Simulation and Optimization of 252 kV Busbar

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This study designed an improved 252 kV busbar structure through AutoCAD software. The simulation and optimization of electric field distributions in 252kV busbar have been investigated employing the Finite Element Method (FEM) and Response Surface Method (RSM) after the improvement of the 252 kV busbar structure. The electric field distribution of the optimal busbar structure was superior to that of the original structure. Under a relative gas pressure of 0.3 MPa, the optimal 252 kV busbar successfully withstood a power frequency voltage of 460 kV and a lightning impulse voltage of 1050 kV at 15 times the positive and negative polarity, respectively. Such improvement enhances the dielectric margin of the 252 kV busbar and reduces production cost by approximately 1000000 Yuan per year, and more meaningfully, the pollution of SF_6 will also be greatly reduced.

***Index Terms*—Finite Element Method, Response Surface Method, Power Frequency Withstand Voltage, Lightning Impulse Withstand Voltage.**

I. Introduction

With the sustainable economic growth and ever-increasing energy demand of China, the country's electricity market has a great potential to develop. An increasing number of domestic and international metal-enclosed switchgear manufacturers are being established because of the large electricity market and profits. Such scenario has resulted in fierce competition, forcing the price of metal-enclosed switchgears to decrease by approximately 50 percent in recent years. A number of manufacturers are struggling to survive, and even a greater number are suffering from poor management.

Enterprises must adopt advanced technology and advanced processing techniques to reduce production costs and improve product quality to ensure survival. Moreover, unnecessary handling and other redundant processes are reduced by changing the structural design, in line with the economizing of national construction. Thus, a 252 kV branch busbar structure is proposed for the alteration of gas-insulated metal-enclosed switchgear through AutoCAD software. The altered structure is optimized and its electric field is calculated and analyzed by using FEM and RSM. Finally, the reliability of improvement is proved by testing the insulation capacity of the busbar.

II. Busbar Structure Before and After Modification

The primary structure of the 252 kV metal-enclosed switchgear branch busbar is shown in Fig. 1. The 252 kV branch busbar consists of shielding ring, conductor, enclosure, shielding case, plum-shaped contact, contact pedestal, and shielding case pedestal.

The modified structure is shown in Fig. 2. The shielding case pedestal 7 is removed, and the shielding case 4 and contact pedestal 6 are directly fixed on the contact pedestal 6 through a type of outline reform. As a result, one shielding pedestal is saved. This setup removes one contact conductive surface, thereby decreasing the contact resistance. The primary structure of the shielding ring 1 is far from the normal condition and is changed into the spinning type with almost the same cost.

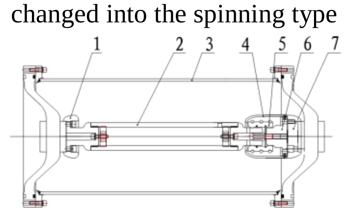

Fig. 1. Schematic diagram of 252 kV busbar before modification.

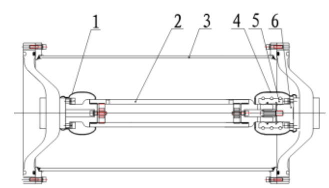

Fig. 2. Schematic diagram of the 252 kV busbar after modification.

III. Optimization of Busbar and Verification Test

In the design of GIS insulation structure, calculation is often based on the peak of the lightning impulse voltage. The electric field distribution of the 252 kV branch busbar with the original design structure is shown in Figure 3. The electric field distribution of the branch busbar with improved structure is shown in Figure 4.

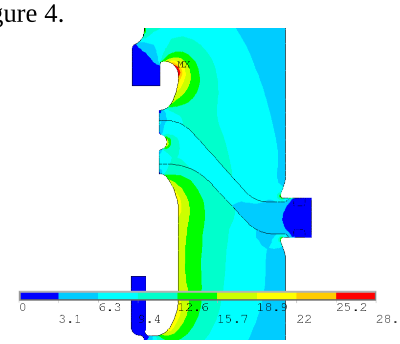

Fig. 3. Electric field distribution of branch busbar with original structure.

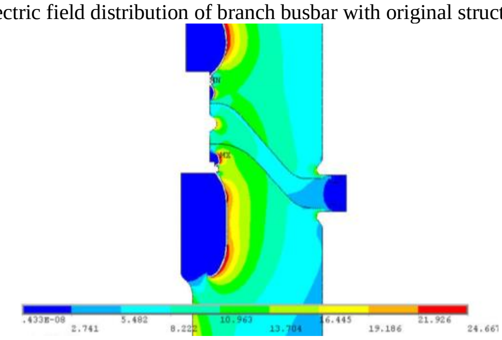

Fig. 4. Electric field distribution of branch busbar with improved structure.

The optimal distribution in Fig. 5 can be found by employing the Finite Element Method (FEM) and Response Surface Method (RSM). TABLE I shows the computational analysis results in the 252 kV branch busbar before structural improvement and the optimal structure.

TABLE I
Calculated field strength of each place when 1050 kV is applied to 252 kV conductor, and allowable field strength of each place (kV/mm)

Serial No.	Item	Shielding part	Insulating part	Insulating surface	Shell surface
1	Design reference	26.2	3	13	14.9
2	Original design	28.3	2.7	12.5	17.1
3	Optimal structure	21.3	2.6	12.5	13.9

The rated inflation and alarm pressures of the 252 kV branch busbar of the gas-insulated metal-enclosed switchgear are 0.4 and 0.35 MPa (meter), respectively. The corresponding allowable field strength values for reference are 28.8 and 26.2 kV/mm, respectively [3].

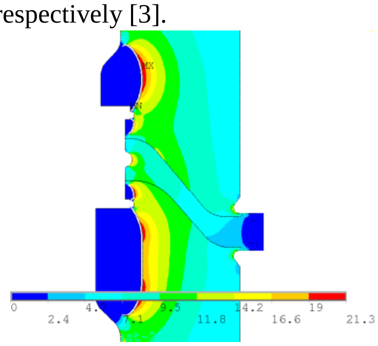

Fig. 5. Electric field distribution of branch busbar with optimized structure.

In Figure 5 and TABLE I, the maximum field strength value of the original busbar structure at the outer surface of the shielding ring is 28.3 kV/mm when the lightning impulse voltage is 1050 kV, higher than the reference value of 26.2 kV/mm. The maximum field strength value of the branch busbar with improved structure is 21.3 kV/mm, lower than the reference value. Generally, the electric field distribution of the improved structure is uniform and removes the redundant shielding cover seat.

Because of the improvement of standards, before the structure of the branch busbar is changed, 15 positive and negative voltage experiments are conducted for the branch busbar at a peak voltage of 1050 kV and an inflation pressure of 0.35 MPa (meter). It occurs five times insulation failures under negative voltage and four times under positive voltage. This result reveals that the original structure does not meet the standard requirements. Figure 6 shows the surface discharge of a basin-type electrical insulator discovered after opening. Figure 7 shows a recorded wave diagram when the lightning impact test fails.

Fig. 6 Surface discharge of branch busbar with original structure

Power frequency voltage withstand tests are carried out on the branch busbar with improved structure at an SF_6 gas inflation pressure of 0.3 MPa (meter) and a test voltage of 460 kV. A lightning impulse test is also performed for verification. The lightning impulse voltage peak is 1050 kV. Fifteen positive and 15 negative voltage experiments are conducted according to the standards. The above tests have no flashover. Figure 8 shows the tooling structure diagram adopted in the power frequency voltage withstand test and lightning impulse test of the 252 kV branch busbar.

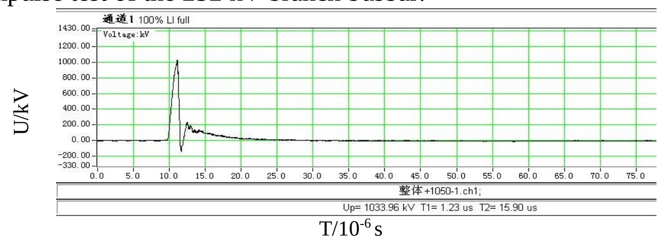

Fig. 7 Wave diagram of branch busbar with original structure when lightning impact test fails

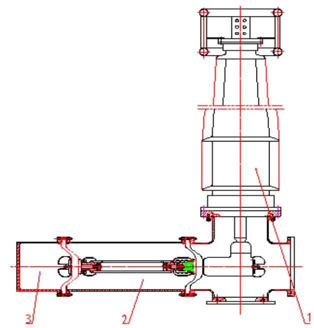

Fig. 8. Voltage withstand tooling of 252 kV branch busbar:1-voltage withstand tooling, 2-branch busbar, and 3-dish head of tooling

The test results show that the original structure cannot meet the requirements of the new standards but the optimal structure meets the standard requirements. In addition, the optimal structure is more cost-effective than the original structure. Meanwhile, the verification test of insulation is carried out under an air pressure of 0.3 MPa (meter). The inflation pressure of the busbar can be reduced to the rated value of 0.35 MPa. This reduction alone can decrease the gas costs of SF6 and protect the atmospheric environment.

IV. Conclusion

The result demonstrates that the electric field distribution of the modified busbar is more uniform than the primary structure. Dielectric test verified that the dielectric margin of the modified structure is larger and that the dielectric reliability is enhanced. The processing of the shielding case pedestal is also eliminated, which decreases the manufacturing cost and improves the enterprise competitiveness. These conditions are clearly in line with social saving.

References

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