# Estimation of Electrical Performance of a Polymer Insulator with Deposited Moss on the Surface under Impulse Voltage Condition in Foggy Weather

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***Abstract*— This paper presents a study about electric field behaviour of 10kV polymer insulator with moss deposition under foggy condition. The aim of this simulation experiment was to determine if this field affect the initiation of pollution flashover. To study this effect, simulations were carried out using High Frequency Structure Simulator (HFSS). The simulation experiment includes the results of electric field distribution along the insulator and also the magnitude of electric field at three different locations in identifying the parts of the insulator's surface that likely to initiate pollution flashover. The moss deposited polymer insulator displayed uniformed and considerably intense distribution of electric field with the clean insulator. The field result showed the likelihood in discharging a corona effect. In short, the results indicated that electric field along the insulator surface would likely be influenced by moss deposition and foggy air.**

**Keywords: Polymer insulator; Moss Deposited; Electric Field**

## I. INTRODUCTION

An insulator is a material that restricts electrical current. It restricts the path of the current and forces it to follow a path on a conductor. An insulator also acts as protection, such that in an overhead electrical system, an insulator is a must-have component. It protects by preventing unwanted flow of current to the earth from the overhead conductors through the grounded towers or poles.

The most common and widely used type of insulator is the polymer insulator. A virgin polymer insulator resists any wetting due to its inherently hydrophobic material and still retained its advantages such as better vandalism and contaminated resistances [1,2,3]. But as years of services and installations gone by, the insulator starts to age and wear out due to the constant exposure of the outside harsh weather and pollution. The level and type of pollution and weather phenomena varies and are associated with the region of the installed insulators. According to the Edison Electric Institute, 70% of power outages in the United States (U.S.) are weather related. These can be caused by natural weather phenomena such as lightning, rain, snow, ice, wind and even dust [4-6]. Even dampness and excessive moisture can also lead to serious damages. In areas with high levels of humidity, the chances of polymer insulator being affected by bio-contamination growth are high.

A number of reports have surfaced from Uruguay, Tanzania, Sri Lanka, Germany, USA (Texas, Georgia, and Florida), Columbia, Japan and Sweden [5-8] concerning visible greenish, blackish and sometimes brownish spots on the surface of a polymer insulator, causing a drop in the withstand level of the wet and dry flashovers and an increase in the leakage current [6-7,9]. These spots have subsequently been identified as algae, lichen, moss, mould or fungal growth [5-8], which are biological-contamination-types typically found in a tropical environment with high rainfall, high humidity, intensive sun radiation and elevated temperature [5-6,8]. When these bio-contaminates colonise the surface of the insulators, they will impeded the drying of the surface and there is a possibility of increasing the degradation of the insulators through secreted enzymes [6,9,10].

Lichens and algae may appear harmless and it can be supposed that the risk of insulator flashover of biologically contaminated insulators under natural field conditions is perhaps not too great as these two symbiotic organisms mainly grow in a clean environment [11], with a low growth rate that can take more than a year [12] to extend over a large area due to the availability of high humidity and temperature. However, the problem soon arises when these biological elements die and form a greasy layer on the insulator surface. When this greasy layer becomes damp again, a layer of dry bands can appear and this may lead to a flashover event on the insulators [13].

In addition, lichens and algae do not penetrate the surface but as they grow on the surface of the polymer insulator, this will set free organic acids especially oxalic acid, which is capable of damaging the surface of the insulator [11,13] and changing the properties of the

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insulator such as reducing the wet flashover voltage. This effect has been reported by many researchers. For example in Tanzania, algae has been observed growing on silicone rubber on a 33 kV distribution line and this caused the withstand levels to decrease by 20 to 30 % under wet conditions [12]. In Sweden, lichen growth on a 11 kV distribution line silicone rubber insulator affected and reduced the wet flashover voltage level by approximately 30 % [12].

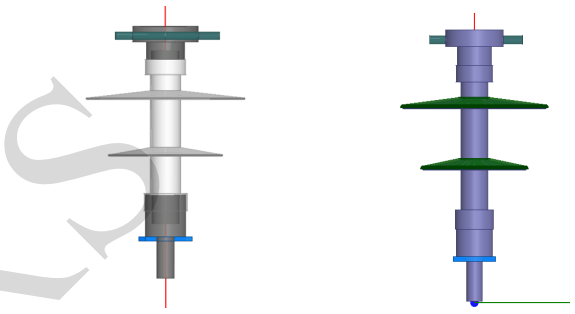
Under laboratory setup and observation, algae indeed exhibits a reduction of silicone rubber wet flashover voltage levels as experimented by S. M Gubanski et al. [11] and H. E. Rojas et al. [14]. S. M. Gubanski et al. experimented on a silicone rubber insulator and reported a 20 to 30 % reduction in the wet flashover voltage, while the experimental results of H. E. Rojas et al. indicated a 3 % wet flashover voltage reduction but stated an increase of leakage currents by up to 60 %. The same experience was reported in Germany and Florida under natural field conditions in which both studies reported an increase in the leakage current due to a bio-contamination growth on the insulator with Germany reporting an increase of up to three times higher during wet conditions compared to dry conditions [12]. This is due to the fact that bio-films (colonisation effects) have an ability of retaining almost 80 to 95 % water on the insulator surface, which results in an increase in the leakage current levels under wet conditions [12,15].

Fungi growth can be hazardous as its roots, the mycelia, can penetrate into polymer materials and create a porous structure on its surface [11,13]. In recent research, a polymeric insulator contaminated with mould in the form of a microscopic fungus in the presence of fungal mycelia and green algae was studied by A. F. Leon et al. [16]. They found that the mould contamination on a polymer insulator not only reduced the dry flashover voltage to between 12 to 16 % but also increased the leakage current at an average of 14 %. This was consistent with the findings of R. S. Gorur et al. [17]. Under electrical tests performed on a silicone rubber insulator (SiR) and ethylene propylene rubber (EPR) insulators to determine the surface resistance measurements and to evaluate the contamination withstand capability (CWC), it was concluded that there was a reduction in the CWC when compared with the same insulator but without the mould. Moreover R. S. Gorur et al. stated that the reduced CWC level was not a concern as it was still higher than the EPR insulator that had no visible growth of the mould.

In short, most research efforts are concentrated on understanding the aging of composite insulators and the flashover mechanism from the effects of the applied voltage but not under a lightning flashover process. The aging and the flashover mechanism resulting from the dry band formation of polymer insulators up to the arcs established at the incomplete icicle bridge of the iced polymer insulators have also been studied and are well understood, as well as research on various factors accelerating the aging and influencing the flashover of polluted polymer insulators. However, the impact of bio-contamination on polymer insulator performance is yet to be fully understood as the growth of any bio-contamination is influenced by the climate and location of the installed polymer insulation.

## II. Specifications of Polymer Insulator

The evaluated polymer insulator was a composite insulator FPQ-10/4T16 with two sheds and its full specification is as shown in Table I. Table II shows the material and air parameters used in simulating the experiment. In this study, a layer of moss deposition on the surface of the insulator (Fig. 1) was artificially prepared within 15 months and its electrical parameter is as shown in Table II. On the other hand, in order to find the range of breakdown voltage to be used in this study, this affected insulator was tested in a fog chamber in a high voltage lab and the range of breakdown voltage were recorded at 230kV to 240kV. The results generated from the simulation experiment were based on a voltage excitation within the breakdown voltage and by the shape of a standard impulse voltage as shown in Fig. 2.



(a) Clean insulator (b) Contaminated insulator

Fig 1: The polymer insulator modelled in HFSS

Table I. Technical Specification of a 10kV Polymer Insulator

| Specification of 10kV polymer insulator | |
|---|---|
| **Parameter** | **Value** |
| Rated Voltage (kV) | 10 |
| Structure Height (mm) | 215 |
| Arcing Distance (mm) | 125 |
| Creepage distance (mm) | 300 |
| Shed Diameter (mm) | 148/118 |
| Lightning impulse withstand voltage (peak) ≥ kV | 105 |
| 1 min power frequency wet withstand voltage (peak) ≥ kV | 42 |

Table II. Material and Air Parameters

| Object | Relative permittivity (εr) | Bulk conductivity (σ) S/m |
|---|---|---|
| Fittings | 1 | $1.67 \times 10^{6}$ |
| Core | 5 | $1 \times 10^{-12}$ |
| Sheds | 3 | $1 \times 10^{-17}$ |
| Foggy Air (80 to 90% moisture) | 1.0008 | $2.25 \times 10^{-14}$ |
| Moss | 1.54 | 26.52585 |

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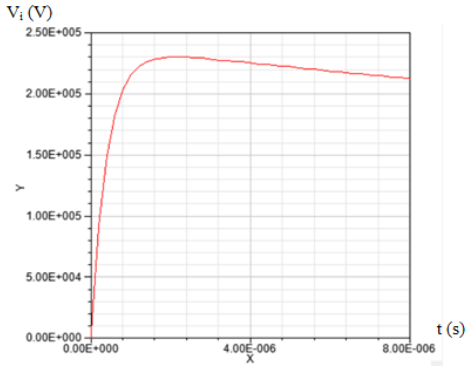



Fig 2: The voltage excitation wave shape

## III. RESULTS AND DISCUSSION

In generating a simulation analysis on the effects of moss contamination on the surface of a polymer insulator under transient conditions and foggy weather, numerical technique called the Finite Element Method (FEM) was applied. For this study, software named High Frequency Structure Simulator (HFSS) was used in analysing the electric field generated by a voltage impulse.

In searching for the relationship between the electric field has upon any pollution flashover ignition, this research was divided into two cases; Case 1: by studying the distribution of this field imposed along the insulator and Case 2: by studying the very location that showed the highest tendency of initiating the pollution flashover.

In analysing the insulator through FEM approach using the HFSS, the model should be meshed first as shown in Fig. 3. Fig. 4 shows the distribution of voltage and electric field for a clean insulator and Fig. 5 shows the distributions for moss deposited polymer insulator. They were simulated under 80 to 90% relative humidity (RH); the lowest plausible of RH that can trigger foggy air [18]; and were analysed at the maximum amplitude of the impulse voltage, 235kV (2.2μs). The findings can be summarized as follows:

### A. *Voltage Distribution*

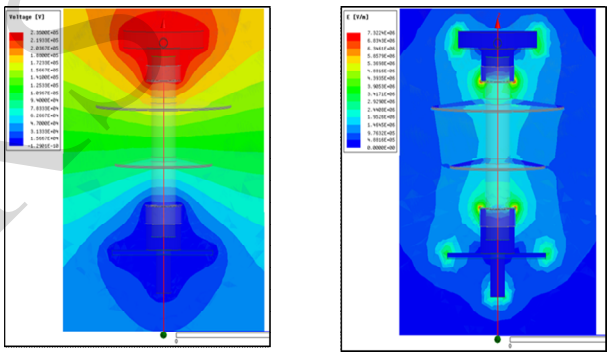
1) Both figures (Fig. 4(a) and Fig. 5(a)) shows an almost similar distribution with high intensity was spotted at the line end as it coincident with the location of the lightning strike. It was 235kV before decreasing to 0V as it propagated downward acknowledging the significant of placing a lower shed. This smaller diameter of the lower shed helps to prevent any continuous conduction thus giving an expression that the moss deposition does not influenced any insulator breakdown.

### B. *Electric Field Distribution*

1) In figures (Fig. 4(b) and Fig. 5(b)), a bright spot was seen at the edge of the seal – sheath region with a range of magnitude between 5857.9kV/m to 7322.4kV/m and 4183.6kV/m to 5229.5kV/m, respectively. However, Fig. 5(b) has a more significant bright speck wrapped in a 2440.5kV/m field (represented by the lime green) at the upper seal - sheath region and lower seal – sheath region. Meanwhile for Fig. 4(b), it displayed a very much alike SPPs pattern. Surface Plasmon polariton (SPPs) is a type of surface wave guided along a metal surface similarly to a light is guided along an optical fibre but with a shorter wavelength [19]. With a field of 2440.8kV/m, it was considered weak for a corona discharge to happen; an aftereffect of an air field breakdown.

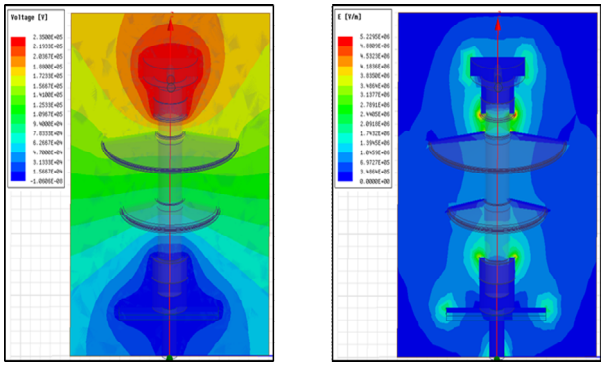
*2)* As fog contains 0.5ml of water per cubic metre and usually forms at 100 feet (30 metres) to 300 feet (90 metres) above ground and builds downward [20]; the field generated must exceed the earth surface field which is 100V/m to allow a corona discharge [18]. Nevertheless, bear in mind that the field is increased by 11% with an additional of 1% water vapour in air [20]. In short, a moss deposition on a polymer insulator would likely initiate a pollution flashover if it succeeded breaks the surrounding air field threshold.

Furthermore, the intensity of these fields was later analysed through three selected locations on the surface of the insulator as shown in Fig. 6. This intention was to analyse which part of the insulator was more prone to initiate the pollution flashover.



(a) Voltage (b) Electric field

Fig 3: The behaviour of the electric field and voltage distribution of a clean insulator under foggy weather conditions



(a) Voltage (b) Electric field

Fig 4: The behaviour of the electric field and voltage distribution of a contaminated insulator under foggy weather conditions

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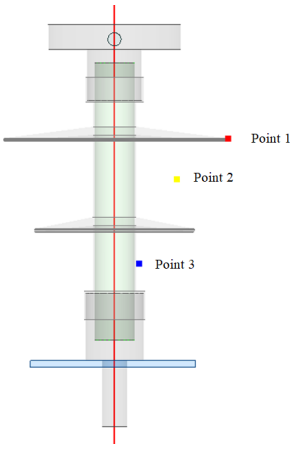



Fig 5: Observation points at three critical locations of a polymer insulator

TABLE III. COMPARISON BETWEEN THE ELECTRIC FIELD OF A CLEAN AND CONTAMINATED INSULATORS UNDER FOGGY WEATHER CONDITION

| AIR CONDITION | POINT | CLEAN | CONTAMINATED |
|---|---|---|---|
| Foggy air (90 %) (kV/m) | 1 | 600.814 | 766.860 |
| | 2 | 1195.066 | 1707.063 |
| | 3 | 2338.580 | 1183.274 |

TABLE IV. COMPARISON BETWEEN THE VOLTAGE DISTRIBUTIONS OF A CLEAN INSULATOR UNDER FOGGY WEATHER CONDITION

| AIR CONDITION | POINT | CLEAN | CONTAMINATED |
|---|---|---|---|
| Foggy air (90 %) (kV) | 1 | 149.765 | 171.708 |
| | 2 | 128.025 | 133.390 |
| | 3 | 49.499 | 38.169 |

By referring to Fig. 6 and Table III, Point 3 of clean insulator and Point 2 of contaminated insulator have the most stress for the electric field distribution. But within those twos, clean insulator was the highest with 2338.550kV/m. Even though, contaminated insulator displayed a much lower electrical stress compared to Point 3 of clean insulator, but it was the highest for the contaminated insulator. As Point 2 position was in mid-air showed that the interaction of this weather does indeed affected the contaminated insulator. And as the field was distributed downward, it led to a discontinuity of the magnitude strength as it passed through the shed, withheld any possible of initiating a pollution flashover.

By referring to Fig. 6 and Table IV, under the influence of foggy air condition and 235kV impulse stress, Point 1 has the highest stress concerning of voltage distribution for both insulators. But within those twos, Point 1 of contaminated insulator has the highest magnitude with 171.708kV. This may cause by its location to be the nearest to the impact point compared to the other points. On the other hand, Point 3 for both insulators had the lowest stress. Point 3 was located on the lower shed of the insulators. If smaller diameter shed promotes discontinuation and prevention of any conduction and leakage current thermal effects; if that was the case, Point 3 would be the best exemplary reaction. With that, a likelihood of a voltage breakdown due to moss deposition was prevented by placing a smaller shed on the lower part of the insulator.

In short, through these analyses by having a uniformly distributed layer of moss deposition on the surface of the polymer insulator under a foggy weather condition, the electric field concentration was forced to slightly increase for both cases. Furthermore, the magnitude of electric field of the contaminated insulator was still considerably than the threshold and the odd of initiating a pollution flashover is still high. This study showed that the moss deposition on the surface of the polymer insulator have a significant role of influencing an initiation of surface arcing.

## IV. CONCLUSION

This research has attempted to assess the behaviour of electric field of a moss deposited polymer insulator in terms of its ability in influencing the initiation mechanism of pollution flashover due to lightning strike under foggy weather. In the first case, which was to examine the distribution of the field by comparing two similar insulators with and without the moss deposition, it can be concluded that electric field along the insulator surface were considerably affected by pollution severity provided that the moss was modelled in uniformly manner. On the other hand, in the second case which was to examine the location that might have the highest tendency of initiation pollution flashover was Point 3 of the clean insulator. It seems clear that both cases were able to explain numerically the behaviour of this field and its impact on the performances of the moss deposited polymer insulator. Therefore, in forest areas, considering the environmental factors, these findings can be helpful in establishing the line stability against lightning effects. Finally, since this research was conducted under the wettest condition, it is intended in the future works to perform similar simulation under a polluted air condition and analysed the behaviour of the electric fields and its impact on initiating any pollution flashover.

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