Effect of Metal Ring on the Field Distribution of Outdoor Polymeric Insulator

Veeresh A G
M.Tech(Power System Engineering)
S.D.M .College Of Engineering and Technology
Dharwad

Meenakshendra A Khamitkar
M.Tech(Power System Engineering)
S.D.M. College Of Engineering and Technology
Dharwad

***Abstract*— in recent decades, polymeric insulators are finding increasing applications due to their superior performance under polluted conditions and light weight. They are hydrophobic in nature as opposed to ceramic insulators, and hence perform better under contaminated environments.**

In the present work .The field estimation of insulator considered is carried out for different pollution levels with uniform and non-uniform distribution of pollutants. Apart from this metal ring and corona rings are placed on various locations and field is analysed. The expected outcome of the project will help in the proper design and/or selection of outdoor insulator(s) for the known level of pollution.

It was inferred that polymeric insulators performed better in contaminated environment as far as flashover voltages are concerned. But these insulators are yet to prove their ageing performance. Corona rings when placed at both ends of the insulator showed least field in all the cases considered in the present study The values of field at various locations under various conditions are found to be well within the specified standard values.

***Keywords*— insulators, electric field, flashover, permittivity, hydrophobicity, corona rings, Quickfield, FEM.**

1. INTRODUCTION

The generation and consumption of electric power is seldom in close vicinity. The bulk of electric power is transmitted via long distance overhead lines at high voltages. The system voltage has been increasing steadily in order to increase power transferred and efficiency of power delivery [1]. 1000 kV ac lines are now operational in China and planning for 1200 kV ac system is presently underway in India. Japan, Canada and The United States of America already have systems operating over 700 kV for many years [1]. Outdoor insulators form an integral part of these transmission systems and have significant impact on system reliability [2].

Porcelain and toughened glass insulators have been used for outdoor insulation for many years. The last few years has witnessed the increased use of composite (also known as non-ceramic or polymeric) insulators for all voltages due to advantages of light weight, ease of installation and lower cost. Composite insulators also have excellent pollution performance due to the hydrophobicity of the housing material [3].

One of the major factors governing the electrical performance of composite insulators is the electric field distribution along the surface. The electric field is more nonlinear for composite insulators when compared to ceramic insulators (porcelain and glass) due to the absence of intermediate hardware which provides a certain degree of stress grading [2]. The resulting electric field concentration can lead to corona and accelerate several failure modes [2].

I. Power frequency overvoltage failure: This is also known as temporary overvoltage failure. Whenever a single line to ground fault occurs, current increases in one phase and voltage becomes high in the other two and thereby result in the above mentioned failure.

II. Overvoltage failure: This type of failure can be further divided into lighting overvoltage and switching overvoltage failure. These are short term failures lasting only for a few micro seconds i.e. 20/200µs for lighting and 250/2500µs for switching.

III. Pollution induced flashover: This type of failure occurs at normal operating voltage.

From the research work of Vosloo et.al. [220], it is observed that pollution induced flashover mainly depends on the voltage gradient or field along the insulator surface. When the field along the surface of the insulator exceeds the critical field, the flashover of the complete insulator may occur. Importantly, this flashover occurs at normal operating voltage due to the pollutant present in the environment. In this regard, the estimation of field of a polluted insulator becomes a field of merit.

For more than 100 years, porcelain insulators have been in widespread use as outdoor insulators. But their performance under polluted conditions does not encourage their further use. This is the reason that most countries are switching over to polymeric insulators, due to their superior performance.

Porcelain is the most commonly used insulator which is hydrophilic in nature and hence affected by pollution and causes pollution induced flashover. In order to reduce the effect of such flashover/s, hydrophobic substances such as polymers like silicon rubber insulators are preferred.

Silicone rubber (SIR) insulators perform better than EPDM (Ethylene- Propylene-Diene) and both composites are better than ceramic insulators [1- 5]. The initial values of leakage current for the SIR insulators were almost half of those for EPDM and a quarter of those for ceramic insulators [1-5]. SIR insulators were found to maintain better hydrophobicity even after more than 7 years in service. However, during heavy salt contaminated conditions and high stress SIR can lose its hydrophobicity and develop considerable surface arcing [6].

The use of EPDM is very common in the USA particularly for lower voltages, whereas the use of SIR is favored in Europe [3]. It has been claimed that SIR has an improved pollution performance of 30% or more compared to porcelain and that porcelain insulators with creepage distance of 25mm/kV can be replaced by composite insulators with creepage

IV.Advantages of Polymers over Ceramics

There are several advantages of polymeric insulator over ceramic insulators as given below -

a) 90% Weight Reduction - Reduced Breakage
b) Low Installation Cost
c) Improved Resistance to Vandalism, Improved Power Frequency Insulation.
d) Improved contamination performance.

2. MODELING IN QUICKFIELD:

The insulator has been modeled in QuickField on a one-to-one basis after measuring the various physical parameters of the real insulator using Vernier callipers. Also, a point to be noted is that only half the insulator cut vertically has been modeled for the sake of convenience. This is not a problem as the results obtained can easily be extended to the second half. The various parts of the insulator can be shown as –

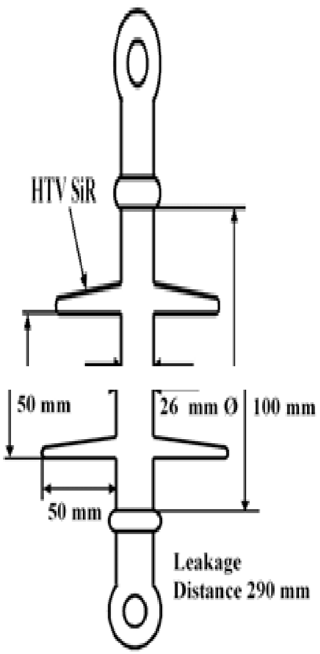

Figure1: A typical modern day insulator

3. CONDITIONS SIMULATED IN QUICKFIELD

The following conditions were simulated in QuickField to obtain results for various levels of pollution –

Case 1: Dry condition

Only the insulator is modeled in an air medium. The simulation model is as follows [fig.2]

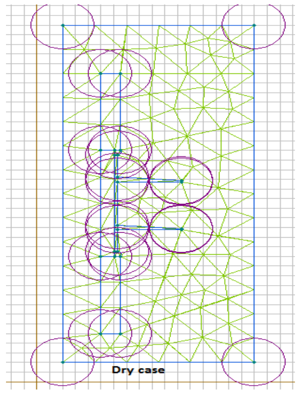

Figure2: Model for dry case

Case 2: One drop of water on top shed

Here, a single drop of water (radius=1 mm) on each of the three sheds of the insulator is considered. The model is as follows [fig.3]

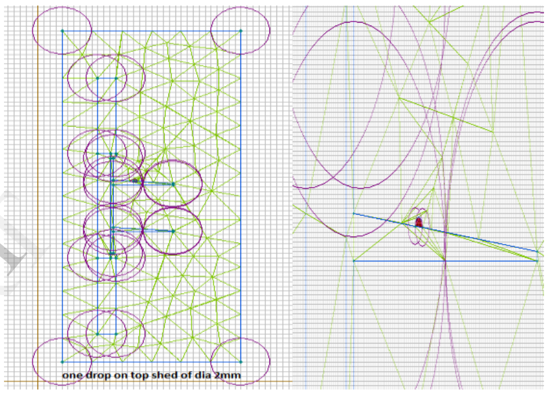

Figure 3: Model for one drop of water on top shed

Case 3: Uniform layer of salt on each shed of the insulator

Here, a uniform layer of salt (thickness=0.1 cm) on each of the three sheds of the insulator is considered. The model is as follows [fig.4]

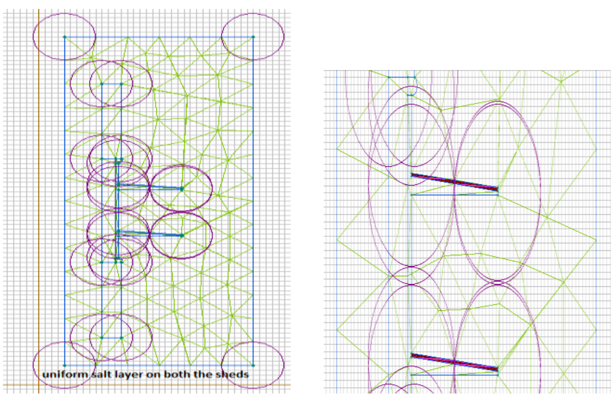

Figure 4: Model for uniform salt layer on both the sheds

Case 4: Non-uniform layer of salt on each shed of the insulator

Here, a non-uniform layer of salt (thickness of 0.1 cm and two gaps of 0.3 cm each) on each of the three sheds of the insulator is considered. The model is as follows [fig.5]

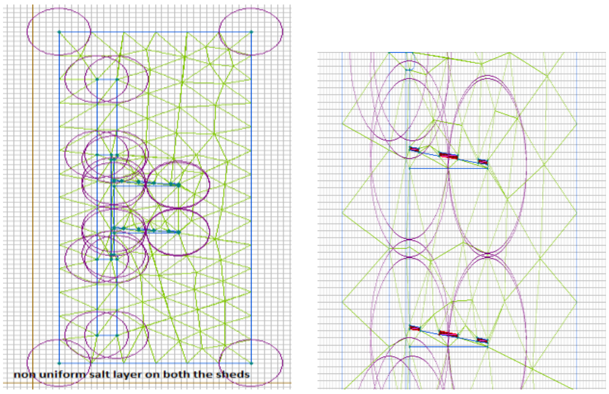

Figure 5: Model for non uniform salt layer on both the sheds

Case 5: Metal ring placed on the insulator

Here, a metal ring is placed between the two sheds of the insulator (thickness=5mm) [fig.6]

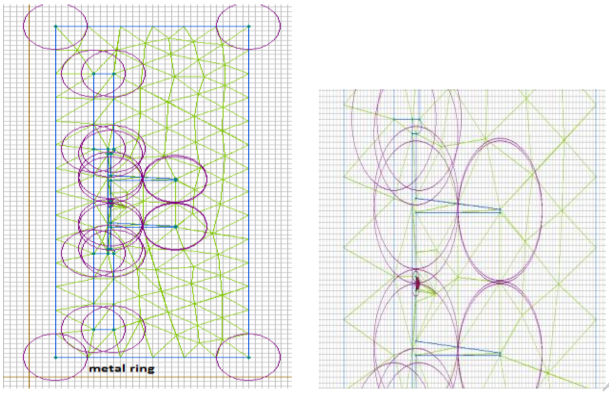

Figure 6: Model for metal ring placed between the two sheds

4. RESULT AND DISCUSSIONS:

Case 1: Equipotential plot for dry and non-polluted condition

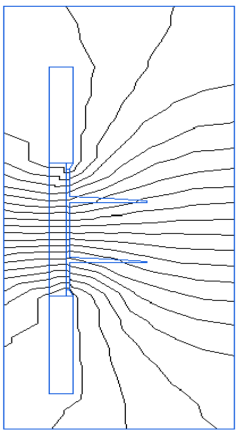

Figure 7: Equipotential plot for dry and clean condition

Field strength plot for dry and non-polluted condition

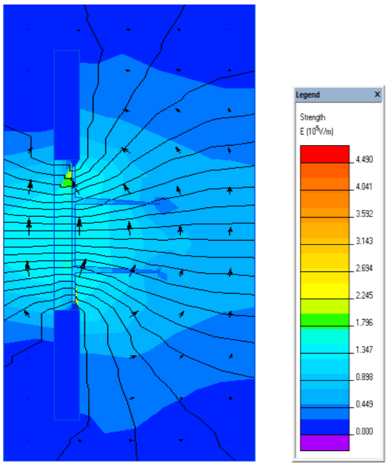

Figure 8: Field strength plot for dry and clean condition

In the clean and dry condition, it is observed that the field has maximum magnitude at the top and bottom sheds due to proximity to the metal contacts fig. [7][8]

Case2: Equipotential plot for one drop on top sheds

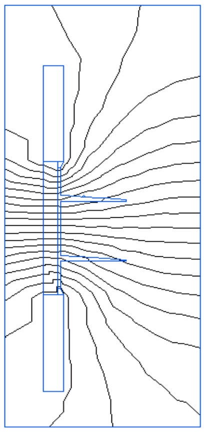

Figure 9: Equipotential plot for one drop on top sheds

Field strength plot for one drop on top sheds

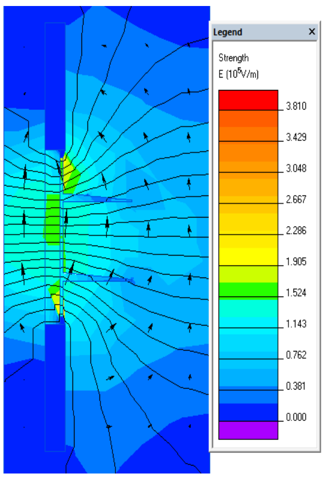

Figure 10: Field strength plot for one drop on top sheds

Field has reduced around the middle shed but concentrated more near the top and bottom sheds fig. [9][10]

Case 3: Equipotential plot for uniform salt layer on all sheds

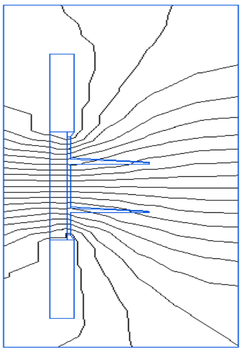

Figure 11: Equipotential plot for uniform salt layer on all sheds

Field strength plot for uniform salt layer on all sheds

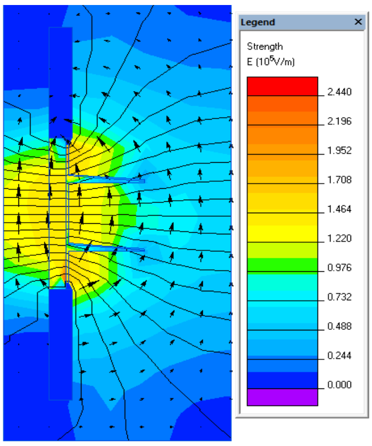

Figure 12: Field strength plot for uniform salt layer on all sheds

Field has concentrated inside SIR along the length between top and top sheds and except this the field has comparatively decreased on all the sheds fig. [11][12]

Case 4: Equipotential plot for non-uniform salt layer on all shed

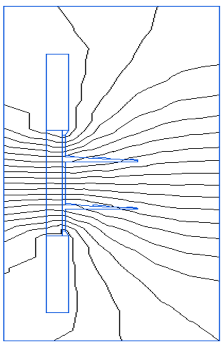

Figure 13: Equipotential plot for non-uniform salt layer on all shed

Field strength plot for non-uniform salt layer on all sheds

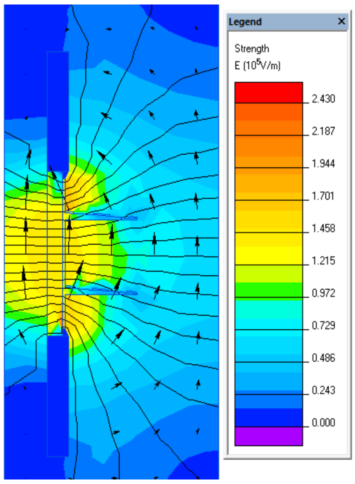

Figure 14: Field strength plot for non-uniform salt layer on all sheds

Here the field is almost constant throughout the sir and the field is minimum in the sheds. We also observe that the field of uniform and non-uniform case are almost same. fig. [13][14]

Case 5: equipotential plot for metal ring placed between the sheds

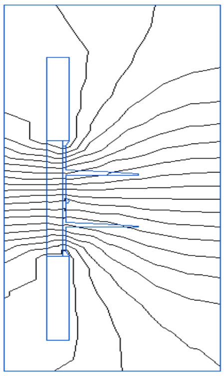

Figure 14: equipotential plot for metal ring placed between the sheds

Field strength plot for metal ring placed between the sheds

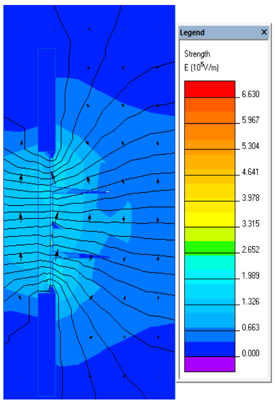

Figure 15:Field strength plot for metal ring placed between the sheds

Field has been increased when a metal ring of thickness of 1.5mm was placed between two sheds.field is maximum in the SIR portion near metal ring. We performed other cases by placing corona rings at various locations and their response has been tabulated as shown below table [1].

1	particulars(cases)	Inside SIR	Inside FRP	Surface of top shed	Surface of bottom shed	Upper triple junction	Lower triple junction	Inside drop	Surface of corona ring		Inside salt layer
2	Dry case	1.66	2.3	1.49	1.58	1.54	4.49	-	-	-	
3	Wet case	1.73	2.16	1.68	1.5	2	3.81	0.18	-	-	-
4	Metal ring	6.63	2.54	1.65	1.62	1.76	1.69	-	-	-	
5	Metal ring with wet case	9.6	2.3	1.67	1.53	1.98	4.03	0.17	-	-	0
6	Uniform salt layer	2.43	2.33	1.58	1.57	1.66	1.67				1.5
7	non uniform salt layer	1.654	2.41	1.84	1.55	1.65	1.632				1.75
8											
9					corona ring at bottom						
10	dry case	1.7	2.08	1.75	1.48	1.86	0.7			1.1	
11	wet case	1.7	5.8	1.54	1.67	1.83	1.23	0.28		1.3	
12	metal ring	6.61	2.35	1.76	1.58	1.8	1.1			1.23	
13	metal ring with wet case	3.06	1.5	1.73	1.51	2.06	1.1	0.23		1.22	
14	uniform salt layer	1.7	2.26	1.69	1.47	1.8	1.09			1.2	1.06
15	non uniform salt layer	1.8	2.1	2.02	1.48	2	0.7			1.1	1.95
16											
17					corona ring at both the ends						
18	dry case	1.6	2.17	1.65	1.54	1.3	0.74		1.44	1.2	
19	wet case	1.6	2.35	1.59	1.55	1.87	1.17	0.42	1.4	1.36	
20	metal ring	4.02	2.35	1.59	1.59	0.88	1.21		1.4	1.38	
21	metal ring with wet case	3.22	1.5	1.61	1.6	1.45	1.21	0.11	1.38	1.38	
22	uniform salt layer	2.37	2.33	1.56	1.48	0.88	1.17		1.38	1.37	1.4
23	non uniform salt layer	1.6	2.35	1.78	1.54	1.23	1.17		1.41	1.35	1.61
24											
25											
26	dry case with air crack	1.68	2.2	1.54	1.6	3.8	4.5				

Table1: table showing the values of electric field in various cases

Bar chart for all the cases

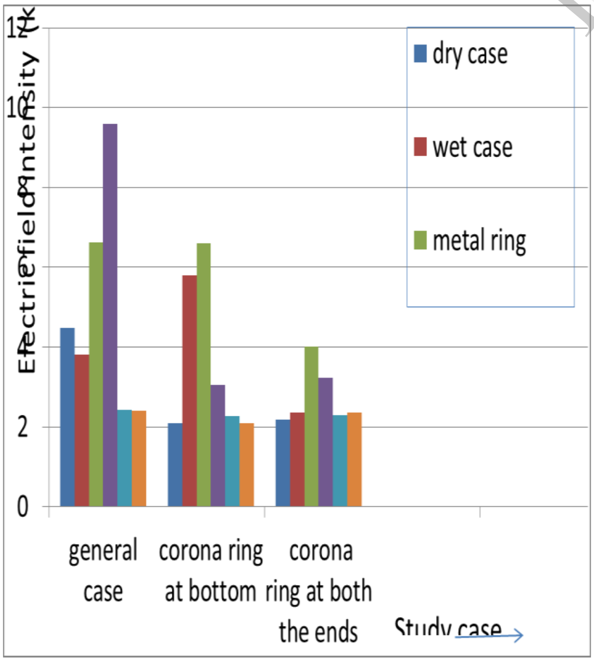

Figure 15; Bar chart showing electric field intensity for various cases

5. CONCLUSION:

The main objective of the present work was to analyse and/or estimate the electric field at different regions of the polymeric/SIR insulator. For this purpose an 11kV, 45kN distribution class SIR insulator has been considered and modeled according to the real dimensions in QuickField. Fields were estimated at different regions of the insulator and also with different conditions. The conditions simulated in the present work are of more practical significance in the field. According to literature, SIR insulator which is hydrophobic in nature performs considerably better in polluted environment when compared with the porcelain insulator. It is also observed in the present work that these insulators can perform better in the contaminated environment because the field obtained in all the regions and different cases are well within the limits specified in the field. The fields obtained may not significantly contribute to the complete flashover of the insulator surface but they will help in triggering local arcs. The local arcs further lead to treeing and tracking resulting in reduction of insulation resistance. As the SIR insulator belongs to organic group, it results in corrosion and erosion that lead to the failure of triple junction. But these insulators are yet to prove their ageing performance. Corona rings when placed at both ends of the insulator showed least field in all the cases considered in the present study.

The work was carried out using a Student version of QuickField where the maximum number of nodes is limited to 256. The performance can be better understood if the full version QuickField is used for the analysis.

Field obtained for the different cases are shown as bar chart. From the figure it can be concluded that,

Highest field is present with metal ring placed between the two sheds under wet condition.

Lowest field is present with corona ring placed at bottom under dry condition.

The field is least in all cases when corona rings are placed at both the ends. With pollution (both uniform & non-uniform) the field is about 2.2kV/cm.

6. REFERENCES

1. Andrew Phillips, 'Ceramic vs. Polymer (non-ceramic) Insulators', EPRI, 2002
2. Mohammad Amin, Mohammad Akbar and Salman Amin, 'Hydrophobicity of Silicone Rubber used for Outdoor Insulation', UET Taxila, Pakistan, 2007.
3. W.L. Vosloo and J.P. Holtzhausen, 'The Electric Field of Polluted Insulators', ESKOM/University of Stellenbosch, South Africa.
4. 'Outdoor Insulators', Ravi S. Gorur,, Arizona State University, USA.