Electric Field Analysis of 220kV Composite Rod Insulator

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Abstract—**in the power transmission equipment, insulator is an important outer insulator part. It is used in electric insulator and machine fixedness. Composite insulator owns some advantages, such as: lighter weight, easy maintenance, etc. It is widely used in high voltage power transmission. In order to understand the insulator characters, this paper uses finite element method to analysis its electric field distribution, based on acquaint the insulator structure characteristic of 220kV composite insulator. First mathematics model of composite insulator is constituted. Then the ANSYS soft is used to calculate it. In the end, some calculated results are analyzed. Some conclusions are got. In this kind of insulator, the most uneven electric strengthen lies in two sharp ends of insulator, as same as it is easiest to appear part-discharge. This conclusion has practical instructional meaning to the usage of this insulator. The analysis method using in this paper can widely applied in more complicated condition of various insulator's electric field analysis.**

Keywords- composite Rod Insulator; analysis of electric field; finite element method

1 Introduction

Insulator is used to connect theses conduct in mechanism which own different voltage; insulate each other in electric, when they are used in power system equipment. The insulators work in outdoor; they endure some influences which come from rain, fog, snow, sunlight, pollution, corrupt electric dust and salinity in the air. Therefore the basic demands of insulator are that they own enough electric insulated strength; they can support stated mechanical load; they can endure disadvantage environment and atmosphere effect.

Composite insulator possesses some advantages, such as: lighter weight, haul difficult, dirty hard, easy maintenance, etc. It is better than porcelain or glass insulator in many aspects. So composite insulator not only can replace porcelain or glass insulator, but also can be widely used in high voltage power transmission[1,2].

The high voltage insulator's usage amount, especially the high voltage line insulator's usage amount is very big in power system. There are several ten thousand to several million insulators which are used in neoteric extra high voltage transmission line, this is necessary that guarantee these insulator can long advanced work. If insulator can't work well in long time, it will continually induce electric power outage and power line abnormal work, because of the insulator's damage and overhaul.

Obviously, the long worse work of insulator is different from the other insulated structures. It not only shortens the insulator's life, but also influences the power system's normal work. If the performance of insulator is ignored for its lower value, the immeasurable loss will happen in power system[3].

Therefore, this paper analyzes the electric field's distribution of 220kV composite rod insulator, based on its insulated structure. These analytic results will be helpful to understand this insulator's characteristic of electric field distribution, and get the location that the disruptive discharge is easiest appearance. At the same time, the insulated structure of insulator can be optimized, it will prolong its useful time.

2 The Mathematic Model of Composite Rod Insulator

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Actually the electromagnetic analytic problem calculates the Maxwell equations of given boundary conditions. The finite element analysis method is a kind of value technique that is used to approximately solve mathematical boundary value problem. The finite element method is already very famous recently; it is widely applied in engineering and math problem. It is abroad used in electromagnetism problem's analysis and calculation too[4].

This paper needs analyze the two dimension electric field of composite rod insulator using finite element method. So the mathematical analysis model is constituted firstly.

According the actual situation, it can be seen from the figure 1 that composite rod insulator is compose with core rod, parachute tray, protecting sheath, up and down gossans. Its core rod is made from glass fibre reinforced plastic. Its parachute tray, protecting sheath, etc. are made from silicone rubber. In order to avoid the flashover's occurrence along with the interface of core rod and protecting sheath, some adhesive material need be fill in them.

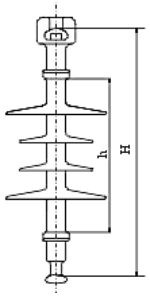


Figure 1. Construction of composite insulator

This paper analyzes 220kV composite rod insulator's electric field distribution located in core rod, parachute tray, protecting sheath, based on ignoring the influence of power line and iron tower to insulator, and considering without the equal voltage ring. Basing on above supposition, the scalar potential ϕ is used to denote the electric intensity of composite rod insulator. The equation is $E=-\nabla\phi$. The boundary value question which the ϕ meets is easily described by Maxwell's equation:

$$\begin{cases} \dfrac{\partial}{\partial x}\left(\varepsilon\dfrac{\partial\phi}{\partial x}\right)+\dfrac{\partial}{\partial y}\left(\varepsilon\dfrac{\partial\phi}{\partial y}\right)=0, & (x,y)\in G \\ \phi=U_0, & (x,y)\in \Gamma_1' \\ \phi=0, & (x,y)\in \Gamma_1'' \\ \left(\varepsilon\dfrac{\partial\phi}{\partial n}\right)^{-}=\left(\varepsilon\dfrac{\partial\phi}{\partial n}\right)^{+}, & (x,y)\in \Gamma_{in} \end{cases} \quad (1)$$

in which ε is dielectric constant of medium; Γ_1' represents the bottom of insulator which near the cable hanging, its voltage is 200kV, it is Dirichlet boundary; Γ_1'' represents the top of insulator which near the iron tower, its voltage is 0kV, it is Dirichlet boundary too.; Γ_{in} is the interfaces of different mediums.

Equation (1) becomes the extreme question of equivalent functional analysis:

$$\begin{cases} I(\phi)=\iint_G \dfrac{\varepsilon}{2}\left[\left(\dfrac{\partial\phi}{\partial x}\right)^2+\left(\dfrac{\partial\phi}{\partial y}\right)^2\right]dxdy=\min \\ u|_{\Gamma_1}=U_0 \end{cases} \quad (2)$$

After discrete process basing on dividing up and inserting value, the team of linear equations is given as follow:

$$[K][\varphi]=[F] \quad (3)$$

in which the scalar potential ϕ is finite element node, it becomes the unknown quantity, Dirichlet boundary condition is forced to load, then the ϕ on the node is solved. Finally, basis of the definition of scalar potential, the distribution of electric field strength can be figured out in the field [5,7].

3 The Calculation and Analysis of 220kV Composite Rod Insulator

Ansys software is kind of large-scale and universal CAE software; it blends mechanics, calorific, electromagnetism, etc. It owns many functions and applied tools, such as geometry modeling, automatic dividing mesh, solving, post disposal, optimization design, etc. In this paper, the two-dimensional modeling analysis of the Ansys software is applied to analyses the electric field of 220kV composite rod insulator.

3.1 Modeling

The 220kV composite rod insulator is composed with core rod, parachute tray, protecting sheath, up and down gossans etc. Its structure height is 1800mm. The diameter of parachute tray is 150mm. The diameter of protecting sheath is 100mm. The diameter of core rod is 16mm. Considering there is air around the insulator, the outside air's size is designed as 7200mm length and 750mm width at building the model. According to the very strict symmetrical feature of composite insulator, the half model of corresponding

structure is built. They are shown in Figure 2, Figure 3, and Figure 4. Figure 2 is the single insulator model. Figure 3 is the insulator string model which was composed of the single insulator. Figure 4 is an analysis model after considered the insulator string surrounding air.

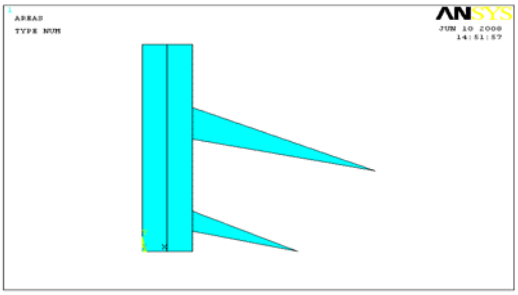


Figure 2. Model of single composite insulator

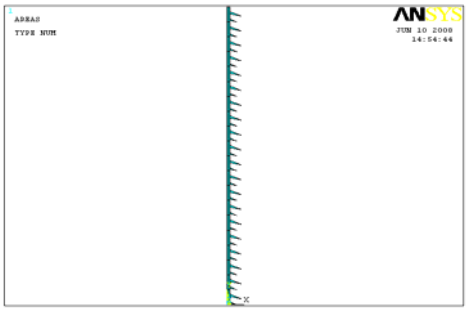


Figure 3. Model of composite insulator series

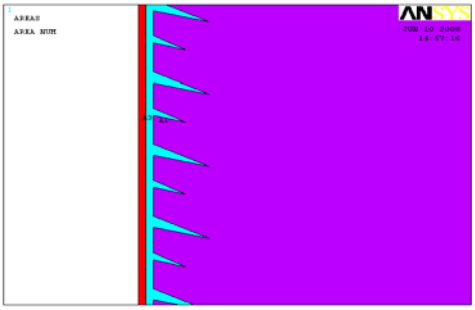


Figure 4. Local model of composite insulator series include air

After the insulator's model building, it is necessary to set up the material attribute of insulator. The core rod is made from glass fibre reinforced plastic, its relative dielectric constant equals 5. The parachute tray and protecting sheath are made from silicone rubber, their relative dielectric constant equal 2.5. Air's relative dielectric constant equals 1.

3.2 Dividing Mesh

In allusion to two-dimensional model which has been established, the triangle element is used to divide mesh automatically. At the same time, the tine horn of parachute tray needs mesh refinement process, in order to improve the calculation accuracy. The finite element mesh of two-dimensional local model is given in Figure 5. The total number of nodes is 9691. The total number of elements is 4730.

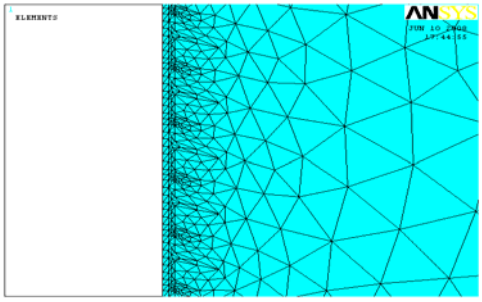


Figure 5. Local meshing graphics of composite insulator series model

3.3 Loading and Solving

In order to use FEM to analyze the composite insulator's electric field distribution, the corresponding load is set at its structure. Firstly the Dirichlet boundary condition is set. The under bottom edge of insulator model connects with cable, it is loaded 220kV potential. The top bottom edge of insulator model connects with iron tower, it is loaded ground potential. Secondly the Neumann boundary meets automatically, it doesn't need to set. At last, the symmetry order is used to set symmetry boundary at model. After completed all of setting, the default wave front method is used to solve.

3.4 Post Disposal

These commands, including PLNSOL, PLVECT, *GRET etc, which belong to the function of post disposal, are applied to get the corresponding graphics and data of selected region. It can be used to analyses.

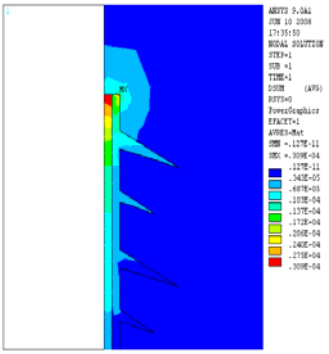
3.5 Calculation Results and Analysis

The stronger electric strength easily induces the appearance of local discharge. 220kV composite rod insulator's electric field distribution is shown in Figure 6 and Figure 7. It includes cloud picture and **vector picture** of 220kV composite rod insulator. According to the results, the maximum electric strength locates in two tine horn of insulator, and the electric field strength distribution of

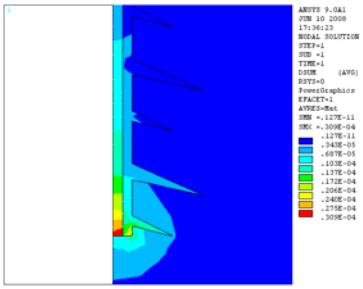
insulator is very uneven.

Applied the data show approach in post disposal, some calculations of insulator can be gotten: the strongest electric field intensity in X direction is located at node 10, 13, 229~281, it is 1.50V/m; the strongest electric field intensity in Y direction is located at node 13, 15, 285-295, it is 3.60V/m; and the synthetically strongest electric field intensity is located at node 13, 15, 285-295, it is 3.09V/m.

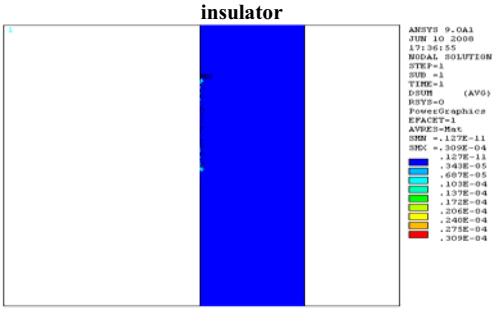
According to these results, the most uneven electric field strength distribution lies on two tine horn of insulator. At the same time, this place is easiest appear local discharge too. In the actual utilization, it should be emphatically done that monitor this part of insulations, and strengthen this part of insulation design.



（1） Electric strength cloud picture in the top of composite insulator

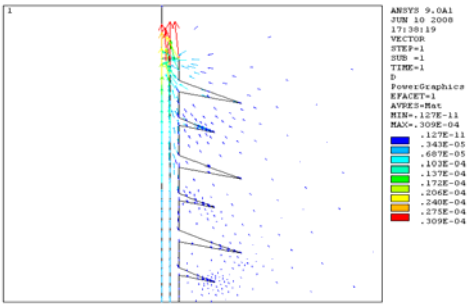


（2） Electric strength cloud picture in the bottom of composite insulator

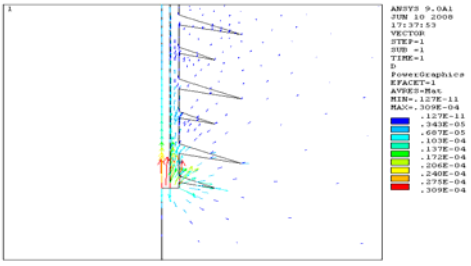


（3） Electric strength cloud picture of composite insulator series

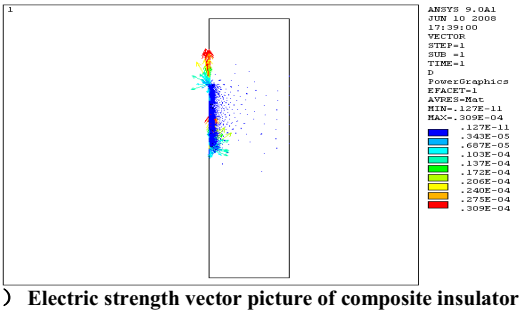
Figure 6. Cloud picture of 220kV composite rod insulator



（1） Electric strength vector picture in the top of composite insulator



（2） Electric strength vector picture in the bottom of composite insulator



（3） Electric strength vector picture of composite insulator series

Figure 7. Vector picture of 220kV composite rod insulator

4 Conclusions

Since many years, it is our country's basic state policies that developed the electric power industry. Composite insulator is an important parts of strong electricity transmission. Therefore the research composite insulator is very necessary, and has very good future.

The ANSYS software is employed to analyze the electric field distribution of 220kV composite rod insulator in this paper. The intuitional result can be obtained through FEM modeling and analysis. The electric field distribution can be clear understood through viewable pictures. It provides theory foundation for insulator’s insulation design and optimization.

In this paper, the maximum electric intensity and its

position of insulator are given, and the distribution of electric intensity is analyzed. The most uneven electric field strength distribution lies on two tine horn of insulator. This place is easiest appear local discharge too. At the same time, the kind of insulator's insulation is safe, because the electric intensity of insulation is less than its breakdown strength accordingly.

The research work of this paper owns engineering value to design the insulation structure of 220kV composite rod insulator. The analysis method can be used in the similar calculation.

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