The Electrical Performance of Epoxy Resin Insulator under Rain Contaminants

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***Abstract*—** A polymeric insulating material as outdoor insulator has been developed and used on transmission lines and power distribution network. Each material has its own advantages and disadvantages. Generally, polymeric materials have dielectric properties better than the ceramic, glass and porcelain material. Factors affecting performance of outdoor insulators are like rain, humidity, ultraviolet rays, condensation and contaminant. When rain water flow at the insulator surface, they will be easily contaminated and flow current. These events can cause damage to the surface of the insulator and finally cause flashover. To improve the surface properties of materials, silicon rubber material that has the ability to repel water were added. Silica sand was mixed with silicon rubber to improve the mechanical properties.

This paper presents the electrical performance of epoxy resin insulator under rain contaminants. The tests were conducted at high voltage laboratory with AC high voltage 50 Hz. Leakage current characteristic of 20 kV outdoor insulators with silane epoxy resin has been investigated under dry and wet condition. The chamber was used to placing the insulator.

The research results showed that the leakage currents on insulator surface were affected rain contaminant and magnitude of applied voltage. A minimum leakage current achieved at outdoor insulator without contaminant. For outdoor Insulator under rain contaminant, leakage current tends to increase. Shape of insulator influence the leakage current also was analyzed.

Keywords—epoxy resin, leakage current, rain contaminant

I. INTRODUCTION

Since the development of power systems, more than a hundred years ago, insulation design for polluted conditions has involved the modification of the size, spacing and shape of the individual insulators, or sheds, to obtain as much leakage distance per unit length as possible, while maintaining high dielectric strength to avoid puncture by lightning impulses. Although parameters such as shed spacing, shape and diameter are important, leakage distance has become the single most important design parameter and has been the key to achieving optimal performance[1]. As we know, the bulk of power delivery from the generating sites to the load centers is done by overhead lines. The distances involved could span several thousand kilometers. To minimize line losses, power transmission over such long distances is more often carried out at higher voltages than at lower voltages. A network of outdoor lines operating at different voltages has been found to be the most economical method of power delivery. The energized high voltage line conductor has to be physically attached to the support structure. Also the energized conductor has to be electrically isolated from the support structure because this structure is at ground potential. The device used to perform the dual functions of support and electrical isolation is the insulator[1]. Recently, polymeric insulating materials such as epoxy resin and silicon rubber have been widely used in the distribution and transmission lines for their good dielectric properties, light weight and compact, when compared to the porcelain or glass insulators. Epoxy resin is an important electrical insulating material. It is a thermoset polymer which two components are mixed to eventually form a glassy product at room temperature. Epoxy is widely used for the housings of distribution apparatus such as transformer bushing, fused cut-outs, insulators, switches etc. When polymeric insulating materials used as outdoor insulator showed degradation due to climate stresses such as ultraviolet in sunlight, moisture, temperature, humidity, acid rain and the other contaminants so that the surface discharge, tracking, and erosion can occur, and degradation may reduce the performance. This reduction is actually the result of chemical and physical changes taking place on the surface of polymer [2]. The presence of contaminants on the surface of the insulator becomes a serious problem. Different materials have different contamination performance. Generally, polymeric insulators perform better than ceramics when new. Berahim[3] has investigate that epoxy resin is a hydrophilic material, therefore in particular in tropical area: humidity, temperature, ultraviolet radiation and rainfall play an important role in accelerating of degradation process on the surface of the insulator.

Contamination layer will be formed on the surface of the insulator and it would spread on the surface. Surface tracking can occur and lead leakage current increase, especially when the insulator surface wet caused by fog, dew or light rain. Leakage current initiates a process of heat conduction which occurs on the surface of an insulator and finally flashover or insulation breakdown would occur.

This paper presents the electrical performance of silane epoxy resin insulator under rain contaminant. The electrical performance investigated is leakage current at dry and wet surface conditions. Magnitude of applied voltage also was analyzed when subjected on different insulator.

II. ELECTRICAL PERFORMANCE

A. *Surface Dielectric Strength*

The insulator's dielectric material is largely responsible for the electrical performance of the insulator. It is important to distinguish between the bulk or volume properties and surface properties. The volume dielectric strength is determined by defects in the form of impurities and voids. The surface dielectric strength is determined largely by surface deposits and moisture. Resistivity values which are indicative of the dielectric strength are typically > 10^{10} Ohm per square for the bulk material. Under dry conditions, such high surface resistance is also obtained. However, in the presence of humidity and rainfall, surface resistance values are lowered by several orders of magnitude, and are even further lowered in the presence of ionic contaminant on the surface[1].

B. *Leakage Current*

Any current flowing from hot conductor to ground over the outside surface of a device is called leakage current. In case of insulators on a transmission line, it is the current that flows over the surface of insulator, and, if no ground exists, the current flowing from a conductive portion of a device to a portion that is intended to be non-conductive under normal conditions [2].

The major part of leakage current in insulators is contributed by DC resistance of the surface. This is contrary to case of electrical devices where capacitive leakage current dominates. The reason is that insulators are used at power frequencies. The power frequency is not higher than 60 Hz anywhere.

At this frequency, the skin effect and capacitance are low and constant; the change occurs only in resistive component of leakage current. Therefore, in most of research regarding characteristics of insulators, only surface resistance and resistive portion of leakage current are taken into account [2].

Flashover is formation of arc over surface of insulator. This arc may sustain for long duration to cause insulator break down or for short duration to cause dips in transmission voltage. It is quite necessary to prevent flashovers in all conditions of weather. This requires regular checking of pollution deposit on every insulator and cleaning/replacement of dusty/faulty insulator respectively. But it is very difficult to examine energized insulators due to their height, voltage across them, and their location. Transmission lines pass through mountains, terrains, and horrible places.

III. EXPERIMENTAL TEST SET UP

This set up consist of polymeric insulator made from silane epoxy resin as sample test, chamber test and test circuit used for measuring the leakage current.

A. *Materials and sample test*

The test materials used in this research were epoxy resins formed from diglycidil ether of bisphenol-A (DGEBA) and metaphenylene-diamine (MPDA) compound with silicon rubber (SiR) and Silica sand. Composition of the sample test was 30% DGEBA, 30% MPDA 20% Silicon Rubber and 20% silica[5]. The sample test used in this research is shown in figure 1

Figure 1 Silane epoxy resin insulator with 3 shades

B. *Rain contaminant*

In this research, rain water contaminant is used. Based on Water and Waste Quality test in Environment Laboratory was obtained data as follow:

Conductivity of contaminant	= 72 μS/cm
Ferrit (Fe)	= 0.0273 mg/l
Kalium (K)	< 0.001 mg/l
Magnesium (Mg)	< 0.005 mg/l
Chromium (Cr)	< 0.004 mg/l
Cuprum (Cu)	< 0.005 mg/l
Cadnium (Cd)	< 0.001 mg/l
Plumbum (Pb)	< 0.004 mg/l

Rain water contaminant was sprayed on insulator surface.

C. *Test circuit*

All components and sample test were arranged is shown in Figure 3. AC high voltage applied to the sample test and leakage current was detected by voltage divider circuit and recorded by oscilloscope. Measuring data were recorded and saved through USB port for analysis.

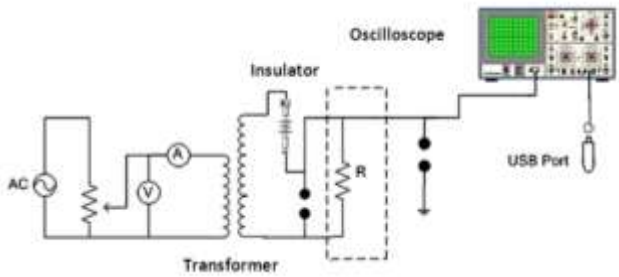


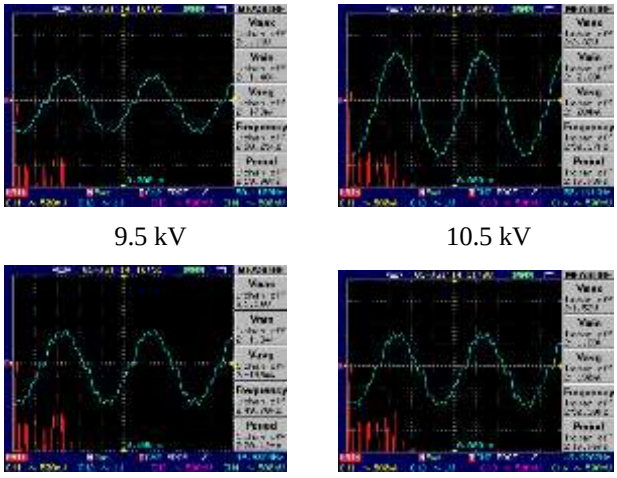
Figure 2 Leakage current test circuit

IV. Results And Discussion

A. *Waveform of leakage current*

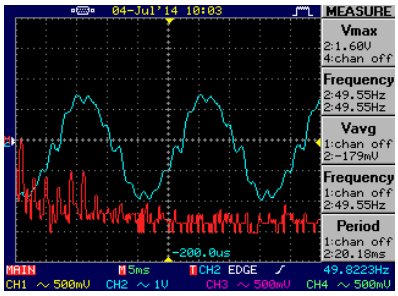
Wet and dry test was conducted in high voltage laboratory at various applied voltage. The AC voltage values used are 9.5 kV, 10.5 kV, 11.5 kV; 12.5 kV; and 13.5 kV.

1. Wet test conditions at different shed



9.5 kV 10.5 kV

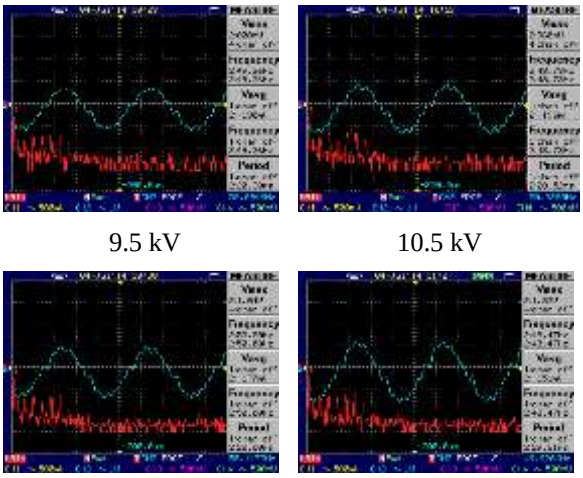
11.5 kV 12.5 kV



13.5 kV

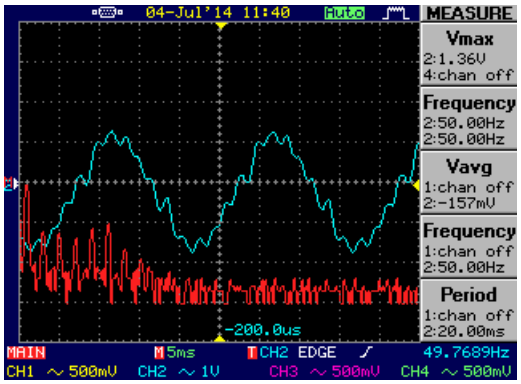
Figure 3 leakage current waveform at insulator different shed under wet test conditions

2. Wet test conditions at same shed



9.5 kV 10.5 kV

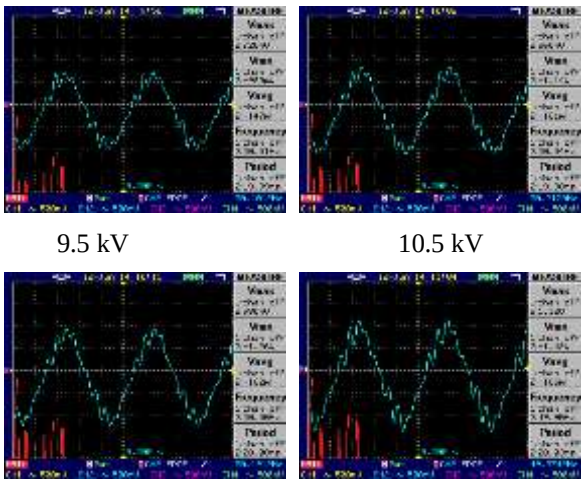
11.5 kV 12.5 kV



13.5 kV

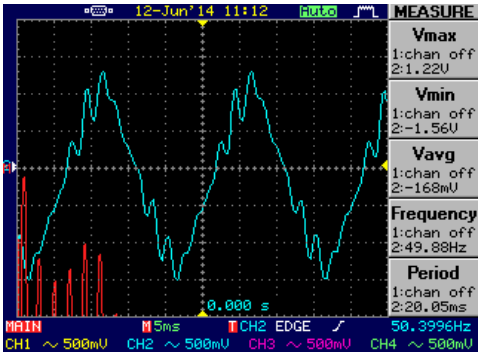
Figure 4 leakage current waveform at insulator same shed under wet test conditions

3. Dry test conditions at different shed



9.5 kV 10.5 kV

11.5 kV 12.5 kV



13.5 kV

Figure 5 leakage current waveform at insulator different shed under dry test conditions

B. *Characteristics of Leakage Current*

Contamination on the surface of insulators give rise to leakage current, and if high enough, flashover. We can see at Fig 6 leakage current graphic under wet test conditions higher than dry test conditions. Leakage current on silane epoxy resin insulators if high enough, will cause erosion and possible tracking of some materials exposing the fiberglass core to moisture and voltage stress, which can lead to rapid failure of the insulator. The rain contaminant was sprayed on the surface insulator influence of leakage current. Conductivity of contaminant is 72 μS/cm makes the surface insulator more conductive and easily to flow the leakage current.

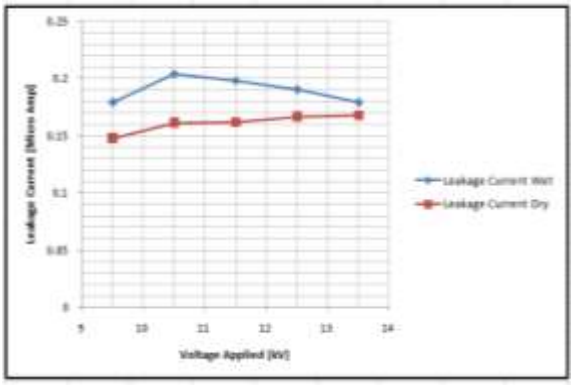


Figure 6 Graphic of leakage current under wet and dry test

Electrical devices at outdoor can be wetted due to rain and moisture. Leakage current easily flow when at the insulator surface was wetted. Leakage current initiates a process of heat conduction which occurs on the surface of an insulator and finally flashover or insulation breakdown would occur. Based on experimental test we got the leakage current characteristics under dry and wet test is shown in Figure 4. From the figure 4 we know that leakage current under wet condition were higher than dry condition, because when insulator surface wetted has more conductive. A hydrophobic surface provides a high surface resistance under wet conditions, but according Berahim[3] epoxy resin materials is hydrophilic. When insulator surface was wetted by moisture and rain there are some water droplet at insulator surface and they will form conductive path. It is easily to flow the leakage current at insulator surface.

Mostafa Refaey[8] was investigated that partial discharge intensity is dependent on the magnitude of the test voltage and reaches significant level at higher voltages. His observation was actually expected from the equation used to calculate these quantities, where energy is dependent on the test voltage. Also increasing the voltage with a pre-assumed constant impedance of the capacitance, in which the discharge takes place, necessitates the increase in the charge magnitude. It can be also seen the number of pulses per cycle is increased with the applied test voltage rise.

The presence of moisture, in particular the duration of surface wetness, is probably an important feature in determining the rate of breakdown of composite[7].

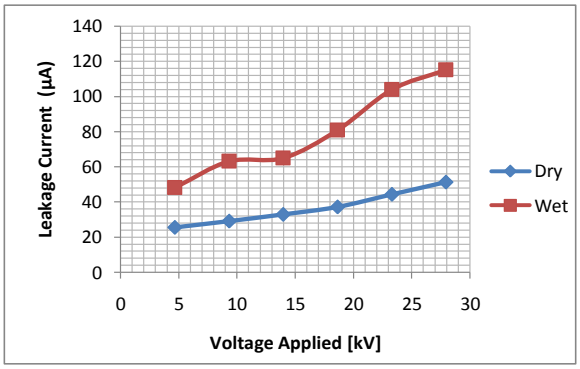


Figure 7 Leakage current under dry and wet test[7]

The frequency of precipitation can be considered as some indication of this factor. Recognition of the importance of surface wetness in deterioration of certain polymeric materials has led to the development of instruments.

V. CONCLUSION

Based on discussion can be concluded that leakage current characteristics of insulator made from silane epoxy resin was influenced by rain contaminant or wet test and magnitude of applied voltage. From this result data can be know the electrical performance of insulator was better used for dry condition.

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