simulation analysis of UHV ± 1600kV DC generator electric field distribution

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Abstract—UHVDC(ultra high voltage direct current) is an important method for State Grid Corporation of China to achieve inter-regional long-distance power transmission. ± 1600kV ultra high voltage DC generator is an important equipment to provide high voltage DC test voltage ,mainly used for testing the DC electrical equipment.In order to guarantee the safe operation of DC transmission equipment,Using electric field analysis software to simulate the electric field distribution in the space around the DC generator and carry out numerical Analysis.Through analyzing of changes in the radius of curvature and variation of the electric field strength and influencing factors ,providing a favorable numerical basis for laboratory layout of DC voltage generator and preparation of safety regulations in field trials.Finally proposing targeted measures to optimize the electric field distribution.

Keywords—DC voltage generator; field calculation; corona; field optimization

I. INTRODUCTION

As China's Sichuan hydropower important energy base, but also to send located west to east end of the project, the construction area of the inner plurality of power points, including major projects Jinping, Xiangjiaba, Xiluodu and so on. Secure and stable UHV power grid used in a variety of high voltage power transmission equipment operation, but also in the implementation of the "west to east, the national network" HVDC transmission project in primary prerequisite [1]. Sichuan power grid have been built so far 3 ± 800kV UHV Converter Station. ± 1600kV UHV DC voltage generator to provide a DC high voltage test equipment important, it will be used to test a DC electrical equipment, high voltage test Trent four bases for the key test equipment. Test equipment Corona will bring results in the future to be a great impact, and the intensity of corona depends directly on the surface of the field generator component intensity distribution. In order to better provide comprehensive technical support to the UHV power transmission equipment, carry ± 1600kV DC generator electric field distribution simulation analysis, the DC voltage generator selection, site preparation and layout of the laboratory test safety procedures is important.

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II. DC VOLTAGE GENERATOR SCHEMATIC

In this paper, analytical DC voltage generator voltage of ± 1600kV HVDC voltage generator, using four times the pressure circuit. Principle of the DC voltage generator is constituted by the voltage doubler rectifier circuit, an n-stage voltage doubling circuit voltage doubler rectifier unit as the basic unit, the maximum no-load DC output voltage, the output voltage amplitude of the charging transformer. Positive halfwave of the AC power supply and the negative half-wave voltage doubler circuit are the capacitance C is charged while the DC voltage generator body design allows the filter capacitor ripple voltage and voltage drop can be fully optimized to improve. Schematic DC voltage generator shown in Figure 1.

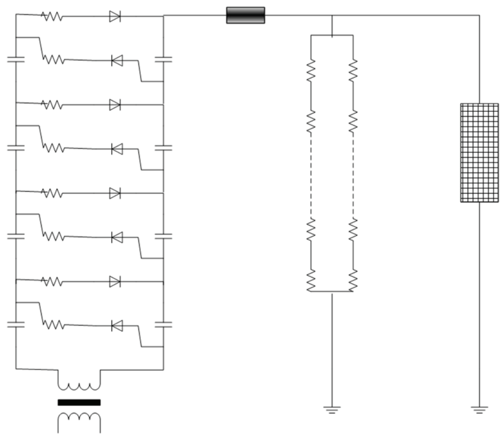

Figure 1 Schematic DC voltage generator

Derived formula no-load output voltage levels of the voltage doubler unit and voltage doubler circuit output voltage drop and the pulsation amplitude of the DC voltage generator as follows:

$$U_o = 2nU - \Delta U$$

$$\sigma U \approx \nu(\nu+1) I_{\alpha\varpi}/4\ \phi\chi \qquad (2\text{–}1)$$

$$\Delta U = I_{av}/\ 6fc\ (4n^3+3n^2+2n)$$

n is the number of stages, the average output current; f for the power frequency, C is the capacitance of the capacitor to the right levels. As used herein, analytical DC voltage generator rated output voltage 1600kV, rated output current of 30mA. The body is two-column structure, AC and DC column column are arranged symmetrically, the diameter of the top of the grading ring is 6.1m, the overall height of the body of 12.1m, corresponding divider top grading ring diameter of 3.8m, the grade 6 resistive and capacitive voltage divider unit cascade composition, height 12.1m; connected by a protective resistor between the DC voltage generator body and the divider, while the body and the ground voltage divider capitals cover made of stainless welded pipe, and then decreases at a high voltage corona strength.

III. CALCULATION OF ELECTRIC FIELD THEORY AND SIMULATION MODELING

Since its borders DC voltage generator is more complex, with the analytical method it is difficult to draw its expression, so a value calculated using this method. In the numerical method, is divided into finite difference method (FDM), finite element method (FEM), boundary element method (BEM), the method of moments (MOM) and other forms herein to calculate the spatial electric field of finite element selection method (FEM) calculation. Energy electrostatic field can be expressed as a function of potential and pending derivative integral. While for the electric, magnetic Boundary Value Problems, the electrostatics in Thomson theorems that is described electrostatic phenomena "principle of least action." That is: in a medium fixed charged conductor system, on which the surface charge distribution, should be synthesized with minimal electrostatic field electrostatic energy[2-6]. 3.1 Theoretical calculation

Variation when considering only shield electrode alone. Shield electrode, its oval shape with a rotating body similar, so strong formula oval rotating body first available field theory to estimate the size of its field strength, calculated as follows: electric field on the ellipsoid conductor surface ($\theta = 0$) of Strength

$$E_{\theta=0} = \frac{2|A|}{abc}\left[\frac{x^2}{a^4} + \frac{y^2}{b^4} + \frac{z^2}{c^4}\right]^{-\frac{1}{2}} \tag{3-1}$$

$$A = -V_0\left\{\int_0^{\infty}[(a^2+\theta)(b^2+\theta)(c^2+\theta)]^{-\frac{1}{2}}d\theta\right\}^{-1} \tag{3–2}$$

In the two formulas a, b, c respectively ellipse rotation axis of the body length (b = c), the potential of the ellipse rotation surface size.

1, ellipsoid, when x = 0, y = 0, z = c, the

$$|E|_c = \frac{2A}{ab} \tag{3-3}$$

2, when x = 0, y = b, z = 0, the

$$|E|_b = \frac{2A}{ac} \tag{3-4}$$

3, when x = a, y = 0, z = 0, the

$$|E|_a = \frac{2A}{bc} \tag{3-5}$$

Thus, in the ellipsoidal surface, it appears in the longest axis radius of the place. Because this article is primarily concerned with the maximum electric field strength, so by (2-2) and (2-3) equation maximum electric field strength oval rotating body [7-11].

3.2 Simulation Model

Referring HVDC voltage generator manufacturing parameters, the simulation analysis using the column capacitor dielectric filling simulation, the relative permittivity ξr take 2.55. Metal flange and the top of the equalizing ring ξr 1. Taking into account the region can only handle a limited space problem in a finite element calculation, due to the calculation accuracy and computing time, the border area of analysis and calculation is taken as 30m, 30m high cylindrical domain boundaries, the internal medium is air.

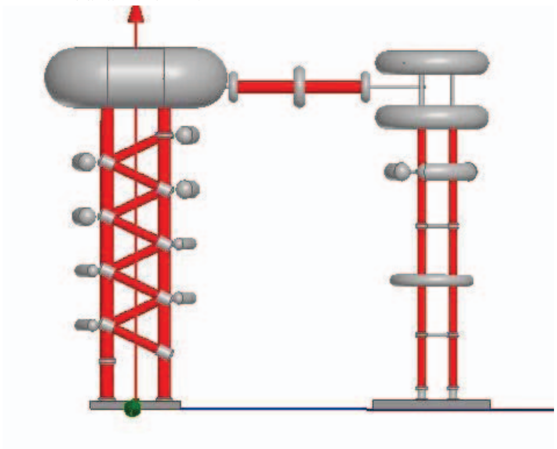

Figure 2 DC generator simulation model

3.3 spatial electric field distribution simulation

During field simulation, when the major axis of the shield electrode is maintained constant, with the increase of the short axis, the maximum value of the surface electric field strength has decreased as it is because the maximum electric field intensity of the shielding electrode main value It is determined by the radius of curvature. In the DC voltage generator electric field simulation concerned with the size and distribution of the maximum electric field strength, and the boundary conditions of a DC generator in another part of the exchange exists. Therefore, this article first calculate a transient situation, it found little effect on the exchange part of the shield electrode, and the flange of the electric field distribution is very strong, and take part in the exchange of the maximum (, n is a positive integer) , the electric field strength reaches a maximum value of the flange, so that later calculations are taken to calculate the instantaneous boundary conditions.

3.4 DC voltage generator spatial electric field distribution

The reference DC voltage generator to establish the actual parameters of the model simulation analysis carried out by the electric field distribution of the electrostatic field simulation software, field division situation is more clear understanding of the various parts of the generator. In the generator body and the divider are not taken pillar flange pressure ring simulation results as shown below:

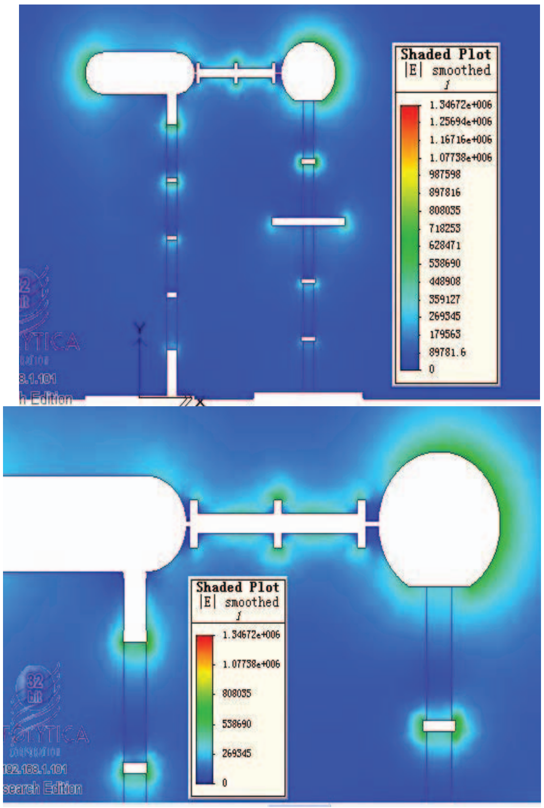

Figure 3 overall electric field distribution map generator

To measure the size of the electric field intensity values of the DC voltage generator through the electric field strength around the probe, the maximum electric field strength at this time appears in the vicinity of a body and a current generator flange divider level of about 4 15.66kV / cm, again its value has been reduced electric field strength, the maximum electric field intensity in the third position of the flange to be measured is 11.5kV / cm, the maximum electric field intensity of the fourth flange position is measurable 6.2kV / cm, then down has little time to consider. These high field intensity distribution is mainly because of the high voltage on the flange and its own small radius of curvature smaller size caused.

Reference to the current DC high voltage generator design maximum field strength is generally controlled at about 10kV / cm, apparently by simulation largest field generator body appeared strong exceeded this requirement. As the main factors affecting the segment of the electric field is the size and shape of the voltage and the electrodes, in order to further improve the current generator electric field distribution of the body, the body with flanges mounted generator voltage divider and body connection equalizing ring and other measures to improve farm division. By analyzing the calculated diameter corresponding to the generator body and the divider antihalation grading ring is taken as 300mm. After the installation of equalizing ring as shown in the following figure locally.

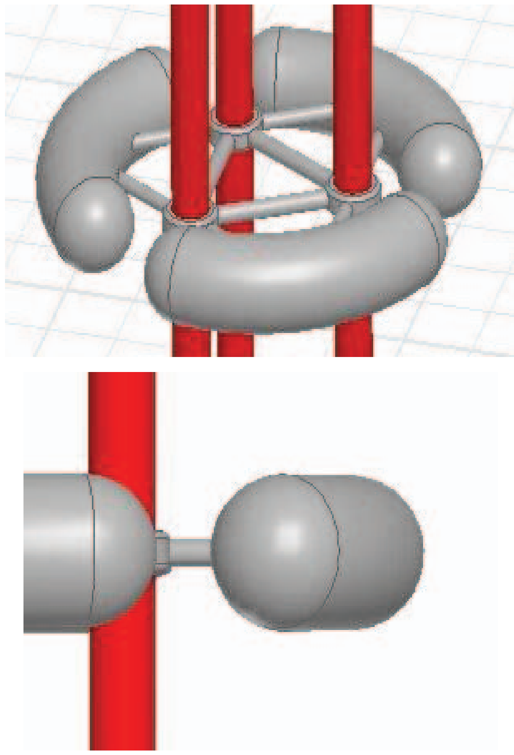

Figure 4 generator and the installation of equalizing ring divider

The simulation results of the analysis as shown below:

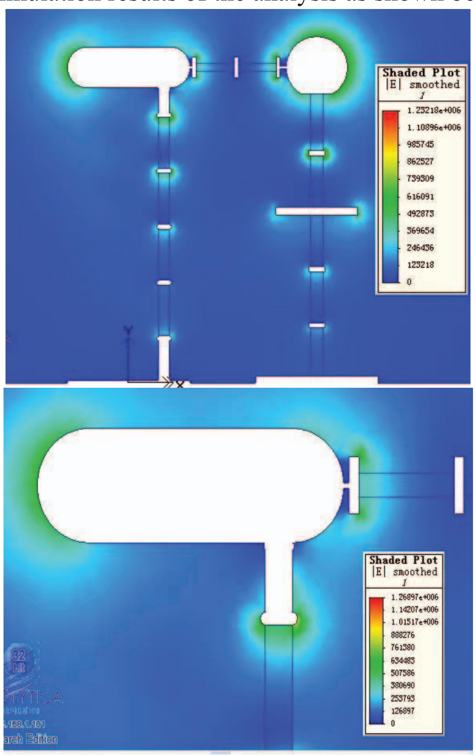

Figure 5 after the overall improvement of the electric field distribution generator

In this case by an electric field strength test probes measure the size of the electric field intensity value of the DC voltage generator around, analysis shows that the maximum electric field is still at the top of the generator body and the divider, about 12.1kV / cm, in order to retain a certain margin degree, consider adding a grading ring here, so that the electric field strength can be further reduced. However, the rear flange shape change, the maximum electric field strength of the column does not exceed DC 8.9kV / cm, satisfy the requirements of conventional design.

3.5 practical application

After above with flanges mounted on the generator body pillar grading rings and other measures, the DC high voltage generator in 2012, 12 in Sichuan Electric Power Research Institute hyperbaric laboratory officially put into operation, and through the concrete to carry out high-voltage DC electrical equipment laboratory test equipment currently operating normally, due to the influence of the corona caused by experimental data does not appear abnormal phenomenon.

IV. Conclusion

Factors affecting the distribution of DC voltage generator electric field strength, the shield electrode to the largest share, relatively weak impact of the stent, the stent itself, but because of a high voltage, the shape is small, the maximum electric field is generated in the bracket instead of law blue surface, and hence, the radius of curvature of the flange size and surface finish attention; grading ring can change the distribution of the electric field, the electric field in the local adjustment effect is large. Radius of curvature of the flange through the installation of equalizing ring and optimizing the grading rings are simulated, so that the DC voltage generator of electric field control in 10kV / cm near the corresponding body and the divider antihalation equalizing ring the diameter is taken to be approximately 300mm.

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