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On the behaviour of polymer insulator with deposited moss on the surface against lightning in polluted air condition

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Abstract— **Deposited moss on the surface of polymer insulators can be effective on the electrical performance of insulator and network as well. This problem can be sensed especially in the forest areas and tropical countries. In the tropical countries like Malaysia beside of local factors for creation of moss on the surface of insulator, the air pollution plays an important role as well. In this study a 10kV polymer insulator has been chosen an the electrical performance of insulator against lightning was considered through both simulation and experimental works and the results have be discussed accordingly. The results show that the contaminated insulator have different behaviour against lightning and in order to reach a proper insulation level for line , the local factors should be taken into account.**

Keywords: Polymer insulator; Moss; Electric Field ;Lightnig

I. INTRODUCTION

An insulator is an essential component in power transmission and distribution networks as it serves as a mechanical support for power lines. The outdoor insulators also act as front line protection by preventing any unwanted flow of current to earth via the supporting structure. However, this feature is dependent on the rate of environmental pollution deposited on the surface of an insulator, which tends to mask its performance. There are at least six known factors of environmental pollution, namely, temperature, UV radiation, altitude, rain, icing and pollution. Moreover, the local factors especially in the tropical countries can prepare a proper domain for growing the moss on the surface of insulator and combination of this additional layer with existing pollution in the air can change the electrical behavior of insulator especially in the lightning case. Therefore, the main aim of this study has been set on the mention objective.

A number of reports have been presented from Uruguay, Tanzania, Sri Lanka, Germany, USA (Texas, Georgia, and Florida), Colombia, Japan and Sweden [1-4] 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 [2-5]. These spots have subsequently been identified as algae, lichen, moss or fungal growth [1-4], which are biological-contamination-types typically found in a tropical environment with high rainfall, high humidity, intensive sun radiation and elevated temperature [1-2,4]. When the bio-contaminates cover the surface of the insulators, they electrical surface pattern of insulator will be changed and it should be considered as a new case [2,5-6]. 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 [7], with a low growth rate that can take more than a year [8] 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

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again, a layer of dry bands can appear and this may lead to a flashover event on the insulators [9]. 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 [7,9] and changing the properties of the insulator such as reducing the wet flashover voltage. Many other researchers have reported this effect as well, for instance 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 [8]. In Sweden, lichen growth on a 11 kV distribution line silicone rubber insulator affected and reduced the wet flashover voltage level by approximately 30 % [8].

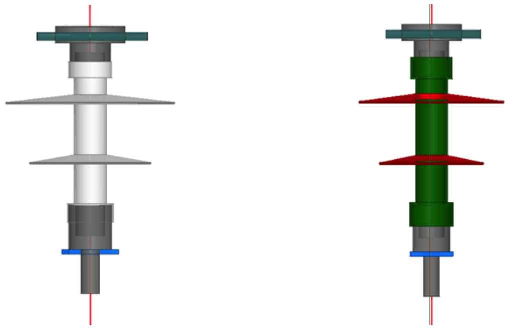
Under laboratory setup and observation, algae indeed exhibits a reduction of silicone rubber wet flashover voltage levels as experimented by S. M Gubanski et al. [7] and H. E. Rojas et al. [10]. S. M. Gubanski et al. experimented on a silicone rubber insulator and reported a 20 to 30 % reduction in the 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 [8]. This is due to the fact that bio-films (colonization 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 [8,11].

Fungi growth can be hazardous as its roots, the mycelia, can penetrate into polymer materials and create a porous structure on its surface [7,9]. In recent research, a polymeric insulator contaminated with moss in the form of a microscopic fungus in the presence of fungal mycelia and green algae was studied by A. F. Leon et al. [12]. They found that the moss 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. [13].

In short, most research efforts are concentrated on understanding the contamination of polymer insulators and the flashover mechanism from the effects of the applied voltage but not under a lightning impulse voltage. It should be mentioned that Malaysia is also a tropical country that has the especial conditions that will make biological growth along the territory more probable as Malaysia is one of hot spots in the case of lightning occurrences.

II. SPECIFICATIONS OF POLYMER INSULATOR

The considered insulator is a composite insulator FPQ-10/4T16 with two sheds and its parameters has been shown in Table I. Table II illustrates the material and air parameters that have been used in the simulation and experimental work as well. In this study, a layer of moss deposition on the surface of the insulator (see Figure 1) has been prepared (in 15 months) and its electrical properties have been defined in Table II. It should be mentioned that the electrical parameters have been measured in the Lab. On the other hand, in order to find the voltage range, an experimental work has been done in HV lab as the breakdown voltage has been reported in the range 230kV ~ 240kV. Figure1 illustrates considered clean and contaminated insulators. Moreover, the standard impulse voltage wave shape (1.2/50 µs) was illustrated in Figure 2. Noted that the experimental work using impulse voltage had been done in the HV lab and clean insulator (without any contamination) and contaminated samples have been considered and the values of breakdown voltages have been evaluated and the results have been studied.



(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	$1.67x10^{6}$
Core	5	$1x10^{-12}$
Sheds	3	$1x10^{-17}$
Polluted Air	0.36	0.000007
Moss	1.54	26.52585

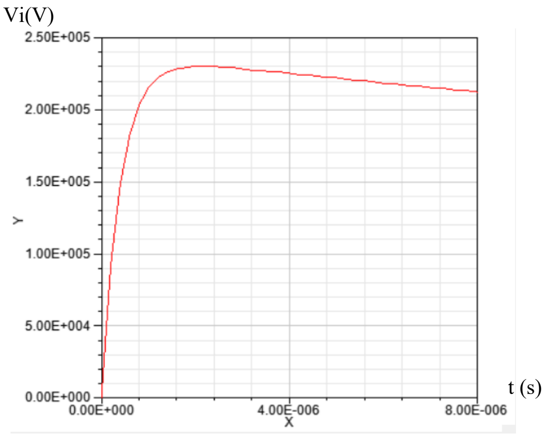


Fig 2: The excitation voltage

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 polluted 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 lightning voltage impulse.

Fig.3 illustrates the mesh model that has been used in the simulation as the sensitivity analysis on the mesh sizes had been done.

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. Polluted air condition was imposed in replicating the ambient stresses that leads to the reduction of the insulation strength. There are no standardized methods available at present for the polymer insulator's artificial pollution testing. Thus salt fog test was applied based on procedures as described in IEC60507 and IEC60060-1 standards which are intended for ceramic insulators. These works 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 4(a) and 5(a) show 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. This smaller diameter of the lower shed helps to prevent any continuous conduction.

B. Electric Field Distribution

1) In Fig. 4(b), the highest field concentration was at the seal to sheath junction with a range of magnitude between 6346.1kV/m to 7322.4kV/m. Furthermore with Surface Plasmon polariton (SPPs) pattern together with field intensity magnitude ranging 976.32kV/m to 1952.6kV/m, this clean insulator under the pollution air was likely to discharge the corona effect due to the pollution air dielectric breakdown is at 10kV/m [14]. If it was not because of the field breakdown was increased by 11% with an additional of 1% water vapour in air owing to the test conducted under wet polluted condition [15], the corona discharge was plausible. 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 [16].

2) On the other hand, the color distribution of the electric field for the contaminated insulator is different with the corresponding clean one. This can be seen in Fig. 5(b). What was previously a bright speck at the edge of the seal to sheath region had extended forming a stream of field strength from end to end of the shed. The stress was less severe compared to Fig. 4(b) which was around 6147.9kV/m to 8197.2kV/m. Furthermore, the air surrounding the insulator was calmer than previous, suggesting that probably the corona discharge was suppressed due to the hydrophobicity characteristic of the polymer that had been transferred to the surface of the moss.

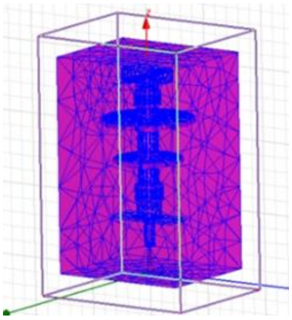
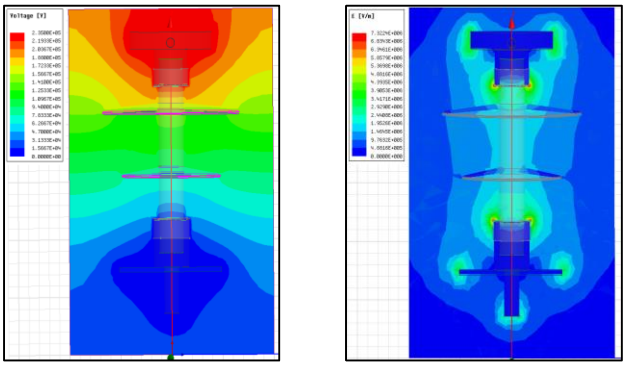
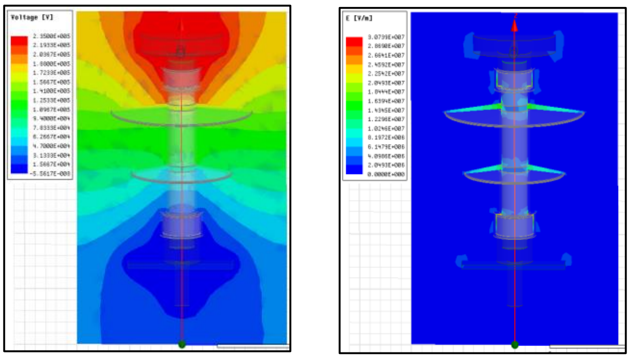


Fig 3: The mesh model in the simulation



(a) Voltage (b) Electric field

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



(a) Voltage (b) Electric field

Fig 5: The behaviour of the electric field and voltage distribution of a contaminated insulator(with moss on the surface) under polluted weather conditions

The evaluated values of electric field and also voltage at three observation points (see Fig.6) have been presented in tables III and IV, respectively.

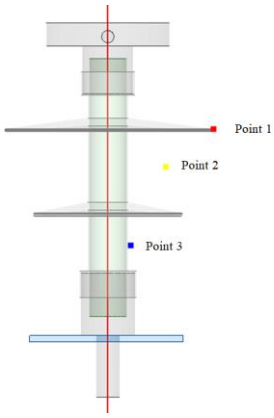


Fig 6: Observation points at three critical locations of a polymer insulator

TABLE III: COMPARISON BETWEEN THE ELECTRIC FIELD VALUES FOR THE CASES OF CLEAN AND CONTAMINATED INSULATORS UNDER POLLUTED WEATHER CONDITION

AIR CONDITION	POINT	CLEAN	CONTAMINATED (WITH MOSS)
Electric field (kV/m)	1	2557.882	2565.882
	2	532.215	1052.880
	3	274.775	809.309

TABLE IV: COMPARISON BETWEEN THE VOLTAGE VALUES FOR THE CASES OF CLEAN AND CONTAMINATED INSULATORS UNDER POLLUTED WEATHER CONDITION

AIR CONDITION	POINT	CLEAN	CONTAMINATED (WITH MOSS)
Voltage (kV)	1	146.808	149.685
	2	113.685	161.761
	3	55.605	104.016

Comparison between the evaluated values from above mentioned cases shows that the deposited moss could be effective on the increasing the values of electric fields and voltages at different observation points. It can be found out that the deposited moss can be effective on the discharge path and it can change the value of insulation level of line. Figure.7 demonstrates the experimental work that has been done in the high voltage lab and the corresponding discharge path. Noted that the considered insulator has been taken from existing network (service).

Fig 7: Flashover path of contaminated insulator during polluted air test

Moreover, Table V shows the values of breakdown voltages (U50%) under negative impulse voltage. The results show that the deposited moss on the surface has an effective impact on the values of break down.

TABLE V. BREAKDOWN VOLTAGE UNDER NEGATIVE IMPULSE VOLTAGE (POLLUTED AIR CONDITION)

VOLTAGE	CLEAN INSULATOR	CONTAMINATED INSULATOR (WITH MOSS)
BREAKDOWN VOLTAGE (KV)	186.5	168.5

In this study, the electrical behaviour of polymer insulator in presence moss on the surface has been studied and the influence of the moss layer on the electrical performance of polymer insulator has been considered. Therefore, in order to meet the proper insulation level for line, considering the local factors including the potential situation for growing moss on the surface and also air specification can helpful.

VI. CONCLUSION

In this study the influence of deposited moss on the surface of polymer insulator has been considered. The phenomenon plays an important role on the reduction of insulation level of distribution lines especially in tropical countries and forest areas. The behaviour of polymer insulator has been studied through both experimental and the simulation works. The result showed that the deposited moss on the surface could reduce the value of breakdown voltage. Noted that the polluted air was set as a basic assumption of present study. Therefore, considering the local parameters from project place and taking them into account could be helpful to increase insulation level of line based on facts in the project place.

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