Modeling of High Voltage Insulator Strings through Finite Element Method

Zubair Ali*, Mohsin Ali Tunio, Suhail Khokhar***, Nadeem Ahmed Tunio** and Muhsan Ali Mari ****

*(i) Master of Engineering Student, Department of Electrical Power Engineering, Mehran University of Engineering and Technology Shaheed Zulfiqar Ali Bhutto Campus Khairpur Mir's, Sindh, Pakistan.
(ii) Lecturer, Vocational Training Centre Khairpur, Sukkur IBA University.
** Department of Electrical Engineering, Mehran University of Engineering and Technology Shaheed Zulfiqar Ali Bhutto Campus Khairpur Mir's, Sindh, Pakistan.
*** Department of Electrical Engineering, Quaid-e-Awam University of Enigneering, Science and Technology Nawabshah, Sindh, Pakistan.

Abstract
The computation of electric potential distribution across suspension insulator strings used for high voltage overhead transmission lines is very important from design perspectives. The voltage distribution along insulator string is not uniform that is responsible for deterioration, corona discharge and flashover. In this paper different discs of insulator strings were modeled and simulated through finite element method. The potential field distribution of suspension insulators were investigated and compared for different materials like porcelain, glass and composite (porcelain and glass).

Key words:
Insulator String, Electric Potential Distribution, COMSOL Multiphysics, Solid Dielectric Material.

1. Introduction

The insulators used in over head electrical power transmission lines for suspension of over head conductors, perform significant role in the transmission of power. They are used to provide support to the conductors and to provide electrical isolation between live conductors and supporting tower to ground. Moreover, porcelain, Glass and composite insulators have been used as insulators since many years [1].

Suspension type insulators are generally used for high tension transmission lines and always under high electrical and mechanical stresses. Nevertheless, due to stray capacitance existing between the discs and conductors around them, the electric potential distribution is greatly uneven across string [2]. The potential field nearer to the live conductor disc is greater than others discs in string, which may be the possible cause of corona discharge, insulator deterioration and flashovers. Therefore, the calculation of potential field and electric field distribution is a very important for reliable system.

In order to avoid unwanted breakdown due to failure of insulator in a string, the knowledge of potential field distribution and electric field within the suspension string is of paramount significance for the design engineer [3], [4]. In past literature, various numerical methods are presented such as Boundary Element Method (BEM), Charge Simulation Method (CSM), Finite Difference Method (FDM) and Finite Element Method in order to calculate electric potential in solid dielectrics [5]. In this present work, the model of insulator string is developed using FEM. The potential distribution is analyzed under different conditions.

2. Insulator String Model

Figure 1 shows actual insulator disc model [5]. The nominal parameters of this insulator are given in Table 1.

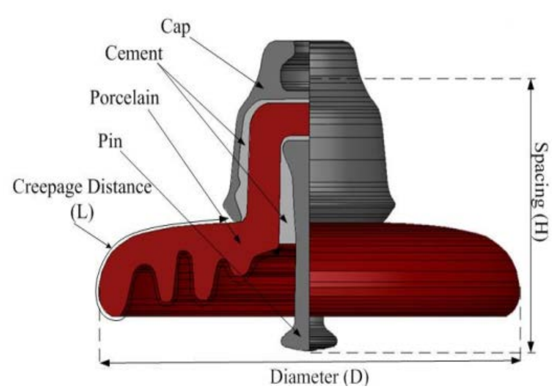

Fig. 1 Dimension parameters and material

suspension type insulator [5].

Manuscript received August 5, 2018
Manuscript revised August 20, 2018

Table 1: Nominal Parameters of the insulator [5].

Material	H (mm)	D (mm)	L (mm)	F min (kN)
Porcelain	146	255	295	120

Figure 2 shows the developed 2-D axial symmetry insulator model geometry using finite element analysis. The dimensions of developed model are based on actual model as shown in Figure 1. The insulation material used in developed model is given in Table 2.

Figure 3 shows the defined boundary conditions of a developed model. Referring to Figure 3, an AC voltage at power frequency is applied to the pin of a disc (attached to conductor) whereas cap of the last disc in a string is grounded. After completing the steps; model structure, defining material properties and the boundary conditions, then the developed model was meshed as shown in Figure 4. The potential field distribution is calculated through solving differential equation given in equation (1).

$$-\nabla \cdot \frac{\partial(\varepsilon o \cdot \varepsilon r \cdot \nabla r)}{\partial t} - \nabla . = Qj \qquad (1)$$

Where,

Je= external current density (A/m2)
Qj= current source (A/m3)
σ = electric conductivity (S/m)
ε = permittivity

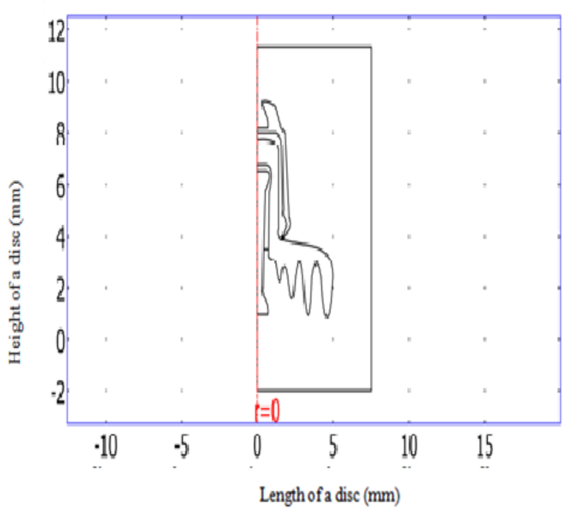

Fig. 2 Developed 2-D axial symmetry insulator.

Table 2: Technical Parameters of the simulated insulators.

No.	Material	Relative Permittivity	Electric Conductivity(S/m)
1	Porcelain	6	2×10-13
2	Glass	4.2	1×10-14
3	Cement	14	1×10-13
4	High Steel Alloy	01	4.03×106
5	Air	01	0

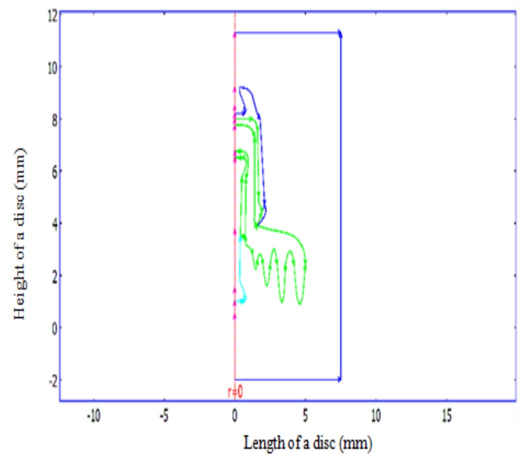

Fig. 3 Setting boundary conditions for the disc.

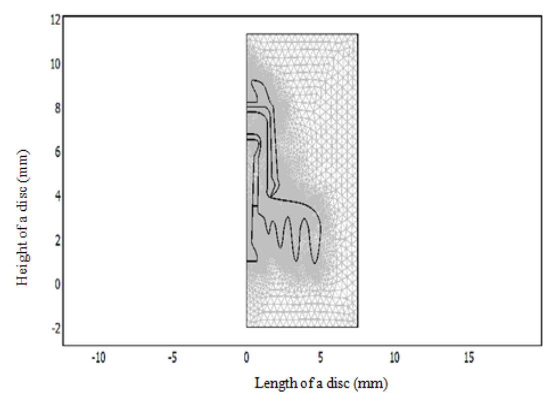

Fig. 4 Meshing of a developed model disc.

3. Results and Discussions

The simulations results that have been obtained are presented in this section. The electric potential of suspension type insulators strings were simulated with different materials such as porcelain, glass and composite (porcelain and glass) insulators. The model was also investigated under number of discs and electric potentials.

3.1. Potential field distribution across single disc:

Figure 5 shows electric potential distribution in a single disc with different materials at 11kV. The discs were simulated at a time t= 0.005. Referring to figure 5, differences in potential distribution can be seen through contour lines.

Figure 6 shows the electric potential field distribution through graph for the materials porcelain, glass and composite. It was observed from the graph that the potential decreases as distance from a point of applied potential increases.

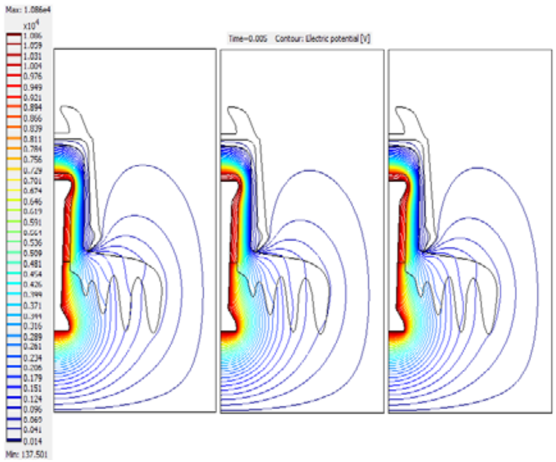

Fig. 5 Potential field distribution across single disc (a) Porcelain (b) Glass and (c) composite.

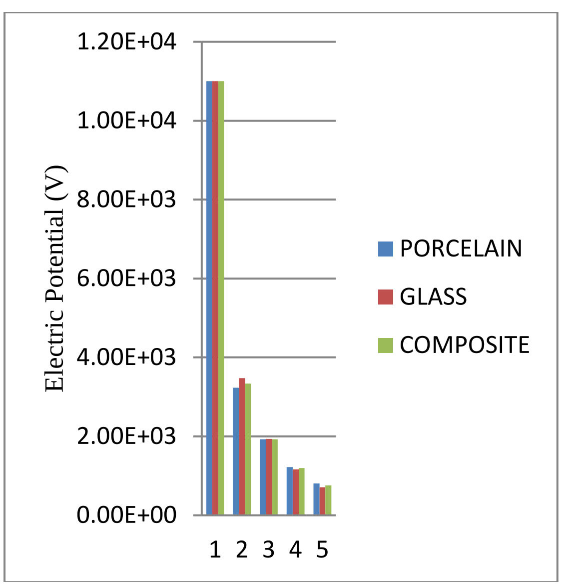

Fig. 6 Variation of potential at a single disc.

3.2. Potential Distribution across 3 discs:

Figure 7 shows electric potential distribution across insulator string having three discs under various materials at 33kV. The discs were also simulated at a time t= 0.005. Referring to figure 7, differences in potential distribution can be seen through contour lines.

Figure 8 shows the electric potential field distribution through graph for the materials porcelain, glass and composite. It was also observed from the graph that the potential is found higher at each pin of a disc in a string and it was also found that potential decreases as distance from the pin was increased.

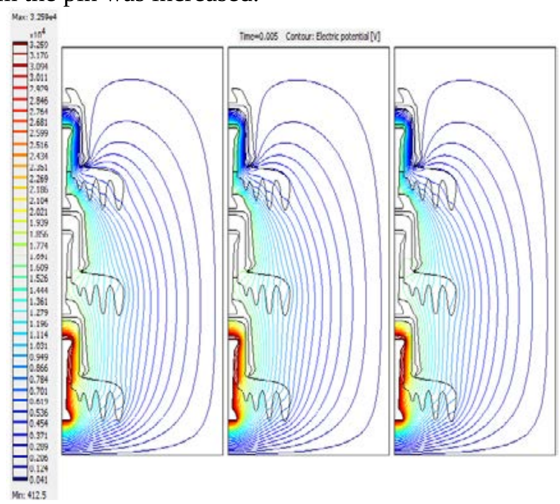

Fig. 7 Potential field distribution across three disc (a) Porcelain (b) Glass and (c) composite.

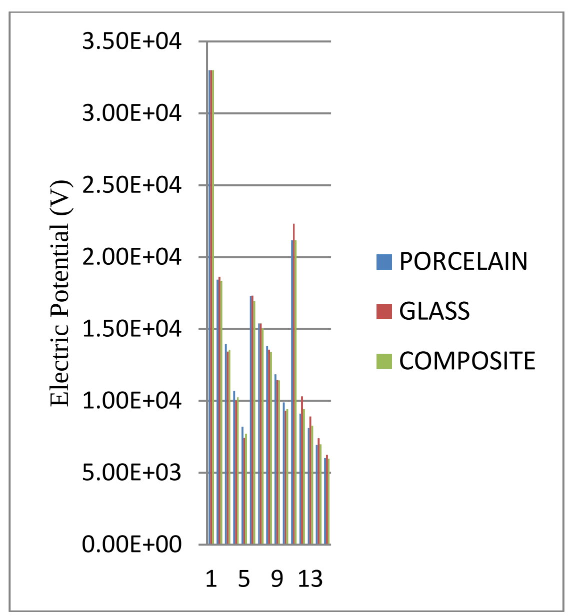

Fig. 8 Potential field distribution across three disc string at 33kV.

3.3. Potential field distribution across 7 discs string at 132kV:

Figure 9 shows electric potential distribution across insulator string having seven discs under various materials at 132kV. The discs were also simulated at a time t= 0.005. Referring to figure 9, differences in potential distribution can be seen through contour lines.

Figure 10 shows the electric potential field distribution through graph for the materials porcelain, glass and composite. It was observed from the graph that the value potential is found higher and equal at the pin (near to the conductor) for porcelain, glass and composite insulating materials where as it electric potential at each pin of a disc in a string. Form the simulation result it has been observed that the potential decreases as the distance increases form pin the each disc moreover the value of electric potential for glass insulator string is found lower compare to porcelain and composite. It has been observed from simulation results that string made of glass insulating material is per favorable under high voltages.

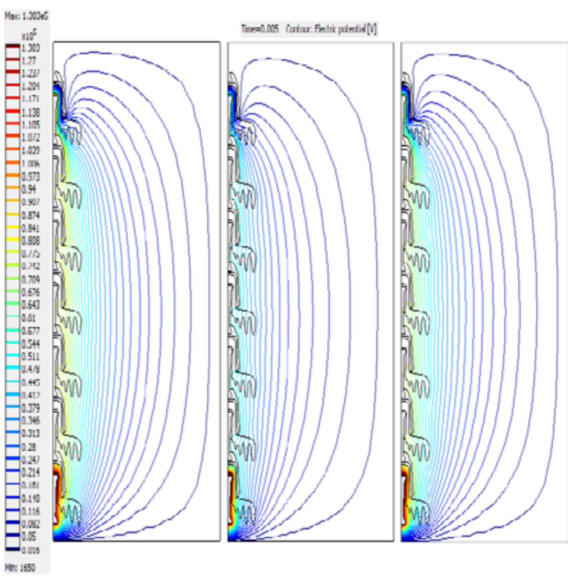

Fig. 9 Potential field distribution across 7 discs (a) Porcelain (b) Glass and (c) composite.

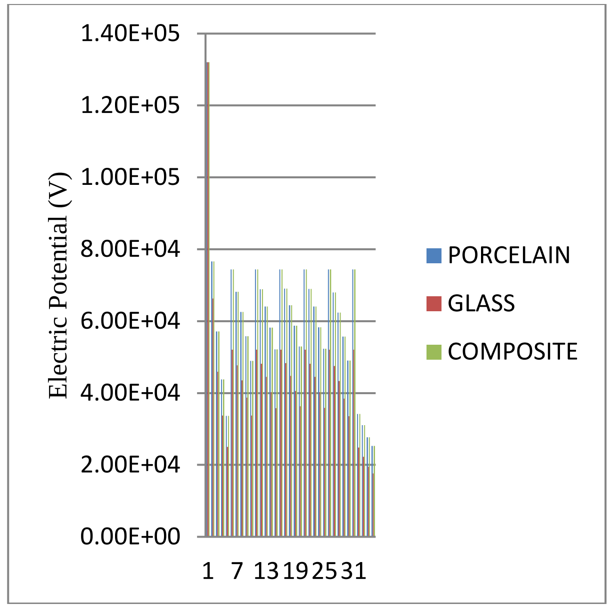

Fig. 10 Potential field distribution across seven discs string at 132kV.

4. Conclusion

In this work insulator string was successfully modeled using COMSOL Multiphysics software. The developed model was analysed under different stress conditions. From simulation results, it was found that the electric potential distribution across string was non linear and varies from disc to disc and the disc nearer to conductor has higher stress than other discs connected to same string. The insulator string model was also examined under different materials. Three types of discs Porcelain, Glass and Composite (porcelain and glass) were investigated. Referring to simulation results, porcelain, glass and composite insulator string have different Potential distribution due to permittivity of the insulating material. Nevertheless, It was concluded from insulator strings with single, three and seven discs model that the porcelain, composite and glass material is found reasonable for single disc, three and seven discs respectively.

References

[1] Gouda, O. E. and A. El Dein (2015),“Simulation of Overhead Transmission Line Insulators (porcelain and composite types) under Desert Environments”, 16th International Middle- East Power Systems Conference - MEPCON'2014 Ain Shams University, Cairo, Egypt, December 23 - 25, 2014.

[2] Mehdi Ashouri, Mohammad Mirzaie & Ahmad Gholami, “Calculation of Voltage Distribution along Porcelain Suspension Insulators Based on Finite Element Method”, Electric Power Components and Systems, 38:7, 820-831, May-2010

[3] C.L. Wadhwa, Electrical Power System, 2005

[4] V.T. Kontargyri, I.F. Gonos, I.A. Stathopulos, A.M. Michaelides, "Measurement and verification of the voltage distribution on high-voltage insulators", Proceedings of the 12th Biennial IEEE Conference on Electromagnetic Field Computation (CEFC 2006), Maimi, FL, April, 2006

[5] Mohammad Bagher Asadpoor, Mohammad Mirzaie, "Simulation and measurement of the voltage distribution on high voltage suspension Porcelain insulator string under pollution condition." Int. Journal of Applied Sciences and Engineering Research, Vol. 1, No. 2, 2012

[6] Subba Reddy B, Satish Naik B, "Simulation of Potential and Electric Field Across Faulty Ceramic Disc Insulator String", TECHNIA –International Journal of Computing Science and Communication Technologies, Vol.5 N0.2, Jan-2013.

[7] V.T. Kontargyri, L.N. Plati, I.F. Gonos, I.A. Stathopulos, "Measurement and Simulation the voltage distribution and the electric field on a glass Insulator string", School of Electrical and Computer Engineering, Electric Power Department, High Voltage Laboratory, July 24, 2007

[8] S. Reddy, N. A. Sultan, P. M. Monika, B. Pooja, O. Salma and K. V. Ravishankar, "Simulation of potential and electric field for high voltage ceramic disc insulators", International Conference on Industrial and Information Systems (ICIIS) 2010, Indian Institute of Science, Bangalore, India, pp. 526 – 531

[9] E. Akbari, M. Mirzaie, A. Rahimnejad and M.B. Asadpoor, "Finite Element Analysis of Disc Insulator Type and Corona Ring Effect on Electric Field Distribution over 230-kV Insulator Strings", International Journal of Engineering and Technology, 1 (4) (2012) 407-419.