GENERATION HVDC AND TEST ON INSULATOR (PLYWOOD)

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"I hereby declare 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 : ……

Date : ……

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This Report Is submitted In Partial Fulfillment Of Requirement For The Degree of Bachelor In Electrical Engineering (Industrial Power)

Fakulti Kejuruteraan Elektrik
Universiti Teknikal Malaysia Melaka

MAY 2008

"I hereby declare that this report is a result of my own work except for the experts that have been cited clearly in the reference."

Signature : ……

Name : ……

Date : ……

ACKNOWLEDGEMENTS

First of all, I would like to thank Allah, who has give me a chance and strength to complete my Projek Sarjana Muda 2, „Generation HVDC and Test on Insulator (plywood)" and my report. I would like to thank Universiti Teknikal Malaysia Melaka (UTeM) especially Faculty of Electrical Engineering(FKE) for give an opportunity to do my Projek Sarjana Muda 2 (PSM 2) in fulfillment for Bachelor of Engineering.

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ABSTRACT

The purpose of this project is to develop the Heafely type DC configuration, for high voltage testing. The new equipment which available in the high voltage lab will be used in order to study and analyzed the characteristics of high voltage. Several different level of high voltage will be tested. However, this project is focus on generation of high voltage direct current Beside that, the high voltage DC circuit should be study to determine how the circuits function and how the supply generate using „Half Wave rectifier" and „Greinacher Doubler-Circuit". The generation of high voltage also should be study before doing this project. The simulation using Pspice will be done in order to compare the test result with the experimental. In this project, insulator test also have been done to find insulator breakdown voltage. The plywood has been chosen because it easy to find and have potency to be an insulator. After the test, the characteristic of plywood and dielectric strength will be analysis. Conclusion of this project is to develop the testing procedure as a manual for laboratory learning process.

ABSTRAK

Tujuan projek ini adalah untuk membangunkan konfigurasi Heafely arus terus untuk ujian voltan tinggi. Peralatan baru yang terdapat di makmal voltan tinggi akan digunakan teratur untuk mengkaji dan menganalisis ciri-ciri voltan tinggi. Terdapat beberapa peringkat voltan tinggi yang akan teruji. Bagaimanapun, projek ini adalah tumpuan di generasi arus terus voltan tinggi. Selain itu, litar arus terus akan dikaji untuk menentukan bagaimana litar-litar berfungsi dan bagaimana bekalan menjana menggunakan *'Half Wave rectifier'* dan *'Greinacher Doubler-Circuit'*. Kajian tentang generasi voltan tinggi perlu dilakukan sebelum melakukan projek ini. Simulasi menggunakan Pspice akan dibuat untuk membandingkan hasil ujian dengan simulasi. Dalam projek ini, ujian penubat juga telah dilakukan bagi mencari voltan runtuh penebat. Papan lapis telah menjadi pilihan kerana ianya mudah untuk dicari dan ada potensi menjadi penebat. Setelah ujian, cirri-ciri papan lapis dan kekuatan dielektrik akan dianalisis. Kesimpulan projek ini adalah untuk membangunkan proses ujian sebagai sebuah panduan untuk proses pembelajaran makmal.

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LIST OF ABBREVIATION

DC	-	Direct current
V	-	Volt
AC	-	Alternating current
PSM	-	Projek Sarjana Muda
KV	-	Kilo Volt
HV	-	High Voltage
DMI	-	Digital Measuring Instrument
ANSI	-	American National Standard Institute
OT	-	Operating Terminal
IEEE	-	Institute of Electrical and Electronics Engineers
IEC	-	International Electrotechnical Commission
AEIC	-	The Association of Edison Illuminating Companies
LCD	-	Liquid Crystal Display
Ω	-	Ohm
mA	-	mili Ampere
nF	-	nano Farad
pF	-	piko Farad
M	-	Mega
Hz	-	Hertz
W	-	Watt
mm	-	mili meter
Kg	-	kilogram
LV	-	Low Voltage

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CHAPTER I

INTRODUCTION

1.1 Introduction of High Voltages

The International Electrotechnical Commission (IEC) and its national counterparts (IET, IEEE, VDE, etc.) define high voltage circuits as those with more than 1000V for alternating current and at least 1500V for direct current, and distinguish it from low voltage (50–1000V AC or 120–1500V DC) and extra low voltage (<50V AC or <120V 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 600V. British Standard BS 7671:2008 defines high voltage as any voltage difference between conductors that is higher than 1000V 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 (100–250V 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 24V control circuits, but may not be permitted to connect the 240V power circuits of the equipment.

Voltages over approximately 50V 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.

1.2 Problem Statement

Haefley High Voltage Test Set is the new equipment that available in the High Voltage Lab 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 100kV for first stage, up to 280kV for second stage and up to 400kV for third stage. 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 there is a new oscilloscope from Tektronik which is much advance and the waveform can be captured much easier. But there‟s still a problem as did not have enough time to maximize the usage of it for much advance task. For time being we only able to use it for basic waveform capturing tasks.

The main purpose of test object is to get breakdown voltage for the object. Breakdown voltage is important in electrical field especially to make insulator. Plywood has been chosen for this test because this objects easy to find and have potential as an insulator.

Limited knowledge of the equipment also makes it hard to do the lab 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 test bed 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 objectives of this project are:

1. To develop the high voltage testing procedures and safety precaution for high voltage lab purpose.
2. To simulate Hafl Wave rectifier and Greinacher Doubler circuit using LT Pspice.
3. To study and analyze the characteristics of high voltage DC configuration.
4. To test object (plywood) while do experiment.
5. To compare the result data between experimental

1.4 Scope

This project scope is to learn the theory of produce DC high voltage from „Greinacher Doubler-Circuit‟ and to make the experiment base on HEAFELY kit. Besides that, this project also needs to make simulation for compare the data between experiment and simulation.

1.5 Thesis Outline

Chapter 1 is basically the introduction part of the project chosen. In this chapter, the project background and problems statements will be discussed clearly. Besides, the project objectives and project scope will be explained details so that a better view of the project can be obtained.

In chapter 2, the literature review of the project will be discussed. Basically, there are few methods to generate the high d.c. voltage. Some of the methods are using the half wave rectifier circuit, full wave rectifier circuit, voltage doubler

circuit. As for this project, the high d.c. voltage can be generated using the half wave rectifier circuit. In this chapter also will discussed IEEE standard technique to test insulator using high voltage.

In chapter 3, simulation using LT Pspice will be showed. In this chapter, Half Wave rectifier circuit will be used for simulation first stage. For second and third stages, Greainacher Doubler circuit will be used for simulation.

In chapter 4, this chapter will discuss about experimental setup using HEAFELY KIT. All components will be listed and all block diagrams for three stages will show. This chapter also has explanation about test object (plywood). The result for generation and test object will be analysis.

In chapter 5, project methodology of this project will be explained. Project methodology is the most important part that will describe the flow of the project, will be mention and elaborated details in this chapter. In this chapter, three flow chart will be showed. First flow chart is about overall project, second flow chart is about simulation method and last flow chart is about experimental method.

CHAPTER II

LITERATURE REVIEW

2.1 High Direct Current Voltage

Generation of high DC voltages is mainly requited in research work in the areas of pure and applied physics. Sometimes, high direct voltages are needed in insulation tests on cable and capacitor. Usually, for generate DC voltage up to 100kV, electronic valve rectifiers are used and the outputs current are about 100mA. There have several ways to produce high DC voltage:

1. Half wave rectifier
2. Full wave rectifier
3. Voltage doubler rectifier type

These entire type rectifier convert AC voltage to high DC voltage using power diode. For this project, Half Wave rectifier will be used at single stage and Greinacher Doubler-Circuit will be used for second and third stages.

2.1.1 Half Wave Rectifier

A half wave rectifier is a special case of a clipper. In half wave rectification, either the positive or negative half of the AC wave is passed easily, while the other half is blocked, depending on the polarity of the rectifier. Because only one half of the input waveform reaches the output, it is very inefficient if used for power transfer. Half-wave rectification can be achieved with a single diode in a one phase supply.

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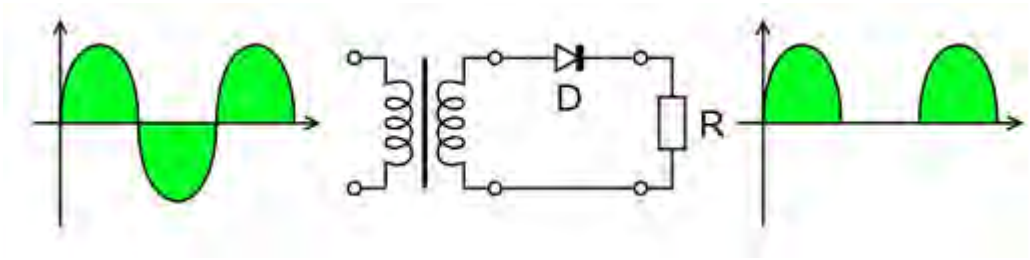


Figure 2.1: Half Wave rectifier

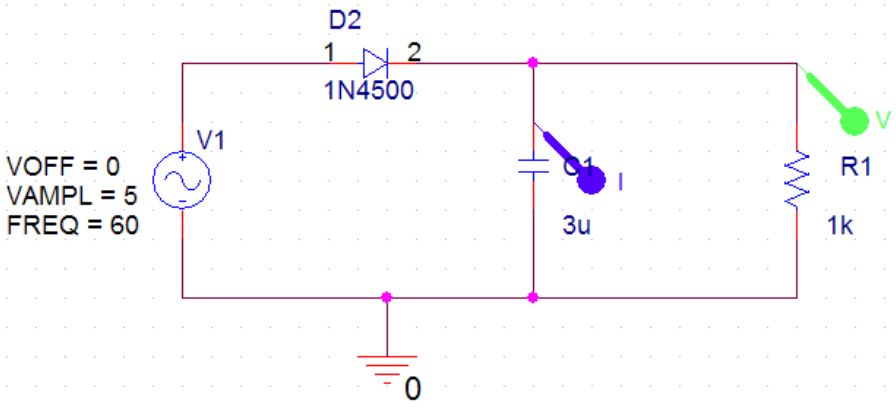


Figure 2.2: Basic circuit of Half Wave rectifier

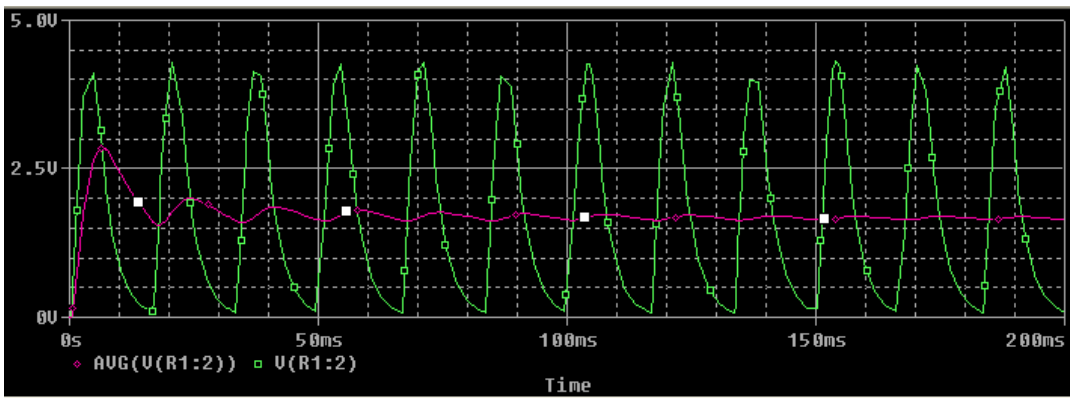


Figure 2.3: Basic waveform for half wave rectify

2.1.2 Greinacher Doubler-Circuit

One of the cheapest and popular ways of generating high voltages at relatively low currents is the classic multistage diode/capacitor voltage multipler, known as Greinacher Doubler-Circuit or Cockcroft Walton multiplier. This circuit was invented by Heinrich Greinacher, a Swiss physicist at 1919.

The Cockcroft Walton or Greinacher design is based on the Half-Wave Series Multiplier, or voltage doubler. In fact, all multiplier circuits can be derived from its operating principles. 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). The following description for the 2 stage CW multiplier assumes no losses and represents sequential reversals of polarity of the source transformer Ts in the figure 2.4. 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.

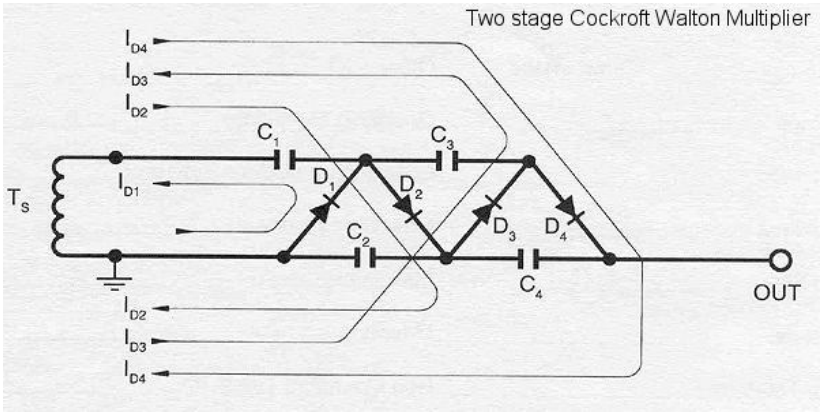


Figure 2.4: Two Stages Voltage Multiplier

Figure 2.4 show the circuit flow start from transformer T_s, negative peak, C_1 charges through D_1 to E_{pk} at current I_{D1}. While T_s at positive peak, E_{pk} of T_s adds arithmetically to existing potential C_1, thus C_2 charges to $2E_{pk}$ through D_2 at current I_{D2}. This cycle continue with negative peak, C_3 is charged to E_{pk} through D_3 at current I_{D3}. While T_s positive peak, C_4 is charged to $2E_{pk}$ through D_4 at current I_{D4}. Output is then $2n*E_{pk}$ where N = number of stages

2.2 IEEE Standard Technique For High-Voltage Testing

The test on insulators can be divided into three groups. These are the type test, and sample test

Test type

These tests are done to determine whether the particular design is suitable for the purpose.

a) Withstand test

The insulators should be mounted so as to simulate practical condition. A 1/50 μs wave of the specified voltage (corrected for humidity, air density) is applied. Flashover or puncture should not occur (if puncture occur, the insulator is permanently damage). The test is repeated five times for each polarity.

b) Flash-over test

1/50 μs wave is applied. The voltage is gradually increased to the 50% impulse flashover voltage. There should be no puncture of insulation during these tests.

c) Dry one-minute test

The insulator clean and dry should be mounted as specified and prescribed voltage (corrected for ambient condition) should be gradually brought up (at power frequency) and maintained for one minute. Thee shall not be puncture or flash over during the test.

d) One-minute Rain test

The insulator is sprayed throughout the test with artificial rain drawn from a source of supply at a temperature within 10^{o}c of the ambient temperature of the neighborhood of the insulator. The rain is sprayed at an angle of 45^{o} on the insulator at the prescribed rate of 3mm/minute. The resistivity of the water should be 100 ohm-m ± 10%. The prescribed voltage is maintained for one minute.

e) Visible discharge test

This states that after the room has been darkened and the specified test voltage applied, after five minutes, there should be no visible signs of corona.

Sample tests

The sample is tested fully, up to and including the point of breakdown. This is done only on a few samples of the insulator.

a) Temperature cycle test

The complete test shall consist of five transfers, each transfer not exceeding 30 s.

b) Mechanical loading test

The insulator should be mechanically loaded up to the point of failure. When failure occurs, the load should not be less than 2000 lbf.

c) Electro-mechanical test

The insulator is simultaneously subjected to electrical and mechanical stress. It will be subjected to a power frequency voltage and a tensile force simultaneously. The voltage shall be 75% of dry flashover voltage of the unit. There should be no damage caused.

d) Over voltage test

The insulator should be completely immersed in an insulating medium (oil), to prevent external flashover occurring. The specified overvoltage must be reached without puncture. The voltage is then gradually increased until puncture occurs.

e) Porosity test

Freshly broken pieces of porcelain shall show no dye penetration after having been immersed for 24 hours in an alcoholic mixture at a pressure of 2000 p.s.i.

CHAPTER III

SIMULATION

3.1 Introduction

Switchercad III LTspice by Linear Technology is a freeware and much easier to be understand. This software is downloaded from the Linear Technology website at www.linear.com/company/software.jsp. This software has the same ability as the PSpice software but with an advantage over easiness of use and simpler interface.

3.2 Stage 1 simulation

The project circuit was simulated using the LT Spice software. As mention before, the project circuit is a half wave rectifier circuit. The input voltage, V1 is set to140 kVAC p-p that equal to 100 kVAC rms. The GSD2004W-V is a HV rectifier that will change the alternating current (AC) to direct current (DC) and this process is normally known as rectification.

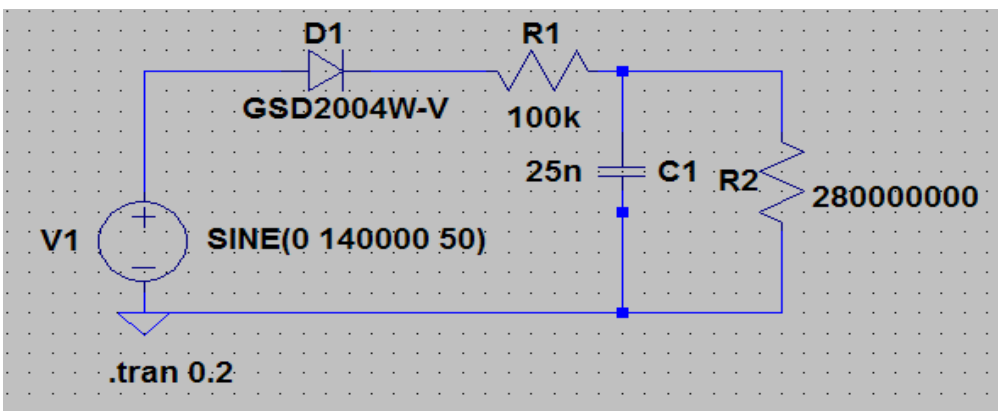
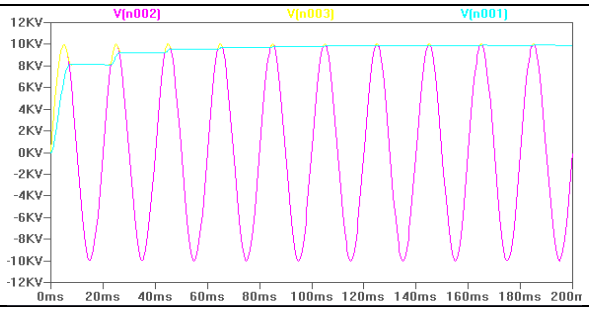
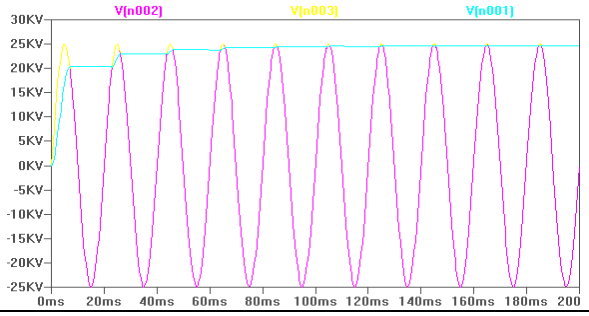
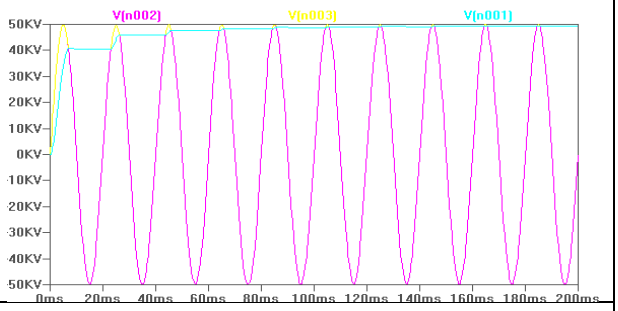


Figure 3.1: Project circuit simulation for first stage

Table 3.1: Simulation result for first stage

Nominal output voltage (% x 240V)	Output voltage (kV)	Simulated waveform
7	10.04	
18	25.02	
35	49.96	
70	99.7