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DEVELOPMENT OF HIGH VOLTAGE RECTIFIER

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“I hereby declare that I have read through this report entitle “Development of High Voltage Rectifier” and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power) with Honors”

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DEVELOPMENT OF HIGH VOLTAGE RECTIFIER

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A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

I declare that this report entitled "*Development of High Voltage Rectifier*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and it is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : Muhammad Ridwan bin Yusoff

Date : ....

To my beloved parents and siblings

Yusoff Mohamad

Khatijah Jusoh

Radhiyah Yusoff

Rashidah Yusoff

"Thank you for your support"

ACKNOWLEDGEMENT

Alhamdulillah, with the willing of Allah SWT, I have successfully completed my final year project, with the title of "Development of High Voltage Rectifier". This report was prepared in order to fulfil the requirements of the undergraduate program of degree in Bachelor of Electrical Engineering (Industrial Power) in Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka (UTeM).

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I hope that all the knowledges gained during the process of completion of this project will brings benefits to anyone who read it.

ABSTRACT

A lot of researches and studies had been carried out on the non-ceramic (polymeric) insulation since it was well accepted and applied in high voltage engineering. One of the key indicators to determine the polymeric insulation performance is its tracking and erosion resistance. In order to study the tracking and erosion resistance of outdoor polymeric insulation, an Inclined Plane Tracking and Erosion (IPT) test is conducted according to standard BS EN 60587: 2007 under AC voltage. However, with the increasing of the HVDC systems across the global, then the polymeric insulation has to deal with the DC voltage. Therefore, the rectification of AC-to-DC voltage is compulsory in order to conduct the DC IPT test in high voltage laboratory. The aim of this project is to develop a full-wave bridge high voltage rectifier with the rated output voltage up to 6kV DC. In addition, the rectifier circuit is first simulated by using PSpice software to obtain simulation waveform of the desired DC output voltage. The simulation waveform obtained from PSpice shows that the DC output voltage is pure and it contains low ripple. By this simulation result, the hardware of the DC high voltage rectifier will be developed. The development of the high voltage rectifier will be using several power electronic components such as power diodes and power capacitors as the waveform filtering element. The power capacitors used have two different values of capacitance which are 0.01uF and 820pF. With 0.01uF capacitor, the ripple percentage of the rectifier when 6kV DC output voltage is 25.1%. Meanwhile, with 820pF capacitor, the ripple percentage of the rectifier when 6kV DC output voltage is 18.6%. Therefore, it is proven that the high voltage rectifier developed with 820pF capacitor has better performance compared to the rectifier that developed by using 0.01uF capacitor.

ABSTRAK

Banyak penyelidikan dan pengajian telah dijalankan terhadap penebatan bukan-seramik (polimer) sejak ia telah diterima and diaplikasikan dalam kejuruteraan voltan tinggi. Salah satu petunjuk utama untuk menentukan prestasi penebatan polimer ialah rintangan mereka terhadap aliran dan hakisan. Untuk mempelajari rintangan aliran dan hakisan terhadap penebatan polimer luar premis, ujian *Inclined Plane Tracking and Erosion* (IPT) dijalankan mengikut piawaian BS EN 60587: 2007 dibawah voltan AC. Walaubagaimanapun, dengan peningkatan system HVDC di seluruh dunia, penebatan polimer perlu berurusan pula dengan voltan DC. Oleh itu, penukaran voltan AC-ke-DC adalah wajib untuk menjalankan ujian DC IPT di dalam makmal voltan tinggi. Maklamat projek ini adalah untuk membangunkan sebuah alat penukar voltan tinggi *full-wave bridge* dengan nilai voltan keluaran 6kV DC. Selain itu, litar alat penukar pada mulanya akan disimulasi dengan perisian PSpice untuk memperoleh bentuk gelombang simulasi voltan keluaran DC yang dikehendaki. Bentuk gelombang simulasi yang diperoleh daripada perisian PSpice menunjukan bahawa voltan keluaran DC ialah tulen dan mengandungi tahap ganguan yang rendah. Melalui keputusan simulasi, perkakasan alat pengubah voltan tinggi akan dibangunkan. Pembangunan perkakasan alat pengubah voltan tinggi akan menggunakan beberapa komponen electronik kuasa seperti beberapa diod kuasa dan kapasitor kuasa sebagai elemen penapis bentuk gelombang. Kapasitor-kapasitor kuasa yang digunakan mempunyai dua nilai kemuatan iaitu 0.01uF dan 820pF. Dengan kapasitor 0.01uF, peratusan gangguan daripada alat penukar semasa voltan keluaran 6kV DC ialah 25.1%. Sementara itu, dengan kapasitor 820pF, peratusan gangguan daripada alat penukar semasa voltan keluaran 6kV DC ialah 18.6%. Oleh hal yang demikian, ia telah terbukti bahawa alat penukar voltan tinggi yang dibangunkan dengan menggunakan kapasitor 820pF mempunyai prestasi yang lebih baik jikalau dibandingkan dengan alat penukar yang dibangunkan dengan menggunakan kapasitor 0.01uF.

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LIST OF ABBREVIATIONS

SiR	Silicon Rubber
EPM	Ethylene Propylene Monomer
EVA	Ethylene Vinly Acetate
HTV	High Temperature Vulcanized
AC	Alternating Current
DC	Direct Current
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
ATH	Alumina Trihydrate
IPT	Inclined Plane Tracking and Erosion
DBA	Dry-band Arching
RBV	Reverse Breakdown Voltage
PIV	Peak Inverse Voltage
FVD	Forward Voltage Drop

LIST OF SYMBOLS

kV	Kilovolt
mV	Milivolt
pF	Picofarad
µF	Microfarad
Ω	Ohm
A	Ampere
f	Frequency
%	Percent
V_{max}	Maximum output voltage
V_0	Average output voltage
V_p	Peak voltage
V_{rms}	RMS voltage
Hz	Hertz
X_C	Capacitive reactance
C	Capacitance value

CHAPTER 1

INTRODUCTION

1.1 Introduction

In modern times, high voltage is used in many applications including the power system industry and research laboratories. Such applications are vital to maintain our modern civilization. The insulators are the most important material in high voltage applications to ensure the current flow in its own path [1].

Previously, the insulation industries were dominated by the ceramic and glass insulator. However, in the middle of the twenty century, a new concept of composite insulation introducing polymeric materials was developed in USA [2]. Non-ceramic (polymeric) insulation is well accepted by the industries and utilities to replace the old-type porcelain and glass insulation due to their advantages such as light in weight, easy to handle, good contamination performance and low installation and maintenance costs [3]. Besides, polymeric insulation has good hydrophobic characteristic in fog, dew and rain condition [4]. These good hydrophobic characteristics will lower the transmission losses during early year of installation [5]. Silicone rubber (SiR), ethylene propylene monomer (EPM) and ethylene vinly acetate (EVA) are the examples of most common polymer composites used in high voltage insulation [3].

However, the polymeric insulation has main disadvantage which is the deterioration due to environmental and operation conditions [6]. For instance, although the polymeric insulation is hydrophobic at the beginning of their service, it may become hydrophilic under certain condition especially in polluted environment. This will lead to leakage current flow, dry-band arching (DBA) and ageing by tracking and erosion [7].

Nevertheless, insulation with silicone rubber (SiR) composite has extraordinary performance in the contaminated environment. In spite sharing the hydrophobic surface characteristic with others polymeric insulation materials, the surface of silicone rubber (SiR) composite remains hydrophobic in contaminated area and the hydrophobicity losses in extreme condition are temporary. According to R. J. Hill [8], the High Temperature Vulcanized (HTV) silicon rubber (SiR) is favorable insulation in extremely polluted environment.

Polymeric outdoor insulation is the suitable option for High Voltage Alternating Current (HVAC) power transmission lines to replace ceramic insulations. Since the introduction of power electronic devices, High Voltage Direct Current (HVDC) has become the possible option in power transmission [5]. Nowadays, it is an undeniable proof that HVDC system is growing rapidly around the world as lots of power transmission projects are adopting this type of system [9]. The first polymer insulator for DC transmission was introduced in the mid-1970 on the Pacific DC Intertie line at +/- 400kV, at the southern terminus of the line near Los Angeles [10]. One thing to be concerned about the HVDC power transmission is its line insulator, as for the same electric field condition, the insulator accumulated pollutant under Direct Current (DC) voltage is 1.2 to 1.5 times larger compared to Alternate Current (AC) voltage [5].

A rectifier is very crucial in HVDC power transmission system. Theoretically, the purpose of rectifier is to produce the purely output DC voltage or current waveform that has specified DC components [11]. Therefore, the design characteristic of a rectifier must be able to deal with the high voltage application. Moreover, in the reference [5], the high voltage DC power supply was used as the input voltage for Inclined Plane Tracking and Erosion (IPT) test under DC voltage of insulating polymeric material. This highlights the importance of rectifier in producing DC voltage. In this project, the high voltage rectifier with maximum output of 6kV positive DC will be developed. The rectifier built will be used to generate high voltage DC power supply that will be used as the input voltage for DC IPT test of insulating polymeric material which usually done according to the standard BS EN 60587: 2007.

1.2 Problem Statement

The IPT test is carried out to analysis the ageing performances of the polymeric insulation under AC voltage previously. However, the use of DC polymeric insulation has gained a lot of interest in the HVDC projects worldwide. Besides, study on silicone rubber properties of high voltage insulation is moving towards the DC voltage lately such as in the reference [12] and in the reference [13] .Therefore, the use of the polymeric insulation under DC voltage needs to be examined [10]. Nowadays, the standard IPT tests involve only for AC voltage. Even though there is no standard test method for DC voltage, a lot of researchers carry out the IPT test under DC voltage by referring to the AC IPT test standard [14]. Therefore, more researches need to be done to allow the development of new standard of DC tracking and erosion. Since the power source AC voltage needs to be changed to DC voltage in order to carry out IPT test under DC voltage, a high voltage rectifier is required to rectify the high voltage AC waveform to high voltage DC waveform through a process called rectification. Therefore, with the construction of the rectifier, the DC IPT test can be carried out in the high voltage laboratory and thus it opens up larger opportunity to study the ageing performance of polymeric insulations under DC voltage.

1.3 Objective

The following are the objectives of the project:

1. To develop a high voltage rectifier that could produce DC voltage up to 6kV for high voltage insulator application.
2. To apply full-wave bridge rectification technique to study the behavior of DC IPT Test.
3. To produce a high quality of rectifier that has low ripple DC output voltage waveform.

1.4 Scope

The following are the scopes of the project:

1. Designing of full-wave bridge rectifier circuit which will be developed for DC IPT test.
2. The input voltage of the rectifier is varied from 0V to 240V.
3. The rated output DC voltage of the developed high voltage rectifier is 6kV.

1.5 Project Outline

Chapter 1 is an overall outline of the project including the problem statement, objectives and scopes. The project works that will be carried out are based on the objectives and scopes that have been reviewed earlier.

Chapter 2 explains the literature review and previous studies that have been carried out previously. In this chapter, the selection criteria and the development of high voltage rectifier is explained. Next, the review of DC IPT Test procedures and the study of ageing mechanism toward the polymeric insulation in laboratory were also discussed.

Chapter 3 discusses about the methodology that was adopted for this project. It includes the development process of high voltage rectifier by using software and hardware approach. The software approach uses the PSpice simulation software while the hardware approach applies the usage a few of power electronic components and several high voltage equipment in the high voltage engineering research laboratory.

Chapter 4 presents the result and discussion regarding the developed high voltage rectifier. The DC voltage output waveform characteristics are obtained by using PSpice simulation software and also from the digital oscilloscope. The calculation of ripple percentage is also done in this chapter to determine the performance of the rectifier.

Chapter 5 concludes the all the procedures that has been presented and carried out in previous chapters and the overall result of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Electrical insulation is one of the important issue to be considered in the electrical engineering field. The generation and transmission of electrical power system critically depend on the performance of electrical insulation. The polymeric composite insulation is widely used in high voltage engineering due to its advantages compared to old-type glass insulation. Since the development of HVDC power transmission system, a large number of significant research and studies has been made to improve the insulation performance under DC stress.

The following subsections of this literature review discuss the overview of polymeric insulation composite including its major components and the factor that influence the ageing performance of insulators. It also explains the development of high-voltage rectifier, as a DC power source to be used in the DC IPT test of insulation materials.

2.2 History of Polymeric Insulation

The history of polymeric insulation began in the 1940s when epoxy as organic material was used in indoor high voltage insulation. The discovery of alumina trihydrate (ATH) filler that increases the tracking and erosion resistance in 1950s led the usage of polymeric insulator in outdoor high voltage insulation. Until late 1960s and early 1970s, there was no development of outdoor polymeric insulators until they became operational on transmission lines system in the 1980s [15]. Since the introduction in high voltage applications, the polymeric composite insulation has been improved in its quality and performance involving material formulation, manufacturing process and reliable testing and monitoring methods. The applications of polymer insulating composite in electrical engineering field include the arrestors, bushings, joints and cable terminations [16][17]. The early design of a polymeric insulation design is illustrated in Figure 2.1.

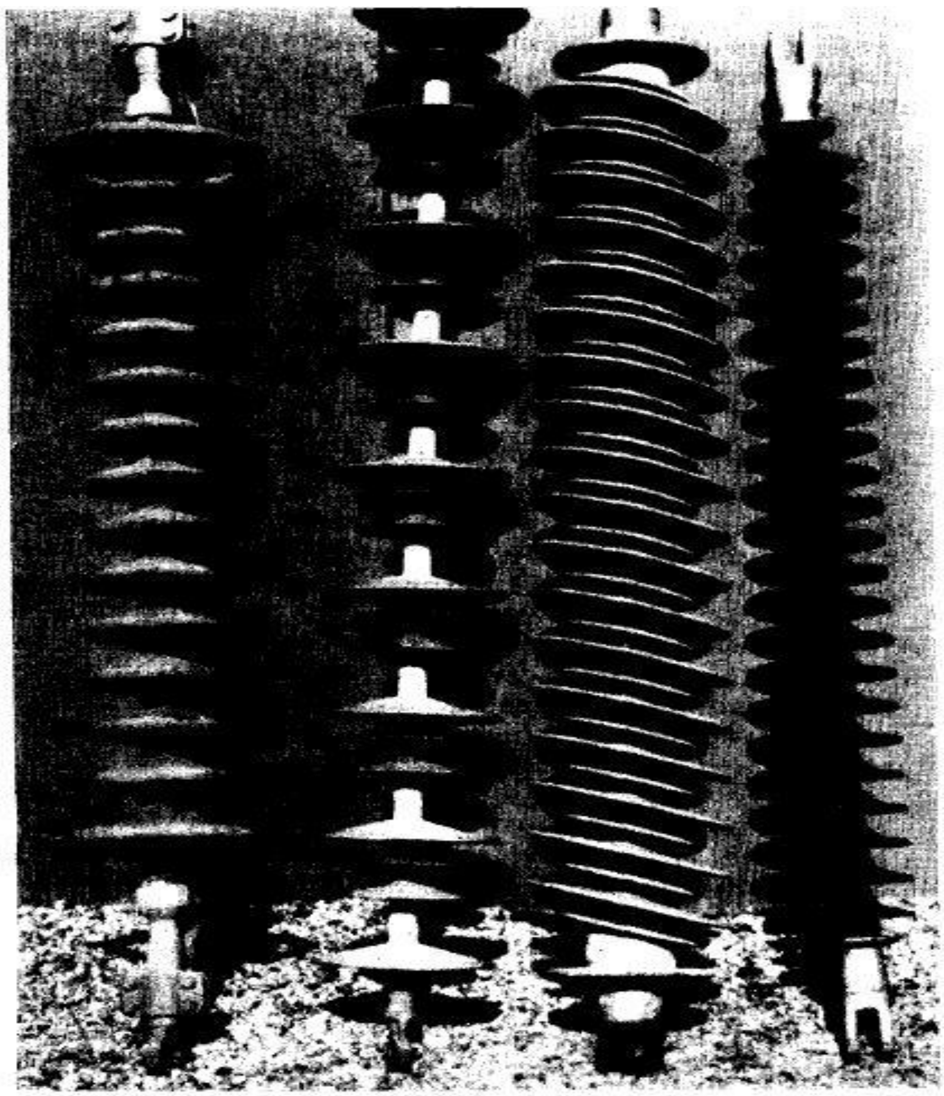

Figure 2.1: Example of early polymeric insulation design [15].