APPLICATION TECHNOLOGY OF COMPOSITE INSULATORS FOR ±800KV UHVDC STRAIN TOWERS

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Abstract: In this paper, based on the finite element method, a 3D model of a ±800kV UHVDC power transmission system considering tower configuration, bundled conductors and tension insulator strings was established to study the electrical characteristics of the tension composite insulators used in the strain tower. The effect of the grading ring for improving the electric field on the composite tension string was investigated by changing the parameters of the grading ring, and finally the optimal design of the grading ring was given. Furthermore, the mechanical characteristics of the composite tension string affected by the operator's walking activity were studied by the experimental test. The results show that the operator's walking activity could not lower its mechanical strength and interface performance.

1 INTRODUCTION

In recent years, the application of polymer insulators to both distribution and transmission lines has been increasing rapidly because they have advantages over porcelain insulators, such as light weight, high mechanical strength, and superior contamination resistance [1-2]. In particular, surface hydrophobicity is one of the factors that contribute to the superior performance of silicone rubber in resisting wetting, due to its low free surface energy.

For the ±800kV UHVDC transmission lines under construction in China, the application of conventional porcelain or glass insulators will cause high construction cost, high maintenance requirements, and high risk of pollution-flashover etc.. The operation experience of transmission lines worldwide have approved that composite insulators can play a great role in suppressing pollution flashover and reducing maintenance cost. Thus, the composite insulator is preferred for the UHVDC project, especially in heavy pollution area.

At present, the application quantity of composite insulators for tension string is very small in China, because it is worried that composite insulator's strength is not enough in anti-bending and anti-torsion, which might cause the big deformation under small load stress. It is necessary to break the barrier of composite insulator's application for tension strings used in the UHVDC transmission lines.

The purpose of this paper is to develop the composite insulators applied in UHVDC tension strings and propose the design guideline and inspection standard. In this paper, simulation analysis and experimental test were conducted to study the electrical and mechanical properties of the composite tension string. The optimal design process of the grading ring was introduced for the case of three composite tension strings in parallel. In addition, the interface performance of the composite tension string was verified by a steep-front impulse test after the operator's walking activity.

2 OPTIMAL DESIGN OF GRADING RING

Electric-field and potential distributions along composite insulator surface are extremely uneven because of their structure characteristics and high-resistivity of silicone rubber housing. Corona discharges caused by the field-enhancement at the joint of FRP rod and end fitting will result in the electrical erosion and further accelerating the degradation of the insulator [3-4]. Installation of grading ring is an effective way to improve the electric-field distribution, especially at the high-voltage side of the composite insulator.

As for the composite tension string used in strain towers, it is very important to make an optimal design for the grading ring, which covers the several horizontal composite insulators in parallel. Thus, based on the finite element method (FEM), a 3D simulating model was established to achieve an optimal arrangement of the grading ring.

2.1 Simulation Model

FEM is mainly applied to domains with bounded boundaries, while the field domain to be solved contains the composite insulators, the conductors and the tower, which is a 3D field problem with open boundaries. Based on the domain decomposition algorithms, the domain is separated into a bounded region and an unbounded region. In the bounded region, the FEM is adopted to calculate the electric-field distribution [5].

According to the actual project, a simplified model of strain tower J-30 is used in the calculation. The height from the lowest transverse plane of the tower to the ground is 45m, and the full height is 60m. The 550kN composite rod insulators with the structure length of 10600mm and arcing distance of 10120mm are adopted. The conductors are 6× ACSR-630/45 ACSR.

The simulation model is shown in Fig.1. The length of each conductor is 96 meters, and the bounded region to be solved by FEM is a cube with a 110 meter edge. The ground is simulated as a 110× 110 m^2 plane with zero potential, where the tower is located in the center. The following simplification rules are adopted:

(1) Ground wires are omitted in the field calculation because of their little influence on the electric-field distribution along composite insulators;

(2) The composite insulators, tower, conductors and grading rings are kept clean and dry;

(3) Weathersheds are omitted to reduce the computation time because of very little difference introduced.

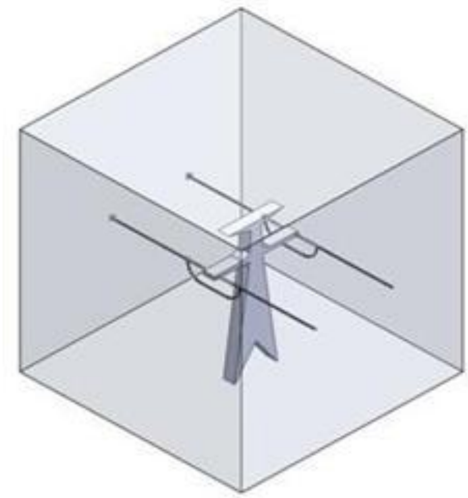


Figure 1: 3D simulation model

2.2 Grading Ring Parameters

As for the case of three composite tension strings in parallel, the grading ring is adopted as a structure of racetrack torus with double rings. Three parameters are considered: the ring diameter (D), diameter of the ring tube (Φ) and position of the ring above the end fittings (H). The grading ring structure is shown in Fig. 2.

After the installation of the grading ring, the maximum electric field should be limited to a threshold of 5kV/cm for the insulator surface and 15kV/cm for the surface of end fittings and grading ring, which is the target of optimal design.

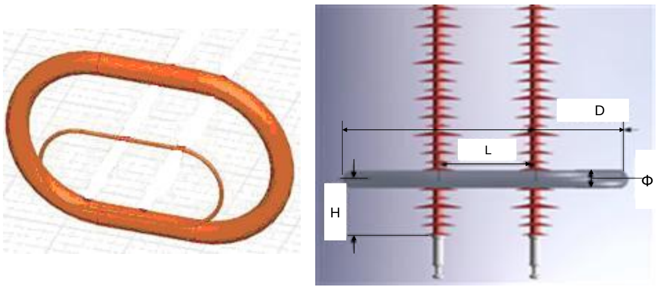


Figure 2: Diagram of the grading ring structure

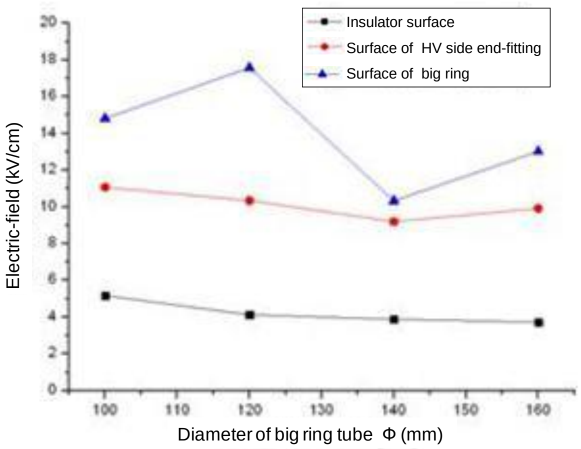
According to the actual project, the distance L between the adjacent strings is 400mm. As the first step of optimal design, only the big grading ring is considered. Among the above-mentioned three parameters D, Φ and H, one parameter acted as variable during the calculation, while the other two are kept constant. The computation results are shown in Fig.3.

As seen from Fig.3, the electric-fields on the surface of insulator and end fitting trend to decrease when the diameter of big ring tube increases from 100mm. Considering the field strength on the grading ring, the optimal tube diameter Φ should be 140mm. With the diameter of bing ring increasing, the surface electric-field of end fitting decreases and those of insualtor and grading ring appear fluctuation. To achieve the minimum surface electric-field for all the parts, the optimal big ring diameter D is 1200mm. It can also be found that the surface electric-field of end fitting increases with the increase of distance between ring and end fitting, while few field changs could be found on the insulator surface. Thus, the optimal distance between ring and end fitting H is 500mm.

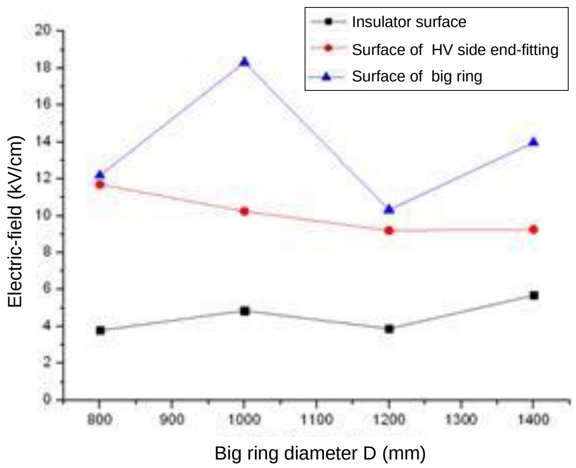
Based on the above-mentioned optimal parameters for the bing ring, the parameters of small ring are introduced for analysis by the same way. The computation results are shown in Fig.4. The optimal values of Φ, D and H are 40mm, 400mm and 200mm, respectively.

2.3 Final Optimal Design

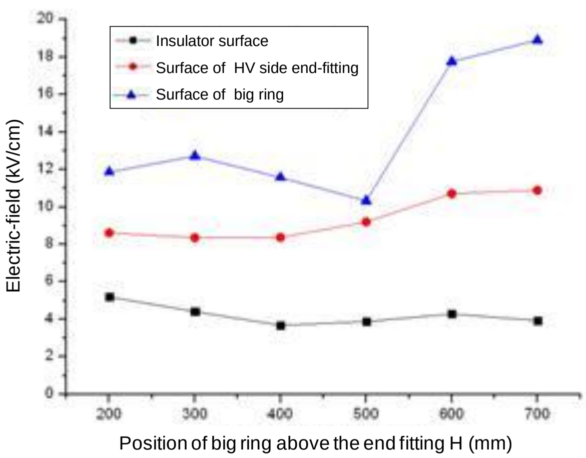
With the parameters Φ=140mm, D=1200mm and H=500mm for the big ring and Φ=40mm, D=400mm and H=200mm for the small ring, the electric-field distribution for the case of three composite tension strings in parallel are calculated and the results are shown in Fig.5. The maximum electric-fields on the surface of insulator housing, end fitting, big ring and small ring are 3.47kV/cm, 8.13kV/cm, 12.8kV/cm and 9.88kV/cm, respectively. All these electric-fields match the design requirements.



(a) D=1200mm, H=500mm

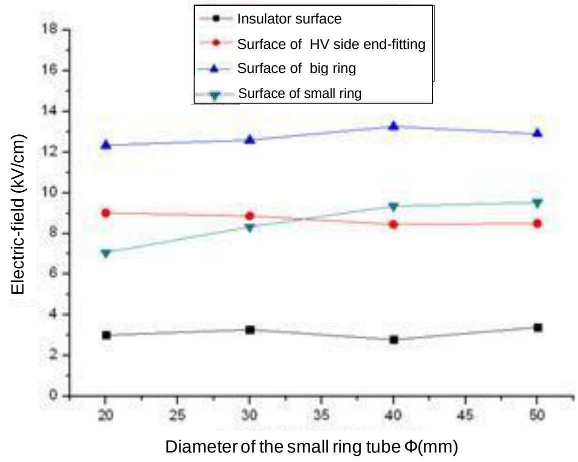


(b) Φ=140mm, H=500mm

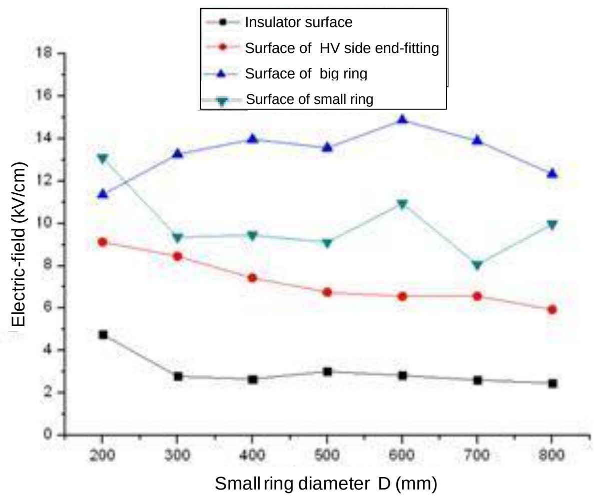


(c) Φ=140mm, D=1200mm

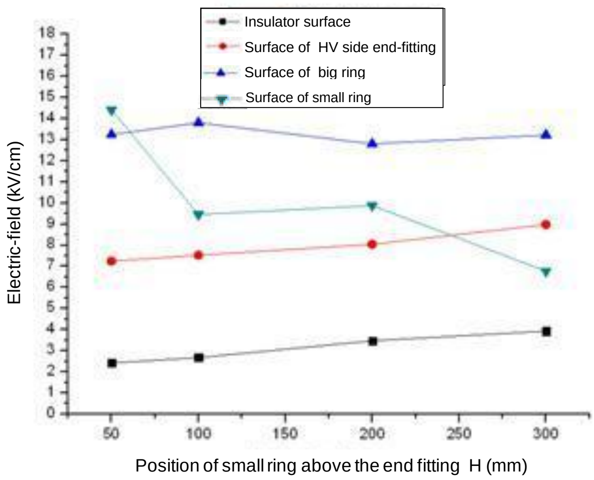
Figure 3: Influence of the big grading ring's parameter on the electric-field distribution



(a) D=300mm, H=100mm



(b) Φ=40mm, H=100mm



(c) Φ=40mm, D=400mm

Figure 4: Influence of the small grading ring's parameter on the electric-field distribution

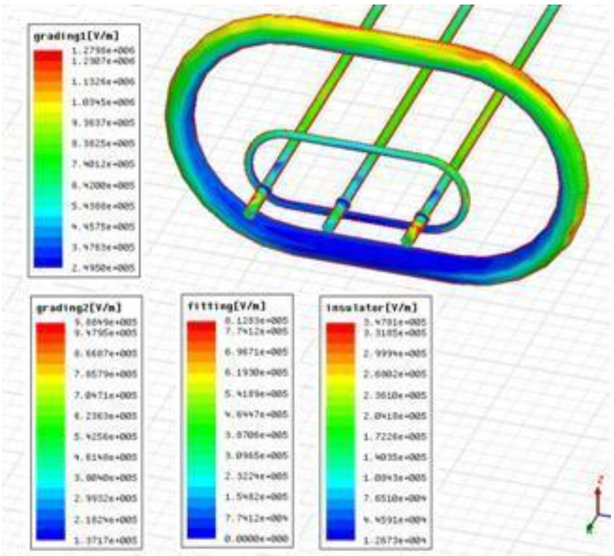
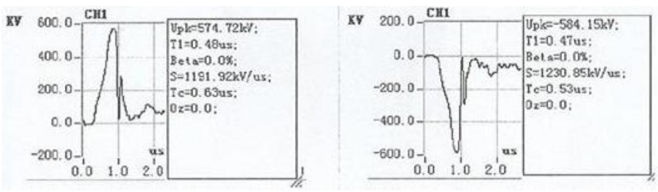


Figure 5: Electric-field distribution for the case of three composite tension strings in parallel

3 STEEP-FRONT IMPULSE TEST

During the line maintance, the influence of operator's walking activity on the mechanical strength of the composite tension string is a noteworthy problem. A simulating test was carried out to verify this performance. The test sample of FXBZ-800/550 composite insulator was set on a tensile strength tester under the applied axial tensile load of 190 kN. Thereafter, an experimenter with the weight of 100kg walked along the insulator surface. After this walking activity, no abnormity could be found on the insulator surface and the joint between the FRP rod and end fitting.

To further verify the interface performance after this walking test, a steep-front impulse test was also carried out . The waveforms of the steep-front impulse are shown in Fig.6, and the test results are listed in Table 1. It is shown that the interface between the silicone rubber housing and the FRP rod kept good performance.



(a) Positive polarity (b)Negative polarity

Figure 6: Waveforms of steep-front impulse test

Table 1: Results of steep-front impulse test

Sample section	Positive polarity		Negative polarity	
	Shoot number	Breakdown	Shoot number	Breakdown
Section 1	25	No	25	No
Section 2	25	No	25	No
Section 3	25	No	25	No
Gradient kV/μs	1075~1470		1054~1460	

4 CONCLUSION

In this study, to develop the composite tension strings for ±800kV UHVDC strain towers, theoretical computation and experiment test were conducted for electrical and mechanical analysis. The results are summarized as follows:

(1) With the parameters Φ=140mm, D=1200mm and H=500mm for the big ring and Φ=40mm, D=400mm and H=200mm for the small ring, the optimal design of grading ring is achieved for the case of three composite tension strings in parallel.

(2) Operator's walking activity can not destroy mechanical strength of the composite string

(3) Operator's walking activity could not lower its interface performance.

5 REFERENCES

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