Feasibility Study on PRTV of Suppressing insulator Iron Cap from Corrosion

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Abstract. UHVDC transmission line porcelain and glass insulator iron caps are seriously corroded, safe and effective anti-corrosion measures are of great significance for the stable operation of the power system. In order to determine the key parameters of PRTV spraying on the surface of insulator iron cap, a three-dimensional finite element model of insulator is established, and the test verified the feasibility of PRTV anti-corrosion of iron cap. The research results show that PRTV can effectively reduce the leakage current density of the insulator iron cap. PRTV can effectively prevent corrosion of the insulator iron cap, and can reduce the surface fouling speed of the insulator, improve the surface resistance of the insulator, and inhibit the insulator flash. The research results can provide reference for the research of anti-corrosion of insulator iron cap.

1. Introduction

China has become the country with the largest DC transmission capacity and the longest total transmission line length. [1]. With the completion and operation of multiple DC transmission lines, the problem of corrosion of DC insulator iron caps has become increasingly serious. In 2012, more than 2,000 V-shaped string insulators were found to have corrosion of iron caps on the negative side of the DC ±800kV in Hubei province. [2]. The corrosion of the insulator iron cap exhibits a wide distribution range, a large amount of corrosion, and a high corrosion rate. It has a great impact on the mechanical bearing capacity and insulation performance of the insulator, and seriously threatens the safe and stable operation of the power system.

There are few studies on the corrosion of insulator iron caps in foreign countries. The domestic research on the corrosion of insulator iron caps mainly focuses on the accelerated corrosion test method, the calculation of corrosion amount, and the calculation and improvement of the service life of zinc sleeves. Related scholars believe that the main cause of corrosion of insulator iron caps is electrolytic corrosion caused by leakage current [3-12]. However, it can be seen that there is still little research on the corrosion of PRTV coating anti-insulator iron caps.

In this paper, the three-dimensional finite element simulation of the insulator is carried out based on COMSL. The leakage current density and potential of the insulator iron cap when spraying different PRTV coatings are calculated. The influence of PRTV on the leakage current and surface
potential of the insulator iron cap is obtained. The anti-corrosion effect of the PRTV coating on the insulator iron cap was verified by an accelerated corrosion test.

2. Effects of PRTV on potential and leakage current
PRTV is a common electrical insulation material. Due to its good hydrophobicity, it is often sprayed on the surface of insulator insulation parts to increase the ice-covered flashover voltage and pollution lightning voltage of insulator.

2.1. Simulation model
3d modeling of insulators was carried out through Auto CAD, and the basic parameters of edge elements were shown in table 1. Since PRTV coating has basically no effect on the electric field and current density at the ball-and-socket connection, the influence of PRTV coating on the leakage current density and the overall potential distribution on the outer surface of the insulator is mainly analyzed. Therefore, the ball-and-socket connection of the insulator is simplified here. PRTV coating thickness is 1mm. The outer air of the solution domain is a cylinder with the same axis as the insulator. The height of the cylinder is three times the height of the insulator structure, and the bottom radius of the cylinder is three times the radius of the insulator, as shown in figure 1. The Settings of various material parameters are shown in table 2.

Table 1. Parameters of insulator

| Structural height H | Nominal diameter D | Creepage distance L |
|--------------------|-------------------|-------------------|
| 195mm              | 320mm             | 545mm             |

Table 2. Parameters of various materials

| Material       | Iron  | Ceramics | Air  | Cement | PRTV |
|----------------|-------|----------|------|--------|------|
| Resistivity/Ω•m| 4E-8  | 1E14     | 1E10 | 1E4    | 1E14 |
| Relative permittivity | 1E10  | 5.7      | 1    | 14     | 6    |

Fig.1 Three-dimensional computing model

Considering that the potential distribution rule and leakage current density distribution rule of the insulator will not be different with different withstand voltage, only one case under the withstand voltage need to be discussed. In each simulation process, 10000V voltage is added to the iron cap of the insulator while the steel foot is grounded. Additionally, air is set as a natural boundary.

2.2. PRTV coating height’s influence of leakage current density and potential on iron cap surface
Four sets of different spraying heights on the iron cap were simulated, that is, the PRTV was not sprayed, the PRTV was sprayed at the gap of the iron cap, the PRTV was sprayed to the middle of the
iron cap, and the PRTV was sprayed to the ball joint of the iron cap. The simulation results of spraying PRTV shows the surface potential distribution and leakage current density distribution of the insulator in Fig. 2 and Fig.3. In the picture (a), (b), (c) and (d) respectively represent Simulation results about that the PRTV was not sprayed, the PRTV was sprayed at the gap of the iron cap, the PRTV was sprayed to the middle of the iron cap, and the PRTV was sprayed to the ball joint of the iron cap.

![Fig.2 Insulator surface potential distribution](image)

As can be seen from Fig.2, the potential on the insulator ceramics of (b), (c), and (d) is slightly increased compared to (a), but the whole is uniformly distributed, and there is no sudden change in local potential. Comparing (b), (c), (d), it was found that the surface of the insulator iron cap was sprayed with different heights of PRTV coating, and the surface potential of the insulator remained basically unchanged.
As can be seen from Fig.3, the part of the insulator cap is exposed to the air portion, and in this part the maximum current density of (a), (b), (c), and (d) appears near the gap of the iron cap, the middle of the iron cap, the middle of the cap, the end of the PRTV coating. It can be seen that the maximum current density of the insulator iron cap varies depending on the height of the PRTV coating. When the PRTV coating does not cover the gap of the iron cap, the leakage current density at the gap of the iron cap is maximized; when the PRTV coating covers the gap of the iron cap and does not cover the middle portion of the iron cap, at the middle portion of the iron cap and the leakage current density is the highest; when the PRTV coating covers the gap of the iron cap and covers the middle portion of the iron cap, the end leakage current density of the PRTV coating is the largest.

3. Accelerated corrosion test

3.1. Experiment method
To simulate the suspension mode of the V-shaped insulator string, test group and control group of insulators are suspended in accordance with the inclination angle of 45°. Reference standard [13] and literature [5], and use the drip method to test for accelerated corrosion test. The 2g of sodium chloride is dissolved in 500mL of water to prepare sodium chloride solution in a certain concentration, and the solution is dropped to the insulator with medical infusion line at a constant speed in order to reduce the resistance of the insulator surface and reduce the duration of the test. For the test group, the sodium chloride solution is added dropwise to the PRTV coating of the insulator’s iron cap; for the control
group, the sodium chloride solution is added dropwise to the surface of the insulator’s iron cap to make sodium chloride solution contact with the iron cap directly. The applied voltage of insulator sample is 25kV in this test, that the iron cap is applied +25kV voltage and the steel feet is grounded. The duration time of voltage application is 60 hours. The test circuit is shown in Fig.4.

![Test Circuit Diagram]

1. Experimental transformer; 2. Fairing; 3. Limiting resistor; 4. Smoothing capacitors; 5. Divider; 6. Test sample

Fig.4 Test circuit

3.2. Test results and analysis
The insulator after accelerated corrosion test is shown in Fig.5.

![Insulator Images]

(a) The control group (b) The test group

Fig.5 Insulator after accelerated corrosion test

After seen from Fig. 5, the iron cap of the insulator of the control group after accelerated corrosion test appears traces of corrosion, and the porcelain surface of this insulator appears white corrosion products. There was no corrosion mark on the insulator cap of the test group, and there was no corrosion on the porcelain. And the PRTV coating itself does not appear significant local damage and aging phenomenon. From the above, it can be known that the PRTV coating of the iron cap of the insulator can slow down the corrosion of iron cap. Further, the corrosion products of the porcelain surface of insulator obviously decrease when the corrosion of the iron cap of insulator is slowed down, so that this insulator has a surface resistance which is much larger than the surface resistance of the insulator that it’s attached by corrosion products, and it makes the flashover voltage of the insulator be raised.

4. Conclusion
The following conclusions are drawn from the study of this paper:

1) Spraying PRTV on the surface of the insulator iron cap can reduce the leakage current density of the iron cap surface. The maximum leakage current density on the insulator iron cap increases as the height of the PRTV coating increases;

2) The height of the PRTV coating on the insulator iron cap should take into account two factors such as rainwater dampening and leakage current density reduction. The basic principle is to minimize the height of the PRTV coating while ensuring that the iron cap is not wetted by rain;
3) PRTV can reduce the corrosion of the insulator iron cap, reduce the accumulation of corrosion products on the surface of the insulator, improve the surface resistance of the insulator, and help to improve the flashover voltage of the insulator.

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