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Drones in Power Systems

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ABSTRACT

Modern drone technology has practically transformed the landscape of every industry. While numerous tools and methods already exist for power line inspection and maintenance tasks, the drones are slowly proving that they offer a practical and valuable approach. Drones are increasingly used in the power industry. They make it much easier for us to inspect the overhead wires and the national grid, which transmit electricity from power stations across the nation. They can improve efficiency, speed, safety, and cost from the design, pre-construction, and development stages through to commissioning and ongoing maintenance. This paper examines the applications, benefits, and challenges of drones in power systems.

KEYWORDS: *drones, unmanned aircrafts, unmanned aerial vehicles (UAVs), power systems*

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INTRODUCTION

The power sector is one of the world's most rigid industries. It is now in the midst of a profound transition. Disrupted not just by economic and environmental forces, the industry is facing rapid technological changes that have forced companies to reevaluate business models to stay profitable. The interest in drone by the power industry is soaring. The reason drones are being adopted so quickly in the power sector is because they make good business sense and for their multitasking capabilities [1]. The task of maintaining and inspecting high voltage transmission and distribution lines can be difficult, dangerous, and expensive. As a result, utilities are increasingly using drones as a safe and effective tool to assist them in their operations. Drones drastically cut the costs of power line inspections for utilities. They also improve safety, increase reliability, and reduce response time across transmission and distribution systems.

Commercial drones have come a long way in the last decade. The use of drones, in the power industry is relatively new, with many companies still unsure about the value the drones could bring to their operations. Drone technology can assist engineers in the process of designing the electrical infrastructure. It can drastically reduce asset inspection time and save labor costs, while providing higher-quality data that enables companies to maximize energy production. Today's energy and utilities companies are using drones to capture data that was previously too dangerous, difficult or expensive to obtain. National grid is also actively deploying drones to help improve power line inspections, especially fault response in rural power grids, help restore power supply, and improve the safety, efficiency, and reliability of power systems.

WHAT IS A DRONE?

The FAA defines drones, also known as unmanned aerial vehicles (UAVs), as any aircraft system without a flight crew onboard. Drones include flying, floating, and other devices, including unmanned aerial vehicles (UAVs), that can fly independently along set routes using an onboard computer or follow commands transmitted remotely by a pilot on the ground. A typical drone is shown in Figure 1 [2]. A drone is usually controlled remotely by a human pilot

on the ground, as typically shown in Figure 2 [3]. Drones can range in size from large military drones to smaller drones. Drones, previously used for military purposes, have started to be used for civilian purposes since the 2000s. Since then, drones have continued to be used in intelligence, aerial surveillance, search and rescue, reconnaissance, and offensive missions as part of the military Internet of things (IoT). Today, drones are used for different purposes such as aerial photography, surveillance, agriculture, entertainment, healthcare, transportation, law enforcement, etc.

Commercial drones have come a long way in the last decade.

Drones work much like other modes of air transportation, such as helicopters and airplanes. When the engine is turned on, it starts up, and the propellers rotate to enable flight. The motors spin the propellers and the propellers push against the air molecules downward, which pulls the drone upwards. Once the drone is flying, it is able to move forward, back, left, and right by spinning each of the propellers at a different speed. Then, the pilot uses the remote control to direct its flight from the ground [4].

Drone laws exist to ensure a high level of safety in the skies, especially near sensitive areas like airports. They also aim to address privacy concerns that arise when camera drones fly in residential areas. These include the requirement to keep your drone within sight at all times when airborne. In the United States, drones weighing less than 250g are exempt from registration with civil aviation authorities. If your drone exceeds 250g in weight, you will also require a Flyer ID, which requires passing a test [5]. It is necessary to register as an operator, be trained as a pilot, and have civil liability insurance, in addition to complying with various flight regulations, and those of the places where their use is permitted.

Most drones have a limited payload, usually under 11 pounds. Drones are classified according to their size. Here are the different drone types:

- Nano Drone: 80-100 mm
- Micro Drone: 100-150 mm
- Small Drone: 150-250 mm
- Medium Drone: 250-400 mm
- Large Drone: 400+ mm

One of the emerging trends in drone use for factories is the utilization of LiDAR technology. LiDAR stands for Light Detection and Ranging. This technology provides accurate depth information essential for understanding the three-dimensional structure of the environment. LiDAR sensors emit laser beams to measure distances to objects, creating high-resolution 3D maps of the surrounding terrain and objects. The ability to capture detailed data through LiDAR technology has opened up opportunities for better predictive maintenance, reduction in inspection times, and overall cost savings [6].

APPLICATIONS

A drone in the power system environment is shown in Figure 3 [7]. Drones are used in power systems for a variety of applications. Common applications of drones in power systems include the following [3,7]:

- *Inspecting Power Lines:* Companies in almost every industry use drones for inspections, as it is a cost-conscious and effective way to inspect at heights and inaccessible areas. Drones can inspect parts of a network that are difficult or expensive to reach, such as overhead wires, pylons, transmission towers, and substations. Inspectors usually conduct power line and utility pole inspections on foot, by car, or in a helicopter, with most inspections taking place on the ground. For rural power lines and utility poles, rough terrain makes walking or driving challenging and incredibly slow. Drones offer a cleaner, cheaper option for power line and utility pole inspections. By performing frequent drone inspections, companies save time, keep the environment and employees safe, and ensure that assets function efficiently. The 3-D images obtained give inspectors a highly accurate snapshot of power lines and poles. Compared to traditional manual inspection, the main advantage of drone inspection lies in greater quality and detail in the inspection. Figure 4 shows line inspection with drones [7].
- *Power Line Mapping*: Drones can map thousands of kilometers of electrical lines to help optimize maintenance and monitoring plans. This can include monitoring vegetation, verifying maintenance work, and checking the general condition of the power lines.
- *Overhead Lines:* Drones are expected to become increasingly autonomous, with enhanced real-time decision-making and problem-solving capabilities. Automatic inspection of power lines has become a big trend. Previously, overhead cable lines were only repaired after problems occurred. Today, with drone supervision, many problems can be eradicated in their initial phase. Drones automatically take off from the substation, carry out autonomous inspections strictly in accordance with the predetermined inspection area, and complete on-site inspection. Drones can fly close to the power line and send real-time data to the operators. Autonomous inspection with

drones has achieved point-to-point and point-to-line inspections, and is also significantly reducing the difficulty of operation for personnel and the risk of damage to drones. A drone for inspecting the national grid is shown in Figure 5 [8].

- *Transmission Line Maintenance:* Factors like environmental conditions, vegetation encroachment, and structural deterioration pose risks to the integrity of these lines, leading to power outages and often safety hazards. Proactive, or preventative, maintenance can help to mitigate these incidents. Transmission line safety is critical for maintaining an uninterrupted and reliable power supply. Drones have revolutionized the way maintenance inspections are conducted for transmission lines. Drones with high-definition cameras can fly close to power lines and take high-resolution images, allowing operators to identify any problems on the wires, such as breaks, wear and tear, weather damage, etc. They automate inspections and provide accurate data on all parts of the power grid, enabling timely repairs, removing risk of accidents, and reducing downtime. Drones enhance transmission line safety through proactive maintenance. Figure 6 displays a drone used for power line maintenance [9].
- *Integration with Smart Grids*: Drone inspection will be further synchronized with smart grid operations. Drones will not only collect data, but they will also interact with the network infrastructure in real time, facilitating more proactive maintenance and faster response to network fluctuations or detected problems.
- *Renewable Energy:* Renewable energy production contributed 18.5 percent of the earth's total electricity in 2018. This was mainly generated from the hydroelectric power systems. Although the use of wind energy is not new, the introduction of drones to help in electricity production has given it a new dimension.
- *Corona Discharge*: Corona discharge is a luminous partial discharge from conductors and insulators due to ionization of the air, where the electrical field exceeds a critical value. Corona discharges can generate corrosive materials, like ozone and nitrogen oxides. Utilities are typically made aware of corona by complaints of faulty radio or television signals. Because corona are invisible in daylight with the naked eye, maintenance crews will investigate by aiming devices such a corona camera or radio antenna at suspected areas, and track corona. Drones equipped with corona cameras can detect corona discharges on power lines from a safe distance and generate real-time images of problem areas.

BENEFITS

Drones drastically cut the costs of power line inspections for utilities. They also improve safety, increase reliability, and reduce response time across transmission and distribution systems. Drones in the power line industry have been thriving due to the benefits it brings to the table. With these benefits, it is easy to understand the growing attraction to drones in power systems. Other benefits of drones in power systems include the following [8]:

- *Efficiency:* One of the primary benefits of utilizing drones for power line inspections is the significant cost-efficiency versus traditional inspection methods. Drone inspection not only allows inspection work to be completed quickly and accurately in a short period of time, but also prevents the risk of injury from falls to personnel, greatly increasing work efficiency and safety coefficient. Drones significantly enhance maintenance efficiency by streamlining the inspection process.
- *Automation:* By establishing three-dimensional models of power lines and improving databases, drones expected to be able to perform automatic energy inspections.
- *Decision-Making:* Drones equipped with advanced sensors and AI algorithms provide utility companies with accurate and real-time data. With this data maintenance schedules can be optimized based on the condition of transmission lines, prioritizing areas that require immediate attention and efficiently allocating resources.
- *Cost Savings:* Manual inspections involve significant costs associated with labor, equipment, and logistics. Drones equipped with high-resolution cameras and advanced imaging technologies efficiently capture detailed visual data of the power lines at a fraction of the cost. These cost savings can be significant in the long run.
- *Time Saving:* Another significant benefit drones have is the substantial time savings they offer through efficient data collection and faster overall inspections. Drones provide a safe way to get a detailed view of terrain in the shortest amount of time. They can cover long distances quickly, conduct thorough inspections, and collect comprehensive data in a fraction of the time required for manual inspections.

- *Improved Safety:* Inspecting power and transmission lines is hazardous work. Using drones improves safety by minimizing risks to personnel. Drones can navigate close to power lines and infrastructure while keeping human operators at a safe distance. They provide a safer alternative to manual inspections by reducing the need for personnel to physically access hazardous or hard-to-reach areas. Manual inspections often require workers to climb transmission towers or traverse challenging terrain, putting them at risk of falls, electrical hazards, or other accidents. By deploying drones, utilities companies can minimize these risks and prioritize the safety of their personnel.
- *Improved Accuracy:* Drones equipped with high-resolution cameras, LiDAR sensors, and thermal imaging technology offer superior, accurate data collection capabilities compared to human inspectors. Drones capture detailed imagery and generate accurate 3D maps, allowing for precise identification of potential risks such as vegetation encroachment, structural deformations, or temperature anomalies.
- *Remote Accessibility:* Transmission lines are often located in remote or inaccessible areas, such as mountainous regions, dense forests, or vast expanses. Drones, with their ability to fly over diverse terrains and navigate difficult environments, provide remote accessibility to these areas.

CHALLENGES

Drones for power line inspection still face challenges such as battery autonomy and signal transmission. Climate change and extreme weather events present new challenges for electrical infrastructure. Other challenges of drones in power systems include the following:

- *Regulations and Standards:* As technology evolves, so will the regulatory framework. Continued development in drone regulations is anticipated to ensure safe operations and protect privacy and data. Collaboration between regulators, drone manufacturers and electric companies will be key to establishing safety and operational standards.
- *Hiring Pilot is Expensive*: Drone licensed pilots are highly trained and qualified to conduct transmission line inspections. It is costly to hire an experienced, licensed drone pilot. The drone pilot must have a solid understanding of the regulations governing drone operations. Knowing the local laws and regulations is essential to ensure compliance and avoid any legal issues. *Security:* Perhaps the deepest shadow cast by drone use for power company applications concerns their security implications. Security concerns on the cyber front are an added worry for power companies, which are already constantly grappling with the vulnerabilities of other critical components. While drones offer many beneficial inspection uses, they can also be unlawfully used for surveillance, including video, audio, and spoofing. Drones can disrupt operations if they malfunction, posing a danger to both employees and customers.
- *Safety:* This is paramount in the drone industry, driving the adoption of robust systems and redundancies to mitigate risks. Fail-safe mechanisms are integrated into drones, triggering emergency actions during signal loss or critical failures. Redundancies in critical components like flight controllers, power systems, and communication links further bolster reliability. Parachute systems can be added for controlled descents during emergencies. These comprehensive measures promote responsible and secure drone operations in diverse environments.

CONCLUSION

Drones allow us to look at parts of our electric grid that are more difficult or costly to reach. Drone technology and power industry applications are growing at a rapid pace. This market segment is fast-growing with a potentially bright future. The use of drone in power systems is constantly changing, with exciting future trends and innovations on the horizon. Drones for the power industry are becoming a top-tiering technology that every industry utilizes to provide improved power line inspections. Drones that use artificial intelligence (AI) offer us many options that could make condition assessment operations even more efficient. More information about drones in power systems can be found in the books in [10-12].

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Figure 1 A typical drone [2].

Figure 2 A drone is usually controlled by operators on the ground [3].

Figure 3 A drone in the power system environment [7].

Figure 4 Line inspection with drones [7].

Figure 5 A drone for inspecting the national grid [8].

Figure 6 A drone for power line maintenance [9].