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Effect of RTV coating on the electrical performance of porcelain insulator string under dry condition

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Abstract. Pollution flashover is one of the primary reasons cause to power system failure in Malaysia. The presence of accumulation on the porcelain insulator surface reduces the electrical performance and also causes the failure of insulation in transmission and distribution lines. This research presents a study on the effect of Room Temperature Vulcanize (RTV) coating on the performances of a string porcelain insulator and their impact on environmental contamination. An attempt has been made to simulate the electric field distribution of 33 kV insulators using the finite element method (FEM). From the simulation results, the maximum electric field distribution is obtained at the pin insulator of a clean insulator, while the cap insulator indicated the minimum electric field. With the existence of the contamination layer, the electric field distribution of the porcelain surface results in a reduction trend.

1. Introduction

Nowadays, the consumption of electric energy in developing countries increases dramatically due to fast population growth and rapid development in economic activities. Malaysia is the most developing country in the Southeast Asia region, with an annual average growth rate under Eleventh Malaysia Plan is 6.2%, as referred to the Malaysian National Development Strategy. Electricity consumption of commercial sectors and residential had recorded 7559 ktoe in 2015 and contributed around 53.6% of the total electricity consumption. Moreover, the electricity demand for both sectors has increased up to 53.7% for five years, which is from 2000 to 2015[1]. Hence, the power systems industries keep updating the information to develop long-distance transmission and high voltage [2]–[5]. For distribution and safe transmission of electric power, the insulator is the most critical part of power systems to prevent the current flow from the wire to the earth through ground supporting towers.

Porcelain insulator was first made in China in the year 1909 and are used until today in electrical power application, for instance, distribution and power transmission. They also provide excellent insulation from the power plant to distribution lines. The selection of porcelain insulators compared to other types of insulators could consider as a safe decision due to material that made from raw material such as clay, fillers and feldspar, which is naturally available, prevent from industrial processes materials and cheaper. The essential material for a porcelain insulator is clays that contain ball clay and kaolin, which have different chemical properties and physical depending on the geological and geophysical environment. Traditional porcelain formulations for hard porcelain consists of 50% clay, 25 % silica and 25 % flux[6]–[8]. While, soft porcelain usually consists of 25 % plastic component clay, 25 % filler and 50 % flux. Other than that, porcelain insulators offer some advantages such as high electrical stability, high mechanical strength and corrosion resistance, especially in humid or wet conditions.

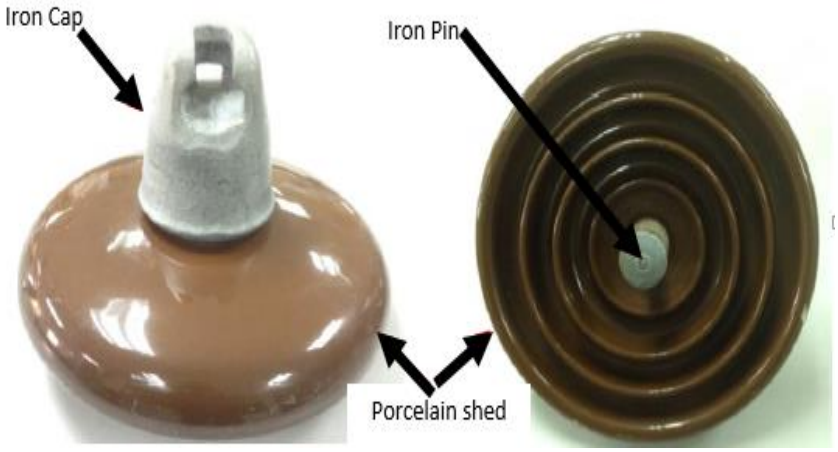

Figure 1. Porcelain insulator.

From previous studies, most of the researchers found that outdoor environmental exposure, for instance, ultraviolet radiation (UV), contamination (salt, dust and bird secretions), rain and humidity contribute to porcelain insulator degradation due to chemical changes from dry band arcing and environmental especially in wet conditions. These contaminants allow electric field distribution of the insulator to become unstable, which acts as a nonlinear or highly variable resistor[9]–[11]. Thus, a path of leakage current is created and heat is generated until a flashover is caused. Room Temperature Vulcanize (RTV) coating has been chosen as the most alternative way to recover electrical power insulation performances in ceramic insulator due to excellent hydrophobicity, excellent electrical insulation properties, excellent self-cleaning and water resistance and excellent arc resistance for preventing insulator surface from contamination. It has been proven that the coating reduces the number of flashover voltages and extends the life of ceramic insulators. The life of the insulator can be as long as 15 years, depending on the material being manufactured[12]. However, for the type of porcelain insulator string, there is still a minor approach from previous researches. Thus, an attempt of Room Temperature Vulcanize coating on a porcelain insulator string is essential to solve the accumulation of contaminants on the surface insulator and to prevent flashover as a safety step. Evaluation of the withstand voltage capability and electrical performance of the insulator string is compulsory to determine the effectiveness of transmission lines and to prevent the power systems engineering from fire hazard, which in turn of low carbon economy[13]–[15]. This paper aims to study the effects of an RTV coating on a porcelain insulator string in order to increase electrical insulation under clean and contaminated conditions[16]–[18].

2. Methodology

Flashover phenomenon is one of the most serious problems detected in high voltage outdoor insulators[19]–[23]. This phenomenon exists by many factors, for instance, the accumulation of contaminants in different environments such as dry and wet conditions and non-uniform contamination distribution on the insulator surface. In this paper, simulation work was used to investigate the performance of a insulator string with the effect of RTV coating under the dry condition on 33kV high voltage. The 2-D CAD model of four-unit suspension porcelain insulator has imported into the finite element method (FEM) software, COMSOL multiphysics. The dimensions of each insulator are tabulated in Table 1.

Moreover, the cap insulator at the top of the insulator is assigned 0 kV, which is referred to as ground and the pin insulator at the bottom of the insulator is assigned 33 kV as high voltage input, while the rectangular shape represented as the air surrounding the insulators. Ceramic insulators divided into three main parts, such as pin & cap, ceramic disk, and cement. The material properties consist of relative permittivity and conductivity, as tabulated in Table 2. RTV coating was applied on the upper surface for each porcelain insulator with a 0.2 mm dimension. The electric field is simulated under electrostatic mode. In this case, the operating frequency of the porcelain insulator is 50 Hz, assuming electric and magnetic fields change slowly. In addition, the induced current of electric field and magnetic field are neglected.

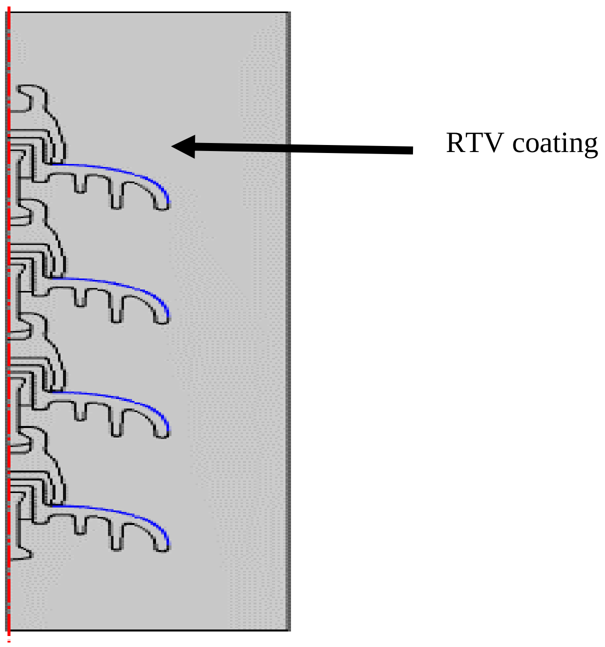

Figure 2. Geometrical model of string porcelain insulator.

Table 1. Dimensions of coated insulator.

Parameters	**Dimensions (mm)**
Maximum diameter	250
Height	145
Creepage distance	320
Pin diameter	15
Coating thickness	2

Table 2. Material properties.

Material	**Relative permittivity**	**Conductivity (S/m)**
Cement	2.1	1×10^{-14}
Porcelain	6	1×10^{-14}

RTV coating	2.9	1×10^{-13}
Air	1	1×10^{-15}

3. Results and discussion

Figure 2 shows the effect of RTV coating on the electric field distribution without contamination. From the simulation, it shows that the electric field close to the pin or high voltage input is the highest under dry condition compared to other surfaces of the insulator. The bottom insulator displays in red color represent "hot" temperature due to resistance heating along the insulator surface. This was for the same reason as explained in [24], that is, the maximum electric field is obtained close to the pin of some dielectric mediums such as air, pin and silicone. The second upper insulator is "cold" as shown in a greenish-blue color because of low resistance through the insulator surface. Lastly, the upper insulator is the best insulator represented in blue color, it has the lowest surface heating as a result of surface leakage currents due to weak electric field.

Figure 3. Electric field distribution of clean insulator under dry condition.

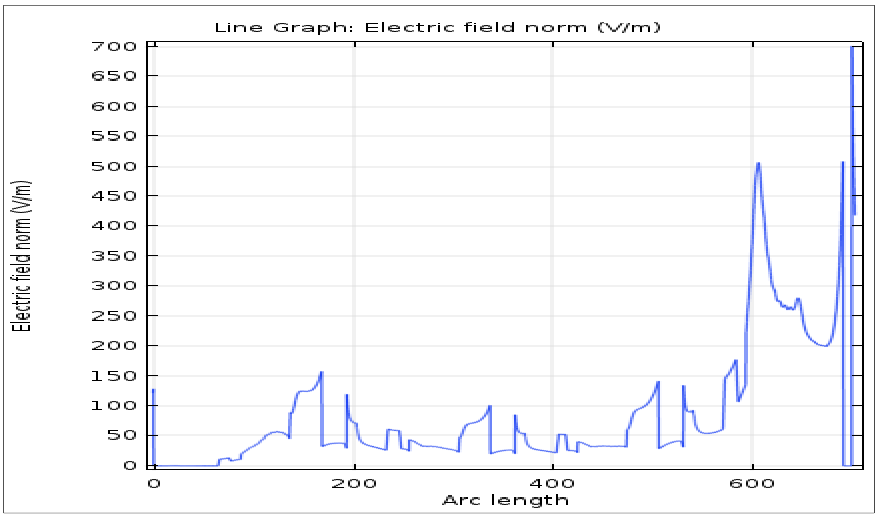

Figure 4. Electric field distribution of contaminated insulator during dry condition.

Figure 4 shows the electric field distribution with non-uniform contamination applied to the RTV coating. The presence of contamination layer decreases electric field at the overall insulator surface. By increasing the contamination conductivity, the electric field will be decreased especially for both areas of pin and cap insulator.

4. Conclusion

In the present work, the application of the Room Temperature Vulcanize (RTV) coating was proven to be an effective method in high-voltage insulation and can solve the accumulation of contamination on the porcelain insulator. The simulation results summarized that the maximum electric field distribution is obtained at the pin insulator of a clean insulator, while the cap insulator indicated the minimum electric field. The presence of the contaminated layer leads to a decrease in the distribution of electrical field on the porcelain surface.

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