UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF CASCADED H-BRIDGE MULTILEVEL INVERTER BASED ON PWM

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology (Industrial Power) with Honours.

by

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours. The member of the supervisory is as follow:

……

(Project Supervisor)

ABSTRAK

Teknologi Penyongsang berbilang telah banyak digunakan dalam pelbagai aplikasi yang menggunakan tenaga yang boleh diperbaharui dan indusri sebagai alternatif yang sangat penting dalam bidang kuasa tinggi dan kawalan tenaga voltan tinggi. Pada asasnya, penyongsang adalah alat elektronik kuasa yang menukarkan arus terus (DC) kepada arus ulang-alik (AC) namun tidak sesuai digunakan untuk bidang kuasa tinggi dan voltan tinggi. Terdapat beberapa jenis penyongsang bertingkat (MLI) seperti penyongsang berbilang H-Bridge, kapasitor diapit penyongsang berbilang, diod diapit penyongsang berbilang dan hibrid penyongsang berbilang. Tujuan projek ini adalah untuk mengkaji serta menyelidik penyongsang bertingkat H-Bridge pada satu fasa dan tiga fasa. Dengan menggunakan MOSFET sebagai komponen pensusisan dan menggunakan modulasi lebar denyut (PWM) kaedah kawalan untuk menghasilkan output yang dikehendaki iaitu lima tingkat, tujuh tingkat dan sembilan tingkat. Kawalan kod dan simulasi dilakukan dengan menggunakan MATLAB. Penyongsang berbilang digunakan secara meluas dalam, tenaga solar dan lain-lain tenaga boleh diperbaharui.

ABSTRACT

Multilevel inverter technology has been widely used in various applications that use renewable energy and industry as an extremely important alternative in high power and high voltage energy control. Basically, the inverter is a power electronic device that converts direct current (DC) to the alternating current (AC) but is not suitable for high voltage and high voltage fields. There are several types of multilevel inverters (MLIs) such as cascaded H-Bridge multilevel inverters, flying capacitors clamped multilevel inverters, diodes clamped multilevel inverter and hybrid multilevel inverters. The purpose of the project is to study and investigate the single phase and three phase cascaded H-Bridge. Using MOSFET as a switching component and using pulse width modulation (PWM) control method to produce the required output is five levels, seven levels and nine levels. Code and simulation controls are done using MATLAB. Multilevel inverter is widely used in solar energy and other renewable energy.

DEDICATION

To my beloved parents

Mahayuddin Bin Osman (Father)

Suaibatun Islamiah Binti Hassan Shaari (Mother)

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I thank Allah, the lord of the worlds, for His mercy and limitless help and guidance. May peace and blessings be upon Mohammed the last of the messengers.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

MLI		Metal Oxide Semiconductor Field Effect Transistor
CHB		Cascaded H-Bridge
FC		Flying Capacitor
DC		Diode Clamped
THD	-	Total Harmonic Distortion
IGBT	-	Insulated Gated Bipolar Transistor
GTO	-	Gate Turn-Off Thyristor
DC	-	Direct Current
AC	-	Alternating Current
PWM	-	Pulse Width Modulation
SPWM	-	Sinusoidal Pulse Width Modulation
SVPWM	-	Space Vector Pulse Width Modulation
SHE	-	Selective Harmonic Elimination
NPC	-	Now Playing Character
IPD	-	In phase deposition
POD	-	Phase opposition deposition
APOD	-	Alternative phase opposition deposition

CHAPTER 1
INTRODUCTION

1.0 Introduction

Multilevel inverters are attractive topologies for high voltage high-power applications. The most dominant topologies of multilevel inverters are the diode clamped multilevel inverter (DCMLI), the cascaded H-bridge multilevel inverter (CHBMLI), and the flying capacitor multilevel inverter (FCMLI). Due to modularity, flexibility, extensibility and easy maintenance of CHBMLI, among these topologies, CHBMLI is deemed to be the most promising topologies for applications in which multiple DC sources is not of concern, such as high-power power quality conditioning applications, solid-state transformers, and photovoltaic systems.

However, it suffers from the voltage balancing problem and complex modulation schemes the imbalance of DC capacitor voltages is caused by different duty cycles for different cells and parameter variations of switches and passive components of the cells. The unregulated DC-link capacitor voltage will introduce some problems, such as the increased total harmonic distortion (THD) of the output voltage, and high stresses on semiconductor switches which may lead to serious system problems. Therefore, it is necessary to use an additional control to balance DC voltage

1.1 Background

This project is to study a single phase and three phase cascaded h-bridge multilevel inverter for 5-level, 7-level and 9-level output. The multilevel inverter should be able to use for certain application. Multilevel inverters are a source of high power, often used in industrial applications and can use either sine or modified sine waves. This inverter consists of two H-bridge inverters that are cascaded. For example, 5-level cascaded H-bridge multilevel inverter 8 switching devices are required. For this project pulse width modulation (PWM) will be used and MOSFET will be used as replacements because of low power consumption and waste. Cascaded H-bridge multilevel inverter have been applied where high power and power quality are essential, for example static synchronous compensators active filter and reactive power compensation applications, photovoltaic power conversion, uninterruptible power supplies, and magnetic resonance imaging. This main objective is to examine the quality output voltage of the multilevel inverter design is that to generate nearly sinusoidal output voltage waveform and to eliminate lower order harmonics.

1.2 Problem statement

Now a day's many industrial applications have begun to require high power. Some appliances in the industries, however, require medium or low power for their operation. Using a high-power source for all industrial loads may prove beneficial to some motors requiring high power, while it may damage the other loads. Some medium voltage motor drives and utility applications require medium voltage. The multilevel inverter has been introduced since 1975 as alternative in high power and medium voltage situations. The multilevel inverter is like an inverter and it is used for industrial applications as alternative in high power and medium voltage situations.

1.3 Objectives

Based on the problem statement above, this study is motivated by the following objectives which are:

i. To explain a single phase and three phase cascaded H-bridge multilevel inverter.
ii. To simulate a proposed topology using MATLAB/Simulink
iii. To compare the THD of different level of CHBMLI.

1.4 Scope of work

This project is to study a single phase cascaded H-bridge multilevel inverter. By using pulse width modulation (PWM) control method to produce the desired output that is 5- level, 7-level and 9-level output and MOSFET as a switching device. A project will cover the scope of analyzing a simulation circuit that utilize cascaded H-bridge multilevel inverter to convert direct current to alternate current. In this project will be divided into several stages. First is involving the understanding of various types of inverter and multilevel inverter focusing on the cascaded H-bridge multilevel inverter. Besides, before analyze the purposed topology, it is important to study about switching devices especially the MOSFET as switches. Then, pulse width modulation (PWM) control method to produce the desired output that is a 5-level, 7-level and 9-level output.

The limitation of this project is the hardware implementation of the proposed topology is costly due to complexity in assembling the circuit. Other than that, this project requires a long duration of time due to the time taken in understanding the design of purposed topology and the time taken in learning in simulation using MATLAB.

1.5 Report outline

This documented thesis consists of five chapters. The first chapter of this thesis is Introduction which covers the project background, problem statements and the objectives of this project. The scope of study and report outline are also included in this chapter.

The second chapter of the thesis is Literature review which focuses on reviewing previous researches or works that relates to the scope of this study. This chapter review on the implementation of various inverter and multilevel inverter for example cascaded H-bridge multilevel inverter, a flying capacitor clamped multilevel inverter, a diode clamped multilevel inverter and hybrid multilevel inverter. Besides that, this chapter reviews on different type of switching devices which insulated gated bipolar transistor (IGBT) and metal oxide semiconductor field effect transistor (MOSFET).

The third chapter of this thesis is Research methodology elaborates in detail of the procedures and steps taken in conducting the experiment of this project. Design and simulate circuit from software which are used to complete this project also explained in this chapter.

The forth chapter of this thesis is Result and Discussion. This chapter discusses about the result from the 5-level, 7-level and 9-level output of the single phase and three phase cascaded H-bridge multilevel inverter. The structure and setup of the cascaded H-bridge multilevel inverter and total harmonic distortion will also be discussed.

Lastly, the fifth chapter of the thesis is Conclusion. This chapter will discuss on conclusion of the project by analyses the result in chapter four. Also, this chapter will give suggestions and recommendations for future works. The next section of this thesis is Chapter 2, Literature review.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter will study about the overview of multilevel inverter including 2-level inverter. Mainly about cascaded H-bridge multilevel inverter, flying capacitor clamped multilevel inverter, diode clamped multilevel inverter, hybrid multilevel inverter and their switching devices and related result by other researches will also be discussed.

2.2 Power Electronic

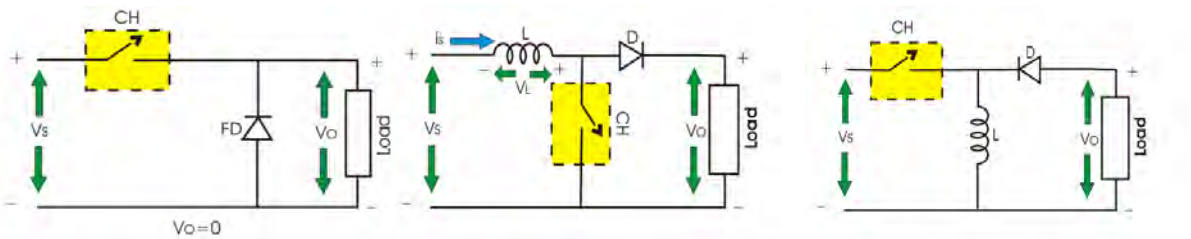
Power electronic is the application of electronics to control and conversion of electrical power. The extensive use of power electronic based appliances and several adjustable speed drives in almost all areas, which leads to low pf low efficiency and so on become the reason for the power distribution networks and the point of common coupling to be highly distorted. (Kotturu & Argawal 2016). There is some type of power conversion such as DC to DC (chopper), AC to DC (rectifier), and DC to AC (inverter). Each conversion is performed using switching devices such as MOSFET, BJT and diodes. Each type of conversion has its own working principle.

2.2.1 AC to DC Rectifier

AC/DC converters, also known as rectifiers, are the crucial power electronic facilities that build the interface between the AC grid and massive DC equipment's. Following the emerging of high power DC applications such as the modern data center or commercial building DC distribution system, high power AC-DC converters are required. (C. Li et al. 2017).

2.2.2 DC to DC Chopper

Chopper is a basically static power electronics device which converts fixed dc voltage/power to variable DC voltage or power. It is nothing but a high-speed switch which connects and disconnects the load from source at a high rate to get variable or chopped voltage at the output. Chopper converter has 3 type which is step down converter or Buck converter, step down converter or Boost converter and step up step down converter or Buck-Boost converter. The performance of these applications will be improved if we use a variable DC supply. It will help to improve controllability of the equipment's also. Examples of such applications are subway cars, trolley buses, battery operated vehicles etc. We can control and vary a constant dc voltage with the help of a **chopper.** Figure 2.1. show a type of DC to DC converter, Buck converter, Boost converter, Buck-Boost converter respectively.



(a)Buck converter (b) Boost converter (c) Buck-Boost converter

Figure 2.1: a) Buck converter b) Boost converter c) Buck-Boost converter

2.2.3 DC to AC Inverter

Inverters are called the conversions of DC to AC. Change the DC input to the AC output voltage and current of an optimal amplitude and frequency are the functions in inverter. The output voltage might be variable or fixed. Voltage Source Inverter (VSI), Current Source Inverter (CSI), Resonant pulse inverter and all other types except multilevel inverters are operated as mentioned the following kinds of inverters. It is called a two-level inverter because conventional inverters can either produce the output levels at zero or maximum. These types of inverters are not used for a high-power application because of it consists of losses with ripple content, frequency deviations, switching losses and device ratings (N. Maheshkumar et al. 2013).

An important constituent of modern set -up of generation, transmission, distribution and utilization of electric power is DC-AC power conversion. In variable frequency drives, uninterruptible power supplies, induction heating, air conditioning, high voltage DC power transmission, electric vehicle drives, static var compensators, flexible AC transmission systems and renewable energy based power generation, DC-AC power converter has played a critical role. The inverters are classified as: square wave, quasi-wave, two-level PWM multilevel inverters based on the nature of the output waveform. (K. K Gupta et al. 2016).

2.3 Multilevel Inverter

Multilevel Inverters are tremendous interest to use in power inverters. And it is also suited for compensation of reactive power. MLIs are providing the high power and high voltage inverters with its structure. By increasing the number of output levels, it is not requiring high power rating devices. With a configuration of MLIs allows the high ratings with minimum losses without use of transformers.

The harmonic content in MLI can be significantly reduced by increasing number levels (N. Maheshkumar et al. 2013).

In many high-power application, multilevel inverters are widely used in industry (S. Ouni et al. 2016). The concept of multilevel inverter (MLI) was primarily introduced for high power and medium voltage applications. It is based on the methodology of using power semiconductor switches along with several lower voltage dc levels to synthesize a staircase voltage waveform. Thus, in general, the voltage stress on a power switch is much lower than the operating voltage. In addition, there are many other advantages such as: reduced common mode voltages, reduced dv/dt stresses on the load, staircase waveform with better harmonic profile, smaller filter requirements, flexibility to operate on low- and high switching frequencies and possibility of fault-tolerant operation (K.K Gupta et al. 2016).

In general, MLIs are producing an approximate sinusoidal voltage from several input dc levels. It provides more steps which produce a staircase stepped output. The different kinds of MLIs are following, Diode clamped MLI, Flying capacitor MLI, Cascaded MLI, H-bridge MLI. All the MLIs have a various switching state with several levels. The important features of MLIs are possible to operate at lower frequency, reducing the stress in switches and motor bearings due to it does generate minimum common mode voltage, the input current can be drawn with low distortion, the most important is to generate a multi output levels with low distortion and less dv/dt. (N. Maheshkumar et al. 2013). Figure 2.2 shows an output for 5-level multilevel inverter.

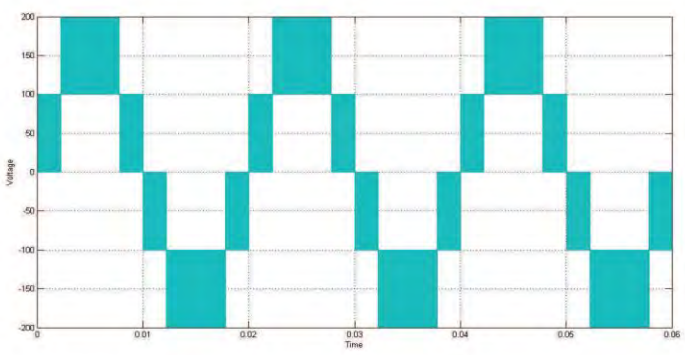


Figure 2.2: Output voltage waveform of five-level Multilevel inverter

2.3.1 Cascaded H-Bridge Multilevel Inverter

Cascaded H-Bridge Multilevel Inverter (CHB-MLI) is popular in high-power medium-voltage applications thanks to its modular structure. Because of this modularity, it is possible to increase inverter reliability by using redundant cells, which become operative once the faulty cells are bypassed. Hence the inverter can continue working similar to its pre-fault condition (S. Ouni et al. 2016).

Cascaded inverters use a series connection of single phase H-Bridges with lower voltage DC sources to achieve higher power. Multilevel cascaded H-bridge inverter consists of series connected H-bridges. A cascaded inverter with '*N'* number of DC sources gives (*2N+1*) levels at the output phase voltage. (A. Anand et al. 2016).

The cascaded H-bridge inverter is considered as one of the preferred solutions for medium and high power industrial drive applications due to its simple structure, high redundancy and modularity. This multilevel inverter based motor drive system has capability to synthesize superior waveforms with reduced distortions and to limit the motor winding insulation stress. Hence, it can reduce operational costs and increase efficiency at higher number of voltage levels. Cascaded H- bridge topology is the most suitable for the integration of renewable energy. There is used separately DC source can be fed from PV panel. Cascaded H-bridge multilevel inverter is better than the other two types of multilevel inverter because of it require least number of component. Cascaded topology allows the use of dc source with different voltage values, Same input voltage the output voltage obtain with cascaded H-bridge multilevel inverter is twice than the output voltage with diode clamped and flying capacitor and H-bridge power cell connected in series to produce high AC voltage. (S.S. Katkamwar & V.RDoifode 2016). Figure 2.3 and Figure 2.4 shows a circuit of cascaded H-bridge multilevel inverter and output or result from study show THD analysis of five level cascaded H-bridge multilevel inverter.

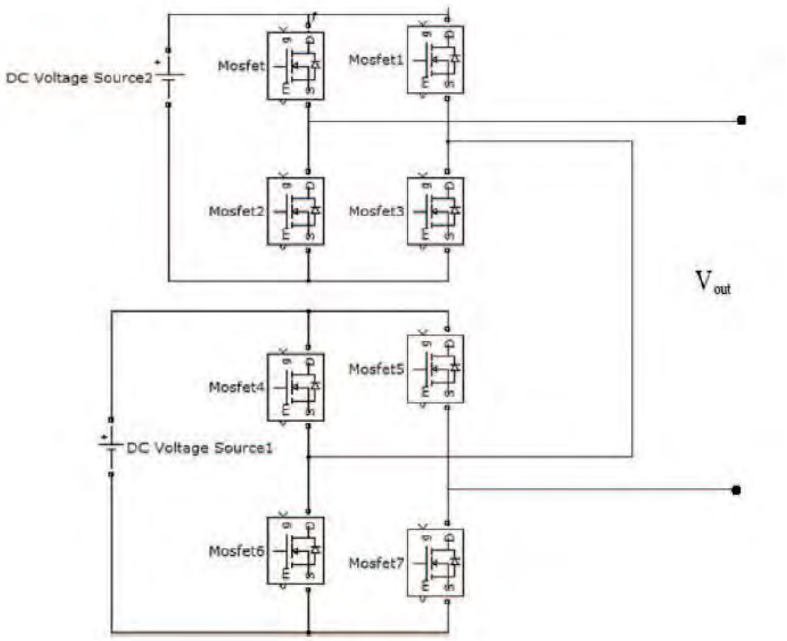


Figure 2.3: D. Sankar and C.A. Babu 2016 conducted on expert on topic CHBMLI Topologies for PV Application:A Comparison

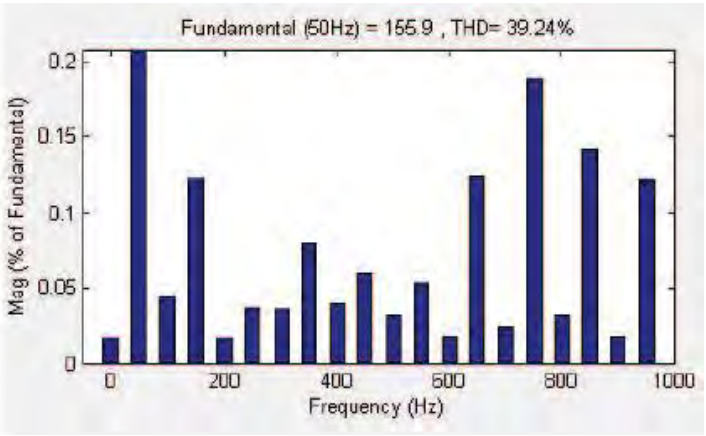


Figure 2.4: THD analysis of five level Cascaded H-bridge multilevel inverter