The Electrical Behaviour of a Medium Voltage Polymer Insulator with Deposited Moss Layer on the Surface

F A Abd. Rahman, M Izadi, M Z A Ab. Kadir, M Osman

Abstract: This paper presents a study on the voltage and electric fields behaviours of a 10kV polymer insulator with moss deposited under dry (air) condition. The aim of this study is considering on the electrical behaviour of insulator by having a surface layer of moss on it that can change the withstand voltage of insulators. It should be mentioned that these moss layers are commonly crated in the jungles especially in the tropical countries. To study on the above mentioned case, simulations were carried out using ANSYS High Frequency Structure Simulator (HFSS). The simulation insulator modelling includes the computerized evaluation of voltage and electric field distribution at three different locations for both clean and moss contaminated insulators. Noted that the electric field and also voltage profiles at different parts of insulators has been determined using applied simulated model. The moss contamination polymer insulator displayed a discontinuous distribution of the electric field compared to the clean insulator and their voltage distribution decreased with distances from the source. The results indicated that electric field along the insulator surface were greatly affected by hydrophobicity characteristic of the polymer. Therefore, the surrounding air of the moss contaminated insulator was prone to initiate a flashover. This study can be helpful for designing the distribution lines especially in high risk areas to set a proper design from the point of view of insulation coordination.

Keywords: Electric field, Polymer insulator, Tropical countries and Voltag

I. INTRODUCTION

Researchers from tropical climate countries have a keen interest in studying the impact of bio-contamination has on the electrical performance of a polymer insulator. Bio-contamination thrives well in this kind of climate. Consequently, it is important to consider the local bio-contamination issue when designing new power lines.

Several researches have been reported from USA, Columbia, Uruguay, Japan, Germany, Tanzania, Sweden and Sri Lanka [1-5] about an apparent greenish spot, sometimes blackish or brownish visible on the surface of a polymer insulator, have the influential towards the withstand level of flashovers (dry and wet) moreover influencing the increment of the leakage current [2,4,6]. Later, they were classified as the commonly tropical biological-contamination-types such as moss, algae, mould (fungal) and lichen [1-4]. As 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 deposit enzymes [2,5-6]. The research gap among previous research refers to considering the abovementioned case under lightning conditions.

Many reports have cited the effects of these bio-contaminates, and yet researchers are still unclear as to how much the growth of these contaminates can affect the performance of polymer insulators under high humidity conditions, let alone under natural field conditions. Thus, it is necessary to perform thorough research and share the findings with the community of researchers.

Malaysia is a country that is blessed with heavy rainfall; humidity that reached an all-time high, harsh sun radiation and lofty temperature. All these conditions encourage biological growth within the territory [1-2,4]. Further, the occurrence of lightning in Malaysia is among the highest levels recorded in the world [7]. Therefore, considering the impact of the bio-contamination materials has in terms of its electrical performance under impulse lightning voltage conditions can be helpful in increasing the line stability level. This research considers the case of a clean and moss contaminated insulators in points of view and the results will be explained and discussed accordingly.

II. DETAILS RELATED WITH THE BIO-CONTAMINATION PROCESS

Specifications of applied Polymer Insulator

FPQ-10/4T16 with two sheds was chosen to be evaluated in this study. It was a composite insulator with two sheds and Table 1 shows its full specifications.
Table 1 Technical Specification of FPQ-10/4T16

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

Green Wet Moist Moss

The selected moss was the green wet moist moss which is very common in Malaysia’s rainforest as shown in Fig. 1. The conductance of the moss was calculated through a 0.02m x 0.02m x 0.02m square casing as shown in Fig. 2. It should be mentioned that the electrical parameters had been evaluated using RLC meters in different frequencies and the measured values had been converted to the required parameters in the simulation model like conductivity, permittivity and permeability.

Table 2 The condition of and material specification

| Object                          | Relative permittivity (εr) | Bulk conductivity (σ) S/m |
|---------------------------------|---------------------------|---------------------------|
| Fittings of Insulator[8]        | 1                         | 1.67x10^6                 |
| Core of Insulator[8]            | 5                         | 1x10^{-12}                |
| Shed of Insulator [8]           | 3                         | 1x10^{-17}                |
| Dry Air (20 °C) [9]             | 1.000536                  | 8x10^{-15}                |
| Moss                            | 1.54                      | 26.52585                  |

Fig. 1 Green Wet Moist Moss

Fig. 2 0.02m x 0.02m x 0.02m square case

Simulation Setup and Test Procedures

A numerical technique called the Finite Element Method (FEM) was applied in the applied software. Software named ANSYS High Frequency Structure Simulator (HFSS) was used in analysing the voltage and electric field generated by the lightning. There are six main steps to creating and solving a proper HFSS simulation. They are:

1. Create model/geometry
2. Assign boundaries
3. Assign excitations
4. Set up the solution
5. Solve
6. Post-process the results

Modeling

In creating a model in HFSS, a cross sectional drawing of the polymer insulator was done in AutoCAD before imported it into HFSS. In HFSS, the cross sectional drawing was swept around axis-Z to transformed it into 3D modellers as shown in Fig. 3. This 3D modeller is fully parametric and will allow a structure that is variable with regard to geometric dimensions and material properties being created. The polymer insulator with the technical specification is summarized as in Table I; while in Table 2 are the material parameters. A moss deposition of 0.002m was also drawn on the surface covering shed surfaces of the polymer material.

Boundaries

A square box was created with the insulator inside it. All 6-face of the box was highlighted and set as boundaries for this study. These boundaries are used to decrease the geometric or the electromagnetic complexity of this insulator as shown in Fig. 4. And inside the boundaries, there was another square box in representing the air-type being studied, which was dry as shown in Table 2.
Excitation

A voltage excitation of lightning (235kV) was injected onto the strip of the conductor simulating a strike has happened as shown in Fig. 5. The lightning wave shape is as shown in Fig. 6.

Solution Setup

After the boundaries and excitations were set, next was setting the solution setup. This setup comprises of setting up convergence criteria, maximum number of adaptive steps to perform, with the value of end time and starting time of saving and ending each fields as shown in Table 3. After all of the settings were done, the model was analysed. And the resulted fields were as shown in Fig. 8 – Fig. 9.

Table 3. Solution setup settings

| Setup                      | Setting value |
|----------------------------|---------------|
| Convergence Refinement     | 30            |
| per pass                   |               |
| Minimum Number of Passes   | 2             |
| End time                   | 8 µs          |
| Initial Step               | 0.2 µs        |
| Maximum Step               | 0.5 µs        |

III. SIMULATION RESULTS AND DISCUSSION

In the quest of finding the relationship between the electric and voltage fields have upon any flashover ignition due to pollution, this research was divided into two cases; Case 1: to study the impact of these fields imposed along the insulator and Case 2: to study the exact location that has the highest probable of initiating the pollution flashover.

Figure 7 shows the meshed model as it is requirement by the ANSYS as the insulator was analysed through FEM approach. Electric and voltage field distribution of insulator either with or without the presence of moss contamination under dry air can be seen in Fig. 8 and Fig. 9.
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Fig. 8: The properties of the voltage (a) and electric field (b) of a clean insulator

Fig. 9: The properties of the voltage (a) and electric field (b) of a moss contaminated insulator

Fig. 10: The selected observation points

Table. 4 Comparison between the voltage distributions of a clean and moss contaminated insulator under dry air conditions

| Point | Clean Dry air (kV) | Moss Contaminated Dry air (kV) |
|-------|-------------------|-------------------------------|
| 1     | 149.765           | 171.707                       |
| 2     | 128.025           | 133.390                       |
| 3     | 49.498            | 38.168                        |

Table. 5 Comparison between the electric field of a clean and moss contaminated insulator under dry air conditions

| Point | Clean Dry air (kV/m) | Moss Contaminated Dry air (kV/m) |
|-------|----------------------|----------------------------------|
| 1     | 600.787              | 766.856                          |
| 2     | 1195.090             | 1707.073                         |
| 3     | 2338.550             | 1183.264                         |
Figure 8 and Figure 9 show the properties of electric and voltage fields for both the moss contaminated and clean insulator under a 20°C temperature at 235kV lightning voltage. In Fig. 8(a) the voltage distribution from the polymer insulator was highly intense at the line end when it was struck by a 235kV impulse source. But as it propagated downwards, the level of the voltage decreased from 235kV to only 58.698nV. This was as a result of a smaller diameter of the lower layer of the shed compared to the upper layer which prevent any continuous conduction [10]. Moreover, a smaller lower shed layer also hinders any leakage current thermal effects; let alone to cause insulator flashover.

On the contrary, the electric field in Fig. 8(b) showed no significant intensity to raise an alarm, except there was a fringe field at the junction: sheath-shed and surrounding air interface; with a magnitude of 5857.1kV/m. Likewise at the boundary between the conductive metal end fitting and the surrounding air displayed a peculiar phenomenon known as surface plasmon polariton [11]. Surface plasmon polariton (SPPs) is a surface wave that is guided along a surface of a metal equally to that guided light along an optical fibre but with a shorter wavelength [12]. But with the deposition by moss on the surface of the polymer, the pattern of the electric field seems to counteract the electrical field that built up should be more than 3000kV/m for that corona discharge to happen. 3000kV/m is the electrical breakdown limit for dry air. Therefore, having a layer of moss deposition on a polymer insulator surface under a dry weather, the moss deposition was uniformly distributed forcing the electric concentration to decrease.

**IV. CONCLUSIONS**

This research has attempted to assess the behaviour of insulators with moss contamination on surface in terms of pre-processing for starting of flashover due to lightning strike and comparing the results obtained from the corresponding clean insulator. The two attributes that were analysed were voltage and electric field. In the first case, which was to examine the distribution of the two attributes by comparing two similar insulators with and without the moss deposition, it can be concluded that the electric field along the insulator surface were greatly affected by hydrophobicity characteristic of the polymer. As this case was studied under the dry air conditions, thus for a similar case studied under difference weather conditions the results would likely be differ. On the other hand, in the second case which was to examine the very location of might be has the highest tendency of initiation pollution flashover was the Point 2 (the weather surrounding the insulator). It seems clear that both cases were able to explain graphically the behaviour of these two fields and their impact on the performances of the moss deposited polymer insulator. Finally, since this research was conduct under the dry condition, it is intended in future works to perform a similar case but different environment condition and analysed the behaviour of these two fields and their impact on initiating any pollution flashover.

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