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Modelling & Analysis of Silicone Rubber Based Composite Insulators for HV Application

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Abstract - *The main objective of this work is to study distribution of Electric field on the surface of insulators. A geometric model of insulator was designed and studied using the finite element method as implemented in COMSOL Multiphysics. One of the reasons of insulator failure is the deposition of pollutants on the insulators which start conducting during foggy weather conditions resulting in flashover and interruption of power. Amongst the non-ceramic insulators, silicone rubber insulator is better equipped to deal with flashover problems due to its unique hydrophobicity property. Because of these properties it is gaining popularity worldwide and replacing the conventional ceramic and glass insulators in power transmission all over the world. Silicone rubber insulators have many advantages over the ceramic and glass insulators such as good performance in contaminated environment, easy handling, maintenance free, light weight, high strength to weight ratio, high impact resistance etc. So, By adding Nano filler materials (Alumina) in silicon rubber insulator above properties can be more improved. We have modelled silicon rubber insulator of proper dimensions in COMSOL Multiphysics during work and also plotted electric field lines on the surface using the same. We have achieved better field distribution and conclude that chances of Flashover and Puncture of insulator is reduced.*

***Key Words*: Insulators, Composite materials, Electric field distribution, Flashover, Puncture, COMSOL Multiphysics**

CAHPTER 1. INTRODUCTION

An electrical insulator is a material whose internal electric charges do not flow freely, and therefore make it nearly impossible to conduct an electric current under the influence of an electric field. For any transmission line, an insulator is a vital component which decides the performance and availability of the line. The material must have high mechanical strength so that it carries the tension and weight of the conductors. They must have high dielectric strength. The material is highly resistive for preventing the flow of leakage current from the conductor to earth. The material is non-porous and free from impurities. The electrical and chemical property of the material should not be affected by the temperature.[4]

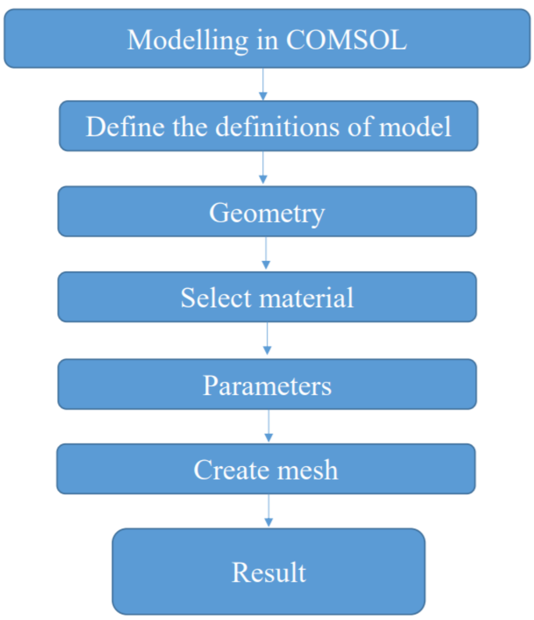
1.1 Objective

Characterize Silicone Rubber insulators for HV applications. Observe the effect of composite material fillers in Silicon Rubber. Modelling & Analysis of Silicon Rubber insulator using COMSOL Multiphysics. Compare filled and unfilled insulators in terms of Electric field distribution on surface by using COMSOL software.

1.2 Problem Specification

In India, a transmission line may be spanning over a variety of surroundings such as hot, humid, pollution, etc. So, there is a chance of damage or puncture of insulators and because of that chances of blackout and other faults in transmission line will occur. Polymeric insulator has a good properties like, hydrophobicity, dielectric strength, tensile strength, self-cleaning quality, etc. as compare with the ceramic one. So, there is a need to test the various performance of polymeric insulators to get the better improved insulator in future.

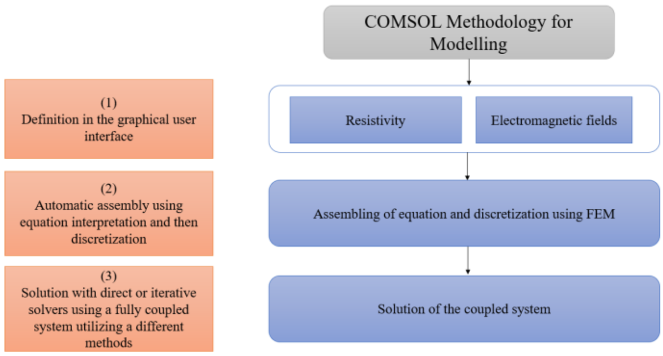
CHAPTER 2. Design Approach



2.1 Introduction to COMSOL Multiphysics

COMSOL was started in July, 1986 by Svantte Littmarck and Farhad Saeidi.Computer Solution(COMSOL) Multiphysics is a cross platform finite element analysis, solver and Multiphysics simulation software[6]. COMSOL provides a unified workflow for electrical, mechanical, fluid, and chemical applications. It is software which provides facility to modelling & simulation of different quantities and parameters. It uses Finite Element method(FEM) for solving partial differential equation[5]. COMSOL Server is the software and engine for running simulation apps and the platform for controlling their deployment and distribution. User developed apps can be run in COMSOL Server through web browsers or a Windows-installed client.

2.2 Methodology for Modelling

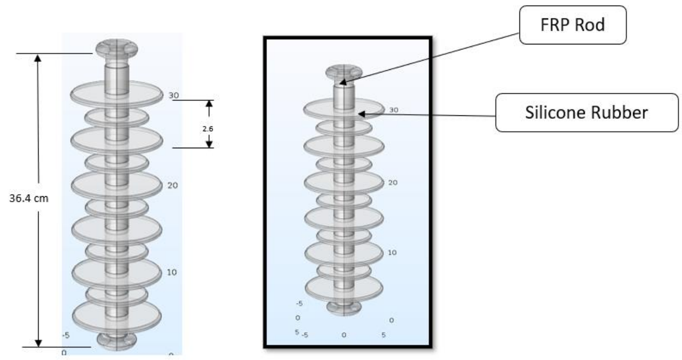


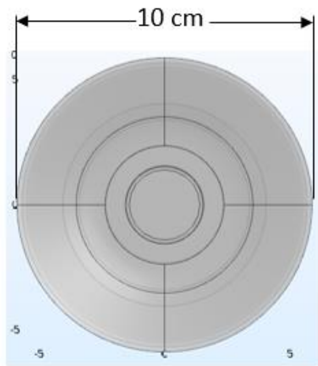
CHAPTER 3. Modelling & Analysis

Utilizing FEM analysis to incorporate the effect of materials microstructure and interfaces for improving the predictability of the dielectric properties of polymer matrix nanocomposites. The presented 3D simulation was able to reasonably predict the effective real permittivity of composites with and without alumina fillers.

3.1 Modelling of Silicone Rubber Insulator

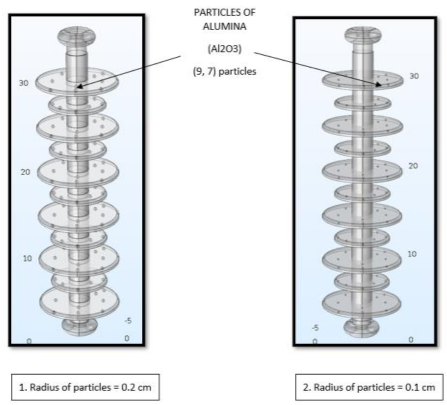
For modelling the Insulator in COMSOL first of all we have to define the Definition for insulator. Then we have to make geometry as per our need of insulator for that we have to add some kind of shapes from the geometry section in COMSOL. Here in this case Silicone Rubber material is added in the disc and glass fiber polyester material in rod. and in final for getting result we have to mesh this whole geometry





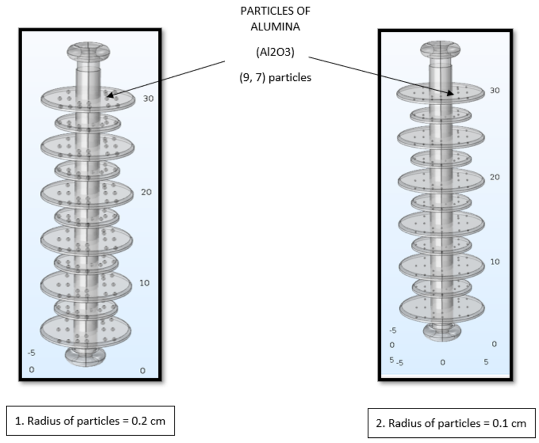
Here, this model is of 66 kV line and 11 discs are used as per the standard model of Siemens. Here, the height of the insulator is 36.4 cm as shown in the figure. Distance between two insulator discs is 2.6 cm. Diameter of the bigger disc is 10 cm. Diameter of inner disc is 7 cm.

5.2 Modelling of Composite Silicone Rubber Insulator



Particles of Alumina (Al2O3) is added in the unfilled SR insulator as shown in the fig. on the disc of the insulator. The permittivity of Alumina is 10 which is higher than the permittivity of silicone rubber which is 4. In fig 1 the radius off particles is 0.2 cm in the fig. 2, the value of particles is 0.1 cm. In this fig.1 inner disc has 7 particles of Al2O3 and in bigger disc, it has 9 particles of Al2O3.Analysis of these filled and unfilled insulator has done.

Model with more fillers

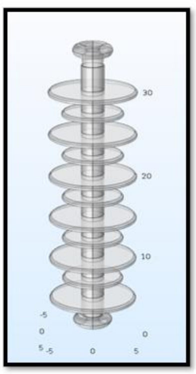


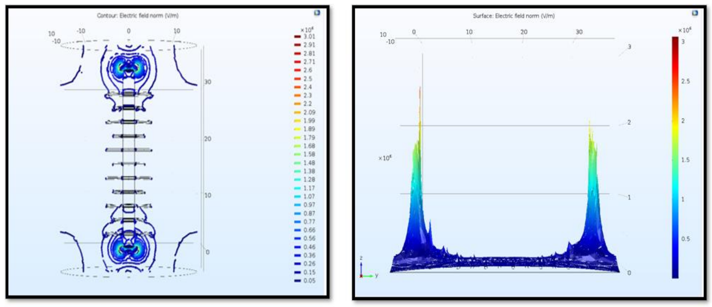
Particles of Alumina (Al2O3) is added in the unfilled SR insulator as shown in the fig. on the disc of the insulator. The permittivity of Alumina is 10 which is higher than the permittivity of silicone rubber which is 4. In fig 1 the radius off particles are 0.2 cm in the fig. 2, the value of particles are 0.1 cm. In this fig. inner disc has 14 particles of Al2O3 and in bigger disc, it has 18 particles of Al2O3.Analysis of these filled and unfilled insulator has done.

CHAPTER 4. Results and Discussion

4.1 Silicone Rubber Insulator

Silicone rubber insulator model is simulated in COMSOL. Electric field distribution is shown in the figure

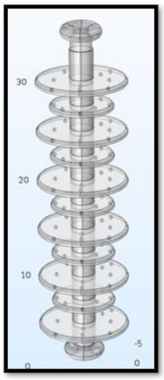




Received field distribution among its surface is **3.01 Mv/m**

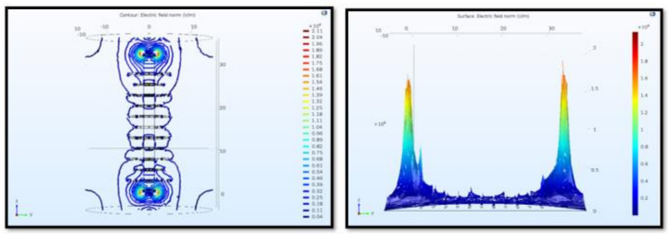
4.1.1 Filled SR Insulator with 0.2 cm radius particles

Electric field distribution is shown in the fig.

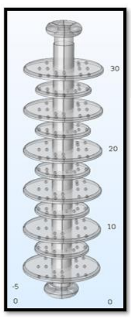


Disc	No. of particles
small	7
big	9
Radius – 0.2 cm	

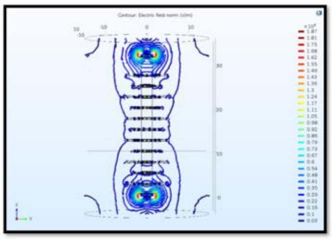
Here the value of alumina particles are 9, 7. 9 is in the big disc and 7 is in the small disc. Radius of each particle is 0.2 cm.

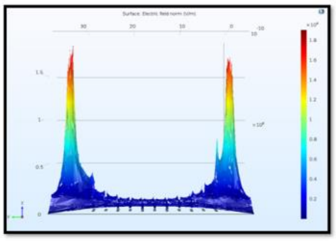


This value is lesser than the silicone rubber based insulator.



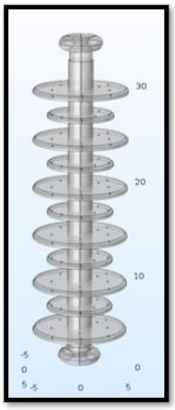
Disc	No. of particles
small	14
big	18
Radius – 0.2 cm	





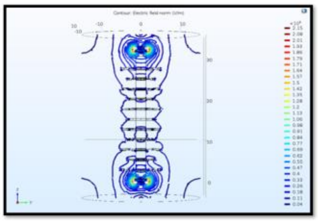
Here the value of alumina particles are 18, 14. Eighteen particles are in the bigger disc and fourteen particles are in the small disc. Radius of each particle is 0.2 cm. Received field distribution among its surface is **1.87Mv/m.**

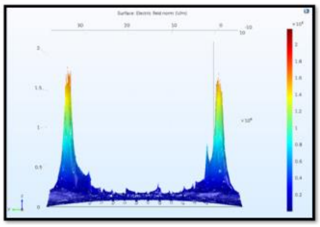
4.1.2 Filled SR Insulator with 0.1 cm radius particles



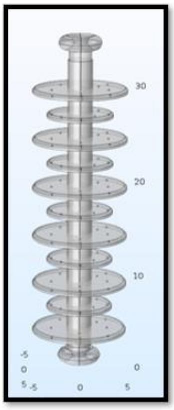
Disc	No. of particles
small	7
big	9
Radius – 0.1 cm	

Nine particles are in the bigger disc and seven particles are in the small disc. Radius of each particle is 0.1 cm.



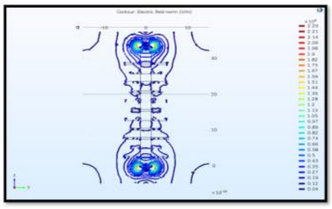


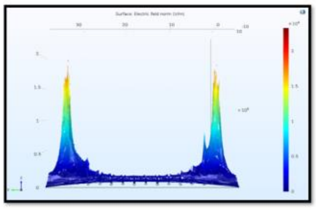
Received field distribution among its surface is **2.15Mv/m.**



Disc	No. of particles
small	14
big	18
Radius – 0.1 cm	

Eighteen particles are in the bigger disc and fourteen particles in the small disc. Radius of each particle is 0.1 cm.





Received field distribution among its surface is **2.29Mv/m.**

4.2 Comparison

By adding fillers of alumina value of electric field is reduced and field distribution is uniform.

Material used in insulator	Electric Field
Silicone Rubber	3.01×10^6 V/m
With Alumina Composites	2.11×10^6 V/m

Almost 27-30% improvement is measured with this result which indicates that alumina fillers are best for composites.

4.2.1 Field distribution with different number of particles

By increasing the number of particles in disc we get the minimum field distribution along the surface and the improvement in voltage distribution is there.

No. of particles in small disc	No. of particles in big disc	Electric Field
7	9	2.11×10^6 V/m
14	18	1.87×10^6 V/m

4.2.2 Comparison of different radius particles

Composite material: Al2O3.By above comparison we can say that, by reducing the size of particles of composites the value of field goes up.

No. of particles			
9,7		18,14	
R(cm)	Electric Field	R(cm)	Electric Field
0.1	$\mathbf{2.15 \times 10^6}$ **v/m**	0.1	$\mathbf{2.29 \times 10^6}$ **v/m**
0.2	$\mathbf{2.11 \times 10^6}$ **V/m**	0.2	$\mathbf{1.87 \times 10^6}$ **V/m**

By increasing the radius of fillers values of field goes down.

CHAPTER 5. Conclusions

In this project, Electric field effect on Silicone Rubber insulator has been explored by adding composite particles of Al_2O_3.for this purpose 0.1 and 0.2 cm radius particle has been added in the discs of insulator. Electric field results of filled and unfilled insulators are obtained by simulating it in COMSOL software. From that we have conclude that, Electric field around the surface of insulator with filler is less compared to the unfilled insulator, because of that, this new filled insulator has improved parameters as compared to unfilled silicone rubber insulator. By adding fillers of Alumina (Al_2O_3) in base SR insulator, Electric field value around the surface decrease around 26-30% which means that Filled SR insulator has improved Electrical parameters than initial one. By changing the radius of fillers from 0.2 cm to 0.1 cm in (9,7) particles model, the electric field intensity is increased around 5%, so we get the less uniform field distribution than the 0.2 cm. From the results, model with 0.2 radius and (18,14) particles has the minimum field distribution around the surface so this model will help to reduce the chance of flashover in insulator.

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