Study on Surface Discharge Test of Combination of Insulating Shielding Covers for Live Working

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ABSTRACT
In the distribution network live working, in order to improve the insulation protection area, insulation shielding covers are often used in combination. In this paper several common insulating shield appliance, surface discharge tests were carried out. The surface discharge test uses a ball-rod electrode to simulate field operation conditions and observe the discharge path with a high-speed camera. The test results show that the material types of insulating masks have a great influence on the surface insulating properties, the insulating properties of rubber masks and plastic masks are close, and the surface insulating properties of resin masking utensils are lower. Resin insulation blanket used in combination, overlapping parts of the more closely fit. When the overlap length is 15 cm, the surface discharge voltage in the overlap region of the resin insulating blanket is close to that of the rubber blanket. Considering the maximum operating voltage of 10kV distribution line is 11.5kV, the length of the overlapping parts is not less than 5cm.

Keywords: Live working; Insulation shielding cover; Surface discharge; used in combination.

INTRODUCTION
In recent years, China has witnessed a rapid development of live work in the distribution field. In 2016, SGCC carried out 801,000 power distribution live operations, of which over 60% of the project operations were conducted using insulated gloves. In the insulation glove operation method, in order to improve the safety of the operation, the principle of multiple protections is generally adopted, and the insulating shielding device is used as the auxiliary insulation [1]. In field work, insulating shielding covers are often used in combination because of their limited protective area. At this time, the overlapping parts between the covers become the weak points of the insulation protection. The creeping discharge at the overlapping parts may cause insulation failure and cause serious operation accidents.

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Scholars have done a lot of research on the breakdown at the solid-insulated and gas-insulated interfaces. Lei Zhi-peng of Taiyuan University of Technology analyzed the surface breakdown and surface discharge characteristics of ethylene-propylene rubber insulation [2]. Lv Liang of Xi'an Jiaotong University studied the space charge on the interface of silicone rubber and ethylene-propylene rubber composite insulation, and proved that the interface between different dielectrics is generally the weak point of insulation [3]. P.M. Mitchinson through the study of oil and paperboard interface traces found that the interface is more likely to accumulate space charge, resulting in the breakdown voltage at the interface is relatively low [4]. Although scholars have conducted more studies on the discharge characteristics of insulating materials, there are few studies on the discharge characteristics of the overlapped parts when used in combination with insulation shielding covers insulating masking tools for live working.

TEST SYSTEM

Experiment Material

Live working commonly used insulation shielding devices are mainly divided into wire cover, insulating blanket, pin insulating cover, jumper cover and so on. In this paper, several kinds of insulation masks used daily are selected as the test materials, as shown in Table 1. The test needs to be pre-treated before testing. The surface of the sample was wiped with alcohol and placed in the test 24h later; in order to keep the sample surface clean, reduce the impact on the test results.

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>wire cover</td>
<td>Salisbury,OR125-45C</td>
<td>rubber</td>
</tr>
<tr>
<td>insulating blanket</td>
<td>Salisbury,300</td>
<td>rubber</td>
</tr>
<tr>
<td>insulating blanket</td>
<td>YS241</td>
<td>resin</td>
</tr>
</tbody>
</table>

Test Device

The surface discharge test circuit is shown in Figure 1. Power frequency test power supply rated capacity is 100kVA, the output voltage is 0-100kV. T_a in Figure 1 is a voltage regulating transformer, T_b is a step-up transformer, R_c is a current limiting resistor, R_P is a voltage meter internal resistance, R_d is a shunt resistance, and X is an electrode and sample. The rod electrode is a hollow aluminum tube with a diameter of 10 mm and a length of 6 m. It is used as a high-voltage analog live conductor in the test. The ball electrode is a solid aluminum ball with a diameter of 50 mm, simulating the body part of the operator.

Figure 1. Surface discharge test circuit.

In order to be consistent with the field work as much as possible, we used the rod-ball electrode as the test electrode. The surface discharge test setup is shown in Figure 2. The two
pieces of insulation shielding covers are arranged on the rod electrode with an overlap length of $S$ there between. The ball electrode is located at the upper cover edge of the overlap portion.

![Test layout.](image)

**Experiment method**

The uniform voltage step-up method was used to apply the AC voltage on the test. The boosting rate was $1.0$kV / s. When the sample occurs along the surface discharge, the voltage value applied at this time recorded as discharge voltage. The test was repeated 10 times under each condition, and the discharge voltage was averaged over 10 times. In order to observe and analyze the creeping discharge path of the insulation shading tools, all tests were conducted in a dark room to reduce the influence of ambient light sources on the discharge path observation. The test process was recorded with a high-speed camera at 900 frames / s.

**SURFACE DISCHARGE TEST RESULTS AND ANALYSIS**

**The Surface Discharge Test of Wire Cover**

The ends of the two wire masks are connected and placed on the rod electrodes. The cover overlap distance $S$ is adjusted to carry out the discharge test. The test results are shown in Figure 3.

![Surface discharge voltage of the wire shield.](image)

It can be seen from the figure that the surface discharge voltage increases linearly with
the increase of the overlapping length of the wire shield. In field work, increasing the overlap length of the wire cover can effectively improve the insulation protection ability of the overlap part. As the voltage gradually increases, the hissing sound begins to develop around the ball electrode and a white, filamentous spark begins to develop around the point of contact of the ball electrode with the shield. As the voltage continues to rise, a bright white arc is finally formed between the ball electrode and the rod electrode, and the arc penetrates from the overlapping portion to the rod electrode along the surface of the cover, as shown in Figure 4.

![Figure 4. Surface discharge path of the lead shield.](image)

**The Surface Discharge Test of Insulating Blanket**

As the commonly used insulating blanket is divided into American-made rubber blanket and Japanese-made resin blanket, and the type of material has a great influence on the surface discharge characteristics, a discharge test is carried out for the two types of insulating blanket respectively. Two rubber blankets and two resin blankets were placed on the rod electrode; adjust the overlap distance of blankets for discharge test, the test results shown in Figure 5.

![Figure 5. Insulation blanket surface discharge voltage.](image)

It can be seen from the figure that the creeping discharge voltage of the rubber blanket is obviously higher than that of the resin blanket. Both the discharge voltages increase linearly with the overlapping length. However, the discharge voltage gradient of the rubber blanket is obviously larger than that of the resin blanket. When the overlap length is 15 cm, the discharge voltage of the blanket is very close. This is because the resin material is softer than the rubber material. When the two insulating blanket are overlapped and arranged, the overlapping parts of the resin blanket come into contact with each other more closely, and there are more traps in the overlapping gap between the two upper and lower interfaces, as
shown in Figure 6. The average free path of free electrons generated by the discharge at both ends of the electrode is relatively short. After many collisions, it falls into the surface trap of the insulating material quickly, which restrains the development of the discharge. Therefore, the discharge voltage increases rapidly with the increase of the overlap length.

![Figure 6. Insulator cover surface discharge path.](image)

**Insulation Blanket and Wire Cover Combination Along the Surface Discharge Test**

The insulating blanket and the wire cover to be used in combination to adjust the length of the overlapping parts of the frequency discharge test, the test results shown in Figure 7. As can be seen from the figure, the combination of resin blanket and rubber blanket and wire cover is closer to the surface discharge voltage. However, as the overlap length increases, the resin blanket overlaps with the wire cover more closely, causing its discharge voltage to increase beyond the combination of the rubber blanket and the wire cover.

![Figure 7. Insulation blanket and wire cover combination along the surface discharge voltage.](image)

![Figure 8. Insulation blanket and wire cover combination along the surface of the discharge path.](image)
As can be seen from the discharge path in Figure 8, when used in combination, the discharge path is still through the two electrodes along the surface of the overlapping portion without layer-wise breakdown of the insulating shield or along the lower opening.

EFFICIENCY ANALYSIS OF COMBINED USE OF INSULATION COVERS

When the combination of the insulating covers utensils is used, the junction of the two masking utensils is the insulation point of weakness. Therefore, the overlapping arrangement is required to enhance the creeping discharge voltage as much as possible to enhance the insulating performance. Due to live working requirements can not be carried out under thunderstorm weather, so the operation of the main consideration of the line operating voltage and operating voltage over the impact of [5]. As the insulating shielding device is used as an auxiliary insulation, during operation by accidentally workers exposed to different potential components are covered when suddenly encountered the possibility of over-voltage line operation is very low, so only need to withstand the maximum operating voltage insulation device that is can. The maximum operating voltage of 10kV distribution network is 11.5kV, considering the safety margin of 1.2 times, using the common method for insulation coordination [6]. According to the combination surface discharge test, when the overlap distance of 5cm, the discharge voltage of 24kV is much larger than the maximum operating voltage of the system. Therefore, it can be considered that the combination of insulating shielding covers should ensure that the length of the overlap is not less than 5cm.

CONCLUSION

In this paper, the commonly used insulation covers appliances along the surface discharge test to study the overlap of the insulation properties along the surface, reached the following conclusions:

(1) The material types of insulating masks have a great influence on the surface insulating properties.

(2) The insulating properties of rubber masks and plastic masks are close, and the surface insulating properties of resin blanket utensils are lower. Resin insulation blanket used in combination, overlapping parts of the more closely fit. When the overlap length is 15 cm, the surface discharge voltage in the overlap region of the resin insulating blanket is close to that of the rubber blanket.

(3) Considering the maximum operating voltage of 10kV distribution line is 11.5kV, the length of the overlapping parts is not less than 5cm.

REFERENCES