THE USE OF UNMANNED AERIAL VEHICLES IN THERMAL IMAGING STUDIES OF ENERGY INFRASTRUCTURE

Matej Ščerba [1] – Adam Tomaszewski [2] – Maja Foryciarz [3]– Adam Turac [4]
Tatiana Gajdušková [5]– Jozef Mário Jusko [6]

Abstract: *Unmanned aerial vehicles (UAVs) are gaining prominence as a diagnostic tool in the electric power industry, enabling safe, precise and cost-effective inspection of infrastructure. Using RGB cameras, thermal imaging and LiDAR scanners, drones allow early detection of damage, analysis of temperature distribution and creation of spatial documentation of the network. This enables effective predictive maintenance, reduces the risk of failure and lowers operating costs compared to traditional inspection methods.*

Keywords: UAV, energy industry, critical infrastructure inspections

1 INTRODUCTION

Unmanned aerial vehicles (UAVs), popularly known as drones, are gaining popularity as diagnostic tools in many industries, including the power industry. The rapid development of aerial technology, the miniaturization of sensors and the increasing availability of high-end devices for remote image recording have made it possible to create efficient and safe systems for inspecting critical infrastructure, such as overhead power lines. Until recently, these tasks were mainly performed using helicopters, which, despite their effectiveness, are expensive in exploitation, energy-intensive and subject to high operational risks.

An example of this is the Robinson R66 helicopter, used by the company that manages the highest voltage power grid (transmission lines of more than 200 kV) in the Republic of Poland - Polskie Sieci Elektroenergetyczne S.A. (Polish Power Grid). The average fuel consumption of this model is as much as 87 liters per hour of operation, which, at current JET-A1 fuel prices, translates into an operating cost of more than PLN 270 per hour of flight. Additional financial burdens should also be taken into account, such as the cost of the purchase of the machine itself (PLN 4-6 million), insurance, technical inspections and the need to hire a pilot with a license for highly specialized flights in the vicinity of electric power infrastructure.

In the context of the above limitations, UAVs represent a new quality in network diagnostics. Thanks to the use of a variety of sensors, such as RGB cameras, thermal imaging cameras and 3D scanning systems (LiDAR), drones enable inspections to be carried out remotely, safely and cost-effectively, and with high measurement precision. While on the ground, the operator can conduct a full-fledged assessment of the technical condition of network components - from support structures to line accessories, insulator systems to working and lightning protection conductors. [1, 2]

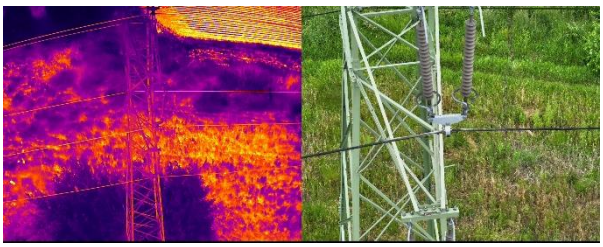

Figure 1. Isolator arrangement on the working conductor of a 110 kV HV line, left, thermal imaging photo, right, RGB photo.

2 VISUAL INSPECTION

RGB cameras mounted on the UAV allow visual inspection of infrastructure both in real time and from recorded images available after the device lands. With these images, utility company personnel can assess the condition of pole structures and their protective coatings against corrosion. In addition, they can check the quality of the construction and installation of connectors, as well as visually assess the condition of critical components such as insulators, brackets, vibration dampers and surge arrestors.

Unmanned aerial vehicles make it possible to reach places that are difficult to reach by a pedestrian assembler or standard power company vehicles. Drones with thermal imaging can be used not only for routine inspections, intended to lead to the detection of any irregularities and their subsequent rectification, but also during emergencies. The theoretical range of drones is usually above 5 km (using the DJI Matrice 30T as an example, the range declared by the manufacturer is 7 km), but it is limited by any obstacle that causes distortion of the radio wave (2.4 or 5.8 GHz) controlling the UAV. In addition, it is limited by the law (according to Regulation (EU) 2019/947), in BVLOS (beyond visual line of sight) flights the maximum distance between pilot and drone, without an airspace observer is 1 km, with an observer it is just 2 km. However, this distance allows, under real conditions, for electricians to reach the region close to the probable place of failure, to fly over the critical area and visually assess the damage and, consequently, to plan emergency restoration. [3]

Figure 2. Detailed view of isolators - with the help of hybrid zoom it is possible to accurately inspect the technical condition of the implemented devices.

Figure 3. The attachment of the isolator system bracket with an apparent anomaly (unscrewed nut of the attachment clamp). The photo was taken from a distance of 8 m using a camera with 16x optical zoom and 200x hybrid zoom.

3 THERMAL IMAGING INSPECTION - PRINCIPLES OF OPERATION AND DIAGNOSTIC SIGNIFICANCE

One of the key tools used in diagnostics with UAVs are thermal imaging cameras. These advanced optoelectronic devices make it possible to record infrared radiation emitted by all bodies with temperatures above absolute zero. The thermal energy emitted by objects is received by a sensor and then converted into an electrical signal, which is converted into an image visible to the operator in the form of a so-called thermogram.

From a physical point of view, the phenomenon is based on the principle of blackbody radiation. The fundamental dependence of the phenomenon lies in the directly proximate amount of radiated heat in the infrared range, varying from temperature. A thermal imaging camera does not measure temperature directly, but the intensity of radiation, which correlates with surface temperature. These images - usually presented in the form of a color gradient (depending on the settings, usually the so-called IronRed indicating the hottest areas in red, the rest monochromatic) - show the temperature distribution within the object under study.

In the context of power grids, thermal imaging technology is invaluable. It allows detection of so-called hot spots, i.e. places where there is excessive heating of infrastructure components. The most common causes of this phenomenon are material defects, mechanical damage, degradation of insulation coatings or poor quality of electrical connections. In practice, this means increased electrical resistance at a given point, which - according to Joule's law ($P = R*I^2$) - results in increased heat emission. A conductor with increased resistance heats up more than other components, which can be easily identified on a thermal image. [4]

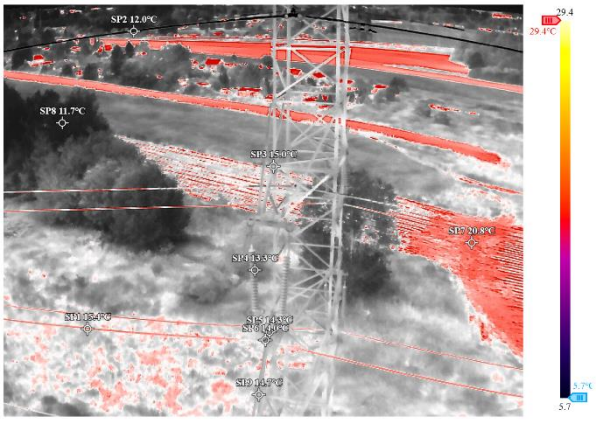

Figure 4. Thermal imaging photo of 110 kV HV power line transmission line pole, measuring points on key elements (lightning conductor, working conductors, pole structure, insulators and surroundings) are marked.

Abnormalities of this type often go unnoticed during classic visual inspections, as they do not manifest themselves in the form of physical damage. Meanwhile, local overheating can lead to gradual degradation of the component, and in extreme cases - to short circuits, insulator damage, fires or emergency shutdowns of entire sections of the network. Early detection of temperature anomalies allows them to be quickly remedied before they become a threat to the continuity of power supply. [1]

4 3D INSPECTION - LIDAR

The use of LiDAR (Light Detection and Ranging) technology enables 3D scanning of a given section of the transmission network, poles and elements on the poles, such as the insulator system, using a laser beam. The LiDAR system emits short pulses of light, usually in the infrared range, which, upon contact with an obstacle - such as the ground, elements of technical infrastructure or vegetation - are reflected and recorded by a receiving detector. The time-of-flight of the pulse is measured with high accuracy and forms the basis for calculating the distance between the sensor and the reflection point.

As a result of this process, a so-called point cloud is generated, a collection of spatially distributed data describing the geometry of the environment. Each point

contains information not only about XYZ coordinates, but also about the intensity of the reflection and, in advanced systems, also about the number of reflections from a single pulse, making it possible to distinguish layers of vegetation or complex structures.

In the context of electric power applications, LiDAR makes it possible to precisely map the course of overhead lines, the location of poles, and the position of wires in relation to the ground and neighboring objects. This makes it possible to assess the compliance of infrastructure with normative requirements for phase separation and minimum safe distances. In addition, regular scanning of the same areas allows analysis of changes over time, identification of potential collisions with vegetation and planning of preventive measures. High spatial resolution and the ability to operate in difficult lighting conditions make LiDAR technology a particularly useful tool for critical infrastructure inspections.

5 ADVANTAGES OF USING UAV IN TERMS OF SAFETY AND ECONOMICS

In addition to its technical advantages, the use of UAV comes with a number of safety and operational cost advantages. Traditional methods, such as inspections by workers climbing pole structures, are fraught with the risks of falls from heights, electrocution and unpredictable situations resulting from sudden weather changes. Helicopter inspections, on the other hand, while less direct, still carry a high risk of collisions, high costs and a not inconsiderable environmental impact (exhaust emissions, noise, fossil fuel consumption).

Unmanned aerial vehicles eliminate the need for human presence in danger zones, allowing thorough inspections from the ground. Their high maneuverability and ability to hover near network elements make it possible to take pictures from very close distances (even 5-10 m), using multiple optical and digital zoom. What's more, data from the flight can be analyzed immediately, and if necessary, a repeat flight can be scheduled on the same day.

The economics of this solution are equally compelling. The cost of purchasing a modern UAVs ranges between PLN 30,000 and 40,000, while the cost of operator training and required permits (STS) oscillates between PLN 1,000-6,000. Unlike helicopters, drones do not require expensive fuel or servicing by certified aircraft mechanics. Operating costs are limited to battery charging, periodic maintenance, propeller replacement or sensor cleaning.

6 SUMMARY

Figure 5. A wide-angle camera view of the surveyed pole, without use of zoom. Shows the actual distance of the drone from an overhead line pole in Chorzow, Poland, during trial measurements.

Unmanned aerial vehicles are revolutionizing the approach to power infrastructure diagnostics and monitoring. Using RGB cameras, thermal imaging, and LiDAR scanning systems, drones make it possible to conduct high-precision inspections remotely, safely, and cost-effectively. Thermal imaging analysis is particularly valuable for detecting local temperature anomalies associated with malfunctioning network components - even before visible damage or failure occurs. Combined with the possibility of 3D documentation and historical analysis, UAVs provide a modern tool for predictive maintenance of infrastructure. All this translates into greater reliability of energy supply, loss of energy reduction and operational savings.

ACKNOWLEDGEMENTS

Publication supported by the Excellence Initiative - Research University programme implemented at the Silesian University of Technology, year 2024/2025.

REFERENCES

[1] Łatka M., Piechota T. (2016). Kamery termowizyjne w ocenie jakości energii elektrycznej. *Prace Instytutu Elektrotechniki*, zeszyt 272, 83-92.

[2] Robinson R66 Maintenance Manual: https://www.donaldsonaerospace-defense.com/wp-content/uploads/2020/07/r66_mm_full_book.pdf

[3] Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft

[4] Dolego M. (2016). *Podstawy elektrotechniki i elektroniki.* Warszawa: Wydawnictwo Łączności i Komunikacji.

AUTHORS ADDRESSES

[1]Ing. Matej Ščerba, MBA
Technical University of Kosice
Faculty of Aeronautics
Rampová 7, 040 01 Košice
Slovak Republic
e-mail: matej.scerba@tuke.sk
ORCID: 0009-0004-0479-508X

[2] Maja Foryciarz
Silesian University of Technology
Faculty of Transport and Aviation Engineering
ul. Zygmunta Krasińskiego 8, 40-019 Katowice
Poland
e-mail: mf305745@student.polsl.pl
ORCID: 0009-0000-4208-2882

[3] Adam Tomaszewski
Silesian University of Technology
Faculty of Transport and Aviation Engineering
ul. Zygmunta Krasińskiego 8, 40-019 Katowice
Poland
e-mail: at305858@student.polsl.pl
ORCID: 0009-0007-6319-936X

[4]Ing. Adam Turac
Technical University of Kosice
Faculty of Aeronautics
Department of Flight Training
Rampová 7 ,040 01, Košice
Slovak republic
e-mail: adam.turac@student.tuke.sk

[5]Ing. Tatiana Gajdušková
Technical University of Kosice
Faculty of Aeronautics
Department of Air Transport Management
Rampová 7 ,040 01, Košice
Slovak republic
e-mail: tatiana.gajduskova@tuke.sk

[6] Ing. Jozef Mário Jusko
Technical University of Kosice
Faculty of Aeronautics
Department of Flight Training
Rampová 7 ,040 01, Košice
Slovak republic
e-mail: jozef.mario.jusko@student.tuke.sk