Electric Field and Potential Distributions due to Water Droplets and Water Film Formation on the Surface of Polymeric Insulators

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Abstract: This paper investigates the electric field and potential distribution along the surface of polymeric insulators under wet condition. The field enhancement due to water droplets on the surface of insulator is studied by means of computational simulations. The effect of increase in number of droplets and water film formation on the surface of insulator is studied through boundary element method. The results show that the field enhancement due to water drops along the surface of insulator is considerable and reaches to the extent of corona formation thereby ageing of insulator.

Keywords: Polymeric Insulator, Electric Field, Water drops, Hydrophobicity, Ageing.

I. INTRODUCTION

The use of polymeric insulators is increased significantly over the years because of their superior performance over ceramic insulators due to hydrophobic property under pollution conditions. The other advantages of polymeric insulators include lower weight, higher mechanical strength, reduced maintenance and high resistance to vandalism. The high surface resistance due to hydrophobic nature of the polymeric insulators reduces with service in field and results in ageing under pollution conditions. The water droplets play major role in pollution flashover and ageing of insulators because of their high permittivity and conductivity. One of the ageing mechanisms responsible for the failure of the insulators is discharges on the surface of the polymeric insulators. Under rain and fog conditions, the presence of water droplets intensifies the electric field strength on the surface of a polymeric insulator. As a result, the surface corona discharges from water droplets accelerate the ageing of the shed material of polymeric insulator.

II. INSULATOR MODELLING

In order to study the effect of water drops on the surface of insulator, a 3D modelling method using coulomb software is employed. Voltage, electric field distribution are examined with the simulation results.

The basic design of polymeric insulator consists of fibre reinforced plastic (FRP) core covered with silicone rubber weather sheds and equipped with metal end fittings with relative dielectric constants such as 6, 4.5, respectively. The lower metal fitting is energized with 19 kV AC and upper metal fitting is connected to ground.

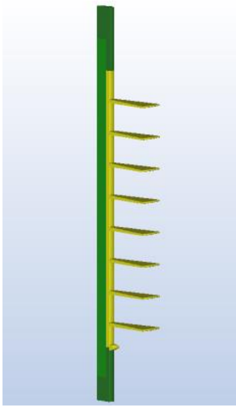

FIG.1. POLYMERIC INSULATOR MODELLING

There are two regions of interest for the study of electric field distribution-

1) On the surface of shed
2) On the surface of sheath

A. On the surface of shed:

Water drops on the surface shed are modelled as shown in the figure. An array of 20µl water droplets are modelled on the surface of each shed of the polymeric insulator. The permittivity of water drops is 80.

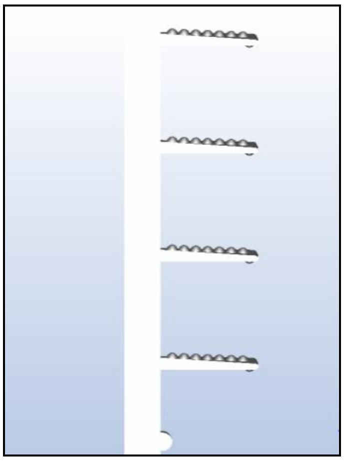

FIG.2. WATER DROPLETS ON THE SURFACE OF SHED OF INSULATOR

B. On the surface of sheath:

An array of 20µl water droplets are modelled on the surface of sheath between two sheds of the polymeric insulators as shown in figure below.

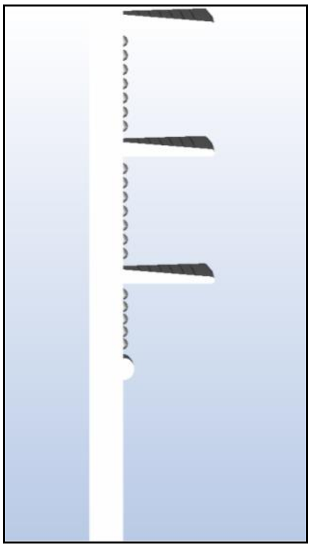

FIG.3. WATER DROPLETS ON THE SURFACE OF SHEATH OF INSULATOR

C. On the surface of sheath as well as shed:

An array of 20µl water droplets are modelled on surface of each shed and on the surface of sheath between two sheds of the polymeric insulators as shown below.

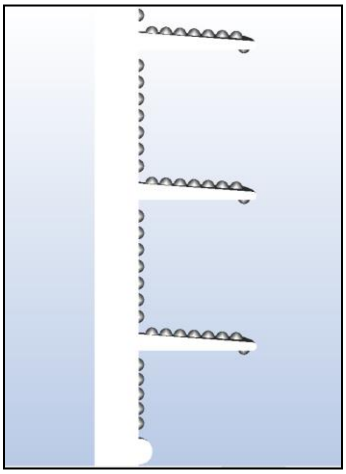

FIG.4. WATER DROPLETS ON THE SURFACE OF SHEATH AND SHED OF INSULATOR

D. On the surface of complete insulator:

An array of 20µl water droplets are placed on the top surface as well as bottom surface of the each shed and on the surface of sheath between the sheds of the insulators as shown below.

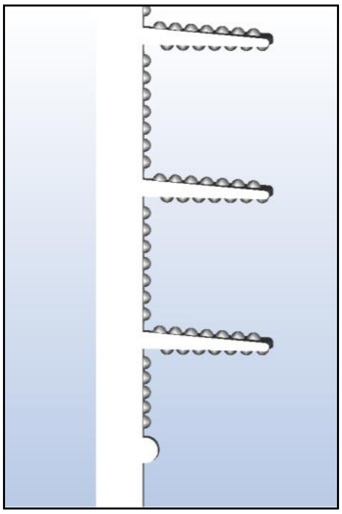

FIG.5. WATER DROPLETS ON THE SURFACE OF COMPLETE INSULATOR

III. WATER FILM FORMATION ON THE SURFACE OF INSULATOR

The state of water film formation on the surface of polymeric insulator is evident even insulator losses its hydrophobic nature completely or it can be called as insulator is of HC 6 class as per STRI guide for hydrophobicity classification. Hence to study the effect of water film on the surface of polymeric insulator, a thin layer of water film of thickness 0.1 mm is considered on the surface of polymeric insulator as shown below.

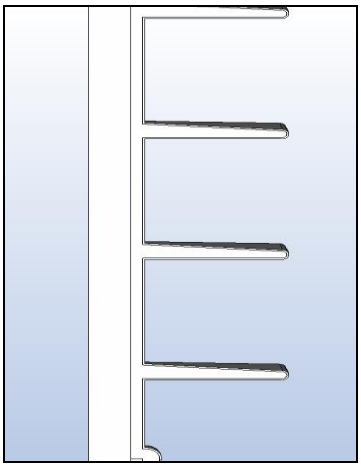

FIG.6. WATER FILM ON THE SURFACE OF INSULATOR

IV. RESULTS

The results in fig.7 show that, with the increase in number of water droplets on the surface of insulator there is increase in the magnitude of electric field and the increase of water droplets also causes non-uniformity in electric field distribution.

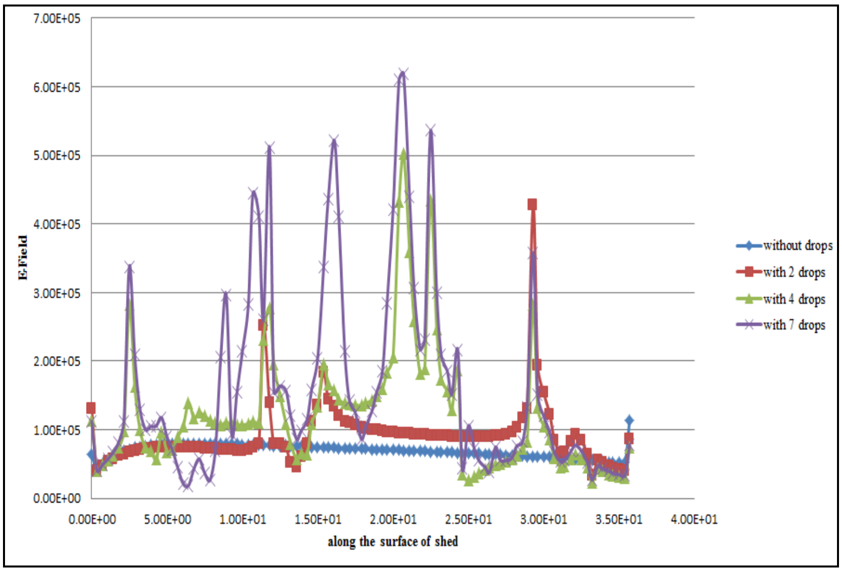

FIG.7. ELECTRIC FIELD VARIATION ALONG THE SURFACE OF SHED WITH INCREASE OF WATER DROPS

The comparison of water film formation on the surface of insulator and insulator completely wet with water droplets modelled all over the surface gives the comparison of behaviour of insulator in hydrophilic and hydrophobic cases respectively. The variation of electric field for the above mentioned cases is shown in fig.8.

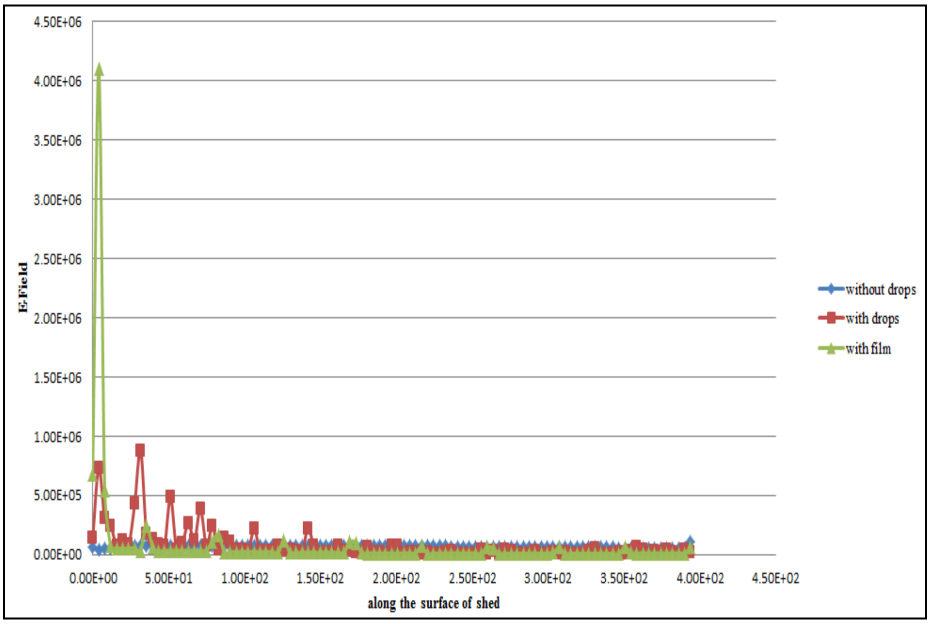

FIG.8. ELECTRIC FIELD VARIATION ALONG THE SURFACE OF SHED FOR INSULATOR WITH WATER DROPS AND WATER FILM

It is evident from results shown in fig.8. that electric field due to water film formation is highest when compared to water droplets on the surface of insulator and exceeds the air breaking strength of 30 kV/cm.

The fig.10. shows the comparison of electric field variation on the insulator with water droplets and water film on the surface of sheath. Though the electric field due water film formation is highest, the electric field due to water drops is also near to the air breaking strength. This shows that discharges may be higher on the sheath region of the insulator and the prolonged discharges may results in damage the insulator through ingression of moisture onto the surface of FRP rod. Such ingression is a result of material ageing and the force which drives the moisture ingression is named as electrohydrodynamic force.

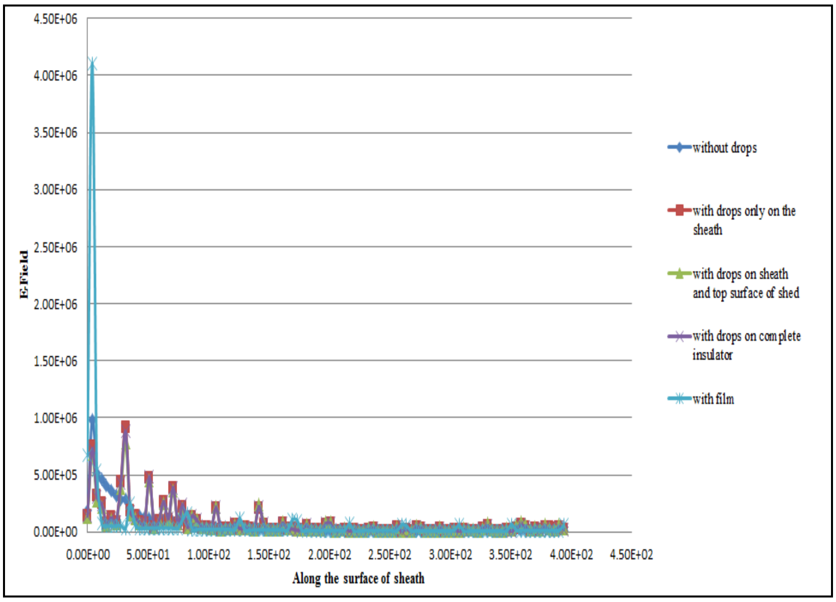

FIG.10. ELECTRIC FIELD VARIATION ALONG THE SHEATH OF INSULATOR

V. CONCLUSION

From the results of the simulation studies conducted on polymeric insulators with water droplets and water film the following conclusions can be drawn:

a) The electric field on the surface of complete insulator with water droplets and water film can be evaluated on a section of an insulator.

b) Electric field and potential distribution in water droplets on the surface of insulator is a function of droplets number and their position. Hence higher discharges are expected for the surfaces covered with more number of water droplets due to higher field concentration.

c) The difference observed in the electric field enhancement for hydrophobic and hydrophilic cases through simulation of polymeric insulator suggests that the discharge activity could also differ for hydrophobic and hydrophilic cases.

The electric field enhancement on the surface of sheath in both hydrophobic and hydrophilic cases observed through simulation suggests higher discharge activity and could result in electrohydrodynamic force that helps moisture ingression into the body of insulator.

ACKNOWLEDGMENT

The authors wish to thank technicians and management of UHVRL, CPRI for helping and permitting to publish this paper. The first author hereby thank VTU Belgaum, for permitting to carryout this research work as a part of M.Sc. Engg. (by research) work.

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