Research on the Protection Range of Bird Droppings of 110kV Transmission Line Based on ANSYS Maxwell

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Abstract. The falling of bird droppings near the insulator of overhead transmission lines will cause distortion of the electric field distribution near the insulator, resulting in air gap breakdown and flashover. Studying the area where there may be a risk of breakdown near the insulators in such a situation is of great significance for bird damage prevention of overhead transmission lines. Based on the finite element method, this paper established the 110kV transmission line model using ANSYS Maxwell finite element software and calculated the variation of the electric field distribution around the insulator when the bird droppings fall. Using the air gap average breakdown electric field strength as the criterion to judge whether breakdown occurs or not, the risk area of the air gap breakdown is determined, thereby determining the protection range of the transmission line for the flashover caused by the falling of bird droppings.

1. Introduction
With the continuous extension of the power grid and the improvement of the ecological environment in recent years, the activities of birds near the overhead transmission lines are increasing, and the number of transmission line faults caused by bird activities has increased significantly. The causes of bird-related line faults include bird droppings flashover, bird nesting fault, bird predation fault, and bird flight fault. Among them, bird droppings flashover is the main cause of bird-related line faults [1-3]. The bird droppings flashover is divided into the flashover caused by bird droppings contaminating the insulator and the flashover caused by the falling of bird droppings. Among them, the process of flashover caused by the falling of droppings is the formation and elongation of the bird droppings channel, the severe distortion of electric field around the insulator, and the breakdown of air gap [4]. Therefore, this paper used ANSYS Maxwell software to establish the model of bird droppings near the transmission line to analyse the distortion of the spatial electric field when the bird droppings fall, to determine the risk area of the air gap breakdown, and to determine the protection range against bird droppings. It provides reference for the installation of the bird-related fault prevention devices on transmission lines, which is conducive to the safe and stable operation of the power system.
2. The criterion of air gap breakdown
The air gap between the bird droppings and the insulator fittings can be approximately considered as a rod-rod gap or a rod-plate gap, and the relationship between the gap power-frequency breakdown voltage and the gap distance is as shown in Figure 1.

![Figure 1. Relationship between power-frequency breakdown voltage and distance of rod-rod and rod-plate air gap.](image)

It can be seen from the figure that when the gap length is less than 1 m, the power frequency breakdown voltage of the two gaps is proportional to the gap distance, and when the distance is the same, the power frequency breakdown voltage is approximately equal. Therefore, according to the above figure, it can be determined that the average breakdown electric field strength near the insulator in the presence of bird droppings is 4 kV/cm, and it can be determined whether the air gap breaks down by comparing with the simulated electric field strength of air gap.

3. Principle of finite element method
The main methods for measuring the electric field distribution of insulators are on-site measurement, analytical method and finite element method. The on-site measurement method is costly and vulnerable to external factors; the analytical method is complex and time-consuming, and it is difficult to analyse geometric models with complex structures using this method; the finite element method can adapt to the complexities of field boundary geometry and media physical property variation. It has great advantages in solving complex insulator electric fields, and many simulation calculation software based on finite element method has appeared recently, which improves the calculation efficiency and saves a lot of time.

The finite element method is a numerical calculation method based on the variation principle. First, the differential equation mathematical model is transformed into the corresponding variation problem, that is, the functional extremum problem. Second, the disparity difference is used to discretize the variation problem to the extremum problem of ordinary multivariate functions, which ultimately comes down to a set of multivariate algebraic equations. Last, the equations are solved to get the numerical solution of the original problem.

4. Simulation process
In this paper, ANSYS Maxwell finite element simulation software was used to calculate the electric field distribution near the insulator when bird droppings fall. The simulation steps of the software are creating and importing models, setting material properties and boundary conditions, meshing, solving and post-processing.
4.1. Model building and property setting

Bird-related line faults occur mostly in transmission lines with voltage levels of 110kV and above. Therefore, this paper selected 110kV overhead transmission lines for modeling and simulation. Bird droppings fall near the middle phase insulator.

The overall model includes towers, insulators, wires, connecting fittings, bird droppings, etc.

The tower is the 67-Z3-type linear tower. The tower size and simplified model are as shown in Figure 2.

![Figure 2. Tower size and model.](image)

The insulator is the FXBW4-110/160 composite insulator, and there are grading rings at both ends. The dielectric constant of the shed is 3.5. The size and model of the insulator are as shown in Figure 3.

![Figure 3. Insulator size and model.](image)

The model of the connecting fittings is simplified and replaced with cuboids. The wires are single-split with a diameter of 21.66 mm. Since bird droppings have a certain viscosity and electrical conductivity, the bird droppings are considered as a slender cylindrical conductor for the convenience of analysis. The radius is 3 mm and the ends are rounded.

The low-voltage side fittings of insulators and the tower are loaded with zero potential. For middle phase, the high-voltage side fittings of insulator are loaded with a high potential to 69.86 kV. For the other two phases, the high-voltage side fittings of insulators are loaded with potential to -34.98 kV. The bird droppings are regarded as conductors and the potential degree of freedom is coupled.

4.2. Meshing

The meshing results of air, tower and insulator are as shown in Figure 4.
After meshing, the model can be solved, and the spatial electric field and potential distribution can be obtained through post-processing.

5. Protection range

The specific process of flashover caused by bird droppings can be divided into two steps [5]. First, the bird droppings form a floating potential when they fall, in a certain region, the electric field strength between the lower side of bird droppings and the high-voltage side fittings of insulator exceeds the breakdown field strength that the air gap can withstand, causing the lower side of air gap to break down. Second, after the air gap breakdown, the bird droppings turn into high potential. If the electric field strength between the upper side of bird droppings and the low-voltage side fittings of insulator exceeds the breakdown field strength that the air gap can withstand, the upper side of air gap will also break down, and the insulator will have a strong breakdown and flashover.

Therefore, when the bird droppings fall, there is a risk of breakdown in the air gap both in upper and lower side. Through simulation and calculation, the position and length of bird droppings can be determined when two sides of air gap critically break down, and the risk area of breakdown near the insulator when the bird droppings fall can be determined. Thereby determining the protection range of the transmission line for the flashover caused by the falling of bird droppings.

5.1. Critical breakdown position

If the electric field strength between the lower side of bird droppings and the high-voltage side fittings of insulator exceeds the breakdown field strength, the air gap will break down, and the potential of bird droppings will be raised to 69.86 kV. At this time, if the electric field strength between the upper side of bird droppings and the low-voltage side fittings of insulator exceeds the breakdown field strength, both sides of air gap will break down. According to the breakdown field strength of 4 kV/cm, it can be calculated that the critical breakdown distance of the upper air gap is 175 mm after the bird droppings are raised to a high potential.

Keep the air gap distance between the upper side of the bird droppings and the low-voltage side fittings of the insulator at 175 mm, and the falling position is 125 mm away from the centre of the insulator. Change the length of the bird droppings so that the lower side of the bird droppings is closer to the high-voltage fittings of insulator. The software simulation results showed that when the distance between the lower side of bird droppings and the high-voltage side fittings of insulator was 125 mm, the potential of bird droppings was 20.53 kV and the electric field strength of the lower side of air gap was 3.95 kV, which means the lower side of air gap critically break down. The simulation result of potential distribution near the insulator is as shown in Figure 5. It can be seen from the figure that the bird droppings increased the potential difference of the air gap, making breakdown possible.
Figure 5. Potential distribution near the insulator.

By changing the horizontal distance from the falling position of the bird droppings to the centre of the insulator, the relationship between the falling position and the length of bird droppings when the air gap critically break down is simulated as shown in Figure 6. Since the minimum shed radius of the insulator is 90 mm, the shortest horizontal distance is 90 mm. As can be seen from the figure, the shortest length of bird droppings when the air gap critically break down is 880 mm.

Figure 6. The relationship between the falling position and the length of bird droppings.

5.2. Protection range

It is known from the above that the critical breakdown distance between the upper side of bird droppings and the high-voltage side fittings of insulator is 175 mm, and the critical breakdown distance between the lower side of bird droppings and the low-voltage side fittings of insulator is 125 mm. When the distance between the two sides of bird droppings and two sides of fittings is less than the critical breakdown distance, the breakdown may occur. According to the critical breakdown distance, the front view of the three-dimensional risk area of the air gap breakdown near the insulator when the bird droppings fall can be drawn as shown in Figure 7. Area 1 and area 2 are fan-shaped with radii of 175 mm and 125 mm. When the upper side of bird droppings is in the area 1 and the lower side is in the area 2, there is a risk of breakdown in the air near the insulator. Therefore, for insulator flashover caused by bird droppings, when installing protective devices such as bird guards, it should be ensured that the protection range is larger than or equal to the range of risk areas shown in Figure 7.
6. Conclusion
In this paper, the model of bird droppings near the 110kV transmission line was established by using ANSYS Maxwell, and the spatial electric field and potential distribution were obtained by simulation. According to the simulation results, the critical breakdown distance of air gap between insulator and bird droppings was determined, thereby the protection range was determined, which has certain reference significance for the installation of the bird fault prevention and control devices on transmission lines.

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