INSPECTION AND ASSESSMENT OF THE TECHNICAL CONDITION OF ASSETS USING AUTONOMOUS ROBOTIC SYSTEMS

INSPECȚIA ȘI EVALUAREA STĂRII TEHNICE A ACTIVELOR CU AJUTORUL SISTEMELOR ROBOTICE AUTONOME

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Abstract: *Electrical substation's inspection plays a crucial role in upholding the reliability of the power system infrastructure. Absence of periodic inspections can lead to equipment malfunctions, triggering power outages and disturbances. Furthermore, the cost associated with equipment malfunctions can be substantial. The robots equipped with a multitude of sensors can effectively examine various types of electrical equipment in unsuitable conditions. They excel in accessing hard to reach areas and solving tasks that can represent a risk for the operational staff.*

Keywords: sensors, AI based platforms, autonomous systems, innovation, drones, robots.

Rezumat: *Inspecția stațiilor joacă un rol crucial în menținerea fiabilității infrastructurii energetice Absența inspecțiilor periodice poate duce la defecțiuni ale echipamentelor, declanșând întreruperi și perturbări]n alimentare. În plus, costurile asociate cu defecțiunile echipamentelor pot fi substanțiale. Roboții echipați cu diferiți senzori pot examina în mod eficient toate tipurile de echipamente electrice aflae în condiții nefavorabile. Ele excelează în accesarea zonelor dificile și în rezolvarea sarcinilor care pot reprezenta un risc pentru personalul operativ.*

Cuvinte cheie: senzori, platforme bazate pe IA, sisteme autonom, inovare, drone, roboți.

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1. Introduction

This article introduces another approach for the classical periodic inspections within the electrical substations. The conventional methods consist of inspections in the visible spectrum, in the infrared spectrum (thermal imaging) and in the ultraviolet spectrum (partial discharges) to determine irregularities or potential issues. All these methods are time consuming, expensive and may present risks for the operational staff and the people assigned for these activities have to go through high-voltage environments, exposing themselves to hazardous surroundings.

Conventional inspection techniques mostly depend on the knowledge and expertise of personnel. Even if their expertise is priceless, human mistake is still a bottleneck in these cases. This is especially noticeable when inspections are carried out in difficult circumstances or when the staff has a short deadline to finish specific assessments.

Lately, there's been a gradual shift towards using robots instead of classical inspection methods. This transition aims to enhance both the efficiency of inspections and the security and automation standards in substation maintenance [1].

Robotic inspection solutions enhance safety, boost efficiency, and promote sustainability in power transmission facilities by conducting autonomous, real-time digital inspections and integrating data workflows seamlessly. Engineers are consistently searching ways to attain optimal levels of safety and technical advantages while mitigating the expenses associated with substation construction and operations [2]. These objectives can be realized through the utilization of robots within substations. Thanks to the progress in artificial intelligence (AI) and sensor technologies, various types of robots have evolved, being capable of substituting or helping the operational staff in their activity.

The complete autonomy and mobility of the robotic systems make them able to monitor and evaluate assets even in challenging conditions such as adverse weather and darkness, thus eliminating the need for operators to undertake additional risks. For instance, in high-voltage substations, where electromagnetic fields are typically excessive and installations are usually de-energized for human interventions, the robots are able to perform routine inspections safely during operations.

2. Challenges and requirements

The robots are equipped with inspection sensors, such as thermal cameras, ultraviolet cameras, and partial discharge sensors, capable of performing various inspection or patrol duties. These tasks involve activities like capturing photos, reading meters, verifying switch statuses and data analysis. The development of autonomous robotic systems for electrical substations can present several challenges and requirements, such as environmental adaptability and high stability. A few of them are summarized below [3]:

- **Weather conditions** pose a significant challenge. In Romania, weather fluctuations range from sunny temperatures reaching +30°C during summer to winter conditions, often reaching -10°C or even lower in mountainous and northern areas;
- **Topography** of the substation which may include obstacles, varying terrain, and tight spaces;
- **Permanent residency** of the robot in the substation is necessary, ensuring uninterrupted performance during extended "on-call" periods and is also accessible at short notice;
- **Long-term autonomy** because the electrical system and the robot battery should be able to stay charged for numerous inspections and have the capability to recharge autonomously, without requiring human intervention. Figure 1 presents an aerial perspective of two substations with different voltage levels and from different regions from Transelectrca's power grid;

Figure 1. Aerial view of two different substations from Transelectrica's grid

- **Data Interpretation** regarding the autonomous robots which generate vast amounts of data gained from sensors during the inspections. They must be equipped with advanced algorithms for

real-time data processing, analysis, and interpretation, in order to identify and prioritize issues accurately;

- **High-voltage** equipment can also have an impact on other electronic devices or navigation systems. To prevent incidents, strict limits on localization accuracy and control precision are required.

3. Inspection technologies

3.1. Visual inspection

Autonomous robotic systems during periodic inspections can be equipped with different sensors and cameras. The most common one are the Hi-Res RGB (red, green, and blue) Sensors that can be fixed on autonomous robots or drones. They will be able to capture high-resolution images of different parts of the substation, including transformers, circuit breakers, insulators, switches and other critical components and these images provide further valuable visual data about the condition and integrity of equipment.

Figure 2. Inspection provided by robot / drone [4]

3.2. Infrared camera for thermal inspections

IR cameras detect infrared radiation emitted by objects and convert it into a visible image. The primary benefit of these cameras is their high image capture frequency, enabling swift identification of any hot spots and abnormal behavior.

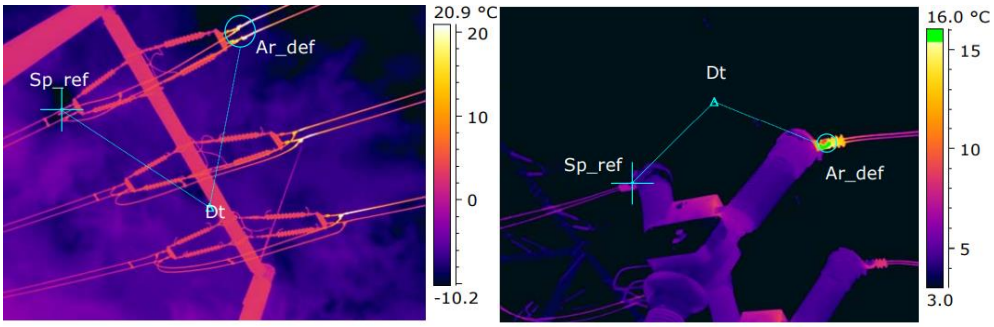

Figure 3. Thermal images provided by a drone / robot [7]

3.3. Corona Camera for partial dischargers (PD)

Corona cameras detect ultraviolet (UV) light emitted by partial discharges occurring within the electrical equipment. Partial discharges are localized breakdowns of insulation or dielectric materials, which produce UV radiation as a byproduct. Corona cameras capture this UV radiation and convert it into a visible image, allowing the visualization of PD activity.

Figure 4. Partial discharge detection provided by a drone / robot

3.4. Gas Leaks Sensor

The gas sensor delivers rapid responses to identify hydrocarbon gases, preventing dangerous situations. By using optical absorption detection technology, this gas detector projects infrared light through a sapphire lens and analyzes the reflected light to determine gas levels. The automated inspection is able to monitor gas concentration for hydrocarbon and toxic gases and to generate real-time gas concentrations placed on visualisation maps [4].

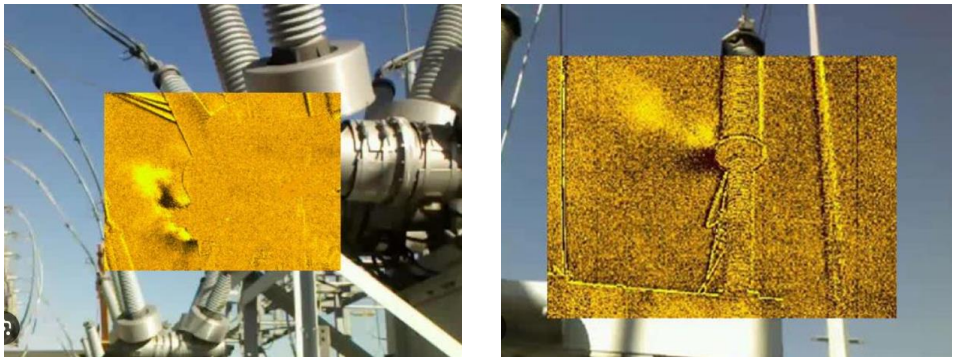

Figure 5. SF6 gas detection provided by a drone / robot

4. The steps to obtain autonomous inspection

4.1. LiDAR scanning of the substation

LiDAR systems consist primarily of three components: a laser, scanner, and a specialized GPS receiver. LiDAR works by accurately measuring the distance from the camera to the ground. A collection of measurements in the form of LiDAR points is called "point cloud" and is used to create a 3D representation of the surrounding area or object.

To have an accurate localization and navigation of the robotic systems, a LiDAR scanning is necessary. This approach is available even in the presence of strong magnetic fields commonly found in substations. Additionally, it effectively filters environmental moisture, including raindrops, mist, and snowflakes, ensuring that patrol duties can proceed smoothly regardless of weather conditions.

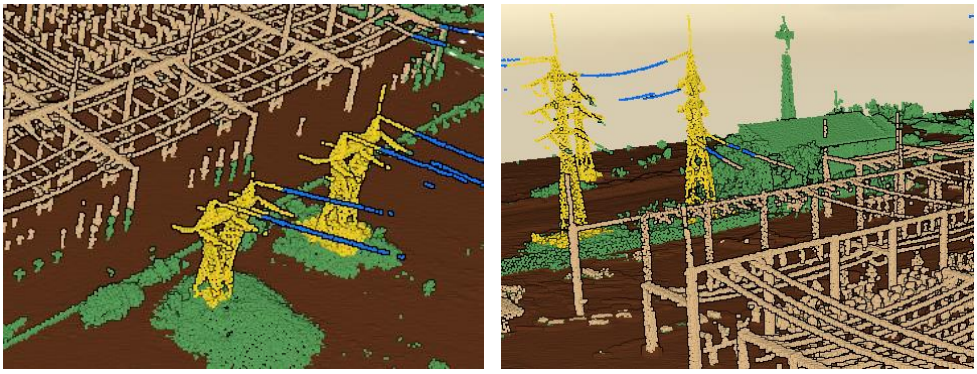

Figure 6. Substation LiDAR scan [7]

4.2. Mission planning

The map obtained after the LiDAR scans will serve as the basis for planning robots / drones movements and identifying key points of interest.

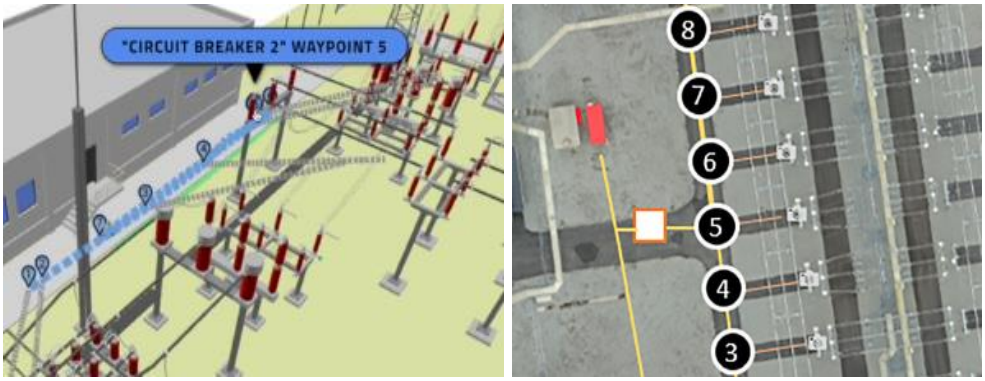

Figure 7. Inspection plan with several points of interest [4]

4.3. AI Data Processing

The data gathered by the robots is suffering a transformation into practical insights with the help of AI applications.

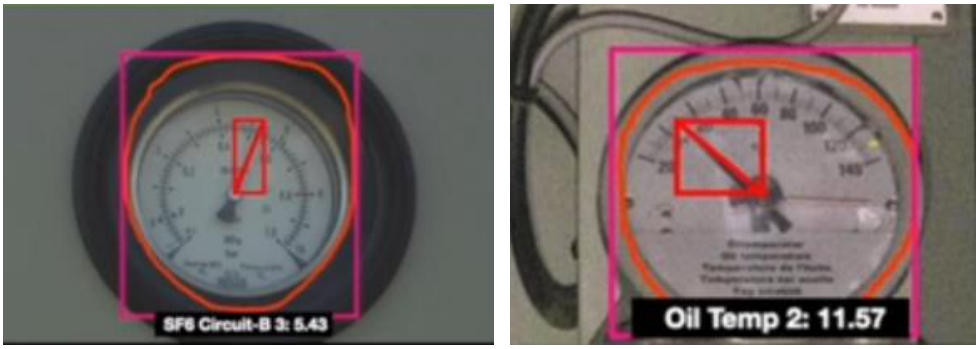

Figure 8. Data analytics with the help of AI [6]

4.4. Data delivery to the asset management platform

The derived insights are directly transmitted to the asset management platform after the autonomous system is returning to its dock.

Figure 9. Self charging dock for autonomous systems [6]

5. Conclusions

By implementing this project within Transelectrica and consistently capturing high-quality images and extracting data from various sources placed along the substation, a comprehensive AI-based robotic system can be established for efficient monitoring and management of Company's assets.

The project is currently in its initial phase, where foundational groundwork has been established. With the preliminary steps completed, we are now transitioning into the designing phase. This next stage will focus on creating detailed plans and blueprints, setting the stage for the subsequent development and execution phases.

The integration of autonomous systems and AI not only boosts the effectiveness and precision of substation inspections but also elevates safety by diminishing the necessity for human inspectors to operate in high-voltage facilities.

Besides the periodic inspections, the flexibility of AI-powered systems enables streamlined gathering and analysis of data, thereby improving the overall efficiency of maintenance tactics.

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