UAV Inspection Path Planning Based on Transmission Line Technology

Wuneng Liu1,*, Lilong Liu1, Gengli He1, Peng Li1

1The diqing power supply bureau, yunnan power grid co., LTD, Yunnan Shangri la, China, 674400

*Corresponding author e-mail: leng909210257@126.com

Abstract. With the continuous progress of human society and the rapid development of economy, the power industry closely related to human production and life is also developing rapidly. Electric power industry is also playing an increasingly important role in the development of national economy. Subsequently, transmission security becomes more and more important. However, at present, the traditional single manual line inspection has the characteristics of high labor intensity, high safety risk, high safety risk, low operation efficiency, and many deficiencies seriously restrict the intelligent transformation of transmission line operation and maintenance. Therefore, this paper proposes a new transmission line detection scheme based on unmanned aerial vehicle (UAV) detection path planning. Transmission line detection system based on UAV and ground monitoring equipment basically meets the requirements of transmission line detection. It is found that the UAV based transmission line inspection work arrangement efficiency is higher, and the fault detection rate is higher. The accuracy rate of UAV line inspection method proposed in this paper reaches 93.7%, which can effectively reduce the workload of staff and improve the work efficiency.

Keywords: Power Industry, Transmission Security, Unmanned Aerial Vehicle, Line Inspection

1. Introduction

In recent years, the State Grid of China draws lessons from the advanced experience of UAV application in power system[1-2], and strategically proposes to use helicopter, UAV and manual inspection collaborative mode to conduct comprehensive inspection of transmission lines. Domestic helicopter transmission line detection research work carried out earlier, the technology is relatively mature, but the cost is high, personal safety risk increases in complex environment. At present, UAV
detection is in the stage of scientific research, and the key technologies need to be broken through. Based on the research results of UAV inspection and research, the headquarters of State Grid Corporation of China has carried out "UAV detection technology research". Several provincial power companies have strengthened the application, operation and maintenance, emergency response and other fields of UAV in smart grid, so as to further improve the operation and maintenance level of smart grid and the lean management of transmission lines [3-5].

UAV is often affected by obstacles such as trees, buildings, power lines, overhead communication cables, etc. This situation will have an impact on the inspection results. Therefore, in order to keep the detection requirements consistent with the current complex environment, it is necessary to ensure that the UAV not only has the control function of GPS autonomous route navigation [6-8], but also has the ability of automatic tracking flight control of power line tower. Through the continuous identification and avoidance of obstacles, the detection process can be completed quickly. From the analysis of the actual development of current technology, the domestic UAV automatic obstacle avoidance system can complete the identification of obstacles in the flight process, and can also effectively complete the route detour selection, which can be used for some complex and changeable transmission line detection.

Based on the analysis of the advantages of UAV [9-10] technology in the transmission line inspection path, this paper studies how to ensure the transmission safety more effectively under the rapid development of the current power industry, compares the intelligent UAV transmission line inspection technology with the traditional manual inspection method, and expounds that the UAV transmission line inspection technology has more efficient operation in the work. The advantages of higher fault detection rate provide power for the planning and research of UAV inspection path in transmission lines.

2. Corridor Inspection Path Planning

2.1. Constraints of Path Planning

When fixed wing UAV is used for corridor inspection, its path planning is constrained by inspection tasks and UAV performance parameters. Combined with these constraints, it is difficult to find a corridor inspection flight path that meets the actual needs. In this paper, the constraints in corridor path planning mainly include the following aspects.

(1) Maximum range

During the whole inspection process, the maximum range of UAV is recorded as $V_{\text{max}}$, let's assume that there are all tracks $n$ nodes, among them, No $i$ the track range of the section is $v_i$, then the total range of the track $V$ must satisfy:

$$ V = \sum_{i=1}^{n} v_i \leq V_{\text{max}}, $$

(1)

(2) Maximum path deflection angle
The path deflection of current UAV flight path segment relative to the previous path segment is called the path deflection angle of UAV. Because the former path is affected and restricted by UAV’s maneuvering speed and performance, the requirement of path deflection angle must be met $-\Delta \varphi_{\text{max}} \leq \varphi \leq \Delta \varphi_{\text{max}}$. The maximum calculated path deflection angle of current UAV flight path segment relative to the previous path is defined as:

$$\Delta \varphi_{\text{max}} = \arcsin \left( \frac{L_{\text{min}}}{(2*r_{\text{min}})} \right)$$  \hspace{1cm} (2)

2.2. New Inspection Mode

For the area with close distance and high power supply density, the substation with conditions is selected to arrange unmanned aerial vehicle nest. Combined with laser navigation, visual recognition, RTK precise positioning and other technologies, it can realize accurate landing, independent battery replacement and fast charging and discharging operation. The relay endurance between "nest nest" and UAV autonomous detection is realized by remote command, which solves the problem of low duration of UAV and ensures high reliability operation and maintenance of transmission lines in important load areas.

The deployment of UAV nest will require huge economic and maintenance costs for the lines with long distribution and long distance. Therefore, manual control UAV is mainly used to configure mobile charging vehicle for fine detection of tower body, and fixed wing UAV is used for remote channel detection.

3. Technical Index of Experiment

This experiment aims to explore the best relay mode of UAV Communication Data link. The research group has studied scientific research institutions, universities, aerospace units and telecom operators, and understood the application prospects, technical advantages and limitations of various relay methods in power line detection. UAV technology is a modern technology application complex integrating a series of advanced technologies and equipment, such as civil aviation, reconnaissance, obstacle avoidance, communication, geographic information, navigation satellite positioning, image recognition, etc. UAV transmission line fixed wing detection technology UAV can be divided into small and medium-sized fixed wing detection UAV and rotor (such as helicopter) detection UAV. According to the structure size and load of the line detection aircraft, it can be divided into large, medium and small transmission line fixed wing detection UAV. The main technical indexes are shown in Table 1.

**Table 1.** Major technical indices of various types of unmanned helicopters for transmission line inspection

| Serial number | Indicator items             | mainframe | medium-size computer | Minicomputer |
|---------------|-----------------------------|-----------|----------------------|--------------|
| 1             | Maximum takeoff weight / kg | ≥215      | <215                 | ≤15          |
2 Endurance time (full load) / h ≥5 2~5 1~2
3 Normal task load / kg ≥15 3~15 1~7
4 Maximum level flying speed / (km / h) ≥160 ≥80 ≥40
5 Hover limit (altitude) / m ≥2100 ≥700 ≥600
6 Measurement and control radius (visibility) / km ≥120 ≥30 ≥15
7 Dynamic rise limit (altitude) / m ≥3600 ≥900 ≥500
8 type of machine Single rotor (helicopter) Single rotor / fixed wing Four rotor / multi rotor

4. Discussion

4.1. Simulation of Transmission Line Corridor Inspection Route Planning Based on UAV

In the research of UAV transmission line inspection route planning, this paper uses genetic algorithm to optimize the optimal path. In genetic algorithm, the fitness function is usually derived from the objective function, so the fitness function cannot directly reflect the change trend of the objective function. At present, there are two common termination methods: (1) terminate the algorithm when at least one fitness value of all the generated solutions is close to the theoretical optimal value; (2) the algorithm ends when the maximum number of iterations is set in advance. Since the optimal theoretical value cannot be estimated in advance, the quadratic termination method is used to set the maximum termination algebra g. When the contemporary number G ≥ g, the algorithm is terminated. In this paper, G is generally chosen between 95 and 458.

For the above calculation method, matlab2012 is used for simulation experiment. In the simulation process, it is assumed that there are 11 monitoring points on the transmission line, which are (0.1,0.2), (0.31,0.26), (0.55,0.34), (0.89,0.56), (0.98,0.69), (1.15,0.82), (1.28,0.95), (1.41,1.02), (1.7,1.2), (1.9,1.4), (2.3,1.35), and the unit is km. The coordinates of takeoff point and landing point are (0,0) and (3.5,1.1). The distribution diagram is shown in Figure 1. The black dot in the figure represents the target tower, and the white dot is the shooting point of the traverse between each span. In this paper, only two points between each span are selected as the research object.
The simulation results are shown in Figure 1. It can be seen that the 30th generation of optimal individuals basically meet the maximum path deflection angle constraint, and the path can pass through most of the points to be monitored, which is more in line with the actual needs, but cannot monitor the target points (1.7,1.2), (1.9,1.4) and (2.3,1.35).

According to different voltage levels, the corresponding safety distance of UAV during patrol operation is also different, so the safety distance is determined according to the actual situation. The safety distance of UAV is calculated according to the following figure.

As can be seen from Figure 2, the UAV is equipped with ultrasonic ranging sensors in four directions. In the process of UAV detection, the UAV detection and obstacle avoidance system is established. The input and output of the system are sensor detection data and UAV flight direction adjustment signal respectively. According to the detection information of ultrasonic ranging sensors in four directions, the UAV can judge whether the UAV is within the safe range, and then issue the correction command to adjust the flight attitude of the UAV to avoid obstacles safely. For UAV how to avoid obstacles, it is necessary to set warning distance first. Considering the flight swing of UAV and the delay of control command sending, the alarm distance must be set reasonably. During the inspection, if the distance between the UAV and the obstacle is greater than the set warning distance, the flight status of the UAV does not need to be changed.
4.2. Application of UAV in Transmission Line Detection

UAV mainly uses wireless remote control device and program control device to control small aircraft. There is no one on board and there is no cockpit, but it has autopilot and program control. At present, the control mode of UAV can be divided into two types: self-program control and radio remote control. At first, UAV was mainly used in the military field, but with the continuous development of economy and technology, it is gradually applied to all walks of life, and it is also widely used, such as monitoring, search and rescue, mapping, search and so on. It can effectively improve the real-time and accuracy of the work. The application of UAV in the field of transmission line detection is an important embodiment of the development of UAV to civil field. In recent years, it has been widely used in China. Many power companies have begun to use UAV transmission lines under complex terrain and special conditions. It has low cost, low risk, strong adaptability, good liquidity and relatively convenient use. This not only greatly improves the inspection efficiency, but also releases labor to a large extent, and also reduces the inspection cost for power supply companies.

The traditional manual detection has high labor intensity, high safety risk, low defect identification rate and accuracy, and is easily affected by the weather and terrain, which is far from meeting the needs of universal power Internet of things construction. The UAV intelligent detection realizes the efficient collection of transmission line operation status data and accurate identification of defects by carrying Internet of things equipment (including lidar, camera, infrared thermometer, etc.), which effectively improves the safe operation level of the line. Compared with the traditional manual detection, the efficiency of UAV intelligent detection is improved by 3.2 times, which alleviates the plight of insufficient line operation and maintenance personnel to a certain extent. With the continuous development of new UAV technology, UAV intelligent detection will gradually replace manual detection as the main means of line operation and maintenance.

In the near future, UAV will be widely used in transmission line inspection, but the adaptability of UAV in the current market is far from meeting the demand. Therefore, in order to adapt to the characteristics of transmission line detection, the future transmission line UAV should have more functions. Many accessories on the transmission tower are the main detection objects, which are small in size and difficult to find. In addition, due to the strong electromagnetic interference around the UAV transmission line, the UAV transmission line cannot work close to each other. Therefore, the digital camera equipped with UAV must have better photographing performance and stronger automatic zoom detection ability, so as to timely detect various problems and defects of UAV transmission line, and improve the quality and technical level of UAV detection. With the further development and expansion of power information transmission and detection industry in China, the detection task of UAV will be further intensified. In order to meet the rapidly increasing workload, it is not advisable to increase the number of UAVs. This requires a long endurance time for the UAV. However, due to the characteristics of UAV working mode, the weight of battery needs to be guaranteed within a certain range. Therefore, first of all, we should actively explore new high-energy density battery materials to improve the capacity of UAV batteries under the actual situation that the capacity and volume of UAV batteries remain basically unchanged; secondly, improve the reliability and operation management efficiency of UAV system, reduce the consumption and energy loss of solar energy on UAV system, so as to improve and extend the system's endurance flight time; finally, The development of its UAV photovoltaic power generation system, the use of photovoltaic solar
energy for the UAV system to provide sustainable flight power, improve the reliability of the UAV and the duration of flight.

5. Conclusion

This paper mainly studies the problem of transmission line detection line planning based on UAV. With the development of the times and the maturity of UAV intelligent cruise technology, the application prospect in the market is more and more bright. Due to the shortcomings of traditional manual line inspection, such as high labor intensity, high safety risk and low operation efficiency, the intelligent transformation of transmission line operation and maintenance is seriously restricted. The traditional transmission line detection method has great defects, and the intelligent detection of transmission line using UAV is particularly effective. With the power industry and people's production and life more and more inseparable, so the inspection of transmission lines is particularly important. The UAV technology is combined with transmission line detection. Through the establishment of UAV detection system, determine the detection items, clear the detection process, and ensure the UAV transmission line detection smoothly.

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