Application of 5G in Electric Power Inspection UAV

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Abstract. At present, under the background of the social development of the increasing popularity of 5G technology, the automatic inspection of power lines through 5G UAV has become an inevitable demand for the development of smart grid. 5G has brought advanced technical advantages to the power inspection UAV, overcoming the difficulties in flight environment, data transmission and image analysis. The use of 5G UAV realizes the intelligent panoramic operation of power inspection and is an important means to ensure the reliable operation of power grid. However, due to the constraints of relevant factors, the use of 5G inspection UAV is both challenging and imperative in the future. This paper mainly introduces the basic meaning and advantages of 5G technology and UAV, compares and analyzes the differences between manual inspection, traditional UAV and 5G UAV in power inspection, discusses the technical advantages of 5G UAV, and combines with application cases to prospect the development prospect and trend of 5G UAV inspection.

1. Introduction
In recent years, China’s power grid infrastructure has achieved rapid development. In 2020, the total mileage of transmission lines reach more than 1.59 million km, and will maintain sustained growth of about 5% per year, which puts forward higher requirements for power grid inspection, maintenance and maintenance[1]. With the continuous advancement and development of the aircraft patrol business, UAV, as one of the important means of transmission line patrol, has carried out normalization operations. China State Grid Corporation has gradually formed a new mode of transmission line patrol, which is “aircraft patrol is given priority to, and human patrol is supplemented”[2]. As the main feature of today’s era, the information technology revolution sweeping the world is evolving towards integration, ubiquitous and intelligent, becoming the main driving force of social change. The new generation of information technology is becoming a powerful engine of smart grid, and greatly promotes the innovation and development of UAV technology. At present, the UAV is accelerating the integration with new technologies such as 5G, Beidou, Internet of Things, artificial intelligence and big data, continuously optimizing and reconstructing the technical system and framework of UAV power inspection, and promoting UAV power inspection into a new stage of intelligence.

In this paper, combined with the application status of UAV power inspection and 5G technology, the 5G UAV power inspection technology is analyzed, and the actual landing application of the technology in a power supply company of the State Grid is introduced in combination with the actual project. The application prospect of the 5G UAV power inspection technology in the future is prospected, which has good practical reference significance in the industry.
2. Concept and characteristics of 5G

2.1. Concept of 5G
5G network refers to the fifth generation mobile network communication technology, which has the characteristics of small size, fast speed, powerful function and high reliability. It is widely used and has a wide coverage. Compared with 4G network, 5G has a higher rate, larger capacity and lower latency.

2.2. Characteristics of 5G
According to the basic requirements of IMT-2020 propulsion group for 5G communication, 5G communications should contain at least five basic features including high speed, high capacity, high reliability, low delay, and low energy, consumption.

2.2.1. High speed
5G communication rate includes peak rate, region rate and edge rate. Peak rate refers to the maximum rate under the best conditions, which requires no less than 20Gbps. Area rate refers to the total rate supported by the communication system at the same time, generally described by the rate per unit area, which will increase more than 1000 times than 4G communication; Edge rate (5% rate) refers to the communication rate obtained by the worst 5% quantile user, which is generally required to be between 100Mbps and 1Gbps.

2.2.2. High capacity and reliability
The number of terminals connected by traditional 4G communication is limited, which is generally dominated by mobile phones. 5G communication can connect massive devices, and 1 million mobile terminals can be supported per square kilometer. The success probability of 5G sending a 32-byte layer 2 protocol data unit requires up to 99.999%...

2.2.3. Low delay and low energy consumption
Communication delay refers to the time needed to transmit information from one end to the other. The delay of the traditional 4G communication is about 50 ms, which has little effect on the conversation between people and does not apply to some industrial applications. The delay of 5G communication is 1ms, and the end-to-end delay is less than 10ms, which provides support for timely and flexible response to various changes[3]. If sensor and communication devices require frequent battery replacement or charging, the Internet of Things will be greatly hampered. The low energy consumption characteristics of 5G communication by optimizing communication hardware protocol will effectively solve this problem. Table 1 shows the 5G network capability diagram.

| item          | 5G                                                                 |
|--------------|--------------------------------------------------------------------|
| rate         | 0.1-1Gbps 4G*100 more quickly than 4G                              |
| Connection density | 1 million/km2 higher than 4G                                      |
| flux density | 10-100Tbps/km2 higher than 4G                                    |
| uu interface latency | 4G*1/5 (1ms) lower than 4G                                       |
| peak rate    | 4G*20(10-20Gbps) higher than 4G                                  |
| mobility     | 4G*4(500+km/h) more quickly                                      |
3. UAV

3.1. UAV
UAV is an advanced unmanned autonomous vehicle. The power line inspection of UAV is a complex system that integrates aviation, electricity, meteorology, remote sensing, communication, geographic information, image recognition and information processing. Modern UAV has the ability to operate at high altitude, long distance, fast and independently. It can cross the mountains, rivers, and even patrol the power lines in harsh weather. It can also make full spectrum fast camera and fault monitoring of overhead towers, supports and conductors.

3.2. 5G UAV
With the rapid development of the UAV industry, new requirements are also put forward for the UAV communication link, showing the development trend of closely combining with the cellular mobile communication technology, and forming the connected UAV. The UAV terminal and the ground control terminal of the 5G UAV are transmitted through the 5G network for data transmission and control instruction transmission, and the applications of various scenarios are loaded through the business server.

| Time  | Service attribute | Uplink rate | Downlink rate | Service end-to-end delay | Control end-to-end delay | Location  | Cover height |
|-------|-------------------|-------------|---------------|--------------------------|--------------------------|-----------|--------------|
| 2020  | 4k video          | UL 25Mbps   | 300Kbps       | <200ms                   | <20ms                    | <0.5m     | 100m         |

4. Technical Advantages of 5G UAV Inspection

4.1. Working advantages of UAV inspection
Most of the traditional power line inspection is carried out by human inspection, which is inefficient, difficult and high-risk. In remote areas or some harsh weather conditions, the work risks faced by inspectors will be more serious, and even threaten the health and safety of life. The UAV inspection is not restricted by terrain environment, high efficiency. The UAV can be used to survey and urgently investigate potential dangers of lines, such as tower collapses, and are not affected by road conditions at all. Compared with helicopter patrol, the UAV can carry visible light, infrared thermal imaging, ultraviolet imaging and other equipment for all-round observation of the line in addition to the advantages of cost and personnel. The UAV can also be suspended at a fixed point to conduct more detailed detection of the line. The UAV with built-in GPS positioning and navigation system can also avoid the risk of disappearance and minimize the risk.

4.2. Problems in Operation of 4G UAV Inspection
At present, the 4G network already has the communication requirements to support some scenes of UAV, but it has many challenges. There is a certain optimization space for 4G network in bandwidth, delay and interference coordination.

It is not easy for people to operate the UAV. To photograph the details clearly, the inspectors need to shoot the towers and lines at a close range, and improper operation is easy to cause accidents caused by crashes or touching the lines, which affects the safety and quality of flight inspection.

It is difficult to get data transmission. The image captured by the UAV inspection is stored on the memory card by default. After completing the flight task, the memory card is removed and imported into the computer for analysis and processing. Image cannot be transmitted back in real time, which seriously restricts the timeliness of defect detection. If there is a risk of power information leakage through public network transmission, the channel of data security transmission needs to be solved[6].
Image analysis is difficult. The inspection images taken by the UAV need to be manually classified, and then the defects are amplified one by one, marked and named. This series of image analysis and processing processes occupy a lot of time, which restricts the improvement of the comprehensive efficiency of the UAV inspection.

4.3. **Technical Advantages of 5G UAV Inspection**

The 5G network capability meets the communication requirements of most UAV application scenarios. The networking of UAV has been first Some applications are implemented in the 4G network, and 5G can be better and more perfect. Networked UAV will drive multiple scenarios to upgrade.

In the use of 5G technology to carry out UAV power inspection work, mainly equipped with a visible light camera or camera, the UAV is close to flying to the base station, flying to the standard height, using the camera to shoot the base station, and then the specific photographs and data information obtained are transmitted to the hands of the power patrol personnel on the ground, the staff can use the corresponding APP to watch in real time on the mobile phone. In the current practical application, there are obvious advantages in three aspects.

5. **Application Cases of 5G UAV**

The first power line inspection system based on 5G + Beidou UAV in State Grid was put into operation in 2021. In practice, there are obvious advantages in three aspects.

Firstly, with the help of Beidou intelligent space-time service and three-dimensional laser point cloud data, the autonomous planning and one-click start of UAV inspection lines are realized, and the inspection task is automatically completed and returned. The intermediate process does not require manual intervention.

Secondly, the 5G power slice network can be used for real-time transmission, and the fuselage images and high-definition videos can be read in real time. Through the 5G slice network, it can be remotely transmitted to the UAV inspection control platform, the UAV inspection status, the first perspective video, and inspection photos. Other information can be monitored in real time.

Thirdly, The advanced image recognition algorithm is used to build an artificial intelligence recognition platform. The automatic diagnosis and analysis of the image after inspection are carried out, and the inspection report is generated and sent to the line maintenance personnel to provide auxiliary decision-making for UAV inspection.

6. **Research Prospect**

The purpose of this section is to give some future research direction[7].

6.1. **First stage is networking**

Based on a fully connected network carrying UAVs and MBB users, the UAV network is promoted to connect to the cellular network to realize the safe flight of UAV. At present, it has been basically realized. The International Telecommunication Union (ITU) has carried out a number of gateways during the 2017-2020 study period. In the standard research project of UAV, the research content covers the UAV network function architecture, communication requirements, identity, spectrum and other aspects.

6.2. **The second stage is real-time**

To carry out regional UAV full connection business research. Combined with the enhanced mobile broadband and low delay and high reliability technologies of 5G wireless network access, the full connection scenario of regional UAV is studied. This will promote the landing of advanced technologies such as over-the-horizon UAV interconnection, high-definition video transmission, high reliability and low delay data transmission. This effectively solves the safety problems related to casualties and harsh environment in the fields of inspection, security, surveying and mapping and rescue.
6.3. The third stage is intelligent
Combined with 5G and AI cloud processing technology, the cellular network combined with AI technology can realize the autonomous operation of UAV, complete 7 * 24 hours without intermittent operation, further liberation of manpower, improve efficiency, and avoid personnel injury in the process of operation, let people get rid of repeated labor.

7. Conclusion
At present, the demand and trend of cross-border integration of UAV and wireless communication have been obvious. The industrial ecology of UAV 5G applications is also initially mature from the aspects of UAV application scenarios and communication requirements, terminal communication capabilities, and wireless technology. The use of 5G UAV realizes the intelligent panoramic operation of power inspection, which is an important means to ensure the reliable operation of the power grid. However, due to the influence of electromagnetic fields in the workplace, it will be out of control and crash, and even cause accidents that staff cannot control the flight status and affect human-machine safety. Therefore, the use of 5G inspection UAV is full of challenges and imperative under the constraints of 5G service and UAV performance.

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