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Monitoring of overhead power lines in real time

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Abstract. Based on the application of quality control methods, an analysis of the technological disturbances (accidents) causes on overhead power lines with a voltage in the range from 0.4 to 110 kV AC was made. The main causes of accidents on overhead lines were systematized. The need to control the operational parameters of overhead lines that affect the sustainable functioning of electric power systems has been proved. The structure of the information-measuring system for monitoring the overhead lines parameters has been developed. The purpose of its implementation is to ensure a reliable power supply to consumers, improve the level of operational and technological control of networks and reduce the economic costs of eliminating the consequences of accidents in electrical networks.

Keywords: overhead power lines, electric power systems, accelerometer, information-measuring systems, automation, digitalization, monitoring, parameter control, reliability

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Материалы конференции
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Мониторинг воздушных линий электропередачи в режиме реального времени

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Аннотация. На основе применения методов контроля качества выполнен анализ причин технологических нарушений (аварий) на воздушных линиях электропередачи напряжением в диапазоне от 0.4 до 110 кВ переменного тока. Систематизированы основные причины аварий на воздушных линиях. Доказана необходимость контроля эксплуатационных параметров воздушных линий, оказывающих влияние на устойчивое функционирование электроэнергетических систем. Разработана структура информационно-измерительной системы контроля параметров воздушных линий. Целью ее внедрения является обеспечение надёжного электроснабжения потребителей, усовершенствование уровня оперативно-технологического управления сетями и снижение экономических затрат на ликвидацию последствий аварий в электрических сетях.

Ключевые слова: воздушные линии электропередачи, электроэнергетические системы, акселерометр, информационно-измерительные системы, автоматизация, цифровизация, мониторинг, контроль параметров, надежность

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Introduction

The current development pace of science and technology makes it possible to create conditions for the sustainable functioning of electric power systems (EPS). Network companies introduce modern types of equipment, elements, devices that have high technical and economic indicators at their facilities [1]. Also, today in a number of the Russian Federation regions there is a tendency to increase the volume of electricity consumption in rural areas. This is due to the development of agricultural enterprises, an increase in the number of consumer electronic devices, the growth of tourist bases and recreation centers. Based on the foregoing, not only the technological development of power supply systems, but also ensuring their reliability becomes relevant.

To date, the main part of the equipment in operation in rural distribution networks has a high level of wear and tear [2–4], which excludes guarantees of reliable power supply to consumers from grid organizations. The high level of accidents in the EPS, in turn, leads to significant economic costs. In view of the design, overhead power lines (OHL) are the most vulnerable elements of the EPS, which have the greatest impact on the reliability of power supply to consumers [5]. A lot of research has been directed to solving the problems of ensuring the stable functioning of overhead lines. For example, in [14], the authors proposed an intelligent system for melting ice on the wires of overhead power lines. In [15], the authors considered the use of sensor networks technology to increase the observability and controllability of overhead power lines during operation. Research [16] is aimed at applying technologies and techniques based on the radar method and ice detection equipment on overhead power lines, first introduced at electrical substations in Russia. A method for controlling wires of overhead lines by analyzing their twisting is proposed in [17]. Based on the analysis of statistical data on the causes and consequences of accidents on overhead lines, the authors propose the development and implementation of an information-measuring system for monitoring parameters that affect the stable operation of overhead lines.

Materials and Methods

When developing a block diagram of the proposed information-measuring system for monitoring the parameters of overhead power transmission lines, methods of the theory of electrical circuits, circuitry, and metrological analysis were used.

Results and Discussion

The authors analyzed the accident rate in the power grid complex [6]. Figure 1 shows a diagram of the distribution of electrical equipment damage by electrical installations types.

Based on the analysis of the damage distribution to electrical equipment by electrical installations types, it can be concluded that overhead lines are the most damaged elements of the EPS, which is about 94% of the total number of accidents. Figure 2 shows a diagram of the causes of the main accidents on overhead lines.

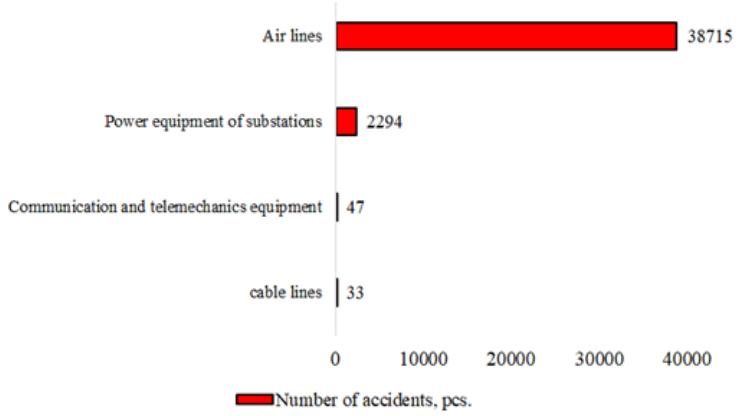

Fig.1. Diagram of electrical equipment damage distribution by electrical installations types

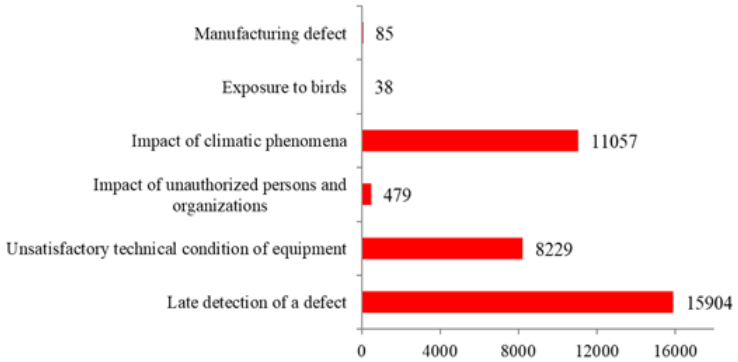

Fig.2. Diagram of the main causes of accidents on overhead lines

Based on the analysis of the number and causes of technological disturbances (accidents) in electrical networks with voltage in the range from 0.4 to 110 kV AC, the following main causes of overhead line failures were identified:

- 44.43% of the total number of accidents occur due to late defects detection;
- 31% of the total number of accidents occur due to the impact of climatic phenomena;
- 23% of the total number of accidents occur due to the unsatisfactory technical condition of the equipment due to aging, changes in the properties and the material structure.

Figure 3 shows a histogram of the percentage distribution of damage causes from the total number of accidents on overhead lines.

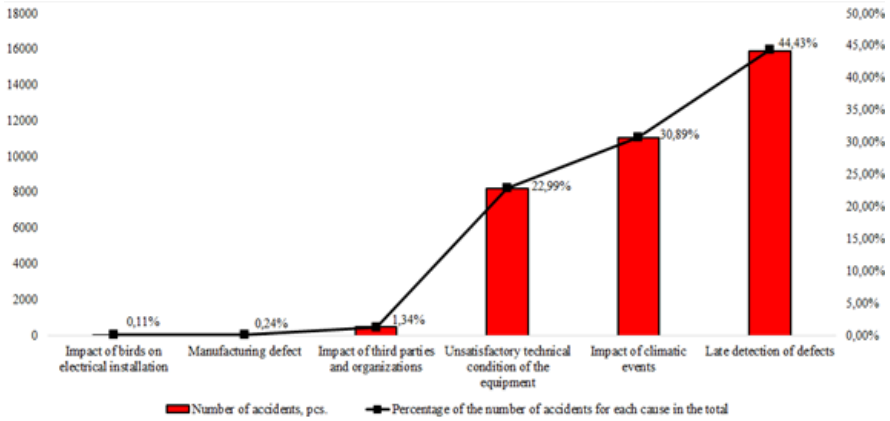

Fig.3. Histogram of the percentage distribution of damage causes from the total number of accidents on overhead lines

In order to reduce the number of technological disturbances at the facilities of the power grid complex, improve network monitoring indicators, as well as to improve the services quality provided to consumers for the transmission of electrical energy, the authors propose the development and implementation of an information-measuring system (IMS) for monitoring the overhead lines parameters.

During the overhead lines operation, the IMS monitors the parameters that affect its stable operation, namely: control of the wire sag; ambient temperature control; wind speed control. In parallel, short circuit indicators (SIC) on the line can be used to determine the overhead line operation mode and increase the network observability. Table 1 presents the characteristics of the IMS measuring channels.

Table 1

Characteristics of the IMS measuring channels

Channel name	Measuring device name	Measured value	Measurement range	Limits of permissible absolute error
Distance measurement channel	Laser distance meter	Distance	0.5–35 m	±0.1
Ambient temperature measurement channel	Hot-wire anemometer	Ambient temperature	-45–+45 °C	±0.5
Channel for measuring the wind loads speed	Hot-wire anemometer	Speed	0–30 m/s	±1
Fault location	Fault indicator	Short circuit direction	20–120 A	±1

The authors analyzed the possibility of controlling the wire sag using the following methods: 3D modeling, optical, capacitive, mechanical, frequency, thermodynamic, inclinometric. Based on the results of the analysis, a device was selected based on the inclinometric method. The device proposed earlier in [5] based on the optical method (laser rangefinder) has a number of disadvantages, namely, in terms of installation complexity and dependence on external natural factors (fog, heavy rain and snowfall). Thus, it is proposed to use the MPU-6050 device, which includes a three-axis gyroscope and a three-axis accelerometer on a single silicon chip, as well as an integrated Digital Motion Processor (DMP) as a primary measuring transducer for monitoring the wire position.

The functionality of this device allows to control the position and movement of the controlled object (overhead line wires) in space (tilt angles, trim) based on the vector of gravity and rotation speed.

Table 2

The MPU-6050 characteristics

Characteristic name	Measurement range	Unit
Supply voltage	3.7–5.5	V
Current consumption	≤ 10	mA
Maximum I2C interface frequency	400	kHz
Gyro Range	± 250 – ± 2000	deg/s
Accelerometer range	± 2, ± 4, ± 8 and ± 16	g
Data output	16	bit
Resonance frequency	27	kHz
Distance between contacts	2.54	mm
Size	20×16	mm

At the same time, the temperature is measured. When moving, linear acceleration and angular velocity along three axes are determined. The MPU-6050 chip contains two devices: an accelerometer and a gyroscope. Their data is pre-processed and transmitted via the I2C serial interface to the microcontroller. A complex of a gyroscope and an accelerometer is used to stabilize an object in a required position under external influences. The MPU-6050 device characteristics are presented in the table.

Conclusion

Improving the power supply reliability to consumers is possible through the use of the proposed information-measuring network, which includes the following measuring channels: a channel for measuring the wind loads speed, a channel for measuring distance, a channel for measuring ambient temperature, a channel for determining the location of a fault. The information-measuring system enables electric grid companies to solve a number of operational tasks, namely:

- identify defective areas in a timely manner;
- reduce the time of power supply restoration to consumers.

The IMS use is expedient in the operational maintenance and electrical networks management.

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