Study on dynamic flashover characteristics of iced insulators

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Abstract. In this paper, based on fxbw4-10/100 insulators, the flashover dynamic characteristics of iced insulators are studied. The insulators are artificially iced and flashover experiments are carried out with water of different conductivity in the laboratory, and different flashover voltages are obtained. The dynamic changes of insulator temperature field, electric field and potential are simulated by using finite element software. Finally, the influence of different physical parameters on insulator flashover characteristics is studied.

Keywords: Electric field intensity, potential, icing test.

1. Introduction

So far, there is no uniform regulation on the methods of insulator contamination icing experiment, the most commonly used methods are solid coating method and icing water conductivity method [1]. Shu Lichun and others compared the two methods, and the experimental results showed that: the results obtained by the ice-covered water conductivity method were similar to the actual results [2]. Based on the electrical conductivity method of iced water, the change of flashover characteristics of iced insulators under different pollution degrees was studied by artificial pollution icing in artificial climate laboratory in reference [3]. The AC flashover characteristics of polluted iced insulators were tested in the artificial climate chamber in reference [4]. The test results show that the ice-free zone is usually located at the upper and lower steel feet of the insulator string.

In this paper, the insulator pollution icing simulation experiment is carried out in the laboratory by using the icing water conductivity method, and the dynamic change process from arcing to flashover of iced insulator surface is recorded. By comparing the experimental phenomena with the simulation results, the influence law of different icing water conductivity on insulator pollution ice flashover is obtained, which provides theoretical reference for reducing the probability of insulator contamination ice flashover test.

2. Experimental study

The insulator used in this experiment is suspension composite insulator, model fxbw4-10/100. The basic structural dimensions are shown in Table 1.
Table 1. Dimension parameters of fxbw4-10/100 composite insulator.

| Large umbrella diameter/mm | Small umbrella diameter/mm | Umbrella skirt number | Structure length/mm |
|-----------------------------|-----------------------------|-----------------------|---------------------|
| 143                         | 107                         | 4                     | 400                 |

2.1. Experimental methods

Refer to GB4585.2 for the method of simulating pollution icing [5]. When the surface area of insulator is not more than 2000cm², 300 ml of pure water with conductivity less than 10us/cm is used to add salt density and ash density required by insulator area calculation into pure water, and mix them evenly. Finally, the conductivity water as shown in Table 2 can be obtained by measuring the test agent with conductivity meter automatically converted to 20°C by the above methods.

Test steps: clean the insulator surface with pure water with conductivity less than 10us/cm, hang the cleaned insulator vertically in the air, cool the conductivity water prepared by the above method to about 0°C outdoors in winter, and spray the insulator evenly with the conductivity water when the outdoor temperature is about -10°C. When the icing thickness on the insulator surface reaches the expected thickness, the ice coating shall be stopped, and the outdoor freezing shall be continued for about 15 min. then, the flashover characteristics of the insulator shall be tested in the laboratory.

Table 2. Configuration of different conductivity of iced brine.

| ESDD/(mg.cm⁻²) | NSDD/(mg.cm⁻²) | Conductivity/(us.cm⁻²) |
|----------------|----------------|------------------------|
| 0.01           | 1.0            | 160                    |
| 0.03           | 1.0            | 430                    |
| 0.05           | 1.0            | 640                    |
| 0.10           | 2.0            | 1120                   |
| 0.30           | 2.0            | 2700                   |
| 0.50           | 2.0            | 3350                   |

2.2. Analysis of experimental results

As shown in Figure 1, with the increase of ESDD, the flashover voltage of insulators changes significantly at the beginning. When the ESDD increases further, the flashover voltage changes slightly, the reason for this change is that when the ESDD is small, there are less conductive ions dissolved in the water film on the ice layer of the insulator. With the increase of the Edythe conductive ions in the water film gradually increase, the conductivity of the water film increases obviously, and the flashover voltage decreases sharply with the increase of the conductivity. When the ESDD continues to increase gradually, the conductivity of water film tends to be stable due to the small difference of water film content on the surface of Iced Insulator. Therefore, the minimum flashover voltage of insulator has little change.
Figure 1. Relationship between flashover voltage and equivalent salt density

As shown in Figure 2, the ice-free zone of iced insulator is located at the high and low voltage ends. The whole flashover process is that the arc extends from the high and low voltage ends to the flashover. The existence of ice-free zone greatly changes the surface potential distribution. When the applied voltage reaches a certain value, the partial pink arc discharge occurs first near the high and low voltage ends, and the voltage continues to increase, and intermittent white arc appears on the surface of the insulator. Part of the energy provided by the voltage applied by the insulator is used to melt the ice layer of the Iced Insulator, and part of the energy is used to maintain the development and combustion of local arc. The results show that the two local arcs at the upper and lower steel feet stably burn and dissolve ice layer and develop to the other pole stably. When the applied voltage reaches the flashover voltage of the insulator, the local arc of the insulator will quickly connect with the high and low voltage ends of the insulator to form flashover.

Figure 2. Local arc formation to flashover process

3. Simulation calculation
Due to the dispersion and uncertainty of the experimental results, in order to better study the flashover mechanism of insulators, a simulation model of polluted iced insulators is established. The simulation results of the insulator arcing position and local arc dynamic development process are compared with the experimental results.
3.1. Material parameters

Based on the actual size of fxbw4-10/100 composite suspension insulator, the ice layer thickness on the insulator surface is set as 3mm. The simulation model shares five kinds of materials. The specific parameters of materials are shown in Table 3.

| Simulation materials | Relative permittivity | Conductivity (s.m⁻¹) |
|----------------------|----------------------|---------------------|
| Silicon rubber       | 3.5                  | 1x10⁻¹³             |
| Air                  | 1                    | 1x10⁻¹⁰             |
| Mandrel              | 8                    | 7.1x10⁻¹⁰           |
| Fittings             | 1×10⁻¹⁰              | 5.998x10¹⁰          |

3.2. Analysis of simulation results

Because the diameter of insulator is different. The distribution of leakage current density is also different. Because the leakage current density is the largest at the high and low voltage ends of the insulator, when the voltage reaches a certain value, the local arc appears first at the high and low voltage ends of the insulator. Due to the Joule heat effect of the leakage current, a high resistance dry area is formed at the upper and lower steel feet of the insulator. As shown in Figure.3, most of the voltage of the insulator is applied to the dry area, and the potential distribution on the ice surface is relatively uniform, and the potential changes sharply, forming a high field strength in the dry area.

![Figure 3. Dynamic changes of electric field and potential in flashover process](image)

4. Conclusion

In this paper, the fxbw4-10/100 insulator is taken as the test object, and the simulation model is established and the experimental platform is built. The artificial pollution icing test is carried out, and the dynamic arc model of ice flashover of composite insulator is established. The dynamic process of pollution ice flashover is studied by the method of combined analysis of test and simulation. The results show that the distribution of high field strength is easy to form at the upper and lower steel feet of the insulator due to the difference in the diameter of the insulator along the creepage distance. The higher the conductivity is, the lower the flashover voltage is, and finally tends to be stable.

Acknowledgments

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