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MODERN APPROACHES OF HIGH-VOLTAGE TRANSMISSION LINES MONITORING

Transmission lines require timely inspection and monitoring to prevent emergency situations during operation. System emergency situations as blackout are very undesirable, so they need their previous detection and prevention. Accordingly, this can be avoided by detailed monitoring the functioning of all elements of the power system. The directions of remote control for researching the operational state of electric power facilities through the use of special equipment, in particular aerial vehicles, have gained sufficient development. Possibilities of practical means of remote monitoring of power transmission lines are also considered. Due to their relatively inexpensive use and ease of operation, distant controlled aerial vehicles are an effective approach for surveying high-voltage power lines. A number of advantages of using distant controlled aerial vehicles are the extended functionality of monitoring quality provided by modern equipment. Functional analysis of modern on-board equipment indicates the possibility of detecting research objects on a real-time scale, due to the use of telemetry, satellite and combined television and thermal imaging systems, with the possibility of detailed observe. The most perspective is the use of combined heat-television systems, which allow improving the technical characteristics of the surveillance system significantly. This method provides monitoring of heat losses, detection of overheated elements of transmission lines and assessment of the performance of elements. Such technology ensures more safer and timely detection of malfunctions, threats to operation and carrying out work on their elimination. In addition, the fields of application of distant controlled aerial vehicles as surveys for the design of energy systems are increasing.

Keywords: transmission lines; high voltage; blackout; remote control; information-measuring; remotely controlled aerial vehicle; ground control system.

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СУЧАСНІ МЕТОДИ МОНІТОРИНГУ ВИСОКОВОЛЬТНИХ ЛІНІЙ ЕЛЕКТРОПЕРЕДАЧ

Лінії електропередач потребують своєчасного обстеження та моніторингу для запобігання аварійні ситуації при експлуатації. Системні аварійні ситуації є дуже небажаними, тому потребують передчасного їх виявлення і запобігання. Відповідно, цього можна уникнути, якщо проводити ретельний моніторинг роботи всіх елементів енергосистеми. Достатнього розвитку набули напрямки дистанційного контролю для дослідження експлуатаційного стану електроенергетичних об'єктів за рахунок використання спеціального обладнання, зокрема літальних апаратів. Також розглянуто можливості з практичних засобів дистанційного моніторингу ліній електропередачі. Завдяки порівняно недорогому використанню і простоті експлуатації, дистанційно керовані літальні апарати є ефективним інструментом для обстеження високовольтних ліній електропередач. Низка переваг використання дистанційно керованого літального апарата полягає у розширених функціональних можливостях з якості моніторингу, що забезпечується сучасним обладнанням. Функціональний аналіз сучасного бортового обладнання вказує на можливості виявлення об'єктів дослідження в реальному масштабі часу, за рахунок застосування телеметричних, супутникових та комбінованих телевізійних та тепловізійних систем, з можливістю детального обстеження. Найбільш перспективним є застосування комбінованих тепло-телевізійних систем що дозволяє істотно підвищити технічні характеристики системи спостереження. Такий підхід забезпечує моніторинг теплових втрат, виявлення перегрітих елементів ліній електропередачі та оцінку працездатності елементів. Така технологія забезпечує більш безпечне та своєчасне виявлення несправностей, загроз експлуатації та проведення робіт з їх усунення. Крім того, збільшуються галузі застосування дистанційно керованих літальних апаратів у якості обстежень задля проектування енергосистем.

Ключові слова: лінії електропередач; високовольтний; системна аварія; віддалений контроль; інформаційно-вимірювальний; дистанційно керований літальний апарат; наземний комплекс керування.

Introduction. In order to prevent emergency situations during the operation of high-voltage transmission lines, it is necessary to carry out a timely study of the functioning and survey of the technical condition. Which is essential, since malfunctions of the power system as a whole may occur. System emergency situations or blackouts are very undesirable, so they need their early detection and prevention.

The means of remote control and monitoring have gained sufficient development due to the use of special equipment [1–3], including aerial vehicles for researching the operational state of electric power facilities.

Thanks to modern digital and measurement systems for monitoring transmission lines, a method of distant control using remotely controlled aerial vehicles was proposed [4]. This technology [5] can provide safer and timely detection of faults to eliminate them.

The purpose of the article. The purpose of the article is to review modern means of distant monitoring of high-voltage transmission lines using remotely controlled aerial vehicles. The task of the work is to analyze the possibilities of obtaining information about the state of energy facilities using a method based on the use of remotely controlled information-measuring systems.

Possibilities of transmission lines distant monitoring. Ensuring the necessary measures for the functioning of high-voltage transmission lines can prevent the avoidance of a system emergency fault.

Observing high-voltage transmission lines, it is possible to detect: the presence of breaks and melting of wires or sheaths; presence of insulator's damage; technical condition of supports, fasteners and grounding devices; the presence of a spark; correct adjustment of wires; the state of protection devices on high-voltage lines.

After analyzing the specific causes of emergency situations, they came to the conclusion that insufficient functioning of protection devices, automatic generator regulation systems, deficiencies in the functioning of the equipment, and the use of the emergency protection automation algorithm can cause a system failure of the transmission lines.

In consideration of such an approach as the appliance of controlled aerial vehicles, it provides certain opportunities for remote non-contact monitoring. For instance, conducting infrared aerial photography of transmission lines elements provides faster detection of unreliable contacts, overheating of elements in each part of the line and identification of power losses sources [6].

To carry out technical maintenance with the help of photogrammetry, it is possible to test the instant condition state of transmission lines: the location and dimensions of supports; sagging wires; support for visible corrosion; wires, phase separators, dampers.

Aerial photography of the area is necessary to identify the need to illuminate natural growth near transmission lines, which poses a danger at a distance according to standards. Carry out an assessment of the possibilities of expanding the territory for the use of a high-voltage transmission lines as well. Such a video analysis allows you to study the area in detail and choose the most appropriate plan for the construction of the transmission lines.

Stages of monitoring of high-voltage lines. At the first stage of the linear section of high-voltage lines aerial surveying with a video camera installed on it using a distant controlled aerial vehicle is carried out, and the survey in the visible or infrared range is carried out. The coordinates of power lines supports and the parameters of the survey corridor are also taken into account.

At the second stage, the received data is processed using software. A three-dimensional reconstruction of electrical supports and wires is being performed.

At the third stage, an assessment of the state of high-voltage lines within spans, parameters and their characteristics is carried out: amount of sag arrow, maximum and minimum deflection; span lengths of high-voltage lines; horizontal and vertical distances from the wires of high-voltage lines to vegetation within the protection zone; longitudinal and transverse profiles of spans of high-voltage lines within the security zone with metric information; metric characteristics with reference to a digital terrain model; the actual width of the crossing within the limits of the high-voltage lines; heights and location of visible threatening separate trees and their number on the digital surface model of the protection area and also the height of which does not exceed the permissible level.

At the fourth stage, a comprehensive analysis of the received data is carried out and recommendations for the functioning of high-voltage lines are formed.

Analysis of information-measuring systems for transmission lines monitoring. The automated system of the inspection of transmission lines by remotely controlled aerial vehicles consists of two subsystems: flight control and payload. The flight control system performs mission control, signal synthesis and flight translation. Thus, the air system includes subsystems:

- ground control system, which includes the system operators;
- aerial vehicles carrying a payload;
- communication system between the aerial vehicles and the ground control system for information exchange.

The payload consists of a video transmitter, color and mobile detail video cameras.

The ground control system performs the functions of the operator’s graphical interface, displays physical parameters from the aerial vehicle’s devices and provides control of flight parameters, such as the flight route and manual control. Accordingly, the software of the ground control system is applied to perform monitoring and transfer data exchange with the aerial vehicles.

The vehicle can transport equipment and perform transmission lines monitoring functions at once. So, contemporary transmission lines monitoring system can include: a thermal infrared imaging camera to detect frayed conductors and hot spots; a video camera for observing the gaps of sagging conductors; radio frequency and acoustic detector for monitoring insulator cracks or other corona noise emissions; an ultraviolet detector for monitoring light spectrum emissions of corona or spark discharges; a high-resolution camera for taking pictures of problem elements detected by other sensors; electrostatic and additional backup electromagnetic field sensors to maintain a minimum safe distance; laser altimeter for height control; radio frequency telemetry for two-way satellite or terrestrial communication.

Navigational devices are simplified for use for transmission lines observing because the conductor itself is a known, continuous path. Flight control can be located either in a ground vehicle or in regional operational control centers.

The main characteristics of the aerial vehicles (range and flight time, range of operating altitudes, operating temperature, positional accuracy) that can be used for test of transmission lines require attention, accordingly, to the required amount of assignment [7].

To ensure detailed monitoring of selected areas of terrain in real time, as well as determination of coordinates, the payload of a distant controlled aerial vehicles [8] should contain: a satellite navigation system; devices of radio lines of video and telemetry information; command-navigation radio line devices with antenna-feeder devices; device for information and command exchange; on-board digital computing; device for storing received information.

The ability to detect objects is determined by the characteristics of the photo receiver and the optical system of the television camera. The adaptation of thermal imaging cameras allows for round-the-clock use of distant controlled aerial vehicles.

The most promising are combined heating and television systems. At the same time, the operator is broadcast a synthesized image containing the most informative parts, which allows to significantly improve the technical characteristics of the monitoring system [9].

The use of radar systems allows receiving information on a twenty-four hour basis, even in adverse weather conditions, when television or thermal imaging channels do not provide information.

The design with interchangeable modules allows to reduce the cost and to obtain the necessary configuration of the on-board equipment accordingly to specific needs.

Functional analysis of the on-board equipment configuration. The survey course device is fixed stationary at a certain angle to the aerial vehicle’s alignment axis, which provides the necessary capture zone on the terrain. The observing device can include video camera with a wide-field lens, which can be replaced or supplemented with a thermal camera, a digital photo camera as needed.

For a thorough analysis of a specific area of the terrain a detailed inspection rotary device is used. It consists of a detailed video camera with a narrow-field lens and a three-coordinate rotary device, which ensures its reversal along the course, roll and pitch according to the operator’s commands. To ensure operation in low-light conditions, a thermal imaging camera on a micro bolometric matrix with a narrow-field lens can be additionally included.

Devices of the radio line of telemetry information (transmitter and antenna-feeder device) must ensure the transmission of information in real time to the control device within the range of radio vision.

The devices of the command and navigation radio line (receiver and antenna-feeder device) must provide signal reception within the range of radio vision of remote-controlled aerial vehicles piloting commands and control of its equipment. The command information exchange device ensures the distribution of navigation commands.

The information exchange device provides the distribution of species information between on-board sources, the radio line transmitter and the on-board storage device. This device also provides information exchange between all functional devices included in the payload of the distant controlled aerial vehicles using the selected interface. Through the external port of this device, before the take-off of the distant controlled aerial vehicles, the flight task is uploaded and the pre-launch automated built-in control of the functioning of the main nodes and systems of the device is carried out.

The satellite system ensures the anchoring of the coordinates of the distant controlled aerial vehicles and the observed objects according to the signals of the global satellite navigation system. The satellite navigation system consists of one or two receivers with antenna systems. The use of two receivers makes it possible to determine, in addition to the coordinates of the aerial vehicles, the value of its heading angle.

The on-board digital computer provides control of the on-board complex of the distant controlled aerial vehicles.

The species information storage device ensures the accumulation of the information selected by the operator (or in accordance with the flight assignment) until the moment of landing. This device can be discrete or integrated with a channel for reading the stored information, which allows more detailed analysis of the information received at the time of the flight.

The built-in power supply unit provides coordination of the voltage and current consumption of the power source and devices installed on the aerial vehicles, which are part of the payload, as well as operational protection against short circuits and overloads in the transmission lines. Depending on the class of distant controlled aerial vehicles, the payload can be supplemented with various radar systems for environmental, radiation and chemical monitoring.

The distant control complex is a sophisticated, multi-level structure designed for remote drive of aerial vehicles to a given area, and, accordingly, performing the necessary functions, as well as ensuring the collection and storage of information obtained by means of remote observing [10–12].

For instance, the use of a thermal imaging camera for a remotely controlled aircraft allows obtaining thermal video recording and photo thermal images. This approach provides monitoring of heat losses, detection of overheated elements of power transmission lines and assessment of performance, for example, of solar batteries. The technical characteristics of the thermal imaging camera are such that it is acceptable for use: the weight can be about 130 g, while the range of measured temperatures is 40...160 °C, and the working height of shooting is up to 150 m.

Conclusions. According to the analysis of the conditions of occurrence of emergency situations, the conclusion follows that the main cause of a system accident may be the uncoordinated functioning of the elements of the power system. Accordingly, this can be avoided by carefully monitoring the operation of all elements of the power system.

The most perspective is the use of combined heat-television systems and radio line systems. The application of such systems allows twenty-four hours a day use of distant controlled aerial vehicle, which is a significant advantage in the present conditions.

Due to their relatively inexpensive use and ease of operation, distant controlled aerial vehicles are an effective tool for surveying high-voltage power lines.

A number of advantages of using a remotely controlled aircraft are the extended functionality of monitoring quality provided by modern equipment. In addition, the fields of application of remotely controlled aircraft as surveys for the design of energy systems are increasing.

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