THE EFFECT OF TEMPERATURE RISE ON THE ELECTRICAL CHARACTERISTIC OF SOLID MATERIAL

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Bachelor of Industrial Power

MAY 2010

"I hereby declare that I have read through his report entitle *The effect of temperature rise on the electrical characteristic of solid material* and found that he has comply the partial fullfilment for awarding the Bachelor of Electrical Engeneering (Industrial Power)"

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THE EFFECT OF TEMPERATURE RISE ON THE ELECTRICAL CHARACTERISTIC OF SOLID MATERIAL

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A report submitted in partial fulfillment of the requirements for the degree of Electrical Engineering (Industrial Power)

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MAY 2010

I declare that this report entitle *The effect of temperature rise on the electrical characteristic of solid material* is the result of my own research except as cited in the references. The report has not been accepted any degree and is not concurrently submitted in candidature of any degree.

Signature :..

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Date : 12/5/2010

To my friends and parent for their motivation, support and encourage

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ABSTRACT

The most important things in HV systems there are the insulator which is also known as dielectric. It provides safety to the livings. There are 4 types of dielectric which are solids, liquids, gasses and high vacuum. This is an experimental work project which is focus on electrical characteristic of solid insulation. In this project, the solid insulation that was chosen is waste wood and it will focus on the electrical characteristic of their insulation against the high voltage stress. There a lot of electrical characteristic such as breakdown, resistance, voltage drop and more. The electrical characteristic that will be study is the breakdown voltage of solid insulation. Beside that, it also studies the effect of rising temperature on electrical characteristic of solid insulation. The solid insulation will be tested in different kind of nature of high voltage stress such as HVAC, HVDC and Impulse Voltage.

ABSTRAK

Penebat merupakan benda yang penting dalam sistem voltan tinggi dimana ianya boleh mengelakkan berlakunya kebocoran elektrik. Terdapat 4 jenis penebat iaitu pepejal, cecair, gas dan udara. Projek ini merupakan projek eksperimen dimana ianya mengkaji kriteria terhadap penebat pepejal. Untuk projek ini, penebat pepejal yang dipilih adalah kayu dan kajian ini fokus kepada kriteria elektrik terhadap voltan tinggi. Kriteria elektrik yang dikaji adalah voltan pecah tebat pepejal terhadap voltan tinggi yang dikenakan. Selain itu, projek ini juga mengkaji kesan suhu terhadap kirteria elektrik penebat pepejal tersebut. Penebat pepejal akan diuji dalam pelbagai jenis voltan tinggi iaitu voltan tinggi arus terus (HVDC), voltan tinggi arus ulang-alik (HVAC) dan voltan pusuan.

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HV	-	High Voltage
HVAC	-	High Voltage Alternating Current
HVDC	-	High Voltage Direct Current
kV	-	Kilovolt
PNH	-	Penarahan
KSK	-	Kembang Semangkuk

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CHAPTER 1

INTRODUCTION

1.1 Project Background

For the previous solid insulation, it is using wood as the test object but there only two types of wood with the same thickness. It is test the withstand voltage without any other effect like temperature or moisture wood. The test was carrying on with the high voltage stress such as HVAC, HVDC and Impulse Voltage.

This project is an experimental work approach that study and analyze the effect of temperature rise on the electrical characteristic of solid material against high voltage stress with several temperature ranges. The electrical characteristic to be study is breakdown voltage.

The different types of woods will be test in different kinds of nature of high voltage which is High Voltage Alternating Current (HVAC), High Voltage Direct Current (HVDC), and Impulse Voltage.

1.2 Problem Statement

There are no piece of electrical equipment that does not depends on electrical insulation in one form or an other to maintain the flow of electric current in desired path of the circuit. In real insulation systems with solid insulation, partial discharges usually occur far below the breakdown voltage.

There are several different definitions for what defines high voltage. The definition of high voltage is any electric potential capable of producing breakdown in air around 600V [1]. That why, this is the preliminary study for the high voltage testing and high voltage strength again different types of testing (HVAC, HVDC and Impulse). This is the preliminary study of different types of treated wood as test object in order their performance against different type nature of HV stress. But still, we never know the capability of withstand electric stress of treated wood or it electrical characteristic. By do some experiment in this study, a new insulator could be develop by our local trees or treated wood.

1.3 Project Objectives

This project focuses on the following five objectives:

1) To conduct HV test on treated wood where the types of nature HV that use is HVAC, HVDC and Impulse Voltage.
2) To determine electrical characteristics of these test wood as a sample against the HV test.
3) To make comparison and conclusion between each treated wood sample result in order to determine their breakdown strength

1.4 Project Scopes

1) Two types of wood as a sample test which is kayu penarahan (PNH) and kayu kembang semangkuk (KSK).
2) Different thickness of sample test.
3) Same thickness of sample test but with different temperature level.
4) Determine breakdown voltage of sample test.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter also covers the researches related to the subject. This will provide a clearer understanding of the system and its design. This project is about the experimental work to test breakdown level of the solid materials.

2.2 Breakdown in Solid Dielectric

The most important when we talk about electric is insulator or dielectric. The dielectric can avoid us from getting electric shock. A good dielectric should have low dielectric loss, high mechanical strength, free from gaseous inclusions, and moisture, and be resistant to thermal and chemical deterioration [2]. There are 4 types of dielectric which is air, high vacuum, liquid and solid. Each types of dielectric have it own breakdown level.

There are two types of solid insulating material known as organic materials and inorganic materials. Organic materials are paper, wood, and rubber while inorganic materials are mica, glass, porcelain and synthetic polymers When breakdown occurs, solids get permanently damaged while gases fully and liquids partly recover their dielectric strength. The dielectric strength means the maximum electric field it can withstand intrinsically without breakdown, the minimum electric field that produces breakdown, and the maximum electric stress the dielectric material can withstand without breakdown. Solid dielectric has a high breakdown voltage compared to liquids and gases. The breakdown of solid is as high as

10MV/cm if the solid is homogenous and free form the imperfection. There are several factors that affect the dielectric strength likes [2][3]:

a) It increases with the increase in thickness of the specimen.
b) It decreases with the increase in operating temperature.
c) It decreases with the increase in frequency.
d) It decreases with the increase in humidity.

2.3 Mechanism of Breakdown in Solid Insulation

The mechanism of breakdown is a complex phenomenon in the case of solids, and varies depending on the time of application of voltage as shown in Figure 2.1. The various breakdown mechanisms can be classified as follows:

a) Intrinsic or ionic breakdown
b) Electromechanical breakdown
c) Treeing and tracking
d) Thermal breakdown
e) Electrochemical breakdown
f) Internal discharge

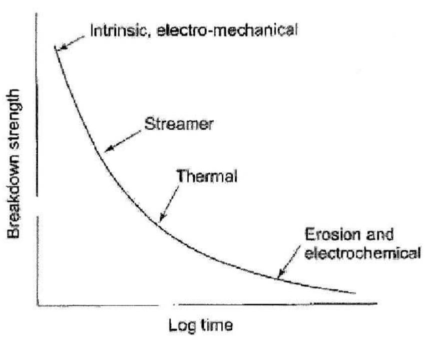

Figure 2.1: Variation of breakdown strength with time after application of voltage

2.3.1 Intrinsic or Ionic Breakdown

Usually small numbers of conduction electrons are present, with some structural imperfections and small amounts of impurities. The impurity atoms or molecules act as traps for the conduction electrons up to certain ranges of electric fields and temperatures. When these ranges are exceeded, additional electrons and trapped are released and participate in the conduction process. If the material under test is pure and homogeneous, the temperature and environmental conditions are carefully controlled, and the sample is do stressed that there are no external discharges. With undervoltages applied for a short time the electric strength increases up to an upper limit which is called the intrinsic electric strength [2][4]. The maximum strength usually obtainable ranges from 5 - 10 MV/cm. It is depends upon the presence of free electron which capable of migration thru the lattice of the dielectric. There are two types of intrinsic breakdown mechanisms;

a) Electronic Breakdown
b) Avalanche or streamer breakdown

2.3.2 Electromechanical Breakdown

Failure will occur due to electrostatic compressive force exceed the mechanical compressive strength when the solid dielectric subject to high electric fields. If the thickness of the specimen,d_0 and is compressed to a thickness d under applied voltage V, the highest apparent electric stress before breakdown is [2];

$$E_{max} = \frac{V}{d_0} = 0.6\left[\frac{Y}{\varepsilon_0 \varepsilon_r}\right]^{1/2} \qquad (2.1)$$

This treatment ignores the possibility of instability occurring in the lower average field because of stress concentration at irregularities, the dependence of Y on time and stress, and also on plastic flow [4]. The Figure 2.2 shows the breakdown channel in Perspex between point-plane electrodes.

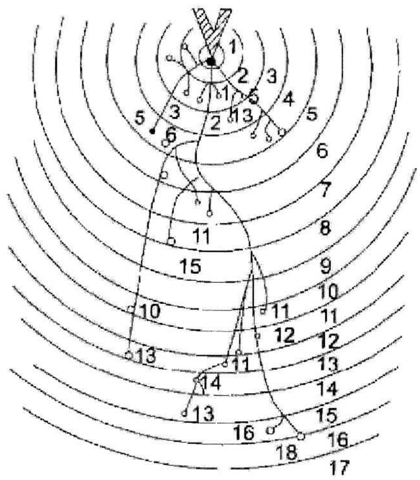

Figure 2.2: Breakdown channels in Perspex between point-plane electrodes

2.3.3 Treeing and Tracking

When a solid dielectric subjected to electrical stresses for a long time fails, two kinds of visible markings are observed on the dielectric materials. They are:

a) Presence of conducting path across the surface of the insulation
b) A mechanism whereby leakage current passes through the conducting path will lead to the formation of spark.

The spreading of spark channels during tracking in the form of the branches of tree is called treeing. Treeing occurs due to the erosion of material at the tips of the spark. Erosion results in the roughening of the surface and becomes a source of dirt and contamination. It will increase conductivity resulting either in the formation of conducting path bridging the electrodes of in a mechanical failure the dielectric.

Tracking is formation of continuous conducting paths across the surface of the insulation mainly due to surface erosion under voltage applications. The insulator progressively gets coated with moisture that causes increased conduction leading to the formation of surface tracks. It will occur at very low voltages of the order of about 100V, whereas treeing requires high voltages [2].

2.3.4 Thermal Breakdown

The conduction currents and dielectric losses due to polarization will cause the heat continuously generated within the dielectric. In general, the breakdown of a solid dielectric should increase with its thickness. When an electric field is applied to a dielectric, conduction current flows through the material. A current heat up the specimen and the temperature rises. The heat generated is transferred to the surrounding medium by conduction through the solid dielectric and by radiation from its outer surfaces. Equilibrium is reached when the heat generated (W_{dc} or W_{ac}) equal to the heat dissipated (W_T) [2] [4].

$$W_{dc} = E^2\sigma \text{ W/cm}^2 \qquad (2.2)$$

Where, σ : dc conductivy of the specimen

$$W_{ac} = \frac{E^2 f \varepsilon_r \tan\delta}{1.8\times10^{12}} \text{ W/cm}^2 \qquad (2.3)$$

Where, f = frequency in HZ
δ = loss angle of the dielectric material
E = rms value

The heat dissipated (W_T) is given by

$$W_T = C_V \frac{dT}{dt} + div(K \text{ grad T}) \qquad (2.4)$$