SINGLE PHASE SINGLE STAGE HIGH DC VOLTAGE MULTIPLIER CONVERTER

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This report is submitted in partial fulfillment of the requirements for award of Bachelor of Electronic Engineering (Industrial Electronics) With Honours

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MAY 2008

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UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

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PROJEK SARJANA MUDA II

Tajuk Projek : Single Phase Single Stage High DC Voltage Multiplier Converter

Sesi Pengajian : 2007/ 2008

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Especially for my beloved father and mother, my siblings and family.

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ACKNOWLEDGEMENT

Alhamdullillah, thanks to Allah because of his blessing, I manage to finish this 'Projek Sarjana Muda' in good condition and sharp on time. I also would like to take this opportunity to give appreciation especially to my beloved father and mother because of their support and understanding in helping me to finish this project, then this appreciation goes to my honourable lecturer's which is Mr. Zulkarnain bin Zainudin because of his guidelines and sharing some useful advice in order to help me to give the best effort and commitment to finish this project. Finally, I would like to thanks to all my lovely friends and other persons who always help and give support to me along accomplished this PSM. Lots of thanks to them and hopefully Allah will pay their kindness.

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ABSTRACT

This project paper proposed a single-phase single-stage high DC voltage multiplier converter. The convertion of high DC voltage converter without a DC link is involved. A high frequency transformer using ETD 59 ferrite core with ratio 1:1 is used as energy storage and also providing isolation. Cockroft-Walton circuit is connected at secondary side of the transformer. AC input is controlled by IGBT switch which the current flow in both directions of the transformer to fully utilize the transformer core. The current flow is controlled by the IGBTs using PWM technique.

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ABSTRAK

Kertas kerja ini adalah cadangan untuk projek 'single-phase single-stage high DC voltage multiplier converter'. Projek ini melibatkan proses penukaran pengubah voltan tinggi arus terus, tanpa menggunakan talian arus terus. Litar ini menggunakan pengubah berfrekuensi tinggi iaitu teras ferit ETD 59 dgn nisbah 1:1 yang berfungsi untuk menyimpan tenaga di mana penebat juga turut disediakan. Litar 'Cockcroft Walton' akan disambungkan pada bahagian sekunder tranformer. Suis IGBT dikawal oleh arus ulang alik, dimana arus yang mengalir pada kedua-dua arah pada litar transformer ini akan membuatkan teras pengubah berfungsi sepenuhnya. IGBT mengawal arus yang mengalir melalui teknik denyut lebar modulasi (pulse width modulation).

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LIST OF ABBREVIATION

AC	-	Alternating Current
CPLD	-	Complex Programmable Logic Devices
CRT	-	Cathod Ray Tubes
CW	-	Cockcroft Walton
DC	-	Direct Current
HV	-	High Voltage
IGBT	-	Insulated Gate Bipolar Transistor
LCD	-	Liquid Crystal Display
MOSFET	-	Metal-Oxide Semiconductor Field-Effect Transistor
MPWM	-	Multiple-Pulse Width Modulation
PWM	-	Pulse Width Modulation
SPWM	-	Sinusoidal Pulse Width Modulation
V	-	Voltage

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CHAPTER I

INTRODUCTION

1.1 Introduction of the Project

This project proposed about the single phase single-stage high Direct Current (DC) voltage muliplier converter which is used to produce high voltage at low power. In this project, a new method of controlling Cockcroft Walton Voltage Multiplier circuit using a digital controller is presented. The digital controller is developed using analog method where the comparator will be used to compare the triangular wave and the sine wave (input signal). The proposed system utilizes a single phase Alternating Current (AC) input supply. The power switching devices in the controlled bridge are controlled by the multiple-pulse Pulse Width Modulation (PWM) switching technique so as to minimize the low order harmonics present on the AC side of the converter system. A low pass filter is incorporated in the circuit to filter out unwanted harmonics provide a sinusoidal AC supply current.

1.2 Objective of the Project

The main objectives of this project are:

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1. To design and simulate the circuit for the single-phase single-stage high DC voltage multiplier converter by using analog method.
2. To build the prototype for the single-phase single-stage high DC voltage multiplier converter circuit.
3. To analyze and compared the results between the simulation and prototype results.
4. To generate higher output voltage compared to the input.

1.3 Problem Statement

There is no information about controlling the Cockroft Walton using digital technique controller. So, in this project the conventional Cockroft Walton will be controlled by six switches where the AC supply are chopped to high frequency AC using PWM technique and coupled using high-frequency transformer. The analog method will be used to develop the PWM switching pattern.

1.4 Scope

This project will include the explaination of the single phase single stage high DC voltage multiplier converter. Then, by using the Multisim, Pspice, Protell 99 SE and other related software, the circuit will be design and simulate to ensure that the result was almost same with the theoritical results. The prototype of the circuit will be built and tested in order to make sure the circuit works properly. Finally, the comparisons between the simulation and the experimental results and were observed.

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1.5 Methodology

In this project, the understanding about the Cockcroft Walton voltage multilier is needed.The conventional Cockcroft Walton (CW) connects AC supply directly to the input of Cockcroft Walton voltage multiplier circuit.The CW controlled by using analog method controller. Six switches of IGBT's will be used to chop the AC supply to high frequency AC using PWM technique and coupled using high-frequency transformer. Comparator will be used to develop the PWM switching pattern.

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CHAPTER II

LITERATURE REVIEW

2.1 Introduction

The conventional technique of generating high DC voltage is by using multi-stage or cascaded power conversion. The technique requires less sophisticated controller to control its operation. However, due to the inherent characteristics of a multi-stage system, it requires more components and more complex [1]. The present of lower order of harmonics current injected back to the utility supply requires a large LC filter size to minimize these effects. A low-power active filter can also be used to control the harmonic current, but at some additional cost.

The high DC voltage can also be generated using a simple AC-DC topology, which consists of a high ratio of a step-up transformer but requires a large size of transformer. Although the topology is simple, the harmonic current generated on an AC side is uncontrollable [2]. Single-stage power conversion is as topic that has been of substantial interest to power electronics researchers in recent years, and numerous converters have been proposed such as resonant converter, PWM converter etc. Most of the single-stage AC-DC converter using a full bridge diode rectifier and a smoothing inductance (DC-link) to maintain the ripple free current before it fed to the boost

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converter. Again a bulky inductance is used. There is also single-stage converter without a DC-link which is very attractive because they have very high input power factor but unfortunately it is not suitable for all application because of some drawback [3].

Cockcroft-Walton (CW) voltage multiplier or cascaded rectifier is a well known topology and have been widely used in many high-voltage low-power industrial applications where a low cost, compact system is required [4]. Conventional CW connects AC supply directly to the input of CW voltage multiplier circuit. There is no papers wrote about controlling the CW using digital technique controller. In this paper, the conventional CW will be controlled by six switches where the AC supply is chopped to high frequency AC using PWM technique and coupled using high-frequency transformer. Comparator is used to develop the PWM switching pattern.

PWM is a well-known wave shaping technique in power electronics converter system. It has a wide range of applications that create interests in many researches in this area. It has been used in all types of converters such as AC-DC, AC-AC, DC-AC, and DC-DC various schemes of PWM have been reported. Some schemes are produced for a specific converter topology and not suitable for others. In general, most of the research is focused on optimizing the PWM switching pattern. The PWM was designed to reduce the low order harmonics present in the system due to the switching and also to reduce the switching stress imposes on the power switching devices [5].

Most PWM is generated by comparing a modulating signal with a triangular carrier signal. However, the modulating signal may come in various shapes to suit the converter topology, such as sine wave and constant DC. A sinusoidal modulating signal is used for PWM in DC-AC converter where it is used to produce output AC voltage with less low order of harmonics components, thus small size of LC filter is adequate. However, a constant DC voltage as a modulating signal is used for PWM in AC-DC converter to shape the input AC current to be close to sinusoidal with small LC filter and having unity power factor [6]. These two popular PWM patterns are applied to the

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converter as well as the other two modified PWM to investigate the performance of the converter.

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CHAPTER III

METHODOLOGY

3.1 Introduction

In this chapter, the explanation of the methodology of the project will be discussed in details. Basically, this project needs more understanding about the Cockcroft Walton voltage multiplier and the PWM switching pattern that used to trigger the IGBT. However, the important part is the understanding about the project title, which is about single phase single stage high dc voltage multiplier converter where the overall information about the project needs to be understood. So, this chapter will explain in detail about the title definition, proposed topology, circuit operation, simulation, hardware measurement and others.

3.2 Single Phase

In electrical engineering, single-phase electric power refers to the distribution of electric power using a system in which all the voltages of the supply vary in unison. Single-phase distribution is used when loads are mostly lighting and heating, with few large electric motors. The generation of AC electric power is commonly three phases, in

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which the waveforms of three supply conductors are offset from one another by 120°. Standard frequencies of single-phase power systems are either 50 or 60 Hz.

A single-phase load may be powered from a three-phase distribution system either by connection between a phase and neutral [120 V or 220 V], or by connecting the load between two phases [120 V and 120 V, the total being 240 V or 220 V and 220 V, the total being 440 V]. The load device must be designed for the voltage in each case.For example, in places using a 415 volt 3 phase system; the phase-to-neutral voltage is 240 volts, allowing lighting to be connected phase-to ground and motors to be connected to all three phases.

In North America, a typical three-phase system will have 208 volts between the phases and 120 volts between phase and ground. If heating equipment designed for the 240-volt three-wire single phase system is connected to two phases of a 208 volt supply, it will only produce 75% of its rated heating effect. Single-phase motors may have taps to allow their use on either 208 V or 240 V supplies.

On higher voltage systems (kilovolts) where a single phase transformer is in use to supply a low voltage system the method of splitting seems to vary by country. In North America the primary of the step-down transformer is wired across a single high voltage feed wire and ground, at least for smaller supplies (see photo of transformer on right). In Britain the step-down primary is wired phase-phase. No arrangement of transformers can convert a single-phase load into a balanced load on a polyphase system.

3.3 Single Stage

A single stage single switch AC/DC converter is an integration of input current shaper and a DC/DC cell with a shared controller and one active switch. The converter is applicable for digital input power supply with high input power factor and tight output

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voltage regulation. The focus of the topology is to reduce the DC bus voltage at light load without compromising with input power factor and voltage regulation. The concept behind this topology is direct power transfer scheme. Using special configuration of DC/DC cell does reduction of DC bus voltage and DC/DC cell works on the principle of series charging and parallel discharging. The power output of this converter can go up to 200W.

3.4 Voltage Multiplier

A voltage multiplier is an electrical circuit that converts AC electrical power from a lower voltage to a higher DC voltage by means of capacitors and diodes combined into a network. Voltage multipliers can be used to generate bias voltages of a few volts or tens of volts or millions of volts for purposes such as high-energy physics experiments and lightning safety testing.

3.5 Cockcroft Walton Multiplier

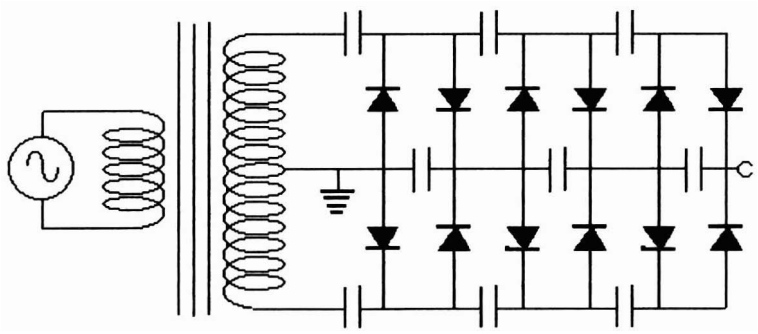

Figure 3.5.1: Cockcroft Walton Multiplier circuit.

One of the cheapest and popular ways of generating high voltages at relatively low currents is the classic multistage diode/capacitor voltage multiplier, known as Cockcroft Walton multiplier, named after the two men who used this circuit design to be

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