

**TRACKING AND EROSION PERFORMANCE OF SILICONE RUBBER UNDER  
AC AND -DC VOLTAGE**

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**A thesis submitted in fulfilment of the requirement for the degree of Bachelor of  
Electrical Engineering (Industrial Power)**

**Faculty of Electrical Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**JUNE 2017**

I declare that this report entitle “*Tracking and Erosion Performance of Silicone Rubber under AC and -DC Voltage*” is the result of my own research excepts as cited in the references. This report has not been accepted for any degree and is not concurrently submitted in candidature of any degree.

Signature : .....

Name : Omar Bin Ismail

Date :

**To my beloved mother and father**

*For their endless love, support and encouragement*

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## ABSTRACT

Silicone rubber (SIR) are broadly used as the insulation materials in high voltage engineering either in AC or DC electrical power system due to their advantages. The increase of interested in polymeric high voltage insulation technology has been driving the force for a lot of research on silicone rubber performance. However, the life term performance or aging of silicone rubber is still questionable. The most common method to determine their aging is by conducting tracking and erosion test, but the tracking and erosion test is only available in AC voltage. Thus the study on silicon rubber (SIR) in DC voltage is vital. In this study, tracking and erosion of SIR were evaluated under DC and AC voltage. Since there is no standard method for DC tracking and erosion, AC Incline Plane Tracking (IPT) BS EN 60587:2007 international standard was complied. Method 1 in BS EN 60587:2007, the application of constant tracking voltage was applied in this test. The test parameter voltage and flow rate for this test are -3.5kV DC, 3.5kV AC and 0.3ml/min respectively. Besides, surface temperature of SIR was measured for every 30 minutes during both AC and DC IPT test. The surface temperature was measured by using IRISYS IRI – 4010 Thermal Imager. In terms of tracking and erosion, SIR under -DC voltage test experienced more severe damage as compared to SIR under AC voltage test. Moreover, surface temperature of SIR in -DC IPT test were also higher than surface temperature of SIR in AC IPT test.

## ABSTRAK

Getah silikon secara umumnya digunakan sebagai bahan penebat dalam bidang kejuruteraan voltan tinggi sama ada dalam sistem kuasa elektrik arus ulang-alik (AU) mahupun arus terus (AT) kerana kelebihan mereka. Peningkatan tumpuan terhadap teknologi penebatan polimer voltan tinggi telah membawa kepada pelbagai penyelidikan mengenai kebolehan getah silikon. Walau bagaimanapun, prestasi jangka hayat atau penuaan getah silikon masih menjadi persoalan. Kaedah yang biasa digunakan untuk menentukan penuaan mereka adalah dengan menjalankan ujian pengesanan dan hakisan, tetapi ujian pengesanan dan hakisan hanya terdapat dalam voltan AU. Oleh itu, kajian mengenai getah silikon dalam voltan AT adalah sangat penting. Dalam kajian ini, pengesanan dan hakisan terhadap getah silikon telah dinilai dengan menggunakan voltan AU dan voltan AT. Oleh kerana tiada kaedah khusus untuk menilai pengesanan dan hakisan terhadap getah silikon dengan menggunakan voltan AT, piawaian antarabangsa Pengesanan Satah Condong (PSC) BS EN 60587: 2007 telah digunakan sebagai panduan. Kaedah 1 dalam BS EN 60587: 2007, penggunaan voltan pengesanan tetap telah digunakan dalam ujian ini. Nilai voltan dan kadar alir bagi ujian ini adalah masing-masing -3.5kV AT, 3.5kV AU dan 0.3ml/min. Selain itu, suhu permukaan getah silikon diukur bagi setiap 30 minit semasa ujian AT dan ujian AU. Suhu permukaan diukur dengan menggunakan IRISYS IRI - 4010 Pengukur Haba. Dari segi pengesanan dan hakisan, getah silikon yang diuji menggunakan voltan -AT mengalami kerosakan yang lebih teruk berbanding getah silikon yang diuji menggunakan voltan AU. Selain itu, suhu permukaan getah silikon dalam ujian -AT juga lebih tinggi daripada suhu permukaan getah silikon dalam ujian AU.



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## LIST OF ABBREVIATIONS

IPT	-	Incline Plane Tracking
DC	-	Direct Current
AC	-	Alternating Current
SIR	-	Silicone Rubber
LC	-	Leakage Current
UV	-	Ultraviolet
STRI	-	Swedish Transmission Research Institute
LMW	-	Low Molecular Weight
FYP	-	Final Year Project
LV	-	Low Voltage
HV	-	High Voltage

## CHAPTER 1

### INTRODUCTION

#### 1.1 Research Background

Insulation is the most important part to avoid the flow of current to the unwanted path in high voltage engineering or its application [1]. There are two type of solid insulation in high voltage application which are glass/ceramic and polymer. In 1940s, the history of polymeric insulation material had begun when epoxy resin was used as insulating material [2]. Then, in 1950s polymeric insulation material was develop for AC transmission line [3]. Previously, before the introduction of polymeric insulation, the industry of high voltage insulation was dominated by the ceramic and glass insulation. The ceramic insulation were slowly replaced by polymeric insulation due to the excellent properties of polymer such as their light weight which reduces the installation cost, transporting and easy of handling. Polymeric insulation materials are also flexible in design and it has a hydrophobic nature. The hydrophobic properties of polymer reduces transmission losses especially during the initial years of their service [4][5].

The most temptation characteristic of polymeric insulation is the hydrophobic behaviour. Hydrophobic properties can be defined as a water repellent properties on the surface of the material. The hydrophobic characteristic of materials can reduce the existence of contaminant since it avoid the water droplets from spreading over the surface of the insulation material. Thus, preventing the occurrences of tracking and



erosion on the surface of polymer during wet condition. Besides of tracking and erosion, the major factors that determine the insulation failure are the dielectric strength and electrical field strength which are the main properties of insulating material [1].

Moreover, polymeric insulation materials has high capability of handling of mechanical shock loads which also improved the resistance to vandal damage Next, their performance in contaminated condition also improve since polymeric insulation might be produced with a slighter surface area and longer leakage part [6].

The used of polymeric materials are widely applied in many application of outdoor high voltage insulation such as the bus bar insulation, surge arresters and cable termination. However, despite of their great function ability, polymeric insulation materials also have their weaknesses such as the temporary loss of hydrophobicity which will affect their long term endurance as a high voltage insulator [4]. Thus, the questions about the life long performance of polymeric insulation still exist even though this type of insulator had been used for decades of service. The capability of the polymeric insulation to resist physical and chemical degradation effectively when expose to continuous voltage stress and variety of environmental stress such as rain, heat, salt fog, ultraviolet radiation and industrial pollution were still dubious. The degradation of polymeric insulation materials will usually lead to failure of the insulation and this was due to the tracking and erosion phenomenon caused by the contaminated condition and environmental factors [1][7].

In addition, mostly the study done on polymeric insulation were usually based on AC voltage [8]. Less study were done on DC voltage supply. Therefore, this study focused on comparison between alternating current (AC) and the direct current (DC) tracking and erosion on polymeric insulation material. The reliability of DC outdoor insulation need to be understand since the market share of high voltage transmission distribution is increase

[9]. There were some reports propose that the insulator under DC have higher conductivity and higher leakage current than under AC since the contaminants are more easily to accumulate on insulation`s surface under DC [10][8]. That means there will be greater challenge face by the insulator under DC transmission lines. Furthermore, there are standard tests to evaluate the performance of the material based on tracking and erosion by using AC voltage while the standard test method for DC voltage has not yet been standardized. However, there were many researchers did the test for DC voltage by using the standard test for AC voltage [11].

## **1.2 Problem Statement**

There are a few type of polymeric insulation materials but SIR is the most common materials that have been used as high voltage insulation. Some advantages of silicone rubber such as their light in weight and high hydrophobicity is well known but this type of insulator still have their own disadvantage which is the aging. Aging can be defined as the degradation of the insulator due to electrical stresses and different environmental effects. The ability of polymeric insulation and their long term performance need to be evaluated in order to know their reliability on the AC and DC transmission lines. Nowadays, the high voltage DC technology is increasingly applied in electrical power system. There is standard test to investigate tracking and erosion of AC on polymeric insulation materials which is IPT test (BS EN 60587:2007) international standard. However, there is no standardized test under DC voltage tracking and erosion on polymeric insulation. Besides, several study suggest that the tracking and erosion of insulation materials are more severe on DC voltage. Therefore, there is a need to study the comparison in terms of tracking and erosion and thermal characteristics for DC and AC IPT test for this type of materials for a better understanding and knowledge regarding the performances of Silicone Rubber under DC and AC voltage.

### 1.3 Objective

The main purposes of this study are as follows:

1. To conduct -DC and AC tracking and erosion test on silicone rubber (SIR) material by complying AC IPT test BS EN 60587:2007 standard as a reference.
2. To compare the performance of silicon rubber (SIR) polymer in terms of thermal characteristic, tracking and erosion under -DC and AC voltage.

### 1.4 Scope

The scopes of study are limited to:

1. The IPT test comply with BS EN 60587:2007 will be use as a reference to determine the tracking and erosion on polymeric insulation material.
2. IPT test will be conduct by using constant tracking voltage method at -3.5kV DC and 3.5kV AC voltage.
3. Silicon rubber which are readily processed with no filler will be use as the polymeric insulation material.
4. The performance of SIR are compared in terms of thermal characteristic, tracking and erosion for both AC and DC IPT test.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

Insulation is one of the aspects that have to be consider in order to determine the obtainability and dependability of the AC and DC power system. Nowadays, polymeric material is commonly used as insulation due to the advantages of it over glass and ceramic materials. Besides, there were a lot of important studies have been made for improvement on the performance of polymeric insulation material since they were accepted as an insulator material.

This chapter include the sub topic that discusses about the general idea of AC and DC in high voltage power system, solid insulation materials, the advantages of SIR material, hydrophobicity behaviour, aging of polymeric insulation materials, tracking and erosion, and IPT test. Besides, this chapter also discuss about previous study on DC tracking and erosion on polymeric insulation material.

#### **2.2 AC and DC**

AC can be defined as a current that varies sinusoidally with time while DC is a current that remains constant with time. The first polymer insulator for AC transmission lines was develop in the late 1950s while the first polymer insulator for DC was trialled in the mid-1970s [3]. The reliability of both AC and DC transmission

line is depend on the ability of the insulator on the transmission line. DC system have been used in submarine cable links for many years and the technology is regularly used for long distance transmission where it is more economic and energy efficient than AC [9].

### 2.3 Solid Insulation Material

There are two types of solid insulation materials which are glass/ceramic materials and polymeric materials. Both ceramic/glass insulation materials and polymeric insulation materials have their own advantages and disadvantages in certain properties. Table 2.1 shows the comparison of this two type of solid insulation materials.

Table 2.1: Comparison between polymeric and ceramic insulation materials [1].

Property	Ceramic	Polymer
Compressive strength	+	-
Size	--	++
Weight	--	++
Breakage	-	+++
Processing and Fabrication	-	++
Material cost	+	-
Aging	+++	++
Compatibility		
Pollution flashover	---	--
Resistance/Weathering		
Degradation		
Hydrophobicity	--	++
Creepage/Unit length	-	++

+ good, -weak

### **2.3.1 Glass and Ceramic**

Ceramic material such as porcelain has over one century of service history as an insulating material. This type of materials were said not generally degraded by environmental stress such as humidity, surface electrical activity and UV. Besides, ceramic insulation were also tend to be very stable. Ceramic materials housing such as porcelain that used for cable termination, surge arresters and bushing do not need other materials or mechanisms for strength.

However, ceramic materials are easily broken in handling, transit and installation due to their properties which is hard but liable to break easily. Ceramic materials are also easily broken by vandalism that is a primary contributor to in-service mechanical damage. Moreover, ceramic materials bodies are very heavy due to their very dense nature. This means that expensive and large support are also necessary due to difficult in handling which will require the use of cranes [12].

### **2.3.2 Silicone Rubber**

The broadly used of Silicon Rubber as insulation material in transmission lines is due to the brilliant electrical and mechanical properties of the material [10]. SIR insulator have a hydrophobic surface which is water form separate droplets instead of making a water film. This phenomena have make this type of insulator to be better than traditional insulator in terms of formation of a conducting surface layer. However, the hydrophobicity behaviour of SIR will be reduced due to the build-up of contaminant on the surface of the insulator, environmental effects and electrical discharge activity. The reduced in hydrophobicity behaviour will lead to the degraded insulation performance but the hydrophobicity properties of SIR has been reported that its may recover even in the present of surface contaminant.

Thus, SIR insulators is one of the most reliable insulator for use in polluted environments [13]. Besides, SIR composite insulators are an attractive alternative to traditional ceramic insulators in almost all new builds, replacements and upgrade. Thus, a lot of research on SIR including AC tracking and erosion tests have been done due to the phenomena [9].

#### **2.4 Advantages of Silicone Rubber Material**

One of the important infrastructures in the world is the power sector. Power sector can gets affected due to disasters leading to disruption in generation, transmission and distribution of electric power. The deposition of pollutants on the insulators which start conducting during foggy weather condition resulting in flashover and interruption of power in one of the reasons of the disasters.

SIR insulator is better equipped to deal with flashover problems as compared to others polymeric insulation materials, due to its unique hydrophobicity property. The formation of water forming on surface of SIR can be avoided due the hydrophobicity property. Therefore, it prevent the flow of leakage current (LC) on the surface on the insulation materials [14]. Moreover, there are many advantages of SIR insulator as compared to ceramic and glass insulators such as easy handling, light weight, maintenance free high strength to weight ratio, high impact resistance and perform well in contaminated environment. Therefore, SIR materials are accepted universally and replacing the traditional ceramic and glass insulators in electrical power system all over the world due to their advantages over ceramic and glass insulation materials [15].

### 2.4.1 Hydrophobicity Behaviour

Hydrophobicity can be defined as the ability of the insulators to repel water on its surface. Thus the water droplet forming as individual droplets rather than a film. It is more difficult for water to bridge the gap between adjacent shed edges on a hydrophobic insulator than on hydrophilic insulator. The measurement of hydrophobicity has been very widely used and investigated since it is the most important property of polymeric insulation materials. Hydrophobicity can be quantified using static or dynamic contact angles, the Swedish Transmission Research Institute (STRI) index, sliding angle or a water soaking test.

Nevertheless, the simplest way in order to quantify the hydrophobicity is by measuring the static contact angle of a water drop. The smaller the contact angle, the more wettable is the surface, when the contact angle is less than  $35^\circ$  the surface is assumed to be hydrophilic while for contact angle greater than  $90^\circ$  the surface is assumed to be hydrophobic. Figure 2.1 shows that the material which easily wettable allows water to touch a large surface area and hence makes a contact angle less than  $90^\circ$  while hydrophobic material allow less water surface contact and therefore makes a contact angle greater than  $90^\circ$ . However, hydrophobicity is not a fixed property instead can be lost and gained depending on the surface conditions [16][14].