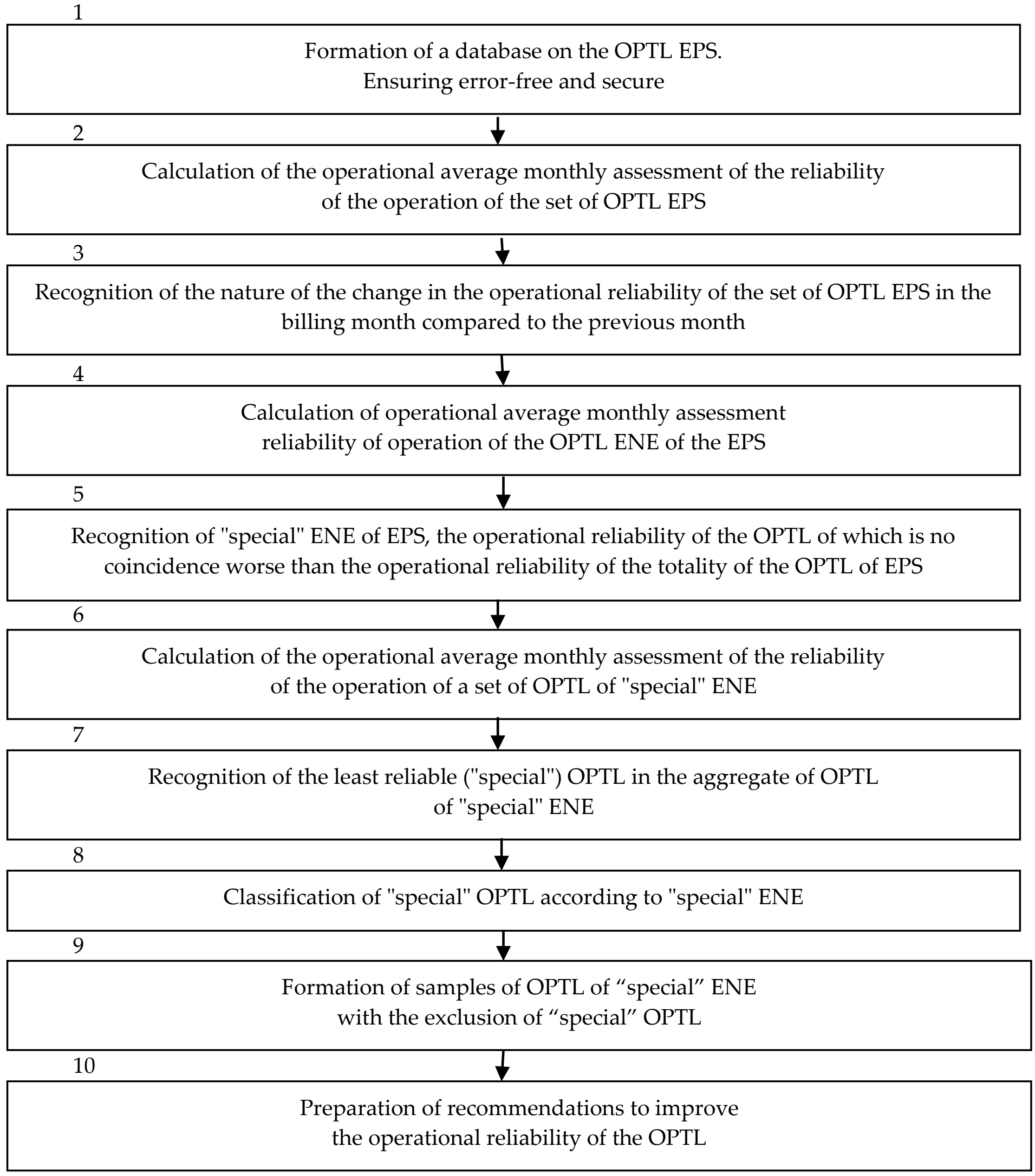

Fig. 1. An enlarged block diagram of the algorithm for improving the operational reliability of the OPTL EPS

Date of analysis
05 may 2021 year

EPS Chief Engineer
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Information
on the operational reliability of OPTL
in the month of April 2021

1. Compared to the previous month, the operational reliability of the OPTL EPS has ***decreased***;
2. Table A shows the average monthly estimates of the operational reliability of the operation of the OPTL ENE EPS, arranged in descending order.

Table A. Information about the operational reliability of the OPTL ENE EPS

№	Name ENE	Rating ENE	№	Name ENE	Rating ENE
1	***ENE 5***	***Good***	6	***ENE 9***	***Satisfactory***
2	***ENE 3***	***Good***	7	***ENE 6***	***unsatisfactory***
3	***ENE 7***	***Good***	8	***ENE 2***	***unsatisfactory***
4	***ENE 8***	***Good***	9	***ENE 4***	***unsatisfactory***
5	***ENE 1***	***Satisfactory***	10	***ENE***	***unsatisfactory***

3. Table B1 shows the passport data of the OPTL EPS, the operational reliability of which, as well as the rating of their ENE, is ***unsatisfactory***.

Table B1.

№	Name		Voltage class, kV.	Service life, year	Length, км	Execution
	ENE	OPTL				

4. Table B2 shows the passport data of the OPTL EPS, the operational reliability rating of which is unsatisfactory, and the service life does ***not exceed*** the standard value.

Table B2.

№	Name		Voltage class, kV.	Service life, year	Length, км	Execution
	ENE	OPTL				

5. Recommendations for improving operational reliability:
5.1. Carry out a selective survey of the OPTL indicated in Table. B1
5.2. Establish and eliminate the causes of automatic shutdowns of OPTL, given in Table. B2.
5.3. Arrange for the personnel of the ENE indicated in Table. B1, advanced training courses on the problem of maintenance of aging OPTL.

Fiq. 2. The results of the analysis of the average monthly operational reliability of the OPTL EPS

Conclusion

1. The relevance of improving the methods of operating reliability management confirmed not only for EPS, but also for many other production systems.
2. The solution of this problem proposed to carry out by the transition to the analysis of integral indicators of operational reliability.
3. Methods for calculating the integral indicators of operational reliability, taking into account the random nature of quantitative estimates, assessing the feasibility of classifying data according to varieties of comparison features and ranking the estimates form the methodology of the operational reliability management system in EPS.
4. These methods based on a fiducial approach, simulation modeling of representative samples, taking into account errors of the first and second kind
5. The science-intensive, cumbersome and labor-intensive manual calculation, the high risk of subjective errors and prerequisites necessitate the transition to intelligent control systems for objects whose service life exceeds the standard value.
6. Automated management of operational reliability increases the importance of an intuitive approach in the implementation of methodological recommendations, which limits the risk of an erroneous decision.

References

[1] Basic provisions of the concept of an intelligent power system with an active-adaptive grid. M, FSKES, 2012

[2] Safe lifetime management of nuclear power plants INSAG-14 (Report of the International Nuclear Safety Group)/IAEA, Vienna, 2014, 47 p.

[3] Kuzmin A.A. Organization of ensuring the safety of a hazardous production facility based on a quantitative assessment of the state of its safety system. "Technology of civil security", 2011, volume 8 No. 4 (30), pp. 72-79

[4] Aburakhmanov N.Kh., Shaibakov R.A., Markov A.B. Information models for managing the risk minimization of potentially hazardous production facilities//GIAB 2015, No.57, URL, pp. 729-736.

[5] Kolesnikov F.Yu. Main problems of accident risk analysis methodology. Fire safety, 2016, vol.25 No 2, pp. 4-8.

[6] Lisanov M.V., Pecherkin A.S., Shvyryayev A.A. Methodological support and problems of accident risk analysis at hazardous production facilities of the oil and gas complex - M. “Improving the reliability and safety of gas industry facilities” No.1 (29), 2017, pp. 179-184.

[7] Lisanov M.V., Sumskoy S.I., Shvyryayev A.A. Uncertainty in the quantitative assessment of the risk of accidents at oil and gas facilities. M: “Improving the reliability and safety of gas industry facilities”, No2 (34), 2018, pp. 125-135.

[8] Methodology for assessing the technical condition of the main technological equipment and transmission lines of power stations and electrical networks. https//meganorm.ru>Index2. Approved by the Ministry of Energy of the Russian Federation in 2017. Appendix to Order No. 676. Year of update 2021 30 s.

[9] Guidelines for calculating the probability of failure of a functional unit and a unit of main technological equipment and assessing the consequences of such a failure https//meganorm.ru.>Index2. Ministry of Energy of the Russian Federation, 2019 Appendix to Order No. 123, 35 p.

[10] V Scientific-practical conference "Control of the technical condition of electric power facilities"./Electricity. Transfer and distribution. – 2018

[11] VI Scientific-practical conference "Control of the technical condition of electric power facilities"./Electricity. Transfer and distribution. – 2019

[12] Fedorets A.G. Application of modern risk management methodology in safety and labor protection management systems. / Safety and labor protection. - 2018, No.1 p.1-18.

[13] Antonenko I.N. Analysis of the risk-oriented approach to the management of physical assets. M. "Industrial Energy" No.10, 2020, pp. 57-60.

[14] Farkhadzadeh E.M., Muradaliyev A.Z., Abdullayeva S.A., Nazarov A.A. Automated analysis of the service life of overhead transmission lines of electric power systems. Minsk, Energy. Izv. higher textbook institutions and energy. associations of the CIS. Energy Problems Vol. 64, No. 5, 2021, pp. 435-445. DOI: 10.21122/1029-7448-2021-64-5-435-445

[15] Farhadzadeh E.M., Muradaliyev A.Z., Abdullayeva S.A., Nazarov A.A. Assessment of the technical condition of overhead high-voltage power lines at the stage of their aging. M:, Reliability and safety of energy. Volume 14, No 2, 2021, pp. 100-107. DOI: 10.24223/1999-5555-2021-14-2-100-107

[16] Farkhadzadeh E.M., Muradaliyev A.Z., Abdullayeva S.A., Nazarov A.A. Quantitative assessment of the operational reliability of overhead power lines "M: Electric stations, No.2, 2021, pp. 28-34. DOI: 10.34831/EP.2021.1081.8.004

[17] Farhadzadeh E.M., Muradaliyev A.Z., Abdullayeva S.A. Estimation, comparison and ranking of operational reliability indicators of overhead transmission lines of electric power systems. Journal: Reliability: Theory&applications. RT&A (Vol.4 No (65)) 2021, Desember, USA, p.186-197. DOI: 10.24412/1932-2321-2021-465-186-196

[18] Farhadzadeh E.M., Muradaliyev A.Z., Abdullayeva S.A. Quantitative analysis of operational reliability of overhead transmission lines. M:. Operational management in the electric power industry, No.5, 2021, p.16-24
[19] Farhadzadeh E.M., Muradaliyev A.Z., Abdullayeva S.A. Improving the operational management of the efficiency of distribution networks. M:, Industrial Energy No.12, 2021, pp. 16-23. DOI: 10.34831/EP.2021.77.85.002