Application Simulation Research of Unmanned Aerial Vehicle Maintenance System Based on Mechanical Arm

W L Zhang¹, W Y Wang², G Y Ji¹, H Shi², J Pan³, P J Niu⁴and G Q Su¹

¹ State Grid Tianjin Electric Power Company Chengnan Power Supply Branch, Tianjin, Tianjin, 300000, China
² School of Electrical Engineering and Automation, Tianjin Polytechnic University, Tianjin, Tianjin, 300000, China
³ School of Electronics and Information Engineering, Tianjin Polytechnic University, Tianjin, Tianjin, 300000, China
⁴ Tianjin Polytechnic University, Tianjin, Tianjin, 300000, China
zwllb@qq.com

Abstract. When the unmanned aerial vehicle (UAV) maintenance system based on mechanical arm contacts high-voltage transmission lines for maintenance, the insulation parts of the UAV maintenance system are prone to breakdown risk, which affects its own operation safety. In this paper, combined with the actual parameters of the transmission line and the UAV maintenance system, the finite element software is used to establish the simulation model of the mechanical arm, rotor, frame and fuselage under the transmission line and UAV maintenance system. The influence of electric field around the transmission line on the UAV maintenance system of the mechanical arm is mainly considered. The research results show that: the mechanical arm and other insulation components of UAV maintenance system will not break down during the maintenance of 35kV transmission lines. At the same time, the maximum electric field intensity and voltage value of each component in the working process of unmanned aerial vehicle maintenance system based on mechanical arm are obtained according to simulation. The research data not only provides a basis for the safe operation of transmission lines and UAV maintenance system, but also provides a reference for the design of related parts such as mechanical arm.

1. Introduction
The most important work of the power system is to ensure the safe and reliable operation of transmission lines[1]. Traditional manual maintenance is of great intensity, long cycle and low efficiency, and it is difficult to carry out maintenance work in some areas with complex or even dangerous terrain. Compared with the traditional maintenance method, the unmanned aerial vehicle maintenance system based on mechanical arm has the advantages of high efficiency, good operability and flexibility, little terrain restrictions, and reduced casualties[2-3].

At present, many scholars have carried out relevant researches on transmission lines and unmanned aerial vehicle inspection system. By reading a large amount of literature, the literature[4-6] mainly studies the electric field environment and distribution around high-voltage transmission lines. Literature[7-8] mainly studies the image recognition and fault location functions of unmanned aerial vehicle inspection system. Literature[9-10] mainly studies the impact of unmanned aerial vehicles (UAVs) on electric field around transmission lines and the safe distance between UAVs patrol inspection
system and transmission lines. In addition, literature[11-12] is also introduced about the impact of electromagnetic field around high-voltage transmission lines on human body, oil and gas pipelines. With the development of unmanned aerial vehicle technology, the concept of unmanned aerial vehicle maintenance technology based on robotic arm is proposed. Therefore, there are few researches on the influence of transmission lines on UAV maintenance system of robotic arm.

This paper takes 35kV overhead high-voltage transmission line and UAV maintenance system as examples to establish the simulation model. Under the normal working condition of the transmission line, the influence of electric field around the transmission line on the maintenance system of unmanned aerial vehicle based on robotic arm is mainly studied. At the same time, the maximum electric field intensity and voltage value that the robotic arm, rotor, frame and fuselage must bear in the unmanned aerial vehicle maintenance system when the distance between them is 0.84m, 0.34m and 0.02m from the transmission line is analyzed. This research data provides reference for safe operation of unmanned maintenance system based on mechanical arm and structure design of unmanned maintenance system.

2. Method
In this paper, the finite element software is used to establish a simulation model, through which the maximum electric field intensity and voltage value of each component can be obtained in the working process of unmanned aerial vehicle maintenance system based on mechanical arm. As shown in figure 1 (a), the high-voltage transmission line is the 35kV transmission line used by Tianjin Electric Power Company. According to the design literature of the tower provided by Tianjin Electric Power Company, the total height of the tower is 31200mm, the radius of the large umbrella is 2400mm, and the radius of the middle umbrella is 3200mm. The radius is 2700mm, and the transmission line conductor adopts LGJ-150 model with a diameter of 17.48mm.

The UAV inspection system is built based on the prototype of the UAV inspection system designed by Tianjin Electric Power Company. The mechanical arm is made of epoxy resin, and the rotor, frame and fuselage of the UAV are made of carbon fiber. See figure 1 (b).

The simulation model of the unmanned aerial vehicle maintenance system based on the robotic arm approaching the transmission line is shown in figure 2. The distance from the left end of the robotic arm to the geometric center of the line is set as d, and the maximum phase voltage of the transmission line is set as $35/\sqrt{3}$kV.

![Figure 1. (a) transmission line tower's floor plan (b) based on arm unmanned aircraft maintenance system](image-url)
3. Simulation and analysis
In order to analyze the influence of electric field around the transmission line on the maintenance system of unmanned aerial vehicle based on robotic arm. This paper studies the maximum electric field intensity and voltage value of each component of UAVs based on the distance transmission line \( d = 0.84m,\ d = 0.34m \) and \( d = 0.02m \) in the unmanned aerial vehicle maintenance system.

3.1 Case 1

Figure 3 (a) and (b) respectively show the electric field distribution with or without robotic arm UAV maintenance system. By comparison, it can be seen that when the robotic arm UAV maintenance system is placed at a distance of 0.84m from the transmission line, the impact of the unmanned aerial vehicle maintenance system based on the robotic arm on the electric field around the transmission line is almost zero. However, it is obvious from figure 3 (a) that the UAV maintenance system shows an obvious increase in field intensity at the left end of the robotic arm under the electric field environment. Considering that the local field strength of the unmanned aerial vehicle maintenance system based on mechanical arm is greater than the breakdown strength of the rod-plate gap 3kV/cm-3.5kV/cm or greater than the air breakdown strength of 30kV/cm, system components will produce breakdown hazards, affecting the operation of the unmanned aerial vehicle maintenance system. Therefore, according to the electric field distribution in figure 3 (a), the maximum electric field intensity value around each component of the unmanned aerial vehicle maintenance system based on mechanical arm can be obtained, as shown in table 1. It can be seen from table 1 that no breakdown occurs when the distance of the unmanned aerial vehicle maintenance system based on the robotic arm is 0.84m from the transmission line.
Figure 4. Shows the potential distribution when \( d = 0.84 \text{m} \).

According to figure 4, when \( d=0.84\text{m} \), the electric potential distribution of each component of the UAV maintenance system can be seen. Considering that each insulation component has certain voltage resistance ability, the voltage value of each component in the UAV maintenance system can be obtained from the electric potential distribution on the component in figure 4, as shown in table 1. It can be seen from table 1 that \( d=0.84\text{m} \). Among the components of the unmanned aerial vehicle maintenance system based on the robotic arm, the mechanical arm bears the largest electric field intensity and voltage value, respectively 3712V/m and 2069V.

### Table 1. Maximum electric field strength and voltage when \( d=0.84\text{m} \).  

| Component       | Field strength (V/m) | Voltage (V) |
|-----------------|----------------------|-------------|
| Robotic arm     | 3712                 | 2069        |
| Left-wing       | 1838                 | 224         |
| Right rotor     | 1371                 | 193         |
| Frame           | 1730                 | 470         |
| Body            | 720                  | 166         |

### 3.2 Case 2

Figure 5. Electric field distribution (a) system diagram (b) partial map.

Figure 3 (a) and figure 5 (a) are respectively when \( d = 0.84 \text{ m} \) and \( d = 0.34 \text{ m} \) of the electric field distribution system. It can be seen that the distance based on the mechanical arm unmanned aerial vehicle maintenance system is 0.84m to 0.34m. The influence of the field strength at the left end of the manipulator of the man-machine maintenance system becomes large. Figure 5 (b) clearly shows that the electric field distribution of the transmission line at the left end of the robotic arm changes slightly when the distance between the unmanned aerial vehicle maintenance system and the transmission line is 0.34m. Considering that the breakdown phenomenon of unmanned aerial vehicle maintenance system based on mechanical arm is easy to occur under high voltage field, the electric field intensity of each component of the unmanned aerial vehicle maintenance system can be obtained according to the electric field distribution in figure 5 (a), as shown in table 2.
Figure 6 shows the potential distribution when \( d = 0.34 \text{m} \).

Figure 6 shows the potential distribution of each component of the UAV maintenance system when \( d=0.34 \text{m} \). The voltage on each part of the system can be obtained from the potential distribution of the components in figure 6, as shown in table 1. It can be seen from table 1 and table 2 that the closer the mechanical arm UAV maintenance system is to the transmission line, the greater the electric field intensity and voltage borne by each component will be.

| Component       | Field strength (V/m) | Voltage (V) |
|-----------------|----------------------|-------------|
| Robotic arm     | 4656                 | 3353        |
| Left-wing       | 2334                 | 338         |
| Right rotor     | 1260                 | 236         |
| Frame           | 1337                 | 700         |
| Body            | 940                  | 229         |

### 3.3 Case 3

Figure 7 (a) shows the electric field distribution of the system when \( d=0.02 \text{m} \). \( d=0.02 \text{m} \) means the UAV has almost come into contact with the transmission line maintenance system, the figure 7 (a) shows that the electric field around transmission lines inspection system for unmanned aerial vehicle, unmanned aerial vehicle under the maintenance system of mechanical arm, frame, fuselage and other edges are visible field strength increasing, at the same time from figure 7 (b) and figure 3 (b) contrast can see at this time under the influence of mechanical arm in the unmanned aircraft maintenance system, change the electric field distribution around the transmission lines. Considering that the breakdown phenomenon of unmanned aerial vehicle maintenance system based on mechanical arm is easy to occur under high voltage field, the electric field intensity of each component of the unmanned aerial vehicle maintenance system can be obtained according to the electric field distribution in figure 7 (a), as shown in table 3. According to table 3, when \( d=0.02 \text{m} \), the mechanical arm bears the largest electric field intensity compared with other parts, which is 34363 V/m. At this time, it is the maintenance state of the
UAV maintenance system in contact with the transmission line. The electric field intensity of each component is the maximum value of the whole working process. At this time, the maximum electric field intensity of each component is less than the air breakdown intensity and the bar-plate gap breakdown intensity.

Figure 8 is a diagram showing the potential distribution of each component when \( d = 0.02 \) m, and the voltage withstand by the component at this time according to the potential distribution is as shown in Table 3.

| Component       | Potential (V) |
|-----------------|---------------|
| Robotic arm     | 7679          |
| Left-wing       | 287           |
| Right rotor     | 822           |
| Frame           | 298           |
| Body            | 1179          |

Based on the above analysis of the influence of the unmanned aerial vehicle maintenance system based on the electric field around the transmission line, the research concludes that the electric field intensity and voltage variation range borne by each component of the unmanned aerial vehicle maintenance system is within the range of 0.84m to 0.02m from the distant and near transmission line.

4. Conclusion

In this paper, the influence of electric field around high-voltage transmission line on unmanned aerial vehicle maintenance system based on mechanical arm is analyzed by using finite element software. The distance of UAV maintenance system based on mechanical arm is within 0.02m to 0.84m from the transmission line. The maximum electric field intensity around each component of UAV maintenance system is far less than the air breakdown intensity and the bar-plate gap breakdown intensity. Therefore, no breakdown accident occurs during the maintenance of transmission line of UAV maintenance system based on mechanical arm. At the same time, the maximum electric field intensity and voltage value data obtained according to the electric field distribution of the system and the electric potential distribution of each component provide valuable data reference for the transmission line and the design of safe operation of UAV maintenance system.

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