I hereby declare that I have read through this report entitle "*Thermal Characteristics As Diagnostic Tools To Determine Surface Condition Of Polymeric Insulation Material*" and found that it has complied the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)

Signature : ……

Supervisor's Name : Dr. Aminudin Bin Aman

Date : 29/05/2015

THERMAL CHARACTERISTICS AS DIAGNOSTIC TOOLS TO DETERMINE SURFACE CONDITION OF POLYMERIC INSULATION MATERIAL

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

I declare that this report entitle "*Thermal Characteristics As Diagnostic Tools To Determine Surface Condition Of Polymeric Insulation Material*" is the result of my own research excepts as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……

Name : AHMAD FAIZ BIN AHMAD MORLY

Date : 29/05/2015

DEDICATION

To my truly beloved parents, my late father Ayahanda Ahmad Morly Bin Sawidi and Bonda Faridah Binti Lebai Salleh, and my siblings for their encouragement, supports and understanding towards me. Also goes to everyone that involved indirectly in completing this project, thanks for your love and kindness.

May Allah bless all of us, Amin.

Wassalam.

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ABSTRACT

High voltage insulation technology has undertaken continuous development and improvement over time, from ceramics to synthetic polymer composite insulating material. Although synthetic polymer composite have several advantages compared to ceramics, but their ageing or long term performances is still lacking. A lot of studies have been conducted by the researchers in terms of their surface condition, ageing performance and leakage current signal as diagnostic tools. In this study, High Density Polyethylene thermoplastic polymer is choosing as material under study. In order to determine the surface condition of the composite insulation material, the test specimen are subjected to tracking and erosion conducted. The test under standard test is complied with International Standard Inclined Plane Tracking Test (IPT) BS EN 60587 : 2007. IPT is used to simulate leakage current on initial and continuous tracking voltage. Instead of LC parameters, this study focuses on identifying its thermal characteristics as analytical tools to determine surface condition of polymeric insulation material. In addition, the thermal profile of the sample during the tracking process is analyzed based on thermal images captured by an IRISYS IRI – 4010 infrared thermal imager. The correlation between visual observations of damage, the leakage current and thermal behaviours of test specimens under constant voltage stressed is investigated. From the results, it can be concluded that thermal characteristic of the tracking and erosion can be used as diagnostic tools to determine its surface condition.

ABSTRAK

Pembangunan teknologi penebat voltan tinggi telah melalui proses penambahbaikan dari semasa ke semasa daripada seramik kepada bahan penebat polimer sintetik. Walaupun polimer sintetik masih mempunyai banyak kelebihan berbanding seramik, namun kelemahan sintetik polimer masih lagi berada di tahap yang rendah terutamanya terhadap keupayaan keadaan permukaannya untuk jangka masa panjang. Pelbagai kajian telah dijalankan oleh pengkaji dengan menggunakan keupayaan permukaan dan isyarat arus bocor sebagai alatan diagnostik. Dalam kajian ini, polimer polietilena berketumpatan tinggi telah dipilih sebagai bahan untuk menjalankan kajian. Untuk menentukan keadaan permukaan bahan penebat komposit, pengujian spesimen dikaitkan dengan ujian pengesanan dan hakisan telah dijalankan. Ujian yang dijalankan adalah di bawah ujian mengikut piawaian antarabangsa ujian satah condong (IPT) BS EN 60587 : 2007. IPT digunakan untuk mensimulasikan arus bocor pada awalan dan berterusam pengesanan voltan. Berbeza dengan parameter arus bocor, kajian ini member tekanan kepada mengenal pasti cirri – ciri terma sebagai alat analisis bagi menentukan prestasi permukaan bahan penebat polimer. Di samping itu, sampel profil haba semasa proses pengesanan dianalisis berdasarkan imej haba yang ditangkap pengimej haba inframerah IRISYS IRI – 4010. Hubungan antara pemerhatian visual kerosakan, tingkah laku semasa dan terma kebocoran specimen ujian di bawah tekanan voltan dikaji. Daripada keputusan yang diperolehi, ciri – ciri terma bagi pengesanan dan penghakisan boleh digunakan sebagai alatan diagnostik untuk keadaan permukaan.

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NOMENCLATURE

HV	High Voltage
BS	British Standard
IPT	Inclined-Plane Tracking
PVC	Polyvinyl Chloride
PE	Polyethylene
PEHD	Polyethylene High-Density
PP	Polypropylene
EPDM	Ethylene Propylene Dienemonomer
FEP	Fluroinated Ethylene Propylene
XLPE	Cross – Linked Polyethylene
P	Density
Ω·m	Resistivity
mS/cm	Conductivity
Mm	Millimeter
kV	Kilovolts
Rpm	Revolution Per Minute
NH4CL	Ammonium Chloride

CHAPTER 1

INTRODUCTION

1.1 Research Background

Electric utilities are now restructured worldwide according to a global de-regulation trend. This will give a new concept that cables and power equipment must be run in suitable way as long as possible. This requires the evaluation of future and the extension of residual life. In most cases, their life might be determined by insulating materials used for them. Organic insulating materials used for that purpose are subject to ageing and degradation. In order to improve quality and lengthen the life expectancy, it is necessary to investigate ageing phenomena. Many researchs have been done on ageing phenomena and mechanisms and it is hard to review all the issues related to ageing of insulating materials and systems [1].

Basically, to determine the surface condition of polymeric and composite materials, the standpoint of their interfacial performance are being reviewed. Insulating materials are divided into two categories that is simple polymers and composites. Simple polymers with some additives are used for power cables, transformers, insulators and rotating machines. They consist of thermoplastics, elastomers, and thermosets. Thermoplastics include polyethylene (PE), polyethylene terephthalate (PET) and polyphenylene sulphide (PPS). Elastomers are silicone, ethylene propylene rubber (EPR) and ethylene propylenedienemonometer (EPDM), for instance, while thermosets are represented by epoxy composite materials with inorganic substances are applied for gas - insulated system (GIs), rotating machines,

and insulators. They constitute epoxy/glass, epoxy/silica, and/or alumina, and epoxy/mica system [2].

In practically, ageing processes are complicated and will undergo many stresses at the same time or sequentially. For example those stresses are such as electrical, mechanical, environmental and thermal. Some of the conditions are related with the degradation by tracking and erosion and the loss of hydrophobicity in case of surface properties, and with partial discharge (PD), electrical treeing, water keeing and combined phenomena. PD, electrical treeing and water treeing are of traditional interest, and are now understood~to such a deep degree that insulation systems might be improved with the aid of recent computer technology for calculation of electrical, thermal and mechanical stresses [2].

The relevant factors generally recognized as causing ageing of insulation include thermal stresses, electrical stresses, mechanical stresses, and moisture exposure. Thermal stresses are caused by internal heating due to current overloads and ambient temperature meanwhile the voltage gradient in the insulation is the cause if electrical stresses. Mechanical stresses are caused by manufacturing techniques, centrifugal forces, vibration and assembly configurations. Moisture exposure is an additional crucial cause of lowering dielectric properties that can form a conductive path on the surfaces of solid insulating material or react with it to initiate the chemical reversion. Above all aspects, thermal ageing is the main ageing factor [2,3].

While the gradual ageing becomes critical, the leakage current tends to get bigger and arcing discharge might come about. This can be explained as an sign of an incipient fault that will eventually lead to shorts between adjacent turns. Thus the key issue to anticipate and detect transformer incipient fault is to investigate the insulation performance. In this work, effect of thermal ageing on the dielectric performance of polymeric insulation material has been investigated experimentally [3].

1.1 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 behaviour of insulating material in actual application can be determined. This project is driven by using the inclined plane test according to the international standard BS EN 60587 : 2007. This project also use the infrared camera in order to get the result on the surface of the specimen. The result from this study explain more detail the thermal characteristic of the polymeric insulation material after IPT test have been conducted. Then the result is used for further research and development of insulation material in term of their tracking and erosion performance.

1.2 Problem Statements

The studied of an ageing problem that is related to the polymer insulator has been studied for a few decades. Polymers and composites applied in the utility industry are subjected to multiple kinds of stresses under their normal and possible operating conditions. Insulating materials are then aged due to stresses, mainly represented by thermal, electrical, mechanical, and environmental, for long runs. Polymers and composites used for cables, power apparatus and insulators are aged according to some of the different aspects as stated above. Oxidation, decomposition, pitting, dry-band arcing, erosion, tracking, treeing, and cracking, for instance, represent phenomena of ageing possibly caused by those factors [1]. In this report, the determination of ageing of polymeric insulation material is measured based on its surface condition. There are several method that can be conducted to get the result but in this report, the appropriate method for conducting the ageing test was determined by choosing the inclined - plane test to get the satisfied result. In getting the result and effect to the insulation, the thermal endurance in ageing insulation was being analyzed. Furthermore, the thermal characteristic of the insulation material and the specimen change of temperature were also being analyzed to observe the physical change of the specimen. This method is carried out exactly according to the international standards of BS EN 60587.

1.3 Objectives of Study

The objectives of this project are :

1. To apply a new method by using thermal characteristic as diagnostic tool for polymer surface condition
2. To observe the thermal characteristic on the surface material under test based on its severity.
3. To show the correlation of thermal condition of polymeric material with voltage value based on thermal characteristic.

1.4 Scope of Works

The scope of this project are :

1. The thermal characteristic as diagnostic tool to determine the surface condition of polymeric material.
2. The new method that need to adopt standardized test according to incline – plane test (IPT) according to international standard of BS EN 60587.
3. The selected polymeric material that was chosen to run this test is HDPE.
4. The manipulated variable is the voltage value meanwhile the flow rate of the contaminant and the type of contaminant used are fixed.

1.5 Report Outline

The report is organized as follows :

Chapter 1 : An overview of the research project in whole. This chapter describe the research background, problem statements, objectives, scopes and outline report of the project.

Chapter 2 : Describes about the literature review related to this project, including theory of high voltage insulation and types of insulation in electrical system. Beside that this chapter also explained about temperature measuring units, tracking and erosion test, and incline-plane test.

Chapter 3 : Consists of the system design and the experimental set-up of incline-plane test. In addition the procedure taken throughout this experiment also discussed in this chapter.

Chapter 4 : Discuss about the results and discussion of this experiment. Consist of analysis of thermal characteristics of the specimen and followed by analysis of leakage current behaviour related to the surface tracking phenomenon.

Chapter 5 : Consist of conclusion of this study and some suggestions for future work.

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

Insulation is a material that having great dielectric properties utilized on wire parts as a part of link as a rule as immediate covering on conductors. It is an important part of the wire. Insulation choice is controlled by various factors, for example, stability and long life, dielectric properties, resistance to high temperature, resistance to moisture, mechanical strength and flexibility. It is important to choose a cable with the kind of protection that completely meets the requirements of the application. There are a few applications where the wire must be resistance to fluids or chemicals. The best insulating material for an application is chosen focused around the requirements. The selection may include test of numerous different performance properties. Thermoplastic and thermoset are two significant subdivisions of the large group of insulation materials. The division is based on their behaviour to high temperature. Thermoplastic are materials which are softened by high temperature. The material will become rigid again upon cooling. This procedure of moulding and firming these materials by heating and cooling can be repeated. Thermoset are materials, which are softened once heated amid one phase of preparing. They can be moulded and extruded at this state after which they are cured. In the wake of finishing the setting process, they cannot be softened again on consequent heating [4].

2.2 Insulation In Electrical System

A non-conducting material that provides electric isolation of two parts at different voltages. To accomplish this, an insulator must meet two primary requirements : it must have an electrical resistivity and a dielectric strength sufficiently high for the given application. The secondary requirements relate to thermal and mechanical properties. Occasionally, tertiary requirements relating to dielectric loss and dielectric constant must also be reserved. A complementary requirement is that the required properties not deteriorate in a given environment and desired lifetime. Electric insulation is generally a vital factor in both the technical and economic feasibility of complex power and electronic systems. The generation and transmission of electric power depend critically upon the performance of electric insulation, and now plays an even more crucial role because of the energy shortage [5].

Flexible hydrocarbon insulation is generally either thermoplastic or thermosetting. Thermosets are initially soft, and can be extruded by using only pressure. Following heat treatment, when they return to ambient temperature, they are tougher and harder. After thermosetting, nonrubber thermosets are harder, stronger, and have more dimensional stability than the thermoplastics. Thermoplastics are softened by heating, and when cool become hard again. They are heat-extruded [4].

Cellulose paper insulation is neither thermoplastic nor thermosetting. It is widely used in cables and rotating machinery in multilayers and impregnated with oil. It has a relatively high dielectric loss that hardly decreases with decreasing temperature, which rules it out for cryogenic applications. Because of its high dielectric strength, the high loss has not been a deterrent to its use in conventional ambient-temperature applications. However, the high dielectric strength deteriorates quickly if moisture permeates the paper [4].

Rigid insulation includes glass, mica, epoxies, ceramoplastics, porcelain, alumina, and other ceramics. Rather than being used to insulate wires and cables, except for mica, these materials are used in equipment terminations (potheads) and as