ELECTRIC STRESS ANALYSIS ON 11KV INSULATOR

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Abstract - *Insulators are one of the most important equipments in power system operation. The insulator's operation may affects the power flow, line loss and moreover reliability. Insulator will loosen its insulating property when it undergoes to more electric field for normal operating conditions and for more surface leakage currents from conductor to grounded terminal through insulator surface. The electrical parameters that influence the performance of insulator are surface leakage currents, corona and dry band arcing. So it is very important to study the electric field on insulator and surface leakage currents. To improve porcelain insulator performance RTV coating is applied on insulators, which suppress the leakage currents and improves the flashover voltage levels. In this paper electric stress analysis is performed on 11KV uncoated porcelain insulator and RTV coated insulator with different coating thicknesses (0.15mm, 0.2mm, 0.4mm, 0.5mm and 0.6mm) and pollution performance is compared between uncoated and RTV coated porcelain insulator. Similarly surface current density analysis is performed. This work is carried out in Maxwell's ANSOFT software.*

Key Words: **electric stress, leakage currents, RTV silicone rubber coating, pollution performance and finite element method.**

1. INTRODUCTION

Insulators are the most important over head transmission line equipment. The main purpose of the insulator is to passes the conductor from one point to another point in network without any failures and it separates the charged body from grounded body. Its performance may affect the power system operations such as power loss and reliability of system. Better the performance of insulator, will better the power system operation. The insulators installed at the coastal areas will get contaminated due to bad weather condition like rain, fog, salt layer formation, ice falling, dew and moisture etc. If such pollution forms on insulator surface, the conductivity of insulator surface will increase. It causes more electric stress on insulator for rated operating voltages and higher the leakage currents will flow from conductor to grounded terminal through creepage path. The dry band arcing distance is reduces which is a minimum distance from conductor to grounded terminal through air. Then such type of insulators will have the low flash over voltage than that of unpolluted insulator which is not desired. Higher the electric stress on insulator will results in failure of insulating property. Once the insulator will undergoes to more electric stress for continues operation, definitely insulator gets damaged. Similarly higher surface leakage currents through insulator surface will leads to failure of insulating property if soon it becomes a conductor. So study of electric stress on insulator and leakage currents through insulator surface is very important to manufacturers for desired designing of insulator [1].

In general, the installed insulating equipments are exposed to outdoor bad weather conditions so such type of insulators will get contaminated due to rain, moisture in the wet air and salt layer formation at coastal areas. Hence coatings on porcelain insulators are preferred to improve its pollution performance [2]. RTV (Room Temperature Vulcanizing) coating on porcelain insulator helps in reduction of surface leakage currents by improving hydrophobic property and increases the flashover levels of insulator. The dry film thickness of RTV coating is recommended as 0.38 mm to 0.5 mm for coastal and severe environment conditions. Here the electric stress analysis on 11KV porcelain insulator is performed. The analysis is done on 11KV uncoated porcelain insulator and RTV coated with different thicknesses like 0.15mm, 0.2mm, 0.4mm, 0.5mm and 0.6mmand current density values are also evaluated. Similarly electric field analysis is made on both uncoated and 0.4mm RTV coated porcelain insulators with pollution layer of 1mm thickness. The work is carried out in ANSOFT Maxwell design suite software.

2. INSULATOR PROFILE

The insulator profile is very important factor to its performance, especially creepage diatance from conductor to grounded terninal. For this, 11KV pin and cap type porcelain insulator considered for analysis.

Table-I: Insulator geometry for porcelain

Parameters	Dimensions in mm
Maximum diameter	120
Axial height	130
Creepage distance	350
Pin diameter	12/24 (In/Out)

The technical specifications are taken from IEC-60383 standards for porcelain insulator. The axis symmetry view is designed in ANSOFT 2D software with their respective dimensions as shown in Table-I.

Fig-1: axis symmetry view of 11KV insulator

Fig-1 shows the typical axis symmetric view of 11KV porcelain insulator designed in ANSOFT software for the analysis.

3. ELECTRIC FIELD SIMULATION

The designed model of 11KV insulator in software is assigned with their respective material properties like conductivity and relative permittivity for porcelain, cement and iron as shown in Table-II. For simulating the model electrostatic solver is selected for electric field analysis and AC conduction mode is selected for current density analysis. The input supply of 11KV is given to cap and ground is taken as pin of the insulator.

Table-II: Material properties for porcelain insulators

Material	Relative permittivity	Conductivity S/m
Iron	1	1×10^{7}
Cement	2.1	1×10^{-14}
Porcelain	5.7	1×10^{-14}
RTV silicone coating	2.9	1×10^{-12}

4. RESULTS

4.1 Electric Field Analysis

a) For uncoated porcelain insulator:

The Fig-2 shows the electric field values of uncoated insulator after completing the post process in ANSOFT software. The colour code of field lines denotes the intensification levels of electric field around the insulator surface.

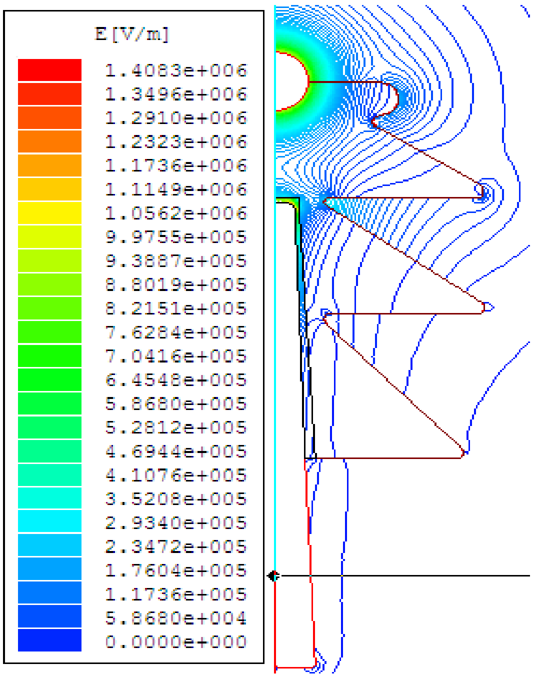
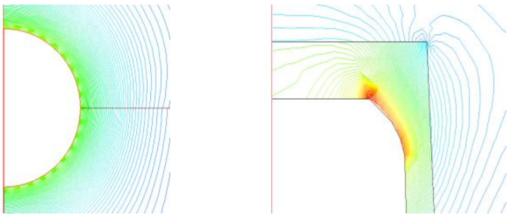


Fig-2: electric field values of uncoated insulator



(a) (b)

Fig-3: electric field at (a) cap and (b) pin

The maximum field value is observed at the pin and cap as shown in Fig-3, the field intensity at pin is gteater(red colour) than field at cap (green colour) due to unsymmetrical configuration of pin and cap [1]. As the electric field is inversly proportional to redius of the electrodes, here the pin redius is lesser than that of cap redius. The electric field is nonunifomly distributed around the outer surface of the insulator due to unsymmetrical configuration of end fitting at both high voltage side and low voltage side. The maximum field value obtained at pin is 14.08 KV/cm and minimum field values are obseved at the shed regions of insulator (blue coloured field lines).

b) RTV coated insulator:

As per the IEEE 1523-2002, the proposed dry film coating thickness range is 0.38mm to 0.5mm for coastal and severe environments [3]. The Fig-4 shows the electric field values of 0.4mm RTV coating thickness. The electric field simulation is executed for different thicknesses like 0.15mm, 0.2mm, 0.4mm; 0.5mm and 0.6mm RTV coated porcelain insulators. The electric field simulation for different RTV coated models is executed and their values are tabulated in below Table-III. Among that 0.4mm coated insulator gives minimum electric field value. Here also same principle followed by uncoated insulator; that is maximum electric field values are observed at high voltage side and as well as low voltage side this is due to triple point junction at end fitting. The triple point is referred to as the point of interface of three dielectric mediums i.e. solid, liquid and air. The electric field enhancement at the triple point may lead to either partial discharge or even flashover. As the RTV coating is applied on porcelain insulator with different thicknesses; the resultant conductivity of both RTV coating and porcelain will changes foe their respective coating thicknesses.

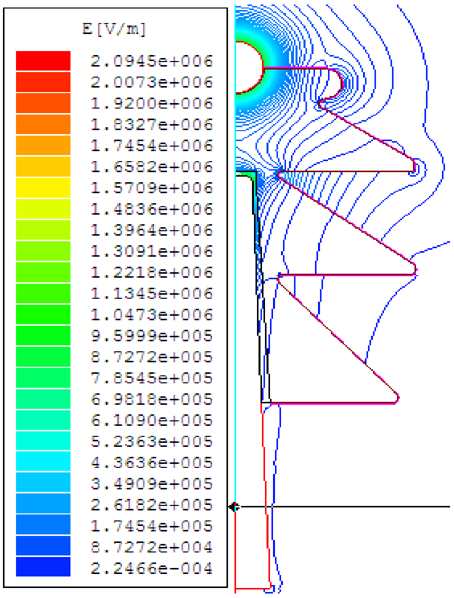


Fig-4: electric field value for 0.4mm RTV coated insulator

Table-III: Comparison of electric field values

S.NO.	Type of Insulator	Electric Field Values E (KV/cm)
1	Uncoated	14.08
2	0.15mm	46.76
3	0.2mm	38.01
4	0.4mm	20.94
5	0.5mm	51.83
6	0.6mm	62.17

The relation between electric field and conductivity is inversely proportionality [4], so decreasing the conductivity of RTV coated insulator will results in relative increasing in electric field values. Similarly the relative permittivity of RTV coated porcelain insulator will changes compared to uncoated porcelain insulator. Here also the relation between electric field and relative permittivity is inversely proportionality and nonlinear relation; hence there is a nonlinear variation of electric field values for 0.15mm, 0.2mm, 0.4mm, 0.5mm and 0.6mm thickness of RTV coated porcelain insulator [5].

From above Table III; uncoated porcelain insulator has field value of 14.08 KV/cm and polymeric insulator has 14.94 KV/cm. Among all RTV coated insulators, 0.4mm coated insulator will give minimum electric field value of 20.94 KV/cm.

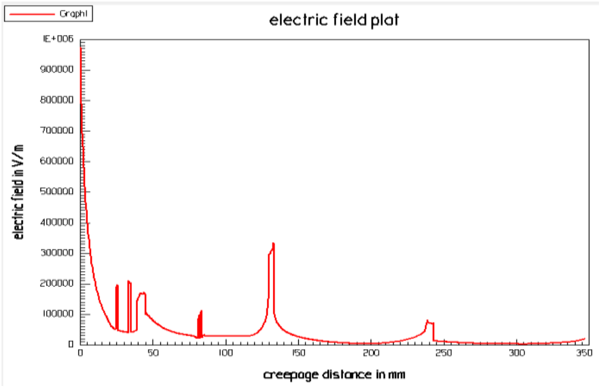


Fig-5: electric field along creepage distance for uncoated porcelain insulator

The above Fig. 5 shows that, electric field along the creepage distance of uncoated porcelain insulator. Here creepage distance is measured from high voltage end to low voltage end i.e. 350 mm approximately. Higher the electric field intensification is observed at the high voltage side and second peak point is observed at pin point which is in distance between 100 mm to 150 mm. field intensification is minimum at shed region of insulator. As the RTV coating is applied on porcelain insulator with 0.4 mm optimal thickness, the electric field values are changed from uncoated insulator. But along the creepage distance of coated insulator is almost similar to that of uncoated insulator. Such that maximum field intensification is observed at both high voltage side and at pin point. And field at shed region is minimum as shown in above Fig.-5.

After applying RTV coating on porcelain insulator, there is a small variation in creepage distance for different coating thicknesses. For this small variation, corresponding changes occurs in electric field values on insulator surface and along the creepage distance of an insulator as shown in Fig.-6.

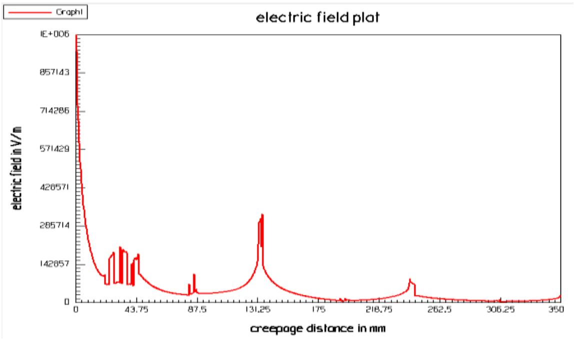
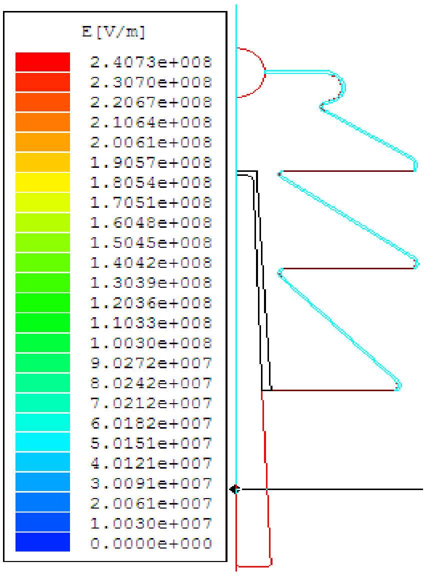


Fig- 6: electric field along creepage distance for 0.4 mm coated porcelain insulator

From the results obtained in software, uncoated insulator has low field value 14.08 KV/cm than that of RTV coated insulators. Similarly among all RTV coated insulators, 0.4 mm thickness coated insulator has very low field value as 20.94 KV/cm.

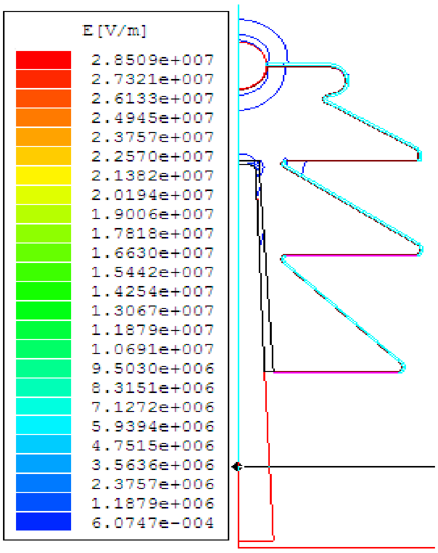
C) Porcelain insulators with pollution:

Porcelain insulators installed at coastal areas will get contaminated with ice and salt layer formation in insulator surfaces. The thickness of pollution layer is dependent on severity of contamination that may be low, medium and heavy pollution levels.



(a) Uncoated

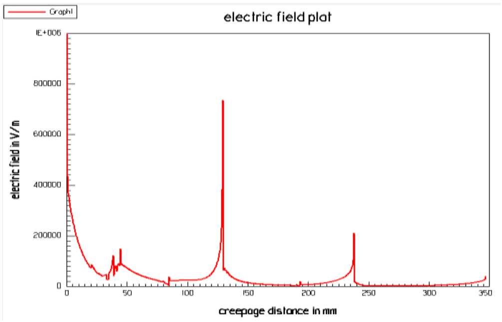
Here the pollution layer thickness is taken as 1 mm, relative permittivity is as 80 and conductivity of that layer is chosen as 0.1 nano S/m. The electric field values are inversely proportional as well as nonlinear relation to conductivity and relative permittivity of pollution layer. Hence the polluted insulator of both uncoated and RTV coated porcelain insulators shows higher electric field values as shown in above Fig. 7.



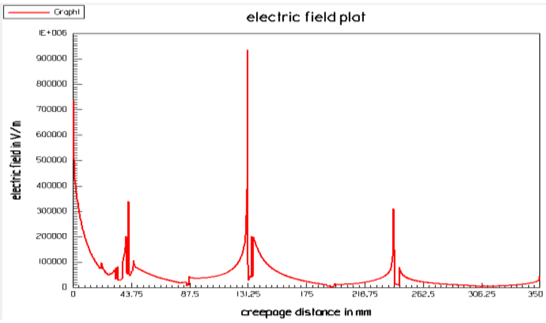
(b) 0.4 mm coated

Fig-7: electric field values of insulators with 1 mm pollution layer

If the conductivity of the pollution layer increases then the electric field values are also increases. The maximum electric field value for uncoated insulator is 2.40×10^{8} V/m and for coated insulator is 2.85×10^{7} V/m. The field value of uncoated insulator is very greater than that of RTV coated insulator.



(a) Uncoated



(b) 0.4 mm coated

Fig-8: electric field along creepage distance of porcelain insulator

The above fig shows that electric field plots along the creepage distance of uncoated and 0.4 mm RTV coated porcelain insulators. Highest field value is occurred at high voltage end, second peak point is at pin which is at distance of 132 mm approximately from high voltage end and shed regions have minimum field values.

4.2 Current Density Analysis

The current density values for uncoated and RTV coated porcelain insulators also investigated in ANSOFT software. RTV coating on porcelain insulator will improves their surface hydrophobicity property which results in improvement of surface leakage current suppression through creepage path of insulator [6].

Table-IV: Comparison of Current density values

S.NO.	Type of Insulator	Current Density Values J(A/m^2)
1	Uncoated	33.6
2	0.2mm	0.343
3	0.3mm	0.49
4	0.4mm	0.30
5	0.5mm	0.346
6	0.6mm	0.37

The table IV shows current density ($J = \frac{I}{A}$ amps /m^2) values for uncoated and RTV coated porcelain insulator with different thicknesses. By applying RTV coating on porcelain insulator; the surface resistivity will improves which results in reduction of leakage currents through creepage path of insulator. Effective thickness of coated insulators will vary in small dimension but there is more reduction of flow of leakage currents. As the relation between current and current density is proportionality and between area and current density is inverse proportionality so that very fewer currents will flow through surface of insulator.

The maximum current density value is 33.6 A/m^2 for an uncoated porcelain insulator and almost all RTV coated insulators have very less current density values but minimum current density value is 0.30 A/m^2 for coated insulator with 0.4mm thickness. The relation between coating thickness and area of coating to the current density values is nonlinearity; such that variation of current density values for different coating thicknesses is also nonlinear manner.

5. CONCLUSION

From electric field analysis

1) Electric field is more at both high voltage side and low voltage side compared to shed region of porcelain uncoated and RTV coated insulator.
2) Maximum electric field value is observed at pin than that cap; this is due to smaller radius of cast iron pin at low voltage side.
3) The RTV coated porcelain insulator has more electric field than uncoated porcelain insulator because the resultant conductivity of RTV coated insulator is very less than that of coated insulator. The relation between conductive-ity and relative permittivity of coated insulator to electric field is inverse proportionality.
4) Increasing of RTV coating thickness will results in nonlinear variation in electric field values around the porcelain insulator.

From current density analysis

1) RTV silicone rubber coating is used to reduce flow of leakage current from conductor to grounded terminal through insulator surface length.
2) Increasing of RTV coating thickness (for a small variation of area) results in large reduction in flow of leakage currents through surface length of insulator.
3) Smaller the variation in coating thickness but larger reduction in leakage currents together results in nonlinear variation of current density values.

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BIOGRAPHIES

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