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Electric networks of energy-intensive enterprises: the protection of 6–10 kV lines and access ways from overvoltage

ABSTRACT: The purpose of this research work is to study the issues of the protection of 6–10 kV lines and access ways overvoltage in the electrical networks of modern enterprises of high-energy intensity, as well as the search for real technical opportunities to improve the protection of power

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lines directly in conditions of their operation. The methodology of this scientific research is based on a combination of methods of system analysis of the principles of the functioning of electric networks of energy-intensive enterprises with an analytical study of the fundamental aspects of ensuring the protection of 6 to 10 kV lines and access ways from overvoltage. The results of the conducted scientific research indicate the relevance of the issues of ensuring the protection of lines and electrical networks of energy-intensive enterprises from overvoltage and the need to develop special technical devices to ensure the proper level of such protection in real conditions. The results and conclusions of this research work are of significant importance for developers and designers of electric networks of enterprises with increased energy capacity, as well as for employees of various power supply systems who, by their occupation, face the tasks of servicing electric networks, which include lines and access ways with specified operating voltage parameters and ensuring the proper level of safety and practical use of these electric networks of energy-intensive enterprises.

KEYWORDS: electric networks, energy-intensive enterprises, overvoltage, power lines, protection of electric networks, energy security

Introduction

The most important elements of modern power supply systems are 6–10 kV power distribution grids since their long stable functioning is the key to the reliable provision of end consumers with generated electric energy (Bayliss and Hardy 2021). According to official statistical information, about 80–90% of malfunctions occur in such networks due to single-phase earth faults (SPEF), which in most cases are caused by emerging overvoltage (OV). Single-phase short circuits mainly occur in places of insulation defects of cable lines (CL) and substation equipment due to the gradual obsolescence of insulation, improper compliance with manufacturing technologies of insulation structures at manufacturing plants, norms, and instructions during installation and operation of equipment, as well as mechanical damage, which cause only a partial decrease in the electrical strength of insulating materials (Yang et al. 2004). Internal overvoltage most often occurs during transients from an intermittent arc and the danger for the insulation of electrical installations lies in the duration and breadth of coverage of the network that has an electrical connection to the site of damage.

Factors related to manufacturing technology and operating conditions have a significant impact on the ageing processes of insulating materials. It is customary to attribute some design and installation defects to factors of a technological nature as well as to the use of materials that do not meet operational requirements. Operational factors, such as various overloads, the presence of short-circuit currents in the circuit as well as arc and thunderstorm atmospheric overvoltage. It is the presence of this kind of overload that causes the occurrence of defects that subsequently develop in the main mode of operation (Fuchs and Masoum 2019).

Similar problems are also characteristic of electrical networks equipped with weakened insulation, which is mainly found on cable lines with long periods of operation, the total number

of which is steadily increasing. In some situations, substations are used in practice, in which the frequency of single-phase earth faults reaches five or more times a month per bus section. At the same time, the problem is most acute due to the practical application of an outdated method for determining a damaged feeder by alternating disconnections and the switching on of outgoing lines with a significantly overestimated number of commutations. These circumstances and problems are also relevant for modern networks containing XLPE (with insulation made of cross-linked polyethylene).

The features of XLPE are that all the switching occurs in working and emergency situations within the network in various situations, both working and emergency. As a rule, this results in additional overvoltage, which leads to problems in the depth of the insulation layer associated with the occurrence of side conduction bridges between the conductive cores and the grounded shell – the accumulation of various defects in the insulation layer (Su and Huang 2018). This explains the adoption of significantly lower levels of test voltages for XLPE than for traditional insulation coatings. Their connection to substation sections is also not recommended, since in this case, it is often necessary to deal with outdated insulation. Therefore, overvoltage that periodically occurs in the networks of energy-intensive enterprises leads to problems in electrical networks, mainly SPEF and other negative manifestations (Gabbar 2016).

Modern electrical networks that are morally and physically obsolete by now should be characterized in strict accordance with the accepted classification as electrical networks with thinned insulation. This assessment is confirmed by the analysis of damage statistics in 6–10 kV power grids of AO “AZHK” Almaty.

To avoid overvoltage damage to electrical networks, it is recommended to develop and consistently implement measures aimed at ensuring an adequate level of network security. Consistent compliance with all safety standards contributes to the safety of electrical networks and their long uninterrupted operation. The purpose of this research work is to study the issues of protection of 6–10 kV lines and access ways overvoltage in electric networks of energy-intensive enterprise, as well as to search for real technical opportunities to improve the protection of power lines directly in the conditions of their operation.

1. Materials and methods

The methodology of this research work is based on a combination of methods of system analysis of the principles of the functioning of electric networks of energy-intensive enterprises with an analytical study of the fundamental aspects of ensuring the protection of lines and access ways with voltage parameters from 6 to 19 kV from overvoltage in the atmosphere. The combination of systematic and analytical research makes it possible to achieve an optimal quality of scientific research in the context of the objectivity of reflecting the issues of diagnostics of electrical networks and the formation of the principles of their protection from atmospheric overvoltage.

The theoretical basis of this research is numerous scientific studies in the field of electronics and electrical engineering, covering issues of the protection of 6–10 kV lines and access ways from atmospheric overvoltage. Domestic and foreign researchers of issues submitted for consideration in the subject of this scientific work or related to them performed these research studies. To facilitate the perception of the information provided and to create an optimal and high-quality picture of scientific research, all the achievements of foreign authors, cited in the order of citation in this scientific work, have been translated into Russian. Thus, the theoretical basis of this research was selected in strict accordance with the declared subject of scientific research and contributes to its optimal disclosure within the framework of the tasks of scientific research. This scientific study assumes compliance with a strict sequence of work stages, including three main stages.

In the first stage of this scientific research, a theoretical analysis is carried out of various aspects of the protection of lines and access ways of 6–10 kV electric networks of energy-intensive enterprises from atmospheric overvoltage. The presented analysis forms the foundation of this scientific research and contributes to the search for optimal opportunities to disclose its topics to obtain the most objective results and conclusions based on them. In addition, a systematic analysis of electric networks of energy-intensive enterprises was carried out at this stage of the research work, based on the theoretical analysis, which was necessary for the subsequent structural development of the questions included in the subject of the study.

At the second stage of this research, an analytical study was carried out on the fundamental aspects of ensuring the protection of 6 to 19 kV lines and access ways from overvoltage. At the same time, preliminary conclusions of the scientific research were obtained at this stage, as well as their analytical comparison with the results of other researchers on the issues submitted for consideration, which generally contributes to the most objective and qualitative coverage of the issues submitted for consideration.

At the final stage of the presented scientific research, based on the results obtained, conclusions were formulated, summing up the entire complex of works performed within the framework of this scientific research. Thus, the issues of ensuring the proper level of protection of 6–10 kV lines and access ways from atmospheric overvoltage are considered in the conditions of their use in the electric networks of energy-intensive enterprises and in strict accordance with modern energy security requirements taking into account the real possibility of the practical application of the results obtained in this research work in matters of ensuring the safety of electric networks of energy-intensive enterprises.

2. Results

When conducting an analytical study of the scientific information available within the framework of the stated topic, it can be concluded that the damage rate of voltage-measuring trans-

formers (VMT) is 7–10% of all functioning VMTs in existing power grids, and the average operating time does not exceed 3–5 years. These factors determine the relevance of the problem of damage to VMT and develop a set of measures to protect them in the most common 6–10 kV distribution power grids (Murty 2017).

The following may be the main causes of damage to the voltage transformers of electric networks of energy-intensive enterprises from atmospheric overvoltage:

- ◆ design defects,
- ◆ ferro resonance processes,
- ◆ excessive voltages in the electrical networks of voltage transformers and the oversaturation of their magnetic wires.

Design defects of the most common OTPVTs (oil three-phase voltage transformers), SP-GVTs (single-phase grounded voltage transformers with cast insulation), such as a small constructive margin along the magnetic wire cross section of parameters about 1.9 times compared with the nominal voltage parameter (Zare and Nojavan 2018). The accumulated experience of practical operation indicates that there is a high probability of emergencies with a multiplicity of more than 1.9 times against the background of a deep oversaturation of the magnetic circuit, with a sharp decrease in the inductive resistance parameter and the occurrence of strong currents, which as a result, leads to the burnout of protective fuses or the ignition of VMTs themselves.

It is noted that the use of OTPVTs changes the voltage arc constant component from the discharge at the SPEF site, which may cause overheating and oversaturation in the future since the inductance of the main high-voltage windings and an additional single-phase transformer included in the cut of the zero grounding wire are practically inactive current-limiting resistances for the main component.

It should also be borne in mind that the requirements for the overvoltage protection of voltage transformers imply the installation of additional resistors with a resistance of 25 ohms in the secondary winding, although resistors with a resistance parameter of 10 ohms should be included in the grounding conductor of the primary winding. At the same time, the following current is expected through VMTs with SPEFs and a 10 kOhm grounding resistor at 650 V:

$$650 \text{ V} / (10000 \text{ ohms} + 844 \text{ ohms}) = 0.057 \text{ A} \quad (1)$$

This is not enough for a magnetic circuit. Thus, measuring both typical and antiresonance types of voltage transformers requires additional protection against overvoltage and high electric currents. To solve this issue, it is required to calculate the resistance of the grounding resistor VMT, taking into account a set of initial conditions: type VMT – 3 x SPGVT-10; $U_f = 6.3 \text{ kV}$; $I_{dl} = 0.1 \text{ A}$; $U_{dl} = 2.2 \times U_f = 2.2 \times 6.3 = 13.86 \text{ kV}$. The parameter of the maximum level of OV, which is limited to arc-extinguishing reactors (AER), is $U_{\max} = 2.6 \times U_f = 16.38 \text{ kV}$ for 10 kV networks. The voltage drop will then be on the grounding resistor as a part of the voltage divider at SPEF:

$$U^2_r = U^2_{\max} - U^2_{dl} = 16.38^2 - 13.86^2 = 8.72^2 \text{ kV} \quad (2)$$

As a result, the voltage drop is $U_r = 8.72$ kV on the grounding resistor. The saturation current of the magnetic circuit of the voltage transformer is $I_{sat} = 0.3$ A at SPEF. In this case, to limit the saturation current of the magnetic circuit, the resistance parameter of the grounding resistor will be in VMT:

$$R_z = U_r / I_{us} = 8720.0 : 0.3 = 29066.0 \text{ ohms} \quad (3)$$

30.0 kOhm is accepted. The saturation current of the magnetic circuit from the constant component of a 650 V OV with arc SPEF will be:

$$I_{sat} = 650.0 : (30000 + 844) = 0.021 \text{ Ah} \quad (4)$$

Thus, accounting for about 7% of the initial saturation current, the saturation current is not dangerous. Figure 1 shows a diagram of a device for diagnostics and the protection of electrical equipment in electrical networks.

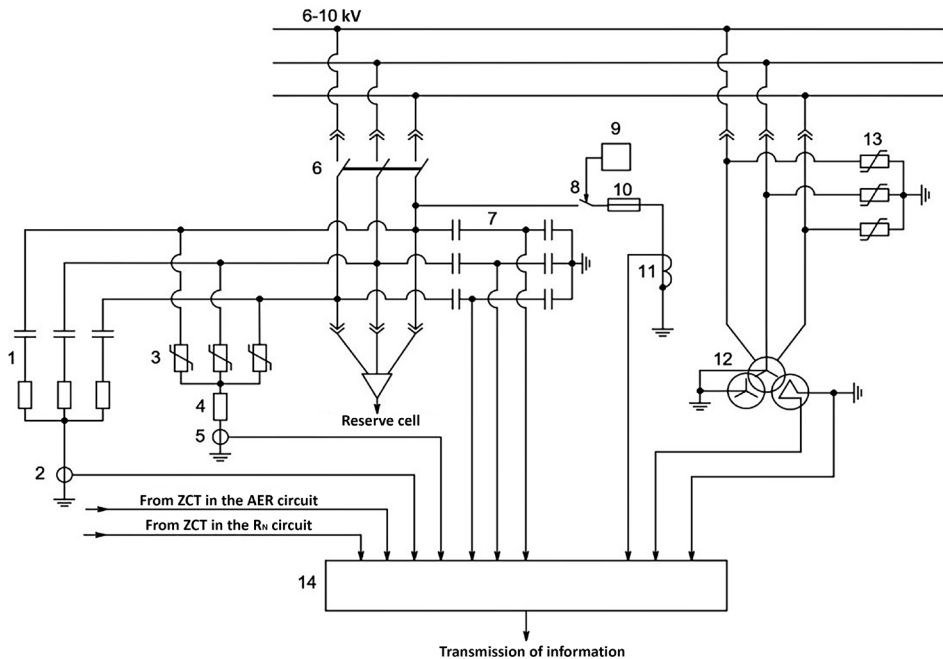


Fig. 1. Electrical diagram of a diagnostic and protection device of electrical equipment in electrical networks: 1 – resistive-capacitive (RC) dampers, 2 – an actuation sensor of RC dampers, 3 – a nonlinear overvoltage suppressor (NOS) with a reduced level of actuation (NOS–RAL), 4 – a resistor, 5 – a NOS–RAL actuation sensor, 6 – a switch, 7 – a voltage divider, 8 – a contactor, 9 – a start unit, 10 – a fuse, 11 – a current transformer, 12 – a voltage measuring transformer (VMT), 13 – a NOS, 14 – a signal recorder

Rys. 1. Schemat elektryczny urządzenia diagnostyczno-zabezpieczającego urządzenia elektryczne w sieciach elektrycznych

Real-time high-quality diagnostics of the studied electrical network require a preliminary connection for up to one month, while all elements, except for the artificial instant closure (AIC) chain, are in full working order. Recording device 14 records stable corresponding signals, including with SPEFs. Figures 2–3 show changes in the current and voltage parameters, including the busbar sections with a harmonic composition of current and voltage at AIC on the busbar sections with AERs in steady-state conditions.

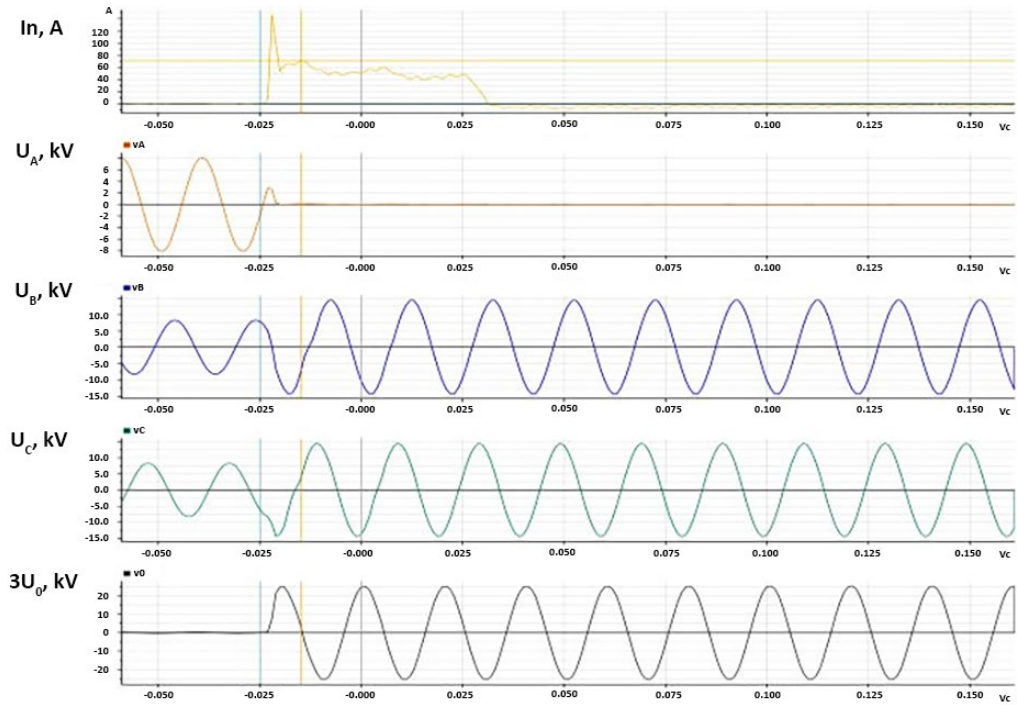


Fig. 2. Oscillograms of current and voltage at AIC on the bus section with AER

Rys. 2. Oscylogramy prądu i napięcia na AIC na odcinku magistrali z AER

The practical application of a special device to diagnose the operation of electrical networks in the AIC mode at a problematic substation with frequent SPEF (the decoding of part of the waveforms is shown in Figures 2–3) allowed us to draw some general conclusions.

The value of the delay in the planned functioning of the AER is assumed to be equal to three periods from the moment of the creation of the AIC, and when using an arc-type SPEF, it will be significantly higher. This is extremely undesirable in real SPEFs to limit ground fault currents and is the basis for the revision of the AER.

The harmonic composition of the zero-sequence current ($3I_0$) in the ground phase circuit in a steady-state mode indicates the specific effective values of the total current, the main harmonic, the constant component, and the higher harmonics. This is the initial information for the deve-

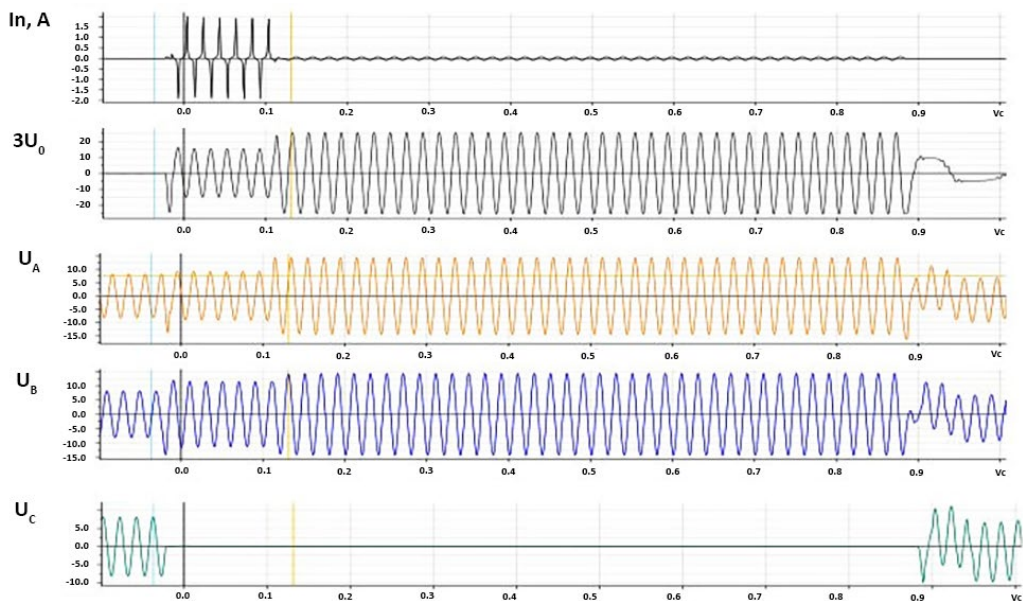


Fig. 3. Waveforms of the AIC process and two-phase short circuit on the bus section with AER and without NOS-RAL and RC extinguisher

Rys. 3. Przebieg procesu AIC i zwarcia dwufazowego na odcinku magistrali z AER i bez gaśnicy NOS-RAL i RC

lopment of relay protections with algorithms for the steady-state mode. However, to develop the most effective high-speed protection against OV and SPEF, information is also recorded about the parameters of transients.

The constant component in the $3I_0$ current in the AER mode is much larger and longer than in the non-AER mode.

The presence of the constant component in the total number of phase voltages and zero-sequence voltage ($3U_0$) indicates the need to consider this additional circumstance when developing protections. This is important for the protection of VMTs, which is confirmed by the results of experiments.

The determination of the active component in the $3I_0$ current, the appearance of which is caused by leakage currents through the insulation of electrical networks, allows us to formulate a general assessment of the condition of the insulation coating (for normal insulation, the proportion of the active component does not exceed 5% of the capacitive current). At the same time, it is necessary to take into account this current in the relay protections of power grids with a resistive neutral grounding.

A two-phase short circuit that occurs at the initial moment of the AIC (without a NOS-RAL, and RC-extinguisher) indicates the inadmissibility of such diagnostics in power grids with weak insulation and in which there is no system for limiting OV at reduced levels.

In experiments with AER, the harmonic composition of the 3Io current also contains a constant component in the standard mode, in addition to higher-order harmonics, when the main harmonic is compensated. Its value is commensurate with the total current of the OPC and is sufficient as the main factor to apply algorithms in relay protections based on the parameters of the steady-state OPC mode.

The electric networks of energy-intensive enterprises require high-quality measures to protect their 6–10 kV lines and to access ways from atmospheric overvoltages, following the requirements of their trouble-free operation.

3. Discussion

The issues of 6–10 kV electric networks should be considered while taking into account the wide prevalence of such networks in the electric power supply systems of cities and various industrial enterprises. This is largely because approximately 80–90% of problems and accidents occur on cable lines of power supply networks and they result from single-phase earth faults, which are caused by switching and arc overvoltage in the electrical network (Sarin et al. 2008). This situation is worsened by increases in the total volume of such damages and the transition of single-phase earth faults into multi-phase circuits, which result in emergency shutdowns of associated outgoing lines to end consumers. In addition, voltage-measuring transformers are very vulnerable to overvoltage. The consequences of the considered accidents lie in a significant decrease in the reliability of power supply systems and an increase in the costs of repair and restoration of damaged sections of electrical networks.

The current situation is explained by the fact that the bulk of cable power lines, which account for over 70% of their entire length, have already completely exhausted the warranty resource of safe operation, while their insulation coating is completely outdated and has completely lost its insulating properties, which should be considered the main cause of accidents in the electrical network and their damage (Shirkovets and Ilinykh 2008). It should also be taken into account that the condition of power grids tends to unexpectedly deteriorate due to the practical use of modern electrical equipment, which is beneficial for many reasons. In particular, the use of high-voltage vacuum circuit breakers leads to significant overvoltage during switching. Recently, cable lines with cross-linked polyethylene insulation have been widely used in power grids, which have less resistance to damage due to overvoltage, unlike traditional types of cable insulation (Pedraza 2019). In such a situation, the practical operation of electrical networks is significantly complicated due to the aggravation of problems caused by the almost universal use of an outdated method for determining a damaged connection with a single-phase earth fault by alternating on-off lines departing from the bus sections of substations.

Modern systems for limiting the currents and voltages of single-phase earth faults used in electric networks of energy-intensive enterprises, where nonlinear surge suppressors, RC dam-

pers, arc-extinguishing reactors, and resistors are installed in the neutral of power grids as well as a relay protection, have a list of significant advantages that determine the broad prospects for their subsequent practical use (Crowder 2019). At the same time, there are also disadvantages and operational problems that negatively affect the reliability of the networks and the safety of their use, which affects the reliability and efficiency of electrical supply to consumers and which are especially characteristic of electrical networks with weakened insulation. High levels of overvoltage limitation, delay in operational use, as well as the inability to function effectively in certain emergency modes should be noted as the most important factors.

The study of overvoltage limitation systems and the calculations of the protection parameters of voltage-measuring transformers led to the identification of their shortcomings and an approximate design of a modern device that allows diagnosing 6–10 kV power grids and ensuring their reliable protection at reduced levels (Letcher 2020). Its design features provide for the joint operation of surge arresters with a reduced trigger threshold and include a current-limiting resistor in the grounding conductor, RC surge suppressors, as well as a device for recording incoming signals. This device enables high-quality diagnostics of electrical networks in their normal operation mode when conducting tests by intentional short-circuiting, as well as with real arc earth faults at the site of damage. Practice shows that it is possible to achieve high levels of overvoltage protection in this way since it is possible to determine the effectiveness of protection separately for any of the means used to limit overvoltage. An important circumstance should be considered that is carried out, the maximum amount of information is recorded during the tests required to develop methods of protection and the selection of electrical equipment for protection against overvoltage and parameters of earth fault currents. This contributes to recording switch overvoltage, which makes it possible to determine their sources (Steffenson et al. 2021).

The results of real experiments conducted in full-scale conditions prove the possibility and necessity of the practical use of such specially designed devices with advanced functions, especially for electrical networks with weak insulation. The maximum economic effect of using this device is to significantly reduce the accident rate in 6–10 kV distribution power grids and reduce the cost of repair and restoration work.

The issues of ensuring the proper level of protection of electric networks of energy-intensive enterprises from overvoltage are closely related to a wide range of issues of ensuring industrial environmental safety. The ecological situation in modern Kazakhstan is a consequence of some crisis phenomena that took place in the country's economy after 1991 (Asi et al. 2020). The decline in the technological discipline affected not only the manufacturing sector but was also noted in the energy supply system of the country as a whole and was also reflected in the low technical equipment of energy-intensive enterprises and the weak overvoltage protection of electrical systems. In the current situation, the issues have acquired great importance in creating effective devices to ensure the proper level of protection of electrical networks used at enterprises that are part of the unified energy supply system of the Republic of Kazakhstan.

The operation of modern energy systems involving the use of electric networks of energy-intensive enterprises, which are characterized by wear after the expiration of the operational use period established by the regulations, leads to a deterioration in the level of protection of ne-

networks from possible overvoltage. The large branching of the electrical networks of the specified enterprises contributes to the aggravation of the described situation, even if there is protection against earth faults triggered in the presence of an outgoing signal of the specified parameters. Capacitive short-circuit currents of such networks, as a rule, have higher values, which is caused by a large number of outgoing power lines, especially when it comes to distribution networks (Tahir et al. 2016). Overvoltage that occurs due to atmospheric influences or single-phase short circuits in the network can cause serious accidents that reduce the safety of using electrical networks as a whole and sometimes have unpredictable consequences. The high probability of the occurrence of more severe accidents, such as single-phase and two-phase short circuits in the network, causes an urgent need to find opportunities for the development and implementation of devices capable of ensuring the continuity of monitoring the condition of the insulating network coverage. It should be noted that it would not be easy to determine network damage in this case since today there are almost no criteria to determine network damage that can be applied in a practical situation with various methods of neutral grounding (Shahbazi et al. 2021).

Devices capable of monitoring and protecting 6–10 kV approach lines from excessive overvoltage occupy a special place in the complex of measures for the development of short-circuit protection systems. A significant increase in the operational reliability of electric power supply networks can be realized through the formation of a comprehensive solution to the problem of eliminating the consequences of short circuits of this kind and the introduction of preventive measures to reduce the likelihood of the recurrence of such short circuits in the future. Such measures imply the need to regularly monitor the insulation coating of power transmission networks, carry out measures to diagnose the equipment of electrical networks, and thus prevent short circuits to the ground (Calderon-Mendoza et al. 2019). At the same time, the rejection of the deliberate displacement of the neutral in combination with the symmetry of the network also significantly reduces the likelihood of a short circuit to earth, which, in turn, has a positive effect on the overall condition of the equipment of energy-intensive systems, contributing to the extension of the overall life of its operation.

The rapid and timely disconnection of the damaged section of the electrical network is also essential from the point of view of ensuring the safety of its subsequent operational use; therefore, the creation of appropriate conditions for rapid disconnection through a sharp increase in the active component of the current in the area of the occurrence of a short circuit is one of the priorities in the general context of ensuring the safety of the operation of the electrical network. When operating electric networks of energy-intensive enterprises, special attention should be paid to reducing the level of overvoltage during arc intermittent SPEF (Wang et al. 2021). As practice shows, the placement in the network of a resistor with high resistance values on a neutral parallel to the inductance and configured following the requirements of the instructions for safe operation makes it possible to reduce the multiplicity of overvoltage to a level necessary for the safe operation of the electrical equipment of the network. The timely determination of damages received during the operation of electrical networks is the most important factor in terms of ensuring the overall safety of their operation. For this purpose, the creation of selection devices that effectively monitor the state of an unlimited number of power lines makes it possible to trace the

probability of short circuits occurring in circuits and prevent their occurrence. The methods of grounding the neutral in this case can be different, including the fact that grounding through the AER is allowed (Wang et al. 2019).

In electrical networks with a voltage of 6–10 kV, a variety of methods for determining the degrees of phase conductivity have become widespread, and the data obtained through the use of these methods provide a choice of operating principles of compensating devices for capacitive currents. The most accurate methods using the principles of solid fault are very time-consuming, which causes difficulties in their practical implementation, while there is a great danger of the failure of electrical equipment. When using some indirect methods, the accuracy of the determination is significantly lower, while almost all of them provide for an assessment of the capacitive value of the current strength during a short circuit to select the AER mode. If constant monitoring of the condition of the insulation coating is not carried out, the choice of additional devices and research methods to assess the degree of change in the properties of the electrical network of energy-intensive enterprises and ways to protect them from overvoltage, in networks of 6–10 kV, there is a high probability of occurrence of a SPEF (Das and Mao 2020). This is facilitated by a large number of uncontrolled AER in these networks, the inductance of which is regulated on a stepwise basis.

In any case, a qualitative solution to the issues of the protection of lines and access ways of 6–10 kV from overvoltage involves the use of special devices that ensure the timely resolution of these issues, the use of which allows the timely and qualitative monitoring of the state of insulation of electrical networks. Otherwise, the frequency of short circuits to earth will not allow achieving high efficiency of the operation of electric networks of energy-intensive enterprises and will negatively affect the service life of systems of this kind, significantly reducing this parameter.

Conclusions

The conducted scientific study of the protection of lines and access ways of 6–10 kV electrical networks of energy-saving installations from overvoltage led to the following conclusions. Well-known recommendations on the practical use of 10-ohm resistors included in the section of the grounding conductor as restraining devices for limiting currents of high values in electrical networks with voltage parameters up to 10 kV have shown their complete practical inefficiency, which is confirmed by statistical data. The practical results obtained in the course of this scientific study demonstrate the need to increase the sensitivity of electrical networks with a voltage of 6–10 kV, primarily through the use of voltage measuring transformers and cable lines, from OV and SPEF, which are based on the principles of limiting and registering switching and arc OV at reduced levels using NOS–RAL and RC extinguishers. This will allow the obtaining of higher indicators of the level of protection of networks from overvoltage.

The development of an electrical circuit of a device that enables diagnosis and the provision of protection of electrical networks in AIC modes, as well as real arc-type SPEF, provides opportunities to obtain significant amounts of information of a high degree of reliability necessary to prepare the protection of electrical networks from sudden overvoltage. The proper level of overvoltage protection can also be achieved in networks with significantly weakened insulation.

Conducting scientific experiments using a specially designed device has scientifically proven and confirmed the necessity and expediency of its practical application to ensure the proper level of protection of electric networks of energy-intensive enterprises from overvoltage, as well as the efficiency of functioning in 6–10 kV power grids with different neutral modes and the condition of the insulation coating. Thus, this study experimentally confirms the need for the development and practical implementation of special devices to ensure the reliable protection of lines and access ways of 6–10 kV electric networks of energy-intensive enterprises from overvoltage.

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Sieci elektryczne przedsiębiorstw energochłonnych: ochrona linii 6–10 kV i miejsc dostępu przed przepięciami

Streszczenie

Celem pracy badawczej jest zbadanie problematyki ochrony linii 6–10 kV i przepięć w miejscach dostępu w sieciach elektroenergetycznych nowoczesnych przedsiębiorstw o dużej energochłonności, a także poszukiwanie realnych technicznych możliwości poprawy ochrony linii elektroenergetycznych bezpośrednio w warunkach ich eksploatacji. Metodologia niniejszych badań naukowych opiera się na połączeniu metod analizy systemowej zasad funkcjonowania sieci elektroenergetycznych przedsiębiorstw energochłonnych z analitycznym badaniem podstawowych aspektów zapewnienia ochrony linii od 6 do 10 kV oraz miejsc dostępu do nich od przepięcia. Wyniki przeprowadzonych badań wskazują na istotność zagadnień zapewnienia ochrony linii i sieci elektrycznych przedsiębiorstw energochłonnych przed przepięciami oraz konieczność opracowania specjalnych urządzeń technicznych zapewniających właściwy poziom tej ochrony w warunkach rzeczywistych. Wyniki i wnioski z tej pracy badawczej mają istotne znaczenie dla wykonawców i projektantów sieci elektrycznych przedsiębiorstw o podwyższonej energochłonności, a także dla pracowników różnych systemów zasilania, którzy z racji wykonywanego zawodu mają do czynienia

z zadaniami serwisowania sieci elektrycznych obejmujących linie o określonych parametrach pracy oraz odpowiadają za odpowiedni poziom bezpieczeństwa i praktycznego użytkowania tych sieci elektrycznych przedsiębiorstw energochłonnych.

SŁOWA KLUCZOWE: sieci elektryczne, przedsiębiorstwa energochłonne, przepięcia,
linie elektroenergetyczne, ochrona sieci elektrycznych, bezpieczeństwo energetyczne

