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To the issue of the inspection of overhead power lines

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Abstract. The paper is devoted to the analysis of the possibility of using unmanned aerial vehicles to examine overhead power lines. Based on the analysis of the regulatory documents, conclusions were drawn on the required number of members of the brigade of electricians. Some technical means that could be used to inspect power lines were proposed, including unmanned aircraft. Based on a comprehensive analysis, conclusions were drawn and recommendations were made on the advisability of using unmanned aircraft for inspecting overhead power lines.

1. Introduction

Timely detection of faults in power grid facilities is one of the main means aimed at ensuring reliable power supply to consumers. For example, the maintenance of the normal technical condition of overhead power lines (OPL) is carried out by means of periodic and extraordinary rounds, which is regulated by clause 2.3.8 of the Rules for technical operation of electrical installations of consumers in the Russian Federation [1].

Periodic OPL inspections along the entire length of the route are carried out at least once a year and, taking into account the specific operating conditions, the frequency of these inspections can be increased. In addition, at least one time per year, selective inspections of peculiar OPL and all OPL to be repaired are conducted.

OPL inspections can be visual or aerial.

Visual inspections do not require disconnecting the line and they are carried out from the ground. Such inspections do not allow performing full diagnostics of OPL; therefore, they are supplemented with aerial ones.

Aerial inspections, unlike visual ones, can involve disconnecting the line, for example, when measuring the transient resistance of bolted joints. In general, the purpose of the aerial inspection is a visual check of the integrity of the insulators, checking the wires and cables in the clamps and distance struts. Aerial inspections for overhead power lines of 35 kV and above are made at least once in 10 years. Aerial inspections should be carried out at least once every 5 years for overhead power lines with a voltage of 35 kV and above, operated for 20 years or more, or for their sites, and for OPL passing through zones of intense pollution, as well as in open areas. Aerial inspections for OPL of 0.38-20 kV should be carried out in case of necessity.

In addition to periodic inspections, during the formation of ice on wires and cables, during wire dancing, during freezing and spilling of rivers, during fires in the area of the OPL route, after severe storms, hurricanes and other natural disasters, as well as after disconnecting the OPL by relay



protection and unsuccessful automatic re-inclusion extraordinary inspections are conducted, which is regulated by paragraph 2.3.9 of the Rules [1]. Whenever the need arises, out-of-order inspections can be carried out after successful re-activation of the OPL.

In accordance with clause 2.3.15 of Cross-sectoral rules on labor protection (safety rules) in the operation of electrical installations [2], one employee who has group II is allowed by an order to perform the following work: inspecting OPL during daylight hours under favourable weather conditions, including assessing the state of the supports, checking the rotting of the wooden bases of the supports; restoration of permanent signs on the support; measurement of dimensions by goniometric devices; fire-fighting cleaning of platforms around supports; colouring of bandages on support.

In accordance with clause 4.15.72 [2], it is not necessary to appoint a work manager during rounds and inspections of OPL.

In accordance with paragraph 4.15.73 [2] in difficult terrain (swamps, water obstacles, mountains, forest obstructions, etc.) and in adverse weather conditions (rain, snow, severe frost, etc.), as well as in the dark, overhead power lines should be inspected by at least two workers who have Group II. In other cases, one worker with group II can inspect the overhead power line.

2. Review and comparative analysis of possible solutions

Thus, we take the standard situation for a calculated one when an overhead power line is inspected by a brigade of two workers with a second electrical safety tolerance group. We believe that the inspection of overhead power lines can be carried out by means of rover, or by means of a helicopter. Table 1 presents the main technical and economic indicators of the inspection of OPL for a given case.

Table 1. Technical and economic indicators of OPL inspection.

	Helicopter	Rover	Electrician
Amount	1	1	2
Cost, USD /	2330	24	6
hour	+ fuel	+ fuel	salary per month 932

It is possible to use unmanned aerial vehicles (UAV), which are intended for conducting airborne optical-electronic (photo, video, infrared) reconnaissance of the terrain and objects.

UAV can be equipped with mounted equipment, with the help of which it is possible to conduct thermal imaging diagnostics of overhead power lines, insulators, contact connections and fittings in order to identify elements that are exposed to temperature heating due to the occurring defects.

Ultraviolet diagnostics of OPL, insulators, contact connections is carried out in order to detect corona discharges on them. Corona formation on the elements of overhead lines indicates closures, cracks or contamination of ceramic insulators or breaks in the strands of wires. At the corona, weak ultraviolet radiation occurs, which cannot be seen in the daytime, but when the camera is equipped with a special filter [3-6], which allows only ultraviolet radiation to pass through, the corona can also be detected during the daytime.

Visual inspection of supports, insulators, contact connections is carried out by means of a high-resolution video camera.

The paper considers several types of UAV [7]: type 1 (figure 1), type 2 (figure 2) and type 3 (figure 3).



Figure 1. UAV of type 1.



Figure 2. UAV of type 2.



Figure 3. UAV of type 3.

Table 2 presents UAV comparative technical and economic characteristics.

Table 2. UAV comparative technical and economic characteristics.

UAV technical characteristics	Type 1	Type 2	Type 3
Maximum range of UAV radio control, m	Up to 3000	Up to 15000	Up to 15000

UAV technical characteristics	Type 1	Type 2	Type 3
Maximum transmission distance of video and other information, m	Up to 3000	Up to 15000	Up to 15000
Maximum flight speed, km/h	70	50	70
Maximum flight height, m	1000	500	500
Flight duration, min	Up to 55	Up to 180	Up to 180
Takeoff weight of UAV, kg	Up to 12,0	-	Up to 20,0
Weight of target load, kg	Up to 1,5	Up to 3	Up to 3
Permissible wind force at the earth, m/s	Up to 7	Up to 7	Up to 7
Operating ambient temperature range, °C	-25...+40	-25...+40	-25...+40
Relative humidity, %	0...95	0...95	0...95
Maximum fuel tank capacity, l	-	-	5
Power planr	Electric motors	Fuel cells	Hybrid
Engine power, W	-	-	1500
Rated power of the onboard generator, W	-	-	1800
Emergency radio search beacon (availability)	Yes	Yes	Yes
The ability of the target load quick replacement	Yes	Yes	Yes
High-precision navigation Mode (availability)	Yes	Yes	Yes

When using traditional specialized equipment, it is necessary to take into account a number of nuances. The main indicators are given in table 1.

For rovers:

- the cost of acquisition and operation, including the purchase of fuel;
- the need to allocate storage space (garage, open parking);
- the need to maintain the state of the driver of the vehicle.

For helicopters:

- the presence in the vicinity of the production site of the helicopter fleet;
- the high cost of rent.

With a sufficiently high unit cost of a UAV (up to 150000 USD), the economic feasibility of using a drone to inspect linear facilities of the power grid complex is considered possible. When conducting a technical and economic comparison, it is necessary to evaluate a number of conditions as a whole.

If the surveyed area is a small part of the overhead power line, then the starting area of the UAV may be the territory of the enterprise, which allows the operator to control the device from his workplace without going to the track. This saves time, allows one to not use special equipment for movement. If the length of the surveyed area is greater than the distance of the radio channel of the UAV control (15 km), then there is a need to accompany the drone along the overflight route, or set the flight program by geographic coordinates, thus making the flight of the UAV autonomous and uncontrollable. Additionally, it is necessary to take into account the presence of access roads in the vicinity of the flight route, choose places where access is possible without the use of special rovers.

During a long flight, it is necessary to choose stopping points where the UAV will be charged.

Since according to paragraph 1 of article 53 [8] for controlling UAVs weighing less than 30 kg pilot certification is not required, then for remote areas of the route, where it is possible to conduct surveys only with the help of helicopter technology, UAVs have a distinct advantage.

In the event that the UAV is used not only by the enterprise's energy service, but also by others (the service of operating linear pipelines, the operation of capital structures), the expediency of using such a device increases, the possible payback period of the device is shortened.

3. Conclusions

Recommendations on the practical feasibility of UAV use for conducting overflights and inspections of linear constructions can be made when considering the specific configuration of the enterprise's electrical grid in a particular region of the country, taking into account seasonal climatic factors. But in general, it can be concluded about the possibility of using such innovative technologies as UAVs for everyday use in industrial enterprises.

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