POLITYKA ENERGETYCZNA – ENERGY POLICY JOURNAL

2023 ✦ Volume 26 ✦ Issue 1 ✦ 43–58

DOI: 10.33223/epj/158467

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Research and modeling of the reliability of overhead lines of 6 to 10 kV with consideration of the influence of the external environment

Abstract: The relevance of this study is due to the fact that the presented object of scientific work, namely 6–10 kV overhead lines, plays an important role in the process of providing electrical energy to consumers of the oil industry. The aim of the work is a detailed analysis of the reliability of overhead lines which are exploited in the difficult natural and climatic conditions of the Caspian region and Mangyshlak and the introduction of effective modeling tools for overhead lines. The methods used include the analytical method, theoretical method, logical analysis method, functional method,

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statistical method, synthesis method and others. In the course of the study, the natural and climatic conditions of the Atyrau region and their differences were noted and the reliability of the power supply systems was also analyzed. The most damaged elements of industrial power supply systems and their part of failures were identified in comparison with other elements of the power supply system. It was determined that the electrical power sector plays a crucial role in the oil and gas sector by determining the solution of the production tasks of all departments which have a significant impact on the formation of economic indicators. The practical value of the revealed results is that they will help to highlight the problems of operational reliability of the 6–10 kV overhead lines, considering the various natural and climatic factors, which in turn will help to change the power supply scheme and increase the resistance to external influences.

Keywords: exploitation, ensuring, power system, refuse, meteorological factors

Introduction

Overhead lines of 6–10 kV are one of the important elements of external and internal power supply of production facilities that ensure the transmission of electrical energy. The problem of the reliability of the 6–10 kV overhead lines is related to the issues of determining and optimizing the reliability indicators at the stages of design, operation and development. The implementation of this task will provide an opportunity to develop effective methods for improving and calculating the reliability of power-supply systems.

According to Dzhumamukhambetov et al. (2016), the 6–10 kV overhead lines are the most damaged in the oil and gas fields. This is due to the rapid deterioration of the object's characteristics during operation under the influence of natural and climatic conditions and insufficient control over the state of elements of the industrial power-supply systems. In addition, the peculiarities of the consumers of electric energy of oil and gas fields are the dispersal over a large area, as well as power supply from extended and branched 6–35 kV overhead lines and work in complex natural and climatic influences. It follows that the study and analysis of characteristics of the overhead lines is an important link in calculating their reliability (Bondarenko and Galich 2015; Bondarenko et al. 2018).

According to Yang et al. (2022), the problems of managing production assets occupy a significant place in modern conditions in the operation and development of electrical complexes of electrical networks and power-supply systems. The main problems arise in assessing the current and remaining technical resources of electrical equipment, the stages of its operation, deactivation and replacement, predicting the life cycles of mechanism based on diagnostics and the evaluation of object functioning. In electrical networks and power-supply systems, the moral and physical deterioration of objects is currently characteristic. They often fundamentally differ not only in their technical conditions but also in the principle of operation, which requires careful technical control and technological support for joint performance.

Considering weather models when developing the models' reliability will enable the obtaining of a more realistic assessment of reliability of electrical networks and power-supply systems. According to Zhu et al. (2016), the 10 kV overhead power lines are more susceptible to the influence of many external factors, such as natural and climatic and anthropogenic factors that reduce the reliability of overhead lines and lead to their failure and, as a result, to the corresponding undersupply of electric energy to consumers. The main causes of failures in power lines are damage to their structural components, such as high-voltage insulators, dischargers and other linear fittings, as well as possible insulation flashover. The problem of increasing the reliability of power supply at the present stage of development of industrial production has become relevant since the technical progress of any industry is largely determined by reliability.

Oliveira-Pinto et al. (2019) note that power supply disturbances in the form of voltage dips in load nodes due to a short circuit are inevitable during the operation of overhead lines of external power-supply systems. This problem of power supply is aggravated due to the development of automated production. According to Li et al. (2022), the problems of power-supply-system reliability are difficult to solve due to their incomplete knowledge – they predetermine the need for further research and the development of methods for improving and calculating the reliability of power-supply systems. An integral part of the overall task of optimizing the development of power-supply systems is the technical and economic aspect of reliability. The calculated reliability should be economically feasible; the reliability factor should be included as one of the components of calculating the problem of optimizing the development of power-supply systems. When calculating the power supply system's reliability, a zone of stable damage is first identified and it is then considered as a set of such zones.

The aim of the work is a detailed analysis of the reliability of overhead lines, which are exploited in difficult natural and climatic conditions of the Caspian region and Mangyshlak and the introduction of effective tools for modeling overhead lines.

1. Materials and methods

Scientific research in the field of studying the problems of modeling overhead lines 6–10 kV with consideration for natural and climatic factors has been performed using methods that reveal the theoretical and practical content of the object of study. Applying the theoretical method, the concept of "overhead lines 6–10 kV" was revealed and the characteristic features, principles of operation of this mechanism and its problems were identified. The logical analysis method helped to highlight the features of modeling problems of 6–10 kV overhead lines in use at oil and gas facilities with consideration to the external environment. Using the statistical method, the main indicators were considered. This helped to analyze the number of failures that occur on 6–10 kV overhead lines, the implementation of modeling and the improvement of the reliability of power -supply systems in the oil and gas sector, the development of oil and gas production and development prospects in these industries, due to which, the process of efficiency in the development of this mechanism and its prospects have been determined. Using the functional method, the role and essence of the overhead lines at oil and gas facilities were analyzed as were their advantages and disadvantages as well as the impacts on the national economy and the country's ecology.

The structural-functional method helped in analyzing trends, factors and models of power -supply elements. Due to this, it has been revealed that in order to solve problems associated with modeling overhead lines, improving the maintenance of power-supply elements, reducing failures and determining and optimizing the reliability indicators at the design stages in oil and gas industries, an increase in government funding, a new approach to the management system of power-supply elements and increases in the level and quality of technologies in this industry will be required. The deduction method helped to reveal the concept of "6–10 kV overhead lines" through the prism of highlighting its characteristic features for a full analysis of the operation and problems of this mechanism. Using the synthesis method, the obtained results of theoretical and practical nature have been summarized to identify recommendations that contribute to solving problems and increasing the efficiency and reliability in modeling power-supply elements, namely the 6–10 kV overhead lines in oil and gas production in the energy sector of the country.

Thus, this study was performed in several stages. The first stage consisted in revealing the theoretical aspect of work, namely in defining the concept of "6–10 kV overhead lines", analyzing its characteristic features and operating principles of this mechanism, especially in the energy, environmental and economic sectors of the country. The second stage was based on the study of the mechanisms and problems of the Kazakh approach to the elements of power supply, their advantages and disadvantages, the functioning of oil and gas production and the analysis of activities of this segment in the country's energy sector. An important step of this stage was the analysis of the reliability of overhead lines and other elements of power supply at oil and gas facilities, the development of new approaches and technologies for modeling the 6–10 kV overhead lines, ways to reduce failures and short circuits in production and the impact on the national economy and the ecology of the country in order to determine indicators of development efficiency and the prospects of this mechanism. The third stage, based on the identified results of theoretical and practical content, provided an opportunity to identify problems and recommendations in the operation of the mechanism of power-supply elements and more specifically, the 6–10 kV overhead lines, which will contribute to the solution of these issues and the development of oil and gas production.

2. Results

To ensure the livelihoods of the country's population, development is necessary in all areas, including in the energy sector. An important issue that needs to be solved today is problems in modeling the 6–10 kV overhead lines and the reliability of the system component equipment, the efficiency of oil and gas facilities and their mechanisms, and the development of the energy, economic and environmental sectors of the country. The scientists and engineers of many research and design organizations are engaged in the development of scientific methods for solving problems of reliability in the electrical power industry. The tasks of effective management of the regimes of external power-supply systems and their problems in the oil industry are becoming increasingly relevant and they are of practical value. In this complex process, the revision of problems of modeling the reliability of the 6–10 kV overhead lines and their solution is of particular importance, since the development of the energy sector in the country is one of the most urgent problems of our time. In general, the problem of optimizing the reliability of power-supply systems has not been fully resolved. Currently, methods for determining reliability are most widely used and developed. The condition for the reliable functioning of power-supply systems is to ensure the stable operation of both the system in general and some of its elements.

The oil and gas industry in the country has a longer practice of implementation than other industries for the energy resources extraction. The problem of optimizing and improving the reliability of power-supply systems for oil and gas facilities remains open and unresolved, this is due to insufficient attention being paid to this issue. The solution to these issues requires the introduction of effective tools for modeling the reliability of elements of power supply systems. The emergence of affordable digital complexes for real-time reliability modeling will make it possible to quickly bring the process of solving these problems to a new level in terms of the speed of the solution and the quality of the results obtained. Power-supply systems require improvement at the energy, environmental and economic levels of development. The absence of a minimum base for a qualitative study of the reliability modeling of power-supply systems used in the oil and gas facilities indicates the need to develop new methods that will allow solving the issues relating to the designing and managing of this mechanism: "The main condition for obtaining an adequate picture in modeling is the availability of a knowledge base about the models of electrical network components that most accurately reflect parameters of real devices. The set of models of elements contained in the database of studied models necessarily includes all types of equipment used in the power systems" (Gulkov and Turysheva 2021).

For the accurate modeling and design of elements of the power-supply system, it is necessary to consider the natural and climatic conditions of the region because most of the failures and damages occur due to this. Currently, the problems of elements' reliability of the power supply systems are very important. At the present time, there is some experience in improving the reliability of the power supply systems in various ways. It is very difficult to calculate transient processes in all modes of operation of this mechanism, and moreover, to find the most vulnerable places in it and predict possible problems. The task is complicated by the fact that the considered objects of distributed generation in the country often consist of imported equipment with new dynamic characteristics and management capabilities. The results of analysis of the modern study of problems of the Kazakh oil and gas sector revealed the following conflicts: between the modern requirements of society in efficient and cheap energy and the insufficiently adjusted development of its supply and sufficient assurance of reliability of the overhead lines; between new technologies for designing and modeling the reliability of the 6–10 kV overhead lines and the lack of adequate means of organizing this process. It also highlighted conflicts between the importance of training qualified personnel to ensure the trouble-free operation of power-supply systems and inconsistency of the organization of workplaces with ergonomic requirements and an insufficient number of high-quality computer training programs for the effective implementation of this process.

At the present stage, in order to ensure and maintain a given level of reliability of power -supply systems, the further development and improvement of methods for researching and optimizing the reliability of elements of power-supply systems is needed. The use of innovative methods for the reliability of power-supply systems will make it possible to see the complex transitions of processes at the connection points of energy flows of the centralized power-supply networks and small-scale generation networks in order to consider the quality of generated energy in terms of voltage levels and harmonic composition. It is necessary to develop and create conditions for the advanced training of workers who are engaged in the maintenance of power-supply systems and their elements and to develop effective methods to improve the reliability of this object. Modeling the reliability of the elements of power-supply systems, with consideration to the influence of external environment, enables the obtaining of an objective assessment of reliability. Considering the influence of the external environment makes it possible to identify the features of functioning of the power-supply system and, in particular, to determine the requirements for the mechanism elements that are necessary for the reliable operation of the network with distributed generation. To achieve some progress, special programs are needed that consider the natural and climatic conditions to promote the quality operation of power-supply systems at oil and gas facilities and the energy sector in the country. When designing power-supply systems for oil and gas regions, the specific features of technological processes and natural and climatic conditions are not sufficiently considered. The ability to connect external equipment during the modeling process is currently one of the main tasks. Reliability rationing in power-supply systems should be subject to load nodes, as having connection of outgoing lines and supply groups of consumers, which can be of categories I and II (Gunger and Lavrov 2008).

The reliability of power-supply systems in the Atyrau oil- and gas-producing region of Kazakhstan has been studied. A distinctive feature of the region's climate is aridity. The average number of days with a relative air humidity of 30% is 22–30. Summer is hot and long, with a possible air temperature of +43 to +45°C and soil surface up to +60°C. The annual number of sunshine hours is 2,600–2,700, the average number of thundery days per year is eight to ten. The average annual number of days with precipitation is two to six, the average annual rainfall of a heavy rain nature is up to 14 mm. Winter is unstable, warm, with soil freezing up to 0.5–1 m. The number of days with a temperature of –20°C is 5–10. Blizzards are rare, happening only two or three days per year. The maximum wind speed reaches 28 m/s (the third wind region according to the Rules of Electrical Facilities Maintenance), in terms of the thickness of the ice slick – the second region (10 mm), in terms of the degree of the atmosphere contamination – the fifth one. According to the nature of vegetation cover, the surveyed region belongs to the desert zone. The soil surface is solonchak powder, which is easily blown away at a wind speed of 4–8 m/s, which creates dust storms from eighteen to fifty days per year, causing the deposition of solonchak dust on the elements of power supply systems (Toshkhodzhaeva and Khodzhiev 2020).

The above-mentioned makes it possible to conduct research in real operating conditions of power supply systems and understand what kind of technological approach is needed for this object in order to give a more accurate assessment of the elements' reliability of the power-supply system. The problem of restructuring and transformation in the power-supply systems in oil and gas industries and the energy sector as a whole is relevant and requires consideration. Reliability of the 6–10 kV overhead lines are the most damaged and the largest in number in the composition of elements of the power-supply systems. In 2010–2020, 1,840 km of overhead lines were investigated. To determine the impact of natural and climatic conditions on the damageability of the overhead lines, all emergency cases of damage were divided into failures of the first and second kind. Reasons for damage related to the peculiarities of natural and climatic conditions included: rain; snowfall; sharp fluctuations in temperature; wind and dust storms; rain with wind; rain with a thunderstorm; ice slick with wind; contamination of the insulation with subsequent moistening.

Damage due to reasons not related to natural and climatic conditions, i.e. the design flaws, installation, repair, operation, extraneous influences. This separation makes it possible to qualitatively assess the impact of natural and climatic conditions on the reliability of power-supply systems. As a result, if considering the natural and climatic conditions, it is possible to extend the operation of the power-supply systems and reduce breakdowns at this object. In this regard, the question arises of providing special programs that consider the external environment for each district and unlimited conditions in training and raising the qualifications of working personnel to ensure the reliability of power-supply systems. The classification of failures by damaged nodes and causes is presented in Table 1. According to these tables, it can be seen that the most common damage is wire breaks due to strong winds and dust storms and mismatch of the wire brand with the natural and climatic conditions.

Damage of the overhead lines associated with environmental conditions, namely the natural and climatic conditions, is 50.5%. The main factors are pollution followed by moisture, as well as wind and dust storms. It becomes possible to immediately see the reaction of the elements of the power-supply system at any point when exposed to the external environment. Solutions to the damage can be found in increased funding specifically for the country's energy sector, especially the oil and gas industry, and the development of technologies that aim at progressive changes in the energy sector in general, which will give preference to the Kazakh energy production. These are the main indicators: the failure rate parameter $\omega(t)$, and recovery time tb. An analysis of change in $\omega(t)$ over years made it possible to understand its stable value; therefore, an exponential distribution law $\omega(t)$ was adopted, which is consistent with the nature of failures (the level of failure-free operation of the overhead lines is mainly determined by dynamic effects). Their comparison with the calculated value for the studied area shows that damage to overhead lines in this area is above average coefficient.

Time is spent only on compiling adequate models of elements of the power-supply systems, the accuracy of which will depend on the accuracy of results. In the energy sector, new require-

Table 1. Classification of failures by damaged nodes

Tabela 1. Klasyfikacja awarii ze względu na uszkodzone węzły

Damage	Number/percentage
Crossing of wires	24/20.5
Insulator damage	20/17
Damage of supporting structure	24/20.5
Wire breaks	32/27.4
Failures	16/13.7
Other and unidentified	1/0.9
Damage	Number/percentage
Natural and climatic influences	54/46.2
Design and technological defects	13/11.1
Installation and repair defects	5/4.3
Unsatisfactory operation	15/12.8
Outside influences	18/15.4
Other and unidentified	12/10.2

ments are emerging in the form of specific strategic goals for oil and gas production, in which problem solving and increasing the efficiency of the elements of the power-supply system play a special role (Celentano et al. 2021). The histogram constructed according to the actual data reveals an increase in damage in the spring period, which is characterized by strong winds and dust storms. As a result, deposits of saline dust appear on the insulators, and subsequent moisture causes insulator flashovers or their breakdown (Fig. 1).

The histogram allows approximating the distribution of the overhead-line failures for reasons related to the natural and climatic conditions for more accurate troubleshooting. The organization of the correct compilation of a model for predicting the reliability of the power-supply systems is one of the main problems in this energy field. Oil and gas production is an important component of the country's energy development, the basis for independence from energy imports, the preservation and provision of cheaper Kazakh electricity, and an important prerequisite for the energy industry to become the country's leading one. The energy system is characterized by a high degree of moral and physical deterioration and a low level of reliability. Therefore, the issue of improving the reliability of the power -supply systems is highly relevant. In many countries, work is currently underway to create intelligent electrical networks, which are a set of technical tools that automatically identify the weak and dangerous sections of network and then change the network scheme to prevent accidents and improve reliability. The assessment of reliability of the system elements is the criterion according to which the control is performed in the intelligent systems. The issues of reliability of the power supply, analysis of the reasons for its violation and the forecast of indicators remain relevant at all stages of the power-system operation. From the statistics of

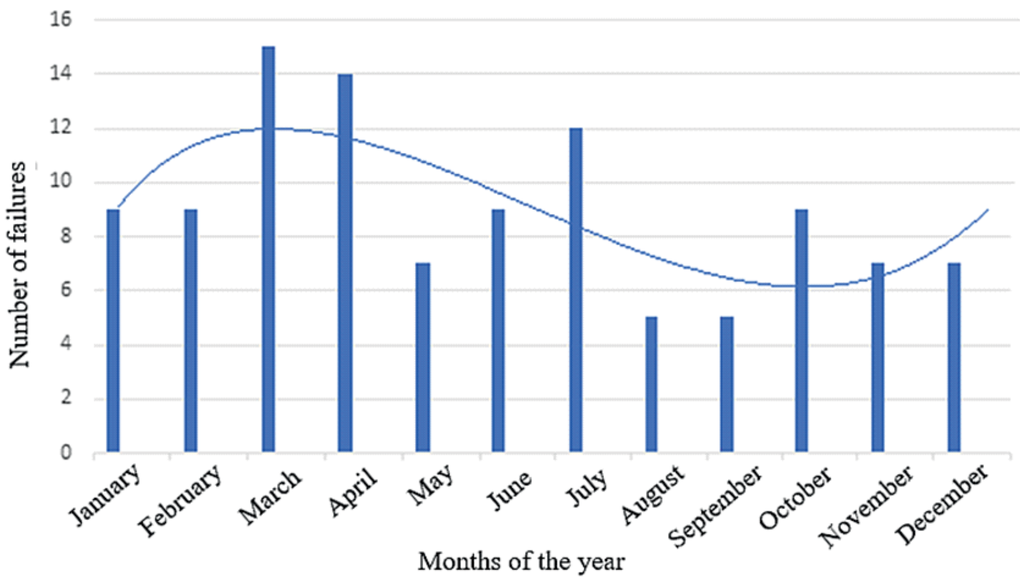

Fig. 1. Histogram of distribution of the overhead line failure

Rys. 1. Histogram rozkładu uszkodzeń linii napowietrznej

reliability of the power-supply systems, it can be understood that the overhead lines are the most unreliable elements of the power systems.

3. Discussion

The quality of power supply in oil and gas production and its efficiency is one of the most relevant issues of modern energy in Kazakhstan, and some problems require immediate solutions. Studies conducted over a ten-year period of operation of the reliability of the most damaged elements of power-supply systems, namely the 6–10 kV overhead lines, made it possible to more qualitatively assess the influence of the external environment on failures and identify the main causes and damage to overhead-line elements. The following characteristics exist for consumers of the electrical energy of oil and gas facilities: location over a vast territory; power supply of the extended and branched overhead lines 6–10 kV; operation in a complex environment. It should be noted that according to modern Kazakh scientists and international experts in the development of the design and reliability modeling of the 6–10 kV overhead lines, the country has made a powerful step forwards over the past few years. In a comparison of the main reliability indicators, the failure-rate parameter and the recovery time with the data from literary sources showed an excess of the calculated indicators by 20–30%, which confirms the hypothesis that when determining the reliability indicators, the real operating conditions of the power-supply systems should be considered (Zhang et al. 2021).

When calculating the reliability of the power-supply systems and elements in oil and gas production with consideration to natural and climatic conditions, models should adequately describe the process and be simple and feasible. The approximation of the distribution of failures is in strong agreement with the data of the Hydrometeorological Center and makes it possible to obtain a model for predicting reliability in the development of maintenance and repair systems. The professionalism of the staff and timely equipment diagnostics play the first role in ensuring the efficiency of power-supply systems and in the oil and gas production of environmentally friendly electricity. This can be solved using special advanced training programs. Therefore, the advanced training of working personnel is a priority in the training of specialists, which contributes to the professional development of communication workers and activates their regulatory framework for the high-quality maintenance of mechanisms. An analysis of factors that determine the damage rate of the overhead lines and other elements revealed the most significant natural and climatic factors, which include dust storms and insulation pollution. The advantage of such an analysis is that as a result, it will be possible to design elements of the power-supply systems that are more resistant to such weather conditions, based on information about the damage of the element in difficult weather conditions.

In the current state and level of complexity, a huge number of failures and short circuits of the power-supply systems require employees to constantly comprehend modern problems, to be dynamic and flexible in their solution, and to adjust to the situation during the production process. Analysis of change in the failure-rate parameter over the years made it possible to accept the hypothesis of an exponential distribution of failures, which corresponds to the real physical process of the occurrence of failures that are of a sudden nature, due to the influence of the external environment or poor service. Since stable failures are significant in the power-supply systems, and especially in the 6–10 kV overhead lines, the full repayment is taken as the calculated state of the node. Significant improvement in communication and the introduction of new technologies to improve the operation of power-supply systems to prevent a large number of failures has become one of the challenges in recent years. The adoption of exponential law of distribution of the failure-flow parameter and recovery time is confirmed by the fact that the law is typical for complex systems consisting of heterogeneous elements with different values of the failure-flow parameter and it allows use of the widely developed apparatus of the queuing theory, and in particular, the apparatus of homogeneous Markov processes. The following reliability characteristics are presented:

- uninterrupted characteristics – failure rate parameter;
- maintainability characteristics – recovery time or the intensity of recovery;
- characteristics of natural and climatic conditions in which the power-supply system operates – the duration of periods of normal and unfavorable weather.

According to the results of recent studies by Ivanov (2022), when compiling equations, it has been decided that other elements included in the consecutive chain have insignificant reliability indicators compared to the 6–10 kV overhead lines. To solve the problems associated with modeling the reliability of overhead lines, it is not sufficient to single out and compare the individual elements. The entire mechanism of power-supply systems was analyzed, and as a result, it was decided that in most cases, faults and failures spread simultaneously in many parts of this mechanism. It is necessary to pay attention to the state of these elements and figure out why the reliability indicators are lower, this will help highlight the problem and find an effective solution. It is important to note that reliability studies can never predict or prevent failures or accidents. Here, one should strive to obtain results that could be interpreted and, with their help, understand the essence of the problem. Damage, maintenance and repairs are not considered.

Referring to the definition of Lansberg et al. (2022), the random factors and external loads upon which the quantitative indicators of the reliability of 6–10 kV overhead lines significantly depend include: atmospheric overvoltages; ice formations on the wires; changes in ambient temperatures; the intensity of thunderstorm activity; wire vibrations; design defects; installation and operation of the overhead lines 6–10 kV; their service life. This indicates that when designing and modeling the reliability of power supply systems, it is necessary to consider all the factors that affect this in order to increase the elements' durability. In addition, the fact that the level of staff knowledge and the quality of service of this mechanism plays a huge role in the smooth operation of elements of the power supply systems was considered (Sarmiento et al. 2021). If to contribute to improving the skills of workers in this area and better maintain the power-supply system, it is possible to avoid accidents and extend its service life. Since overhead lines play a huge role in the power-supply system and because they are most vulnerable to a variety of factors, there is a need to improve reliability of the overhead lines. The researcher Kozlov (2022) determined the malfunctions and their causes of the 6–10 kV overhead lines as well as the number of failures:

1. The reason is reinforcement corrosion, damage, pollution, moisture, insulator defects, atmospheric and switching overvoltages, which in turn leads to breakdowns or flashovers of insulators; the number of failures is 13.5%.

2. In this case, the causes are mechanical effects of external factors, for example, vibrations, galloping, ice-frost formations on wires, supporting structure and power-supply network, which entails phase-to-phase short circuits, ground faults and wire breaks; the number of failures is 44%.

It is very important to consider the importance of the timely study of these faults and causes for the further prospective development of the reliability of overhead lines. For the efficient operation of the elements of power-supply systems, it is necessary to correctly select materials from which they are made as well as their characteristics. It is necessary to monitor the quality of the manufacture of materials and modernize the technologies for their manufacture in order to extend the operation of elements of the power-supply systems. Gu et al. (2021) determined that cross-linked polyethylene is the most common insulating material for overhead lines. It is a modified ethylene polymerization product that has a cross-linked molecular structure with additional bonds resulting in increased strength, thermal and wear resistance, low hygroscopicity, resistance to corrosion and violent temperature changes, and good dielectric properties. This polymer was analyzed and investigated more precisely. It has been found that this polymer has many disadvantages, such as instability to long-term exposure to ultraviolet radiation and this leads to destruction, which does not allow it to be used in the open air. The problems of this material require a solution for the efficient operation of overhead lines.

Kockel et al. (2022) showed in their work that the solution of this problem is the addition of additional inclusions and antioxidants to the composition of the cross-linked polyethylene structure; this will preserve its mechanical properties and allow obtaining a material that is resistant to sunlight. It was identified and decided that this would limit the absorption of light energy by the surface layers and could prolong the operation of overhead lines and increase sustainability. Due to insufficient lightning protection of the power-supply systems, surges can occur and the overvoltage amplitude increases by several million volts. As noted by Okorn et al. (2021), the 6–10 kV overhead lines include reinforced and metal supports, as a result, the use of long-spark lightning arresters is justified (Bishnoi and Chaturvedi 2022; Sakib et al. 2021). They have a simple design and are reliable and economically beneficial. The probability of establishing a power arc after a lightning flash of insulation significantly depends on the average strength of the electric field formed on the channel of overlapping the line voltage by the worker. In order to continue operation of the power-supply systems at oil and gas facilities, it is necessary to increase reliability. In the case of insufficient attention to this problem, the number of failures and breakdowns will increase, and the efficiency of the oil and gas industry will decrease (Zhao et al. 2021; Misuri and Cozzani 2021). It is necessary to increase funding and improve the skills of workers to begin the introduction of new technologies in order to improve the design and modeling of the reliability of the power-supply systems.

Conclusions

The main problems of 6–10 kV overhead lines in oil and gas facilities are the mediocre training of staff, problems of correct modeling and design of the reliability of power-supply systems and insufficient consideration being paid to natural and climatic conditions; these problems are and will continue to be relevant, and they need further research. The objective of this study was fulfilled, namely the problems of improving the reliability of power supply at the present stage of development of the industrial production were identified and highlighted, and ways to solve them were proposed. It was possible to fulfill all the tasks set for the study, namely to highlight the problems of operating the 6–10 kV overhead lines and analyze them more accurately. Methods for solving these issues were also found and proposed for the more efficient operation of this mechanism. The failure rate of the 6–10 kV overhead lines in the Atyrau oil and gas region depends mainly on weather conditions and increases in unfavorable weather, which makes it possible to present a two-state weather model. When analyzing the reliability of overhead lines of 6–10 kV power-supply systems, their operation is considered as a random process, which can be strictly described by a discrete Markov process.

The use of the apparatus of random Markov processes makes it possible to obtain more realistic results in assessing the reliability of power-supply systems. The principle considered in the article for building a reliability model that considers the influence of the external environment and possible assumptions, enables the obtaining of a comprehensive and more accurate assessment of the reliability of power supply systems operated under the influence of meteorological factors. Reliability indicators should be determined with consideration to the specific operating conditions of the power-supply systems. The resulting mathematical model for predicting reliability can be used to optimize the systems and schedules for maintenance, repairs and preventive tests. The analyzed modern approaches to the problems of the Kazakh oil and gas segment will try to respond to the modern needs of the country's electricity consumers in a safe and stable energy system. Further research will be aimed at identifying the problems and prospects for the introduction of new technologies for staff training for better maintenance of the elements of power-supply systems in the oil and gas industries.

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Badania i modelowanie niezawodności linii napowietrznych od 6 do 10 kV z uwzględnieniem wpływu środowiska zewnętrznego

Streszczenie

Znaczenie niniejszej pracy wynika z faktu, że prezentowany w artykule obiekt: linie napowietrzne 6–10 kV odgrywają ważną rolę w procesie dostarczania energii elektrycznej odbiorcom przemysłu naftowego. Celem pracy jest szczegółowa analiza niezawodności linii napowietrznych eksploatowanych w trudnych warunkach przyrodniczo-klimatycznych regionu Morza Kaspijskiego i Mangyszłaku oraz wprowadzenie efektywnych narzędzi do modelowania linii napowietrznych. Stosowane metody obejmują metodę analityczną, metodę teoretyczną, metodę analizy logicznej, metodę funkcjonalną, metodę statystyczną, metodę syntezy i inne. W trakcie badań odnotowano warunki przyrodnicze i klimatyczne regionu Atyrau oraz ich różnice, a także przeanalizowano niezawodność systemów zasilania. Zidentyfikowano najbardziej uszkodzone elementy przemysłowych systemów zasilania oraz ich część awarii w porównaniu z innymi elementami systemu zasilania. Stwierdzono, że sektor elektroenergetyczny odgrywa kluczową rolę w sektorze naftowo-gazowym, determinując rozwiązanie zadań produkcyjnych wszystkich działów, które mają istotny wpływ na kształtowanie się wskaźników ekonomicznych. Praktyczną wartością uzyskanych wyników jest to, że pomogą one uwidocznić problemy niezawodności pracy linii napowietrznych 6–10 kV z uwzględnieniem różnych czynników przyrodniczych i klimatycznych, co z kolei przyczyni się do zmiany schematu zasilania i zwiększenia odporności na wpływy zewnętrzne.

Słowa kluczowe: eksploatacja, zapewnienie, system elektroenergetyczny, odpady, czynniki meteorologiczne