INVESTIGATION ON WITHSTAND VOLTAGE OF SILICONE RUBBER IN VARIOUS CONDITION

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Bachelor of Electrical Engineering

(Industrial Power)

MAY 2009

"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

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This report is submitted in partial fulfillment of requirements for the Degree of Bachelor in Electrical Engineering (Industrial Power)

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MAY 2009

"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references."

Signature : .....

Name : ABDUL RAHMAN HANIF BIN BAHAR

Date : 11/5/2009

For my beloved parents

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ABSTRACT

Polymeric materials are an alternative to porcelain and glass to replace outdoor high voltage insulators. Silicone rubber comes out to be one of the main candidates to replace porcelain and glass. Based on the information, this project is purposely made to develop high voltage testing on silicone rubber which is a polymeric material in order to investigate its performances as a high voltage insulator. The testing procedure focuses on 1 stage of High Voltage Impulse configuration which the voltage can be generated up to 100kV. The impulse test is conducted on the silicone rubber to study and analyze its characteristics and performance as insulator. In order to achieve the objectives of this project, standard lightning impulse as defined in the standard IEC 60060-1 is conducted to the silicone rubber.

ABSTRAK

Bahan-bahan polimerik adalah satu alternatif kepada porselin dan kaca untuk menggantikan penebat-penebat voltan tinggi. Getah silikon menjadi satu daripada calon utama untuk menggantikan porselin dan kaca. Berdasarkan maklumat tersebut, projek ini dibuat untuk membangunkan ujian voltan tinggi ke atas getah silikon yang merupakan satu bahan polimerik untuk menyiasat ciri-cirinya sebagai penebat voltan tinggi. Tumpuan prosedur ujian adalah terhadap peringkat 1 bagi konfigurasi Voltan Tinggi Dedenyut yang boleh menghasilkan voltan sehingga 100kV. Ujian dedenyut dikendalikan ke atas getah silikon untuk mengkaji dan menganalisa ciri-cirinya dan prestasi sebagai penebat. Bagi mencapai objektif-objektif bagi projek ini, standard dedenyut kilat seperti dijelaskan dalam standard IEC 60060-1 dijalankan untuk getah silikon.

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CHAPTER 1

INTRODUCTION

1.1 Project Overview

Polymeric insulators have been increasingly accepted by utilities as suitable replacements for porcelain and glass insulators since their introduction in the early 1970s. This replacement made to overcome some of the conventional insulators disadvantages that can be solve with some of the polymeric insulators advantages such as; lightweight, higher mechanical strength to weight ratio, low surface energy, resistance to vandalism and better performance in the presence of wet contaminated conditions. Polymeric insulators are used in power transmission and distribution systems to provide mechanical support for the conductors as well as providing electrical insulation between the high voltage conductors.

The purpose of this project is to gain knowledge about the behaviour of silicone rubber which is a type of polymer as high voltage insulator. Silicone Rubber has been selected as the polymeric insulator in this project. The polymer has been selected because it has excellent dielectric strength that can contribute for a superior high voltage insulator. High Voltage Impulse is conducted on the selected polymer for measurement and observation purposes. Proper multistage impulse wave shaping circuit is constructed to generate a desired lightning waveform for the purpose of striking the polymers. Laboratory experimental results shows the effect of the polymers when the impulse voltage is applied.

1.2 Problem Statement

Ceramics insulators are very brittle [1]. This means that they are easily broken in handling, transit and installation. These disadvantages may lead to the increase of

maintenance cost of the conventional insulator. Porcelain bodies are very heavy due to their very dense nature of ceramics. This not only makes for difficult handling, which can require cranes, but it also means that expensive and large structural supports are necessary. Therefore polymeric material such as silicone rubber is currently being used as high voltage outdoor insulation structure in distribution and transmission power systems, because of their better dielectric properties, lower cost when compared to the porcelain or glass insulators and lightweight [2].

Ceramics were the preferred materials for insulators, bushings, cable terminations and surge arresters for many years; their high surface energy rendered them wettable when exposed to environmental pollution, causing an increase in leakage current [3]. An increasing in leakage current may lead to reduce the efficiency of the power system. Consequently silicone rubber has been used in high voltage insulator because of its superior surface hydrophobicity and it shows higher contamination withstand voltages than conventional porcelain insulators [4]. For that reason, this project is made to investigate the performances of silicone rubber as a high voltage insulator.

1.3 Project Objectives

Three main objectives in this project are as follow:

i. To test the silicone rubber with high voltage impulse testing (impulse withstand voltage test).
ii. To analyze the performances of silicone rubber as a high voltage insulators.
iii. To investigate the withstand voltage of silicone rubber under standard lightning impulse wave.

1.4 Scope of The Project

The project is focused only on silicone rubber which is a type of polymer. A standard lightning impulse voltage is conducted on the silicone rubber. The withstand voltage characteristic of the silicone rubber under lightning impulse test is studied. This test is necessary to investigate silicone rubber as high voltage insulator.

1.5 Methodology

A necessary project methodology has been followed to complete this project. Figure 1.1 shows the flow of project methodology in conducting this project. At the beginning, the project title is understood. This is very important to ensure the objectives of this project can be achieved successfully.

1.5.1 Literature Review

. Literature reviews have been conducted to learn the basic knowledge and theory about this project. This can help in understanding and give early views before taking this project to another level. Firstly, theory about impulse is studied. This is very important because the test that is conducted in this project is impulse testing. Information about generation, measurement, standard and waveform of the impulse voltage gained before this project proceed.

Next, study about polymers is made to select the suitable polymers for this project. The study is focused on the polymers characteristics as high voltage insulator. After the study has been made, silicone rubber is selected as the test object for this project. The selection has been made due to the advantages that silicone rubber has such as can withstand high temperature, waterproof and lightweight.

1.5.2 Impulse Test

At the same time, the study of fundamental of high voltage engineering is done to gained knowledge about the application and generation of impulse voltage. Detail study is focused on the characteristics parameters of impulse voltage. After that, the impulse test is conducted on silicone rubber to investigate its performances as high voltage insulator. The analysis is done for impulse voltage testing on the silicone rubber.

1.5.3 Data Compilation

The data from the test conducted is compiled and the results which are from the testing on silicone rubber are recorded. The results for the testing conducted on the silicone rubber under various conditions have been recorded in table to make it easy to analysis. The data obtained from the testing conducted are the voltage applied and the condition of the silicone rubber after the testing is done. The graphs of the applied voltages recorded to acquire the peak voltage, the front time and the tail time of the impulse voltage.

1.5.4 Data Analysis

After the data has been compiled, the analysis is done. From the analysis, the withstand voltage of the silicone rubber is determined. The capability of the silicone rubber to maintain its condition depends on the surrounding can be proved. The credibility of the silicone rubber as a high voltage insulator is the outcome of the analysis.

1.5.5 Final Report

The last step of this project is to write a report for the whole project. In the final report, all data obtained from the lab testing is presented. The report covered about the project from the beginning until the project finished. The report is prepared to present all the information gained after the project is done.

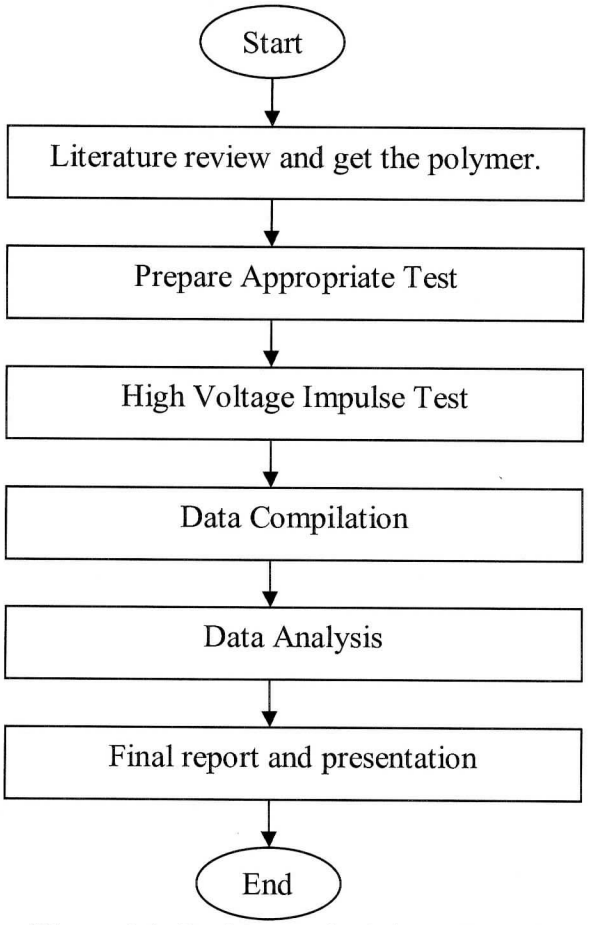

Figure 1.1: Project methodology flow chart

1.6 Thesis Outline

In general, some basic principles, theories, equations, test procedure, experimental result and discussion are included in these five chapter based on the contents requirement for each of every chapter.

In Chapter 1, the project overview and the main objectives of this project are stated. This chapter briefly explains about the problem statement and project methodology used in this project.

Chapter 2 covers the literature reviews on the information about polymer and impulse voltage. This information is extremely needed for this project to achieve the objectives of this project.

Chapter 3 discusses about the experimental setup of high voltage lightning impulse voltage that is conducted on the silicone rubber to investigate its performances as a high voltage insulator.

The experimental results and analysis on the performances of the selected polymers as high voltage insulator is presented in Chapter 4. Finally, Chapter 5 concludes all the works and studies that had been presented in the previous chapters. Recommendation also is added to this chapter for further study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Lightning impulse high voltage test is conducted to determine the behaviour of the high voltage insulator when lightning struck. This is needed to verify the reliability and efficiency of the product because they are use in the system that exposed to the lightning such as; bushings, transformers, cables, etc. In order to study the insulation behaviour of the polymers under all conditions which the apparatus is likely to encounter, high voltage testing equipment is required.

This test is carried out in order to investigate the influence of surges in transmission lines, breakdown of insulators and of the end turns of transformer connections to line. In impulse testing, to represent surges generated due to lightning, the IEC Standard impulse wave of 1.2/50 μs wave is generally used. The total duration of a single lightning strike overshoot about 100 μs, although the total duration of the lightning stroke may be a few seconds. Overvoltages of much higher duration also arise due to line faults, switching operations etc, for which impulse waves such as 100/5000 μs duration may be used.

2.2 Generation of Impulse Voltage

Impulse voltage is an electrical apparatus which produces very short high voltage or high current surges [5]. There are two types of such devices which are impulse voltage generators and impulse current generators. High voltage impulse is use to test the strength of electric power equipment against lightning and switching surges.

Sometimes it also used in nuclear physics experiments. Impulse voltage usually generated by discharging high voltage capacitors through switching onto a network of resistors and capacitors. It also was called a unidirectional voltage that rapidly rises to a peak value and then drops to zero more or less rapidly.

An impulse voltage generator consists of capacitors, resistors, and spark gaps. The capacitors are first charged in parallel through charging resistors by high voltage, direct current source and then connected in series and discharged through a test object by a simultaneous spark over of the spark gaps [6]

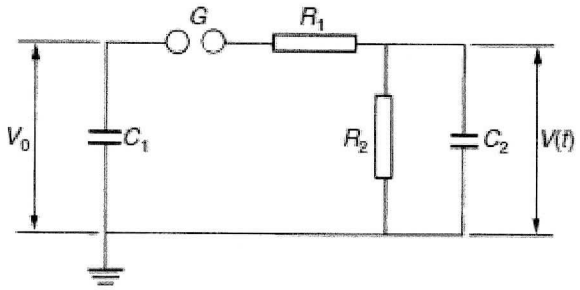

Figure 2.1: Equivalent circuit of impulse voltage

Figure 2.1 shows the equivalent circuit for impulse voltage generation. When the capacitor, C_1 has been fully charged, the circuit is ready for the triggering pulse to cause voltage breakdown at the sphere gap. After the breakdown of sphere gap, voltage will pass through waveshaping consist of resistors R_1 and R_2 that will determine the front and tail time of the impulse voltage [7]. The output voltage is appearing at the load capacitor, C_2 [8].

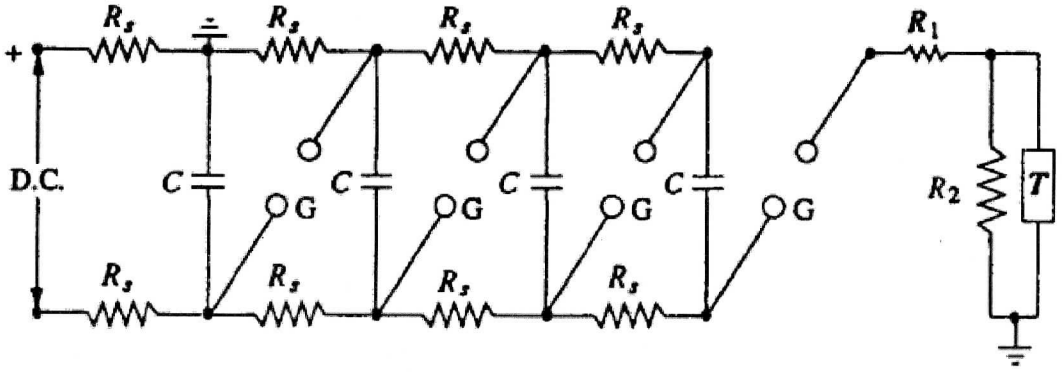

Figure 2.2: Multiplier impulse circuit

Figure 2.2 shows multiplier impulse circuit. It produces high voltage impulse. The arrangement for charging the capacitors in parallel and then connecting them in series for discharging is based on Marx theory [9]. In order to limit the charging current to about 50 to 100mA, charging resistors, R_s is used. Gap spacing is chosen such that the breakdown voltage of the G is greater than charging voltage. The basic principle of this circuit is the rapid connection of charged capacitors whereby spark gaps are used to make the series switching. The gaps, G are made to spark and all the capacitors connected in series when the impulse generator is to be discharge.

2.2.1 Standard Impulse Waveshapes

Transient overvoltages due to lightning and switching surges cause sudden build up of voltage on transmission lines and other electrical apparatus. Experimental investigations showed that these waves have a rise time of 0.5 to 10 μs and decay time to 50% of the peak value of the order of 30 to 200 μs. The waveshapes are random, but mostly unidirectional [10]. Lightning overvoltage wave can be represented as double exponential waves defined by the Equation 2.1 below. The general waveshape of impulse is shown in Figure 2.3.

$$V = V_0 [\exp(-\alpha t) - \exp(-ßt)] \quad (2.1)$$

Where α and ß are constants of microseconds values.

Peak value (Umax) is the maximal voltage of the impulse. The front time of the impulse (Tfront[μs]) is the time between the start and the maximum of the impulse. Usually, it is hard to find the exact time of start and maximum, therefore the time between 0.3Umax and 0.9Umax is measured, it must be divided by 0.6 to get the value of the front time. Half-value time (Thalfvalue[μs]) is the moment, where the impulse reach 0.5Umax at the decreasing part of the curve.

Usual way of describing a voltage impulse: Tfront/Thalfvalue. For example 1.2/50 means an impulse with 1.2μs front time and 50μs half-value time. The Standard impulses (tolerance of Tfront = ±30%, Thalfvalue = ±20%):