

Research on corona characteristics of fittings in valve hall of UHVDC converter station

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Abstract—Aiming at corona control of fittings in valve hall of UHVDC converter station, numerical simulation based on FEM and corona experiment on fitting equipment is carried out. According to the operation condition and potential on the fittings of electrical equipment in the valve hall, the instantaneous potential loading method is proposed, which the maximum electric field intensity on every fittings surface can be obtained in all of working conditions. By sub-model method, the size of meshes on the interface between metal and air has been studied, based on the example of large size grading ball and ring. The reference value is taken to determine the proper size of finite element on the surface of metal. A $\pm 660\text{kV}$ UHVDC converter station pole II valve hall is taken as research model, a 3D FEM simulation model is built according to the CAD drawings. The max values of electric field on the surface of the fittings all over the valve hall are calculated. Two kinds of fabrication process for grading balls with diameter changed from 0.5m to 1.0m every 0.1m are produced for testing in high voltage DC corona. The relationship between corona onset voltage and diameter of grading ball, as well as the relationship between corona onset voltage and atmospheric condition are studied. The corona onset electric field versus diameter curve is carried out by using the method of electric field and electric potential equivalent calculation. The limit value of electric field of grading balls in HVDC valve hall is recommended.

Key words: UHVDC; valve hall; fittings; electric field; corona onset field

I. INTRODUCTION

UHVDC converter station valve hall is the key facility of UHVDC (Ultra high voltage direct current) transmission engineering. In normal operation, there are strict limitations to the value of surface electric field on power fittings (metal grading component). In the design of valve hall, the electric field on the surface of fittings should be calculated and verified to ensure all the values are lower than corona onset values.

The electric field calculation of valve hall equipments helps to find out the electric field distribution characteristic, which can provide guidance to the converter design and guarantee the operation in safety and stability. Improvement of electric field calculation in valve hall is of great significance to guide the design and manufacture of electrical equipment and can promote the development of UHVDC transmission technology [1-4].

Existing literature mainly focuses on the analysis on electric field of partial model, such as valve tower, converter transformer bushing and etc. Few researches and experimental verifications on corona controlling value of high voltage power fittings can be found.

A $\pm 660\text{ kV}$ UHVDC valve hall is taken as research example, the 3D FEM simulation model of Pole II valve hall

is built, calculation and analysis of electric field are present in this paper. Surface electric field distribution of valve hall equipment in normal work condition is calculated. According to corona onset experimental data of grading ball, surface electric field is recommended to determine the control reference of corona onset field in valve hall. The results provide technical support to design of fittings and contribute to electric field control technology of HVDC valve hall fittings.

II. CALCULATION METHOD OF SURFACE ELECTRIC FIELD

2.1 Comparative study about FEM and BEM

The finite element method (FEM) is widely used in electric field calculation with many kinds of medium and complicated boundary problem. And the boundary element method (BEM) is suitable for the field problem with few kinds of medium or open boundary. Due to large number of equipments and big difference in sizes of fittings in UHVDC valve hall, the modeling should be considerably simplified in BEM and hence the approximate level is very poor. With the high fineness of model in FEM, the solving precision of equipment surface electric field can be obtained under the fine control of the meshes. Compared FEM with BEM, an example of electric field calculation of $\pm 500\text{kV}$ HVDC valve hall shows that FEM is more suitable for calculating the electric field of 3D model of UHVDC valve hall equipment.

2.2 Determination of loading method

According to electrical parameters of converter transformer and thyristor valve, the potential waveforms of valve hall main equipments under 1.0 p.u (the rated power) and 0.1 p.u are obtained by UHVDC system simulation. Through comparison of instantaneous potential loading and harmonic loading method, the instantaneous potential loading method is chosen as the potential loading method, which can obtain maximum electric field value on the surface of the fittings under every operation conditions.

2.3 Effects of surface element size on calculation

The 3D solid model is imported into ANSYS and preprocessed. Many control volumes are added to the equipment and taken Boolean operations. The sizes of the element adjacent the interface between fittings and air are set accordingly. The effects of normal element size of the fittings' surface on the calculation results are further discussed.

Through modeling typical grading ball and grading ring, setting precision control to normal mesh size, analyzing the local electric field using the sub-model method respectively, effects of different mesh size on the surface field value is compared and influence of mesh size is obtained.

2.4 Electric field calculation and analysis of 3D FEM model

The 3D whole model of a ± 660 kV UHVDC valve hall is simulated under different operation conditions and phase, combined with further sub-model analysis. Calculation results show that the maximum value of electric field is about 14.66 kV/cm, appears on the surface of the lower grading ring, which is set on the ± 660 kV UHVDC outgoing pipe bus line.

The calculation results of the concerned grading ball are as follows: maximum value of grading ball with radius of 600mm is 7.56kV/cm, maximum value of ball with radius of 800mm is 6.08kV/cm. The electric field distribution on surface of valve hall fittings at the phase of 301.5° is shown in Fig.1:

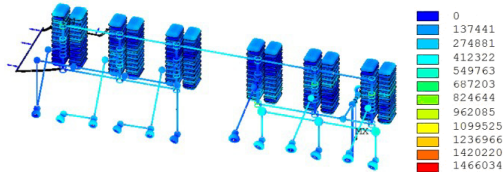


Fig.1. electric field distribution map in 3D valve hall model

III. CORONA EXPERIMENT OF GRADING BALL

3.1 Experimental configuration

Experiments were taken in the test hall of $80 \times 60 \times 50 \text{ m}^3$. The power source is 1800kV/0.2A DC voltage generator. The allocation of equipment is shown in Fig.2.

For DC corona experiment of various sizes of grading ball, the experimental process according to the criterion: GB/T 2317.2-2008 "section 2 of the power experiment method: corona and radio interference experiment". Climate parameters and differences of surface processing technics of grading ball are considered. The experimental data is shown in Table I.

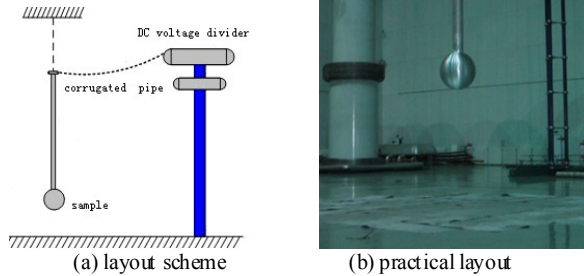


Fig.2. corona test of grading ball with different radius

TABLE I
AVERAGE CORONA ONSET VOLTAGE (kV)

Diameter (mm)	Whole ball		Two hemispheres	
	positive	negative	positive	negative
500	649	597	643	559
600	726	607	\	\
700	783	740	695	672
800	985	820	\	\
900	1075	860	\	816
1000	\	902	\	\

Table I shows that corona onset voltage increases as the diameter of ball increases with a nonlinear relationship. The onset voltage of two hemisphere is lower than that of the whole ball, due to the surface roughness of the joint.

3.2 Experiment results

The corona onset electric field-diameter relationship is obtained through analyzing the finite element numerical model

of the experimental configuration. The diameter-EF relationship curve of grading ball is shown in Fig. 3. The surface electric field decreases as diameter increases with a nonlinear relationship. The bigger ball has the lower corona onset electric field.

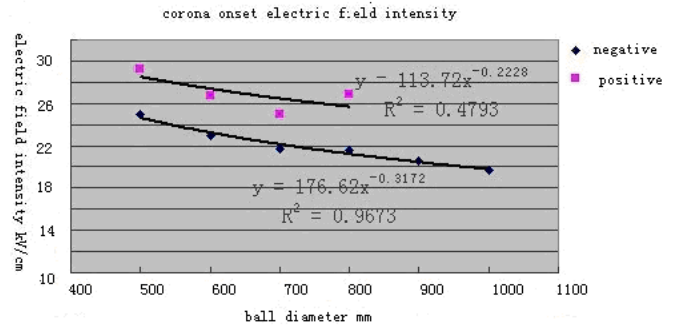


Fig.3. fitting curve of corona onset electric field-diameter

According to the working conditions of the grading ball, taking corona onset electric field under negative polarity as control standard, considering process differences on surface of grading ball, taking roughness coefficient as 0.9, margin coefficient as 1/1.3, the surface electric field control values of grading ball in UHVDC valve hall are recommended as below:

TABLE II
ELECTRIC FIELD CONTROL VALUES (kV/cm)

Diameter (mm)	Whole ball corona onset electric field	Hemispheres corona onset electric field	Electric field control value	Calculation result of balls in whole valve hall
1000	19.73	17.76	13.66	/
1200	18.63	16.77	12.90	8.45
1600	17.01	15.31	11.78	6.45

IV. CONCLUSIONS

Based on FEM, this paper puts forward the instantaneous potential loading method for electric field numerical simulation of power fittings in 3D whole valve hall model. Reasonable control of surface meshes size is used to improve the calculation accuracy.

Through HVDC corona experiment of grading balls with different diameter, the relationship curve of corona onset electric field - radius is obtained, and control reference values of corona onset electric field of three typical grading balls are given. Actual operation situation of valve hall shows that the maximum surface electric field of grading ball is lower than the corona onset electric field intensity presented in this paper, which verifies the correctness of this method.

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