Analysis of radar equipment readings and weight sensors indications during ice deposits detection on power transmission lines

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***Abstract*: The possibility of two methods of ice deposits detection on power transmission lines are being described here, their advantages and disadvantages are being reted. In particular results of measurements of existing overhead power transmission lines, the advantages of radar method to detect ice deposits over strain sensors method.**

Keywords: overhead power transmission lines, ice on wires, method of strain sensors, method of radar detection of ice, measuring technique, comparative experiments to detect icing and melting, advantage of radar detection method of ice.

LEGEND AND ABBREVIATIONS

PTL *Power Transmission Lines*

Control of icing on power transmission lines now a days are carried out by two methods: the method of strain sensors and radar sensing method.

The method of weight sensors is based on comparing the weight of the wires in a passage in absence and presence of ice deposits. The value of wire tension is determined by ice load, wind, as well as ambient temperature. Assessment of the stress state of the wire and comparing it with the maximum permissible value, are carried out with strain sensors. The sensors detect the weight of glaze deposits close to one pillar, their data is transmitted to the receiving station using means of remote control.

In radar sensing method locator pulses are fed through the control line and determined the time to get reflected signal. Locator pulses are fed into power line through coupling filter and coupling capacitor in presence of high frequency line trap. Amplitude U reduces by increasing the absorption of electromagnetic energy, and delay $\Delta\tau$ increases by reducing the speed of impulse propagation [1, 2] for reflected radar pulses in case of ice formation.

The technique of converting values of reflected pulse amplitude and delay into equivalent weight of ice deposits on wires was developed. This technique allows us to compare the results of measurements obtained by location and weight methods on a comparable basis by weight ice deposits.

Experimental studies to detect ice on power transmission lines with radar systems developed by employees of KSPEU, carried out since 2009 in substations “Bugulma-110” and “K Bukash” (the Volga region). From 2012 prototype radar complex, designed and manufactured by employees of KSPEU together with employees of JSC “Scientific-industrial enterprise “Radioelektronika” named after V.I. Shimko” ordered by JSC “Federal Grid Company of Unified Energy System”.

Comparison of data obtained by radar sensing method and by strain sensors have been carring out since 2013 in areas of substations “Baksan” (North Caucasus) and “Shkapovo” (the Urals). The complexes operate continuously in an automatic sensing mode and transmit data every 30 (60) minutes to the control center of KSPEU.

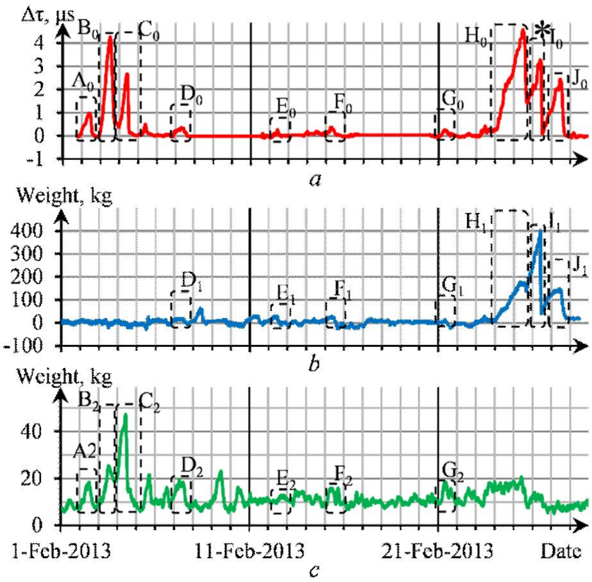

Figure 1. Comparison of registrations ice deposits on line 330 kV (North Caucasus): *a* – by radar sensing (measured delay Δτ); *b*, *c* – by strain sensors method (measured ice weight P in one passage); registration ice formations are marked by dashed ovals; * – the beginning of ice melting [1.02-28.02.2013]

Figure 1, *a* shows the changes of reflected pulse during time delay $\Delta\tau$ for sensing 330 kV PTL (North Caucasus) with radar complex, developed in KSPEU.

In Figure 1, *b*, *c*, corresponding readings P of strain sensors located at distances of 1.3 km (pillar number 243) and 29.3 km (pillar number 134) from the beginning of the 330 kV line are shown.

As shown in Figure 1, *a* by radar data, a large ice formed on the line 2.02-4.02.2013 caused maximum pulse delay $\Delta\tau_{max}$ = 4.5 ms.

Close to pillar number 243 on line 2.02-4.02.2013 ice was not detected by strain sensors (Figure 1, *b*).

On pillar number 134 (Figure 1, *c*) on line 2.02-4.02.2013 ice of maximum load P_{max} = 40 kg was detected by strain sensors.

In the interval 5.02-23.02.2013 (Figure 1, *a*, *b*, *c*) shows a small quantity of ice while using radar method (D_0, E_0, F_0, G_0) and strain sensors method on pillar 243 (D_1, E_1 F_1, G_1) and on pillar 134 (D_2, E_2, F_2, G_2).

Following cases of large ice deposits was observed during the period of 24.02-27.02.2013. According to radar sensing (Figure 1, *a*) ice deposits on line peaked at midday of

25.02.2013 (H_0) with $\Delta\tau_{max}$ = 4.5 ms. Then in some sectors ice was fallen down, and again the growth of ice continued til midday of 02.26.2013 (I_0) with $\Delta\tau_{max}$ = 3.3 ms. At this time ice began melting (Figure 1 and indicated by an asterisk). Throwing of ice deposits as a result of the melting occurred in the afternoon of 26.02.2013. However, growth of ice deposits lasted until noon of 27.02.2013 (J_0) with $\Delta\tau_{max}$ = 2.5 ms. Then there was a natural ice deposits throwing occurred and the line returned to its staffing condition.

According to strain sensors data, on the pillar number 243 (Figure 1, *b*) ice deposits gradually increases until it melts in the afternoon 02.26.2013 (I_1). After melting ice deposits slowly continued to increase (J_1). Then, in the afternoon of 27.02.2013 deposits disappeared naturally.

As seen from a comparison of Figure 1, *a*, *b* the overall dynamics of the ice deposits formation in both registrations are the same. But there are differences in details, as radar sensing monitors the entire line and strain sensors monitor only one flight line.

Comparison of sensors readings on pillar number 243 and number 134 in Figure 1 *b*, *c* show ice deposits, detected by the sensor on pillar number 243, is not detected by the sensor on pillar number 134 (and vice versa) due to uneven deposition of ice.

In radar sensing all resulting ice deposits A_0 – J_0 are fixed precisely without loss (Figure 1, *a*).

Comparative experiments were performed to detect ice deposits in winter 2013-2014 on 110 kV PTL (Urals).

Figure 2 is a graph of weight changes of ice on wire phase *A*, obtained by using radar sensing techniques (Figure 2, *a*) and by the strain sensors, which are mounted on phase conductors *A*, *B* and *C* close to pillar number 23 (Figure 2, *b-d*).

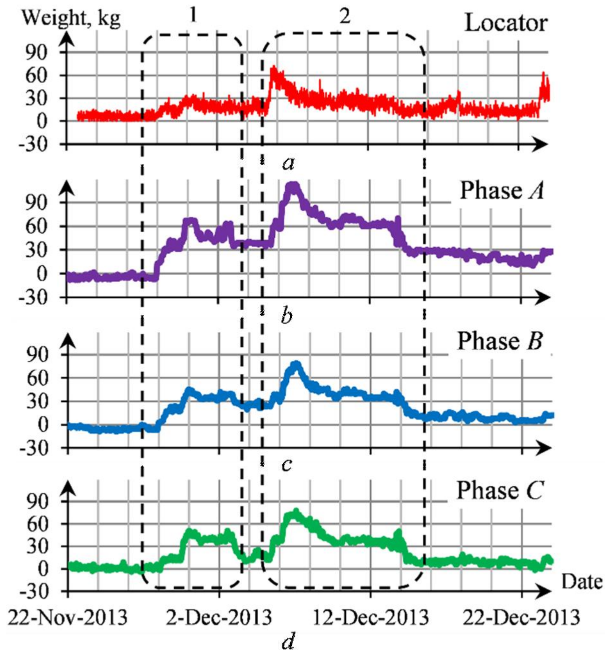

Figure 2. Changes ice deposits weight according to radar device connected to phase *A* (*a*) and according to strain sensors on phases *A*, *B* and *C* (*b-d*) on wires of 110 kV line", where the dashed outline 1 - period 28.11-4.12 2013 .; 2 bar loop - 5.12-15.12.2013 period of [22.11-23.12.2013]

Figure 2 shows how formation of ice deposits began with increasing weight on all three phases on 28.11.2013 (dotted outline 1). According to strain sensors on 30.11.2013 on the wires of the three phases was observed 45-65 kg ice deposits in one passage (Figure 2, *b*, *c*, *d*).

Corresponding readings of radar method, figured out by using modal theory of high-frequency signals propagation through overhead lines, give a figure about 30 kg for a single span (Figure 2, *a*).

The discrepancy reading of radar method and strain sensor method prove the fact that the distribution of the ice along the power line was uneven, i.e. in areas not monitored by strain sensor icing can be less than the place close to pillar number 23 where strain sensor is mounted.

The second period of icing began 5.12.2013 (dashed circuit 2 in Figure 2). According to the sensor reading of wire of phase *A*, were the most susceptible ice deposits. In the two half spans close to pillar number 23 ice deposits reached upto 75-110 kg (Figure 2, *b-d*). According reading of radar system average weight of ice deposits on the wire of phase *A* in one span reached upto 70 kg (Figure 2, *a*). Weight of ice deposits formation on line 14.12.2013 was shortly reduced naturally without interference and ice melting was not required.

By comparing the curves in Figure 2, *a-d* it is evident that the dynamics of wire weight changes with ice deposits during icing is detected by strain sensors as well as by radar sensing quite objectively. However, there are differences in details readings and these devices have different operating principles.

Registration of dynamics of ice deposits weight changes on 110 kV line (Ural) with subsequent melting shown in Figure 3. Intensive ice deposits on wires began in evening, 26.12.2013, the weight of ice reached upto 375-400 kg on 28.12.2014 in the same span according to readings of radar system, and strain sensors on the wire phase A.

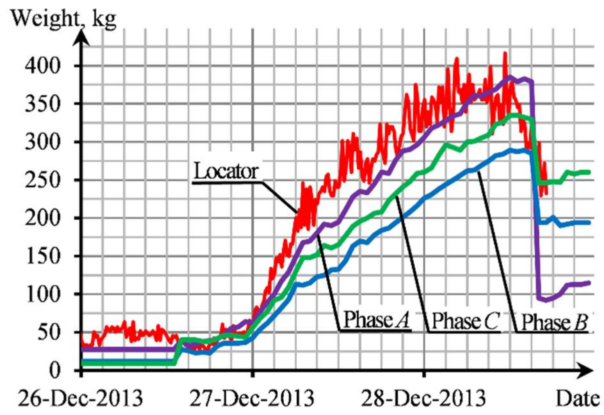

Figure 3. Changes of ice deposits weight according to radar device connected to Phase *A*, and according to strain sensors mounted on wire close to pillar number 23 of 110 kV line [26.12-28.12.2013]

To prevent accident ice melting on wires three phases line was performed. As a result of ice melting on 28.12.2013 wire weights were reduced to permissible values, as shown in Figure 3.

According to readings of strain sensors ,weight of ice deposits on phase lines do not match with each other according to absolute value, as shown in Figure 3. The same phenomenon is observed in the 330 kV line, which can be explained by varying degrees of tension when they were mounted, and all strain sensors are not with similar sensitivity. Mismatching of data of strain sensors by absolute vale mounted on different phase wires of transmission line, reduces the reliability of their redings, causes difficulty to determine the critical weight of ice deposits that can cause an accident on the power transmission lines, and causes uncertainty in taking operational decisions about the beginning of the melting of ice deposits.

Radar method can reliably monitor in real time the dynamics of icing on wires, allows clearly identifying the starting time of ice melting, which is necessary to prevent wire breakage on power lines. In addition, radar method allows monitoring ice melting process.

Radar method has the following advantages compared to the method of weighing conductors that are currently used in rare cases on some power lines:

1) pulse signal simultaneously serves as a sensor and a carrier of information about icing on wire, so there is no need to install separate sensors and data transmitters on wires, which would have collected data from sensors and then transmit data to control center, so is used small, simple and cheap structure of the equipment;

2) it ensures control of the entire line, not just a single span;

3) installation of radar equipment does not require intervention in the power line structure, because radar equipment is placed in the indoor substation, which increases reliability and simplifies its exploitation for operating personnel;

4) commissioning of radar equipment takes a few minutes if the power line has a high-frequency channel;

5) it is possible to monitor all lines outgoing from the substation using periodical switching.

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