Journal of Engineering and Technology

ISSN 2180-3811 eISSN 2289-814X https://jet.utem.edu.my/jet/index

EVALUATION OF ROOM TEMPERATURE VULCANIZATION (RTV) COATING MATERIAL ON BUSHING UNDER ELECTRICAL STRESS CONDITION

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Article history:

Received Date: 12 October 2021

Revised Date: 22 June 2022

Accepted Date: 21 July 2022

Keywords: Porcelain bushing, RTV coating, Electric field, Lightning

Abstract— Bushing is considered an essential part in the transmission lines stations and power plant. It acts as an essential part of its function includes meeting all the requirements of the application which are electrical, thermal, and mechanical. Bushing failures are critical especially in transformer applications as it could lead to total failure of the transformer. Based on previous research, common failures of the bushing are associated with ageing, design, operation and possible quality issues. In this paper, porcelain type bushing coated Room Temperature Vulcanization (RTV) material was modelled and simulated under the lightning impulse voltage which is used as an electrical stress in this project. Objective of this paper is to evaluate the effect of RTV coating material to enhance the performance of porcelain bushing under lightning impulse in term of voltage profile and the electric field distribution along the bushing. ANSYS software is used to design bushings and the criteria of a bushings for a simulation of a real-life bushings. From the simulation work, RTV coating appeared to be useful in that it would protect the bushing and improve the surface to withstand flashover. The RTV coating material also helps in improving the bushing insulator performance and increases the lifespan and the reliability of the power system.

I. Introduction

Bushings history started way back in the 1920s where bushings were dry insulated, made with resin-coated paper and aluminium foil and with a flanged which then glued to the core of the condenser and porcelain-made insulator. In the 1930s the conductive layers were changed to graphite and its concept is currently still being used by some of todays' manufacturer. Bushings improvement eventually evolves through time for a better and enhanced bushing. Recently, the analysis showed that the bushing is initially the faulty component of several cases in terms of transformer failure. A catastrophic event often occurs after high voltage bushing failure, examples of this event such as tank rupture, an explosion, fire, and many more [1].

Pollution flashovers are widespread phenomenon in switchyards, substations, overhead transmission lines located in coastal areas, polluted areas prone to fog, light rain, or any other form of wetting and across industry types. Industrial contaminants such as coastal salt, natural dust, etc. are the pollutions that causes flashover of bushings. One of the major concerns for power generation, transmission and distribution companies is pollution flashovers. Conductive film is transformed due to the presence of a wetting mechanism such as rain, fog, humidity from the contaminants layer which then permits the flow of leakage current going through it in the case of hydrophilic insulation like porcelain [2].

Since Malaysia has high-density of lightning occurrences, evaluation of electrical performance under lightning impulse is crucial [3]. The lightning that strikes power system equipment in two possible ways which are direct and induced strokes. The direct stroke occurs when the cloud directly discharges on the power system equipment which commonly occur on transmission lines and could damage the equipment or worst causes total failures to the system.

The 36kV transformer porcelain bushing typically is designed to withstand standard lightning impulse voltage (1.2/50μs) rated at 170kV where it has a creepage distance to arcing distance ratio of 1.05 to 1.24 with no external flashover occurs [4]. Generally, the use of Room Temperature Vulcanization (RTV) Silicone insulator coatings is one of the common methods embraced to eliminate the pollution flashovers. Based on worldwide field experiences suggestion, that this method could be best solution for eliminating flashovers, even in the harshest environment [5, 6]. Comparing RTV coating to other type of coatings like grease and petroleum jelly, it is considered the best alternative coating where it's easy in term of maintenance and it has long life span between 10 -15 years, and it is economically better because it can be applied without shutting down the power lines [3].

Hence, this research is conducted for the purpose of finding solution for the current issues with bushing specifically on evaluation of RTV coating material on bushing under electrical stress condition. This is to cater and improves the current bushings performance and increase its lifespan and mitigate sudden outages. This project is done by simulating 3-Dimentional clean uncoated and RTV coated porcelain bushing using ANSYS software.

II. Methodology

A. Bushing Profile

Bushing was designed using ANSYS software and tested via simulation to understand the behavior of the bushing under lightning impulse condition. The porcelain bushing was simulated for uncoated and RTV coated with meshing design. As an important factor, the bushing profile is taken into consideration for its performance. Specifically, for this 36kV porcelain bushing is considered for analysis.

The bushing geometry for porcelain is tabulated in Table 1. The porcelain bushing was designed in 3-Dimension view in ANSYS software using the dimensions shown in Table 1. By simulating both uncoated and RTV coated porcelain bushing, an adaptive meshing was done for the purpose of simulation accuracy. The voltage profile of the porcelain bushing was simulated under the lightning impulses.

Table 1: Bushing geometry for porcelain (Manufacturer's details)

Parameters	Dimensions in mm
Sheds diameter	224
Axial height	325
Min. Creepage distance	918
Min. Arcing distance	465

The electric field and potential are calculated by using the finite element method as illustrated in the Equation (1):

$$\nabla . E = \rho \varepsilon o \quad (1)$$

where:
ρ = charge density
εo = permittivity of vacuum
εr = relative permittivity of dielectric material [7]

The parameters shown in Table 2 are the electrical parameters based on the material properties for each configuration. As it is shown in the table, the bulk conductivity and the relative permittivity is obtained from the manufacturer details and from previous studies as well [3]. The bushing model was designed in the software with the respective material properties for the parts such as porcelain, steel, aluminum, and silicone rubber for the RTV coating as shown in Table 2.

Table 2: Material properties in porcelain bushings

Bushing Parts	Material	Relative Permittivity	Bulk Conductivity S/m
Fittings	Aluminum	1	36×10^{6}
Core	Steel	1	2×10^{6}
Sheds	Porcelain	5.7	1×10^{-14}
RTV Coating	Silicone rubber	2.7	1×10^{-17}

The waveform of the lightning impulse generated and used as an electrical stress in this project was based on the equation is shown as below. The following analytical form for the base voltage was proposed by Bruce and Golde as Equation (2):

$$V = V_{max}\ (e^{-\alpha t} - e^{-\beta t}) \quad (2)$$

where:
V_{max} = peak value of impulse
$e^{-\alpha t}$ = charging component
$e^{-\beta t}$ = discharging component of the waveform

In this study, the value of α and β which are 1.47x104 and 2.47x106 respectively were used for generating a 1.2/50μs lightning impulse voltage. The value of V_{max} was adjusted accordingly to obtain the required value of V.

B. Simulation Work

ANSYS software was used to design 3D bushing and simulate the voltage profile and electric-field distribution and generally test the performance of the virtual bushings on the software for further usage. In this project, a 3D porcelain bushing design was modeled and tested under lightning impulse voltage. In the modelling, thickness of the RTV coating material applied onto the bushing is taking into consideration where 3mm thickness was used based on a reference of previous study [8].

Figure 1 shows the critical area known as a triple junction of the bushing where interference of different types of materials is located. The insulation at those regions is considered as weak point because of various permittivity of porcelain, steel, and RTV coating which increases the electric field. On the other hand, Figure 2 shows the 3D design with meshing which generated using the adaptive meshing in the software to increase the accuracy of evaluation. Moreover, meshing would affect the computation of the electric field and the duration for every case of the simulation. The specific mesh size is tabulated in Table 3.

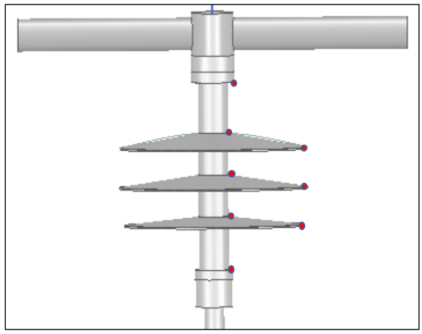

Figure 1: Measurement points at critical area

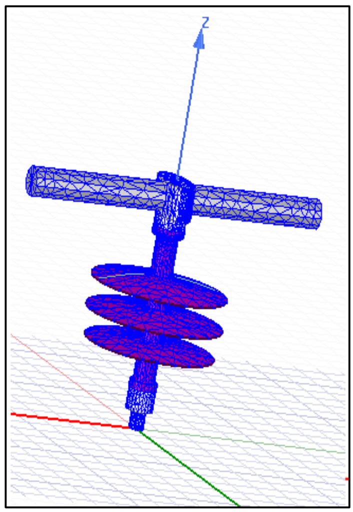

Figure 2: Mesh plot of the bushing

Table 3: Maximum mesh length for bushing model

Model Part	Max Length of part (mm)
Air	176
End Fitting and Conductor	110
Core	64
Sheds	54
RTV Coating	53.2

III. Result and Discussion

For the simulation works, two different levels of lightning impulse voltages were injected to the bushing which are voltage at 145 kV and 170 kV. The voltage levels were selected based on This is based on IEC insulation standard for 36kV under lightning impulse conditions (IEC 60060-1). The voltage levels indicated the voltage breakdown values of the bushing. From this voltage breakdown values, the simulation was conducted to evaluate the profiles of electric field at the critical point areas and comparison were made on basic uncoated and bushing coated with RTV coating material.

A. Voltage Profile

Figures 3 and 4 show the voltage profile along the bushings. Regarding the generated voltage profile, regardless on the bushing 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 bushing. From the simulation, the highest voltage value for uncoated bushing was at 144kV and 169kV was recorded for RTV coated bushing.

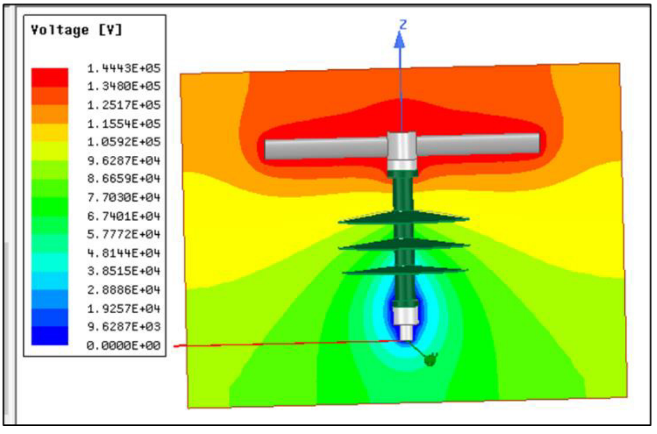

Figure 3: Voltage profile of uncoated bushing

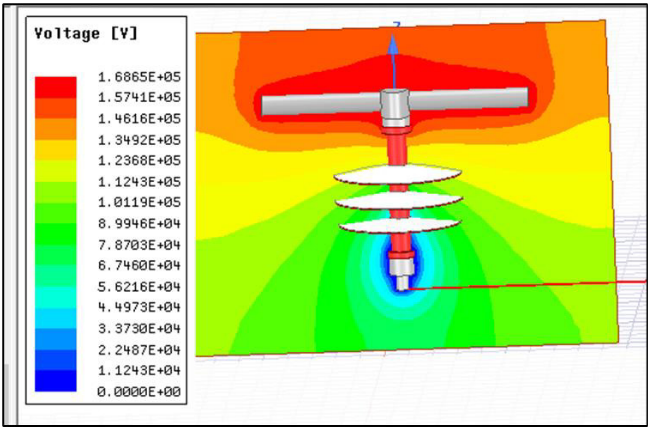

Figure 4: Voltage profile of RTV coated bushing

B. Electric Field Profile

Electric field profiles of the bushing were shown in Figures 5 and 6. 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 uncoated bushing was 4.378x10-06 V/m. On the other hand, in RTV coated bushing, the highest electric field intensity recorded was 3.52x10-06 V/m only. This simulation has proven the experimental work result that shows with additional RTV coating on bushing insulator can increase the breakdown voltage of the insulator and enhance its electrical properties. In addition, Figures 5 and 6 illustrate the electric field distribution around the uncoated and RTV coated bushings under the lightning impulse. The intensification levels of the electric field distributed around the bushing are denoted by the color code on the side of the figure. It can be observed that electric field is intensely gathered at the triple junction points between the end-fitting and edge of the housing areas. From the figures, it can be noticed that the uncoated bushing has higher electric field intensity than the RTV coated bushing.

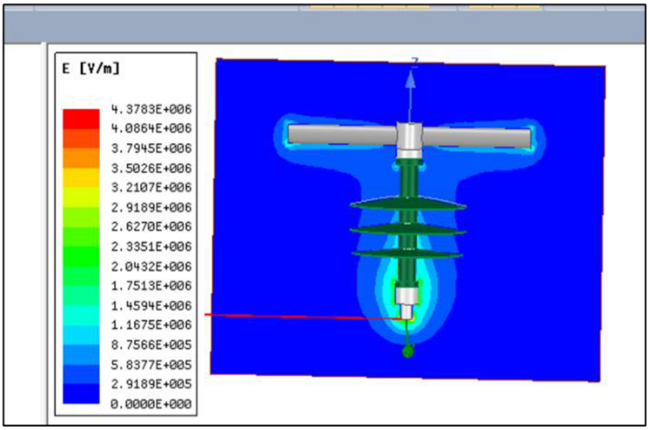

Figure 5: Electric field distribution of uncoated bushing

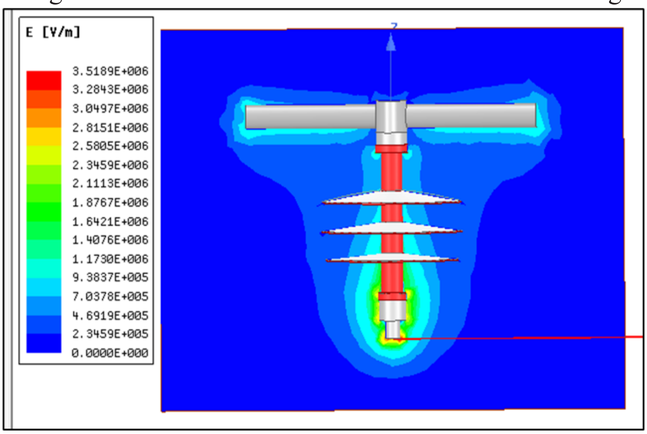

Figure 6: Electric field distribution of RTV coated bushing

In terms of the evaluated electric field profiles, there are intense electric fields around the middle of the shed, where interference of different materials of polymer shed and core located. When insulation materials with various dielectric strengths are placed side by side, the voltage distribution changes, resulting in a large voltage differential at the connection section as shown in Figure 7 and 8 for uncoated and RTV coated bushings. Consequently, the connection part is subjected to a high intensity of electric field. In conclusion, the greater the dielectric strength differential between two materials, the greater the electric field intensity.

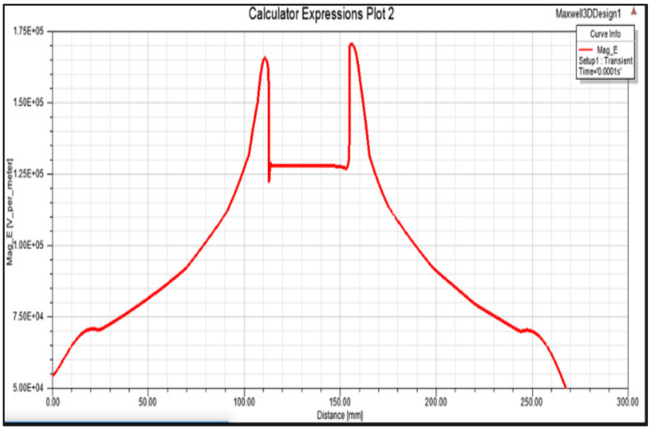

Figure 7: Electric field waveform of uncoated bushing

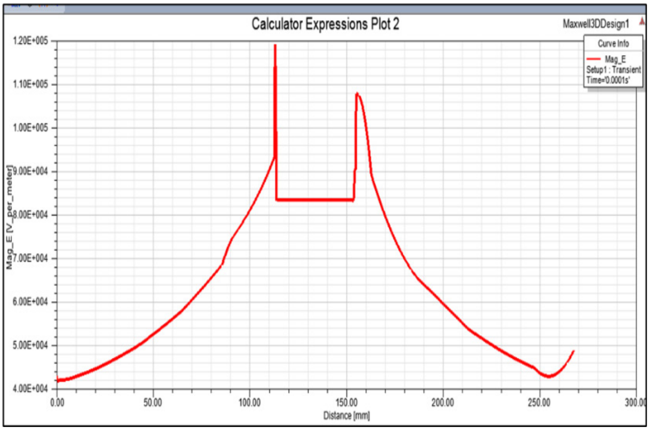

Figure 8: Electric field waveform of RTV coated bushing

Table 4: Comparison of results

Bushing Profile	Voltage Profile	Electric Field Max (V)
Uncoated bushing	1.444×10^5	2.85×10^6
RTV coated bushing	1.6865×10^5	2.36×10^6

Table 4 shows the comparison values of electric field between the uncoated bushing and RTV coated bushing in terms of the electric field. The electric field was intensely higher around the uncoated bushing which was recorded as 2.85×10^6. In different circumstances, the value of the electric field around the RTV coated bushing was $2.36x10^6$ as tabulated in Table 4. Hence, the effect of the RTV coating by increasing the breakdown voltage and improving the electrical properties of the porcelain bushing has been proved by this simulation. This is to cater and improve the current bushings performance and increase its lifespan and mitigate sudden outages.

In addition, the leakage current along the surface of the bushing can be mitigated by using RTV coating. Its application was observed to be operative in terms of increasing the breakdown voltage and supporting the bushing to withstand high voltage strikes of lightning.

IV. Conclusion

In this study, it is found that uncoated bushing cannot handle the perpetual and infinite stresses caused by its surroundings, especially environmental related. However, comparing that with RTV coated bushing models where it showed an effect of the RTV coating on the electric field profile where the porcelain bushing' surface can be improved further and protected under lightning impulse. Applying the RTV coating on the porcelain bushing can help to increase the lifespan of the bushing itself.

Therefore, coating comes in place to protect the surface of the bushing and requires less maintenance and can withstand damage impact from the environment surrounding. As there are many types of coating, these coating are designed specifically for different environment conditions and as the surrounding environment are always in a constant of changes and worsened by time, coating improvement is a necessity to cater and evade any consequences which might occur on the bushings in the future.

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