ANALYSIS OF POLLUTION PERFORMANCE ON INSULATORS

Dr. Pulidindi Venugopal*

Syed Nizamuddin*

Abhishek Guda*

ABSTRACT:

In this work, a model based on field criterion has been developed to represent the flashover phenomenon, which occurs due to surface pollution on high voltage insulators, under ac voltage. The values of potential and electric field on an insulator surface have been determined. To study and compare the performance of a pin type insulator made up of porcelain and used in high voltage electricity transmission lines under normal conditions and under polluted conditions. On simulating these insulators in ElecNet software, Voltage and Electric Field distributions were studied and analyzed on both clean and contaminated insulators and then compared. New designs are available with more mechanical and flash over strength. To prevent the fog or water droplets from reaching the lower layers the post insulators are used with high radius of top most post. Other than this disc type insulators are used to keep the pollutant away from the central axis which is the most prone zone for flash over to occur.

Keywords: Design, electrical field, voltage, pollution

* VIT University, Vellore, Tamil Nadu, India.

INTRODUCTION:

Insulators function in an outdoor environment in many cases. In such applications in cold climate regions, the high voltage insulator surfaces are exposed to atmospheric pollution and also accretion of snow or ice of different natures. Flashover phenomena on ice covered insulators have been reported from a large number of cold climate countries. The performance of a high voltage insulator under an ice-free condition is quite different from those under ice-covered conditions. This is because, for a wet ice-covered insulator, the field distribution is capacitive-resistive depending upon the severity of the ice, while for a clean ice-free insulator the field is purely capacitive. Therefore, it is very important to know the changes in the field distribution around an insulator caused by different severities of the ice accretion. The flashover characteristics of insulators are necessary to determine suitable insulator profiles for a particular application. The flashover voltage depends on the electric field distribution, which is mainly distorted by the presence of a water film and airgaps along the ice-covered insulators. Polymer insulators, which are being used increasingly for outdoor applications, have better characteristics than porcelain and glass types.

Research Method

Flashover of a polluted insulator can occur when the surface is wet due to fog, dew, or rain. Development of partial discharges on the insulator surface and propagation of these discharges over a period of time cause the leakage current to increase on the insulator surface that may result in a flashover. This occurs in three stages. These are the formation of electrolytic conductive film layer, the formation of dry bands and the starting of pre discharges and propagation of pre-discharges. The first two stages can occur frequently; however, the last stage does not occur as often as the others.

Most commonly seen pollution related problems to flashover exist in coastal areas sea salt, industrial areas chemical pollution, and other areas desert sand. Analytical and experimental methods have been developed for calculating the flashover characteristics of polluted insulators, and several mathematical approaches have been analyzed. However difficulties still exist and further studies are needed.

The insulator under normal conditions and under contaminated conditions (by introducing void & water droplets on its surface) is to be simulated in ElecNet software & the distribution of Voltage

&Electric field is to be analysed& compared. We compare the performance of a pin type insulator made up of porcelain and used in high voltage electricity transmission lines under normal conditions and under polluted conditions.

The overall objective is to study the flashover phenomenon on full-scale, ice-covered EHV insulators, in order to improve the existing mathematical model for predicting the minimum flashover voltage such insulators. This study contributes to the understanding of the flashover phenomenon on ice-covered EHV insulators and presents a powerful tool for the design of outdoor insulators in cold climate regions. On completion of the design of normal insulator another model was designed for the insulator with water droplets and sand particles on its surface.

FLASHOVER MECHANISM

Deposition of Contaminants

Outdoor insulators are generally exposed to contamination from a variety of sources. Insulators near coastal areas are contaminated by wind driven salt and those inland, by wind driven dust, agricultural and industrial pollution.

a) Marine Pollution-

Most of the insulator contamination near coastal areas is due to airborne sea salts. Small water droplets are released from the tips of the ocean waves during stormy weather. These small droplets are blown away by winds, which evaporates the water of the small droplets to form even smaller droplets of brine. If the relative humidity is low enough, he water evaporates completely leaving a small, more or less dry, crystalline, salt particle. These salt particles are then deposited and stuck to the surface of the insulator.

Insulators in regions extremely close to the sea can be exposed to direct salt water spray during periods of strong winds. The sun dries the water leaving a white salt layer on the surface of the insulator. The deposition of sea salt onto insulators is thus a function of wind velocity and distance from the sea.

b) Inland Pollution-

The sources of insulator pollution include soil dust, fertilizer deposits, industrial emissions, fly ash, bird droppings, construction activities, etc.

Typical Sources of Insulator Pollution

LOCATION	SOURCE OF POLLUTANT
Coastal areas	Sea salt
Rural areas	Soil dust, fertilizers.
Desert	Sand
Industrial	Fly-ash, Industrial Smokestacks
Highways	Road Salt ,Smoke

Wind drives these airborne contaminant particles onto the insulator surfaces. Also, depending on proximity to highways and how the car traffic is, the wear of car tires produces a slick, tar-like carbon deposit on the insulator's surface. Road salts used on highways during the winter likewise play an important role during insulator surface pollution.

Insulators produce turbulence in airflow, which results in the aerodynamic 'catch' and deposition of particles on their surfaces. The rate at which the insulator catches particles depends on the shape of the insulator, size and density of the particles and the speed of the airflow. The continuous deposition of these particles increases the thickness of these deposits. However, the natural cleaning effect of wind, which blows loose particles away, limits the growth of deposits.

Occasionally, rain washes part of the pollution away and self-cleaning by airflow also removes some types of contaminant. The continuous depositing and cleaning produces a seasonal variation of the pollution on the insulator surfaces. After a long time (months, years) the deposits are stabilized and a thin layer of solid deposit will cover the insulator. Because of the cleaning effects of rain, deposits are lighter on the top of the insulators and heavier on the bottom. The bulk of the pollution on an insulator's surface is generally non-conducting but moisture will intermittently render conductive, much of the soluble part of the pollution layer. The conductivity of the resulting thin conductive layer depends on the amount of moisture as well as the chemical composition of the contaminant.

The severity (degree) of the pollution is characterized by the equivalent salt deposit density (ESDD).Equivalent Salt Deposit Density is measured by periodically washing down the pollution from selected insulators with distilled water and carefully collecting the water. The conductivity of the collected water is measured and the equivalent amount of salt, which produces the same conductivity, is calculated. The obtained mg value of salt is divided by the cleaned area of the insulator to obtain the ESDD value.

Typical ranges for inland pollution severity

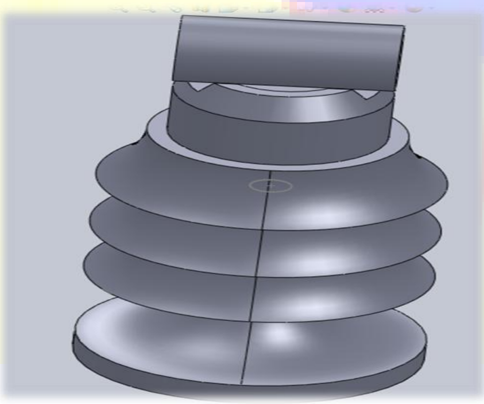
Description	ESDD(mg/cm2)
Very light	0-0.03
Light	0.03-0.06
Moderate	0.06-0.1
Heavy	>0.1

Typical ranges for marine pollution severity

Description	Salinity(kg/m3)
Very light	0-10
Light	10-20
Moderate	20-40
Heavy	40-80
Severe	>80

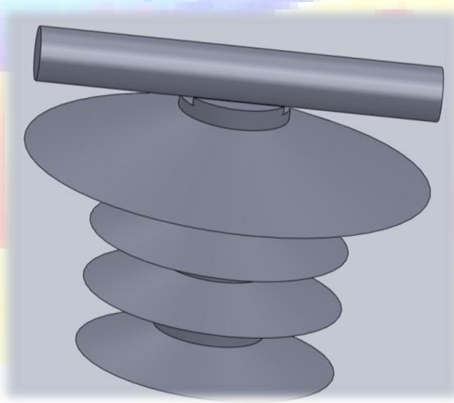
3-D Designs

(a) Insulator under Analysis



To

(b) New Design



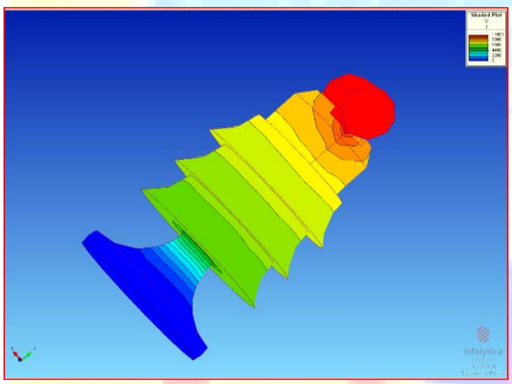
implement the above process, two software are used one is Solid works and ElecNet. The time taken for ElecNet to solve a problem will depend on the complexity of the model and the desired solution accuracy. For this reason alone it is not advisable to attempt an exceedingly detailed model of a practical device with every geometric feature faithfully copied. There is also a practical reason for avoiding complex models initially. The model containing mistakes; if it is very detailed it will take a long time to solve, and an even longer time to rebuild when the solution has revealed the mistakes.

It is generally best to begin with a very simple model that preserves the essential features of the device. Shapes and dimensions can be simplified. Some parts do not need to be modelled at all. For the first solution of a new model, it is desirable to get a field plot as quickly as possible, because this plot is an effective tool for revealing errors in the structure of the model. At this stage, there is no need to use the powerful adoption feature of ElecNet to improve the solution accuracy.

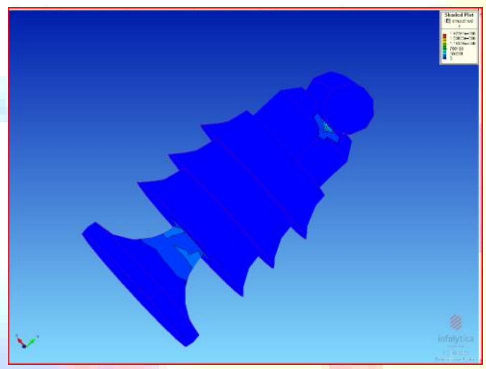
Results and Analysis

The Insulator in Normal Condition

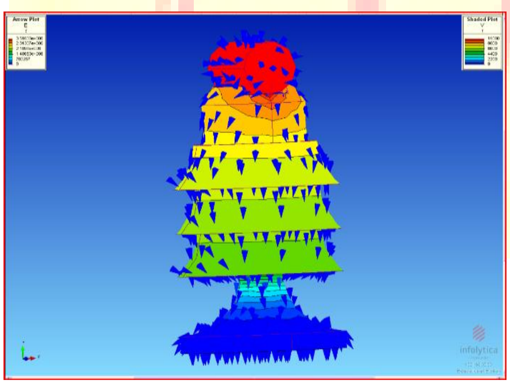
(a)Voltage Variation



(b) Electric Field Variation



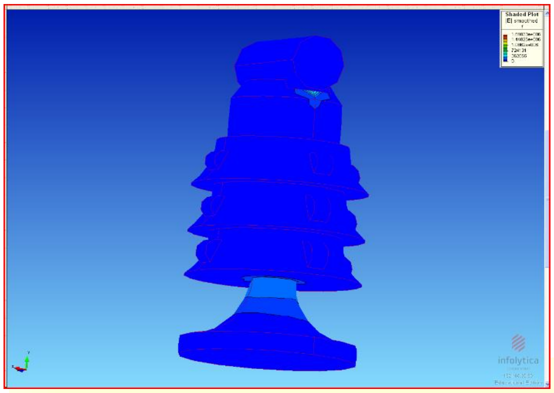
(c) Electric Field and Voltage with Directions



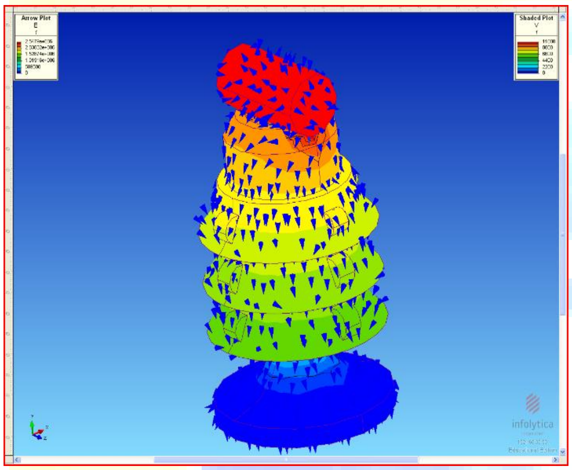
Insulator Polluted With Water Droplets

(a)Electric Field Distributions

(b) Voltage Distribution

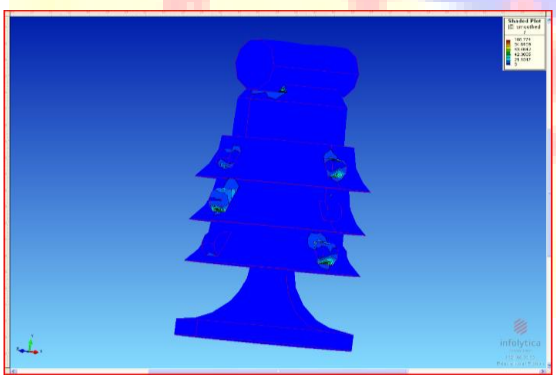


(c) Electric Field and Voltage with Directions



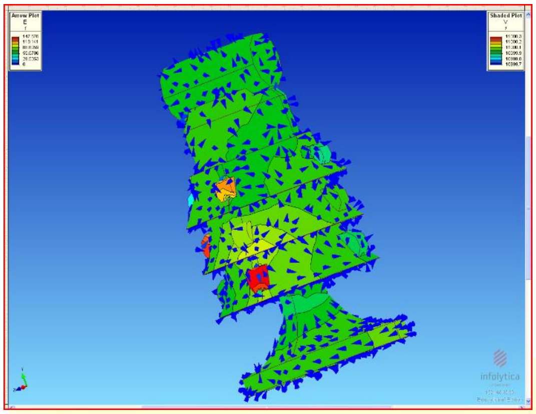
Insulator Polluted With Air

(a)Electric Field Distribution



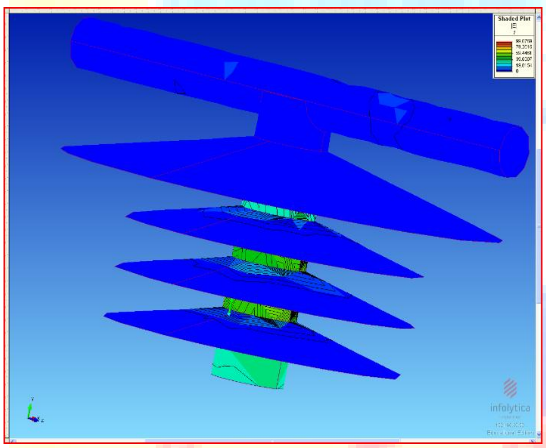
(b) Voltage Distribution

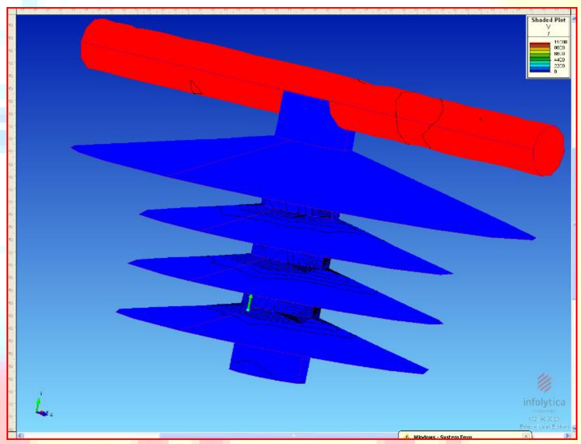
(c) Electric Field and Voltage with Direction



Insulator With Modified Design

(a)Electric Field Distribution (b) Voltage Distribution





CONCLUSION

Here an approach to calculate AC and DC flashover voltage for insulators working under normal condition and polluted condition is given. The mathematical tool used is Finite Element Method (FEM) which divides the surface in to small meshes and then gives the solutions of partial differential equations. The FEM provides satisfactory results when compared with experimental results of flashover calculations.

From the simulation results it was suggested that electric field intensity is very high at the centre and the amount of stress on disc circumference was not much. Similarly the potential gradient increases from top to bottom on insulator. It is maximum at conductor and nearby discs while reduces abruptly after that.

The results of polluted insulator with water shows there is not much of difference created by water droplets on distribution of electric field and voltage. Thus it does not affect the flash over strength much. On the other hand the impurity of air in an insulator affects the potential distributions and it weakens the insulator material. The new design of insulator proposed is with sharp curves to reduce chances of air as impurity and widen radius of central axis to handle the extreme stress.

REFERENCES

- A. Mekhadi, S. Bouazabia, "Conduction Phenomena on Polluted Insulating Surfaces under AC High Voltages," Ninth International Symposium on High Voltages, Subject 3, Paper No. 3174, Graz, Austria, September 1995.
- B. Hampton, "Flashover Mechanisms of Polluted Insulation," IEE Proceedings, Vol.111, pp. 985-990, 1964.
- B. Macchiaroli and F.J. Turner, "A New Contamination Test Method," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-88, pp. 1400-1411, September 1969
- C. K. Yuen, D Fraser, Digital Spectral Analysis, Pitman, East Melbourne, Australia, 1979.
- E. Nasser, "Some Physical Properties of the Electrical Discharges on Contaminated Surfaces," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-87, pp. 957-963, April 1968.
- F.Obenaus, "Kriechweguberschlag von Isolatoren mit Fremdschichten," Elektrizitatsirtschaft, Heft 24, pp 878-882, 1960.
- IEEE Std4-1995, IEEE Standards Techniques for High Voltage Testing, 1995.
- K. J. Lloydand H. M. Schneider, "Insulation for Power Frequency Voltage," Transmission Line Reference Book (345 kV and above), Electric Power Research Institute, Palo Alto, California, USA, 1982.
- L. Alston and S. Zoledziowski, "Growth of Discharges on Polluted Insulation," IEE Proceedings, Vol. 110, pp. 1260-1266, 1963.
- M. Kawai, "Research at Project UHV on the performance of Contaminated Insulators Part II: Application to Practical Design," IEEE Transactions on Power Apparatus and Systems, pp. 1111-1120,

- Peter Sydenham, Signal Processing for Industrial Diagnostics, Elsevier, London, 1996.
- R. Sundarajan and R. S. Gorur, "Dynamic Arc Modelling of Pollution Flashover of Insulators under DC Voltage," IEEE Transactions on Electrical Insulation, Vol. 28, No. 2, pp. 209-218, April 1993.
- Stanislav B. Kesler, Modern Spectrum Analysis II, IEEE Press, 1988, USA.
- T. J. Looms, Insulators for High Voltage, Peter Peregrinus Ltd., London, United Kingdom, 1988.