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Effect of RTV Coating Material on Electric Field Distribution and Voltage Profiles on Polymer Insulator under Lightning Impulse

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Abstract*—Lightning has been known as one of major factors that cause power line failure in Malaysia. Presence of contaminants on polymer insulator surface will reduce voltage withstand capabilities in the event of lightning and could lead to insulator failure or worst power line disruptions. This paper presents a study on effects of Room Temperature Vulcanisation (RTV) coating material in order to improve electrical performances of polymer insulator and its effect towards electric field distribution and voltage profile. This study involves both experimental and simulation works. For experimental works, polymer insulator is tested inside fog chamber and voltage breakdown under lightning impulse were evaluated for clean and salt conditions. 3-Dimensional model of polymer insulator were simulated using ANSYS Maxwell and electric field distribution and voltage profile were evaluated. From the study, it shows that RTV coating material helps to improve voltage breakdown level of insulator and reduce concentration of electric field at triple region.

Keywords-component; ligthning; polymer insulator; electric field (key words)

I. Introduction

Insulators play an important role in overhead power lines and it is subjected to outdoor weathering condition and various stresses. There were many reasons that affected insulator breakdown and one of it is lightning. Lightning affecting insulator performance in a way when it strikes on the power line, it causes surge overvoltage on the overhead lines and may cause flashover and failure to insulator itself or power lines. Over past few decades, most of power utilities in the world have opted for polymer insulator due to its advantages such as lightweight, vandalism resistance, high strength to weight ratio and performs better under contamination. Polymer insulator material properties have a low surface energy, which makes a virgin surface of the polymer inherently hydrophobic [1]. The hydrophobicity characteristics will help to suppress the leakage current by beading waters on contaminated surface and reduce the risk of dischargers and flashover. Apart from its excellence performances under contamination conditions, polymer insulator housing is subjected to chemical changes due to outdoors weathering and its life span is difficult to evaluate. Previous research shows that presence of contaminants deposited under prolonged outdoor weather conditions causes loss of hydrophobicity and causes formation of a conductive layer on the insulator surface, which allows the conduction of a leakage current on the insulator surface, which in turn becomes the main ageing factor for a polymeric insulator [2-3]. Ageing or degradation of shed material can cause damage to the insulator housing and will further lead to mechanical failure of the core or to flashover [2]. Interference between different materials within the polymer insulator such as between the rod-housing and the rod-fitting can also cause electrical and mechanical failure of the polymer insulator [3] .

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Therefore, in this paper, additional RTV coating material is introduced to the polymer insulator in order to increase its electrical performances and its reliability. Previously, RTV coating material is used on ceramic insulators to reduce flashover occurrences due to contamination. RTV is the best alternative coating materials compared to grease and petroleum jelly due to easy to maintain, longer life span from 10 to 15 years, economical and can be applied without the need to shutting down the power lines. The objectives of this paper is to study the effect on RTV coating material on polymer insulator under lightning impulse and its effects towards electric field distributions and voltage profiles.

II. Methodology

A. *Insulator Sample*

Figure 1 shows the insulator samples used for this experiment. Figure 1(a) shows a 10 kV polymer insulator (basic setting) while Figure 1(b) shows the 10 kV polymer insulator with a surface coating (in white). The geometrical details are given in Table 1 and are the same for both types of insulators. Table 2 shows the technical specifications of the RTV coating material used for this test.

Figure 1. (a) 10 kV Polymer Insulator (b) 10 kV Polymer Insulator with Coating

TABLE 1: 10 kV POLYMER INSULATOR GEOMETRIC DETAILS (MANUFACTURER'S DETAILS)

Rated Voltage (kV)	10
Rated Mechanical Load (kN)	4
Min. Arcing Distance (mm)	165
Min. Nominal Creepage Distance (mm)	420

TABLE 2: TECHNICAL SPECIFICATIONS OF COATING(MANUFACTURER'S DETAILS)

Property	coating
surface dry time	27 min
cure time	50 h (at room temp.)
solid content	55.1 %
dielectric strength	24.7-25.3 kV/mm
tensile strength	3.951 MPa
shear strength	3.574 MPa
tear strength	15.2 kN/m
durable years (outdoors)	15 years
suggested coating thickness	0.3-0.5 mm

B. *Experimental Work*

Figure 2 shows the schematic diagram of the test set up for both types of insulator. For the coated insulator, the insulator was cleaned and let dry before applying the coating. The coating was applied using a paint brush with the recommended thickness of 0.3 mm to 0.5 mm [4] onto the surface of the polymer insulator. The coated insulator was left for its curing period of 50 hours as recommended by the manufacturer. The test could only be carried after the curing period. For the testing done under pollution conditions, based on the IEC 60507 standard, the contamination was replicated by mixing distilled water and 40 g of sodium chloride to produce a 4 % Equivalent Salt Deposit Density (ESDD). Both insulators were tested under positive and negative lightning impulses and under clean and pollution conditions to identify the lightning withstand voltage by using the up and down test method as described in IEC60060-1. In the up and down method, the r.m.s voltage was set at the minimum voltage available and increased at a rate of 5 kV/min until a flashover event occurred. A new test was repeated five minutes after each flashover for 20 times. The breakdown voltage value was recorded for each test and the average value (U50) for each insulator was determined [5].

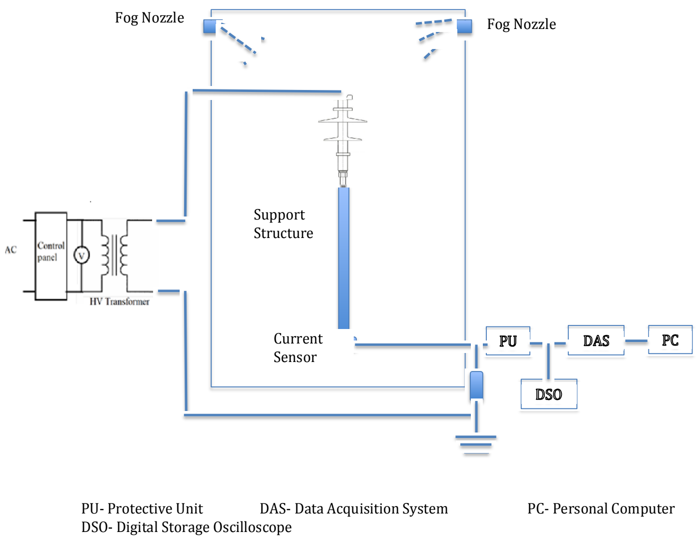

Figure 2. Experimental Set Up

Figure 3 and 4 show the voltage breakdown values for both basic uncoated and RTV coated polymer insulator under clean and salt conditions. Under clean condition, RTV coated polymer insulator shows significant increase in voltage breakdown value. The highest breakdown value recorded for RTV coated insulator is 265kV while the lowest is 240kV. On the other hand, the basic uncoated insulator recorded 245kV as highest value while the lowest is at 225kV. Breakdown value recorded under salt condition shows tremendous increase for RTV coated insulator. The highest breakdown value recorded at 190kV while the lowest is 165kV. The percentage difference between the highest and lowest breakdown value with basic uncoated insulator are 18.5% to 33.3%. From the experiment, it can be concluded that the RTV coating was more effective under the salt or pollution conditions. It showed a significant percentage difference compared to the basic uncoated insulator. From the plotted graph, even after many test conducted, there is still some dispersion in the results obtained. This may due to different frequencies breakdown occurrences.

Table 3 shows U50 for each insulator recorded under positive and negative lightning impulses. The result shows that for the basic uncoated insulator, the U50 is higher under negative impulse regardless the insulator conditions. On the other hand, for RTV coated insulator, U50 for clean condition is higher when tested under negative impulse. However, under salt condition, the U50 has decreased about 10% when compared with U50 under positive impulse. These phenomena can be due to atmospheric factor and ambience temperature during conducting the experiment. This may also due to space charge formation around the high voltage electrode, caused by an electron attachment process. The water-bridged sheds may also influence the reverse polarity effects and finally the same space-charge effects may contribute to an increase of flashover voltage under a positive impulse [5-6]. These phenomena also explain in reference [7] that relate the reduction of breakdown voltage under negative impulse might be due to loss of hydrophobicity on insulator surfaces and also due to flashover conduction through continuous water path rather than through air.

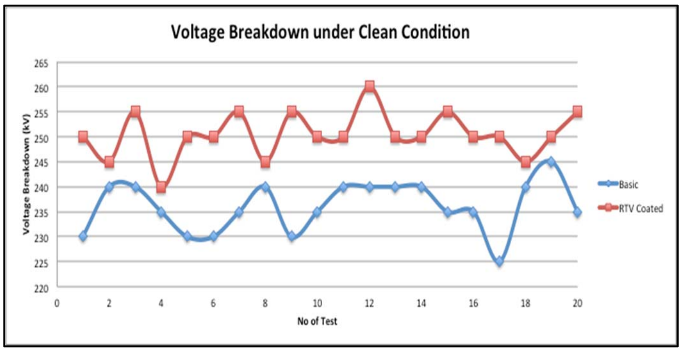

Figure 3. Voltage breakdown under Clean Condition

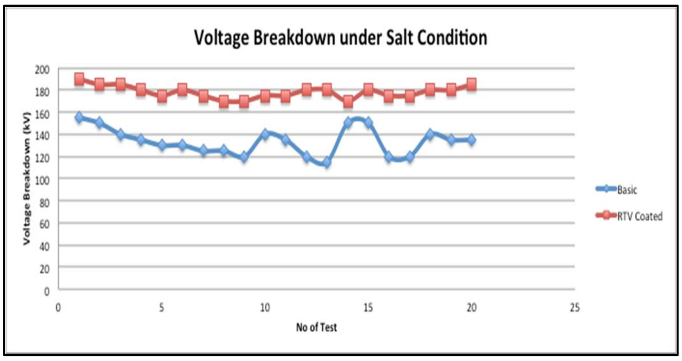

Figure 4. Voltage breakdown under Salt Condition

TABLE 3: U50 UNDER LIGHTNING IMPULSE

	POSITIVE IMPULSE (kV)		NEGATIVE IMPULSE (kV)	
	CLEAN	SALT	CLEAN	SALT
BASIC	236.00	133.50	317.00	146.00
RTV COATED	258.25	181.00	355.50	162.50

C. Simulation Work

In order to evaluate electric field distribution and voltage profile along the insulator, a 3-Dimentional-polymer insulator were modeled in Finite Element Method based software, ANSYS Maxwell. The simulations were based on the U50 value obtained in experimental work. Electrical parameters for each configuration were based on the material properties tabulated in Table 4. From the table, the relative permittivity is obtained from previous study and also from the manufacturer details. The RTV coating thickness is modeled based on the recommended thickness in reference [4] which is 0.5mm. The modeled insulators were then energized using a voltage excitation based on standard lightning waveform wave shape 8/20µs. The excitations were based on U50 obtained in the experimental work. In FEM based software, meshing of the modeled is crucial, as it will affect the duration of computation for each case. It should be noted that the meshing should be optimally refined in order to obtain the best approximation result with the fastest computation. Adaptive meshing was used in this simulation for accuracy. Figure 4 shows the mesh plot of the model and the size of mesh were tabulated in Table 5.

TABLE 4: ELECTRICAL PARAMETERS OF POLYMER INSULATOR

Insulator Parts	Material	Relative Permittivity (ε_r)	Bulk Conductivity (σ)
Fittings	Aluminum	1	3.8×10^{7}
Sheds	Silicone Rubber	3	1×10^{-17}
RTV Coating	Silicone Rubber	2.7	1×10^{-17}
Core	Fiberglass	4.6	1×10^{-12}

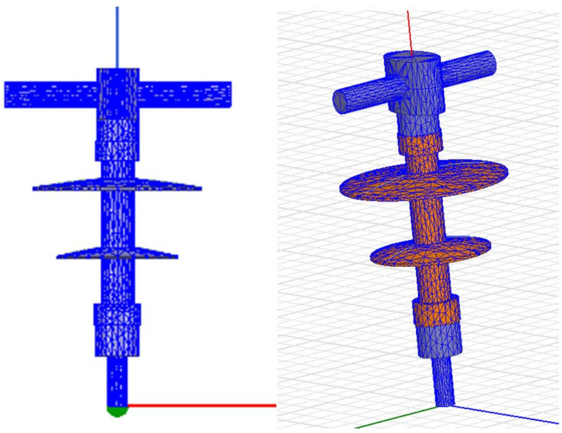

Figure 4. 3D polymer insulator with meshing

TABLE 5: MAXIMUM MESH SIZE FOR FEM MODEL

Model part	**Max Length of Elements (mm)**
Fittings & Conductor	15
Sheds	5
Core	28
RTV Coating	5
Air	60

Figure 5 and 6 shows the voltage profile along the insulators. From the generated voltage profile, regardless on the insulator configuration, the voltage concentrations were high at the high voltage area and low the ground area. Decreasing step trend of voltage is recorded along the insulator. From the simulation, the highest voltage value for basic uncoated insulator was at 1.98×10^{05} and 1.67×10^{05} was recorded for RTV coated insulator.

Electric field profiles of the insulators were shown in Figure 7 and 8. From the figures, it shows the electric field intensities were accumulated at the interference area such as between rod-fitting and rod-housing area. The highest electric field intensity observed in basic uncoated insulator was 7.51×10^{06}. On the other hand, in RTV coated insulator, the highest electric field intensity recorded was 4.10×10^{05} only. This simulation has proven the experimental work result that shows with additional RTV coating on polymer insulator can increase the breakdown voltage of the insulator and enhanced its electrical properties.

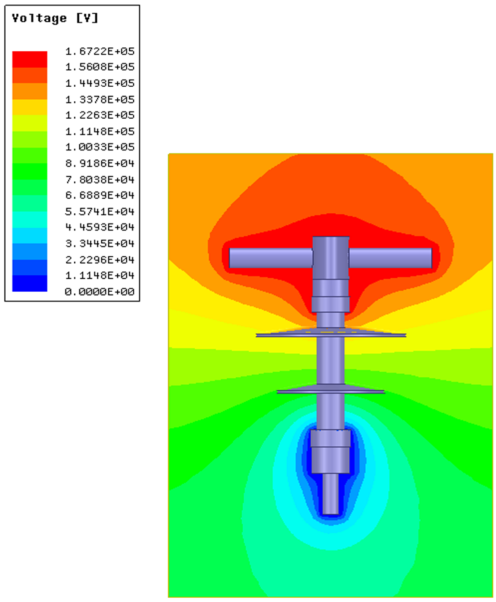

Figure 5. Voltage distribution along basic uncoated insulator

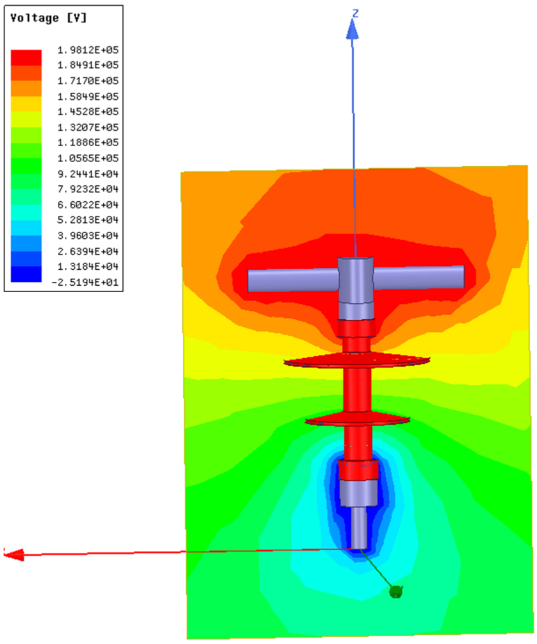

Figure 6. Voltage distribution along RTV coated insulator

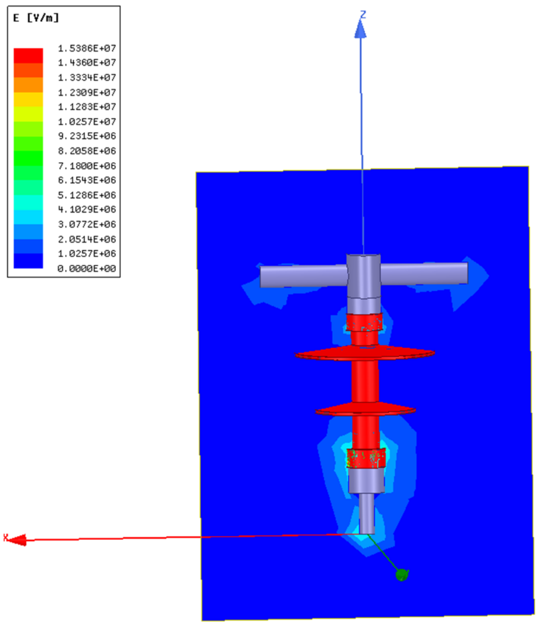

Figure 7. Electric field distribution along RTV coated insulator

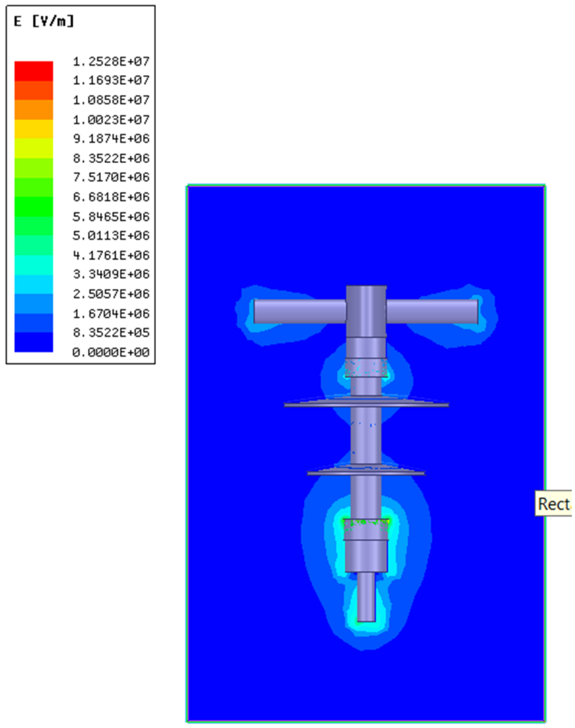

Figure 8. Electric field distribution along basic uncoated insulator

D. Surface Discharge Characteristics

The surface discharges were observed during the experimental works. Basically, there were different types of path that took place during the discharge such as discharges along the insulator surface, spirally along the insulator surface, halfway along the insulator and lastly, in the air. Figure 9 and 10 shows the discharge path along the insulator and in the air. From the observation, under the clean wet condition, some discharge paths were in the air and some on the insulator surface. This was due to wetting which caused the insulator surface to become conductive and initiate surface tracking and arcing. The hydrophobicity of the RTV material helped to bead water on the insulator surface, and when heated it created a dry band and therefore determined the arcing path that normally leapt out at the HV triple junction and discharged at the nearest path whether through the air or along the insulator surface. Under salt condition, the deposited salt on the insulator when wetted created a conductive layer on the insulator surface, thus allowing a flow of leakage current. The leakage current caused a surface discharge on the surface of the insulator and affected the discharge path [5].

In comparison with simulation works, the discharge path may be affected by the static charge that contributed to the localisation of the electric field, especially near to HV electrodes and edges. These arcing paths will help researchers to identify critical points where the electric field was localised. Ageing, degradation and damage of the polymer material strongly depend on the arcing path and therefore utility companies should identify if the material used for the insulators is spark-phobic or otherwise [7].

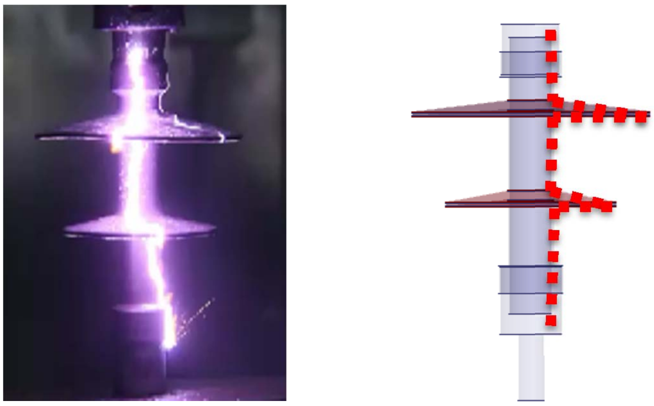

Figure 9. Breakdown path along the insulator

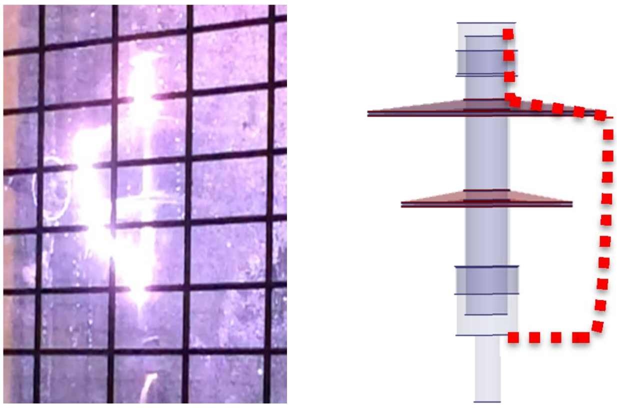

Figure 10. Breakdown path in the air

CONCLUSION

From the study, the application of the RTV coating was found to be effective in terms of strengthening the voltage withstand capabilities under a lightning impulse. The RTV coating can be used in order to improve and protect the surface condition of a polymer insulator. This may help to improve the performance of the polymer insulator and increase its lifespan and power system reliability.

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