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Selection of effective method to reduce the impact of icing on high-voltage POWER GRIDIN KAZAKHSTAN

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Annotation

The article considers the impact of ice-and-wind loads on the operation of the 110 kV high-voltage lines. At the same time, measures of struggle are given. Particular attention is paid to melting icing using electric current in short-circuit mode in three-phase high-voltage power grids. The 110 kV power transmission lines (PTL) of JSC "Taldykorgan joint-stock transport and power grid company (TATEK)" are considered.The types of accidents depending on climatic conditions are shown, as well as a fragment of power grid schemes and the location of the ice melting plant at the substation. In addition, a formula is given to determine the weight of ice accretion on the wires, the procedure of melting. In the future, automation of the melting process is proposed. Reduction of the risk of icingallowscarry out effectively powersupply to the territory of Kazakhstan.

Keywords: electric networks,reliability of power supply,accident,support, ice deposits, wind load,dispatcher,way, melting ice, region,

Introduction

Qualitative and uninterrupted power supply to consumers is ensured by reliable operation of overhead power transmission lines(PTL) taking into account the impact of various natural and anthropogenic factors. The most dangerous situations occur when there is a combination of ice and wind loads on wires and lightning protection cables, leading to severe consequences (destruction of insulation, fixtures, breakage of towers, breakage of wires and cables), which disrupts the operation of power linesand social stability.

In Kazakhstan, ice-and-wind accidents account for more than 50% of their total number on overhead lines, and the duration of breaks in power supply is over 60% of the total duration of all emergency shutdowns.

Therefore, it becomes necessary to conduct research and accumulate experience in reducing the risk of adverse meteorological conditions at energy facilities.

To achieve thisgoal, a comprehensive research method was used, including an analytical review of literature sources onicing control. Theoretical studies were carried out on the basis of the scientific foundations of high-voltage engineering using mathematical statistics, studying and enhancing the experience of operating power transmissionlines in ice-and-wind conditions.

It should be noted the climate of Kazakhstan - sharply continental, which is characterized by high temperatures in summer (up to +40°C and above) and very low in winter (to -40°C and lower, in Eastern and Northern regions).

In addition, there are significant wind speeds (25-45 m/s), which causes galloping and whipping of wires, cables leading to their breakage and breakage of supports, insulators (Figure 1).

The main measures to control icing are removing mechanically ice from wires and cables, as well as preventive heating of wires with electric current. The mechanical method of removing ice is time-consuming, labor-intensive and in most cases cannot be considered as reasonable.

The wire icing control remains an important problem for many years and is solved in various ways. Investigations of mass accidents and failures due to ice showed that it is impossible to design optimally a line by calculating and determining only the geometric parameters of a high-voltage line in strength without using various methods and devices to limit the amount of ice formation [1].

Figure 1 - Damage of towersof power lines

The observation results of the modes of impact of intensive meteorological factors revealed the following:

- the country's territory is characterized by a variety of wind and ice impacts;
- the wind speed with a repeatability of once every ten years varies from 25 to 45 m/s;
- the thickness of the ice accretion of similar frequency is from 10 to 30 mm;

Table 1 - Accidents by types of climatic conditions

Climaticfactors	Number of power failures	
	HVL 110 kV	HVL 220 kV
Strong wind (blizzard, dust storm)	65	8
Icing	20	3
Galloping of wires, cables	12	14
Total	97	25

Weather conditions leading to extreme wind and ice loads are determined by specific atmospheric processes typicalfor a given region and complex configurations of the underlying earth's surface [2].

In the process of ice formation with increasing sediment size, the flow conditions around the wire and the intensity of its icing change. Therefore, for a more accurate description of the icing process, it is necessary to develop a mathematical model that takes into account changes in the flow conditions around the iced body in the process of ice formation [3].

The weight of the ice accretion formed per unit time per unit length of the streamlined body is expressed by the formula:

$$J = \frac{4}{3} \cdot u_0 \cdot d \cdot \pi \cdot \beta \cdot \frac{\rho_в}{\rho_л} \cdot \int_0^{\infty} r^3 n(r) E(r) dr \quad (1)$$

where u_0 isthe velocity of the unperturbed flow;

$d$is the diameter of the streamlined body (cylinder);

β is the coefficient of congelation, equal to the ratio of the mass of growing ice per unit time per unit surface to the mass of water deposited over the same time on the same surface;

$\rho_в \rho_л$is the density of water and ice;

r is the radius of the drop;

$\frac{4}{43} \pi r^3 n(r) dr$is the mass of water per unit volume of air in droplets of radius from$r$to $r+dr$;

$n(r)$is the density of the spectral distribution of droplets in size;

$E(r)$is the total capture ratio, which shows how much of the droplets, from the total volume flowing around the wire, are colliding with the latter.

We conducted research in the following areas:

- analysis of applied methods to melt ice on electric power lines in power grids;
- obtaining of calculated data on prevention and reduction of ice formation on power transmission lines of different voltages;

An ice from the wires of overhead transmission lines is removedusing mechanical and thermal methods. An ice from the wires is removed mechanically by scraping and dropping. Scraping and cutting ice can be done using rollers-ice breakers. Various droppers can also be used to remove ice accretions.

The thermal method of removing ice is to melt the sediment by an electric current. As a result of heating, a groove is formed in the icemuff, wire is passed through the formed saw cut and ice falls to the ground. This method of removing ice is an effective means to prevent accidents and helpsremove quickly ice from the wires of long-distance power transmission lines. In power grids with an isolated neutral, ice is melted by alternating current [4].

The following methods are used to create melting currents:

- three-phase short circuit;
- two-phase short circuit;

- single-phase short circuit. When the wires of all phases are serially connected according to the "snake" scheme;

- opposite connection of phases;
- redistribution of loads;
- superposition of currents.

When melting ice by the short-circuit method, the power line is connected to the source and short-circuited at the end of the power grid. A three-phase short circuit removes quickly the ice on the wires of all phases of the heated line. According to the method of two-phase short-circuit ice melting is first carried on the wires of two phases, and then on the wire of the third phase in combination with one of the wires freed from ice. This method is used only in the case of a shortage of transformer capacity, because the melting current at constant voltage is reduced by 14% in comparison with the melting by the method of a three-phase short circuit.

When the ice is melted by the short-circuit method, the required amount of the melting current is provided by selecting the source voltage and the length of the heated line [5].

With our participation, the following issues were analyzed and investigated:

- the state of the problem of accidents due to ice formation on the power transmission lines in the investigated power grids;
- development of a program for melting ice on the power line.

In power grids of JSC "Taldykorgan joint-stock transport and power grid company (TATEK),"PTL 110 kV № 102, 103, 152 and 157, respectively, with the length of the overhead lines 76, 73, 122 and 46 km are subject to ice formation.

In this region, the meteorological conditions (temperature, humidity, wind speed), is the most favorable for ice formation- frost, fog, temperature from -5°C and below, wind speed of about 10-15 m/s. The diameter of the ice can reach 10-20 cm, the length of the icicles is continuous, the terrain is hilly [6].

Ice formation (ice, fluffy and crystalline frost, icy snow) can form under the following meteorological conditions:

a) at an ambient air temperature ranging from 0°C to -5°C (in some cases up to -10°C);

b) in the presence of drizzling rain (frost, fog, precipitation of supercooled rain, wet snow);

Accretion of ice, frost and wet snow pose a great danger to the overhead lines and causes:

a) disadjustment of wires and cables and their convergence with each other;

b) convergence of wires and cables during the bounce, due to non-simultaneous ice dumping;

c) an intense galloping that causes a short circuit between the wires, as well as between wires and cables, scorch of wires and cables, damage to the overhead line hardware and fixture;

d) significant mechanical overload of wires, cables and their breaks;

e) destruction of towers and breakage of the traverse.

The most important condition for an effective ice removal is timely information on the increase in ice formation and implementation of the developed ice melting scheme. Based on the research results, a program for melting ice was developed for power transmission lines №157 of 110 kV (Figure 2).

An ice on the PTL-110 kV №157, 101, 158 is melted by the short-circuit method with voltage of 35 kV with substation (SS) №151 through transformers T-1 and T-2.

An ice on the PTL-110 kV №157 was melted by installing short-circuiting on PTL-110 kV №101 and switching on the ice-melting scheme at 35 kV from SS №151 "Ushtobe" with an ice melting current of 335 A for 80 minutes. If the ice melting current deviates from the calculated data to an increase of more than 335A, the melting stops before clarification (a short-circuit may have occurred due to the sagging of the wires near the power point, by which the "short circuit" is defined) and elimination of the cause. For the shorting of three phases, a special "short circuit" made of bare copper wire of at least 70 mm^2 should be used [7].

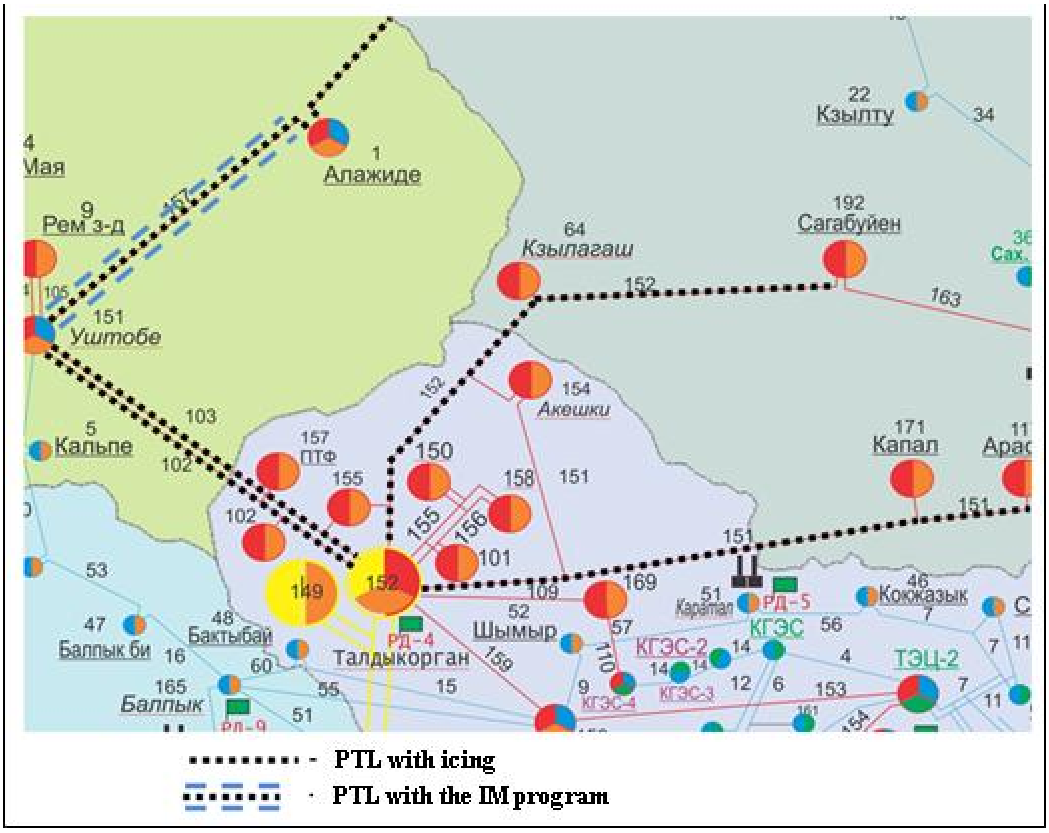

Figure 2. Fragment of the schemes of power grids of JSC "TATEK"

The personnel of the PTL were on the ice-covered section of the PTL-110 kV №157 and controlled the ice melting process. In the case of completion of ice melting, the dispatcher was immediately notified to turn off the ice melting scheme. By the scheme of power gridsSS, consumers are transferred to power from other PTL. The transmission line is put out for repair according to the urgent claim for the “short-circuit” installation, after that the PTL is put into the reserve with disconnected grounded neutralon the adjacent substations and the IM scheme for the SS-151 is being prepared. After the preparation of the IM scheme according to the program, the dispatcher includes the ice melting on the PTL-157 and informs the brigade of the PTL for monitoring the progress of the IM [8].

The location of the ice melting plant (IMP) at the substation is shown in Figure 3. The minimum current for ice melting is approximately 0.85 of admissible continuous current. Atthesametime, themeltingtimeconsiderablyincreases [9].

Figure 3 - Location of the ice melting plant at the substation

The successful melting of the ice depends to a large extent on the timeliness of the assembly of the scheme and the timing of the melting start. It is most profitable to proceed to the ice melting at the beginning of its formation, when the dimensions of the ice are small. In addition, the temperature at the beginning of the increase in the ice cover usually does not occur below -3 and -5°C. By the end of the increase in ice, often the temperature decreases, and the wind speed increases.

In the process of performing scientific research, meteorological factors of the PTL route (wind speed, humidity and air temperature), as well as structural features and characteristics of current-conducting elements (wire diameter, span length, susceptibility of wires to twisting during ice formation, etc.) were taken into account [10].

Conclusion

In the process of performing scientific research, meteorological factors of the transmission line (wind speed, humidity and air temperature), as well as structural features and characteristics of current-carrying elements (wire diameter, span length, susceptibility of wires to twisting during glaze formation, etc.) were taken into account.

In the result of the studies carried out according to the calendar plan, the melting method was chosen; a theoretical and technical substantiation was made, including a mathematical model of the wire icing process.

We assume that the research will reduce the risk of ice-and-wind accidents on power lines and increase the reliability of providing electricity to consumers.

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Түйін

Бұл мақалада мұз-желді жүктемелерде 110 кВ жоғарғывольтты желілерді пайдаланудың ықпалы жайлы сұрақтар қарстырылады. Сонымен қатар олармен күрес шаралары көрсетілген. Мұзқатуларды электр тогы көмегімен үш фазалы жоғарғывольтты желілерде қысқа тұйықталу режимінде ерітуге аса зор назар аударылды. «Талдықорғандық акционерлі транспорттық-электрожелілік компания (ТАТЭК)» акционерлік қоғамының балансындағы 110 кВ электр жеткізу желілері қарастырылған. Климаттық жағдайларға байланысты апаттардың түрлері, электрлік желілер схемаларынан үзінді, мұзқатуларды еріту қондырғысын қосалқы станцияда орналастыру орны келтірілген. Сондай-ақ мұз басқан денеден мұз еру шарттарын ескеретін математикалық модель мен сымдарда мұз шөгінділерінің салмағын анықтау формуласы, сонымен қатар электр жеткізу желілерінде мұзқатуларды қысқа тұйықтау әдісі бойынша еріту тәсілдері көрсетілген. Болашақта мұзқатуларды еріту процесстерін автоматтандыру ұсынылады. Мұзқату қауіпі мәселесін шешу Қазақстан аумағында энергиямен жабдықтауды тиімді қолдануға мүмкіндік береді.

Резюме

В статье рассмотрены вопросы воздействия гололедно-ветровых нагрузок на эксплуатацию высоковольтных линий 110 кВ. При этом приведены меры борьбы. Особое внимание уделяется плавке наледи электрическим током в режиме короткого замыкания в трех фазных высоковольтных электрических сетях. Рассмотрены линий электропередачи 110 кВ АО «Талдыкорганская акционерная транспортно-электросетевая компания (ТАТЭК)». Показаны виды аварий в зависимости от климатических условий, фрагмент схем электрических сетей, расположение на подстанции установки плавки гололеда. Кроме того, приводится математическая модель, учитывающая изменения условий обтекания обледенелого тела в процессе гололедообразования и формула для определения веса гололедного отложения на проводах, а также приведены методы плавки гололеда по способу короткого замыкания налиний электропередачи. В будущем предлагается автоматизация процесса проведения плавки. Решение проблемы снижение риска гололеда позволит эффективно осуществлять энергоснабжение территории Казахстана.

Summary

The paper discusses the impact of ice-and-wind loads on the operation of the 110 kV high-voltage lines. At the same time, measures to control are given. Particular attention is paid to melting icing with electric current in short-circuit mode in three-phase high-voltage power grids. The 110 kV transmission lines of JSC “Taldykorgan joint-stock transport and power grid company (TATEK)” are considered. The types of accidents depending on climatic conditions are shown, as well as a fragment of power grid schemes and the location of the ice melting plant at the substation. In addition, a mathematical model that takes into account the changes in the conditions of flow around the ice-coveredbody during the icing process and the formula for determining the weight of the ice deposits on the wires is presented, as well as the methods for melting ice with the short-circuit way on the transmission lines. In the future,automation of the melting process is proposed. Reduction of the risk of icing allows carry out effectively power supply to the territory of Kazakhstan.