



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**SINGLE PHASE CAPACITOR CLAMPED MULTILEVEL
INVERTER**

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

by

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FACULTY OF ENGINEERING TECHNOLOGY

2014

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: SINGLE PHASE CAPACITOR CLAMPED MULTILEVEL INVERTER

SESI PENGAJIAN: 2014/15 Semester 7

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“I hereby declare that the content in this project is the result of my own work expect references and citations which I have clearly stated the source of origin”

Signature :

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Date : 20TH DEC 2014

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 Honors. The member of the supervisory committee is as follow:

.....

(Project Supervisor)

ABSTRAK

Penyongsang pelbagai peringkat adalah sebuah alat yang mampu menghasilkan aras voltan berperingkat. Terdapat tiga jenis topologi utama penyongsang pelbagai peringkat, penurunan jambatan-H, diod, pengapit diod dan pengapit kapasitor. Topologi pengapit kapasitor mempunyai voltan semulajadi. Pengapit kapasitor pelbagai peringkat terdiri daripada beberapa gabungan keadaan suis untuk membentuk satu aras arus terus bagi penyongsang, jadi pemilihan gabungan keadaan suis sangat penting supaya setiap MOSFET boleh ditukarkan dengan sama. Tujuan projek ini adalah untuk memahami satu fasa pengapit kapasitor pelbagai peringkat dan mensimulasi topologi yang dicadangkan menggunakan perisian Simulink/Matlab. Pelan litar termasuk litar pemacu disimulasi pada perisian Simulink. Selain itu, projek ini menggunakan pemodulatan lebar denyut (PWM) sebagai kaedah pengawalan sementara MOSFET sebagai suis kuasanya.

ABSTRACT

Multilevel inverter is a device that capable of produce different voltage level. There are three main types of the multilevel inverter topology, cascaded H-bridge, diode clamped and capacitor clamped. Capacitor clamped topology has a natural voltage balancing property. Capacitor clamped multilevel inverter (CCMI) consists of several switching state combination for one DC level of the inverter, so the selection of switching state combination is important so that every MOSFETs can be switched on equally. The aim of this project is to study a single phase capacitor clamped multilevel inverter and simulate the proposed topology using Simulink software. The designs of the circuit including the triggering circuit were done on the Simulink/Matlab simulation software. This project is using pulse width modulation (PWM) as its control methods meanwhile MOSFETs as its power switch.

DEDICATION

To my beloved parents

AYOB BIN MAMAT (FATHER)

AZNAN BINTI AWANG (MOTHER)

ACKNOWLEDGEMENT

First and foremost, I would like to take this golden opportunity to express my appreciation to my final year project supervisor, Miss Suziana for being a dedicated lecturer guiding me through this project to run smoothly. This project cannot be completed and perfected if without the valuable suggestion and useful information from my supervisor. Her patience and enthusiastic in guided me through this final year project have gave me a great courage in completing this project.

Apart from that, I also would like to thanks to my lecturers and all my friends for the helped in giving me their morals support during this project development and also shared some information with regards to the multilevel inverter and the software guide.

Last but not least, I would like to express my deepest love and gratitude to my beloved parents for giving me unlimited encouragement during my studies in University Technical Malaysia Malacca (UTeM).

Finally, to the God Almighty (Thank you - Alhamdulillah)

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

IGBT – Insulated Gated Bipolar Transistor

THD – Total Harmonic Distortion

MOSFET – Metal Oxide Semiconductor Field Effect Transistor

PWM – Pulse Width Modulation

AC – Alternating Current

DC – Direct Current

MLI – Multilevel Inverter

CCMI – Capacitor Clamped Multilevel Inverter

CCS – Code Composer Studio

PCB – Printed Circuit Board

CHAPTER 1

INTRODUCTION

Chapter 1 will explained on the background research of this project research. This chapter will also include the problem statement, the objectives, scope, and project significance.

1.1 Background

Multilevel inverter is an alternative structure to the conventional power inverter. Multilevel inverter's operation depends on the structure and the number of the power switches in the inverter. The main feature of the multilevel inverter is it has the ability to reduce the voltage stress on each of the multiple levels in DC bus of the circuit. It also has smaller distortion in the multilevel inverter AC side waveform can be achieved even though at low switching frequency. Besides, switching losses in the inverter are reduced by the increased flexibility for voltage waveform produced by increasing number of voltage level. There are three main types of the multilevel inverter topology, capacitor clamped, diode clamped and cascaded multilevel inverter.

Capacitor clamped multilevel inverter involves in the usage of extra capacitor clamped to the power switches phase rail to provide the DC voltage level. This structure allow for the inverter to supply high capabilities especially during the power outages due to the redundancy in switching states provided by the clamping capacitor. This type of multilevel inverter also provides the switching combination redundancy that is very useful for the voltage level balancing. In this project we are

using pulse width modulation (PWM) strategies. As the switches, the project is using MOSFET. This is because MOSFET are low power consumption and dissipation, low waste heat, and low mass production costs. In the project, the five level output with sixteen MOSFET is constructed.

1.2 Problem Statement

Due to current source inverter has slower dynamic response and big in size, it may cause main problem in power application. In additional, voltage of CSI need to be maintained continuously and causes a complexity system while reduce its reliability. Besides that, voltage source inverter has decreasing power factor with decreasing speed. This type of inverter also has induced harmonics.

Lately multilevel inverter have been accepted and used in many applications such as motor drivers and static power conditioning systems. Due to electromagnetic compatibility (EMC) problem in an inverter, multilevel inverters can minimize electromagnetic compatibility (EMC) problems as well as generate the output voltages with very low distortion and reduce the dv/dt stresses. It also produce smaller common-mode (CM) voltage, therefore the stress in the bearings of a motor connected to a multilevel motor drive can be reduced. Multilevel converters also can draw input current with low distortion. Besides, multilevel converters can operate at both fundamental switching frequency and high switching frequency PWM. It should be noted that lower switching frequency usually means lower switching loss and higher efficiency.

1.3 Objective of Project

The objectives of this project are as follows:

- i. To study a single phase capacitor clamped multilevel inverter.
- ii. To simulate a proposed topology using Matlab/Simulink.
- iii. To implement the hardware of the proposed topology.

1.4 Scope of Study

In order to achieve this objective, several scopes had been outlined. The single phase capacitor clamped multilevel inverter using pulse width modulation (PWM) as its control methods meanwhile MOSFETs as its power switch. Simulation of the proposed configuration will be done in Matlab 2011. A coding control and configuration will be done in m-file/Matlab and Simulink/Matlab respectively. This project will be using eight MOSFETs. In addition, DC power supply and capacitor will be used in this project.

CHAPTER 2

LITERATURE REVIEW

Literature review is a review of a research that has been made regarding the particular problem that has been identified and needs to be solved. This review should describe summarize, evaluate and clarify the project. It also goes beyond the search for information and includes the identification and articulation of relationships between the literature and the field of research.

In this chapter 2, reviews of the previous researches project that are related with this project research will be discussed. The information will be become additional source for the project to make some improvement and more successful. To have a brief understanding of the researches related to the project, a few literature reviews had been done.

2.1 Inverter

The inverter is an electrical device which converts DC input voltage to AC output voltage. Figure 2.1 shows that DC converts to AC using inverter (Mailah, F. Nashiren et al. 2010).

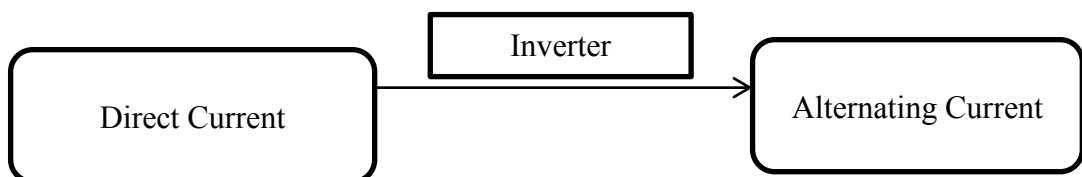


Figure 2.1: Inverter

The DC source can be the voltage or current source, it is VSI and CSI. Inverters allowing portability by providing the AC power in areas where only batteries can make it available. Figure 2.2 below shows the course of VSI segment.

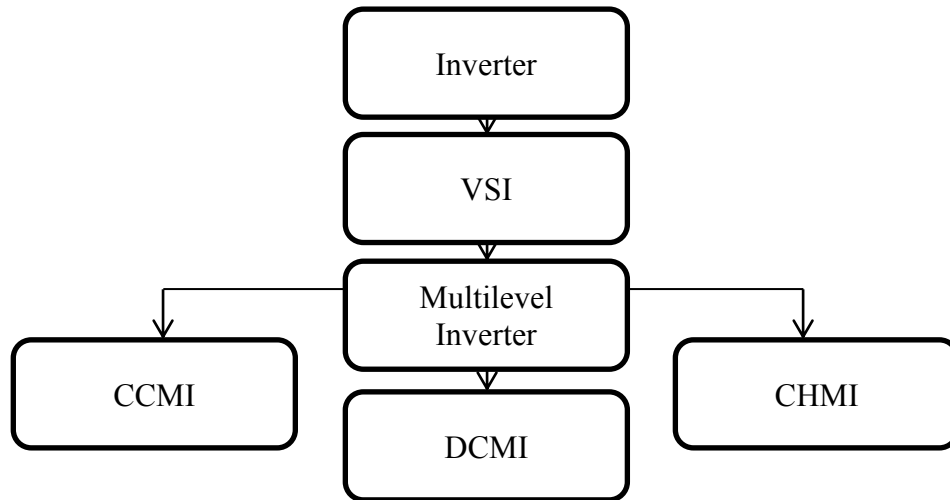


Figure 2.2: The VSI Segment

2.2 Voltage Source Inverter

DC voltage source for the input of the inverter means that the inverter is a voltage source inverter (VSI). VSI circuit has direct control over output and the shape of voltage waveforms output should be vary to the load that connected at the output.

The advantages of VSI as the following (Bogdan M. Wilamowski et al. 2011):

- i. Good speed range.
- ii. Simple regulator design.

The disadvantages of VSI as the following:

- i. Decreasing power factor with decreasing speed.
- ii. Induced harmonics.

2.3 Multilevel Inverter (MLI)

Multilevel inverter is an alternative way to the conventional power converter that had been accepted and used in many applications (Rashid, M. H et al. 2004). The structure and the number of the power switches in the inverter circuit affected its operation. The performance of the inverter can be improved by increasing the number of the power switches in the circuit (A. Tahri, A. Draou and M. Ermis). The main feature of the multilevel inverter is it has the ability to reduce the voltage stress on each of the power switches. Besides, smaller distortion in the multilevel inverter AC side waveform can be achieved even though at low switching frequency.

There are three main type of the multilevel inverter topology (Mailah, F. Nashiren et al. 2010):

- i. Cascaded Multilevel Inverter (CMI)
- ii. Diode Clamped Multilevel Inverter (DCMI)
- iii. Capacitor Clamped Multilevel Inverter (CCMI)

2.3.1 Capacitor Clamped Multilevel Inverter

CCMI involves in the usage of extra capacitor clamped to power switches to provide the DC voltage level. This structure allows for the inverter to supply high capabilities especially during the power outages due to the redundancy in switching states provided by the clamping capacitor. This type of multilevel inverter inverters also provides the switching combination redundancy that is very useful for the voltage level balancing.

The advantages of CCMI as the following (Mailah, F. Nashiren et al. 2010):

- i. Does not requiring diode clamping.
- ii. The real and reactive power flow can be controlled.

- iii. Phase redundancies are available for balancing the voltage levels of the capacitors.
- iv. The big number of capacitors enables the inverter to ride through short duration outages and deep voltage stages.

The switching state is the most crucial part in the CCMI topology. So after the studied on CCMI, Table 2.1 shows the switching combination.

Table 2.1: The Switching State

	Sa ₁	Sa ₂	Sa ₃	Sa ₄	Sa' ₁	Sa' ₂	Sa' ₃	Sa' ₄
Vdc	1	1	1	1	0	0	0	0
3Vdc/4	1	1	1	0	1	0	0	0
Vdc/2	1	1	0	0	1	1	0	0
Vdc/4	1	0	0	0	1	1	1	0
0	0	0	0	0	1	1	1	1

2.3.2 Diode Clamped Multilevel Inverter

Diode clamped multilevel inverter (DCMI) using the diode as the clamping device to clamp the DC bus voltage to achieve the level of output voltage.

The advantages of DCMI as the following (Khomfoi, S. and Tolbert, L. M. 2007):

- i. The efficiency of the inverter is high because all devices are switched at the fundamental frequency.
- ii. The total harmonic contain is very low when the number of level is high to avoid from filtered.
- iii. The capacitor can be pre-charged as group.

The disadvantages of DCM as the following:

- i. The excessive clamping diode is required when the number of level is high.
- ii. The real power of individual converter is hard to control in MLI system.

2.3.3 Cascade H-Bridge Multilevel Inverter (CHMI)

Cascade H-bridge multilevel inverter is using a series of single phase full bridges makes up a phase for the inverter.

The advantages of CHMI as the following (Prattipati, J. and Kommukuri, V.S. 2012):

- i. Lesser components needed to design the same number of voltage level compared to DCM and CCM.
- ii. Since each H-bridge has the same structure, modularized circuit layout and packaging are possible.
- iii. No need extra clamping diode and voltage balancing capacitor.

The disadvantages of CHMI as the following:

- i. Separate dc sources are required, resulting in limited applicability.

2.4 Switching Device

Switching device is mainly used for the turn on and off mode. For multilevel inverter, the common switching device used for it is Insulated Gate Bipolar Transistors (IGBT) and Metal Oxide Semiconductor Field Effect Transistors

(MOSFET). For this project MOSFET have been chose instead of IGBT because of voltage level for MOSFET is lower than IGBT. Furthermore, the price for MOSFET is cheaper than the IGBT. MOSFET have low power consumption and dissipation, low heat waste and low mass production costs (Josefsson, O. 2013). Figure 2.3 shows the type of MOSFET that been used in this project.



Figure 2.1: The MOSFET

2.5 Pulse Width Modulation (PWM)

Pulse width modulation is usually used as switching technique. For industrial purposed, the control of voltage output is important to adjust with variation of dc input voltage, to regulate voltage inverter and satisfy the contain volts and frequency requirement (A. Tahri, A. Draou and M. Ermis). Figure 2.4 shows the PWM waveform.

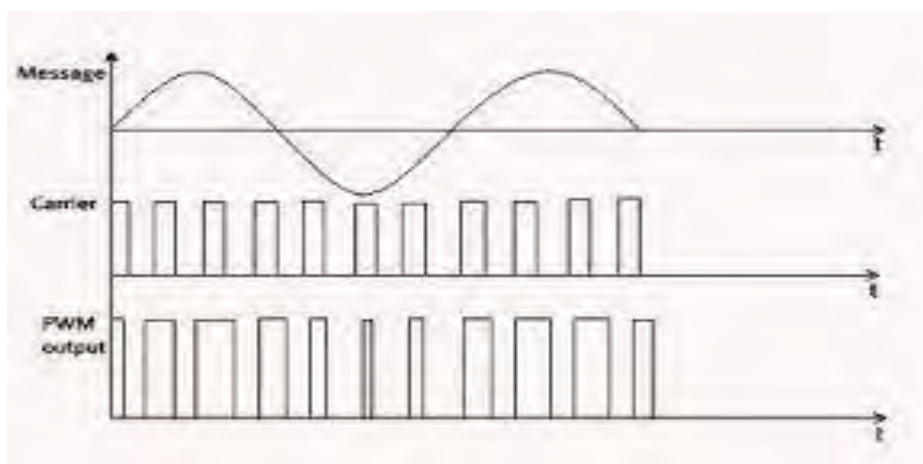


Figure 2.4: Pulse Width Modulation (PWM) Waveform