



Electric Field and Influencing Factors Analysis of Converter Transformer Bushing and Grading Ball

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Abstract. The excessive electric field intensity on the surface of the grading ball of the converter transformer bushing will lead to corona discharge, which may damage the secondary control system of the thyristor. Therefore, it is necessary to calculate the electric field intensity on the surface of the converter transformer bushing and the grading ball. In this paper, a three-dimensional finite element model of bushing and grading ball of converter transformer is established, the electric field distributions on the surface of bushing and grading ball are obtained, and the maximum electric field intensity is extracted. The results show that the maximum electric field intensity is at the end of the grading ball in the upper bushing, which is 9.02 kV/cm. The influence of the maximum diameter of grading ball, the distance to the wall, the distance to the ground and the capacitor core on the electric field is analyzed. The results show that the maximum electric field intensity of the upper grading ball can be reduced to 8.46 kV by reducing the distance to the ground. The results can provide reference for the optimization design of the bushing and grading ball structure of the converter transformer, and ensure the safe and stable operation of the converter transformer.

Keywords: converter transformer · valve-side bushing · grading ball · electric field · finite element method

1 The Introduction

High voltage direct current (HVDC) transmission has become an important development direction of power system due to its advantages such as large transmission capacity, long transmission distance and strong economy [1]. Converter transformer plays an important role in HVDC transmission system. The electric charge generated by the corona of DC hardware fittings will seriously distort the electric field on the insulating material of converter station equipment or the surface of hardware fittings. Therefore, corona must be strictly prevented to avoid the generation of corona charge. The calculation of the electric field intensity on the surface of the hardware fittings inside the valve hall can provide guidance for the design of the hardware fittings and is of great significance for the safe operation of the valve hall [2–4].

At present, some researches have been carried out on the calculation of electric field on the surface of fittings in the valve hall in China. Literature [5–8] has carried out simulation analysis on surface electric field of local fittings. The literature [9–12] focuses on the numerical simulation inside some equipment such as converter transformer bushing in valve hall, or the analysis of insulation coordination in converter station. Literature [13–17] conducted full model numerical calculation for ± 500 kV, ± 600 kV and ± 800 kV valve halls.

In this paper, three-dimensional finite element models of converter valve-side bushing and grading ball of converter transformer are established by finite element method. The electric field distributions on the surface of transformer bushing and grading ball were obtained and the maximum electric field intensity was extracted. The influence of the maximum diameter of the grading ball, the distance to the wall, the distance to the ground and the capacitor core on the electric field was analyzed.

2 Original Model and Calculation Results of Bushing and Grading Ball of the Converter Transformer

2.1 Calculation Model and Parameters

The relevant dimensions of the converter valve-side bushing are shown in Fig. 1. The maximum diameter of the grading ball is 2300 mm. The distance from the end of the grading ball of the bushing located on the top to the wall is 7932 mm, and the distance from the ground is 6472 mm.

In this paper, a three-dimensional finite element model for electrostatic field analysis of bushing and its grading ball is established. Since the electric field distributions around bushing and grading ball are focused on, only bushing, grading ball and air enclosure are established. The overall model is shown in Fig. 2. The outer air enclosure is a 40 m long cube.

The tetrahedron element is used to divide the model, and the total element quantity is 5412066. The bushing and grading ball grids are shown in Fig. 3. The loading potential of the grading ball and capacitor core at the top position is 800 kV, and the loading potential of the grading ball and capacitor core at the bottom position is 715 kV. The shell is loaded with zero potential, and the metal part at the bottom of the bushing is also loaded with zero potential.

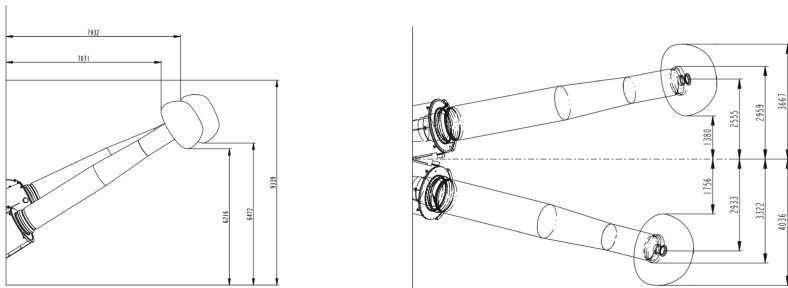


Fig. 1. Schematic diagram of structural parameters of bushing (mm)

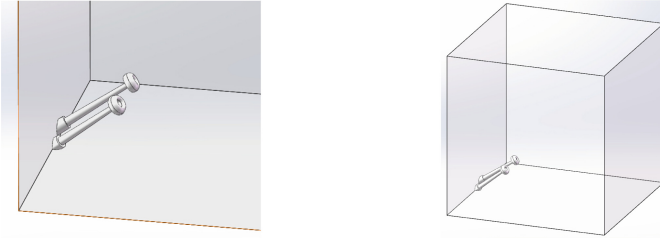


Fig. 2. 3D computing model

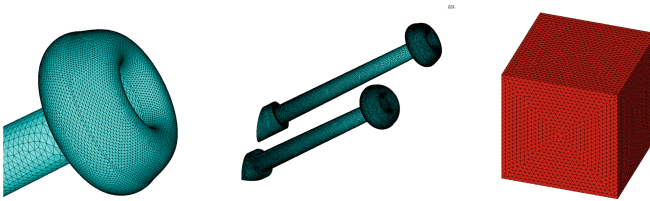


Fig. 3. Schematic diagram of grid

2.2 Calculation Results of the Original Model

The electric field on the surface of the grading ball of the original model is shown in Fig. 4. The electric field distributions of bushing overall surface are shown in Fig. 5. The electric field intensity distributions of the middle section of the bushing are shown in Fig. 6.

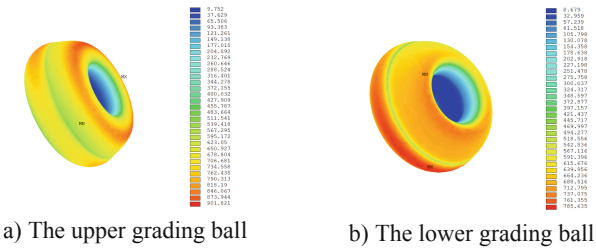


Fig. 4. The original model grading ball surface electric field (kV/m)

It can be seen from Fig. 4 that the maximum electric field on the surface of the grading ball of the high voltage end bushing is at the end of the grading ball of the upper bushing, and the maximum electric field intensity is 9.02 kV/cm, while the maximum electric field on the lower bushing grading ball surface is 7.86 kV/cm.

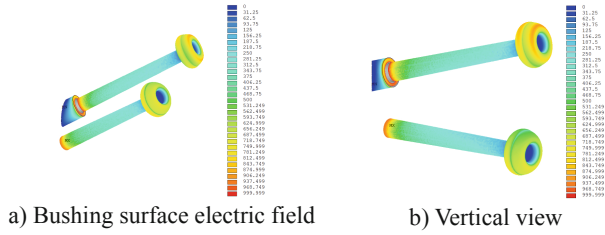


Fig. 5. Overall surface electric field distributions of bushing (kV/m)

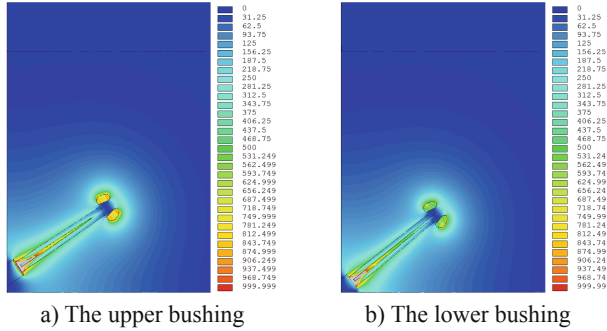


Fig. 6. Electric field distributions of bushing section (kV/m)

3 Electric Field Influence Analysis of Different Factors

The influence of the maximum diameter of grading ball, the distance to the wall, the distance to the ground and the capacitor core on the electric field is analyzed.

3.1 Influence of the Maximum Diameter of the Grading Ball

In the original model, the maximum diameter of the grading ball was 2300 mm, keep other parameters unchanged and change the maximum diameter of the grading ball to 1500 mm. The calculation results are shown in Figs. 7, 8 and 9.

It can be seen from the analysis that when the maximum diameter of the grading ball is reduced to 1500 mm, the maximum electric field intensity of the upper grading ball is 12.86 kV/cm, which is 42.57% higher than the original model, and the maximum electric field intensity of the lower grading ball surface is 10.13 kV/cm, which is 28.88% higher than the original model.

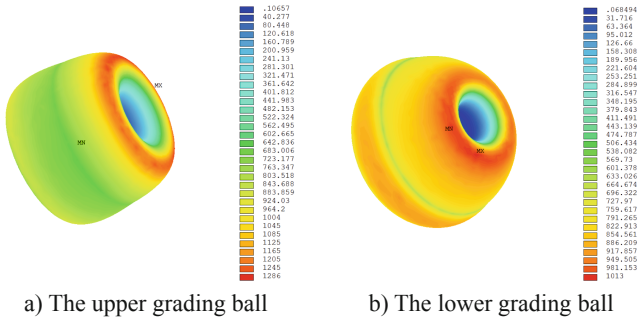


Fig. 7. The original model grading ball surface electric field (kV/m)

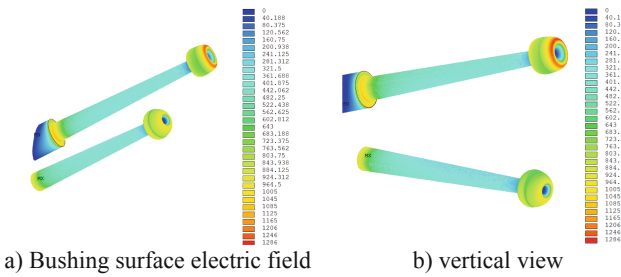


Fig. 8. Overall surface electric field distributions of the bushing (kV/m)

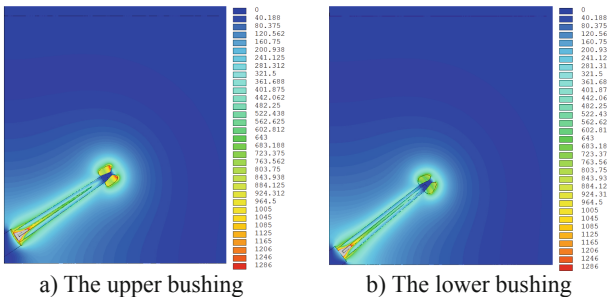


Fig. 9. Electric field distributions of bushing section (kV/m)

3.2 Influence of the Wall Distance and the Ground Distance

The electric field distributions are calculated and analyzed respectively when the distance to the wall is reduced by 1 m, the distance to the ground is reduced by 1 m, the distance to both the wall and the ground is reduced by 1 m, and the distance to the ground is symmetrical to the wall. The distance from the upper bushing to the strong and the ground is 7776 mm when the distance to the wall is symmetrical to the ground.

It can be seen from Table 1 that with the change of the distance between the bushing and the wall and the ground, the change trend of the electric field of the grading ball on

the two bushings is basically the same. When only the distance to the wall is reduced, the electric field intensity on the surface of the grading ball increases, and the amplitude of increase is within 3%. When only the distance to the ground is reduced, the electric field on the surface of the grading ball decreases. Compared with the reduction of the distance to the wall, the reduction of the distance to the ground has a greater impact on the electric field on the surface of the grading ball. When the distance to the wall and the ground is reduced at the same time, the maximum electric field intensity on the surface of the grading ball increases. When the distance to the wall and the ground is symmetrical, it is equivalent to reducing the distance to the wall, increasing the distance to the ground, and the maximum electric field intensity on the surface of the grading ball decreases. The electric field distributions are shown in Fig. 10. Electric field distributions when the distance to both wall and ground is reduced by 1 m and Fig. 11.

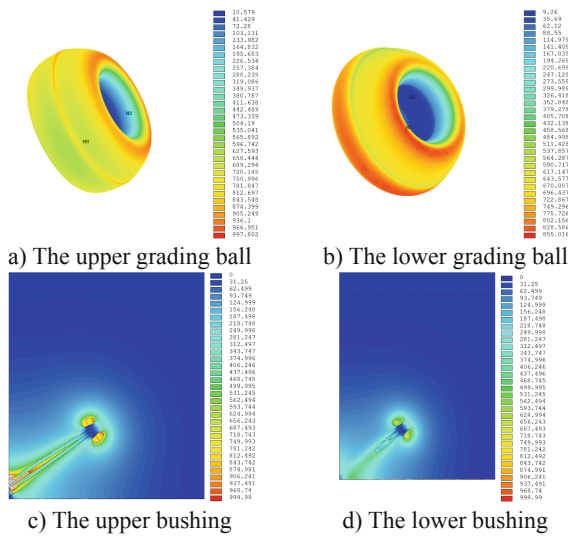


Fig. 10. Electric field distributions when the distance to both wall and ground is reduced by 1 m (kV/m)

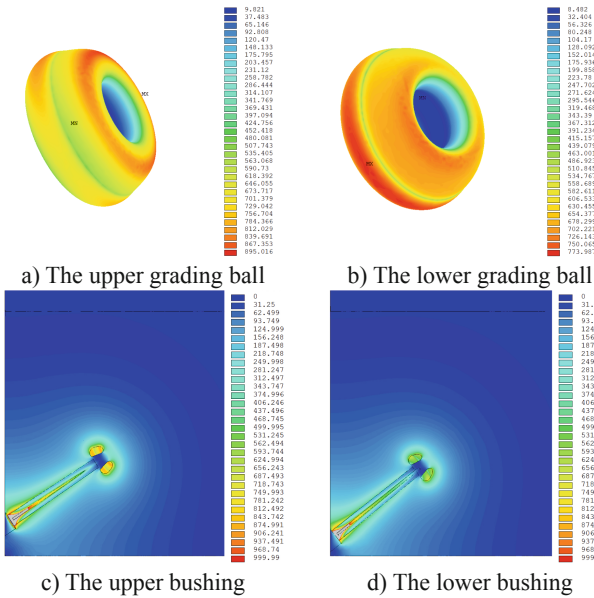


Fig. 11. Electric field distributions under symmetrical condition (kV/m)

3.3 Influence of the Capacitor Core

On the basis of the original model, remove the capacitor core and load the potential. The calculation results are shown in Figs. 12, 13 and 14.

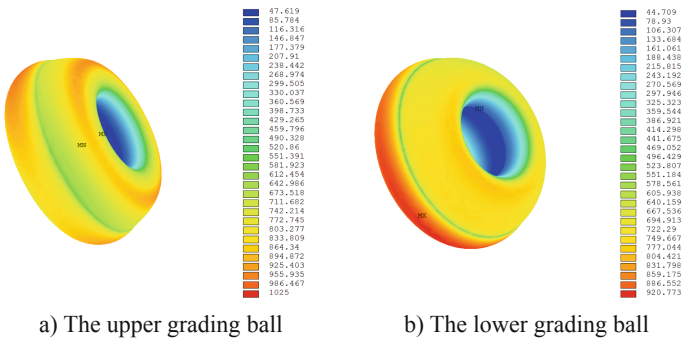


Fig. 12. Electric field on the surface of the grading ball (kV/m)

It can be seen from the analysis that the maximum electric field intensity of the upper grading ball is 10.25 kV/cm without a capacitor core, which is 13.64% higher than the original model, and the surface electric field of the lower grading ball is 9.21 kV/cm, which is 17.18% higher than the original model. It can be seen that the maximum electric field intensity of the surface of the grading ball increases without a capacitor

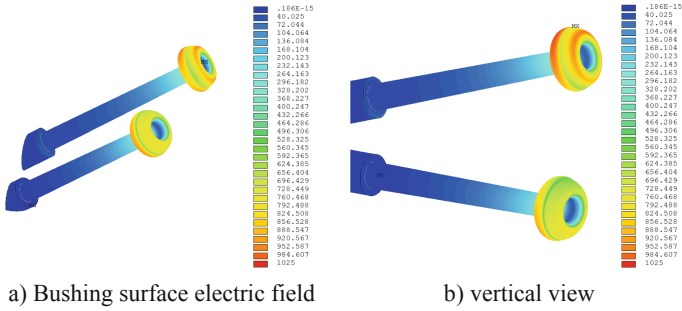


Fig. 13. Overall surface electric field distributions of bushing (kV/m)

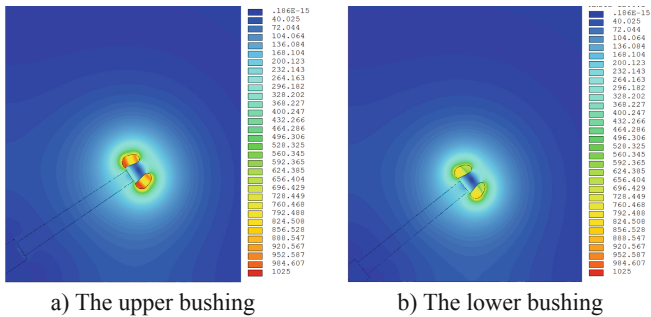


Fig. 14. Electric field distributions of bushing section (kV/m)

core. Because there is no capacitor core, the electric field intensity of the low-voltage end of the bushing is significantly reduced.

Table 1. Calculation results of the maximum electric field intensity

Model	The upper grading ball (kV/cm)	Percentage difference/%	The lower grading ball (kV/cm)	Percentage difference/%
original model	9.02	/	7.86	/
The maximum diameter of grading ball is 1.5 m	12.86	42.57	10.13	28.88
The distance to wall is reduced by 1 m	9.11	1.00	8.02	2.04

(continued)

Table 1. (continued)

Model	The upper grading ball (kV/cm)	Percentage difference/%	The lower grading ball (kV/cm)	Percentage difference/%
The distance to ground is reduced by 1 m	8.46	-6.21	7.06	-10.18
The distance to both wall and ground is reduced by 1 m	9.98	10.64	8.85	12.60
symmetric	8.95	-0.78	7.74	-1.57
Removing capacitor core	10.25	13.64	9.21	17.18

4 Conclusion

In this paper, a three-dimensional finite element model of the converter valve-side bushing and the grading ball is established, and the electric field distributions on the surface of the bushing and the grading ball are calculated and the maximum electric field intensity is extracted. Conclusions can be drawn that:

1. The maximum electric field on the surface of the grading ball of the high voltage end of the bushing is at the end of the bushing ball of the upper bushing, with a maximum electric field intensity of 9.02 kV/cm, and the maximum electric field on the surface of the grading ball of the lower bushing is 7.86 kV/cm.
2. The effects of the maximum diameter of the grading ball, distance to the wall and to the ground and the capacitor core on the electric field intensity were analyzed. It is found that the optimization effect of reducing the distance to the ground is the best. The maximum electric field on the surface of the upper grading ball can be reduced to 8.46 kV/m by reducing the distance to the ground by 1 m, which is 6.21% lower than the original model.

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