GENERATION AND HVDC TEST ON ISULATOR (VULCANIZED RUBBER)

MOHD FAHMI BIN CHE AB AZIZ

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"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)"

Signature	:	
Supervisor's Name	:	Mr. Alias Bin Khamis
Date	:	7 MAY 2008

"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 : Mohd Fahmi Bin Che Ab Aziz

Date : 7 MAY 2008

To my dearest father, Che Ab Aziz Bin Che Ali and my beloved mother Zabidah Binti Yunus and sister, Nurul Farhani BintiChe Ab Aziz for their encouragement and blessing. Special to my supervisors, Mr. Alias Bin Khamis for his fully support and caring from PSM 1 until PSM 2.

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ABSTRACT

The purpose of this project is to develop the DC high voltage testing procedure using the Haefely High Voltage kit. This equipment is available in the high voltage lab will be used in order to study and analyzed the characteristics of high voltage and also the high voltage testing. The first concern of this project is to do the simulation using LTspice in order to compare the test result with the experimental and to give rough idea on the equipment. The next step is to do the high voltage test both with and without the test object. Several different levels of high voltage and dielectric material will be tested in this project. However this thesis will focus on the vulcanized rubber. IEEE std 4-1995 is used as the reference for the testing method. At the end of the project a safe operating procedure will be develop based on the testing and the simulation done both in the PSM 1 and 2.

ABSTRAK

Tujuan projek ini adalah untuk membangunkan system pengujian voltan arus terus menggunakan perkakasan voltan tinggi dari Haefely. Perkakasan ini terdapat di makmal voltan tinggi akan digunakan bagi mengkaji dan menganalisis karakter voltan tinggi dan pengujian voltan tinggi. Perkara pertama bagi projek ini adalah untuk melakukan simulasi terhadap litar bagi mendapatkan gambaran awal tentang alatan dan bagi tujuan perbandingan dengan litar sebenar. Kemudian, pengujian voltan tinggi tanpa beban dan dengan beban dilakukan. Voltan tinggi pada kadaran berbaza digunakan dan bahan penebat akan diuji. Walaubagaimanapun tesis ini hanya akan memfokuskan kepada getah tervulkan. 'IEEE std 4-1995' digunakan sebagai rujukan bagi cara ujian. Pada penghujung projek satu cara pengoperasian akan dibuat berdasarkan pengujian voltan tinggi dan simulasi yang telah dijalankan pada PSM 1 dan 2.

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ABBREVIATION	MEANING
HV	High Voltage
DC	Direct Current
IEEE	Institute Of Electrical And Electronics Engineers
IEC	International Electrotechnical Commission
KV	Kilo Volt
DMI	Digital Measuring Instrument
OT	Operating Terminal
CM	Measuring Capacitor
CS	Smoothing Capacitor

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CHAPTER I

INTRODUCTION

1.1 Introduction To High Voltage Engineering.

The definition of high voltage depends on the context of the discussion. Two factors considered in the classification of a "high voltage" are the possibility of causing a spark in air, and the danger of electric shock by contact or proximity.

In electric power transmission engineering, high voltage is usually considered any voltage over approximately 35,000 volts. This is a classification based on the design of apparatus and insulation. Transmission voltages over 275,000 volts are considered extra high voltage.

The International Electrotechnical Commission and its national counterparts (IET, IEEE, VDE, etc.) define high voltage circuits as those with more than 1000 V for alternating current and at least 1500 V for direct current, and distinguish it from low voltage (50–1000 V AC or 120–1500 V DC) and extra low voltage (<50 V AC or <120 V DC) circuits. This is in the context of the safety of electrical apparatus.

In the United States 2005 National Electrical Code (NEC), high voltage is any voltage over 600 V (article 490.2). British Standard BS 7671:2008 defines high voltage as any voltage difference between conductors that is higher than 1000 V AC or 1500 V ripple-free DC, or any voltage difference between a conductor and Earth that is higher than 600 V AC or 900 V ripple-free DC.

The general public may consider household mains circuits (100–250 V AC), which carry the highest voltages they normally encounter, to be high voltage. For example, an installer of heating, ventilation and air conditioning (HVAC) equipment may be licensed to install 24 Volt control circuits, but may not be permitted to connect the 240 volt power circuits of the equipment.

Voltages over approximately 50 volts can usually cause dangerous amounts of current to flow through a human being touching two points of a circuit, so safety standards generally are more restrictive where the chance of contact with such high voltage circuits exists[10].

1.2 Problem Statement

Haefley High Voltage Test Set is the new equipment that available in the High Voltage Laboratory at Faculty Of Electrical Engineering. Since the equipments are not tested yet, it is necessary to analysis the characteristic and specification in order to apply in the laboratory for learning process. The testing procedures and safety precaution should be prepared because it involved the high voltage up to 400kV. This project will use both simulations using LTspice which has been done in the PSM 1 and the real test involving test objects in the PSM 2.

For time being there have been various problem especially related with the equipment. The major problem that has to be highlighted is the oscilloscope. The provided oscilloscope does not meet the requirement to be used with the Haefely high voltage set. However for PSM 2 a new oscilloscope from Tektronik has been introduced which is much advance and the waveform can be captured much easier.

Limited knowledge of the equipment also make it hard to do the laboratory test and other testing especially when it involves testing it to other object like cables. The standard used for the High Voltage Test is also unspecific and has a lot of unknowns especially for the students. There is also no specific reference regarding to the project title and the only available references is based on the cables and other high voltage equipments.

The testbed used for placing the test object is also a problem. Currently the test bed used is made up of the insulator from the high voltage kit. The clearance for the test bed is set at minimum of 450mm from ground level, high voltage kit and the fence.

Simulations are hard to be done as there's not much simulations software for high voltage analysis related to this equipment. Besides there's also unknown quantity at of high voltage diode breakdown voltage.

1.3 Objective

The objective of this project is stated as follows:

- To simulate the circuit using the LTSpice simulation.
- To study and generate High Voltage DC using high voltage construction kit.
- To compare the results of the PSpice simulation to that obtain practically.
- To build and apply high voltage construction kit as test equipment.
- To create an operating procedure of the equipment that will provide the safety measure for the operator of the equipment

1.4 Thesis Outline

To know the overall function of the instrument a literature review and reference on other books has been made. The components for the projects came from the kit itself and it consists of HV rectifier, HV resistor, HV capacitor and several other components.

Chapter 1 describes the introduction of the project, problem statements, and the objective to give brief idea of what the project is all about.

Chapter 2 is the literature review part where in this part the theory of the circuit will be further analyze with help from other thesis by other researcher. Reference books are also being used to further explain the theory and the formula for the project.

In chapter 3 that is the project methodology explains how the works done to complete the project. The methodology includes the simulation and practical flow of works. The laboratory procedure develops in this PSM2 also included in this section. The procedure develop consist of testing without the test object (no load) and also with the test object.

In chapter 4 there is the simulation of the output voltage of the equipment. The test certificate data is used as reference for the data. In chapter 5 the experiment (practical works) is highlighted. It involves all the testing and works done in the laboratory and how the data gained.

In chapter 6 the analysis of the data gains from both simulation and the experiment works. Also the material used for the testing is also analyzed in this chapter. Finally in chapter 7 the suggestion and the conclusion for the future works is included in this chapter.

CHAPTER II

LITERATURE REVIEW

2.1 Literature Review

To complete the project literature review of the topic has to be done at the first place. This is important to gain the basic knowledge of what the project is all about. There are numerous reference books and websites that being referred however only the relevant reference will be highlighted here. There are three sources used as the main reference for the project especially for the PSM2.

2.1.1 IEEE Standard Technique For High-Voltage Testing STD 4-1995

This standard establishes standard methods to measure high-voltage and basic testing techniques. Generally this standard is applicable, to all types of apparatus for alternating voltages, direct voltages, lightning impulse voltages, switching impulse voltages, and impulse currents. This std 4-1995 is a revision of the std 4-1978 and is considered as latest standard available for high voltage testing. This revised version implements many new procedures to improve accuracy, provide greater flexibility, and address practical problems associated with high-voltage measurements.

This standard is considered as the main reference for the testing procedure. Although full utilization of the standard cannot be performed but there are some of them which suits the project[7].

2.1.2 Direct Voltage Test

The second literature review comes from the book of Electrical Power Cable Engineering. In the chapter 15- Power cable Testing In The Field it talks about both the low voltage DC test (LVDC) up to 5kV and high voltage DC test (HVDC) which is more than 5kV. This chapter also talks about the advantages and disadvantages of the DC test and how to utilize it. Even though this chapter talks about testing power cables but it also can be regarded as insulation test. This chapter is simple and short but did provide basic idea to be used in initiating the High voltage test during the early stages[14].

2.1.3 Experiment On Cockcroft Walton Multiplier

This circuit is dated back at the 1919 and was first invented by the Heinrich Greinacher, a Swiss physicist. The basic operating principle of the circuit which is based on the Half-Wave Series Multiplier, or voltage doubler. Usually it mainly consists of a high voltage transformer Ts, a column of smoothing capacitors (C2,C4), a column of coupling capacitors (C1,C3), and a series connection of rectifiers(D1,D2,D3,D4).

For example purpose it uses the 2 stage CW multiplier, assumes no losses and represents sequential reversals of polarity of the source transformer Ts in the figure shown below. The number of stages is equal to the number of smoothing capacitors between ground and OUT, which in this case are capacitors C2 and C4[15].

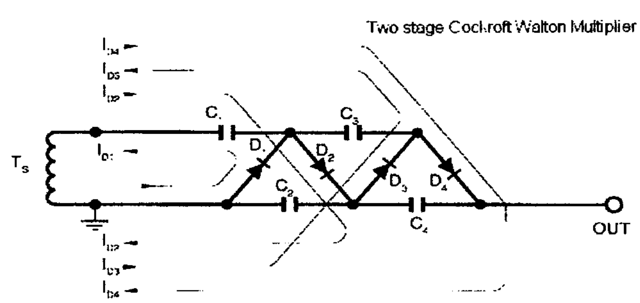

Fig 2.1: Example Of Two Stages Voltage Multiplier.

There's also calculation formula's for the circuit regarded to stages. However for this report the calculation formula is based on the formula taken from the book of high voltage engineering third edition by M S Naidu and V Kamaraju. This to maintain the accuracy of the formula of the report.

Main Formulas

output voltages for the third stage define as

$$U = n \times 2 \times \sqrt{2}\, V_{2\,rms} \quad (2.1)$$

Where:

n is the stage of the experiment

V_2 is the rms value of the transformer's output voltage (100kV)

The voltage drop under load can be calculated as:

$$E_{drop} = I_1 / (f \times C) \times (2/3 \times n^3 + n^2/2 - n/6) \quad (2.2)$$

where:

I_{load} is the load current from the rectifiers

$$I_1 = dq/dt = q/t_2 \quad (2.3)$$

Since $t_1 << t_2$ and t_1 and $t_2 = 1/f$ (the period of a.c supply conducting)

$t_2 = 1/f$

also $q = C_2 \Delta V$

C is the stage capacitance

f is the AC frequency

n is the number of stages.

The ripple voltage, in case where all stage capacitance (C1 through C (2* n)) may be calculated from :

$$E_{ripple} = I_{load}/(f \times C) \times n \times (n+1)/2 \quad (2.4)$$

For a working HVDC test voltage the ripple must be at least 5%

From this equation, the ripple grows quite rapidly as the number of stages increases (as n squared, in fact). A common modification to the design is to make the stage capacitances larger at the bottom, with *C1 & C2 = nC, C3 & C4= (n-1)C*, and so forth. In this case, the ripple is:

$$E_{ripple} = I_{load}/(f \times C) \quad (2.5)$$

For large values of n (>= 5), the $n^2/2$ and n/6 terms in the voltage drop equation become small compared to the $2/3n^3$. Differentiating the drop equation with respect to the number of stages gives an equation for the optimum number of stages (for the equal valued capacitor design:

$$N_{optimum} = (V_{max} \times f \times C/I_{load}) \quad (2.6)$$

Increasing the frequency can dramatically reduce the ripple, and the voltage drop under load, which accounts for the popularity driving a multipler stack with a switching power supply[1].

2.1.4 A Comparison Of The Pollution Performance Of Long Rod And Disc Type HVDC Insulators.

This reference is taken from the IEEE transaction on dielectrics and insulation magazine. This paper is prepared based on withstand and flashover voltages on the overhead transmission and distribution lines insulators. The test object used in this paper is disk type and long rod porcelain insulators. The test equipment used is the Greinacher Cascade (stage 2) type with the dc-test voltage between 300 kV dc and

600 kV dc. This paper will be use as the reference in extrapolating the data acquired from my experiment.

2.1.5 Introduction To Test Object (Vulcanized Rubber)

Rubber in its natural form is highly insulating but it absorbs moisture readily and gets oxidized into a resinous material; thereby it loses insulating properties. When it is mixed with Sulphur along with other carefully chosen ingredients and is subjected to a particular temperature it changes into vulcanized rubber which does not absorb moisture and has better insulating properties than even the pure rubber. It is elastic and resilient. For high voltage testing purpose the material chosen is the vulcanized rubber that has a dimension as shown in figure 2.2 below.

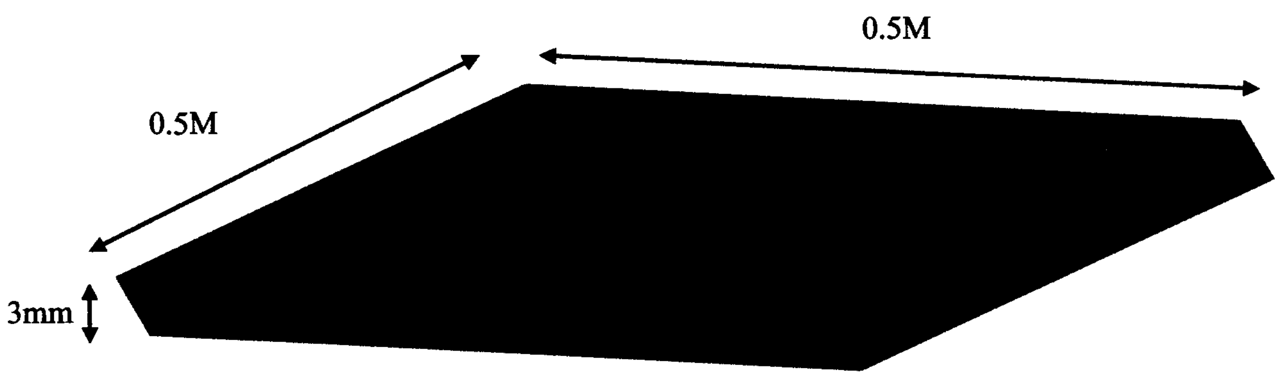

Fig 2.2. The Test Object (Vulcanized Rubber)

The electrical properties expected of rubber insulation are high breakdown strength and high insulation resistance. In fact the insulation strength of the vulcanized rubber is so good that for lower voltages the radial thickness is limited due to mechanical consideration.

The physical properties expected of rubber insulation are that the cable should withstand normal hazards of installation and it should give trouble-free service. Vulcanized rubber insulated cables are used for wiring of houses, buildings and factories for low-power work[4].