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Systematization and monitoring of quality parameters of overhead power transmission lines functioning

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Systematization and monitoring of quality parameters of overhead power transmission lines functioning

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Abstract. On the basis of quality control methods, the analysis of the causes of technological disturbances (accidents) on overhead power lines was carried out. In particular, the Ishikawa diagram, the Pareto diagram were developed, which made it possible to systematize the main causes of technological violations. The necessity of monitoring the indicators of the reliability of the functioning of overhead power transmission lines by means of information-measuring systems has been substantiated. The structure of an information-measuring system for monitoring parameters that have a negative impact on the functioning quality of overhead power transmission lines is proposed. The proposed system is aimed at ensuring the reliability of the electrical networks operation and improving the quality indicators of services provided to consumers for the transmission of electrical energy.

1. Introduction

In recent years, extreme weather events have resulted in a number of serious damage to overhead power lines (OHL) and economic losses. In this regard, the need to study approaches to increasing the stability of power supply systems becomes urgent [1]. For example, in [2], a method was developed for determining the technical state of reinforced concrete supports of overhead lines from the fatigue curve, taking into account additional conditions that affect the formation of defects. The work [3] proposes the use of artificial intelligence based on the Holistically-Nested Edge Detection (HED) algorithm using the Tensorflow structure and deep learning of technical vision systems. The scientific results presented in [4] are aimed at the introduction of fiber-optic technologies, in terms of distributed monitoring of the deformation of the power lines wires. A number of studies are aimed at developing models of overhead lines deformation from the impact of meteorological phenomena and at compiling models depending on the statistical adaptation of weather forecasts [5-6]. The authors analyzed the main causes of accidents on overhead power lines and developed a version of an information and measurement system (IMS) for monitoring the technical condition of power lines of distribution electrical networks of voltages in the range from 0.4 kV to 110 kV by monitoring parameters that have a significant impact on the quality of their functioning. The proposed IMS includes an intelligent information-processing unit that performs the functions of a decision support system. The introduction of this IMS at power facilities will allow promptly identifying defective sections of overhead lines, predicting emergency modes and increasing the level of technological control of power grids.

2. Materials and methods

Uninterrupted operation of electric power systems (EPS) is the most important condition for the effective development of the economy of any modern state. In turn, the uninterrupted operation of the

EPS depends on the reliability and efficiency of the overhead line [7]. The structure of the power grid complex of the Russian Federation includes trunk (voltage from 220 kV to 750 kV) and distribution (voltage from 0.4 kV to 110 kV) power transmission lines. Table 1 shows the parameters of the overhead lines of the distribution electrical networks of alternating current, which are considered in this work.

Table 1. Parameters of overhead lines of distribution networks of alternating current.

Voltage, kV	The highest transmitted active power, MW	The longest transmission distance, km
0.4	0.05-0.15	0.5-1
6-20	2-3	10-15
35	5-10	30-50
110	25-50	50-150

Based on the analysis of statistical data of Russian power grid companies, it can be concluded that, in comparison with other electric power equipment, overhead lines are one of the weakest nodes of the EPS. For example, table 2 shows the distribution of technological violations by types of electrical installations.

Table 2. Distribution of technological violations by types of electrical installations.

Type of electrical installation	Number of technological violations, pcs.
Overhead lines	38715
Cable lines	33
Power equipment of substations	2294
Communication and telemechanics equipment	47

The high level of accidents on overhead lines is due to a number of facts, one of which is external geographic and meteorological effects due to the open design [8]. Figure 1 presents an analysis of the main causes of technological disturbances (accidents) on overhead lines.

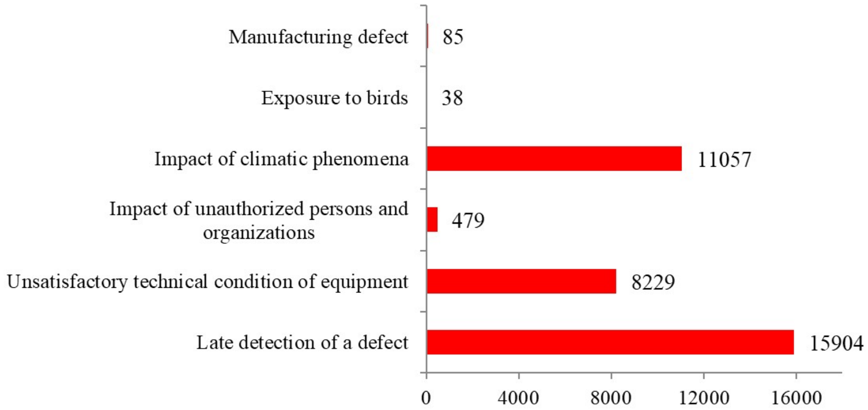

Figure 1. Analysis of the main causes of technological disturbances (accidents) on overhead lines.

Technological violations (accidents) on overhead lines have a negative impact on the quality of services provided to consumers for the electrical energy transmission. Based on the statistical data of the power grid companies of the Russian Federation, table 3 presents an analysis of quality indicators of services provided to consumers for the transmission of electrical energy in the period from 2018 to 2020.

Table 3. Analysis of quality indicators of services provided to consumers for the transmission of electrical energy in the period from 2018 to 2020.

Indicator	2018	2019	2020
Average duration of the accident, h	3.1	1.42	1.41
Number of accidents, pcs.	1743	1437	1390
Undersupply of electrical energy, kW • h	303	127	237
SAIDI (System Average Interruption Duration Index), h	2.2112	1.9975	1.8978
SAIFI (System Average Interruption Frequency Index)	1.9711	1.9007	1.7965

Based on the this statistical data, the authors set the task of the need to reduce the high level of accidents on overhead lines and improve the quality indicators of services for the electrical energy transmission provided to consumers. Thus, in order to achieve the set tasks, it is proposed to develop an information-measuring system for monitoring the parameters of overhead lines.

Based on quality control methods, Pareto diagrams and Ishikawa's causal diagram have been developed to identify the main causes of damage to overhead lines. These methods are used to assess, control and improve the quality of production processes by identifying the main reasons that have a significant impact on the reliability and quality of operation (figure 2) [9-13].

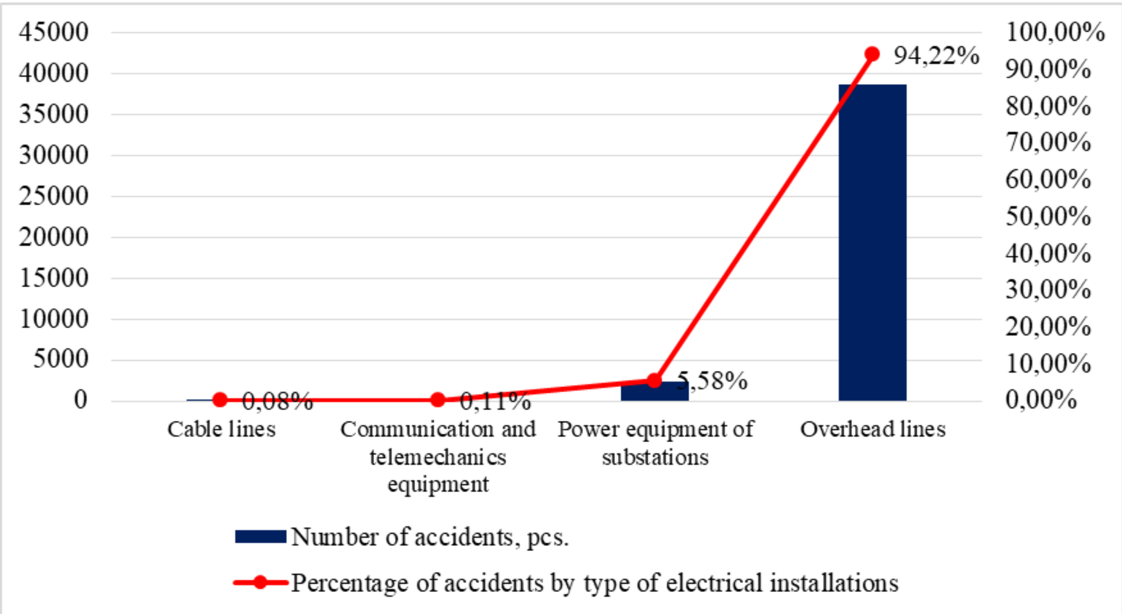

Figure 2. Distribution histogram of electrical equipment damage by types of electrical installations.

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

3. Results

Based on statistical data, Pareto diagrams were built in order to identify the main causes of overhead line failures. Figure 2 shows a histogram of the electrical equipment damage distribution by electrical installations types. Figure 3 shows a distribution histogram of damage causes percentage from the total number of accidents on overhead lines.

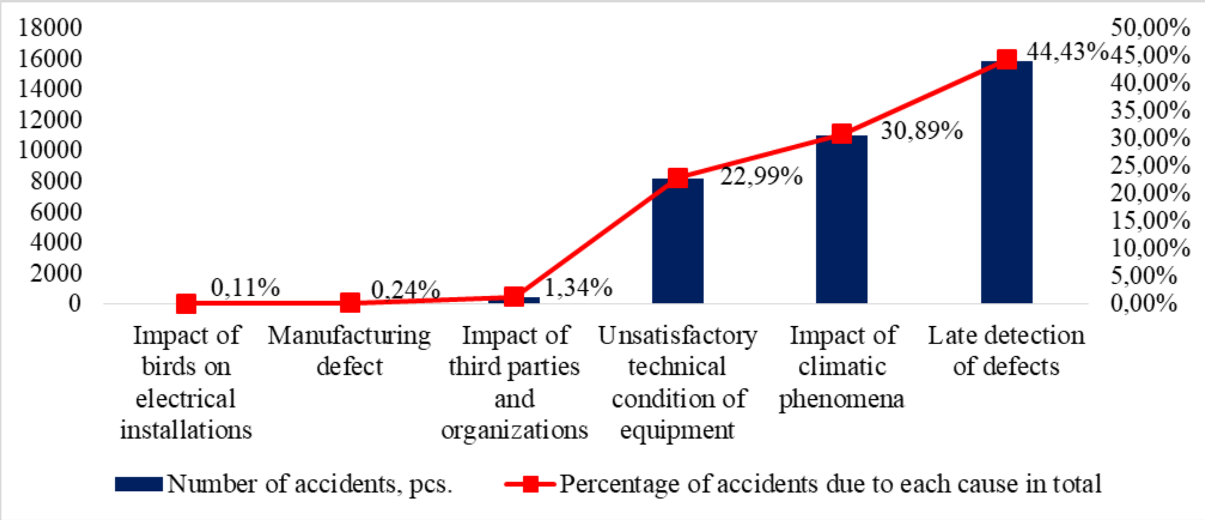

Figure 3. Distribution histogram of damage causes percentage from the total number of accidents on overhead lines.

According to the results of the analysis of Pareto diagrams, it can be seen that the main part of technological disturbances in the EPS occurs on the overhead lines (94.22%). The main causes of accidents on overhead lines are: untimely detection of defects (44.43%), the impact of climatic phenomena (30.89%) and unsatisfactory technical condition of equipment (22.99%).

To determine the main factors affecting the reliable operation of 0.4-110 kV overhead transmission lines, an Ishikawa causal diagram has been developed (figure 4), which demonstrates the influence of an unsatisfactory technical condition of equipment, meteorological influences, the influence of external (third-party) factors, untimely identification of defects for the reliability of overhead power lines operation.

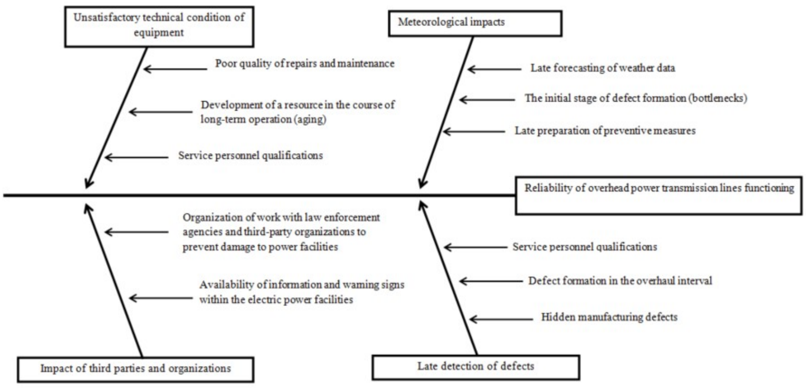

Figure 4. Ishikawa's causal diagram, systematizing factors affecting the reliable operation of 0.4-110 kV overhead transmission lines.

The block diagram of the developed IMS is shown in figure 5.

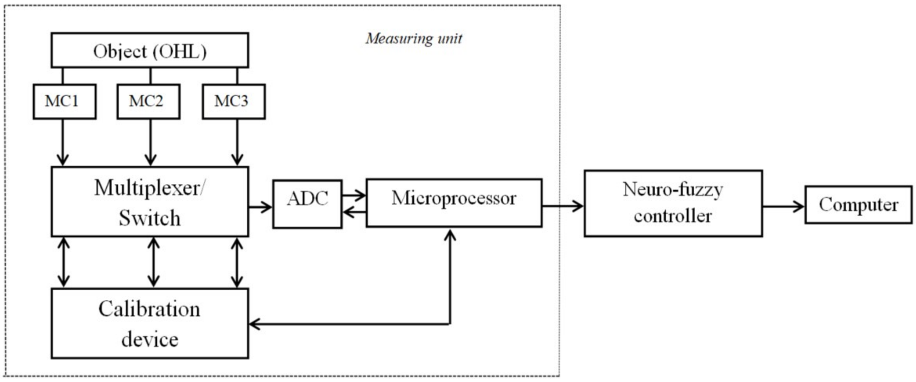

Figure 5. Block diagram of the developed IMS: MC1, MC2, MC3 – respectively, channels for measuring distances from the wire to the ground, wind speed and ambient temperature, readings of short-circuit indicators; ADC – analog-to-digital converter.

4. Discussion

IMS is implemented by installing primary measuring transducers on the overhead line wire in the place of the greatest sag (the middle of the span between the supports). Through the communication channel organized through the built-in GSM module, the information received from the measuring channels (MC) is transmitted to the dispatch center server, where it is processed using an artificial neural network (decision support system). The results in the form of signal messages are displayed on the screen of the dispatching personnel automated workstation. Monitoring of operational parameters of overhead lines is carried out in three stages: 1. Measurement of monitored values (distance from the wire to the ground, ambient temperature, wind speed, indication of the location of a short circuit); 2. Transfer and processing of information; 3. Making decisions by dispatching personnel. IMS must meet a number of requirements for it, namely: resistance to external natural phenomena; contactless power supply; notification in case of malfunctions.

5. Conclusion

Analyzed and systematized the main causes of accidents and the main factors that determine the reliability of overhead lines operation of distribution electrical networks in the range of electrical voltage from 0.4 kV to 110 kV. The structure of IMS for control of parameters influencing the reliable overhead lines operation is proposed. The use of IMS is advisable for the operational maintenance of electrical networks for information support of dispatching personnel. The introduction of the proposed IMS will ensure the reliability of the electrical networks operation and improve the quality of services provided to consumers for the transmission of electrical energy due to the timely identification of defective areas, by detecting the stage of the defect initial formation and timely preparation of preventive measures to ensure uninterrupted power supply.

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