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B2 – OVERHEAD LINES
PS 2 – Latest Techniques in Asset Management,
Capacity Enhancement, Refurbishment

Full-Scale Tests for the Purpose of Verifying the Method for Determining the Boom of the Conductor Sag by the Period of its own Oscillations

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SUMMARY

Background: The efficiency and reliability of energy transmission is determined by the state of the power supply networks. Therefore, monitoring the technical condition of overhead power lines (overhead lines) allows us to solve many problems in this area and is an urgent direction. When examining power transmission lines, it becomes necessary to determine the sag of the overhead line conductor, since this is the most important parameter [1, 2, 3] and many monitoring systems are aimed precisely at determining it. In this regard, a method was proposed for determining the boom of the conductor sag by the period of its own oscillations, taking into account the difference in the heights of the suspension points. To verify the developed method, full-scale tests were carried out on 110 kV overhead lines.

Materials and methods: The method of determining the sag of a overhead line conductor by the period of its own oscillations, taking into account the difference in the heights of the suspension points, and the photogrammetry method based on photographs with reference images were used.

Results: Tests were carried out on a real overhead line, the sag of six phase conductors were measured at different ambient temperatures by two different methods-using data on the period of natural oscillations obtained from video recordings of the conductor and by photogrammetry.

Conclusions: The reliability of the developed method for determining the conductor sag by the period of natural vibrations of the conductor, taking into account the difference in the heights of the suspension points, is confirmed.

KEYWORDS

conductor sag, overhead line, overhead line monitoring, photogrammetry, natural oscillation period, conductor oscillations

I. INTRODUCTION

Climatic conditions are one of the determining factors in the calculation of the oscillatory cycles of overhead power lines (POL). This is due to the fact that the metals used in the manufacture of conductors tend to expand at high temperatures and shrink at low temperatures. Thermal expansion of conductors in the summer leads to an increase in the sag of the transmission line. In winter, during the period of low temperatures, the sag of the conductors, on the contrary, decreases. In order to prevent emergency situations, it is necessary to control the sag of the power transmission line conductor [4, 5, 6, 7, 8, 9]. A method is proposed for determining the sag of a conductor by the period of its natural oscillations, taking into account the difference in the heights of the suspension points.

II. MATHEMATICAL MODEL

Imagine a conductor in the span of an overhead line as a completely rigid monolithic isotropic structure with only one degree of freedom rotating from an axis passing through the suspension points. The overhead line sag is calculated by the formula [1]

$$f \approx 0.31T^2 \quad (1)$$

where: f – conductor dip, m; T is the oscillation period in seconds. A more detailed derivation of the formula is described in article [10]. This method is easy to implement, carried out remotely and has a low cost, in addition, to implement the method for measuring the sag, additional information about the span (span length, conductor type, etc.) is not needed, which makes the method convenient and universal for various types overhead lines, contact networks, etc. We will not dwell on the description of the method, since it is described in our publications [10, 11, 12, 13], but we will go directly to the tests.

III. LOCAL TESTS

In order to confirm the developed method, tests were carried out on a real power transmission line. The period T can measure by counting the smallest time interval for which the conductor returns to its original extreme position in which it was at the initial moment. Deviations of the conductor from its neutral position can measure with an accelerometer (analog accelerometer ADXL311). Sensors installed inside the control device (Fig. 1.).

Fig. 1. Control device of the overhead line condition monitoring system installed on the conductor

The developed method tests were carried out on the Magistralnaya power transmission line (Fig. 2.) The length of the span under study is 378.52 m, the phase conductor is AC-240/56, the difference in the heights of the points of the conductor suspension in comparison with the span length is insignificant.

In the experiment, 6 phase conductors were investigated in one span. The objective of the experiment was to determine the sag of the overhead line conductor by two different methods: 1 - using data on the period of natural oscillations obtained from the video recordings of the conductor; 2 - by the method of photogrammetry.

The first method was used to record the trajectory of the phase conductors (determining the position of the conductor in space) in the immediate vicinity, then, using the developed software (SW) [14, 15], the calculation of the oscillation period was calculated, and the sag of the conductors was calculated using the formula (1).

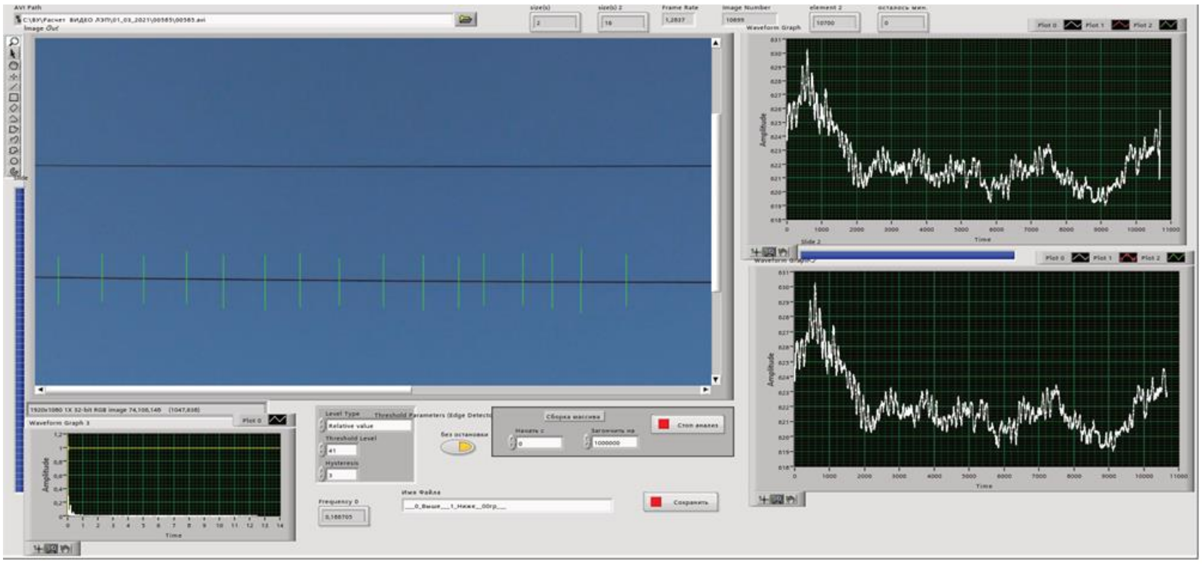

Fig. 2. The front panel of the program "Program for processing video recordings of power transmission lines in order to determine its natural frequency"

The instrumental error of the method for determining the sag of the conductor by the period of natural oscillations, using the data obtained from the video recordings of the conductor, is calculated by the formula:

$$\Delta f = \frac{f(T)}{dT} \Delta T \quad (2)$$

The maximum error in determining the sag is 0.75%. For the purpose of verification, the sag of the conductor was measured using the second method - the photogrammetry method. Simultaneously with the video recording, photographs are taken of the same six conductors in the span that the video camera is filming, but from a different angle, from which the entire span with supports is visible (Fig. 3). Determination of the sag on the photograph was carried out using the specialized software "ImageJ". The application allows you to perform complex image analysis. With the help of this program, distances from pixels were converted into meters. The calibration was carried out according to the previously measured distance between the points of the conductor suspension in the span and the known dimensions of the support, which are shown in the photograph. The maximum relative error of the photogrammetry method is 1 pixel - 0.02%. The tests were carried out from March 5 to April 14, 2021. During this period, the ambient temperature varied from -9^{o}C to + 7^{o}C. This spread in temperature made it possible to observe the change in the sag, as it decreases with decreasing temperature and, conversely, increases with increasing temperature. The results of the tests carried out are presented in the graph (Fig. 4).

Fig.3. Photo of the span with supports, date 05.03.2021.

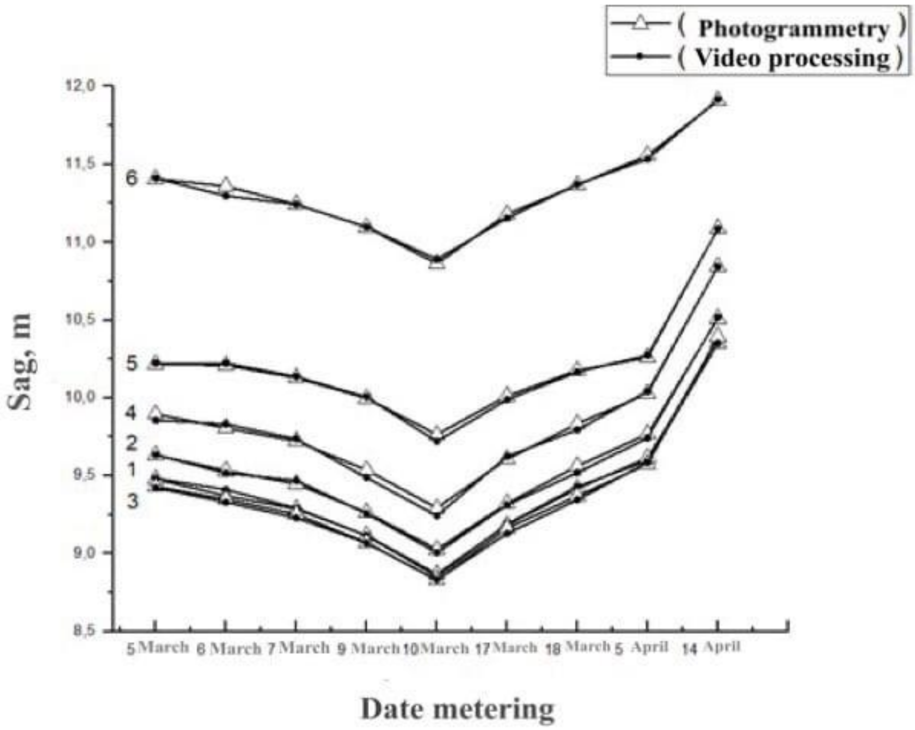

Fig.4. Comparison of the results of calculating the sag in two different ways. The numbers 1-6 indicate the conductor numbers.

IV. RESULTS

Figure 4. the results of measuring the sag of six phase conductors are presented by two methods: using data on the period of natural oscillations obtained from video recordings of the conductor; photogrammetry method, based on photographs with fiducial images. The dates sag were selected in such a way that the ambient temperature was different, since the sag is directly dependent on

temperature. The graph shows that from March 5 to March 10, the sag of the conductors decreased, as the ambient temperature decreased. On April 14 there was a high temperature of +7^{0}C, in connection with which the sag increased.

The results of two methods of measuring the sag of the conductor - by the period of natural oscillations and by the method of photogrammetry, coincide with good accuracy, within the measurement error not exceeding 0.53%. This confirms the reliability of the developed method for determining the sag of the conductor by the period of natural oscillations of the conductor, taking into account the difference in heights of the suspension points. The results can be applied in the previously developed overhead line condition monitoring system.

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