

Electric Field and Electromagnetic Environment analyses of a 500 kV Composite Cross Arm

Gao Yanfeng, Wu Chao, Liang Xidong, Liu Yingyan
Dept. of Electric Engineering, Tsinghua University
Beijing, China

Wang Guoli, Gao Chao
Electric Power Research Institute of CSG
Guangzhou, China

Abstract— In order to further utilize the transmission line corridor, meanwhile, achieve a relatively friendly electromagnetic environment, composite cross arm is developed and employed in the transmission system. The electric field distribution as well as the electromagnetic environment of composite cross arm deserves a detailed and in-depth study to verify its performance. In this research, the three-dimension (3D) finite element method (FEM) was employed to calculate the electric field distribution of composite cross arm. The electromagnetic environment was characterized by electric field intensity on the ground, radio interference and audible noise and these parameters were investigated and analysed. Calculation results indicated that by using proper metal hardware, composite cross arm could obtain a relatively suitable distribution of electric field and potential. The electromagnetic environment calculation results demonstrated that composite cross arm could meet the standard design requirement. Furthermore, some suggestions were made based on this research to achieve an optimization use of composite cross arm.

Keywords—composite cross arm; electric field; electromagnetic environment;

I. INTRODUCTION

In recent years, the power demand of China keeps rising and the power system expands the scale extraordinary [1]. In order to further utilize the transmission line corridor, meanwhile, achieve a relatively friendly electromagnetic environment, composite cross arm is developed and employed in China transmission system. Composite cross arm is a new kind of cross arm which can fully utilize transmission line corridor and reduce the height of transmission tower[2-4].

Composite cross arm make use of composite materials instead of traditional steel materials to form the arm body. The composite cross arm have some advantages such as good insulation performance, high mechanical strength, light weight, resistance to the erosion, easy to install and so on. Composite cross arm is another innovative application of composite materials in transmission line after the use of composite insulator.

Despise composite cross have above advantages, some details investigation still should be carried out, due to the fact that the experience of composite cross arm used in EHV transmission system is not that much and the difference between the composite cross arm and the traditional steel arm is significant, which make the early operational experience and experimental data of steel cross arm can not directly be

used in the design and construction of composite cross arm.

In this paper, the electric field and electromagnetic environment analyses of a 500 kV composite cross arm are presented with the aim of obtaining a better understanding of the electric performance of 500kV composite cross arm.

II. ELECTRIC FIELD ANALYSIS OF COMPOSITE CROSS ARM

A. Electric field calculation method

The three-dimension (3-D) finite element method (FEM) was employed to calculate the electric field distribution of composite cross arm. In order to have a better simulation of the actual situation, in this paper, the actual shape of the composite cross arm, the tower, the ground, the interaction between different phase have been taken into consideration. The basic assumptions and simplifying principles of the calculation are: a) all surface of entities calculated in the paper (including tower, arm, metal hardware, wires etc) are dry and clean. b) the ground wire is neglected due its unobvious effect on the electric field of cross arm [5]. c) the sheds of composite cross arms and composite insulators are also neglected, this simplification is rational and make the calculation faster [5].

The calculation model in this paper is an unbounded 3-D field, FEM method can not directly solve this kind of field. The domain decomposition method [6] was employed in our calculation, i.e, firstly, a large-scale model is used to give the potential distribution near the composite cross arm; secondly, a local domain around the composite cross arm is calculated. Thirdly, a series of iterative solutions is carried out on these overlapping domains to reach the final electric field distribution of composite cross arm. In order to improve the accuracy of calculations, the number of iteration has been controlled to make the convergence of energy error less than 0.1%. By using this method, the electrostatic field of composite cross arm tower in calculated.

The actual tower and calculation model are shown in Figure1, the voltage boundary conditions of calculation are:

a) the voltage of phase A is given by equation (1), in which the maximum operating voltage has been taken into consideration.

$$V(A) = 1.1 \times 500 \times \sqrt{2} / \sqrt{3} = 449 \text{ kV} \quad (1)$$

b) the interaction between phases was also taken into consideration by giving the voltage of phase B and phase C as

$$V(B) = V(C) = -0.5 \times V(A) = -224.5 \text{ kV} \quad (2)$$

In the arrangement of the composite cross arm as shown in Figure 1, the electric field of phase A is the most distortion. When the voltage of phase A is the maximum operating voltage (as shown in equation 1), the voltage of phase B and phase C is the half of phase A (as shown in equation 2).

c) the voltage of ground and tower is 0 kV.

In this kind of boundary condition, the electric field as well as the potential would reach the most serious distortion distribution.

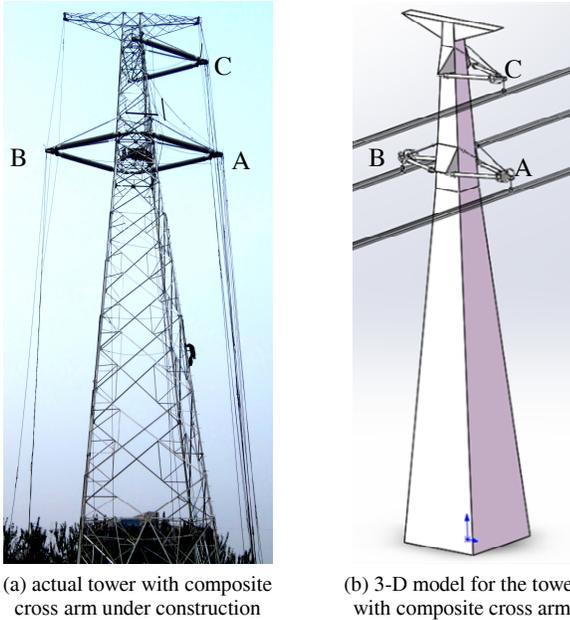


Figure 1. The tower with composite cross arm

B. Electric field calculation results

The geometry of the attachment hardware in ends of composite cross arm have been ingenious designed which make the magnitude of the electric field in the composite cross arm surface less than 5 kV/cm (peak value) and the magnitude of the electric field in the metal hardware surface less than 20 kV/cm (peak value). By this design, the drops corona discharge on the surface of the composite cross arm and corona discharge on the surface of the metal hardware can be avoided as much as possible.

The potential distribution and electric field distribution of cross arm are shown in Figure 2 and Figure 3, respectively. In order to have a clear visualization of the field distribution, both the 3-D and 2-D schematic distribution are presented. It worthy to point out that the 2-D schematic is the field distribution on the plane through the cross arm axis. As can be seen in the figure 3, the metal hardware exhibit a good shielding performance, the high electric field region have been concentrated in the surface of the metal hardware. Furthermore, the shielding effect of the metal hardware is also analyzed by comparing the potential and electric field distribution along the surface of composite cross arm with and without the metal hardware, as shown in Figure 4, it is obviously that after installing the metal hardware, the potential

distribution is more uniform and the maximum of the magnitude of electric field shows a significantly reduction. The electric field distribution of the high voltage end metal hardware is rather complicated, as show in Figure 5. It can be found that the maximum of the electric field occurs at the upper surface of the corona rings, this indicates that in actual use of composite cross arm, this area deserve special attention.

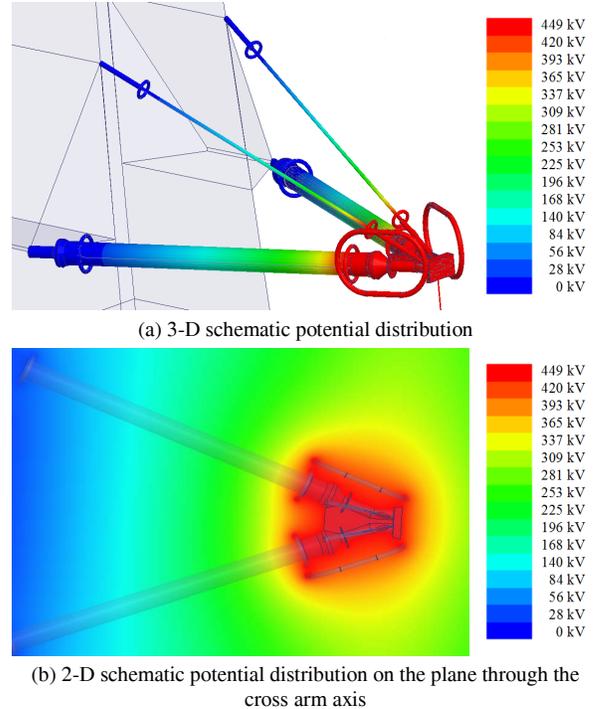


Figure 2 Potential distribution of phase A of composite cross arm

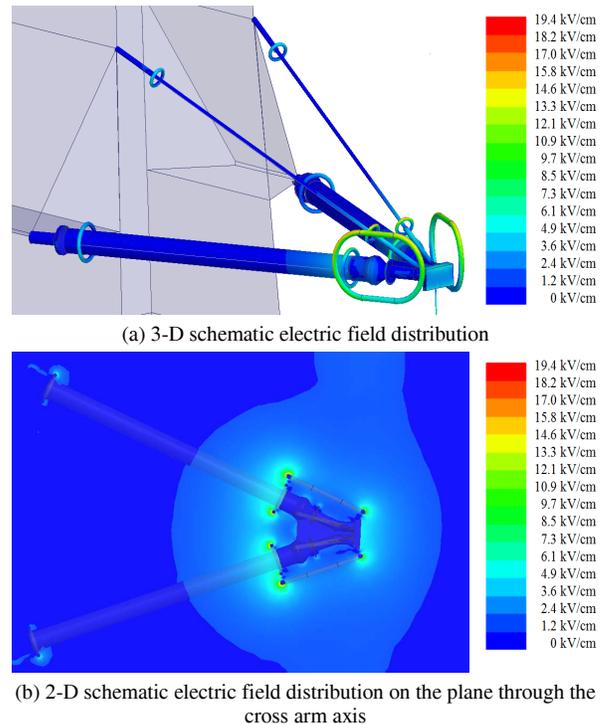
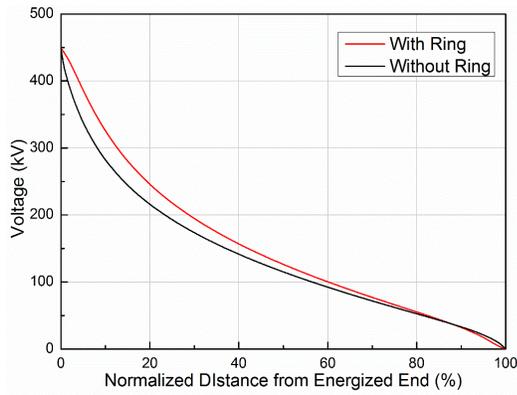
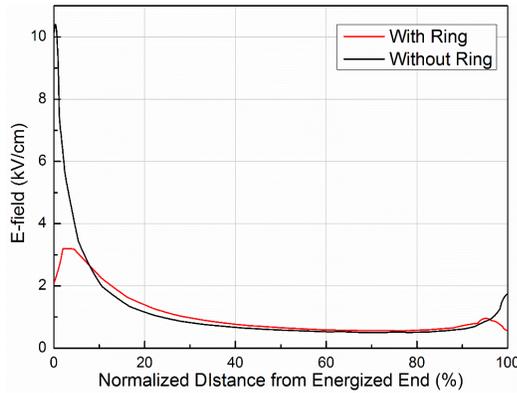


Figure 3 Electric field distribution of phase A of composite cross arm



(a) Potential distribution along the surface of composite cross arm



(b) E-field distribution along the surface of composite cross arm

Figure 4 Comparison of the potential and E-field distribution along the surface of composite cross arm with and without the metal hardware

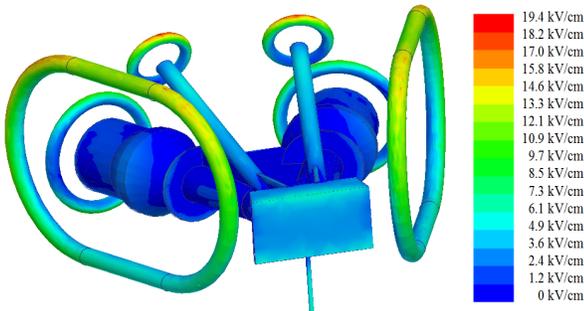


Figure 5 Electric field distribution of metal hardware

III. ELECTROMAGNETIC ENVIRONMENT ANALYSIS OF COMPOSITE CROSS ARM

A. The limit value and calculation method of the electromagnetic environment

The main indices of the electromagnetic environment include a) electric field strength on the ground, b) radio interference and c) audible noise. These three indices have closely relationships with the selection and design of the transmission corridors, as well as the living and production of the surrounding residents. Every countries all give clear limits of the electromagnetic environment.

The detailed parameters and specific coordinates of the wires in the calculation of the electromagnetic environment is listed in Table 1 and Table 2, respectively.

TABLE I. DETAILED PARAMETERS FOR THE CONDUCTOR WIRE AND GROUND WIRE

	Conductor wire	ground wire
Type	LGJ-400/35	LBGJ-150-40AC
Split Number	4	—
Split spacing	450 mm	—
Diameter	30 mm	15.75 mm
DC resistance	0.05912 Ω	0.2935 Ω
Sag	21 m	9 m

TABLE II. SPECIFIC COORDINATES OF THE PHASE CONDUCTOR

	Lateral Coordinate	Height Coordinate
Top Phase	6.4 m	48 m
Left Phase	-6.9 m	38 m
Right Phase	6.9 m	38 m

a) Electric field strength on the ground

In Chinese regulation[7], in the extra and ultra high voltage system, below the transmission line, the electric field strength in the position of 1.5m above the ground should less than 7 kV/m for the public accessible area, 10 kV/m for the place across the farmland. More rigorously, for the houses location, the electric field strength in the position of 1m above the ground should less than 4 kV/m. In this paper, the equivalent charge method was employed to calculate the electric field distribution on the ground below the transmission line [8,9].

b) Radio interference

International Special Committee on Radio Interference (CISPR) recommended the “80%/80%” value to measure the radio interference. The meaning of the “80%/80%” value is that in the 80% of the time, radio interference should not exceed the 80% of the allowable value of the lowest confidence level. According to Chinese regulation [7], in the 500 kV transmissin system, the limit value of the radio interference is 55 dB, which means that in the position of 20 m away from the outside phase conductor, 2 m above the ground, in the 80% of the time, with the 80% confidence level, in the frequency of 0.5 MHz, the radio interference value should less than 55 dB. The 500 kV composite cross arm transmission is consist of 4 bundled conductors, so in this paper, the empirical formula method is employed to calculate the radio interference distribution[8,9].

c) Audible noise

In Chinese regulation[7], for 500 kV transmission system, in the position of 20 m away from the outside phase conductor under wet condition, the audible noise should less than 55 dB(A). In this paper, the recommendation method given by American Transmission Line Design Handbook is used to calculate the audible noise distribution [8,9].

B. Electromagnetic environment calculation results

The distribution of the electric field strength on the ground is shown in Figure 6, it can be seen that the maximum of the electric field strength in the position of 1m above the ground below the transmission line is 5.2 kV/m, which is lower than the limit value 7 kV/m for the public accessible area and 10 kV/m for the place across the farmland. It should be noted that due to the asymmetrical arrangement of the cross arm (as shown in Figure 1), the calculated electric field strength distribution is also asymmetry.

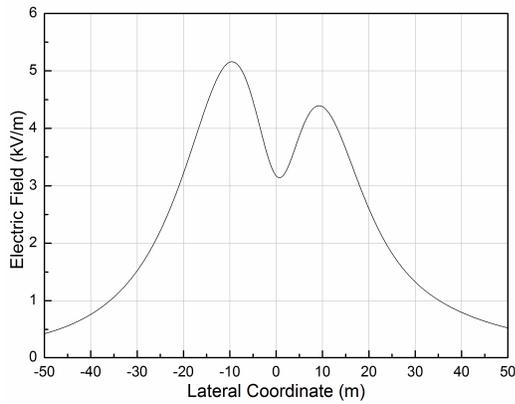


Figure 6 Electric field distribution on 1m above the ground

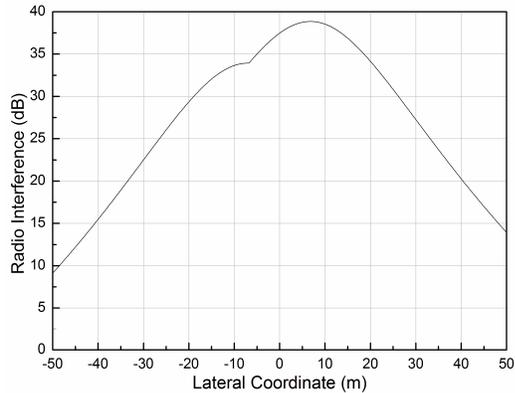


Figure 7 Radio interference distribution under transmission line

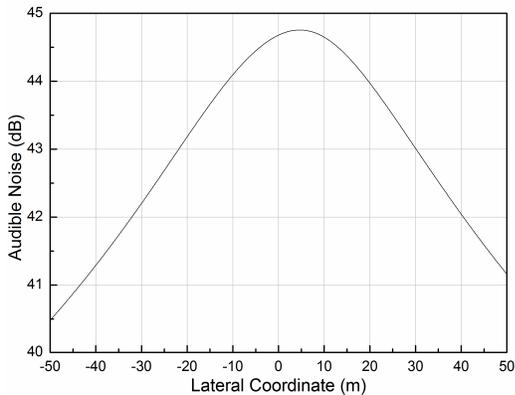


Figure 8 Audible noise distribution under transmission line

The radio interference distribution under transmission line is shown in Figure 7, the maximum of the interference intensity occurs almost directly below the phase conductor with the value of 38.3 dB. In the position of 20 m away from the outside phase conductor, 2 m above the ground, in the 80% of the time, with the 80% confidence level, in the frequency of 0.5 MHz, the radio interference value is far less than the limit value. Similar to the electric field strength distribution, the radio interference distribution is also asymmetry.

The audible noise distribution under transmission line is presented in figure 8. In the range of 50 m to the center of transmission line, the audible noise is distributed between 42dB ~ 45 dB under wet condition. This is also consistent with the provision. Of course, the audible noise distribution is also a asymmetry distribution.

IV. CONCLUSION AND SUGGESTION

The investigations of the electric field and electromagnetic environment of a 500 kV composite cross arm have led to the following conclusions and suggestions:

As for the composite cross arm transmission tower, in order to obtain an excellent performance of the composite materials, the corona discharge should be avoided as much as possible. From this point of view, the optimization design of the metal hardware is essential. In this paper, the geometry of the attachment hardware in ends of composite cross arm have been ingenious designed, through this design, the maximum of the electric field on the surface of composite cross arm and on the surface of metal hardware are less than the limit value. Furthermore, by installing the metal hardware, the potential distribution along the composite cross arm become more uniform. In actual use, the area of the maximum electric field (i.e. the upper surface of the corona rings, as shown in Figure 5) deserve special attention.

The three main indices of the electromagnetic environment including electric field strength on the ground, radio interference and audible noise have been calculated, the distribution of these indices below the transmission line show an asymmetry distribution, and the maximum of these indices are all less than the limit value given by the Chinese regulation. This results give some confidence of the use of the composite cross arm in the 500 kV transmission system.

It worthy to pointed that all the calculated results in this paper is in the typical conditions. In specific engineering applications, some further investigation depending on the specific circumstances should be carried out in order to have a more pertinence analyses of the performance of the composite cross arm.

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