Prospect of Power Inspection Using UAV Technology

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Abstract. With the continuous iterative evolution and integration of new generation information technologies such as artificial intelligence, cloud computing, big data, Internet of Things (IoT), and mobile Internet, the Unmanned Aerial Vehicle (UAV) remote sensing technology will be qualitatively leap, and it will also drive the power industry into a new era of intelligence. This paper aims at reviewing the full-service process of UAV power inspection, expounds the application of new generation information technology in UAV power inspection, and forecasts the intelligent trend of power inspection. 1) Intelligent flight platform: the drone is closely integrated with 5G communication, gradually leading the 5G network UAV from network integration, real-time era to intelligent era; 2) intelligent patrol: the UAV intelligent control and other series of technologies Bottleneck will be overcome, networked "fixed/mobile" drone intelligent airport are developed, and UAV power inspection will be all-weather, unmanned and intelligent; 3) intelligent data analysis, introduction of artificial intelligence technology and continuous optimization of models will greatly improve fast and accurate inspection data intelligent analysis; 4) integration of IoT, big data, cloud computing will improve the multi-dimensional data integration, state monitoring full coverage, data stream and business flow integration coupling, and achieve intelligent equipment state evaluation and prediction; 5) Comprehensive application of the new generation of information technology: the construction of intelligent operation and maintenance system, and intelligent control platform for drone power inspection, will effectively improve management, and create a new situation of power inspection.

Keywords: Unmanned Aerial Vehicle (UAV) · Artificial intelligence (AI) · 5G communication · Internet of Things (IoT) · Power inspection

1 Introduction

During the "Thirteenth Five-Year Plan" period, China's power grid infrastructure construction has achieved rapid development. It is estimated that the total mileage of transmission lines will reach 1.59 million km in 2020, and will maintain a continuous growth of about 5% per year [1]. Inspection, care and maintenance put forward higher requirements. With the continuous advancement and development of the aircraft patrol

Y. Xie et al. (Eds.): GSES 2019/GeoAI 2019, CCIS 1228, pp. 151–159, 2020.
https://doi.org/10.1007/978-981-15-6106-1_12

business, the Unmanned Aerial Vehicle (UAV) has been used as one of the important means of patrol of transmission lines, and normal operations have been carried out. The State Grid Corporation and the relevant departments of China Southern Grid Corporation are continuously deepening the construction of drone teams and improving them. Various types of support and support systems have gradually formed a new mode of inspection of transmission lines based on "machine inspection and personnel inspection" [2–4]. However, the contradiction between the increasing number of transmission equipment and the shortage of operation and maintenance personnel has become increasingly prominent. The transmission line inspection team faces a severe situation in which the total number of missing and structural defects are coexisting. The degree of intelligent inspection of drones is not high, and the application level is difficult to support the development requirements of transmission and inspection.

As the main feature of the modern era, the information technology revolution sweeping the world is evolving in the direction of integration, ubiquity, and intelligence, and has become the main driving force for social change. In this process, many new ideas, new concepts, new methods, and new technologies such as cloud computing, big data, Internet of Things, mobile Internet, and artificial intelligence are emerging. The new generation of information technology is gradually becoming a powerful engine for smart grids. At the same time, it has greatly promoted the innovation and development of drone technology.

The deep integration of the new generation of information technology and drones will inevitably continue to optimize and reconstruct the UAV power inspection technology system and framework, and push the UAV power inspection into a new stage of intelligence, with the "big cloud object shift". The concept of intelligent transportation supported by modern information technology came into being. This paper combines the application status of UAV grid inspection technology, starting from the technical development trend and industry application requirements, and imagining the future development direction and providing reference for the industry.

2 5G Network Connected Drones Lead the New Era of Power Inspection

Mobile communication technology is the key to improving real-time transmission of drone video, flight status monitoring, high-precision positioning and remote control. As a new generation of mobile communication technology, 5G's jump in bandwidth, delay, connection density, network performance, etc., will revolutionize the application of the UAV power industry. In the foreseeable future, the close integration of UAVs and 5G communication technology will lead a new era of power inspection with "network-connected drones" as the core.

Both the 5G network UAV terminal and the ground control terminal transmit data and control commands through the 5G network, and load various scenarios through the service server [5]. The future 5G network UAV system is composed as follows (see Fig. 1):

Fig. 1. 5G network connected drone platform composition

5th generation mobile networks has the characteristics of wide coverage area, low time delay, ultra-high bandwidth, large connection, etc. It can meet the requirements of UAV automatic driving and upgrade of obstacle avoidance technology, and will give UAV on-line real-time ultra-high-definition image transmission. State monitoring, ultra-long-range low-latency control, long-term stable online communication signals, high-precision positioning, secure network, autonomous obstacle avoidance and cluster control, etc., combined with network slicing and edge computing capabilities, will accelerate the innovation and development of UAV industry applications. At the same time, with the maturity of artificial intelligence, edge computing and other technologies, its in-depth integration with 5G technology will promote the application of networked UAV in power inspection from network to real-time, and realize the leap to unmanned intelligent inspection in the near future.

Networking stage: The UAV will be connected to the low-altitude cellular mobile communication network to realize UAV interconnection, over-the-horizon control, multi-machine coordinated flight, and data quasi-real-time return, etc. At present, the networking technology has realized some functions in the 4G network, but it is limited by the bandwidth, delay, interference coordination, etc. of the 4G network, it is imperative to combine 5G communication technology with UAV power patrol to meet the requirements of high speed and real-time.

Real-time phase: Real-time communication between UAV, ground stations, and dispatch management systems to realize real-time monitoring, real-time positioning, remote scheduling and control of UAV status. Based on the large-scale antenna array of 5G base station and single-station or multi-station co-localization, the positioning accuracy of the UAV is effectively improved, and the operation safety of over-the-horizon UAV is guaranteed. With the help of the characteristics of 5G network, such as large bandwidth transmission capability, end-to-end milliseconds delay and high reliability transmission, the existing UAV point-to-point communication technology is broken. The bottleneck of distance between data transmission and image transmission is the real-time return of high-definition images/videos, remote sharing of UAV shooting scenes, comprehensive control the operation site conditions; control the UAV

flight path with ultra-long-range low-latency, carry out cluster cooperative operation, realize the ground station and management center to carry out internal and external field cooperation, and open up the information barriers of the inspection site and the management personnel behind the operation. At the same time, it supports flexible and efficient 5G network technology under ultra-high mobile speed, and combines scenarios such as dual connectivity and coordinated multi-point transmission to enhance the high mobility of the terminal, maintain the continuity of the inspection service and high system performance.

3 Artificial Intelligence Accelerates the Innovative Development of Electric Power Patrol Inspection

A new round of scientific and technological revolution and industrial transformation are emerging. The formation of big data, the innovation of theoretical algorithms, the improvement of computing power and the evolution of network facilities have driven the development of artificial intelligence into a new stage. Intelligentization has become an important direction for technology and industrial development. In July 2017, the State Council issued the "New Generation Artificial Intelligence Development Plan". On December 14, the Ministry of Industry and Information Technology issued the "Three-Year Action Plan for Promoting the Development of a New Generation of Artificial Intelligence Industry (2018–2020)", which raised artificial intelligence to the national strategic level. The deep integration of networked UAVs and the new generation of artificial intelligence technology promotes the UAV power inspection into a new stage of intelligence.

The development of UAV grid inspection technology has now passed the manual operation stage, entered the automatic inspection stage, and realized the automatic driving of the drone based on pre-programming methods such as manual teaching/three-dimensional route planning, as well as the auxiliary analysis of some typical defects and hidden dangers of power equipment, have been realized. With the continuous development of artificial intelligence, the power inspection of UAV will be driven from automation to intelligent leapfrog development. On the one hand, it promotes the intellectualization and operation autonomy of power inspection equipment. On the other hand, it effectively improves the intelligent processing level of patrol data of UAV, and creates a new situation of electric power patrol inspection of UAV.

3.1 Promote the Intelligence and Operation Autonomy of Power Inspection Equipment

With the continuous development and deep integration of information technology and sensor technology such as artificial intelligence, 5G communication, big data, etc., it will overcome a series of key technologies for UAV autonomous inspection, and comprehensively break through real-time perception and avoidance of complex scenes, real-time targets. Intelligent identification and tracking, intelligent path planning, intelligent flight control and self-determination, dynamic and precise positioning,

environmental adaptive shooting, multi-machine multi-task collaborative control, collaborative semantic interaction, etc., a series of technical bottlenecks restricting UAV applications. Through the online environment awareness and information processing of the UAV system, the operating environment is fully perceived and obstacles are avoided, real-time intelligent obstacle avoidance and autonomous route planning, and the patrol inspection route and control strategy are generated independently according to the requirements of the inspection task.

To realize the intelligentization of the UAV power inspection and the intelligentization of multi-machine coordinated inspection under the environment of open, dynamic and complex transmission and distribution, intelligent, safe and efficient power inspection, and greatly enhance the intelligence of power inspection degree, inspection efficiency and quality, as well as power supply reliability, effectively solve structural problems such as lack of staff [6, 7]. And continue to deepen and expand the application of UAV power industry, explore the development of intelligent UAV foreign body removal, live water washing and other live operations, based on UAV's composite insulator hydrophobicity detection and other monitoring operations, and gradually promote the UAV detection and maintenance intelligence.

At the same time, through the development of an integrated UAV intelligent airport, the autonomous inspection technology of UAV based on "fixed platform" and "mobile platform" will be overcome to break through the limitation of the existing UAV's endurance capacity and form the continuous operation capability of the UAV.

The UAV intelligent airport is the infrastructure that guarantees the continuous operation of the drone, providing conditions for the landing site, storage, charging, and data transmission of the drone. The intelligent hangar of UAV can create an all-weather constant temperature and humidity storage space for UAV, which is equipped with precise landing guidance system, grabbing mechanism and selfcharging/automatic battery replacement system to ensure the endurance of UAV [8]. It has an independent environmental monitoring system to automatically judge the flight test conditions, which can support various power supply modes such as solar power supply and external power supply. Meanwhile, it is compatible with various UAV models. Through the deployment of networked fixed/mobile UAV intelligent airport, all-weather, all-day and full-autonomous multi-aircraft collaborative intelligent inspection can be realized, which greatly improves the inspection efficiency.

3.2 Improve the Intelligent Analysis Level of UAV Inspection Data

At present, the intelligent processing of drone inspection data is low, and the coupling with business data is not high, which cannot support the collaborative intelligent patrol mode based on data flow driven UAV.

With the continuous expansion of the inspection service of drones and the increasing number of machine inspection equipment, the processing and analysis of the data of transmission line machines will surely enter the era of "big data". At present, the amount of data on drone inspections has shown an exponential growth trend, which provides a large number of learning samples for artificial intelligence technology. By unifying and perfecting the image labeling rules, the artificial intelligence depth image recognition technology is used to construct and iterate the defect recognition algorithm

to realize the rapid intelligence and standardization analysis of the hidden dangers of power equipment defects, and automatically generate defect hidden danger reports. At the same time, it explores the intelligent identification technology based on AI for airborne front-end defects, combined with interactive field operation technology such as line physical ID information identification, real-time intelligent diagnosis and identification of defects and hidden dangers can be carried out in the patrol inspection process to improve the timeliness of defect identification. Through the introduction of artificial intelligence technology, the efficiency and intelligence level of inspection data processing can be improved comprehensively, transmission line defects and external security risks can be effectively analyzed and mastered, line equipment operation status can be controlled in time, hidden dangers can be eliminated in time. Improve line running stability, safety, save human resources, decrease the cost of inspection.

4 Internet of Things, Big Data, and Cloud Computing Drive Global IoT and Situational Awareness

The Internet of Things (IoT) is an emerging technology involving multiple fields of information technology and has become one of the symbols of the global information age. It is called the third wave of electronic information technology after computers and the Internet. The Internet of Things has become an important part of the construction and operation of smart grids. With the full deployment of the State Grid Corporation of China and China Southern Power Grid Corporation in the Internet of Things, the power system is entering a new era of the IoT power system [8]. As an emerging computing model, cloud computing technology can effectively solve the storage of massive data and parallel computing of big data through virtualization, massive distributed data storage, parallel programming model and other technologies, which is the basis for supporting the application of intelligent technology in the field of power production [9]. The introduction of big data analysis technology can be used for in-depth mining for massive production and maintenance data, carry out situational awareness and global analysis, which has very important guiding significance for power production operation and maintenance management and decision-making. These emerging information technologies are profoundly changing the current way of power operation and maintenance.

Utilize Internet of Things technology, cooperate with multiple monitoring methods, break the barriers of data sharing, and build an all-round intelligent sensing monitoring system to realize online monitoring systems, UAV platforms, ground unmanned inspection platforms, satellite remote sensing platforms, as well as meteorological, geological, hydrological environmental monitoring and other massive multi-dimensional data fusion, full coverage of state monitoring, realizing the global interconnection of the power grid, deep integration of data flow and business flow, complete acquisition of equipment life cycle data, and perceptual measurement of operating parameters of all working conditions, information exchange of influential factors in all scenarios provide data basis for lean management and control of power grid equipment.

Based on the entire IoT data of the power grid, we can control the operation and maintenance status of power lines in a timely and comprehensive manner. By using big data and cloud computing technology, systemic global analysis methods are used to construct equipment state evaluation and trend prediction models, and the mass production operation and maintenance data is deeply mined and multi-dimensional analysis, carry out situational awareness, real-time comprehensive evaluation and evaluation of equipment status, closed-loop management of pre-failure and safety risk prediction and early warning, real-time monitoring in the event, and comprehensive analysis after the event, comprehensively improve the status of transmission line state diagnosis, improve equipment status evaluation and the level of intelligence in trend forecasting. At the same time, based on the situational awareness results, according to the health status of different power equipment such as lines, poles and towers, a scientific differentiated inspection strategy is developed to assist the differentiated inspection of UAV, reduce the operation and maintenance costs, improve the inspection efficiency, and promote the intelligent upgrading of power grid operation and maintenance management.

5 Global Integrated Intelligent Management and Control Platform to Improve Lean Management Level

At present, the operation level and management level of UAV in various regions are uneven, and the requirements of lean management of equipment do not match the level of business development. The inspection operation lacks effective supervision, and the inspection equipment has device information management that relies on formalization. The inspection data storage and management are scattered, lack of effective means of integration and sharing, internal and external industries are out of line, and unified application and closed-loop management have not yet been formed, resulting in the inability to carry out multi-dimensional analysis and comprehensive application of inspection data, and can not provide more accurate decision-making basis for transmission line operation and maintenance departments [10, 11].

Utilizing the technological advantages of artificial intelligence, big data, Internet of Things, mobile internet, etc., we will build a network-wide integrated UAV intelligent management and control platform to promote business standardization, management and control informationization, operation intelligentization, and management leanness [12]. As the data center and intelligent production monitoring command center of transmission operation and inspection management the management and control platform integrate power inspection, online monitoring, power grid resource data, equipment and personnel information, and equipment operation status, meteorological/micro-meteorological data and other multi-source operation and maintenance data, and realizes deep integration of massive inspection data and share the whole network. By means of global analysis, multi-dimensional intelligent analysis and precise positioning of transmission line operation status are carried out, clearly and completely display the operation status, inspection status, elimination of transmission equipment and the implementation of the cycle, etc., provides a comprehensive, real-time and accurate decision-making basis for the intensive command of the transmission inspection.

It has powerful visualization functions, realizing real-time monitoring of UAV patrol and human patrol, recording and playback, grid resources, and 2D/3D visualization display of inspection results; intelligent three-dimensional coordination of intelligent inspection equipment and inspection personnel of drones Control and control, establish a comprehensive centralized management and control capability for the whole business process of "human patrol + aircraft patrol", realize global visual controllability of inspection, and effectively link all aspects of data collection, data processing, results management and elimination management, effectively improve the inspection effectiveness. Realize the interconnection and interoperability of internal and external data, front and back end data, form a complete closed loop of transmission operation and inspection work, comprehensively standardize the inspection of drones, ensure the safe and controllable operation, and promote the intelligent transmission and maintenance operation safely, efficiently and pragmatically. Improve the efficiency of the inspection and the level of lean management, so that the transmission inspection will be transformed from the original extensive management mode to the informatization and refined, and the production command and decision-making will be highly intelligent and intensive.

6 Conclusion

Smart grid is the inevitable trend of the development of the power industry. With the continuous iterative evolution and integration innovation of the new generation of technical information such as artificial intelligence, Internet of Things, big data, cloud computing, mobile communications, it will provide a powerful drive for the intelligent development of the power industry and reshape the new industrial era of power inspection.

This paper introduces the application of new generation of information technology in UAV power inspection from aspects of flight platform intelligence, data analysis intelligence, data application intelligence, etc. And looking forward to the intelligent trend of power inspection.

In the future, we will overcome a series of technical bottlenecks related to intelligent inspection of UAV. By deploying networked mobile/fixed-UAV nests, we using 5G network to connect UAV, ultra-long-distance and low-delay control UAV or multiple UAV cooperate to carry out all-weather, all-autonomous and unmanned intelligent patrol inspection, and simultaneously carry out intelligent analysis of defects. Through the global integrated management and control platform, UAV centralized management and control, unified management of data, deep mining, intelligent analysis and comprehensive application are realized, and multi-dimensional intelligent analysis and early warning are carried out on the operating state of the transmission line. At the same time, we should promote standardization of business, informatization of management and control, intellectualization of operation and lean management. Change the traditional operation and maintenance methods, improve the safety of operations, inspection efficiency and operation quality, continuously improve the intelligent transmission inspection level and the lean management level of transmission industry, and create a new situation of transmission and transportation inspection.

Acknowledgements. The research was jointly supported by China Southern Power Grid Guangzhou Power Supply Bureau Co., Ltd. Key Technology Project (080000KK52190001); Guangdong Provincial Science and Technology Program (2017B010117008); Guangzhou Science and Technology Program (201806010106, 201902010033); the National Natural Science Foundation of China (41976189, 41976190); the Guangdong Innovative and Entrepreneurial Research Team Program (2016ZT06D336); the Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou) (GML2019ZD0301); the GDAS's Project of Science and Technology Development (2016GDASRC-0211, 2018GDASCX-0403, 2019GDASYL-0301001, 2017GDASCX-0101, 2018GDASCX-0101).

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