Scientific Journal Impact Factor (SJIF) : 3.518
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

Electric Field Computation of High Voltage Porcelain Insulator

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Abstract—Paper presents results of electric field computation of high voltage porcelain insulator used in gas circuit breaker. Simulations of the said insulator were carried in axisymmetric domain in software based on finite element method. Voltage and electric field curves were observed for clean and dry condition as well as wet condition.

Keywords—Finite Element Method (FEM), Gas Circuit Breaker (GCB),Sulfur Hexafluoride(SF_6)

I. INTRODUCTION

Electric field computation of high voltage insulator is necessary at design stage in order to check its behavior in different environments. Various numerical techniques are available to compute electric field like charge simulation method (CSM), boundary element method (BEM), finite element method (FEM) etc. Among the said methods, FEM based software was used to carry out simulation of the high voltage insulator. Finite element method converts the complex problem to a problem which is discretized into small elements [1]-[2]. For two dimensional problems, region is generally divided into triangular elements. Insulator geometry was first drafted in CAD based software and then imported to the FEM software.

II. HIGH VOLTAGE INSULATOR

Simulated insulator is used as hollow chamber for interrupter unit in high voltage gas circuit breaker (GCB). Insulator geometry was first drafted in CAD based software and then imported to the FEM software. Electric current module was used for carrying out the simulation which takes relative permittivity and conductivity of material into account. Figure 1 shows section of interrupter unit out of which only one part is simulated for the work presented. All results were calculated for the creepage distance which is sum of shortest distance measured along insulator surface between the energized parts.

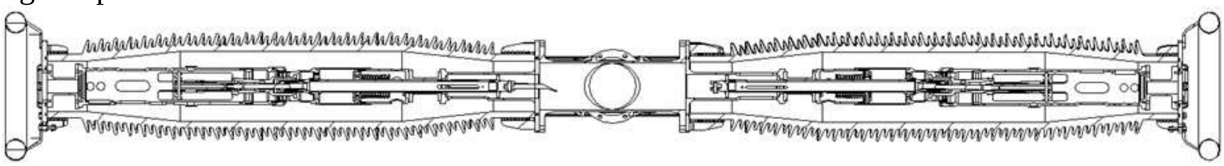


Figure 1 Section of high voltage gas interrupter

As the geometry was essentially rotationally symmetric in nature, two dimensional axisymmetric simulations were carried out which require less computation time and memory requirement. Finite element method by its name implies that problem region should be in finite domain hence to simulate the problem region in real time, periodic boundary condition was employed to transform unbounded problem region into bounded one [3]. Figure 2 shows two dimensional axisymmetric model of the insulator. Voltage was applied to top flange whereas bottom flange was kept at ground potential. All results of electric field were then generalized for the impulse voltage which exerts high stress on the insulators. Region encompassing the creepage distance of insulator was super meshed which guarantees very accurate results of electric field along insulator outer periphery. Typical values of permittivity and conductivity of the materials used in the simulation are listed in Table 1.

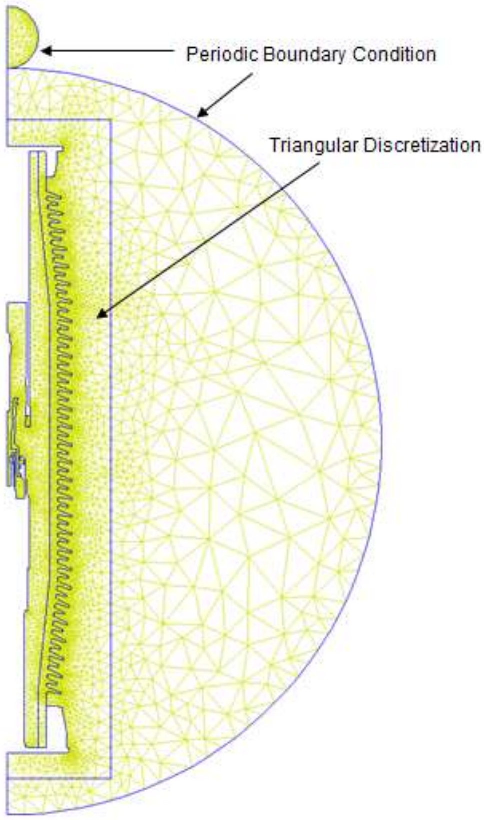


Figure 2 Axisymmetric model of high voltage insulator

Table 1 Simulation Parameters

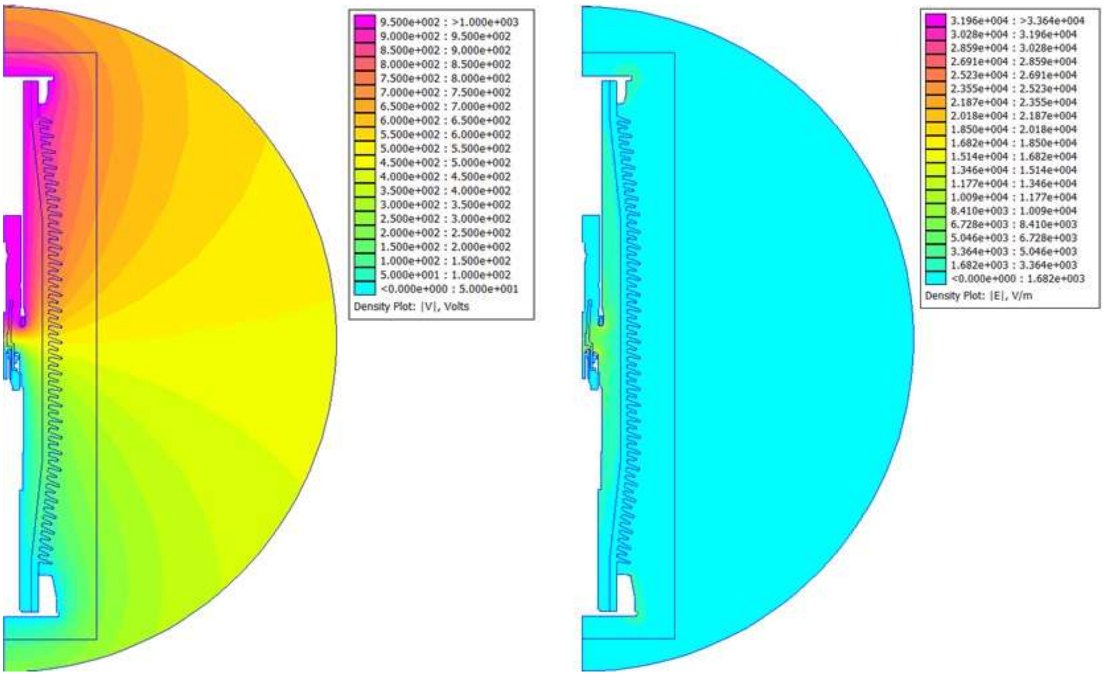
	Conductivity	Dielectric constant	Potential
Aluminium HV Terminal	Yes	-	High Voltage
Aluminium LV Terminal	Yes	-	Ground
Porcelain Insulation	No	6	-
SF_6 Gas	No	1.01	-
Nozzle	No	2.15	-
Moisture Film	Yes	80	-
Corona Ring	Yes	-	High Voltage

III. RESULTS AND DISCUSSION

Electric field for the high voltage insulator was computed for dry insulator surface as well as wet insulator surface. For wet insulator surface simulations, thin conductive film of moisture was modeled over entire insulator surface. All results of voltage and electric field were computed for the creepage distance of the insulator. For all graphs presented, creepage distance is represented in per unit form.

3.1. Density Plots of Voltage and Electric Field

Figure 3 shows post processing density plots of voltage and electric field for the high voltage insulator in clean and dry condition. As seen from electric field density plot, electric stress is more at the sheds adjacent to the contact gap.



(a) *(b)*

Figure 3 (a) Voltage density plot (b) Electric field density plot

3.2. Voltage Curve along creepage distance of high voltage insulator

Figure 4 shows voltage curves along the creepage distance of the insulator in clean and wet insulator surface condition. It is seen from the curve that conductivity tends to smooth the voltage curve. For sufficiently higher value of conductivity, curve becomes linear that that for clean condition.

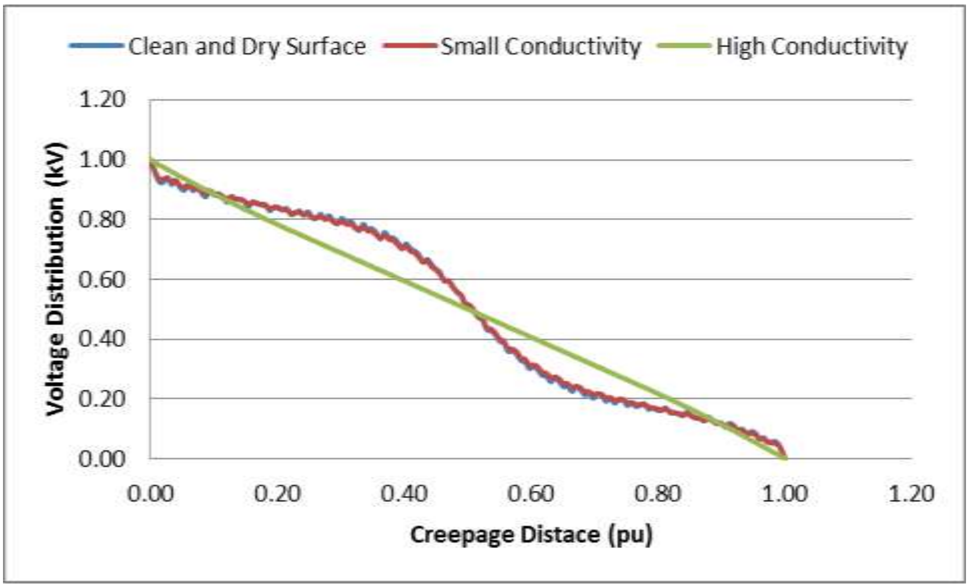


Figure 4 Voltage curve for different environments

3.3. Electric Field Curve along creepage distance of high voltage insulator

Figure 5 shows electric field curves along creepage distance of the insulator in different environmental conditions. Maximum value of 1.78 kV/mm is attained in case of clean and dry insulator surface condition near the energized flange of the insulator. In addition to that, sheds which are beside gap opening experience high stress due to crowding of equipotential lines in the contact gap.

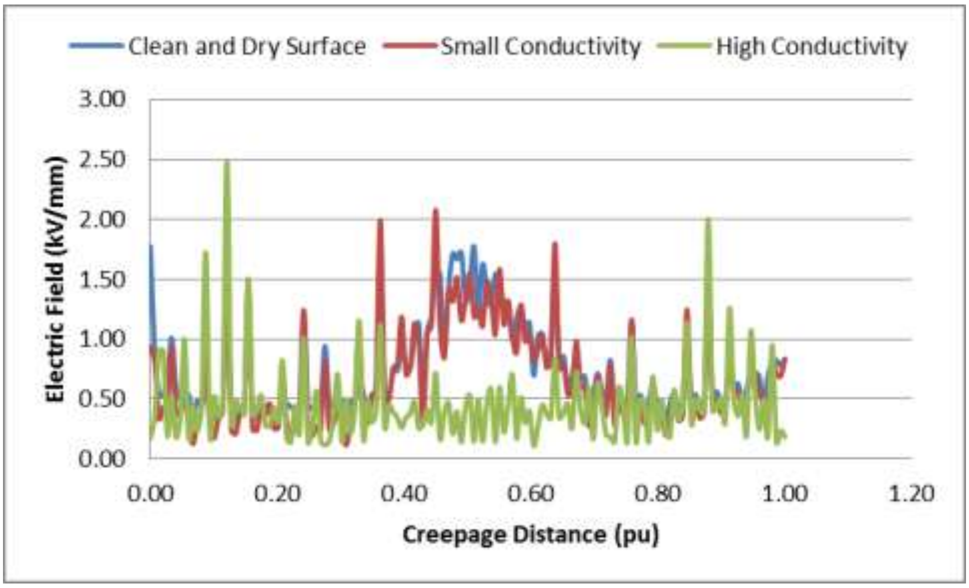


Figure 4 Electric Field curve for different environments

For small conductive wet surface, electric field attains maximum value of 2.08 kV/mm whereas for high conductive surface, it attains 2.49 kV/mm. It is noticed from the high conductive curve that electric field values for sheds adjacent to contact gap are less than that for the rest of the creepage distance. This is due to the relaxation of equipotential lines along resistive moisture layer.

IV. CONCLUSIONS

Electric field was computed for high voltage insulator for dry as well as wet insulator surface condition. From voltage curve, it was seen that conductive layer of moisture over insulator surface results in linearizing voltage distribution. Also maximum value of electric field increases with increase in conductivity of the moisture layer.

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