DIELECTRIC PERFORMANCE OF DIFFERENT TYPES OF POLYMERIC MATERIAL UNDER STANDARD TEST PROCEDURES

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June 2014

" I hereby declare that I have read this fully report entitled *"Dielectric Performance of Different Types of Polymeric Material Under Standard Test Procedures"* and found that it has comply the partial fulfillment for awarding the *Bachelor of Electrical Engineering (Industrial Power)"*

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

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I declare that this report entitle *"Dielectric Performance of Different Types of Polymeric Material Under Standard Test Procedures"* is the result of my own research except as cited in the references. The report has not been accepted for any degree and not concurrently submitted in candidature of any other degree.

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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

High voltage insulation technology has undergone continuous development and improvement over time, from the shelves of ceramics to polymer composite insulating synthetic material. Some research has been done, but still has room to improve the performance of insulating polymer. A synthetic polymer is widely used in high-voltage insulation and was divided into two parts which is thermoplastic and thermoset materials. This study focuses on the performance thermoplastic materials as high-voltage insulation materials. In this study the thermoplastic polymeric material has been selected are high density Polyethylene (HDPE), Polypropylene (PP), and Polyvinyl Chloride (PVC). Among the basic needs to examine and evaluate the performance of selected materials as external high voltage applications is its dielectric strength level. In determining the dielectric strength of the selected material, breakdown test on the specimen was conducted. The test parameters, dimensioning and condition of the specimen prepared based flat sheet material testing accordingly to international standard BS EN 60243-1:1998. The experiment was carried out by complying test methods for determining the strength of the long-term solid electrical insulating materials at power frequencies of 50 Hz. From the analysis carried out, both Polypropylene (PP) and High Density Polyethylene (HDPE) meet the requirements of the breakdown field strength of the polymer. However, Polyvinyl Chloride (PVC) has the lowest value of the breakdown voltage and the breakdown of this polymer does not comply with the request, which must exceed the minimum requirement of 10 KV/mm with reference to the international standard BS EN 62039: 2007. Then, this breakdown results can be used to determine the characteristic of processing variables, aging condition, and other manufacturing or environmental situation in high voltage polymeric insulation application.

ABSTRAK

Teknologi penebat voltan tinggi telah melalui pembangunan yang berterusan dan peningkatan dari masa ke semasa, dari rak seramik untuk polimer penebat komposit bahan sintetik. Beberapa penyelidikan telah dilakukan, tetapi masih mempunyai ruang untuk meningkatkan prestasi polimer penebat. Satu polimer sintetik digunakan secara meluas dalam penebat voltan tinggi dan dibahagikan kepada dua bahagian iaitu termoplastik dan bahan termoset. Kajian ini memberi tumpuan kepada prestasi bahan termoplastik sebagai bahan penebat voltan tinggi. Dalam kajian ini bahan polimer termoplastik yang telah dipilih adalah Polietilena ketumpatan tinggi (HDPE), Polipropilena (PP), dan Polyvinyl Klorida (PVC). Antara keperluan asas untuk mengkaji dan menilai prestasi bahan terpilih aplikasi voltan tinggi luar adalah tahap kekuatan dielektrik. Dalam menentukan kekuatan dielektrik bahan yang dipilih, ujian pecahan pada sampel telah dijalankan. Parameter ujian, pendimensian dan keadaan bagi sampel ujian disediakan berdasarkan rata lembaran bahan ujian sewajarnya untuk piawaian antarabangsa BS EN 60243-1:1998. Uji kaji telah dijalankan dengan menggunakan kaedah ujian yang disediakan bagi menentukan kekuatan pepejal bahan penebat elektrik jangka panjang pada frekuensi kuasa 50 Hz. Daripada analisis yang telah dijalankan, kedua-dua Polipropilena (PP) dan polietilena berketumpatan tinggi (HDPE) memenuhi keperluan kekuatan medan pecahan polimer. Manakala, Polyvinyl Klorida (PVC) mempunyai nilai yang paling rendah bagi voltan pecahan dan nilai ini tidak mematuhi permintaan pecahan polimer, yang perlu melebihi daripada keperluan minimum iaitu 10 KV mm dengan merujuk kepada standard BS EN 62039 antarabangsa:2007. Kemudian, keputusan pecahan voltan boleh digunakan untuk menentukan ciri pembolehubah pemprosesan, keadaan penuaan, dan pembuatan yang lain atau keadaan alam sekitar dalam voltan tinggi aplikasi penebat polimer.

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LIST OF ABBREVIATION

PE	– Polyethylene.
PVC	– Polyvinyl chloride
PP	– Polypropylene
HPE	– High Density Polyethylene
ANSI	– American National Standard Institute
IEC	– International Electrotechnical Commission
CIGRE	–The International Council on Large Electric Systems
NEMA	– National Electrical Manufacturers Association
BS	– British Standard
HV	– High Voltage
IEEE	– Institute of Electrical and Electronics Engineers
AC	– Alternating Current
OT	– Operation Terminal
DMI	– Digital Measuring Instruments
KV	– Kilovolt
r.m.s	–root mean square
SEM	– Scanning electron microscope

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Insulation shows a very important part in determining the performance and lifespan of high voltage equipment. The dielectric strength and electrical field being stressed on the insulating material are the main factors that lead to failure of the insulation [1]. In the last decade, much research has been conducted to study on polymer composite material and effectively the material for electrical application [2, 3]. Polymer such as Polyethylene (PE), Polyvinyl Chloride (PVC), Polypropylene (PP), epoxy resin and silicone rubber are used to be electrically insulated because their dielectric strength characteristic. Polymer materials are widely used in outdoor high voltage insulation system is gradually replacing traditional porcelain and glass used [4, 5]. For this study the thermoplastic polymeric material has been selected are Polyvinyl Chloride (PVC), Polypropylene (PP), and high density Polyethylene (HDPE).This material was selected because this material widely used in high insulating system and has high performance of electrical properties. This study, conducted accordingly British Standard Institution. Selection guide for polymeric materials for outdoor use under HV stress. PD IEC/TR 62039.2007 [6]. This guideline states electrical property to test material and from parameter listed breakdown field strength test was compiled using IEC 60243-1 or BS EN 60243-1 [7] with the minimum requirement need to fulfil in order to test material.

1.2 Project Motivation

Nowadays, a lot of high voltage test was conducted. The high voltage testing used to investigate withstands voltage or other study cases. However, these tests required following the standard to get reliable results, by using the standard test procedure behavior of insulating material in actual application can be determined. The result of the testing for detecting changes can be used to determine the characteristic of processing variables, aging condition, and other manufacturing or environmental situation in high voltage polymeric insulation application. Furthermore, under standard test procedures, the testing laboratory recognized for safety, the result of testing polymeric material is valid, and used for benchmarking of performance. Hence, the standard test accordingly to international standard is vital to be compiled for use of polymeric insulation material research and a safety need for high voltage application.

1.3 Problem Statement

Today a lot of research has been done on the electrical properties of high voltage insulation materials. Normally, there are two types of test can be conducted, standard test used for product test and non-standard test for research work. Where, the breakdown tests are conducted for the analysis of the dielectric strength, performance of polymeric insulation material properties. The high voltage testing used to material in order to get insulation characteristic. Since this experiment generates high voltages, compulsory handling steps and safety precaution need to be taken when handling the equipment. The safety precautions cover the laboratory safety, equipment, safety and user safety. Therefore, the standard test procedure accordingly to international standard is vital to be complied and must follow to get reliable results. And by referring to the British Standard Institution. Selection guide for polymeric materials for outdoor use under HV stress. PD IEC/TR 62039.2007 [6]. The minimum dielectric strength to be fulfilled for outdoor high voltage polymeric insulation shall not be less than 10kV/mm. In order to testing the dielectric strength of the polymer insulation, the international standard BS EN 60243-1:1998 is used. [7].

1.4 Objective

The objectives for this project are stated as follows:

1. To familiarize with high voltage lab testing and procedures.
2. To set up the experiment based on dielectric strength standard.
3. To investigate breakdown characteristics of polymeric material in insulation.
4. To analysis the dielectric strength performance of different type of polymeric material.

1.5 Scope of Research

This main scope of this research to studies, investigate and observe the dielectric performance of polymeric material. For this study polymeric material to be studied are Polyvinyl Chloride (PVC), Polypropylene (PP), and high density Polyethylene (HDPE). For dielectric testing procedure the test was conducted by complying with international standard BS EN 60243-1:1998 with the flat sheet test requirement. This test needs to conduct according to specific parameter such as by following the voltage reference in Malaysia at the power frequency level ≈ 50Hz and have safety precaution when doing the testing. Lastly, by setup experiment according to standard, the result of withstanding voltage of the material can be used to analysis the polymeric material and are more reliable to be used as a reference in other studies.

1.6 Outline of Report

This report consists of five chapters. Chapter 1 describes the overview of overview of the project, motivation of the project, problem statement, objectives, scope and expected of this project, Chapter 2 explain the literature related to this project. Each of the facts and details of the analysis will be described. The information collected is from IEEE journals, articles, books, technical paper, standard and other. Chapter 3 explains the methodology of the project and will cover the methods and procedure that been used in carrying out the study project. Chapter 4 highlight the results obtained from the experimental data collection, preparation and discussion performance of all type polymers that has been tested. Lastly, 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 shows a very important part in determining the performance and lifespan of high voltage equipment. This chapter covers all the related study the characteristic of polymer insulators. It also describes the Development of polymeric insulation, Reviews of Electrical Properties Test, appropriate tests, detection of surface features, standards related to methods

2.2 Degradation and breakdown

2.2.1 Electrical field stress

The most important materials used in high voltage device insulation, dielectric strength of insulating materials and advanced electric field stress when exposed to high voltage and insulation that prevents the flow of current in an unwanted way and dielectric strength maximum stress dielectric materials can withstand. Electrical breakdown strength of insulating

material depends on various parameters, such as pressure, temperature, humidity, type of applied voltage, defects in the dielectric materials, material electrodes and electrode surface conditions. The main reason for the presence of insulation failure in the release of either voids in the insulation or on the surface of the insulation [1]

2.2.2 Short- term breakdown

Electric field due to the very high stresses may not occur in the second or faster without damaging the insulation surface before failure.

2.2.3 Long- term breakdown

Breakdown of long-term aging is also known as insulation. The main effects eventually responsible for the aging of insulation, lead to the damage arising from the heat and partial discharge.

i. Ageing and Breakdown due to partial discharge.

ii. Ageing and Breakdown due to changes in insulating surface.

2.2.4 Accelerated Ageing Test

Aging of polymer insulators depending on the chemical and physical properties of materials and stress exposure. In this case, the aging factor can be determined by careful examination whether directly or indirectly. Although, several international organizations and national standards provided for accelerated life tests such as IEEE, IEC, CIGRE, ANSI, BS and NEMA, there are no specific standards that apply to all applications and conditions. This means that the lack of standards means test all materials. As a continuation of material technology, manufacturing often adjust the current test to suit different products [8].

These tests are designed to reveal the performance of the materials and the pressure is divided into four components, test the electrical properties, mechanical properties testing, physical and chemical testing environmental testing. Typically, the surface condition of polymeric materials under test is used as a diagnostic tool to represent the level of performance and aging. Continuity of technology, manufacturing often adjusts the current test to suit different products [8].

Due to the fact that the effect of aging is a process of long-term, the accelerated aging test is usually done either in materials or complete product samples insulating polymer. This test will be conducted on either polymer insulation under electrical stress or the environment. Usually the test is performed for insulation materials such as UV test experience, tracking and erosion tests, reducing test corona and oxidation stability test. In the meantime, a special test for complete insulation products like insulation, surge arrester and other detection and corrosion testing, salt fog test and test various environmental stresses. These tests are designed to reveal the performance of the materials and the pressure is divided into four components, test the electrical properties, mechanical properties testing, physical and chemical testing environmental testing. Typically, the surface condition of polymeric materials under test is