System for monitoring the parameters of overhead power lines

V A Listyuhin, E A Pecherskaya, O A Timokhina and V V Smogunov

Department of Information and measuring equipment and metrology, Penza State University, Penza 440026, Russia

Abstract. The analysis of disturbances (accidents) on overhead power transmission lines and methods and means of the overhead power transmission lines parameters monitoring was carried out. It is shown that the most promising direction for ensuring the required indicators of the reliability of power supply is the development and implementation of information and measurement systems at the facilities of the power supply network complex. The structure of an intelligent information-measuring system for measuring parameters characterizing the state of wires, external factors influencing the state of power lines is proposed. The proposed decision support system will make it possible to promptly identify defective sections of overhead lines, increase the level of technological management of electrical networks.

1. Introduction

Nowadays, the overhead power lines (OHL) parameters monitoring is the most important task to ensure the reliability of power supply, which is implemented through the development and implementation of information and measurement systems (IMS). For example, in [1], it was proposed to introduce an all-optical information and measurement control system for overhead lines based on acousto-optic switching of fiber-optic cables; in [2], it was proposed to use a "smart" electromechanical system (EMS) to solve problems of operational recognition of the emergency mode of a line. Some studies are aimed at using IMS together with high-speed digital protection of transformers against short circuits in the network [3-4]. The authors have developed a version of IMS for measuring and monitoring the overhead lines state, combined with a neuro-fuzzy block of information processing (decision support), which will allow to identify defective sections of overhead lines quickly and increase the level of electrical networks technological control.

2. Requirements for the developed IMS

In order to reduce accidents on overhead lines, as well as to ensure timely maintenance and repair of power grid facilities according to the actual technical level state, it is necessary to develop an overhead lines operational parameters IMS, which makes it possible to identify defects at the stage of formation and predict pre-emergency modes under extreme weather conditions (mainly wind and ice loads).

The following requirements are imposed on the developed IMS:

- non-contact measurement method (the sensor is powered by a "parasitic" method due to the electromagnetic wire field);
the ability to measure wind speed and ambient temperature as an input device (integrated hot-wire anemometer into the device under development);
measurement results analysis using a neuro-fuzzy controller (information support for decision support);
durability to the impact of external natural phenomena.

3. The operating principle and the main parts of the IMS

The operating principle of this device is realized by measuring the distance from the wire to the ground with a laser distance sensor (rangefinder). In parallel, the wind speed and ambient temperature are measured. The measurement results in real time (online) through the module built into the GSM measuring device are transmitted to the control room, where the data is processed in the neuro-fuzzy controller. Based on the measurement results, the decision support system analyzes the data and displays the following messages on the personnel PC, characterizing the state of the controlled object:

- normal mode (horizontal wire position and the wire position, taking into account the deviation from the horizontal position when exposed to non-critical wind loads);
- the initial stage of wire misalignment (non-critical sag of the wire relative to the normal position);
- pre-emergency mode (critical sag of the wire due to possible collision with other wires and the ground);
- emergency mode (wire snagging with other wires or contact of a wire with the ground).

Figure 1 shows a block diagram of the developed IMS.

Figure 1. Block diagram of the developed IMS: MC1, MC2, MC3 - respectively, the measuring channels of the distances from the wire to the ground, wind speed, temperature; ADC - voltage-to-digital converter.

A phase laser rangefinder and a hot-wire anemometer are used as primary measuring transducers in the developed IMS. Improving the accuracy and speed of laser devices is a topical scientific and technical issue [5-6]. To date, there is a sufficient number of studies aimed at improving the metrological characteristics of laser devices designed to determine the distance. So in work [7] the principles of operation and characteristics of active-pulse television measuring systems are described, the circuit is considered and the characteristics of a high-precision laser rangefinder with a crystal light modulator are described. The measuring device proposed in [8] has high metrological characteristics, but a small measurement range (2.7 m) is a significant disadvantage of the device. Thus, the use of a phase laser rangefinder (PLR) is due to the fact that, in comparison with other types of rangefinders, PLRs have the required measurement range (up to 50 m) and a higher measurement accuracy. Thus,
PLRs meet the requirements for the developed IMS. The principle of PLR operation is based on determining the distance by comparing the phase of the modulating signal at the output from the radiation receiver (the phase of the radiation that has passed the distance to the object and back) with the phase of the reference signal (the phase of the signal at the radiation source). The distance traveled by the light wave in time $t$ is equal to:

$$l = ct,$$

where $c$ — speed of light.

During the same time, the phase of the modulated laser radiation that has traveled from the source to the object and back will change by the following value:

$$\varphi = 2\pi f_M t,$$

where $f_M$ — radiation modulation frequency.

Thus, to calculate the distance to the object, the following formula is used:

$$l = c \frac{\varphi}{2\pi f_M t}.$$

Figure 2 shows a block diagram of a two-frequency laser phase rangefinder, which implements the classical principle of operation.

Figure 2. Block diagram of a phase laser rangefinder: $l_1$ and $l_2$ — laser beam directed to and from the object; $b_1$ and $b_2$ — the number of a roughly defined range and a refined range number to the value of the required error.

At the output of the generators, two signals are generated with a frequency of $f_{1M}$ and $f_{2M}$. These signals are logically summed and fed to the laser driver, which modulates the excitation current of the semiconductor laser. Also, these signals are fed through narrow-band filters to two phase detectors as reference voltages. After reflection from the controlled object (in the case of a device under development, from the earth's surface), the phase-changed laser radiation modulated simultaneously by two frequencies is recorded by a photodetector device (PDD). The voltage from the PDD output is amplified by a broadband amplifier and fed to narrowband active filters tuned to frequencies $f_{1M}$ and $f_{2M}$. Thus, from the received signal of a complex shape, two harmonics are extracted, which are fed to the working inputs of the corresponding phase detectors. At the outputs of the phase detectors,
voltages are generated that are proportional to the phase shift $\varphi_1$ and $\varphi_2$, which are subsequently converted into a digital signal in the ADC. The digitization of the signals results in two binary numbers with the widths $b_1$ and $b_2$. The first number is a roughly determined range, and the second number is a refinement of the range to the value of the required error. To obtain the final result, these numbers are summed up into one number with the digit capacity $b = b_1 + b_2$, which will correspond to the distance to the object (with an error not exceeding the specified value).

To measure the values of wind speed and ambient air temperature in the developed IMS, a hot-wire anemometer is used, which has a remote probe with a built-in hot-wire sensor. The principle of operation of the hot-wire anemometer is based on measuring the temperature resistance of a heated thermistor cooled by an air flow. Miniature platinum thermistors are used as sensitive elements to measure ambient temperature and wind speed.

Implementation of the proposed IMS will allow: timely identification of defective areas by detecting the initial defect formation stage; to raise the level of technological management of power grid complex distribution networks; repair and maintain overhead lines according to their technical condition.

References

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