

INVESTIGATION ON WITHSTAND VOLTAGE OF  
SILICONE RUBBER IN VARIOUS CONDITIONS

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MAY 2009

“Saya akui bahawa saya telah membaca karya ini pada pandangan saya karya ini adalah memadai dari skop dan kualiti untuk tujuan penanugerahan Ijazah Sarjana Muda Kejuruteraan Elektrik (Kuasa Industri).”

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**INVESTIGATION ON THE WITHSTAND VOLTAGE OF SILICONE RUBBER  
IN VARIOUS CONDITION**

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**This Report Is Submitted In Partial Fulfillment of Requirements for the Degree of Bachelor in  
Electrical Engineering  
(Industrial Power)**

**Fakulti Kejuruteraan Elektrik  
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“Saya akui laporan ini adalah hasil kerja saya sendiri kecuali ringkasan dan petikan yang tiap-tiap satunya saya jelaskan sumbernya.”

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**Dedicated to my beloved parents...**

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## **ABSTRACT**

The purpose of this project is to conduct high voltage withstand voltage testing on the silicone rubber insulator which used in high voltage. The testing procedure focuses on 1 stage of High Voltage Direct Current (HVDC) and High Voltage Alternating Current (HVAC) configuration which the voltage can be generated up to 100kV. Prior to that, the new equipment that available in the high voltage lab UTeM is used to study and analyze its performance to be compared with the data manual provided by the manufacturer. As for Research and Development (R&D), this analysis determines the suitability of the test room of HV lab at UTeM and factors that may affect the testing results. The HVDC and HVAC test are conducted on the test object (silicon rubber) to study the withstand voltage that can be applied and analyze its characteristics and performance as high voltage insulator. In order to archieve the objectives of this project, proper HV testing according to IEEE std 4-1995 Standard Techniques for High Voltage Testing are used. Hence, at the end of this project, the paper for the testing including the safety precaution is attached.

## ABSTRAK

Tujuan projek ini dijalankan adalah untuk menjalankan satu pengujian voltan tinggi keatas penebat jenis *silicon rubber* dimana digunakan sebagai penebat pada alatan voltan tinggi. Presedur untuk pengujian ini difokuskan untuk peringkat pertama bagi Voltan Tinggi Arus Ulangalik (*HVAC*) dan Voltan Tinggi Arus Terus (*HVDC*) yang boleh menjana voltan sehingga 100kV. Untuk tujuan tersebut, perkakasan voltan tinggi yang terdapat di makmal voltan tinggi UTeM digunakan bagi mengkaji dan membuat analisis tentang keupayaan alat tersebut untuk dibandingkan dengan data manual daripada pihak pembekal. Untuk tujuan Penyelidikan dan Pembangunan (R&D), analisis ini menentukan kesesuaian bilik pengujian di makmal voltan tinggi dan faktor-faktor yang dapat memberi kesan terhadap keputusan pengujian. Pengujian Voltan Tinggi Arus Ulangalik (*HVAC*) dan Voltan Tinggi Arus Terus (*HVDC*) juga dijalankan keatas bahan penebat (getah silicon) untuk mengkaji dan menganalisis ciri-ciri keupayaan ketahanan voltan bahan tersebut sebagai penebat. Untuk mencapai objektif projek ini, sesi pengujian voltan tinggi ini adalah berdasarkan piawaian yang ditetapkan oleh *IEEE std 4-1995 Standard Techniques for High Voltage Testing*. Pada akhir projek ini, satu kertas kerja tentang cara-cara pengujian Voltan Tinggi Arus Ulangalik dan Voltan Tinggi Arus Terus dapat disediakan beserta langkah-langkah keselamatan turut dilampirkan.

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## LIST OF ABBREVIATIONS

|      |  |
|------|--|
| HVAC | High Voltage Alternating Current                 |
| HVDC | High Voltage Direct Current                      |
| AC   | Alternating Current                              |
| DC   | Direct Current                                   |
| IEEE | Institute of Electrical and Electronic Engineers |
| STD  | Standard   |
| HV   | High Voltage                                     |
| UV   | Ultra Violet                                     |
| HTV  | High Temperature Vulcanizing                     |



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# CHAPTER 1

## INTRODUCTION

### 1.1 Project Background

The focus of this project is to investigate the performance of the silicone rubber, polymeric material as high voltage insulator. This type of insulator is well accepted in high voltage insulation as a replacement of conventional insulator for example porcelain and glass insulators. Silicone rubber is substances whose molecules have high molar masses and are composed of a large number of repeating units. In general polymers are formed by chemical reactions in which a large number of molecules called monomers are joined sequentially, forming a chain. In others, two or three different monomers may be combined. Polymers are classified by the characteristics of the reactions by which they are formed. If all atoms in the monomers are incorporated into the polymer, the polymer is called an addition polymer [1]. There are many types of polymer that commonly use for the engineering applications for examples butyl rubber, natural rubber, silicon rubber, styrene butadiene rubber, ethylene propylene rubber (EPR) and ethylene propylene diene monomer rubber (EPDM rubber). Figure 1.1 shows that the polymerization of ethene into poly(ethene). For this project, the polymer that has been selected to be test is silicon rubber.

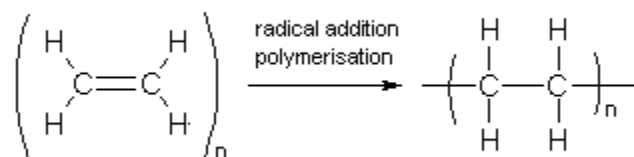


Figure 1.1: The polymerization of ethene into poly(ethene).

The reason silicone rubber is selected for this project because it has many 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. Silicone rubber has a potential to be developed as an insulator other than porcelain or glass. Table 1.1 shows the comparison between the ceramic and polymer insulator [2].

Table 1.1: Comparison between the ceramic and polymer insulator

| FACTORS  | CERAMIC   | COMPOSITE                                      |
|--|---|--|
| Resistance to flashovers in Polluted atmosphere.           | Low   | High   |
| Resistance to puncture                                     | Puncturable (Class: B insulators)                   | Not puncturable                                |
| Resistance to Cracking and Erosion in Polluted atmosphere. | Low   | High   |
| Contamination & Pollution                                  | Highly affected                                     | Performance not affected                       |
| Hydrophobicity   | Non hydrophobic.                                    | Unique Hydrophobicity character.               |
| Self cleaning property                                     | Due to Glaze and inclination of sheds.              | Due to Hydrophobicity recovery characteristic. |
| Maintenance  | Needs maintenance like cleaning, washing, greasing. | No maintenance is required                     |
| Weight   | More  | 10% to 35% of Ceramic Insulator                |
| Resistance to breakage and Vandalism                       | Breakable in Vandalism prone areas                  | Unbreakable                                    |
| Artificial Pollution Test                                  | Mandatory   | Not applicable                                 |
| Power Arc Test   | Mandatory   | Not mandatory                                  |

High voltage testing is done to ensure that the quality of the composite insulators. In general, the tests are divided into three; direct current test, alternating current test and impulse test. Then the result from the test is analyzed. From the analysis, the performance of the polymer can be measured to ensure that it is suitable to be used as an insulator. For the future, polymer can be used to replace the porcelain or glass as an insulator because of its characteristic is better than the others.

One of high voltage lab equipment use in UTeM is HAEFLEY High Voltage equipment. It can be used in multiple applications in high voltage technology. This HV equipment are used in generation of High Voltage Direct Current (HVDC), High Voltage Alternating Current (HVDC) and Impulse Voltage. For this project, the testing are include of HVDC and HVAC test. There are 3 stages for each test. The testing may be reached up to 400kV. The analysis of the withstand voltage characteristics of

the insulators can be made to determine the suitability of the tested insulator to be applied in the industry.

## **1.2 Problem statement**

Today, many insulators that have been used are a porcelain and glass type. But there is an insulator that has many advantages compare to porcelain and glass. A polymer material such as silicone rubber has better dielectric properties, light weight and lower cost when compared to the porcelain or glass insulators. A major advantages of the polymer compared to the ceramic equivalent is that it has 90% weight reduction [5]. Although glass and ceramic are the preferred materials for insulators, bushings, cable terminations and surge arresters for many years, their high surface energy rendered them wetttable when exposed to environmental pollution, causing an increase in leakage current [8, 11]. Leakage currents increase as the material's surface loses its hydrophobicity [4].

Silicone rubber is preferred in highly contaminated areas due to their lower leakage currents and self-cleaning characteristic which make the interval between the cleaning may be extended [3]. It is resistant to sunlight, heat and is flexible over a wide range of temperatures [8]. Silicon rubber is a hydrophobic materials (repels water). This is due to the groups attached to the silicon atom [7]. With regard to pollution performance, the short-term and long-term hydrophobicity characteristics of silicone rubber apparatus insulators are better than of the porcelain insulators at the same site. So the usage of silicone rubber as high voltage insulator is more compatible compared to ceramic insulators such as porcelain and glass type. Hence, this project is conducted to investigate the withstand voltage of silicone rubber in various conditions. This is necessary to use this report as references for the future studies.

## **1.3 Project Objective**

There are four objectives that should be done to complete this final year project:

- 1) To conduct experimental work in high voltage lab using HVDC and HVAC test equipment.
- 2) To study and analyze the performance of the silicone rubber as a high voltage insulator

- 3) To provide information on withstand voltage characteristic of different thickness of the silicone rubber
- 4) To show the ability of the silicone rubber react at different condition

#### **1.4 Project Scope**

The focus of this project is to conduct a high voltage testing which are AC test and DC test to the polymer insulator. There is a test object have been select from the different condition and thickness of polymer which is silicone rubber.

#### **1.5 Project Methodology**

In order to complete this project successfully, a necessary project methodology should be followed. Figure 1.2 shows the flow of project methodology in conducting this project.

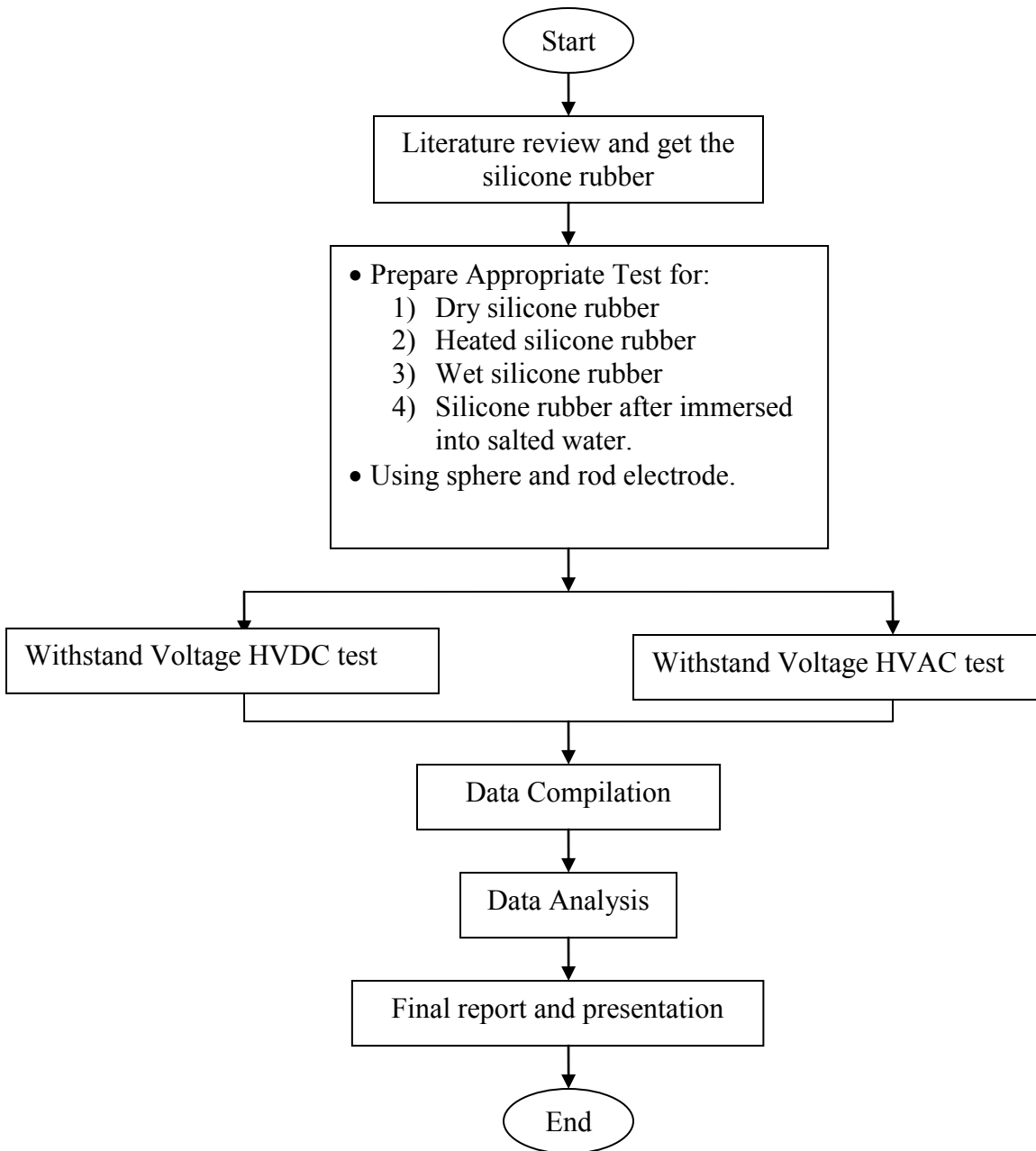


Figure 1.2: Project methodology flow chart.

### 1.5.1 Literature review

Study about the polymer but focusing on the selected polymer which is silicon rubber. This type of high voltage insulator can be applied at transmission line, transformer bushing and rail insulator. The installation process of silicone rubber insulator is easy to install compared to ceramic type because the weight for silicone rubber is less than 25% of the porcelain or glass insulators. Beside that the usage of silicone rubber can reduce the maintenance costs because the ceramic type needs to be maintained such

as cleaning, washing and greasing. As conclusion, many advantages when used the polymer insulator in high voltage compared to the porcelain and glass insulator which get from the existing data. Finally, some revision is studied about the test that can be conducted to test the material.

### **1.5.2 Preparation of The Test**

The appropriate test is prepared. The silicone rubber with 15.5cmX15.5cm dimension and different condition is chosen as follows:

- 1) Dry silicone rubber
- 2) Heated silicone rubber
- 3) Wet silicone rubber
- 4) Silicone rubber after immersed into salted water

The test is conducted using sphere gap and rod gap electrode.

### **1.5.3 HVDC and HVAC Test**

This project involves two tests which are High Voltage Direct Current withstand voltage test and High Voltage Alternating Current withstand voltage test. The aim of this project is to test the withstand voltage of insulator with different conditions using two different type of electrode i.e the sphere and rod shape electrode. The withstand voltage applied for HVAC and HVDC withstand voltage is 30kV and maintain for 1 minute. For the HVDC test, there are two type tests which are positive polarity and negative polarity test. Three thickness of the silicone rubber have been choose to be tested to compared the withstand voltage for each thickness.

### **1.5.4 Data Compilation**

The data from the test conducted is compiled and the results which the withstand voltage from different condition of silicone rubber is recorded.

### **1.5.5 Data Analysis**

From the analysis, the withstand voltage of the insulator can be determined. The capability of the silicone rubber insulator to maintain its condition depends on the surrounding can be proven. The results for the material test using two different of electrode are compared to get the conclusion. The analysis is done for each condition of silicone rubber tested with different thickness. The effect of used the sphere gap and rod gap electrode to the test object is also explained in this part.

### **1.5.6 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 will be presented and the report to be prepared for the whole of the project. The report must be done proper so it can be used as references to the future studies.

## **1.6 Thesis Outline**

Chapter 1 briefly summarizes the project background and problems statements as well as elaborates the objective and scope of the project. The project methodology which is the most important part that describes the flow of the project is also discussed in detail in this chapter.

Chapter 2 explains about the literature review. In this chapter it contains information about the test material which is the different thickness and condition of silicone rubber. Beside that it has some information about the testing conducted in the high voltage lab. The tests are HVDC withstand voltage test and HVAC withstand voltage test. The test conducted to the different condition of silicone rubber which is dry, heated, wet and immersed into salted water silicone rubber. The safety precaution in the lab also discussed in this chapter.

Chapter 3 discusses about the equipment that to be used in the high voltage lab. The HAEFELY High Voltage Kits is introduced in this chapter. The HVAC and HVDC generation for all 3 stages and it hardware configuration are elaborated. Beside that the testing procedure is explain through this chapter.