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BREAKDOWN VOLTAGE OF POLYMERIC MATERIAL UNDER DIFFERENT SHAPE OF ELECTRODE

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A report submitted
in fulfillment of the requirements for the Bachelor of Electrical Engineering
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2017

I declare that this report entitled "*Breakdown Voltage of Polymeric Material Under Different Shape of Electrode*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……..……..…….

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Date : .....

Dedicated to my beloved family, friends and lecturers for their never ending support, encouragement and understanding towards the completion of my work.

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ABSTRACT

The technology of insulation has been evolved from the use of porcelain and glass to the polymeric materials. Since polymeric materials has been accepted as the high voltage application. A lot of study has been conducted to make an improvement to its properties, understand it performance and to develop a new composites as well and it involves in designing, monitoring and practical testing. This study will be focused on practical testing of Silicone rubber (SIR) thermoset type of polymeric material. The electrical SIR parameter to be investigated are its dielectric strength performance. In order to determine this parameter, standard test of dielectric strength is conducted, where it complying to International Standard BS EN 60243-1 : 1998 test method. All the testing procedure and specimen preparation are following this standard. The test was conducted for determining long-term dielectric strength of solid insulation material at power frequency of 50 Hertz (Hz). Three different shapes of electrode were used which are flat end shape electrode, spherical end shape electrode and pin end shape electrode. From the analysis carried out, dielectric strength of SIR using all shapes of electrode meet the minimum requirements of breakdown field strength which must exceed 10kV/mm with reference to International Standards BS EN 62039 : 2007. Then, this results of breakdown voltage can be used for determine the properties of ageing conditions, manufacturing design and other environmental condition in HV insulation application using polymeric materials.

ABSTRAK

Teknologi penebat telah berkembang daripada penggunaan porselin dan kaca kepada bahan polimer. Sejak bahan polimer telah diterima pakai sebagai aplikasi dalam voltan tinggi. Banyak kajian telah dijalankan untuk membuat penambahbaikan terhadap sifat-sifatnya, memahami prestasinya dan juga untuk menghasilkan bahan komposit yang baharu dan ia termasuk juga dalam mereka bentuk, pemantauan dan ujian praktikal. Kajian ini akan memberi tumpuan kepada ujian praktikal terhadap getah silikon (SIR) bahan polimer jenis termoset. Parameter elektrik SIR yang akan dikaji adalah prestasi kekuatan dielektrik nya. Untuk menentukan parameter ini, ujian standard kekuatan dielektrik dijalankan, di mana ia mematuhi Standard Antarabangsa BS EN 60243-1 : 1998 kaedah ujian. Semua kaedah ujian dan penyediaan spesimen adalah mengikuti standard ini. Ujian ini akan dijalankan untuk menentukan kekuatan dielektrik jangka panjang bahan penebat pepejal pada frekuensi kuasa 50 Hertz(Hz). Tiga bentuk elektrod yang berbeza digunakan seperti elektrod hujung berbentuk rata, elektrod hujung berbentuk sfera dan elektrod hujung berbentuk pin. Daripada analisis yang telah dijalankan, kekuatan dielektrik SIR dengan menggunakan kesemua bentuk elektrod memenuhi tahap minima kekuatan medan pecahan iaitu mesti melebihi 10kV/mm dengan merujuk kepada Standard Antarabangsa BS EN 62039 : 2007. Kemudian, keputusan voltan pecahan ini boleh digunakan untuk menentukan ciri- ciri keadaan penuaan, reka bentuk pembuatan dan keadaan persekitaran yang lain di dalam aplikasi penebat HV menggunakan bahan polimer.

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Hz	-	Hertz
HV	-	High voltage
SIR	-	Silicone rubber
HDPE	-	High density polyethylene
EPR	-	Ethylene propylene rubber
BSI	-	British Standard Institution
UV	-	Ultraviolet
AC	-	Alternating Current
OT	-	Operating Terminal
DMI	-	Digital Measuring Instrument
kV	-	Kilo volt
R.M.S	-	Root mean

CHAPTER 1

INTRODUCTION

1.1 Introduction

Electricity supply is a must and one of the most important things in the world. Basically, most of the equipment are using electricity. Electricity can be distributed into several parts which are generation, transmission and distribution.

In order to supply the electricity, two important things are needed which are conductor to carry the current and the other one is the insulation to prevent current from flowing to undesired paths and also as the protection to the human being and living things from the electrical shock [1]. In modern times, high voltages are used in many applications including the power system industry and research laboratories. Moreover, in the high voltage engineering (HV), the insulation is the most important thing that needs to be concerned because any insulation failure will cause an electrical shock, burns and fatalities to human beings.

Previously, the outdoor insulation material was dominated by porcelain and glass material. Even though glass and porcelain-type insulations both have good insulation properties and weather resistance but they also have the disadvantages of their weight that are heavy, easily to fractured, non-hydrophobic characteristic and will undergo degradation of their strength to withstand high voltage stress [2]. However, in the middle of the twenty century a new concept of composite insulator introducing polymeric materials was developed in USA [3]. Non-ceramic (polymeric) insulators are well accepted by the industry and utilities to replace the old-type porcelain and glass insulators due to their

advantages such as light in weight, easy to handle, better contamination performance and low installation and maintenance costs [4]. Therefore, polymer has been widely used and accepted in the HV insulation as a replacement of glass and porcelain insulation that have been used for decades before.

One of the advantages of the polymer insulation is its hydrophobicity characteristic against fog, dew and rain. The hydrophobic characteristic of polymeric insulation is defined as the water repellent ability on the surface of the polymeric insulation especially in highly contaminated area [1][5]. It means that this property does not allow the water droplets to spread all over the surface of the polymeric insulation and cause the surface to polluted and contaminated. Currently used polymeric materials in the insulation field are high density polyethylene (HDPE), silicone rubber (SIR), Ethylene propylene rubber (EPR) and many more [6].

Furthermore, insulation not only must withstand at the rated voltage for the operation, but it must have high dielectric strength that strong enough to hold whenever overvoltage stress occur such as by the lightning strike and by fluctuations in the load or generations [7]. Dielectric strength of the insulation material defined as the maximum level of voltage that it can withstand under ideal condition without loss its insulating properties from high voltage stress. If the injected voltage to the material is steadily increased until it comes at one point where the dielectric strength of the insulating material have passed it limit, a short circuit breakdown channel or track is formed [8]. Electric breakdown describe as the severe loss of the insulation material when exposed to the electric stress that cause the current during test to operate an appropriate circuit breaker [9].

Next, in order to determine the electrical strength of the polymeric material, one test called as the dielectric strength test will be conducted on the polymeric material. In this

project work, the dielectric strength test will be carried out using different types of electrode shape. There are three types of the electrode use which are flat end shaped electrode, spherical shaped electrode and another one is pin shaped electrode. The difference of the electrode shape will give the difference in the radius of the electrode end touching with the polymeric material surface. As a result, this condition affects the dielectric strength of the sample tested. In addition, the dielectric strength test will be conducted by using the selected polymeric material sample which is SIR from thermoset type of polymer.

Lastly, SIR was selected as the test material for this project because of its unique characteristic among others polymer and have superior properties to electrical stress, heat resistance, hydrophobicity, fire retardancy, radiation resistance, low surface energy and flexible for wide range of temperature and weather resistance which is resist to degradation cause by ultraviolet radiation [2] [5]. The study of dielectric strength test of the polymeric insulating material will be associated with the British Standard Institution, BS EN 60243-1: 1998, electrical strength of insulating materials – Test methods – Part 1: Test at power frequencies test standard as the testing and work procedure to obtain the result.

1.2 Project Motivation

Insulation plays a crucial part in determining the prolong performance and lifespan of a high voltage equipment. Nowadays, a lot of high voltage test was conducted. The high voltage testing were used to investigate the withstands capability of the insulation or other study cases. However, these tests have to follow the standard to get a reliable results. By complying to the standard test procedure, behaviour of insulation material in actual application can be determined. The result obtained can be used to determine the aging condition, characteristic of processing variable, manufacturing or environmental condition

in high voltage polymeric insulation application. In addition, under standard test procedure, the testing laboratory recognized for the safety features, the testing results of polymeric specimen is valid and used for benchmarking of performance. Therefore, the standard test accordingly to the international standard is crucial to be complied for the use of polymeric insulation material research and a safety is vital since using high voltage application.

1.3 Problem Statement

Dielectric strength of the insulation material is an important properties that need to be consider as well as the other properties of the insulation materials. Previously, a lot of research has been done for the electrical properties test of the different types of polymeric materials. However, this project will focus on the dielectric strength performance of one type of thermoset polymer material only which is SIR to test this polymeric material using different shape of electrode attached to the polymeric insulation material surface.

The different shape of electrode that involves in this study are flat type, spherical and pin type shape to determine which type of electrode shape affect the most to the dielectric strength of this polymeric material. For the test of dielectric strength of the insulation material, the minimum requirement of the electrical strength of the material for the outdoor insulation usage purpose must at least exceed 10kV / mm. Therefore, in order to carry out this experiment, all the procedure that need to be taken are following the standard of testing which is following standard procedure of International Standard, BS EN 60243-1 : 1998 to validate the result obtain.

1.4 Objectives

The objectives of this project are as follows:

1. To investigate the electrical strength of the polymeric material under high voltage supply based on BS EN 60243-1: 1998 test standard.
2. To determine the dielectric strength performance of SIR insulation using different shape of electrodes.
3. To compare the data and verify the most influence shape of electrode to the dielectric strength of the SIR polymer.

1.5 Scope Of Research

This project will be focused as follow:

1. SIR polymeric thermoset material is used as the test subject for the dielectric strength test.
2. Material is to be tested at power frequency of 50Hz with rapid high voltage injection in the short-time (rapid-rise) testing method.
3. Four different types of electrode shape to be used which are spherical shape, pin shape, equal diameter flat shape and unequal diameter flat shape electrode.
4. Method of testing will follow accordingly to the British Standard Institution, BS EN 60243-1: 1998 test method with requirement of flat sheet.

1.6 Report Outline

Generally, this report consist of five chapters :

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Project Methodology

Chapter 4: Results and Discussion

Chapter 5: Conclusion and Recommendation

Chapter 1 is about the overview of this project and consist of problem statement, objectives, project scopes and the purpose of this project conducted as shown above.

Chapter 2 provide literature review and the theoretical knowledge regarding this project. All the details, facts and terms that related to the dielectric strength test will be presented in this chapter.

Chapter 3 presents the method carry out to obtain the result of this project. Involving all the steps and procedure taken for the electrical strength of polymeric insulation material test. All the set up and the sample dimensioning and specification are follow the British Standard Institution, BS EN 60243-1 : 1998 standard.

Chapter 4 shows the result of the project. . The result obtain from difference type of the electrode use in the testing and discussion of the effect to the polymer electrical strength will be discussed.

Chapter 5 is the conclusion and recommendation of the achievement from the finding study that have been made.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Insulation is as important as conductor because the insulation will prevent the electric from flow to the undesired path and at once deliver the electrical supplies to the equipment and loads in the transmission system. Recently, polymeric material has been choose over the porcelain and glass as the HV insulator due to its advantages and unique characteristic. Therefore, a lot of study has been conducted among the researcher and technologist to study and make an improvement of this material performance. Improvement on this material can be classified into several part such as development and performance of newly invented polymeric materials, electrical and mechanical stresses, proper dimensioning, design and manufacturing process of its composite materials and lastly the practical test of dielectric strength of the material itself in order to monitor, measure and verify its performance [1]. The following sub-sections in this chapter explain about the insulation materials, selected material, testing method, dielectric strength of material and type of electrode used.

2.2 Insulation Materials

Insulation are very important to separate the conductor from another conductor or living things. Practically, insulation material are divided into three parts which are solid, liquid and gas. In this study will be focus on solid type of insulation material only. Then, in the solid materials, it have three types which is organic materials, inorganic materials and

synthetic materials or called as polymeric material. While, this study focuses on polymeric materials.

2.2.1 Polymeric Materials

Synthetic material are better for electrical insulation and more reliable and less weight. It can be divided into three groups which is thermoset, thermoplastic and elastomer. Common widely use polymeric material in practical are high density polyethylene (HDPE), silicone rubber (SIR), Ethylene propylene rubber (EPR) and more [6]. In this project are focus on SIR. These polymeric composite are apply as the cap and pin, supporters, bushings, surge arrestor, wires and cables and energy storage and savings [10].

2.2.1.1 Silicone Rubber

SIR compound have very good properties among other polymer materials. It have advantages of low surface energy, heat and radiation resistance, flame retardancy, good electrical properties and water repellent properties. Besides, SIR have high elasticity and excellent compressibility when given stress. While it have the hydrophobicity surface that does not allow water droplet to spread all over the surface. This properties are important especially at the polluted area. This type of polymeric material are selected as the project sample for the dielectric test. [2][4][5].

2.2.1.2 Classes Of Polymer

Thermoset, thermoplastic and elastomer are three classes of polymeric material. Thermoset polymer can be define as material that cannot be remould once have been cured with heat or with high energy irradiation. This type of material usually need to be heated at

200 degrees and above during curing process. While, thermoplastic are the type that can be remould by applying specific degrees of heat. Then, elastomer have the characteristic of flexible polymer unlike thermoplastic and thermoset material [2].

2.2.2 Advantages Of Polymer

Polymeric material have several advantages as it is has excellent electrical and weather resistance properties, wide range of working temperature, low surface energy, hydrophobicity surface and resist to degradation due to ultraviolet (UV) radiation [2]. Besides, it is less weight, and stronger while easy to moulded and cost efficient.

2.3 Deterioration And Breakdown

Deterioration of material is the degradation of the polymeric material properties. This matter cause when it services in a long time. Where it affect the structural, mechanical integrity and ability of withstand voltage under polluted conditions. Regarding this problem, a lot of study and practical test has been conducted to overcome the problems. Including ageing test by leakage current, dielectric strength or breakdown voltage and tracking and erosion test to determine their performance under high voltage stress [4].

2.3.1 Electrical Strength Breakdown

Electrical breakdown of the insulation material is when the given electrical stress to the insulation material are too high and pass it limit of resistivity and cause severe loss of insulating properties of the material that cause the current in the circuit to operate the circuit breaker during the test. It consider as the failure of the insulation material under high voltages stress [9][11]. Where, electrical strength or dielectric strength of the material