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Electric Potential along Polymeric-insulators using FE Method

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Abstract. Insulator is an important component in electrical power system such as sub stations and power transmission. Silicone rubber (Sr) is an alternative material to porcelain material & glass insulating materials regarding to high voltage (hv) power insulators and Sr has been used mostly by power utilities since 1970 because of their better performances. The objective of paper is to perform simulation work on the electric potential over Sr insulator by use of a tool in MATLAB. Failure of hv insulator sometimes involves the interface of water, solid & air insulation. As result, the potential and field distribution around hv insulators is important to determine the stress occurring on the surface of insulator. Therefore, we would analyze the potential distribution of Sr - hv insulator and the water droplets effect on the surface of Sr insulator. The electric potential distribution is obtained using FE (Finite Element) method. The result from this paper shows that the water drops existence would have an effect on electric potential distribution. Also results from simulation shown that the potential distribution is uniform for alternate shed insulator compared to straight insulator.

Keywords: Electric field distribution, Electric potential, FE method, Silicone rubber insulator, Simulation, Water droplet.

1. Introduction

Non-ceramic insulators have been used in an increasing number in overhead transmission line applications, provide great characteristics over ceramic insulators such as porcelain & glass type of insulators: they have got better overall performance by their hydrophobicity, mild weight, high impact strength and so on. These Non-ceramic insulators are completely different from ceramic insulators such as porcelain & glass type insulators.

Numerical methods were identified as accurate techniques of field calculation in order to make them useful resource in design of non-ceramic insulator. There are some techniques for acquiring solution of equations like Laplace & Poisson equations. Fda (Finite difference approach), Fea(Finite element approach), Bea (Boundary element approach) and Csa (Charge simulation approach) were widely used techniques. In comparison to other methods, the Fea takes into consideration for the result region‘s non-homogeneity. Also, generality of the approach makes it to use for a huge range of problems.

2. Simulation Method

Finite element method (FEM) or Fea, is a product of the digital age, coming to the force with the advent of digital computers in the 1950s. It follows on from matrix methods and finite difference methods of analysis, which had been developed and used long before this time. It is a computer-based analysis tool for simulating and analysing engineering products and systems. FEA is an extremely potent engineering design utility, but one that should be used with great care. For example, it is possible to integrate a system with computer-aided design software, leading to a type of uninformed push-button analysis in the design process.

Finite element computer programs have become common tools in the hands of design engineers. Unfortunately, many engineers who lack the proper training or understanding of the underlying concepts have been using these tools.

The basic concept include dividing the domain under study into a finite wide variety of pieces referred to as elements in which the differential equations are solved. By assembling all equations, the behaviour of whole problem domain can be obtained.

In other phrases, using the FE method, the domain is divided into regions of smaller size called elements, and the answer is acquired in phrases of discrete values of variable φ (e.g. stress in all directions of x, y & z) at all nodes. The degree of freedom is known as number of unknown variables at a node. For example, the domain below created from triangular elements as shown in Fig. 1. In this there is one degree of freedom used for each node.

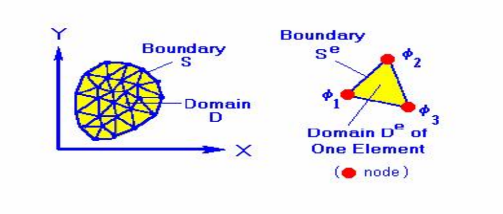


Fig. 1. Typical subdivisions of domain

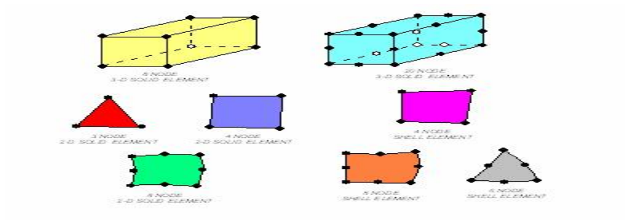


Fig. 2. A variety of finite elements.

Each and every region is known as an element & discretization means sub dividing a entire domain into a number of elements. All elements are connected at nodes, and the process of assembly requires continuous solution along adjacent element's common boundaries.

2.1. Steps in FE method

FE method is composed by successive steps. The steps are

1) Discritization into the element

The given domain is divided into an equivalent system of finite elements, by a process known as Discritization. The equivalent system may consist of triangular or quadrilateral and/or tetrahedron or hexahedron based on whether the problem is solved as in 2-D or 3-D plane.

2) Derivation of the element stiffens matrix

The stiffness matrix consists of the co-efficient of the equilibrium equations derived from the material and properties of an element and obtained by the use of minimum potential. The stiffness relates the potentials at the nodal points to the applied voltage at the boundary.

3) Assembling

This process includes the assemblage of the overall or global stiffness matrix for the entire body from the individual element stiffness matrices. The most common assemblage technique used is called as the direct stiffness matrix.

4) Solution for the unknowns

In a number of types of performed analysis the solution procedure is straight forward & linear. However, in problems in which the conditions of boundary vary with time the user must define the history of loading and solution control parameters.

2.2 Elemental Types:

The various forms of elements in 1, 2 & 3-dimensions are documented. It is up to the consumer to pick simplest elements which are taken for the problem, but also the wide variety of factors required to solution approximation. Engineering judgment is required. In standard, it is a geometric shape bounded with nodes connected by using lines. Some elements are illustrated in Fig. 2.

3. Silicone Rubber Insulator

Compared to other insulators polymeric insulators offer more advantages. They have 1) Light weight 2) High mechanical strength 3) Good performance 4) Less maintenance work 5) Better stability property 6) suitability in heavy contamination areas & 6) Especially anti-pollution performance.

Sr Insulator's Structure is shown in Fig. 3. The Sr insulator design is as follows; fiber reinforced plastic core is used as the load bearing structure. The presence of dust and moisture causes local discharges & deterioration of material. In order to protect core from ultraviolet, acid, ozone etc., sheds are provided over the core. Sr material is used as material for housing of polymer insulators.

To observe the effect of water along Sr insulator surface, drops are used as shown in Fig. 5. A core having relative dielectric constant $€_r$ of 7.1, attached with metal end fittings, is used as the load bearing structure. Sheds made of Sr material having $€_r$ of 4.3 are used outside the core. Surrounding of the insulator is air having $€_r$ = 1.0. A 15 kV voltage source directly applies to the lower end while the upper end of insulator is connected to ground.

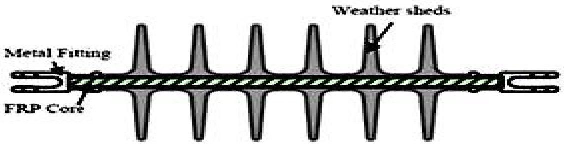


Fig. 3. Sr Insulator structure

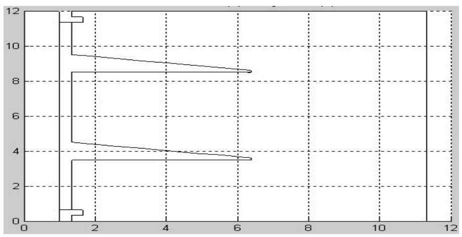
4. Simulation Results

In this paper, simulation was done using FE method under clean & water drops over the insulator. The 2D view of Sr insulator under clean and water drops conditions for FE method are shown in Fig. 4 and Fig. 5. Comparison of Fig. 6 and 7shows that the water drops have effect on potential distribution over the insulator.

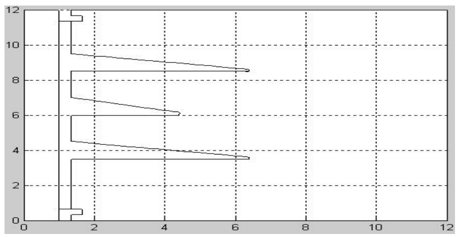
For straight shed insulator, water effect is simulated by using water drops as in Fig. 5.c. The simulation result is illustrated in Fig. 7.c. As per the results, presence of water drops created potential enhancement at the interface of the water, air and Sr material.

For alternate shed insulator, water effect is simulated by using water drops as in Fig. 5.d. The simulation result is illustrated in Fig. 7.d. As per the results, presence of water drops created potential enhancement at the interface of the water, air and Sr material.

The result represented in Fig. 8 shows linear potential distribution along surface of the alternate shed specimen compare to straight shed specimen under clean condition. The result represented in Fig. 9 shows linear potential distribution along surface of the alternate shed specimen compare to straight shed specimen under water drops condition.

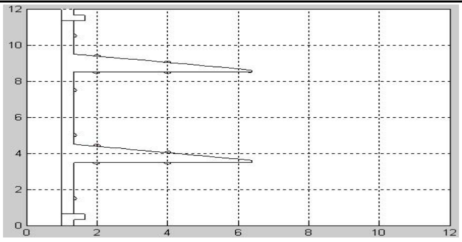
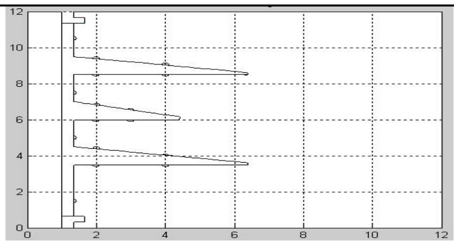


a) Straight Shed Insulator with clean surface



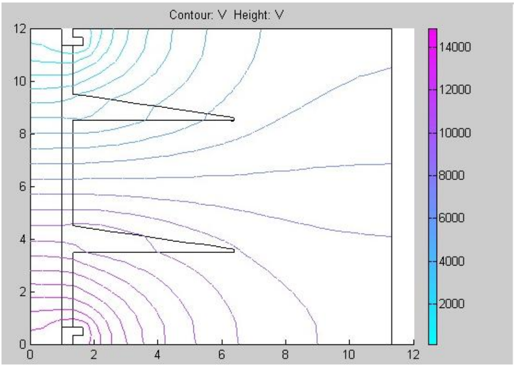
b) Alternate Shed Insulator with clean surface

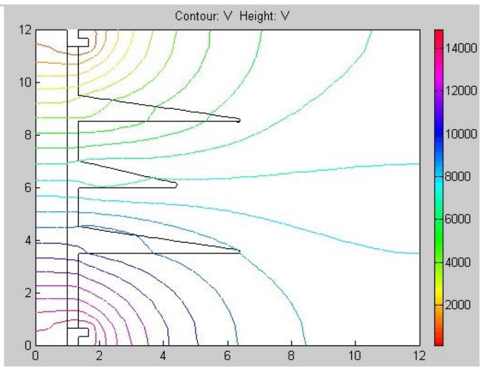
Fig. 4. 2D of Sr insulator under clean condition for FE method

c) Straight Shed Insulator with water drops d) Alternate Shed Insulator with water drops

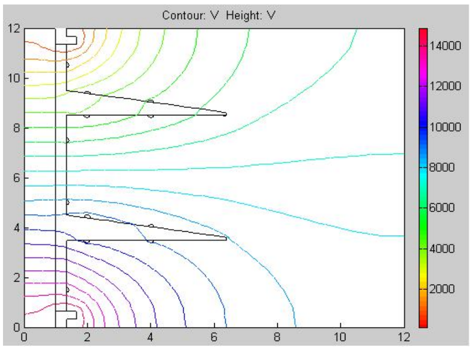
Fig. 5. 2D of Sr insulator with water drops on its surface for FE method

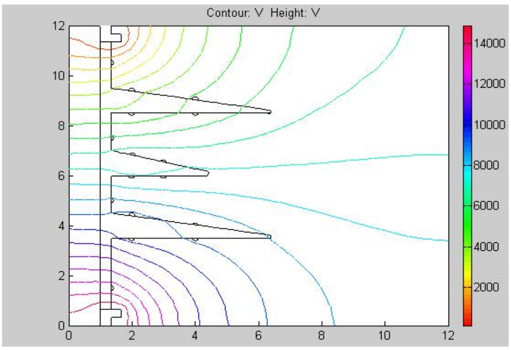




a) Straight Shed Insulator b) Alternate Shed Insulator

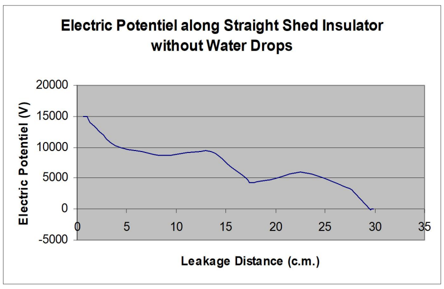
Fig. 6. Electric Potential Distribution under clean condition.

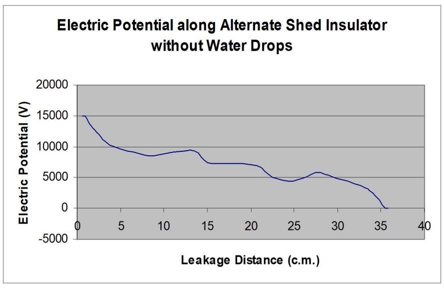




c) Straight Shed Insulator d) Alternate Shed Insulator

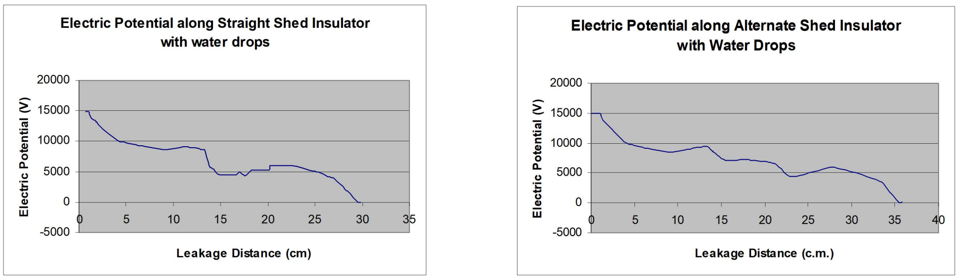
Fig. 7. Electric Potential Distribution with water drops.





a) Straight Shed Insulator b) Alternate Shed Insulator

Fig. 8. Electric Potential along insulator without water drops.



c) Straight Shed Insulator d) Alternate Shed Insulator

Fig. 9. Electric Potential along insulator with water drops.

5. Conclusion

In this paper, electric potential distribution on Sr insulator surface with and without water droplets were investigated by FEM. As per the results, presence of drops created potential enhancement at the interface of the water droplet, air and Sr insulating material. Also, water drops on Sr insulator caused higher electric potential on the trunk portion surface than shed portion surface. Under clean & water drops conditions, higher electric potential distributions are obtained for the straight shed insulator comparing with the alternate shed insulator. So alternate shed insulators are to be used compared to straight shed insulators under contamination condition.

6. References

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