Optimized design of DC shielding fittings for ±800kV UHV converter station

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Abstract. This paper studies the structure of the shielding device of DC device in the UHV converter station. Through simulation analysis, the electric field distribution on the surface of the shielding device is calculated to find the factors that affect the maximum field strength and the maximum electric field of the shielding device at different opening sizes and flange radius. By optimizing the structure and using a lantern-shaped shielding device, the maximum electric field strength on the surface of the shielding device of the same size can be reduced by more than 15%. The research of this project is of guiding significance for the design of shielding devices of UHV DC engineering in high altitude areas, and of great significance for promoting the progress and development of UHV DC transmission technology.

1. Introduction

UHV DC transmission technology will surely get further rapid development due to its advanced technology, long transmission distance, high transmission efficiency, small footprint and other advantages [1]. In recent years, with the extensive implementation of UHV projects in China, the ±800kV UHV DC transmission technology has been relatively mature, but as China’s energy development center continues to move westward, converter stations in high-altitude areas will be gradually constructed, environmental conditions put forward higher requirements on the performance of shielding fittings, and proper shielding structure can be adopted to ensure the reliable operation of fittings products at high altitudes and to promote large-scale clean energy delivery in high altitude areas.

As one of the important equipment of UHV converter station, fittings mainly play the role of electrical connection, electromagnetic shielding and mechanical support. As the transmission voltage level becomes higher and higher, the electromagnetic shielding becomes more and more important. If the shielding structure is unreasonable, corona or even breakdown discharge will occur in the fittings and equipment, which seriously threatens the safety of the power transmission system. Especially in high altitude areas with low air pressure and low air density, corona and discharge are more likely to occur. Therefore, in-depth research on the shielding structure and improving the anti-corona capability of the shielding structure are of great significance to UHV DC transmission.

In recent years, some universities and research institutes have conducted extensive research on UHV DC shielding structures, and some personnel have mainly studied the corona voltage of the shielding structure to obtain the control value of the electric field strength of different shielding structures, which is used to guide engineering design [2-3]. Some researchers also model the valve hall
and the DC field as a whole, calculate the electric field distribution on the surface of various devices at different times, and check the effectiveness of the shielding structure [4-5]. Researchers usually increase the size of the shield structure to reduce the surface electric field strength, and rarely conduct in-depth research on the shield structure itself. Figure 1 shows the discharge of metal fittings during the test.

Figure 1. Discharge of fittings during the test.

2. Common shielding structure
In UHV converter stations, shielding devices mainly include equipment shielding devices and fitting shielding devices. The equipment shielding device adopts different structural forms according to the characteristics of the equipment itself. For example, the valve tower adopts the polar plate shielding structure with rounded corners, the voltage divider adopts the combined ring shielding structure, the multilayer wave shielding structure for the smooth reactor and the PLC reactor, the wall bushing and the UHV transformer bushing use apple-type shielding devices. Combined with the structural characteristics of the equipment itself, different shielding structures are used to reduce the surface electric field of the shielding device.

Figure 2. Main fitting shielding device: (a) Ring; (b) Spherical.

In UHV DC converter stations, areas with low voltage levels, such as neutral lines and grounding electrode areas, there is no need to add a special shielding device, but rather to adopt a reasonable outer contour of fittings to prevent corona. With the improvement of the voltage level, the fittings mainly adopt single ring, double ring and ball shielding to prevent corona. The size of the shielding device also gradually increased, such as the diameter of the equalizing ring increases from 80mm to 300mm. The ball diameter is increased from 1000mm to 1800mm. Subject to environmental conditions, the DC field is usually located outdoors, usually using a ring-shaped shielding structure, the fittings in the valve hall usually use a spherical shielding structure. Taking the ±800kV project as an example, the ring with a diameter of 300mm and a diameter of 1600mm is usually used as the
shielding device on the DC field pole line. A ball with a diameter of 1600mm is usually used as the shielding device in the valve hall (Figure 2). The structure of the ring-shaped shielding device is relatively simple, and the tube diameter and ring diameter can be adjusted appropriately to meet the needs of different occasions. This article mainly discusses the spherical shielding device.

3. Model selection

In the valve hall of the converter station, the high-end valve hall has the highest potential in the polar line area and the best requirements for electric field shielding. Accordingly, the size of the shielding device in this area is also the largest. Take the insulator supporting fittings of the pole part in the high-end valve hall as an example, a ball of S φ1600mm is usually used as a shielding device. Wire connection is required during installation, usually a hole is made on the shielding ball. If it is necessary to connect the conductor, the shielding ball is usually opened, and then the conductor is inserted into the shielding ball through the hole. Due to the electromagnetic shielding effect, the conductor and the shielding ball interact, and the electric field at the junction of the conductor and the shielding ball is reduced, which is beneficial to the shielding of the electric field (Figure 3). Therefore, such holes do not need to be flanged.

![Figure 3](image)

**Figure 3.** Distribution of the potential and electric field strength of the shielding device at the highest operating voltage.

In this paper, a spherical pressure equalizing device with a size of S Φ1600mm and a lantern-shaped shielding device are selected for research, where R1 = 800mm, the height of the insulator is 10m, the shielding device is 10m away from the ground and surrounding buildings, and the highest operating voltage is 816kV. The surface electric field of the shielding device is calculated under
different $\phi_1$ and $R_1$ sizes. The structure of the two shielding devices is shown in Figure 4, and the calculation model is shown in Figure 5.

![Figure 4](https://example.com/figure4.png)

**Figure 4.** The structure of the two shielding devices: (a) Spherical; (b) Lantern-shaped.

![Figure 5](https://example.com/figure5.png)

**Figure 5.** Simulation model and meshing.

### 4. Analysis of spherical shielding structure

Change the opening diameter $\phi_1$ of the insulator connection position and the hole flanging radius $R_1$ in turn to calculate the maximum value of the electric field intensity on the surface of the spherical shield (diameter is 1600mm). Some calculation results are shown in Figure 6. The calculation results of the maximum field strength of the spherical shield with different opening diameters and flanging radii are shown in Table 1.

**Table 1.** Maximum electric field intensity on the surface of spherical shield with different opening diameter and flanging radius (V/cm).

| $R_1$ (mm) | 100  | 200  | 300  | 360  | 390  |
|-----------|------|------|------|------|------|
| R40       | 13775| 15032| 16123| 16711| 17012|
| R60       | 13346| 14210| 15024| 15493| 15726|
| R80       | 13127| 13812| 14459| 14841| 15030|
| R100      | 12994| 13567| 14118| 14436| 14602|
| R120      | 12909| 13339| 13882| 14169| 14312|

It can be seen from the above analysis that under the same size of the opening diameter, the smaller the flanging radius, the higher the electric field intensity value. Under the same flanging size, the larger the opening size, the higher the electric field intensity value. The maximum field strength on the surface of the spherical shielding device all appears at the flanging point. This can be seen from the test results in Figure 1 that the discharge occurs first at the flanging hole, and it can also be seen from the simulation results in Figure 6. The trend of the maximum electric field strength on the surface of the spherical shielding device with the opening size and flanging size is shown in Figure 7.
Figure 6. E-field distribution of spherical shielding devices under different openings and flanging sizes (V/cm).

Figure 7. Curve of the maximum value of the electric field intensity on the surface of the spherical shielding device with the diameter of the opening and the radius of the flanging.
5. Lantern shield structure

The lantern-shaped shielding device with a maximum profile of 1600mm was used for analysis, and the electric field intensity distribution was calculated under the conditions of different opening diameter $\phi_1$ and hole flanging radius $R_1$. Some calculation results are shown in Figure 8. The maximum electric field strength of the lantern-shaped shielding device surface with different opening diameter and flanging radius is shown in Table 2. The trend of the maximum electric field strength on the surface of the lantern-shaped shielding device with the opening size and flanging size is shown in Figure 9.

From the results, the maximum electric field strength did not appear at the flanging hole (except $R_1 = 40$mm). Under the same opening size, the electric field intensity on the surface of the lantern-shaped
shielding device increases with the increase of the flanging size $R_1$ (except $R_1=40\,\text{mm}$), which is contrary to the result of the spherical shielding device. For the shielding device with $R_1=40\,\text{mm}$, when the opening size $\varphi_1$ is small, the hole is shielded by the pressure equalizing device, so the electric field strength at the flange is small, but as the size of the opening increases, the flange is exposed to the air. The flanging radius is too small, and the maximum value of the shielding device always appears at the flanging position. Therefore, for the shielding device on the polar line, the flanging size should not be less than 80mm. Under the same size of the opening size, the effect of different flanging sizes on the maximum electric field strength on the surface of the shielding device is shown in Figure 10.

**Table 2.** Maximum E-field intensity on the surface of lantern-shaped shielding device with different opening diameter and flanging radius (V/cm).

| $R_1$ (mm) | $\varphi_1$ (mm) | $\varphi_1$ (mm) | $\varphi_1$ (mm) | $\varphi_1$ (mm) |
|------------|------------------|------------------|------------------|------------------|
| 40         | 100              | 12082            | 12183            | 12645            |
| 60         | 11368            | 12796            |
| 80         | 11456            | 11704            | 12025            | 12167            | 12266 |
| 100        | 11559            | 11807            | 12103            | 12293            | 12406 |
| 120        | 11653            | 11922            | 12228            | 12434            | 12540 |
| 140        | 11753            | 12043            | 12367            | 12585            | 12694 |

**Figure 9.** Curve of the maximum value of the electric field intensity on the surface of the lantern-shaped shielding device with the diameter of the opening and the size of the flanging radius.

**Figure 10.** The position of the maximum electric field strength of the shielding device under different flanging sizes: (a) $R_1=40\,\text{mm}$, $\varphi_1=360\,\text{mm}$; (b) $R_1=80\,\text{mm}$, $\varphi_1=360\,\text{mm}$.
6. Analysis and comparison of two structures
Two types of shielding devices with a maximum profile of 1600mm, an opening size of 390mm and a flanging radius of 100mm were selected for analysis and comparison, as shown in Figure 11. The calculation results of the surface electric field strength of the spherical shielding device (from A to D) and lantern-shaped shielding device (from A1 to D1) are shown in Figure 12.

![Image](a) ![Image](b)

**Figure 11.** Dimensional drawing of two shielding devices with a maximum profile of 1600mm: (a) Spherical; (b) Lantern-shaped.

![Image](E(kV/cm) vs Path length(mm))

**Figure 12.** Comparison of the surface electric field strength between the two shielding devices.

By comparison, we can see that the maximum electric field value of the lantern-shaped shielding device is significantly lower than that of the spherical shielding device. This is because the arc MBC part of the spherical shielding device protrudes from the outline of the sphere. Due to the small size of R100, the electric field strength in this area is large. However, none of the R100 parts of the lantern-shaped shielding device protrude from the shielding device, and the electric field intensity in this area is generally not large. For the arc B1C1, because the size is smaller than the arc CD, the electric field intensity value of the section of the lantern-shaped shielding device is larger than that of the spherical shielding device. This can be clearly seen in Figure 12. Through optimization, the maximum electric field strength of the shielding device of R800mm can be reduced by 15%, which effectively improves the anti-corona ability of the shielding device at the same size.
7. Conclusions
The results of this study can optimize the shielding devices of conventional converter stations, and the results can also provide a reference for the design of shielding devices of converter stations at high altitudes. This study draws the following conclusions:

1) The maximum value of the electric field of the spherical shielding device appears at the flanging hole. Under the same opening size, the smaller the flanging radius, the higher the maximum value of the electric field intensity on the surface of the spherical shielding device. Under the same flanging size, the larger the opening diameter, the higher the maximum value of the electric field intensity on the surface of the spherical shielding device. The size of the flanging has a greater influence on the spherical shielding device with large openings.

2) The strength of the electric field at the opening of the spherical shielding device increases significantly because the radius of the flanging is too small, and the flanging protrudes from the outer contour of the shielding ball, which is equivalent to the shielding device forming a tip at this location, causing the electric field to concentrate.

3) The maximum value of the lantern-shaped shielding device is usually not at the flanging hole. Under the same opening diameter, the maximum field strength does not increase with the decrease of the flanging radius. That is to say, the maximum electric field strength increases as the opening increases. 800kV shielding device flanging radius should not be too small.

4) The maximum electric field strength did not appear at the flanging hole (except $R_1 = 40\text{mm}$), and the maximum electric field strength also decreased. Under the same opening size, the electric field intensity on the surface of the lantern-shaped shielding device increases with the increase of the flanging size $R_1$(except $R_1 = 40\text{mm}$). For the shielding device on the polar line, the flanging size should not be less than 80mm.

5) Lantern-shaped shielding device can effectively reduce the maximum electric field intensity on the surface, and the electric field intensity distribution on the surface is relatively uniform. The lantern-shaped shielding device of $R_1=800\text{mm}$ has a maximum electric field intensity reduced by more than 15% compared with the spherical shielding device.

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