Locational sensing equipment for detecting ice and damage on transmission lines

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Abstract— **method realized in practice for ice coating detection on wires of overhead power lines is described. 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.***

For reliable operation of the power lines in the conditions of ice formation on the wires of the overhead power lines continuous monitoring of the level of ice formation on the power lines is carried out for timely ice melting, what will allow to prevent any accidents and emergencies on the power lines

The employees of the Kazan State Power Engineering University (KSPEU) together with industrial partner LLC Promenergo, developed a multi-channel locational complex for monitoring of the overhead power lines with voltage of 35–750 kV for detection of glaze-ice and rime depositions and determination of the points of location of the wires damaged under their weight with indication of the distance [1–8].

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.

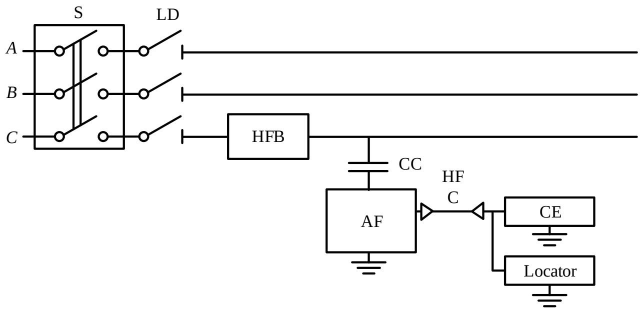

Fig. 1. Scheme of connecting a location device to a line having high-frequency processing elements: S - a switch; LD – linear disconnector; HFB- high-frequency barrier; CC - coupling capacitor; AF - the attachment filter; HFC- high-frequency cable; CE – communication equipment; Locator - locating device

In the hardware and software systems of the multi-channel ice monitoring system, the following main functional nodes can be distinguished (Fig. 2):

- locational probing equipment;
- switching device;
- a computer with a radio modem and an operator monitor;
- central server with radio modem and monitor dispatcher.

The location complex serially carries out probing of 16 power lines by sending of pulses to the line and their subsequent receiving after their reflection from the irregularities of the power line impedance, which is the end of the line. The ice formations on the wires and their damages can be detected by studying the changes in the reflectograms of the power line locational probing.

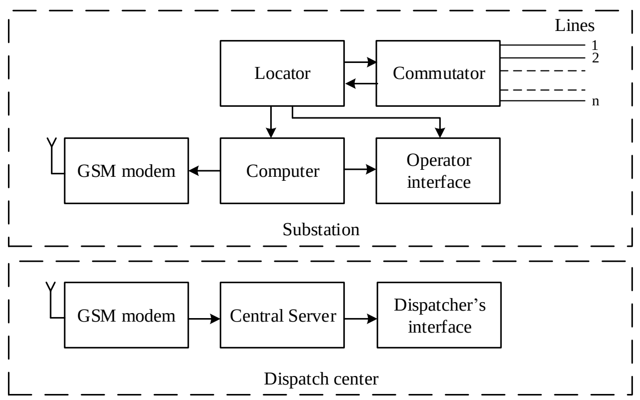

Fig. 2. Functional diagram of the ice monitoring locational complex

The principle of locational equipment operation is the following. The equipment forms a probing impulse with the preset characteristics and sends it to one of 16 connected power lines. The pulse reflects from the irregularities of the line (the end of the line, any line damage). After passing twice through the high-frequency transmission path of the power line, which is a narrow-band filter, the pulse significantly changes.

The model calculations of the pulse signal form when it passes the HF transmission line of the Kutlu Bukash - Ribnaya Sloboda line with the length of 40,800 m were carried out for determination of the tendency of the effect of the high frequency section elements of the power line.

The results of model calculations of the signal form and the corresponding frequency spectra when a rectangular pulse with a duration of 2 μs passes through the elements of the RF transmission line are shown in Fig. 3 with the normalization of the spectrum components relative to the component with the maximum amplitude.

The rectangular pulse (fig. 3, *a*) after passing through the connecting filter transforms into response (fig. 3, *b*) that is approximately similar to one cycle of a sinusoidal signal the approximate value of which is 10 μs (Δf = 100 kHz). At that, the constant component disappears, since the signal passes through the coupling capacitor, and the amplitudes of the low-frequency components (harmonics) decrease sharply, the spectrum maximum is within the range of 80 kHz. Under the influence of the high frequency stopper the spectrum maximum moves to the range of 140 kHz. After passing through the line due to its capacitive reactance the pulse shape will be smoothed, the maximum of the spectrum will be in the range of 100 kHz, and the pulse delay of 272 μs will occur that is determined using the twice passed distance of 40,800 m.

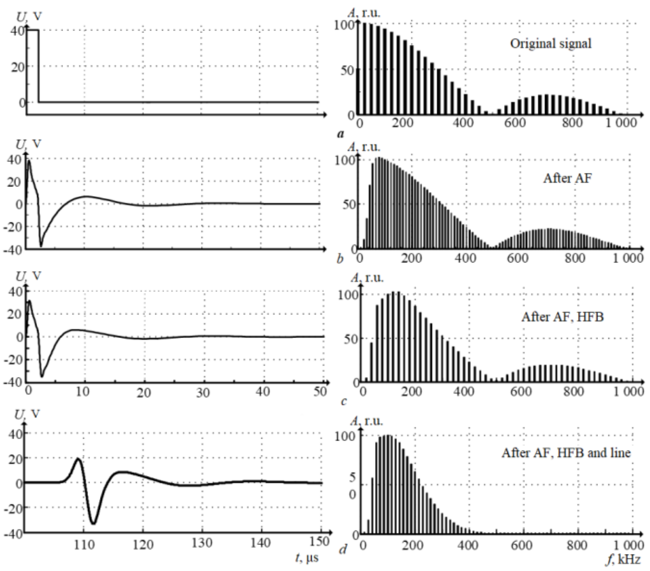

Fig. 3 Changes in the shape of a rectangular pulse signal (*a*) with the amplitude of 40 V and the duration of 2 μs (left column) and its spectrum (right column) after passing through the HF transmission line elements: *b* – connecting filter (CF); *c* – connecting filter and high frequency stopper (VS); *d*– after passing through CF, VS and the line wires

The reflected signal is received by the receiver, it is filtered and compared with the reference reflected signal that is located in the memory of the locational equipment and recorded as a result of probing of the power transmission lines under the normal operating conditions provided that there is no ice coating. Then the thickness of the ice coating is calculated using the impulse data.

Depending on the information received, the equipment generates a certain signal: “Norm” (corresponds to the normal state of the lines without ice coating) or the “Ice formation” signal (with indication of the wall thickness of ice coating) or the “Emergency” signal (in case of a short circuit or wire breakage with indication of the type of damage: short circuit or line break).

Simplified algorithm of the locational complex operation is shown in Fig. 4.

The equipment is designed using the block modular principle and it has standard dimensions of 19”× 6U × 350 mm and it is shown in Fig. 5.

The advantage of this equipment over other systems for ice formations detection and damages on the wires is its versatility, remotability, ease in installation and maintenance, low cost and small sizes. A similar equipment is effectivelly operated since 2009 in 4 Russian substantions as shown in fig. 6.

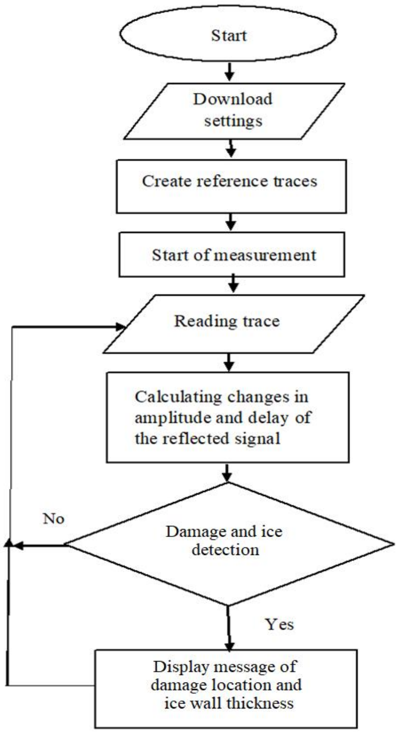

Fig. 4. Simplified algorithm of the locational complex operation

Fig. 5. Locational probing equipment

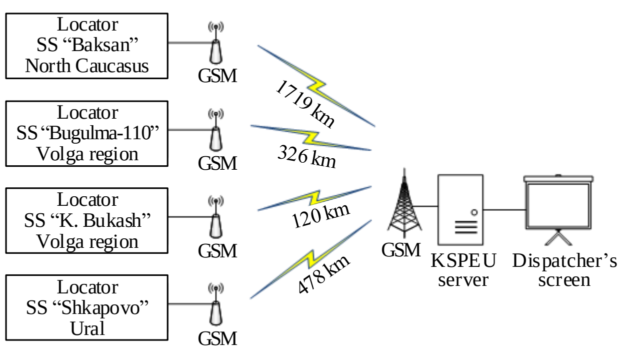

Fig. 6. Simplified scheme for transmitting the data of the local probing from control points to the KSPEU server

From each controlled substation, after their preliminary digital processing the data on the locational probing are transmitted in real time via GSM channels or the Internet to the monitors of the Center of control, collection and storage of the information that is located within the area of the KSPEU (Fig. 7).

With the help of these monitors, it is possible to monitor in real time the occurrence of ice deposits and the dynamics of their changes in each controlled substation. Based on these data and in accordance with the weight of ice deposits, it is possible to make objective decisions on the priority of ice deposits melting on the wires of the power lines.

Fig. 7. Locational complex monitors in the KSPEU Control Center

To test the locational probing equipment was developed test bench (Fig. 8). The test bench consists of two main parts: a personal computer and a transceiver of signals (Fig. 9). The transceiver is controlled from a personal computer by special program “Test bench”.

Fig. 8. Test bench for locational probing equipment

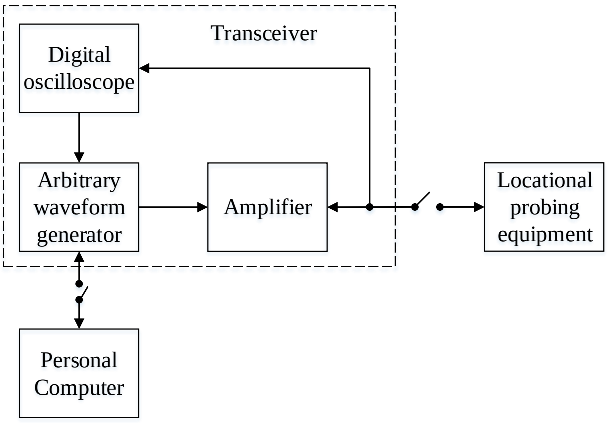

Fig. 9. Functional diagram of the test bench

This program is designed to control the transceiver, the preparation of the script checking the location complex. The main function of a transceiver is to receive a signal from a location complex and to generate a response signal that has the same parameters as the reflected signal on power lines with known characteristics.

Conduct several tests for signals, simulate different control parameters of power lines and different ice wall thickness. Similarly, tests are conducted to determine the location of damage, varying not only the characteristics of the transmission line parameters, but also the distance to the damage and its type.

After successfully conducting several tests, it is concluded that the locational probing equipment is operating normally and is ready to work on the existing transmission lines.

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