INTERNATIONAL CONFERENCE ON LIGHTNING PROTECTION
33rd International Conference on Lightning Protection
25 - 30 September 2016
Estoril, Portugal

Considering the Effects of a RTV Coating to Improve Electrical Insulation against Lightning

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***Abstract*— One of the factors that cause power outages on distribution lines is being struck by lightning. Cloud to ground lightning often affects overhead distribution lines and can occur with negative or positive polarities. It can affect the performance of insulators and cause power line failure. Furthermore, outdoor polymer insulators are exposed to extreme weathering and pollution, which can cause chemical changes in the material properties and further leads to material degradation. These can cause a reduction in the insulator withstand capabilities and may lead to flashover. This paper investigates the effects of a RTV (room temperature vulcanisation) coating on a 10 kV polymer insulator in order to improve the electrical insulation performance against a lightning impulse under clean and polluted conditions. The up and down test method was used to evaluate the withstand voltage capabilities of an RTV coated polymer insulator. For reference, the withstand voltage for a basic setting polymer insulator was measured for comparison.**

Keywords-component; Polymer Insulator, RTV coating, Withstand Voltage, Lightning (key words)

I. INTRODUCTION

Lightning strikes on power lines have become one of the major problems encountered by power utilities worldwide. Lightning strikes can affect the performance of the insulators themselves and could lead to power outages and failure of the system. The insulator plays an important role in power lines as it is used to support and separate electrical conductors and to prevent the flow of current between them. Flashover on the line insulation is determined by the wave shape and the polarity of the lightning surge voltage that is stressing the insulator, the insulator withstand characteristics and the power frequency component of the voltage across the insulator [1-2].

Outdoor overhead insulators are divided into two-types, namely ceramic (glass/porcelain) and non-ceramic (also known as polymer insulators). Nowadays, the polymer insulator has gained popularity among the power utilities all around the world regardless of any level of power network due to its advantages such as being lightweight as well as having a better withstand voltage compared to ceramic insulators, ease in handling and maintenance, and its hydrophobic properties that can suppress the leakage current [2-3].

However, long-term exposure to outdoor weathering such as pollution, ultraviolet radiation (UV), rain, high temperatures and humidity becomes a contributing factor in polymer insulator degradation. This is due to the chemical changes that take place on the surface due to weathering and dry band arcing. The presence of contaminants deposited under different weather conditions causes the 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 [3]. 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 [4] .

Over the years, RTV coatings have been chosen as an alternative to improve the electrical insulation behaviours for the conventional type of insulator (porcelain and glass) due to its hydrophobic properties, ease of application and maintenance and its adhesion characteristic to porcelain or glass in reducing and preventing line outages causes by pollution [5]. With this alternative, such coatings have been proven to lengthen the ceramic insulator lifespan and reduce the number of flashover events [6-8]. The life span of RTV coating can last up to 15 years on glass or porcelain insulators depending on the manufacturing details. However for the case of polymer insulator, there is no any measurement in past researches. Therefore a study of an RTV coating material on a polymer insulator is necessary in order to resolve the pollution accumulation issue on the surface or housing and at the same time act as protection between interference points (rod-housing and rod-fitting). Evaluation of the electrical performance and withstand voltage capability of the insulator is necessary to ensure the efficiency of power lines and to protect the power lines from flashover. The objective of this paper is to investigate the effects of an RTV coating on a polymer insulator in order to improve electrical insulation against different impulse voltages under clean and pollution conditions.

II. EXPERIMENTAL SET UP

A. *Insulator Samples*

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 red). The geometrical details are given in Table 1 and are the same for both types of insulators.

(a) (b)

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. *Test Set Up*

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 [6] 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 breakdown occurred. A new test was repeated five minutes after each breakdown for 20 times. The breakdown voltage value was recorded for each test and the average value for each insulator was determined.

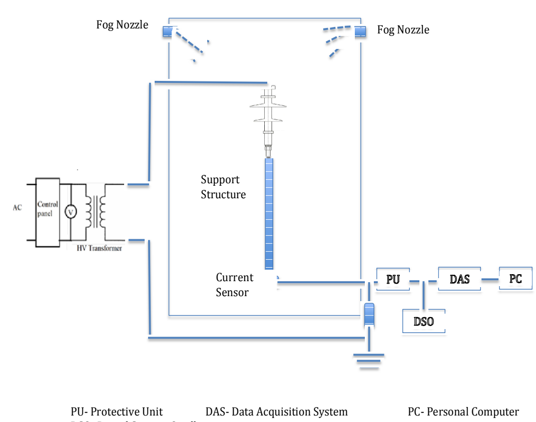

Figure 2. Experimental Set Up

III. RESULTS AND DISCUSSION

The normal procedure for determining the lightning withstand voltage is based on up and down method whereby the 50% probability of the flashover, U_{50} (also known as critical flashover voltage) is recorded after 20 tests.

A. Behaviour under a Positive Lightning Impulse

Figure 3 shows the voltage breakdown values for two different settings of the polymer insulator – with coating and without coating tested under two different conditions – clean wet and with pollution. From the figure, it shows that the insulator with coating has the highest breakdown value under clean conditions compared to the others with an average of 253.5 kV, while for the uncoated insulator, under clean conditions, the average breakdown value is 236 kV. The breakdown value of the coated insulator is 7.41 % higher than the uncoated insulator under clean conditions.

For the insulator tested under pollution conditions, the coated insulator shows an average breakdown value of 210.5 kV while the uncoated insulator shows an average breakdown value of 133.5 kV. The percentage difference between these two types of insulator settings is 57.68 %.

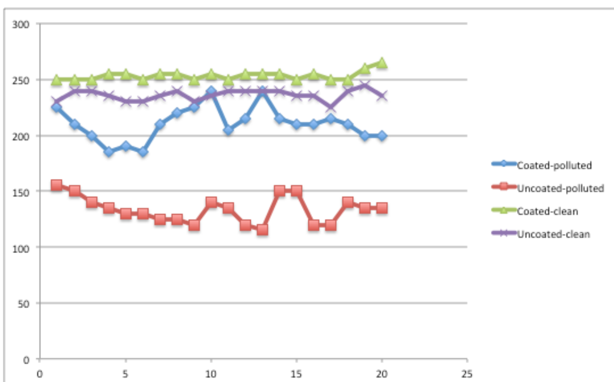

Figure 3. Comparison of Voltage Breakdown Values of a 10 kV polymer insulator (coated and uncoated) under Clean and Pollution (Salt) Conditions

Figure 4 shows the U_{50} for both types of insulator setting – with coating and without coating under clean conditions. Result under positive lightning impulse shows that the peak voltage of the insulator with the coating is higher than the insulator without the coating with values of 253.5 kV and 236 kV respectively. Figure 5 shows the U_{50} for both types of insulator settings – with coating and without coating under polluted conditions. Under polluted conditions, the graph shows that the peak value of the coated insulator is higher than the uncoated insulator by a percentage of 57.68 %. However, the time duration for voltage breakdown of the coated insulator is slightly shorter when compared with the insulator without coating. Based on assumptions, the roughness of the surface coating leads to increased accumulation of the pollutant and this contributes to a decrease in the duration of the voltage breakdown time [5].

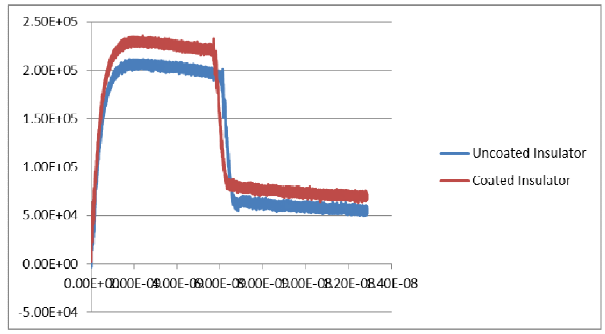

Figure 4. Voltage Breakdown Waveform for Insulator with Coating and without Coating under Wet Clean Conditions

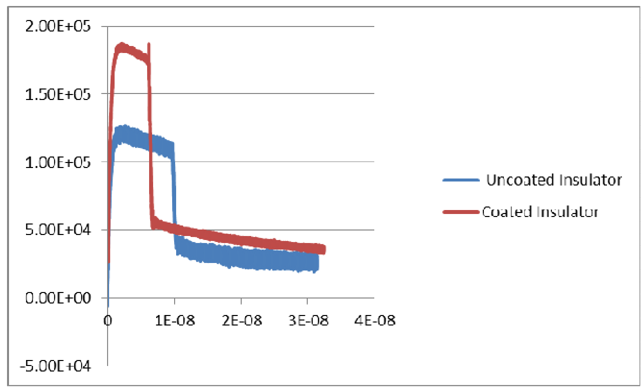

Figure 5. Voltage Breakdown Waveform for Insulator with Coating and without Coating under Pollution (Salt) Conditions

B. Behaviour under a Negative Lightning Impulse

Figure 6 shows a comparison of the U_{50} between the coated insulator and the uncoated insulator. From the figure, it shows that the U_{50} of the coated insulator has slightly the same breakdown value to the uncoated insulator under clean conditions. The U_{50} for this type of insulator settings is 314.5 kV for the coated insulator and 317.0 kV for the uncoated insulator. The percentage difference is 0.79 %.

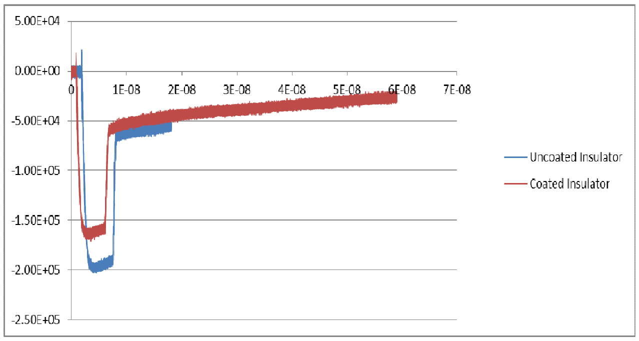

Figure 6. Voltage Breakdown Waveform for the Insulator with Coating and without Coating under Wet Clean Conditions

Figure 7 shows a comparison of U_{50} for the insulators under pollution conditions. From the figure, it shows that the U_{50} for the insulator without the coating is lower compared to the insulator with the coating. The breakdown values are 146.0 kV and 184.3 kV respectively. The percentage difference is 26.23%.

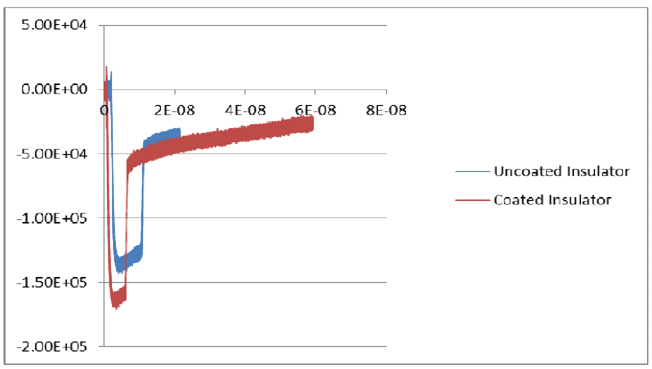

Figure 7. Voltage Breakdown Waveform for the Insulator with Coating and without Coating under Pollution (Salt) Conditions

For both types of insulator setting, the U_{50} is lower under polluted conditions when compared with the clean insulator. When exposed to pollution, contaminants (salt) will accumulate on the insulator surface. After continuously wetting, it creates a surface conductive layer thus allowing a flow of leakage current that leads to flashover [7-8]. As for the breakdown behaviour, the path of the breakdown is different for each condition. The breakdown path is in the air when tested under clean conditions. While for the polluted insulator, the breakdown path is along the insulator [9].

C. *Positive and Negative Lightning Impulse*

In most areas, rainstorms are the primary source of lighting. Lighting can be categorised into three different types, namely intra cloud, cloud to cloud and cloud to ground lightning. Among these three types of lightning, intra cloud lightning is the most frequent but cloud to ground lightning strikes affect overhead distribution lines [10]. Cloud to ground lightning can occur with either positive or negative polarity, although usually with negative polarity. Despite the lower probability of occurring, positive lightning is more dangerous as it carries current ten times higher than negative lighting. Hence, testing under both polarities is necessary to determine the insulator withstand capabilities.

From the tests conducted, the voltage breakdown values for both types of insulator tested under different impulse polarities are tabulated as in Table 3 below. From the table, it can be summarised that under clean conditions, the value of the breakdown voltage is higher when tested under a positive impulse compared to a negative impulse regardless of whether the insulator is coated or not. For the insulator tested under pollution conditions, the voltage breakdown values are higher when tested under a negative impulse regardless the type of insulator setting – coated or uncoated. The average difference for the coated insulator under pollution is 13.94% higher under a negative impulse compared to values under a positive impulse, while for a coated insulator tested under clean conditions, the percentage difference between the positive and the negative impulse is 24.06 %. The breakdown voltage under clean condition is higher than when tested under a negative impulse due to the migration of conductive ions from the electrode onto the insulator surface that causes high electrical conductivity and high leakage current [11].

TABLE 3: COMPARISON OF VOLTAGE BREAKDOWN VALUE BETWEEN POSITIVE AND NEGATIVE IMPULSE

	POSITIVE IMPULSE		NEGATIVE IMPULSE	
	UNCOATED	*COATED*	*UNCOATED*	*COATED*
CLEAN	236.0 kV	253.5 kV	317.0 kV	314.5 kV
POLLUTED	133.5 kV	210.5 kV	146.0 kV	184.3 kV

IV. CONCLUSION

A lightning impulse has a fast rise time with a high magnitude. Such a strike against an insulator could increase the insulator dielectric losses thus causing thermal runaway and failure. This could reduce the insulator life span.

For insulators (coated and un-coated) tested under clean wet conditions against a lightning impulse, moisture on the insulator surface will decrease the surface resistance of the insulator and cause a voltage breakdown. From the result, the breakdown value for the coated insulator is slightly higher than the uncoated insulator as the collection of surface moisture on the coated insulator is lower than the uncoated insulator, which therefore increases its electrical conductivity on the surface. The path of the breakdown for both types of insulator is normally through the air or on the insulator surface.

For insulators (coated and un-coated) tested under pollution (salt) conditions against a lightning impulse, the deposited salt solution on the insulator surface creates a conductive layer and allows leakage current to flow on the insulator surface and thus causes a voltage breakdown. From the result, the breakdown value for the coated insulator is higher than the uncoated insulator due to the ability to prevent the formation of a conductive layer on the insulator surface and hence reduce the flow of leakage current. The path of the breakdown for both types of insulator is normally along the insulator.

As for the effect of lightning impulse polarity on the electrical performance of the polymer insulator, regardless of with or without a coating the breakdown value is higher when tested under a positive impulse under clean conditions. However, with RTV coating on the insulator surface, it helps in increasing the breakdown value under both negative and positive impulses.

In conclusion, it is necessary to evaluate the effects of impulse polarities on the insulator breakdown behaviour as this reversal polarity phenomenon is found both in lightning and in switching impulses. The effectiveness of RTV coating towards polymer insulator needs to be investigated.

ACKNOWLEDGMENT

The authors would like to thank the Centre for Electromagnetic and Lightning Protection Research (CELP) of University Putra Malaysia for providing their facilities and valuable assistance in conducting the experiments.

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