Improvement of energy efficiency of agricultural enterprises through the survey of high-voltage transmission lines using unmanned aerial vehicles

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Abstract. The paper studies the reliability of transmission lines of Michurinsk district electric lines in Tambov Region. It evaluates the quality of overhead power transmission lines in the support-insulator-wire system and determines the reliability factor of overhead lines. The paper proposes methodological approaches to the survey of power transmission lines using unmanned aerial vehicles. Their use seems quite promising and profitable, since the cost of such work is an order of magnitude lower.

1. Introduction

Stable energy supply to agricultural enterprises and organizations is the key to their effective work, and contributes to the production growth. In Russian agricultural enterprises the overhead lines (OL) with a voltage of 35 kV and above are the main lines in power transmission systems. Therefore, their defects and damages require immediate localization and elimination. The analysis of overhead line accidents shows that every year there are numerous OL failures as a result of changes in the properties of the material of wires and their contact connections (CC): wire destruction due to corrosion and vibration, abrasion, wear, fatigue, oxidation, etc. Besides, every year the number of damage to porcelain, glass and polymer insulators is growing. These factors lead to interruptions in the electricity supply, disruption of agricultural equipment and its maintenance periods [1-3].

2. Materials and methods

The operation of power transmission lines causes wear and tear of OL elements. Annual inspections, diagnostics of elements, fire hazard monitoring, thunderstorm monitoring and surveys during ice formation are performed for timely repair of faults and the adoption of corresponding measures at the overhead lines. Usually, direct inspection of each site is carried out by workers, which requires a lot of time and money. The use of unmanned aerial vehicles may reduce costs.

One of the decisive factors of the inspection is the detection time. Inspection using unmanned aerial vehicles (UAVs) will reduce the time to detect the causes of the OL shutdown by determining and evaluating the totality of data received from photo, video, thermal imaging equipment installed on the UAV. The unmanned aerial vehicle (UAV in common terms is sometimes called a “drone” (derived from English drone) is an aircraft without personnel on board. It is designed for aerial survey of surface facilities, observation and other tasks in real time [4].
The tasks of electrical equipment diagnostics may be solved through thermovisional inspection. The purpose of thermovisional inspection is to reduce the volume, duration and cost of repair works, increase the periods between repairs and improve the reliability of the power supply system due to the detection of local defects. Infrared control carried out with the help of modern highly sensitive handheld thermal viewers [1, 5] allows checking the reliability of the monitored object at a minimum financial cost, in a short time and without disabling the equipment, detecting defects at an early stage of their development, reducing maintenance costs by predicting the time and scope of repair works [6].

Currently, thermovisional inspection mainly sets the task of identifying areas of local thermal overheating due to potential defects, and when they are detected, the task is considered completed. This narrows the scope of thermovisional inspection and does not make it fully utilized.

It is possible to turn thermovisional inspection into a full-fledged method of technical diagnosis using unmanned aerial systems, as well as using computer technologies to process the results of such surveys. This paper is devoted to this field of study.

The DJI Inspire 1 2.0 quadcopter is used to survey the overhead power lines, which is controlled remotely using the corresponding program on a tablet. The quadcopter is a helicopter-type unmanned aerial vehicle with four supporting screws located at the corners of a flying platform (Fig. 1). Electric motors, which receive power from on-board accumulators, rotate the screws. The quadcopter is equipped with an autopilot capable of receiving GPS and GLONASS signals, which allows it navigating in space and operating flights with high accuracy along given routes. The flight route and flight parameters are recorded in UAV memory unit.

![DJI Inspire 1 2.0](image)

**Figure 1.** DJI Inspire 1 2.0

The quadcopter makes a survey of an object from a distance of up to 500 m (in some cases, the distance to the object may be reduced to the minimum permissible). Besides, the quadcopter helps to perform thermal imaging. Flight duration – from 18 minutes at normal weather conditions.

| Model               | T601                        |
|---------------------|-----------------------------|
| Weight (including a battery) | 2935 g                     |
| Max Ascent Speed    | 5 m/s                       |
| Max Horizontal Speed| 22 m/s (ATTI mode, no wind) |
| Max Service Ceiling Above Sea Level | 500 m                   |
| Max Flight Time     | About 18 min                |

**Table 1.** Specifications of DJI Inspire 1 2.0.
Zenmuse XT suspension with a thermal imaging camera is used for thermal imaging analysis of the overhead power line. The suspension, equipped with a camera from FLIR, is designed to conduct aerial observations in the infrared range. Table 2 shows its specifications.

**Table 2. Specifications of Zenmuse XT ZXTB19SP**

| Thermal Imager                  | Uncooled VOx Microbolometer |
|--------------------------------|-----------------------------|
| FPA/Digital Video Display Formats | 336 × 256                  |
| Temperature Range              | From -40° to 550°C          |
| Dimensions                     | 103 mm x 74 mm x 102 mm     |
| Weight                         | 270 g                       |

1 – Gimbal Connector; 2 – Pan Motor; 3 – Tilt Motor; 4 – Lens; 5 – Micro SD Card Slot; 6 – Camera; 7 – Roll Motor.

Figure 2. Zenmuse XT gimbal with thermal imager

Thermal imaging from the minimum safe flight altitude of the UAV makes it possible to clearly see transmission lines, large metal structures, dirt and asphalt roads, reservoirs, trees and shrubs. This allows evaluating the state of insulators and wires in the network under voltage by temperature in real time. In case of integrity failure or closure, the conductive elements and insulators will be heated.

3. Results and Discussion

Photogrammetric plotting was carried out using special software, which allows obtaining a digital terrain model (DTM) of the power line passage [6-8]. 3D models of power lines elements were created and measurements of distances from the design position of wires to the surface of the earth, structures, and wood-bush vegetation were made using the DTM tool. Shooting of power transmission elements using a DJI quadcopter equipped with a miniature camera from a distance of 5-30 m made it possible to inspect the upper elements of the nearest power transmission line support without disconnections.

Aerial photography of 35 kV overhead power lines was carried out on the territory of Michurinsk district belonging to the branch of IDGC of Centre PJSC – “Tambovenergo” Michurinsk District Electric Networks. The flight zone has the following coordinates:

1) 52°56'27.5"N 40°30'02.8"E
2) 52°56'26.6"N 40°29'59.5"E
3) 52°55'56.9"N 40°30'19.8"E
4) 52°55'57.4"N 40°30'15.0"E
5) 52°55'40.4"N 40°29'36.8"E
6) 52°55'42.3"N 40°29'34.6"E
The received images were processed in Agisoft Photoscan. The first step is to add photos (Fig. 3) to the project (Process/Add photos). Photos (cameras) are located on the diagram according to the image metadata (GPS coordinates) from the EXIF photo.

![Figure 3. Photograph from a quadcopter.](image)

The lengths of power lines are determined with sufficient accuracy according to the designed orthophotomap (Fig. 4).

![Figure 4. Orthophotomap with power transmission line (35 kV).](image)

Let us give some examples of thermal images shown in Figure 5 processed with Flir Tools. Flir images are stored in *Jpeg radiometric format on the memory card of the device. Their transfer to a personal computer and further processing requires certain actions.

The measurement results were processed according to [4, 5, 7].
Figure 5. Thermal image of 35 kV power line support with temperature distribution schedule on insulator surface.

4. Conclusion
Thermal imaging monitoring of power transmission lines made it possible to obtain unique photo and video materials to assess and analyze the overall state of the overhead power transmission line as soon as possible, and subsequently analyze and determine defects, deviations of wires and insulation from permissible standards.

The practical use of the software will increase the efficiency of thermal imaging diagnostics of power supply devices, develop sound management decisions based on thermovisional inspection, identify factors affecting the damage to electrical equipment, and increase the reliability of power supply systems.

References
[1] Yuan H, Liu Z, Cai Y, Zhao B 2018 Research on Vegetation Information Extraction from Visible UAV Remote Sensing Images 5th International Workshop on Earth Observation and Remote Sensing Applications 8598637
[2] Chunsen Z, Qiyuan Z 2018 Research on Volumetric Calculation of Multi-Vision Geometry UAV Image Volume 5th International Workshop on Earth Observation and Remote Sensing Applications 8598608
[3] Gandhi D A, Ghosal M 2018 Novel Low Cost Quadcopter for Surveillance Application Proceedings of the International Conference on Inventive Research in Computing Applications 8597391 412-414
[4] 2016 Guidelines for the use of unmanned aerial vehicles for the survey of overhead transmission lines and power facilities (St. Petersburg: PJSC FNC UES) 96 p
[5] RD 34.45-51.300-97 “Scope and standards of electrical equipment testing”
[6] 2008 State Program for the Safety of Civil Aviation Aircraft. Retrieved from: http://www.ato.ru/content/gosudarstvennaya-programma-obespecheniya-bezopasnosti-poletov-vozdushnyh-sudov-grazhdanskoy.
[7] Kozhanov N Y 2016 Promising methods of processing specific data flows to improve the effectiveness of UAV application Reports and articles of the annual scientific and practical conference “Prospects for the development and use of unmanned aerial systems” (Kolomna) 274 p
[8] Astapov A Yu, Prishutov K A, Krivolapov I P, Astapov S Yu, Korotkov A A 2019 Unmanned aerial vehicles for estimation of vegetation quality Amazonia Investiga 8(23) 27-36