Prevention of ice accidents on transmission lines using the location method

Kasimov V.A.[1]

[1] *Kazan State Power Engineering University, Kazan, Russian Federation*

vasilkasimov@yandex.ru

Abstract — **method realized in practice for ice coating detection on wires of overhead power lines is described in this work. Examples of location detection of ice coating on ten operating power lines are given.**

Keywords — ***power lines, locational probing, reflectogram, glaze ice on wires, ice coating detection method.***

Excessive ice coating on the wires of the overhead power lines (OPL) results in their breakage and damage of their structure. Timely detection of ice deposits on wires of power lines for prevention of any emergencies caused by ice coating is an urgent task for electricians and power engineer all over the world.

One of the methods for early detection of ice coating on wires of power lines is a location method, which is developed at the Kazan State Power Engineering University (KSPEU) for almost 25 years long [1–8], starting since 1995. This method is unique and it has no analogues in the world practice according to the information search with a depth of 50 years.

The locational probing method consists in applying of a pulse signal to a controlled line and determining of time spent on its propagation along the wire in the forward and reverse directions after its reflection from any irregularity of the line impedance (hereinafter referred to as - irregularity) that is present on it. Irregularities are high-frequency stoppers, points of connection of branches to the power line, points of connection of overhead lines with cable insertions, ends of lines or branches from them.

The locational complex shall be connected to the operating power line through a coupling capacitor and a connecting filter that ensure protection of the low-voltage locational complex against any effects of high commercial-frequency voltage of 50 Hz.

When the line is probed with a pulsed locator (reflectometer), the aggregate of the reflected pulses forms a reflectogram. In case of use of the location method for ice coating detection the information of its forming is obtained with the help of probing pulses reflected from any irregularity that is present in the power line. Occurrence of any ice coating in the line results in changes in the reflectogram.

Ice coating on the wires represents irregular dielectric, which reduces the velocity of signal propagation along the line, as a result of what an additional delay of the reflected signal $\Delta\tau$ occurs. At that, an additional attenuation with decrease of the amplitude ΔU occurs due to the dielectric losses of the electromagnetic wave energy that is used for heating of the ice coating layer. The location method allows to detect the formed ice coatings on the wires of the power lines by comparison of the time of the reflected signal propagation or their amplitudes in the presence and in the absence of ice coatings.

Decrease of the amplitude ΔU and delay $\Delta\tau$ of the reflected impulse signal relative to the reference signal is studied in the process of analysis of the locational probing reflectograms of the corresponding power line as shown in fig. 1. The wall thickness of the ice coating on the wires of the power lines is determined using these data.

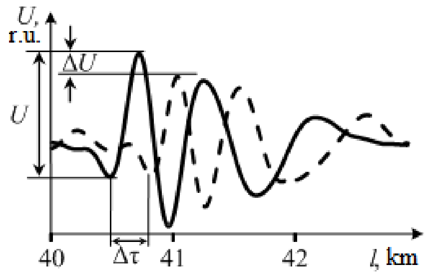

Fig. 1. Indications of decrease in the ΔU amplitude and increase in the delay $\Delta\tau$ of the reflected location signal (dashed line) relative to the reference signal (solid line)

Experimental studies of the special features of ice coating detection on power lines using the locational complexes designed and manufactured by the KSPEU employees have been carried out since 2009 for 35–110 kV lines within the areas of the Bugulma-110 and Kutlu Bukash substations (Volga region).

Figure 2 shows, as an example, 24 hour changes in the amplitude U (upper graph) and the delay $\Delta\tau$ (lower graph) of the reflected pulses in the 110 kV line "Kutlu Bukash - Ribnaya Sloboda" during one week . When any ice deposit forms the amplitude U value and the delay $\Delta\tau$ value change synchronously, as can be seen in fig. 2 (marked with dotted dashed ovals). The use of two criteria U (or ΔU) and $\Delta\tau$ increases the reliability and the accuracy of ice coating detection on power lines.

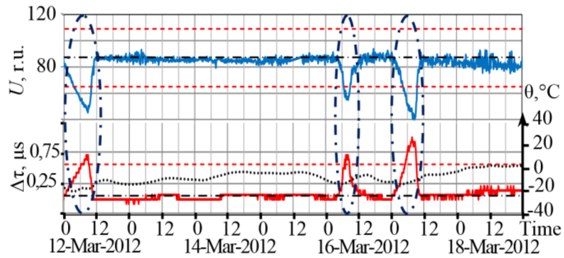

Fig. 2. Daily bases change of amplitude U (top) and the delay $\Delta\tau$ (lower graph) of the reflected pulses of 110 kV power transmission line "Kutlu Bukash-Ribnaya Sloboda"; ovals designated registration of ice formations

Weather conditions, changes in ambient temperature (dotted line in Fig. 2, temperature scale from the right side of the figure), wind effects, etc. can have effect on the indications of amplitude U and delay $\Delta\tau$ of the reflected pulse, in addition to ice deposits.

The method and the computer program for recalculation of the recorded parameters of locational probing were developed and tested earlier, and namely for: amplitude U and delay $\Delta\tau$ of the reflected pulses to the wall thickness of ice formations. At that, the weight of the ice coating in the span shall be calculated. When the weight of ice deposits exceeds the allowable limits, a signal is given to start melting in order to prevent a wire breakage.

Fig. 3 shows an example of calculation of the values of absolute delays $\Delta\tau$ (right axis of ordinates) to the wall thickness of ice coating (left axis of ordinates) according to the measurement data obtained for the period of 29.11 – 5.12.2012. The maximum of ice formation was observed on December 1, 2012 and this ice coating had the thickness of 2 mm, what corresponds to the delay of $\Delta\tau$ = 4.8 μs. The mass of these ice deposits did not pose a threat to the integrity of the wires of the overhead lines, so ice melting was not carried out.

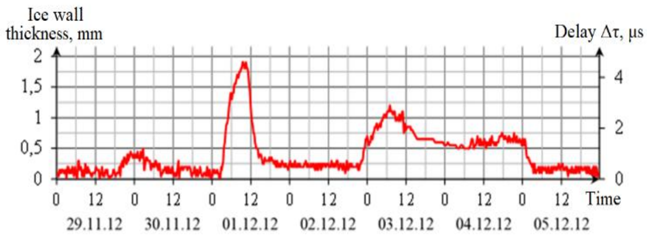

Fig. 3 Control using the location method during the period of 7 day process of building up of the ice wall thickness on the wires of the 110 kV line "Kutlu Bukash - Ribnaya Sloboda"

Today in the Bugulma-110 substation the locational complex services, in total, ten operating power lines with the length of up to 43,000 m, of them one line is for 35 kV ("Bugulma-110 – Sokolka"), six lines are for 110 kV (two phase conductors are used in two lines) and it includes one ground wire ("Bugulma-110 – Bugulma-500").

The layout of the controlled power lines relative to the substation "Bugulma-110" is shown in Fig. 4.

Fig. 4. Layout of the seven power transmission lines of the Bugulma-110 substation controlled by the location complex

Location complexes allow to control up to 16 lines outgoing from one substation. But since the power lines have different lengths, then the parameter "specific delay" shall be used for comparison of the data on delay of the reflected signals received in response to them.

$$\delta\tau = \Delta\tau / l,$$

where $\Delta\tau$ – value of the signal delay when passing along the line, l – length of the line.

Figure 5 shows the results of $\delta\tau$ registration during January 2019 for 10 operating power lines outgoing from the Bugulma-110 substation. The time intervals when ice coating was formed on the wires of the controlled power lines are indicated with dashed ovals.

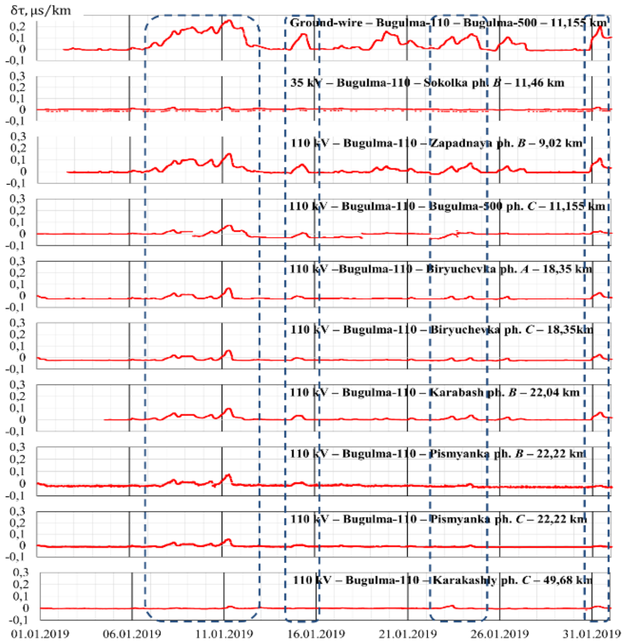

Fig. 5. An example of the change in the specific retardation $\delta\tau$ of reflected location signals in the formation of ice sediments on the monitored lines of the Bugulma-110 substation (information from the operator interface screen)

The analysis of the results of observations for the period from January 7, 2019 to January 13, 2019 according to fig. 5 shows that ice coating is intensively formed on the power transmission lines located in the southwestern part of the Bugulma region (the Bugulma-110 – Zapadnaya line, the Bugulma-110 — Bugulma-500 line). Less intensive ice formations are observed in the northwestern part of the Bugulma region (the lines "Bugulma-110 – Biryuchevka", "Bugulma-110 – Karabash", "Bugulma-110 – Pismyanka"). At the same time, ice deposits are practically not detected in the eastern part of the Bugulma region (line "Bugulma-110 – Karakashly").

Based on these data, we can assume that the intensity of the ice forming flow decreased with its movement from the south to the north of the Bugulma region. At that, when the ice forming flow moved it did not affect the eastern part of the Bugulma region.

Based on the analysis of the results of the current multichannel measurements (Fig. 5), we can objectively determine the line where the ice deposits are maximum for today. At the same time knowing their intensity, it is possible to assess the degree of the threat of a possible emergency with a breakage of the wires in the power lines and promptly determine the priority of ice melting taking into account its weight on them.

CONCLUSIONS

The location method allows reliably to monitor in real time the dynamics of ice formation on the wires, it allows clearly to determine the point of start of the required melting of ice deposits for prevention of wire breakage in the power lines and the resulting customer curtailment of electric power. The method allows to monitor the effectiveness of ice melting and it makes it possible to determine the time point of its timely stopping when the danger of line damage and wire breakage disappears. Optimization of the period of time for ice melting assists in energy saving and allows to save considerable financial resources, since ice melting requires high and costly power consumption.

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