UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF DIODE CLAMPED MULTILEVEL INVERTER BASE ON PWM

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

By

MOHAMAD ZUL HAFIQ BIN NORHAN

B071410349

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I hereby, declared this report entitled Development of Diode Clamped Multilevel Inverter Base on PWM is the results of my own research except as cited in references.

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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

Penyongsang berbilang adalah alat yang mampu untuk menghasilkan tahap voltan berbeza. Penampilan teknologi penyongsang bertingkat adalah alternatif baru yang sangat penting dalam dalam industri voltan sederhana tinggi untuk kawalan tenaga pemohonanan kuasa dengan menambah jumlah herotan harmonik (THD) yang lebih rendah. Konsep projek diod fasa diapit penyongsang bertingkat ialah dengan menggunakan MOSFETs yang bertindak sebagai pensuisan. Dalam projek ini, konsep lima tahap, tujuh tahap, dan sembilan tahap dilaksanakan untuk mengawal gelombang keluaran menghampiri untuk sinusgelombang sehampir mungkin. Hasil simulasi, volatan keluaran membentang profil harmonk yang lebih baik. Perisian MATLAB Simulink digunakan untuk menganalisis voltan keluaran dan THD untuk penyongsang pelbagai peringkat.

ABSTRACT

Multilevel inverter is a device able to generate different voltage levels. Appearance of multilevel inverter technology is a very important new alternative in medium voltage industrial high power for power control applications by adding the lower total harmonic distortion (THD). The concept of project single phase diode clamped multilevel inverter is using MOSFETs that act as switching. In this project, the concept of five level, seven level and nine level diode clamped multilevel inverter simplified, circuit operation submitted and simulation. The concept of five stages, seven stages and nine stages diode clamped multilevel inverter implemented to control the output wave to sine-wave approaching as close as possible. The results of the simulation, the output waveform presents a better harmonic profile. MATLAB Simulink software was used to analyse the output voltage of the inverter and THD for various level.

DEDICATION

To my beloved parents

Norhan Bin Selamat (Father)

Zalina Binti Ramli (Mother)

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

PWM	-	Pulse Width Modulation
DC	-	Direct Current
AC	-	Alternating Current
THD	-	Total Harmonic Distortion
VSI	-	Voltage Source Inverter
CSI	-	Current Source Inverter
EMI	-	Electromagnetic Interference
MLI	-	Multilevel Inverter
NPC	-	Neutral Point Clamped Inverter
DCMI	-	Diode Clamped Multilevel Inverter
FCMI	-	Flying Capacitor Clamped Multilevel Inverter
CHMI	-	Cascaded H-bridge Multilevel Inverter
SPWM	-	Sinusoidal Pulse Width Modulation
SVPWM	-	Space Vector Pulse Width Modulation
SHE	-	Selective Harmonic Elimination
IPD	-	In Phase Disposition
POD	-	Phase Opposition Disposition
APOD	-	Alternate Phase Opposition Disposi

CHAPTER 1

INTRODUCTION

1.1 Background

The inverter is functioned to change the DC source voltage to AC output voltage. The DC source is normally a battery or output of the uncontrolled rectifier. Generally the inverter are widely used in industrial applications. The output waveform of the inverter can be square wave, quasi-square wave or low distorted sine wave. For this project, the multilevel inverter has been decided as a project

This project is to study a single phase and three phase diode clamped multilevel inverter for 5-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 application and can use either sine or modified sine wave. Unlike cascaded h-bridge Inverters, they need clamping devices which is diode. For a 5 level diode clamped multilevel inverter 8 switching devices are needed.

For this project pulse width modulation (PWM) will be used and MOSFET will be used as switches because of low power dissipation. Diode clamped 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, uninterruptable power supplies, and magnetic resonance imaging. The main objective is to study the quality output voltage of the multilevel inverter with the reduced number of switches. The main objective is to generate nearly sinusoidal output voltage waveform and to eliminate lower order harmonics.

1.2 Problem Statement

It is well known for harmonic distortion become a problem that are often occur in the electric power quality. Common inverter has resulted in higher switching losses and less efficiency. Moreover the standard multilevel inverter will produce a high total harmonic distortion.

Basically inverter is a device that converts DC power to AC power at desired output voltage and frequency. The used of multilevel inverter is because of other inverters are less efficiency, high cost, and high switching losses.by using the multilevel inverter the efficiency is high and low switching losses. The need for high power in industry are really demanding because of the use of some high power motor. But some appliance doesn't need a high power and it might make those appliances broken hence the multilevel inverter are needed to face these kind of problems.

The chosen multilevel inverter topology is diode clamped multilevel inverter. The other topology has some large drawback than this topology. As an example cascaded h-bridge need separated isolated dc for a real power transfer. For flying capacitor it requires a huge number of capacitor and make the high level inverter become difficult to work with capacitor. The switching losses also high for real power transmission.

1.3 Objective of Project

The objective of this project are:

i. To analyse a single phase diode clamped multilevel inverter.
ii. To simulate proposed topology using MATLAB/Simulink.
iii. To study the difference of the THD in three type of level.

1.4 Scope of Project

This project is to study a single phase diode clamped multilevel inverter. By using pulse width modulation (PWM) control method to produce the desired output that is five level output. The coding control and simulation is done by using MATLAB/Simulink.

1.5 Thesis Outline

The thesis of this project consist of five chapter,

Chapter 1: The introduction of the project consists of background, problem statement, objective and scope of project.

Chapter 2: Literature review that are taken from selected journal that consists of past research that including all the thing need to know before doing the project. It included all the knowledge that need to be obtained.

Chapter 3: Methodology that are become the outlines how the project must run.

Chapter 4: The result of the project and the discussion about it.

Chapter 5: Conclusion and recommendation of the project.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter will study about the overview of multilevel inverter. Will be focussing on diode clamped multilevel inverter, control method and the thing that needed to be known. This the most crucial part of the project.

2.1 Power Electronic

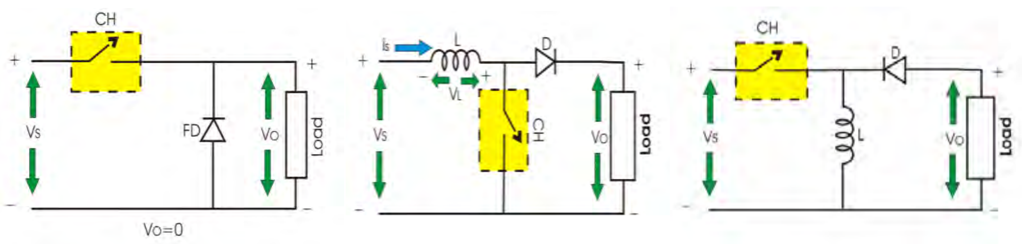
Power electronic is the application of electronics to control and conversion of electrical power. The extensive use of power electronic based appliances and several adjustable speed drives in almost all areas, which leads to low pf low efficiency and so on become the reason for the power distribution networks and the point of common coupling to be highly distorted. (Kotturu & Argawal 2016). There are 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.

2.1.1 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 centre or commercial building DC distribution system, high power AC-DC converters are required. (C. Li et al. 2017).

2.1.2 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 up 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 Inverter

Inverter is a power conversion that switch the direct current (DC) input to alternating current (AC) output. Inverters are called the conversions of DC to AC. Change the dc input to 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) which is an output in voltage waveform, Current Source Inverter (CSI) which is an output in current waveform, 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 as 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 ('inverter') has play critical role. The inverters are classified as: square wave, quasi-wave, two-level PWM multilevel inverters based on the nature of output waveform. (K.K Gupta et al. 2016).

2.3 Multilevel Inverter

There is many reason why the usage of multilevel inverter in high power industry. Multilevel inverters have a lot of advantages to offer in medium to high voltage range of applications -mainly variable speed motor drives and power system applications. The number of switching states in the multilevel inverter have more are known for less total harmonic distortion (THD), electro-magnetic interference (EMI) and reduced common mode voltage compared two level inverter. (V. Najmi et al. 2012). In general for multilevel inverter, the low distortion in the output that they can generate and smaller common mode voltage that the dv/ dt able to generate and lower switching frequency that they operate in compared to the more conventional two-level inverters. (R. V. Thomas et al. 2015). There are also other reason why the multilevel inverter are being used in industry.

Due to their many advantages such as low power dissipation on power switches, low harmonic contents and low electromagnetic interference (EMI) outputs become the reason multilevel inverter topologies (MLIs) are increasingly being used in medium and high power applications. (N. Karnik et al. 2012). The diversity in applications and it affect a wide field of electrical engineering from a few watts to several hundred megawatts. (M. Rasheed et al. 2013). The high frequency switching technique can determined it output quality of the current and voltage of multilevel inverter. (M. Rasheed et al. 2013). Power rating could be upgraded by adding voltage in inverter without any requirement in individual device. By combining several dc voltage sources the desired multi staircase output voltage is obtained. The most common independent sources that being is solar cells fuel cells and batteries used. (Venus & Ramani 2013.)

Over the years, many different multilevel converter topologies have been reported to satisfy particular application requirements or to improve an operational feature hence, numerous variations and even combinations of these topologies have been presented. (V. Najmi et al. 2012). There are four multilevel inverter that are widely used which is diode clamped multilevel inverter also known as neutral point clamped inverter (NPC), flying capacitor multilevel inverter, hybrid multilevel inverter and cascade h-bridge multilevel inverter. All these four inverter have the capability to work in in high power system.

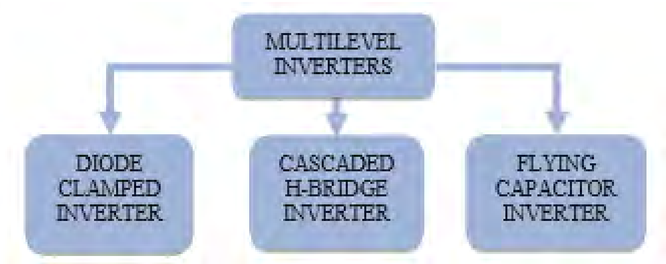


Figure 2.2: Multilevel Inverter topologies (M. Rasheed et al. 2013)

Parameters	Diode Clamped	Capacitor Clamped	Cascaded H-Bridge
Switches	2(m-1)	2(m-1)	2(m-1)
Feedback Diodes	2(m-1)	2(m-1)	2(m-1)
Clamping Diodes	(m-1)(m-2)	0	0
DC Bus Capacitors	(m-1)	(m-1)	(m-1)/2
Balancing Capacitors	0	(m-1) (m-2)/2	0
Total	m^2+2m-3	(m^2+8m-8)/2	(9/2)(m-1)

Table 2.1: Comparison of Number of Parameters among Various Topologies of Multilevel Inverter (N. Karnik et al. 2012)

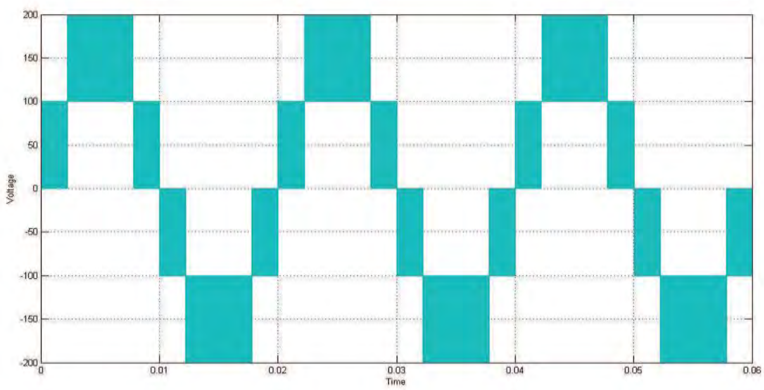


Fig 2.3: Output voltage waveform of five-level multilevel inverter (D. Sankar & C.A. Babu 2016)

2.3.1 Diode Clamped Multilevel Inverter

In order to drive ac motors with voltages greater than 10 kV, Diode Clamped Multilevel Inverter (DCMI), or equivalently Neutral Point Clamped (NPC) inverters are the natural candidates. (P. Fazio et al. 2011). In diode clamped multilevel inverter, the diode is acting as a clamping device. It requires only one DC source that become the main feature of the NPC topology similar to two-level in high power applications, the structure is most suitable, as compared to the conventional structure. (M. Rasheed et al. 2013). The capacitors are in series to divide up the dc bus voltage into a set of voltage levels. (I. A. Altawil et al. 2012).

Thanks to the number of voltage levels offered by this structure it generates a sinusoidal voltage and decreases the harmonics rate. (Z. Oudjebour et al. 2012). Arrangement of semiconductor switches such as IGBT and diodes allows the inverter each phase leg output to be switched to different voltage levels in the order of odd Matrix arrangement. (Kumar & Satyanarayana 2015). The clamping diodes need to have different voltage ratings for different inner voltage level. The switch need 2(n-1), the diodes need (n-1) (n-2) and the capacitor needed is (n-1) in which n is number of level. Figure 2.3 show the topology of 5 level diode clamped multilevel inverter.

Diode clamped multilevel inverter has its own advantage and disadvantage. For the advantage, DC-link capacitors are common to three phases, switching frequency can be low and reactive current and negative-phase-sequence current can be controlled. (N. Karnik et al. 2012). For the disadvantage, clamping uses many diodes and physical layout is difficult because the use of many of diodes, e.g. increase stray inductance. (N Karnik et al. 2012).