Problems of determining ice-wind loads in the seaside zones to prevent accidents on OHLs

Y.V. GOROKHOV, Y.V. NAZIM*
Donbas National Academy of Civil Engineering and Architecture
Ukraine

SUMMARY

The report is devoted to the problem of power supply reliability on the Crimean Peninsula because of the large-scale accidents taking place in the seaside zone on the Overhead Lines connecting the electric power systems of the Crimea and Ukraine. These OHLs are strategy-important structures which provide power transmission to the Crimea. OHLs are situated in the specific environmental conditions of the Perekop isthmus and the Chongar peninsula. Accidents happened during the whole winter period of 2009-2010 on separate sections of the OHL 330 kV. The main character of the accidents was a conductor fall because of failure of conductor/clamp systems. The largest OHL failure happened at night on December 18-19, 2009 on the OHL 330 kV “Kakhovskaya - Djankoy”; 14 metallic tangent-suspension towers on the section, 6 km in length, failed.

The OHL accident rate is considerably caused by the fact that not all climatic factors over the OHL route were taken into account. There was carried out an analysis of the orographic conditions of the territory and the weather situation during the accident. There were considered the main design data of the OHL, a cascade failure of the tangent-suspension metallic towers was analyzed and the site of destruction was found out. There were investigated ice-sleet deposits on the OHL conductors and towers; design loads were determined on the base of different methods, the normative data as well as the data of the nearest weather stations for the 50-year period of observation of the climatic zoning of Ukraine and the Crimea were used as the information source to revise the microclimatic zoning. The problem of determining climatic loads on building structures has been always among those discussed by the Ukrainian scientists. During the last decade the normative base of Ukraine has undergone repeated improvements of the methods of determining climatic loads. The performed analysis made it possible to obtain more exact values of loads on OHLs of higher security.

The results obtained prove a necessity of introducing a system of the branch weather posts, with the use of the devices for efficient measurement of ice deposits. It is also expedient to observe and fix the phenomena of conductor galloping on the OHLs in the Crimea and to apply facilities for limiting icing and galloping to increase reliability of the crucial OHL sections to meet the integrity of the electric power systems of Ukraine.

KEYWORDS

Overhead Line – Icing – Galloping – Conductor/Clamp Systems – Reliability
* ksv@donnasa.edu.ua
1. INTRODUCTION

Analysis of emergency situations on the overhead power transmission lines in the Crimea for the last twenty-five years made it possible to reveal the mechanism of the most probable occurrence of accidents in the north seaside zone, namely on the sections of the power interchange “Ukraine-Crimea” along the Perekop isthmus (Zone 1) as well as on the intersection of OHLs of the Sivash bay close to the Chongar peninsula (Zone 2). At that very time these sections are the zone of higher responsibility of the OHLs as the Crimean electric networks have no their own electric energy generation in practice and are fully dependent on the United Power Grid of Ukraine. The Crimea electric power supply is put into effect by four trunk OHLs, three of them passing over the Perekop isthmus and one – over the Chongar peninsula (Fig. 1).

![Diagram of OHLs connecting the Crimea and the United Power Grid of Ukraine](image)

**Fig. 1. OHLs connecting the Crimea and the United Power Grid of Ukraine:**

This area belongs to the steppe climatic region. The region relief is flat. In spite of the proximity to the large water sources the region climate is continental, winter being warm-temperate and summer being hot and dry. Annual and diurnal variations in temperature are considerable here and that is why constant wind velocity is sometimes very fair. The average annual air temperature is +10°C. The warmest months are July and August (+22°C), the coldest months are January and February (-4°C). A continuous operation of the OHLs on potentially high wind velocities, under higher humidity in the zone close to the Azov and Black seas, salinization of the Sivash bay and the alkali lakes cause the active failure of the conductor/clamp systems and make the available circuit of the Crimea electric power supply less and less reliable and extremely sensitive to external climatic factors. An accident risk increases year after year. That is why the analysis of the accidents in this zone makes the development of measures to increase the reliability of the OHLs under rime and wind influences first and foremost.

2. ANALYSIS OF THE EMERGENCY SITUATIONS

The most large-scale accident which resulted in a cascade failure of the OHLs took place in the Perekop isthmus at night on December 18-19, 2009; two 330 kV OHLs – “Kakhovskaya-Ostrovskaya” and “Kakhovskaya-Djankoy” – became disconnected [1]. On the eve of the failure there were rough meteorological conditions in the zone: air temperature dropped up to -4°C, it was raining, sleet, hailing, the north-east wind was blowing at the velocity of 15-20 m/sec and sometimes even 25 m/sec and was directed perpendicular to the OHL. The one-sided icing on the OHL conductors was accompanied with the intensive galloping of the conductors (Fig. 2, 3).
By the inspection measurements the diameter of the icing on the conductors was as thick as 80 to 100 mm. The values of the loads on day of the disaster were 1.5-2 times larger than the ones assigned by the Rules of the Electrical Facility Arrangement [2]. Under glaze-ice and wind loads on the 330 kV OHLs “Kakhovskaya-Ostrovskaya” the conductors dropped on the ground as a result of the breakdown of the conductor/clamp systems. On the 330 kV OHLs “Kakhovskaya-Djankoy” the accident also started with the breakdown of the conductor/clamp systems on the suspension tower 310, the conductors of the phase A dropped on the crossbeam of the phase C with its further fall (Fig. 4). Dynamic influences because of the conductor fall caused a redistribution of efforts onto the towers and the fall of the adjacent towers in the neighboring spans (Fig. 5). Then a cascade propagation of the failure by the whole anchor span to the opposite directions to towers 303 and 318; as a result 14 metallic suspension towers were broken down on the section of 6 km (Fig. 6). The range of the accident can be seen in the picture (Fig. 7).
Elimination of the consequences of the accident lasted for more than two months. On January 19 and February 12, 2010, the accidents took place on other sections of the OHL on the Perekop isthmus and on the 330 kV OHL “Melitopol’skaya-Djankoy” in the zone of the Chongar peninsula. The damages were minor, but nevertheless they brought a serious threat to the Crimea electric power supply in whole because three of four OHLs were found out of work.

The main reasons of the OHL damages in the Crimea were:

- the difference of the microclimate in the zone of the accidents from the design climatic conditions along the whole OHL route; that was not taken into account before in the practice of the standardized design;
- formation of the overdesigned icing of high density, an intensive galloping of conductors, cyclic dynamic loads acting on the conductor fastener assemblies.

As the events of the winter period 2009-2010 showed a failure of a separate element of the power transmission line, even if it is a bolt, can cause a failure of the electrical power grid section and a power failure of the regions. The conductor/clamp systems removed after an accident (Fig. 8) in most cases have a gross mechanical wear because of a continuous operation in the hostile environment caused by higher humidity and saltiness. The breakdown of the components mainly occurs in the place of the largest loss of the conductor section – either in the thread segment or in the zone of the mechanical abrasion. Analysis of the rupture indicates a brittle failure because of cyclic load in galloping.
3. ANALYSIS OF THE METHODS FOR DETERMINATION OF THE CLIMATIC LOADS

In the last 10 years the normative base of Ukraine has undergone iterative improvements of the methods of determining climatic bearing loads [2-5]. Now there is an adequate volume of the statistic information of the meteorological conditions in all regions of the country which makes it possible to distribute annual maximums of the climatic bearing loads of all types (see an example in Fig. 9). But the load values designed by the Rules of the Electrical Facility Arrangement [2] are generic to some extent because of the underlying rules of rating (leveling, zoning etc.) and do not reflect the OHL features at the borders of the adjacent regions, do not take into account the microclimatic peculiarities of the area [3-4].

The data of the weather stations [5] allow to obtain more accurate values of loads [6]. Here, one can consider both the data of a separate weather station located close to the area under study and, as a rule, the information of the weather stations located within a radius of 100 km, the microclimatic zoning being used. This approach is exemplified in Fig. 10 where the micro-zoning of a part of the territory of Ukraine by the characteristic value of the wind influence on a conductor coated with ice is given.

Considering this OHL section, it is necessary to note that there is no weather station on the Perekop isthmus and glaze-ice and wind loads have not been systematically observed. To design the characteristic values of loads in any place by the technique [4] we need the observation data for some period of time. The observation data about the OHLs on the Perekop isthmus obtained by the weather stations include only those cases when the OHL failures occurred. These data were obtained as a result of the inspection observation of the failures that is why the loads calculated with the use of only this series of observations are overrunning. To obtain more specific bearing loads in this zone one has to recover the loads on the Perekop isthmus, having calculated the loads during those years when there were no observations using the observation data of the nearest weather stations. Round the Perekop isthmus there are some weather stations – the Ishun’, Khorly and Askaniya-Nova stations (see Zone in Fig. 10), – their orographic and climatic conditions are similar to each other and to the Perekop isthmus.
Comparison of the load values obtained with the use of different techniques applied to the orographic conditions of the OHL route passage showed:

- the data of the nearest single weather station do not considerably differ from the design data and are greatly lower than the values determined on the base of the microclimatic zoning of the nearest weather stations within a radius of 100 km which is conditioned by the development shadiness of the weather station Ishun’ and its null location as to the prevailing ice and wind flow;
- in respect to the given district, with regard for the absence of the meteorological watches over the Azov and Black Seas and with regard for the predominance of east and north-east winds from the Azov Sea specified in the Rules of the Electrical Facility Arrangement [2] the data smoothing allows to obtain more accurate and independent values of bearing loads on OHLs.

Here, the design results show that glaze-ice and wind loads on the Perekop isthmus calculated on the base of the observation data obtained by the weather stations, the operation experiment (the data of the inspection measurements obtained in the investigation of the accidents) being taken into account, are considerably larger that the loads calculated on the base of the operational norms.

4. ANALYSIS OF THE REPRESENTATIVENESS OF THE WEATHER STATION DATA

To estimate the radius of the representativeness of the weather station data, one should estimate the spatial distribution of the climatic loads. The spatial distribution of the climatic loads can be most exactly estimated when processing the line data of the meteorological observations. But this analysis requires an involvement of the approximating functions as a result of the non-stationarity of the measurement carried out. But one of the possible variants is the processing of the annual maximums of the weather stations [5] with the help of the mutually correlation function. As the design data are determined on the basis of the annual load maximus, correlation of the annual maximums makes it possible to find out not only a possible spatial distribution of loads along the isthmus but also to estimate the representativeness of a weather station.

On the base of some annual maximums of the data of the weather stations in the Crimea and on the South of Ukraine there were obtained the correlation coefficients [7] for the combination of some adjacent weather stations (Fig. 11), their analysis allowed to draw the following conclusions:

- the correlation coefficients (k) being 0.2 and more, the weather stations can be considered as located in the equal conditions and well enough correlative;
- the design maximums of the ice-loading even for low correlative weather stations become good-enough apparent on a large-enough territory;
- the correlation coefficients being less than 0.2, , the weather stations are low correlative or their data are non-representative.
One should pay attention to “low” and “average” level of the spatial correlation among the weather stations not only on the area of the Perekop isthmus but on the whole territory of the Crimea too. If on the south coast it is connected with the range of the Crimean mountains, in the steppe area it means a complex and unstable situation of the air motion because of the isthmus geographical features.

A tangible extent of ice-loading depending on the geographical conditions of the area, region and height of the object location above-ground level, lack of the operating observation of the meteorological situation make it necessary to create a local net of weather stations of the National Power Supplier “Ukrenergo” for monitoring the climatic parameters (in addition to the net of the weather stations of the system “Ukrhydrometeocenter”) [7].

5. GUIDELINES AS TO MONITORING ICE AND WIND LOADING

Lack of information about the start of icing, of glaze-ice loads on conductors, of wind velocity and direction result in a low efficiency of taking decision on carrying out anti-icing measurements and this, in its turn, leads to OHL accidents. Ice and wind monitoring becomes more and more widely spread to estimate the state of special structures in their operation. That is why the automated information systems of monitoring ice and wind loading on OHLs are being developed and introduced in such countries as Sweden, Finland, Japan, the Czech Republic, Ukraine, Russia and others [8-11].

Analysis of the data representativeness of the weather stations on the territory of the Crimean peninsula and in the South of Ukraine allows to optimally locating additional departmental weather stations to cover the largest area possible [7]. To obtain the information about icing and wind loads, the weather station location must meet the location of the OHLs. On the base of the results obtained there is given a planned location of the departmental automated ice and wind weather stations (AIWWS) and the radii f their representativeness (Fig. 12).

Since 2004 on the Testing area of the Donbas National Academy of Civil Engineering and Architecture (DonNACEA) we have been running the automated ice and wind weather station [7]. It was made of the complete functional units (Fig. 13) by the aggregate-block principle, each unit can be considered as a single measure integrated into a united automated system of monitoring the process parameters in real time.
The information from the measuring transducers is instantaneously represented in the graphic and table form and archived and stored. In 2005-2010 the first seven weather stations were put into operation in the Odessa, Ternopol, Khmelnytsk, Volynskiy, Ivano-Frankovsk and Lugansk regions. To be ready for the autumn-winter period of 2010-2011 there was installed the information exchange through the interface RS-485 between the AIWWS and the control stations of the power systems of Ukraine over the local information network. A positive experience of operating the monitoring system allowed to plan the installation of other two weather stations to the Perekop isthmus in 2012.

Arrangement of additional weather stations in the Crimea will make it possible to collect and take into account the annual extremums, to make measurement more exact. A timely control and adequate measures will make it possible to guarantee a no-break power supply to the Crimean peninsula. The follow-up development and introduction of this technique will allow preventing accidents like those in the 2009-2010 winter in the Crimea and to save resources for recovery works.

Besides the installation of the additional weather stations for monitoring the climatic influences, it is wise to set up the observation of galloping on the OHLs connecting the Power Grid of Ukraine and the Crimea and to use the decisions limiting icing.

The question of studying the causes of loads increase is associated with the analysis of icing on conductors. To do this, there are carried out experimental studies in the climatic chamber in the laboratory of testing building structures at the DonNACEA (Fig. 14).
6. CONCLUSION

Measures to increase the reliability of OHLs in the seaside zone are to be interconnected by some important aspects of designing and operation: a perfect assessment of climatic loads with regard for the improvement of the techniques of their determination, methods and means of monitoring; improvement of the methods of analysis and constructive decisions of the conductor/clamp systems; introduction of the automated systems of monitoring the climatic loads.

For the OHL section responsible for the energy safety of the regions there should be used additional measures for preventing emergency situations including the introduction of the schemes of melting ice on the conductors and ground wires; mounting the insulation inter-phase spacers and dampers of conductor galloping; use of limiters of icing; use of the conductors less liable to icing etc.

BIBLIOGRAPHY

[2] Rules of the Electrical Facility Arrangement. Chapter 2.5 "Overhead power transmission lines from 1 kV up to 750 kV" (Kyiv, GRIFRE, 2006).