UNIVERSITI PUTRA MALAYSIA

SIMULATION, DESIGN AND CONSTRUCTION OF A 15 KV DC POWER SUPPLY USING VOLTAGE MULTIPLIER CIRCUITS

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By

ANAYET KARIM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Partial Fulfilment of the Requirements for the Degree of Master of Science.

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UPM

Dedicated to Allah S.W. T (Most Gracious, Most Merciful)

Abstract of thesis is presented to the Senate of Universiti Putra Malaysia in Partial fulfilment of the requirements for the Degree of Master of Science.

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Chairman: **Associate Professor Nasrullah Khan, PhD**

Faculty: **Engineering**

This thesis describes a PSpice and PSCAD based design and implementation of high voltage DC power supply at 15 kV output. It presents the detail description of the simulation, design, development and implementation of hardware for high voltage DC power supply in the laboratory. The conventional technique is used because the designed DC power supply is intended to be applied either for impulse generator charging units or laser excitation. The main components of a DC power supply are rectifier diodes and capacitors. The output of the power supply is a fairly smooth DC voltage. The simplest unregulated power supply consists of three parts namely, the transformer unit, the rectifiers unit and the capacitors unit. The main emphasis of this project is on the simulation, and design by using two different software (mentioned earlier) to compare simulation results as well as experimental results of the high voltage DC power supply. The economic feasibility of designing doubler or tripler based high voltage DC power supply and observation of the fact that

simulated and experimental values are different. A piece of high voltage generator is made available to the department. Simulation and experimental results are presented. It has been observed that the results are in agreement except due to the tolerances of the capacitor. The system hardware has been implemented and tested in the laboratory.

KEYWORDS: Power Supply, High Voltage, Regulator

PERPUSTAKAAN SULTAN ABDUL SAMAD
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Abstrak tesis yang dikemukakan kepada Universiti Putra Malaysia sebagai memenuhi sebahagian keperluan untuk ijazah Master Sains.

REKABENTUK PENYELAKUAN DAN PEMBINAAN SUMBER KUASA DC 15 KV MENGGUNAKAN LITAR PENDARAB

OLEH

ANAYET KARIM

September 2005

Pengerusi: **Profesor Madya Nasrullah Khan, PhD**

Fakulti: **Kejuruteraan**

Penulisan ini menerangkan rekabentuk berasaskan perisian PSpice dan PSCAD untuk membina sumber votan tinggi DC pada keluaran 15 kV. Ia membentangkan penerangan terperinci tentang penyelakuan, rekabentuk dan perlaksanaan kerja perkakasan untuk membina sumber kuasa voltan DC dalam makmal dan kerja penyelakuan yang telah dijalankan dengan menggunakan perisian PSpice. Teknik lazim digunakan kerana sumber kuasa DC yang direkabentuk bertujuan untuk digunakan bagi unit pengecasan penjana dedenyut atau pengujaan laser. Komponen utama sumber kuasa DC adalah penerus dan pemuat. Keluaran sumber kuasa adalah voltan DC yang agak licin. Sumber kuasa yang teringkas mengandungi tiga bahagian yang dinamakan sebagai unit pengubah, unit penerus dan unit pemuat. Projek ini lebih menekankan tentang penyelakuan, rekabentuk dengan menggunakan dua jenis perisian (telah dijelaskan sebelum ini) untuk membandingkan keputusan simulasi dan keputusan dari eksperimen sumber bekalan kuasa voltan tinggi DC.

Selain dari itu, kajian dari segi ekonomi dalam merekabentuk pekali dua dan pekali tiga berasaskan bekalan kuasa voltan tinggi DC.Didapati bahawa keputusan dari penyelakuan dan eksperimen adalah berbeza. Sebuah alat penjana voltan tinggi diserahkan kepada jabatan. Keputusan penyelakuan dan amali dibentangkan. Ia didapati seperti yang dipersetujui melainkan kerana had-terima pemuat. Perkakasan sistem telah dilaksanakan dan diuji dalam makmal.

KATA KUNCI: Sumber Kuasa, Voltan Tinggi, Pengatur

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LIST OF ABBREVIATIONS

AC	Alternating current
APU	Auxiliary power unit
AIS	Air insulated system
BTOE	Billions tons oil equivalent
CB	Circuit breaker
CT	Current transformer
C1, C2, C3	Capacitors
CVT	Capacitor Voltage Transformer
CRT	Cathode-ray tubes
C-W	Cockcroft - Walton
D1, D2, D3	Diodes
DC	Direct current
EHV	Extra high voltage
EAPU	Electric auxiliary power unit
FFOV	Fast-front over voltages
GIS	Gas insulated system
Hz	Hertz
HV	High voltage
HVDC	High voltage direct current
HVAC	High voltage alternating current
HVPS	High voltage power supply
HVDCPS	High voltage direct current power supply
IEC	International electro technical commission

KA	Kilo ampere
KV	Kilovolts
KV/CM	Kilovolts per centimeter
KJ	Kilojoules
KW	Kilo watt
KM	Kilo meter
KHz	Kilo hertz
LV	Low voltage
mA	Miliampere
MS	Millisecond
MV	Mega volt
MW	Mega watt
MSFC	Marshall space flight center
NS	Nanosecond
OV	Operating voltages
PU	Per unit
PMT	Photo multiplier tube
PWM	Pulse width modulation
RF	Ripple factor
R1, R2	Resistors
SEI	Sumitomo Electric Industries
STD-531	Standard module
Trr	Reverse Recovery time
TOV	Temporary over voltages
TV	Television

UHV	Ultra high voltage
UK	United Kingdom
UPM	University Putra Malaysia
VT	Voltage transformer
V1	Input Voltage
VRRM	Repetitive Peak Reverse Voltage
VFFOV	Very fast-front over voltages
VMD	Voltage multiplier designer
ΔV	Ripple voltage
q	Charge
μF	Micro farad
μsec	Micro second
f	Supply frequency
I_1	Load current
t_1	Conduction period of the rectifiers
t_2	Non-conduction period of rectifiers

CHAPTER 1

INTRODUCTION

1.1 Research Background

High voltage testing equipment is generally used in mostly two places, in the research laboratories and routine testing laboratories. Besides the above places, it can be used to the industry and agricultural application also. The work carried out in research laboratories varies considerably from one establishment to the other and the type of equipment needed varies accordingly. A general high voltage laboratory may include equipment for all classes of tests. The routine testing is concerned with testing equipment such as transformer, switchgear, bushings as well as cables etc. It is sometimes carried out in the factory premises.

The high voltage equipment is required to study the insulation behavior under all conditions, which the apparatus is likely to encounter. Tests are also made with voltages higher than the normal working voltage to determine the safety factor over the working conditions and to ensure that the working margin is neither too high nor too low.

The conventional forms of high voltage in use can be divided into the following classes:

a) Alternating current voltages

b) Direct current voltages

c) Transient voltages

In the industry the main application of the DC high voltage is to test on cables with a relatively large capacitance, which takes a very large current if it is tested with AC voltages. The simplest unregulated power supply consists of three parts namely, the transformer unit, the rectifiers unit and the capacitors unit.

1.2 Project Overview and Problem Statement

This project is divided into two main parts, the circuit design and the hardware development part as shown in Figure 1.1. The first part concentrates on the design aspect, simulation of its circuits using PSpice software, version 6.3 and also using PSCAD 3.8, and selecting its components for the high voltage DC power supply. The maximum output of the power supply will be 15 kV. The second part of the work is the construction of DC power supply in the laboratory. The DC power supply takes AC input voltage from 180 volt to 240 volt.

To develop high voltage DC, it is noted that there are several techniques used such as voltage multipliers circuits, cascaded rectifier circuits with transformers, electrostatic HVDC generators (Van de Graaff Generators) and using induction coils [1]. Cascaded rectifier circuits with transformer multipliers needs excessive insulation for DC power supply, so it is very large arrangements and its range normally starts in MV capacity and it is expensive [2].

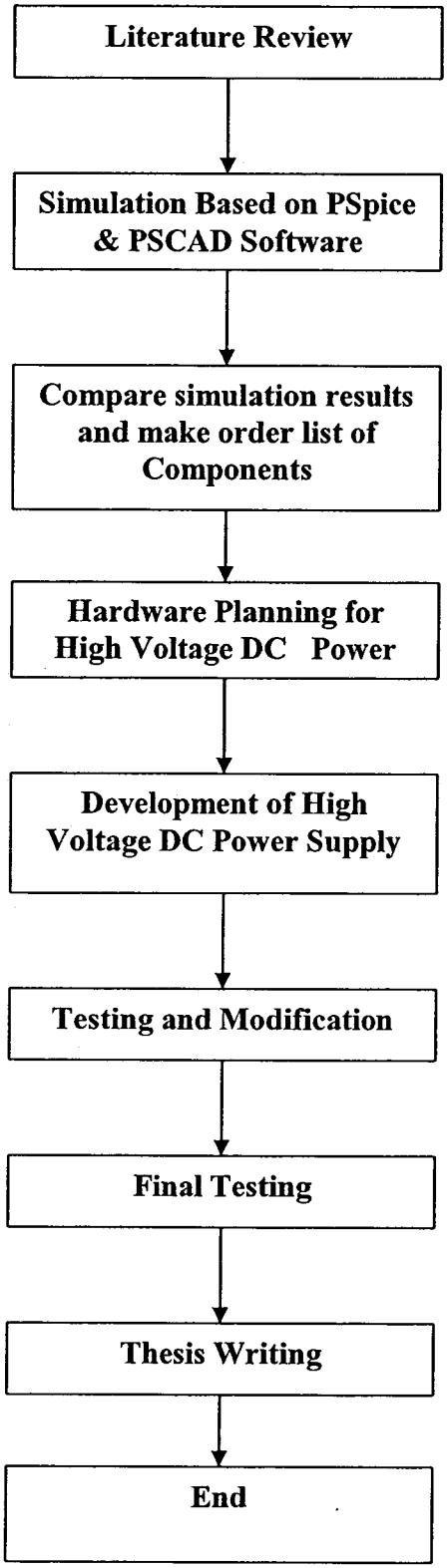

Figure 1.1: The overview of the project

On the other hand, electrostatic HVDC generators (Van de Graaff Generators) technique is mainly for very high voltage of 5-6 MV with output current of microamperes and used for particle accelerators and it is very much expensive [1, 2, 4]. Another idea is using induction coils which generate the high voltages required to create a spark [1].

Therefore it is noted that this project has been developed using voltage multipliers circuits instead of other techniques because below 100 kV, this is most suitable technique for generating high voltage DC. Voltage multiplier circuits are diode circuits that function as power supplies for special applications. They have the advantages of being simple solid state circuits with fairly low parts count and being able to produce output voltages much higher than the input voltage according to project demand.

Most DC test sets are done at lower frequency instead of high frequency [3]. It is less expensive, less insulation is required and its range can start from even 1 kV instead of MV capacity compare to the other methods [1, 2, 3, 4]. This is one of the methods for increasing voltages known as voltage multiplication or voltage multipliers.

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1.3 Aims and Objectives

The aim of this project is to design a single phase high voltage DC power supply and the range of the power supply will be a maximum of 15 kV. The objectives of this project are –

1. To make a simulation study on various types of voltage multiplier circuits such as voltage doubler, voltage tripler and voltage quadrupler circuits.

2. To design and develop high voltage DC power supply (maximum 15 kV) using voltage multiplier circuits based on PSpice simulation and to construct/fabricate in the laboratory.

The contributions of this work are as follows,

1. The main emphasis of this project is on the simulation, design by using two different software (mentioned earlier) to compare simulation results and hardware development of the high voltage DC power supply.
2. The economic feasibility of designing doubler or tripler based high voltage DC power supply.
3. Observation of the fact that simulated and experimental values are different.
4. A piece of high voltage generator is made available to department. It can be used for multiple purposes such as excitation of laser, test on cables in industrial application, insulation testing and lightning impulse testing.