Inspection of high-voltage lines using unmanned aerial vehicles

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Abstract. The paper considers the possibility of using unmanned aerial vehicles for the inspection of overhead power lines in climatic conditions of the Far North. The potential of using unmanned aerial vehicles for the control and diagnostics of power lines is considered. Some examples of unmanned aerial vehicles and their technical specification for the inspection of overhead power lines are given. A comparative technical and economic analysis of the use of unmanned aerial vehicles by applying traditional methods of inspection of overhead power lines is performed.

Keywords: inspection of overhead power lines, high-voltage power lines, unmanned aerial vehicles.

1. Introduction
The climatic zone of the Far North is characterized by a long winter with much snow lasting from 240 to 270 days. The height of the snow cover varies from 35 to 60 cm. One of geographical features of the Far North in a short summer period is a large number of unfrozen rivers, lakes, marshes, and bays [1]. Maintenance of overhead power lines in the Far North is a complicated organizational and technical system of measures, one of the components of which is periodic inspection of overhead power lines [2].

According to the current rules [2], engineers and technicians should inspect the lines in order to identify defects in their parts and structures at least once a year in order to schedule the maintenance and repair. In winter and summer, visual inspection of high-voltage power lines without the use of special equipment, taking into account the geographical and climatic features of the Far North is very laborious or even impossible. The following technical solutions for visual inspection are suggested: marsh buggies "TRAKOL", "GAZ 71", in some cases airbrush inspection using helicopters and aircraft is used, which entails additional costs for fuel, rent or depreciation of equipment, as well as salaries for the driver of special equipment or the pilot.

2. Problem Statement
Maintenance of overhead power lines in the Far North [2] requires inspection of lines in order to identify defects in their parts and structures. Inspection of overhead power lines is a complex and time-consuming process. In accordance with the requirements of the current rules and regulations, the scope of work required and mandatory when performing inspections of overhead power lines includes [3]:
- overhead inspection;
• extraordinary inspection after natural disasters or the impact on the line loadings exceeding the estimated ones;
• checking the distance from the wires to the surface of the earth and various objects to the crossed structures;
• measurement of arrows SAG wires and lightning cables, distances between wires and from wires to the support elements;
• visual inspection of the status of supports, wires, cables, insulation, and tilt supports;
• visual inspection of insulators of all types;
• observation of ice formation;
• checking the state of stationary signs and posters;
• measurement of the width of the clearing, the height of trees and shrubs under the wires, the specification of the volume of vegetation to be cut down.

Performance of works on inspection of air power lines with the use of special equipment takes a lot of time and requires significant material and labor costs. Currently, there is the introduction of modern technology of overhead line maintenance with applying unmanned aerial vehicles (UAVs). This technology has advantages and is a more effective method of visual inspection, because it is possible to inspect the line of more than 100 km length and get an photo thermal imaging with reference to the territory, as well as access to rugged terrain in a short period of time.

A distinctive feature of the UAV is a high degree of automation of all operation stages from the flight task to the automatic landing at a given point.

3. Theory

According to the design differences and the principle of operation all UAVs can be divided into 5 groups (the first 4 groups are aerodynamic type devices):
• with a fixed wing (UAVs aircraft type);
• with a flexible wing;
• with a rotating wing (helicopter-type UAV);
• with a flapping wing;
• aerostatic.

Unmanned systems of domestic production such as Granada VA-1000, GEOSCAN 201 (Fig. 1) [5, 6] are intended for the solution of a wide range of the tasks demanding expeditious reception of aerial photographs of the district or direct visual supervision.

A part of the complex is photogrammetric software Agisoft PhotoScan Pro, allowing to perform the processing of the obtained aerial materials in a short time.

Unmanned aerial photography systems such as Granada VA-1000, GEOSCAN 201 are used for cartographic works, surveying support of open-pit mining, surveys, monitoring the state of power lines, pipelines and other extended infrastructure facilities, assessing the state of farmland and other types of work that require fast geospatial data reception.

Thanks to the increased flight duration, UAV is particularly effective in aerial photography of large area objects and monitoring of long linear objects.

In one flight, the device can shoot up to 210 square kilometers of terrain with a resolution sufficient to obtain a map scale of at least 1:2000 (Fig. 2), the flight duration reaches 3 hours, the permissible temperature limits in operation are the following: from -20 to + 40 °C.
The use of on-board GNSS-receiver geodesic class allows us to obtain the coordinates of the centers of photography with high accuracy, which in some cases can significantly reduce the cost of planning and planned field examination.

4. Experimental results
To determine the technical and economic efficiency and feasibility of the UAV, the analysis of the cost of works with the use of UAVs for maintenance of overhead power lines with a length of 35.19 km was carried out (table 1).
Table 1. The cost of works with the use of UAVs.

| UAV parameter                                      | Parameter value |
|---------------------------------------------------|-----------------|
| Number of employees serving the machine           | 1               |
| Salaries, rub/month.                              | 45 000          |
| Number of working hours per day                   | 3               |
| Number of working months                          | 12              |
| TOTAL:                                            | 540 000         |
| Survey speed km / h                               | up to 210       |
| The cost of the UAV GEOSAN 201 RUB**              | 1 500 000       |
| The cost of the operation of the UAV GEOSAN 201, RUB. |                |
| - 500 takeoffs/ landings, RUB.                    | 3000            |
| TOTAL (247 takeoffs/landings per year), RUB.      | 741 000         |
| TOTAL in RUB.:                                    | 1 281 000       |

In turn, the cost of maintenance of overhead power transmission lines with a length of 35.19 km, with the use of special equipment, taking into account salaries in the Far North is shown in table 2. The data obtained with the use of GrandSmeta program.

Table 2. Maintenance costs of vl-220 kv with a length of 35.9 km, 101 supports.

| Parameter                                      | GAS 71 |
|------------------------------------------------|--------|
| Number of employees serving the machine         | 4      |
| Salaries, rub/month.                            | 45 000 |
| Number of working hours per day                 | 8      |
| Number of working months                        | 12     |
| TOTAL:                                          | 2 160 000 |
| Survey speed km / h                             | 1 (depending on the terrain) |
| The cost of one crew transportation, RUB.        | 56 133 |
| Number of transportations per year.              | 12     |
| TOTAL:                                          | 673 596 |
| TOTAL in RUB.:                                  | 2 833 596 |

Based on the analysis given in tables 1 and 2 cost of inspection of overhead power transmission by ground methods and using UAVs, we can make a conclusion about the economic efficiency of inspecting overhead power transmission using UAVs.

5. Results and discussion
Taking into account the complexity of climatic conditions and rugged terrain, the application of UAVs is relevant nowadays. The results suggest the need to consider the application of this method as an alternative for the inspection of overhead lines.

Given the maneuverability of the considered aircrafts, they can be used for other long objects such as gas pipelines, oil pipelines, as well as objects located in remote places, drilling rigs, compressor units, etc. The increase in the functional application of UAVs will significantly affect the profitability of their use.
6. Conclusion
The use of UAVs is economically justified today.

The possibilities of optical expansion of the used devices allow to obtain high-quality images, and to sufficiently carry out the necessary inspections of the overhead power lines.

The main disadvantage of the application of UAVs is the possibility of accidents, crashes of this device, which is not possible to detect without the use of ground equipment. The use of UAVs will greatly improve the performance of the objects inspection, in connection with the obtaining photo and video data, and the possibility of obtaining a report about the work done confirmed by the photographic materials.

7. References
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