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Reducing high-voltage power outages due to exposure to solar flares and magnetic storms

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ABSTRACT: The article analyzes the harsh climatic factors affecting the operation of high-voltage power lines in Uzbekistan with hot, dry weather and polluted atmosphere. Based on the analysis of all climatic factors affecting the operation of insulation and other nodes of overhead lines and high-voltage equipment in general, the severity of these factors is shown both in terms of insulation and energy efficiency. Another significant factor has been identified that has a very strong impact on the operation of overhead lines and high-voltage equipment, which was not previously listed in the list of influencing factors in any literature.

I. INTRODUCTION

It should be noted that currently, a significant part of the equipment of power plants, substations, and main lines has served its service life, they are significantly worn out and require replacement. However, for some reasons, they cannot be replaced and their work in the power system is required for many years. This, in turn, requires the operating organization to conduct more frequent and high-quality tests of equipment, and the development and implementation of advanced methods for diagnosing the condition of equipment under operating voltage directly under operating conditions. Important factors that reduce the reliability of main and other high-voltage power lines are the severe climatic conditions of our region: prolonged dry hot weather with intense solar radiation; pollution of insulation from industrial and field sources, especially considering that in Uzbekistan, as in the whole of Central Asia, there are vast territories with salt marshes and semi-salt marshes soils, as well as the presence of the Aral Sea and its surroundings with an abundant content of salt dust [1,2].

In this regard, based on the scientific analysis of all factors affecting equipment and power lines of high and ultrahigh voltage, it was necessary to identify the dominant processes in terms of improving the reliability of their operation, developing scientifically sound techniques, modern methods and devices to increase their energy efficiency [3].

II. MATERIALS AND METHODS.

The developed method makes it possible to calculate the values of geoinduced currents in high-voltage power lines depending on the configuration and parameters of the replacement circuit of the power supply system, as well as the orientation angles of the transmission lines relative to the direction of the geoelectric field power lines. Estimation of the values of GIT in power transmission lines of different voltage classes will allow us to study the stability of power supply systems during geomagnetic storms of varying intensity [7].

The degree of elaboration of national strategies to minimize the effects of GMB on technological systems depends on the geographical area. Countries that have faced negative effects over the previous decades are more prepared. The continued development of high and ultra-high voltage lines, on the one hand, and the aging of network equipment, on the other hand, leads to the expansion of the map of “high risk" zones. Consequently, even countries that do not have registered cases of the influence of space weather on the EPS benefit from the analysis of the stability of national EPS to GMB. The purpose of this study was to identify and analyze critical factors affecting the stability of EPS to EMF, and to develop an algorithm for assessing the robustness of EPS based on the data obtained [8].

The science of physical processes on the surface of the Sun, the magneto-ionosphere is young and dynamically developing. The development of this science is associated with the emergence of new technical means of observing the cosmos and processing the received data. Undoubtedly, an important role was played by the factor of shifting priorities to peaceful space exploration, which allowed expanding the range of research conducted. The simultaneous development of the theoretical base and the increase of public awareness expands the map of GMB zones. At the same time, the

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principles of development and operation modern nuclear power plants are also undergoing significant changes: the complexity of architecture, the use of new equipment, etc.The occurrence of an accident caused by GMB is caused by a combination of technical and natural factors. [8].

III. SYSTEM ANALYSIS

The average duration of the daylight period for Uzbekistan in winter (December-January) is about 9 hours, and in summer it is more than 16 hours. Accordingly, the duration of the temperature transition time from the minimum value (early morning) to the maximum value (afternoon) for December – January is only 7.0-7.5 hours. The duration of the time from the maximum temperature value to the minimum is 16.5-17.0 hours, that is, the curve of the daily temperature course for the winter period has a sawtooth character. In spring, as the temperature increases, the duration of the time to reach the maximum increases to 9-10 hours, and only by summer (July), it reaches 12 hours, that is, both half-periods of the curve of the daily temperature graph become equal to each other and this curve practically takes a sinusoidal shape [4].

Significant part of the equipment of power plants, substations, and main lines has served its service life, is significantly worn out and requires replacement. However, for several reasons, they cannot be replaced and their work in the power system is required for a number of years. This, in turn, requires the operating organization to conduct more frequent and high-quality tests of equipment, and the development and implementation of advanced methods for diagnosing the condition of equipment under operating voltage directly under operating conditions [5].

Important factors that reduce the reliability of main and other high-voltage power lines are the severe climatic conditions of our region: prolonged dry hot weather with intense solar radiation; pollution of insulation from industrial and field sources, especially considering that in Uzbekistan, as in the whole of Central Asia, there are vast territories with salt marshes and semi- saline soils, as well as the presence of the Aral Sea and its surroundings with an abundant content of salt dust [6].

The peculiarity of the operation of high and ultrahigh voltage power lines in our region is that the polluted atmosphere of the region leads not only to contamination and overlapping of the insulation of the line and high voltage equipment but also to contamination of the line wires, which significantly increases line losses even in good weather. Prolonged (months-long) hot weather with intense solar radiation contributes to a large sagging of the wires of power lines and to rapprochement with the earth. This leads to an incalculable increase in the electric field strength on the surface of the wires of the lines, especially of the 500 kV class. This is the reason for a significant increase in corona generation, an even greater increase in energy losses in the line, and what is especially dangerous, to environmental disruption - an increase in the incidence of cancer of people working under and near the line. Thus, overhead power transmission lines of high, especially ultra-high voltage, in our region operate in severe climatic conditions, significantly different from the conditions of the central part of Russia, for which they were mainly designed earlier. These difficult conditions lead to excessive heating of wires, contact connections, insulation, equipment that does not have devices that maintain its normal temperature, lead on the one hand to large losses of electricity during its transmission over long distances, and on the other, to a decrease in the reliability of the power transmission itself.

In addition, strong heating of the wires leads to excessive sagging of the wires and to environmental damage under the wires and near the lines. Powerful power transformers with artificial cooling, in extreme heat and working in the open air, spend an additional large amount of electricity, reducing the efficiency of power transmission [7].

In this regard, based on the scientific analysis of all factors affecting equipment and power lines of high and ultrahigh voltage, it is necessary to identify the dominant processes in terms of improving the reliability of their operation, developing scientifically sound techniques, modern methods and devices to increase their energy efficiency. The results of the scientific analysis of multifactorial effects on the elements of main power lines should lead to an increase in the reliability of both overhead high-voltage power lines and substation equipment, primarily responsible power transformers, switches, arresters, and surge arresters. Solving the loss equations taking into account the actual temperature of the wires of the phases of the lines when exposed to hot weather for a long time, intense solar radiation, and practically no wind in hot weather will show ways to significantly reduce electricity losses in power transmission lines and the need to solve environmental problems along ultrahigh voltage transmission lines [8].

At the same time, given the widespread introduction of polymer insulation structures in 500 kV overhead lines under construction, without taking into account the severe climatic features of our region, it is necessary to develop scientifically sound methods for predicting the reliability of high-voltage overhead lines with polymer insulation structures and the

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derivation of mathematical formulas for their service life depending on the impact of real factors and the characteristics of the object itself.A critical analysis of all factors affecting insulation, the derivation of formulas on this basis, their analysis and solutions will allow us to develop new concepts of accelerated testing methods for promising erosion-tracking resistant polymer insulation materials. In addition, as we noted above, the reliability of high-voltage (as well as lower-voltage) power lines is significantly influenced by solar flares and magnetic storms, which have so far been practically not studied and have not been considered as factors affecting the operation of power lines.

Analysis of solar radiation and its effect on the operation of insulating structures of power lines. The effect of solar radiation on the operation of overhead power lines and, in particular, polymer insulation structures in Central Asia, including Uzbekistan, is significant, since the average daily duration of sunshine in the summer months reaches 16 hours, in spring and autumn within 12-14 hours. The number of cloudy days in the hot season does not exceed 1, and the number of semi-cloudy days is from 5 to 10. An important indicator is also the ratio of the observed duration of sunshine to the possible one, which for Uzbekistan is 90-93%. The intensity of total solar radiation from July to September of the year for latitudes 40o, typical for Uzbekistan, is such [7] that the maximum intensity of total solar radiation falls on the time interval between 10 and 14 hours of solar time, and the maximum radiation intensity exceeds 1000 W/m2 [6-7].

High ambient temperatures combined with intense solar radiation, which last for a long time of the year, lead to overheating of a significant layer of the soil surface, its crushing and erosion. This naturally leads to atmospheric pollution and, therefore, to an increase in the degree of contamination of the surface of insulating structures.

Thus, it can be seen that our country, in terms of the impact of climatic factors on the operation of high-voltage overhead lines, including the operation of polymer insulation structures, is a unique region characterized by a very long dry period of the year with high ambient temperatures combined with intense solar radiation, which lead to active spraying the surface layer of the soil. All this is further aggravated by sharp fluctuations in temperature during the day, the passage of line routes through thin layers of air, the presence of salt marshes, soil treatment with chemical fertilizers and pesticides, and exposure to the very salty Aral Sea with its vast dried salt shores.

Analysis of sources of field and industrial pollution of insulation of high-voltage overhead lines. The 500 kV overhead line routes of Uzbekistan pass near industrial enterprises (Tashkent, Chirchik, Kokand, Ferghana, Andijan, etc.) with a polluted atmosphere, over saline and semi-saline lands in areas prone to wet dust storms (the coast of the Syr Darya in the Kokand zone), through agricultural fields where production is carried out for a long period treatment of fields and plants with fertilizers and various pesticides. The deposition of such types of pollutants from the ambient air onto the insulation surface of power lines and its effect on the discharge characteristics and reliability of insulation structures, although well studied, but so far the issues of their degree of contamination from various types of pollution sources, the dynamics of deposition of pollutants on the insulation surface depending on climatic factors in operating conditions have not been sufficiently studied. This explains the sudden accidents of lines and equipment associated with the overlap of contaminated insulation not only during precipitation and fog, but also in the early morning with heavy dew [8-9]. In this regard, it is important to know the sources of pollutants on the territory of Uzbekistan, to know the degree of danger of certain types of pollution sources. Atmospheric pollution in Uzbekistan can occur from three types of sources: a) natural sources of pollution, i.e. atmospheric pollution due to the rise of dust and dirt particles by the wind; b) industrial sources of pollution, i.e. atmospheric pollution due to the operation and emissions of chemical, metallurgical, cement and other plants, thermal power plants, mining plants, construction industry enterprises and others; c) salty reservoirs, meaning the Aral Sea, whose salty water particles can rise into the air and spread over long distances by wind.

Natural sources of pollution. Saline soils are important in this case [9], which are divided into 4 groups: unsalted; slightly saline; medium-saline and highly saline, as well as salt marshes. Unsalted soils include soils with a salinity of 0.3%, moreover, they occupy 59.2% of the territories in Uzbekistan; slightly saline soils include soils in which the salt content ranges from 0.3 to 1.0% and they occupy 16.8% of the territories. Medium–saline (1.0 - 2.0%) occupies 13.7% of the territories, and soils with a salt content of more than 2% belong to highly saline and salt marshes. They occupy 10.3% of the territories.

Highly eroding soils, which make up 17.5% of the territories in Uzbekistan, can be carried by wind for tens of kilometers and deposited on insulating structures of power lines and high-voltage electrical equipment, leading to their overlaps. It was found that on strongly eroding soils, the number of disconnections of overhead lines is almost 5 times greater than on weakly eroding ones. To assess the role of the soil of a certain area of the line route on the degree of its polluted isolation, it is necessary to obtain quantitative data on the content of ion-forming impurities in the soil and data on the

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ability of soil particles to rise from the soil surface under the influence of wind force. Since soil particles are carried by the wind, the pollution of the atmosphere, and therefore the contamination of insulation, is determined not by the salinity of the soil measured at a given point of the route, but by the total salinity of the area through which the route of the line passes.

It should be noted that only the topsoil is involved in the contamination of insulation, therefore, when analyzing its pollution, the characteristics of only the topsoil at a distance of 25-30 km in both directions from the axis of the line should be taken into account. All this applies to the case when the soil in this strip is eroding when dust particles can easily rise from the soil surface. If the analysis of the characteristics of the surface soil layer shows that the soils in the area are not subject to erosion, then the width of the analyzed strip can be significantly narrower.

Industrial sources of pollution. The degree of contamination of the insulation of overhead lines and equipment depends both on the properties of pollutants emitted by industrial enterprises and on the concentration of these substances in the atmosphere. A particular danger from the point of view of a significant increase in the amount of pollutants on the surface of insulating structures is represented by chemically active substances that corrode the surface of the coating of polymer insulators, as well as protective coatings of end caps and screen fittings.

Based on several studies carried out by sanitary and geophysical services, a calculation method was proposed [7], which allows to determine the concentration of emissions at various distances from industrial enterprises, depending on wind speed and pipe height. This technique can serve as an auxiliary material for assessing the contamination of line insulation in the area of operation of industrial enterprises. At the same time, it should be borne in mind that the degree of contamination of the insulator surface is determined both by the pollution of the atmosphere at a given time and by the total accumulation of pollution over a long time.

Sources of pollution from salty reservoirs. On the territory of Uzbekistan, the Aral Sea, located in the north-west of the Republic, is a large salty reservoir. The pollution of the atmosphere on the coast of this sea is determined by the salinity of the water, which is quite high. In addition, it is known that due to the drying of the sea and the withdrawal of water, hundreds of thousands of square kilometers of the seabed area have been exposed and this loose, excessively salty "soil" pollutes the atmosphere of the region for hundreds of kilometers around. At the same time, the atmosphere is particularly heavily polluted, and therefore the insulation of lines in areas exposed to particularly strong and frequently recurring winds. Mists also bring salt deposits, which, drying on the surface of insulators, increase the conductivity of insulaion when it is moistened.

IV. RESULTS.

For Uzbekistan, the period from the second half of April to the second half of October is observed without precipitation or with a minimum amount of it. So almost half of the year can be attributed to its dry period. The daily course of relative humidity repeats the daily course of temperature in the opposite direction, taking the maximum value in the early morning and the minimum in the afternoon, and, as for temperature, the extreme shifts from 14.5 – 15 hours in winter to 17.5 – 18.5 hours by summer.

The maximum value of relative humidity in the absence of precipitation in winter is mainly 75-90%, in spring their values decrease to 60-80%, and in summer they are 45-55%. The minimum values of relative humidity decrease from 45-65% in winter to 30-50% in spring and to 10-25% in summer. Long-term maintenance of weather without precipitation with such low values of relative humidity of the surrounding air favors the appearance of thick layers of dust on the surface of the earth, atmospheric pollution, and the deposition of dust and dirt particles on the surface of objects, including on the surface of power line insulators.

On the other hand, high values of relative humidity in late autumn, winter and early spring contribute to the penetration of moisture particles through microcracks into the inlet node and the fiberglass insulation structure. Thick fog, rain, and wet snow, dissolving the layer of contamination on the insulation surface, can lead to the overlap of insulators.

V. CONCLUSION

It is shown that external insulation contaminated with salt deposits, when it is moistened by rain, sleet, fog, causes the appearance and development of surface discharges, often developing before the entire insulation is blocked and an emergency shutdown of a high-voltage line or equipment.

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It is noted that the reliability of high-voltage power transmission is significantly influenced by their condition, it should be noted that in Uzbekistan currently a significant part of the equipment of electric power stations, substations and high-voltage power lines has served its service life, is significantly worn out and requires replacement. However, for a number of reasons, they cannot be replaced and their work in the power system is required for a number of years. This, in turn, requires the operating organization to conduct more frequent and high-quality tests of equipment, the development and implementation of advanced methods for diagnosing its condition under operating voltage directly under operating conditions.

Our research in recent years has shown that, in addition to the above factors, solar flares and their manifestations on earth – magnetic storms - have a significant impact on the accident rate of high-voltage power lines, which have not been considered or taken into account so far in any power system. There is also no information on this problem in the literature. Based on the scientific analysis of all factors affecting equipment and power lines of high and ultrahigh voltage, the dominant processes were identified in terms of increasing the reliability of their operation.

REFERENCES

[1]. The strategy of action on the five priority areas of development of the Republic of Uzbekistan in 2017-2021, approved by the Decree of the President of the Republic of Uzbekistan No.UP-4947 dated February 7.
[2]. Concepts of providing the Republic of Uzbekistan with electric energy for 2020-2030..
[3]. Kudratillaev A.S. and Raimov R.O. Operational reliability of high-voltage transformers exposed to powerful solar flares and magnetic storms // Energy Technologies and Engineering. Volume 55, No. 5, January 2022. DOI 10.1007/s10749-022-01430-7 USA.
[4]. Kudratillaev A.S., Rayimov R.O. The influence of solar flares and magnetic storms on emergency power outages of high voltage (in the example of Uzbekistan). Proceedings of the conference "Systems and organization of continuous monitoring of the condition of basic electrical equipment and power transmission lines. Surgut, Russia, November 2018, pp. 165-171.
[5]. Savoskin N.E. Reliability of electrical systems. A study guide. - Penza: Penza State University, 2004.-102s.
[6]. Average long-term climatic and agrometeorological data for the Uzbek SSR. The Applied Reference Book // Vol. Hydrometeorological Center, 1991, p. 110.
[7]. Weinberg B.P., Soloveitchik R.A. Experience in the climatic characteristics of the area to meet the demands of solar engineering //Meteorological Bulletin, 1934, No. 1-3. pp. 35-38.
[8]. Rules of technical operation of electric power plants and networks of the Russian Federation. Moscow: SPO ORGRES. 2003.
[9]. Sheremet A.A., Tarasov A.A. Patent RU No. 2328009. A device for monitoring high-voltage inputs and signaling the state of their insulation.
[10]. Kudratillaev, A.S., Rayimov R.O. The influence of solar flares and magnetic storms on emergency power outages of high voltage (on the example of Uzbekistan): Proceedings of the conference “System and organization of continuous monitoring of the condition of basic electrical equipment". -- Surgut, 2018. -- pp. 165 -- 171.