

Calculation Model of Ultra-High Voltage Electronic Circuit based on the Electric Field Correction Model

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Abstract: In order to ensure the safe and reliable operation of transmission lines, a calculation model of electric field of EHV electronic lines based on field strength correction model is proposed. The model is simulated, and the nominal electric field intensity distribution of different models is compared with the four bundles conductor overhead ground wire model. The results show that the influence of the overhead ground wire on the nominal electric field strength around the transmission line is very small, so it is feasible to use the simplified model of ignoring the overhead ground wire in the engineering application; the simplified model of the equivalent conductor is not suitable for analyzing the electric field strength near the line, but suitable for analyzing the area far away from the line and the calculation amount is greatly reduced.

1. Introduction

With the rapid development of China's economy, the demand for electric power is increasing rapidly. It is estimated that by 2020, the total demand for electric power in China will reach 4.6 trillion kw per hour. In view of the imbalance between China's energy distribution and power load, a long-distance "west east power transmission" policy is proposed [1]. For this kind of large capacity, long-distance power transmission, the use of HVDC transmission is more than the same level of high-voltage AC transmission. It is economic and reliable, so HVDC has been used in some transmission projects in China, and has a broad application prospect [2].

The distribution of electric field around DC transmission lines is an important issue to be considered in the design, construction and operation of DC transmission lines. The space electric field under DC line is composed of two parts, one is the nominal electric field formed by the charge on the DC line, the other is the electric field formed by the space charge generated by DC corona. The superposition of the two parts is called the composite electric field [3]. The common methods for calculating the nominal electric field strength of HVDC transmission lines include step by step image method, simulated charge method, finite element method, etc. the finite element method is widely used in various occasions because of its systematic and standardized steps and the ability to develop flexible and general computer programs.

In order to facilitate the analysis and calculation, it is necessary to simplify the transmission line model properly. It is a common simplification method to ignore the overhead ground wire and adopt the equivalent conductor [4]. The simplified results are bound to be different from the actual situation. In order to understand the impact of the simplified methods, it is necessary to establish a two-dimensional simulation model and use the finite element method to simulate the nominal field strength distribution around the HVDC lines [5].

2. Calculation Method

2.1. Basic Ideas

The field quantity of the electrostatic field can be expressed as an integral form of the function of the potential to be determined and its derivative. According to the discretization method of the difference method, the solution field is divided into finite units; then the discrete units are used to approximate the field quantity as the function of a finite number of node potentials, so that the

variational problem of the field extremum is simplified to the extremum problem of the multivariate function, while the latter usually comes down to a set of multivariate linear algebraic equations; finally, with the specific characteristics of the system of equations, the appropriate algebraic method obtains the potential of each node to realize the discrete solution of the variational problem [6].

The electrostatic field calculation model can be used to solve the nominal field strength distribution around the line [7]. The electrostatic field problem follows the Maxwell equation, resulting in the following relationship:

$$\Delta \varepsilon (-\Delta \varphi) = \rho \quad (1)$$

Where, ρ is the amount of charge, ε is the dielectric constant, and φ is the potential at any point in space.

Using the weighted residual method and using the corresponding boundary conditions, the differential equation (1) is transformed into an integral equation, and the linear equations are obtained by discrete elements.

$$KQ = V \quad (2)$$

Where, K is the coefficient matrix formed by the finite element discrete (1) medium left term, V is the finite element node potential vector, and Q is the excitation vector formed after the boundary constraint processing. The solution of the electrostatic analysis consists of the node potential, from which the field strength distribution can be calculated.

2.2. Boundary Conditions

Wire surface:

$$\varphi = \pm U \quad (3)$$

$$\frac{\partial \varphi}{\partial n} = -E_{0\pm} \quad (4)$$

Where, U is the operating voltage of the conductor, n is the number of sub conductors, E_{0+} and E_{0-} are the corona field strengths of the positive and negative electrodes respectively.

Artificial boundary:

$$\varphi = V_n \quad (5)$$

Where, V_n is the potential of the nominal electric field.

Surface of ground and overhead ground wire:

$$\varphi = 0 \quad (6)$$

2.3. Calculation of Electric Field Strength

After given a set of parameters, the power line obtained from the initial conditions of the differential equation is shown in Figure 1.

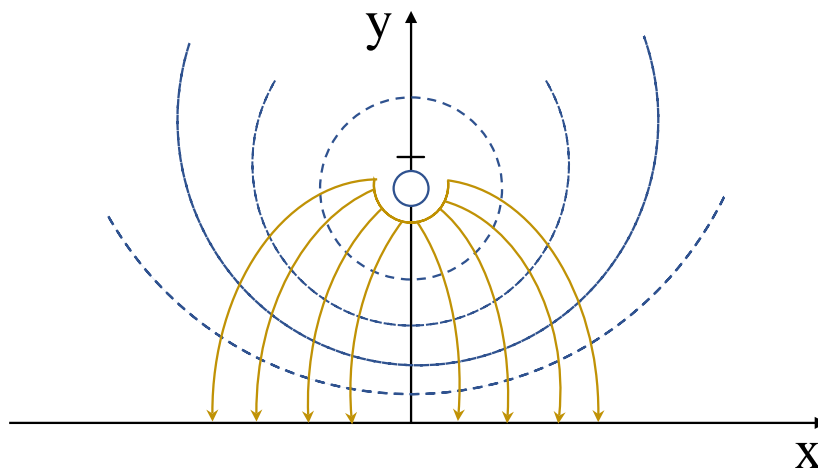


Figure. 1 Schematic diagram of power line and equipotential line of transmission line

3. Model Establishment and Simulation

The three-dimensional electric field calculation model of the three-phase transmission line is adopted for the transmission line based on the ground electric field information, and the N points of the three-dimensional power frequency electric field of the transmission line are laterally distributed in the x coordinate as the measurement point, and the working principle of the three-phase transmission of the transmission line is utilized. Record the measured value of the electric field, as shown in Figure 2.

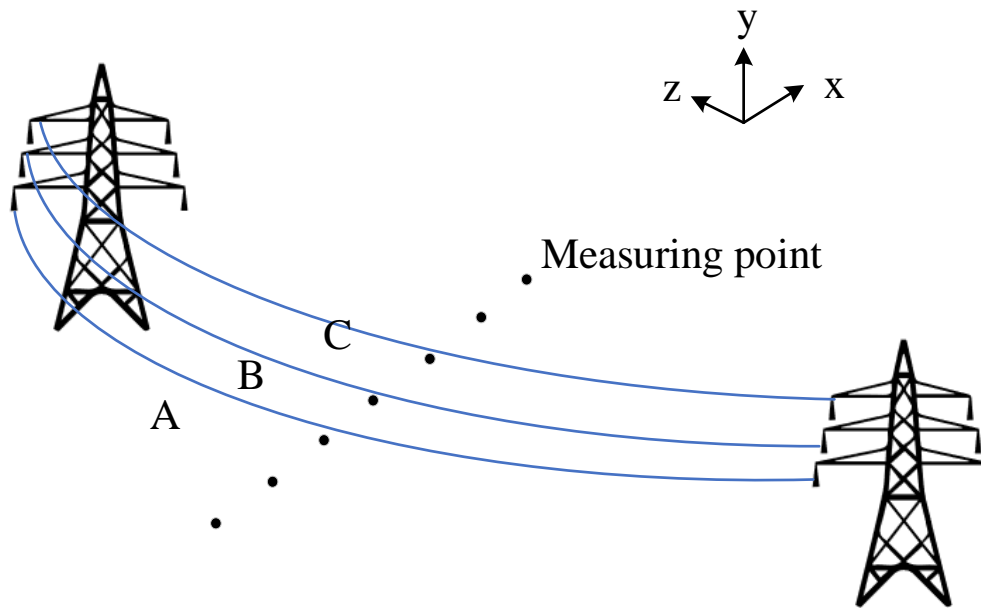


Figure.2 Three-dimensional electric field calculation model of three-phase transmission line

The $\pm 500\text{kV}$ transmission line is composed of positive and negative conductors and overhead ground wire. The pole conductor adopts $4 \times \text{ACSR-720/50}$ steel core aluminum stranded wire, and the ground wire adopts two GJ-100 type galvanized steel stranded wires. Basic data: $r=18.12 \text{ mm}$, $b=0.5\text{m}$, $S=13.7\text{m}$, $R=0.335355\text{m}$, $r'=6.5 \text{ mm}$, $S'=18.3\text{m}$, $\Delta h=9.6\text{m}$, $H=11.5\text{m}$.

In order to clarify the research objectives and facilitate the calculation, under the premise of meeting the actual requirements of the project, the following assumptions are made: the electric field distribution around the transmission line is taken as the research target, so the influence of insulators, towers and other components is neglected; the steel core aluminum stranded wire and galvanized the steel strands are equivalent to regular round conductors; the transmission conductors are long enough and are straight conductors, ignoring the sag. Through the above assumptions, the three-dimensional electrostatic field distribution problem can be transformed into a two-dimensional electrostatic field problem [8].

According to the actual material of the line, the material of the direct current transmission line is aluminum, the material of the overhead ground line is steel, and the wide area around the direct current transmission line and the overhead ground line is the air area. 500kV and -500kV node potentials are applied to the positive and negative conductor coupling surfaces, and other conditions are set according to the mentioned boundary conditions. Since the actual electric field of the transmission line belongs to the open field, and the finite element method needs to divide the field into a finite number of units, it is necessary to artificially select the boundary when the model is established, and it is considered that the electric field has attenuated to zero at the boundary. In order to simulate the actual situation as much as possible [9], the distance between the field boundary and the field source should be as large as possible, but considering the computing power of the computer, the field of this study is selected as a rectangular domain with a length of 100 m and a width of 50 m .

Using the field strength data correction model proposed in this paper, as shown in Table 1, Table 1 describes the ideal, measured and corrected field strength values of the transmission line at

different positions. It can be seen from Table 1 that the objective environment has a great influence on the true value of the ground field strength under the transmission line, which may interfere with the judgment of the staff on the circuit state, and the deviation between the data corrected by the data correction function and the true value is small. The degree of coincidence is high, which largely restores the true field strength value below the transmission line.

Table. 1 Simulation results of field strength correction model

Distance from the center line of the wire/m	Ideal value/(kv.m ⁻¹)	Measured value/(kv.m ⁻¹)	Correction value/(kv.m ⁻¹)
1	1.67	2.2	1.7
2	1.88	2.25	1.78
3	1.95	2.3	1.83
4	2.1	2.9	2.1
5	2.4	3.17	2.27
6	2.6	3.2	2.54
7	2.59	3.5	2.64
8	2.65	3.4	2.73
9	2.55	3.45	2.66
10	2.4	3.1	2.54
15	2.21	3.22	2.52
20	1.22	1.8	1.27
25	0.67	0.82	0.71
30	0.43	0.54	0.43

4. Conclusion

This paper introduces the importance of safe operation of transmission lines. Based on this problem, a field strength detection model based on field strength correction model is proposed. The model can correct the field strength information of the ground measurement points under the transmission line and analyze the line surface and the field strength in the vicinity cannot change the original wiring form, so the simplified line model using the equivalent conductor is not suitable for analyzing the field strength near the line. The nominal field strength distribution obtained by the equivalent conductor is similar with the nominal field strength distribution in the case of the actual split conductor. This method greatly reduces the amount of calculation and can obtain good results and improve the power, the safety and reliability of the system has important practical significance.

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