Monitoring of ice formation of overhead power line wires

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Abstract. Reliable operation of electric power systems is impossible without the creation of modern monitoring devices that control all processes of production and distribution of electric energy. The authors of the article developed an intelligent system for monitoring ice formation and determining the wire sag boom using machine vision technology. The monitoring system under consideration is placed on a support in close proximity to the wire and consists of the following main elements: an electronic unit, an optical sensor, a solar panel and a GSM antenna. The developed monitoring system in close proximity to the thickness of the ice wall and indirectly, by the angle of deviation of the wire relative to the horizontal position, to determine the mass of ice deposits and the arrow of the wire sag.

Currently, during the construction and reconstruction of power transmission lines, the routes of which run in areas with difficult meteorological conditions, are equipped with monitoring systems that control their main technical characteristics. Basically, these are systems that use strain gauges and weather stations that promptly inform dispatching personnel about adverse weather conditions. These monitoring systems have proven their high efficiency only when used together. The installation along the route of the power transmission line monitoring posts based on weather stations to warn of adverse weather conditions, but not with high probability, to assess ice conditions on the wires and lightning protection cables of the line [1]. The installation of strain gauges along the route of the power transmission line is characterized by a high cost and requires disconnecting existing power lines for the duration of installation. The task of creating new monitoring systems that control the important technological characteristics of overhead power lines installed on the considered electrical equipment without disrupting the technological process of electricity transmission, while having high quality characteristics, is relevant [2].

The authors of the article developed a system for monitoring ice formation and monitoring the sag boom of wires and lightning protection cable, based on a new detection technique, using machine vision technology. The developed monitoring system allows you to determine the thickness of the ice wall, the mass of ice deposits and the boom of the wire sag. The mass of the wire, ice deposits, if any, the sag of the wire and the lightning protection cable is determined by calculation, according to the angle of deflection of the wire relative to the horizontal position. The developed monitoring system of the considered technological parameters of the power transmission line consists of the following main elements: an electronic unit; optical sensor; solar panel; The GSM antenna is shown in figure 1. The block diagram of the considered system for monitoring the intensity of ice formation is shown in figure 2. The prototype of the device (figure 3) is assembled as a separate module, with the ability to connect several wired and wireless cameras. The electronic unit, for testing the developed algorithms and the possibility of their prompt correction, allows the connection of external devices for displaying and
entering information. It should be noted that when implementing this system for industrial operation, the size and weight of the electronic unit can be reduced many times.

**Figure 1.** Placement of the developed device on a power transmission line support (1 - optical sensor, 2 - box with electronic components, 3 - solar panel, 4 - transmitting antenna, 5 - temperature sensor).

**Figure 2.** Block diagram of an autonomous subscriber monitoring device.

**Figure 3.** Prototype of an autonomous subscriber monitoring device (there is no solar panel in the photo).
The monitoring system is mounted on a power transmission line support, and during the installation process, the line may be energized. An optical sensor is placed in the immediate vicinity in the horizontal plane from the wire (taking into account the permissible insulation distances). There can be several optical sensors, for example, with the simultaneous detection of ice on a lightning protection cable. A video camera with the ability to work at night in a special box protected from external weather conditions is used as an optical sensor. In the field of view of the video camera, there should be a wire on which the presence of ice is analyzed. The optical sensor is located in the immediate vicinity of the wire, so the resulting image of the wire is practically not affected by weather conditions.

The principle of operation of the device is as follows: with a certain frequency set by the control room, or the current temperature situation, the system visually checks the wire that falls into the field of view of the optical sensor for the presence of ice on it. In the presence of ice formation, the wire diameter will actually differ from the initial diameter, which is the reference for making a decision. The artificial intelligence system, implemented programmatically on a microcomputer, highlights a wire, a garland of insulators and an armature holding the wire against the background of the general image, determines the average wire diameter, taking into account the distance from the optical sensor to the wire, calculates the wire sag angle, sag arrow and the mass of ice deposits [3]. To make a decision on the presence of ice formation, the results of all previous measurements are summarized.

If the maximum value of the ice diameter is exceeded, taking into account the sag angle and the brand of the wire, or if the setting for the increase in the diameter of the ice on the wire (the intensity of the ice growth) is exceeded by means of a modem, information about the ice situation is transmitted to the dispatch center. Attached to the sent message is an image of a wire, the equivalent diameter of ice or wire (in its absence), the weather situation at the place of ice formation control. At the request of the dispatcher, it is possible to transmit a video stream from an optical sensor.

In addition to the device itself, an important point is the use of an adaptive artificial intelligence system that makes a decision on the presence of ice formation. This system automatically detects the presence of ice formation and the intensity of its formation, which makes it possible to reduce the volume of transmitted information and relieve the dispatching personnel from the routine work of decoding images. Detailed algorithms of the developed system, as well as the methods used for the recognition of images of a wire, insulators and supporting armature are presented in works [4].

![Figure 4. Photo of the analyzed wire fragment of the 220 kV line.](image)
The performance check developed for the monitoring system, algorithms for detecting wire, ice and supporting fittings was implemented on a huge number of photographs obtained, both with the help of the system itself, and other similar ones obtained by power engineers during the inspection of power lines. If the system detects an increase in the intensity of ice formation or an increase in the boundary boom of the wire sag, the dispatcher of the network company is sent a photograph of the analyzed wire fragment with technological information applied to it. The dispatcher can also receive the current data of the analyzed fragment of the power transmission line by sending a corresponding request to the system (figure 4). The date and time of measurement, the diameter of the wire or ice, the calculated value of the mass and the sag is attached to the photograph as technological information. Additional information is also applied to the photo, allowing to visually verify that the decision is made by the monitoring system. So, for example, in the form of straight lines in the photo, a garland of insulators, a fixing or supporting clamp, as well as the horizontal level of the wire installation and the route of the wire passage relative to the supporting clamp are indicated.

The developed algorithms are universal and allow analyzing the technological parameters of ice formation and wire sag boom for a wide range of power transmission line supports of different rated voltage classes and wires, including self-supporting insulated wires. So, for example, figure 5 shows a photo with technological information for a 0.4 kV power transmission line, obtained by the developed monitoring system.

**Figure 5.** Photo of the analyzed fragment of the wire of the 0.4 kV line.

It should be noted that the placement of the camera lens should be implemented in the horizontal plane from the place of attachment of the wire to the power line armature. If, for technological reasons, it is impossible to keep the horizontal plane of the lens placement, correction factors are introduced into the calculation, taking into account the distance to the wire and the displacement of the camera relative to the wire [5]. If the camera lens is positioned over the wire, only the wire and the string of insulators can be picked out. In this case, the system can monitor the intensity of ice formation without calculating the mass of ice and the wire sagging arrow (figure 6).

**Conclusion**
Developing a system for early detection of ice deposits on power transmission line wires and wire sag arrows, using machine vision, is a promising idea [6]. The system allows to determine with high
accuracy the presence or absence of ice formations on the power transmission line wires, and the artificial intelligence, which makes a decision on the presence of ice formation, significantly reduces the amount of transmitted information and relieves the dispatching personnel from decoding images.

The developed system is capable of determining the diameter of ice formations with a high probability of correct detection, while the error in determining the geometric dimensions is insignificant. In addition to determining the diameter of the ice formations, the weight of the ice deposits and the wire sag are calculated.

Autonomous subscriber stations are compact in size and unpretentious in service, they are able to interact with the dispatch center and adjacent points, providing timely information on the state of ice information to the dispatcher of the energy company.

The system can control the ice melting process, promptly providing the dispatcher with current information about the ice situation, controlling the diameter of ice formation and the wire sag.

It is possible to install the system without disconnecting the overhead line on any type of supports, wire brand and supporting fittings.

Figure 6. Photo of the analyzed fragment of the 500 kV line.

References
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