Influence of Pollution Degree on Impact Flashover Characteristics of Insulator

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Abstract. The flashover characteristics of polluted insulators under lightning impulse and switching impulse are simulated in laboratory. It is found that when the gray density value is fixed, the flashover voltage begins to saturate under the shielding failure voltage while the salt density value reaches 0.1~0.15mg/cm². And the salt density saturation point under the counterattack voltage waveform is earlier than that under the counterattack voltage waveform, around 0.02mg/cm². When the gray density value is fixed, under the counterattack voltage waveform, the flashover voltage decreases slightly in the gray density of 0.05mg/cm² to 0.10 mg/cm² range, and the flashover voltage begins to rise with the increase of gray density. Under the shielding failure waveform, the flashover voltage always decreases in the gray density of 0.05mg/cm² to 0.20mg/cm² range, and begins to rise gradually after the gray density exceeds 0.20mg/cm².

1. Introduction
At present, the experimental research on pollution flashover at home and abroad mainly focuses on the flashover characteristics of polluted insulators under the action of AC and DC, while the flashover characteristics of polluted insulators under lightning shock and operating shock are less studied. But the relationship between flashover voltage, salt density, gray density and other influencing factors under non-standard voltage waves, such as short tail wave and non-standard lightning wave, has hardly been studied. In the operation of transmission line, the voltage waveform at both ends of insulator string is not the standard lightning impulse voltage waveform when lightning strikes the tower directly and the conductors around. Therefore, the research on the flashover characteristics of filthy insulators under the action of non-standard impulse voltage waveform has certain engineering application value for the design of lightning protection and anti-pollution of transmission lines.

2. Test Products and Test Methods
2.1. Test Products
The LXY1-70 glass insulator is used as shown in Figure 1 and Figure 2, whose nominal diameter D is 25.5 cm, the structural height H is 14.6 cm, the creepage distance is 32 cm, the upper surface area is 648 cm², and the lower surface area is 862 cm².
2.2. Test Methods

The experiment is carried out in an artificial climate chamber. When performing a 50% flashover voltage test, the insulator should undergo at least 30 "effective" tests at a given reference filth. The so-called "effective" test refers to the test that is different from the test produced by the previous test. The applied voltage level in each test should be changed according to the lifting method. The voltage level difference should be approximately 10% of the expected 50% flashover voltage. That is, if there is no flashover, the flashover test should be reduced by 10% voltage. And if flashover occurs, the flashover test should be made by increasing the voltage by about 10%. Only this test and at least 29 subsequent tests are counted as effective tests and used to determine 50% flashover voltage.

3. Effect of Salt density on impact flashover characteristics of insulators

The pollution on the surface of insulators mainly includes soluble filth and insoluble filth. Soluble filth is characterized by equivalent salt density (ESDD) and insoluble filth is characterized by gray dense (NSDD). That is, the pollution degree of insulator is determined by the combination of salt density and gray density. Before the study of pollution degree on flashover characteristics of insulators, the influence of single variable on flashover characteristics of insulators is firstly carried out in this chapter. Based on the study of the effects of salt density (ESDD) and gray density (NSDD) on the flashover characteristics of insulators, the influence of pollution degree on the flashover characteristics of insulators is further studied.

In the test of impact flashover characteristics, the gray density was fixed to 0.1mg/cm² under mild pollution, and the simple impact flashover characteristics of polluted insulators were studied by changing salt density.

The 50% flashover voltage test on the 2*LXY1-70 insulator string is carried out by lifting method. Considering that each insulator flashover test will change the pollution distribution on the insulator surface and affect the validity of results, only 3 or 5 flashover tests have been carried out in each group of 2*LXY1-70 insulator string test products. For the same salt density, the number of valid tests is guaranteed to be more than 30 times. The average flashover voltage of all flashover voltages in
the effective data with a total average error of less than 10% is selected as the 50% flashover voltage of the insulator string under the filth degree, and its standard deviation is obtained. Under the condition of gray density of 0.1mg/cm², the effects of different salt density on the flashover characteristics of insulators under the condition of shielding failure voltage waveform and counterattack voltage waveform are studied respectively. The statistical discharge test results are shown in Figure 4.

By analyzing the test results of Figure 4, we can see that:

1) When the gray density value is fixed, and only the salt density value is changed, the flashover voltage obviously decreases. Under the condition of shielding failure, when the salt density value reaches 0.1~0.15mg/cm², the flashover voltage begins to saturate. The salt density continues to increase, and the flashover voltage is already very little affected. The salt density saturation point under the counterattack voltage waveform is earlier than that of the shielding failure voltage, about near 0.02mg/cm².

2) The sensitivity of the shielding failure waveform to salt density is different from that of the counterattack waveform. From dry flash to salt density 0.15mg /cm², the flashover voltage of counterattack waveform decreases by about 35kV, while the flashover voltage of shielding failure waveform decreases by about 85kV, with a difference of nearly 40kV.

The 50% flashover voltage of the polluted insulator string under the shielding failure waveform decreases with the increase of the pollution grade. The main reason for this phenomenon is that if the filthy attached to the insulator with a certain humidity does not lose, the conductivity of the insulator surface dirt layer will increase with the increase of salt density, and so does the discharge current. Local arcs are more likely to occur at the steel feet and steel caps of polluted insulators, while the arcs have negative volt-ampere characteristics. Therefore, the voltage amplitude needed to maintain the development of local arc is lower than that of filthy insulators with lower salt density. Under the same arc length, if the salt density is large, the resistance of the remaining pollution layer is low, which will be more beneficial to the development of polluted insulator arc, and the flashover voltage of polluted insulator will also decrease.

The surface conductivity of polluted insulators is not only affected by the pollution degree, but also affected by the surface wetting degree. With the increase of salt density, the downward trend of polluted insulators will become slower and slower. The reason for this phenomenon is that the water absorption capacity of the dirty insulator surface is limited. With the increase of salt density, the NaCl contained in the dirt layer on the surface of insulators increases. Conductivity usually increases with the increase of concentration, and the slope of the increase decreases with increasing concentration. When the concentration increases to a certain value, the conductivity of the solution will no longer increase with increasing concentration. After the conductivity reaches a certain maximum, even if the concentration continues to increase, the conductivity does not increase any more, while the
conductivity of some electrolytes decreases with increasing concentration. That is to say, with the increase of NaCl concentration on the polluted insulator surface, the conductivity of the insulator surface increases at a slower rate.

4. Effect of Gray Density on Impact Flashover Characteristics of Insulators

Set the salt density to 0.025mg/cm$^2$ under mild pollution, and study the flashover characteristics of insulators by changing the gray density. The same method of 3.1 section is adopted in the test booster method and the parameter statistical method. The flashover voltage results of insulators under different gray density conditions are shown in Figure 5.

By analyzing the experimental results of the above chart, it can be seen that under the condition of fixed salt density and changing gray density, the flashover voltage of polluted insulator shows different variation laws under shielding failure voltage waveform and counterattack voltage waveform, respectively. Under counterattack voltage waveform, the flashover voltage decreases slightly in the gray density range of 0.05mg/cm$^2$ to 0.10mg/cm$^2$. As the gray density continues to increase, the flashover voltage begins to rise, even exceeding the flashover voltage when it is slightly polluted. Under shielding failure waveform, the flashover voltage always decreases in the gray density range of 0.05mg/cm$^2$ to 0.20mg/cm$^2$, and begins to rise gradually after the gray density exceeds 0.20mg/cm$^2$.

Comparing the influence of salt density on flashover characteristics of insulators, it can be seen that when gray density increases from 0.05mg/cm$^2$ to 0.25mg/cm$^2$, the maximum drop of insulator flashover voltage is about 10kV, while when salt density increases from 0.01mg/cm$^2$ to 0.15mg/cm$^2$, the flashover voltage of insulator decreases by about 35kV. It can be seen that the salt density influence index of glass insulators is larger than that of gray density.

5. Conclusion

1) When the gray density value is fixed, the flashover voltage begins to saturate under the shielding failure voltage while the salt density value reaches 0.1~0.15mg/cm$^2$. And the salt density saturation point under the counterattack voltage waveform is earlier than that under the counterattack voltage waveform, around 0.02mg/cm$^2$.

2) Under the condition of fixed salt density and changing the gray density value, the flashover voltage of the polluted insulator shows different variation laws under the winding voltage waveform and the counterattack voltage waveform, respectively.

3) The influence index of salt density of glass insulators is larger than that of gray density.

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