MATHEMATICAL FORMULATION OF MULTILEVEL VOLTAGE SOURCE INVERTER SWITCHING INSTANTS

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I dedicate this to all my beloved family members. Esspecially to my beloved mother, Puan Paridah Binti Zakaria and my father, Allahyarham Ismail Bin Awang.

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ABSTRACT

Modular structured multilevel inverter is very useful for electrical application especially in high power and high voltage applications. The main function of this multilevel inverter is to produce multilevel AC output voltage from several separate DC sources. This project is to derive a new mathematical formulation of multilevel voltage source inverter switching instants. The proposed method for this project is based on the sinusoidal natural sampling PWM (SPWM) by comparing several modified modulation signal with a triangular carrier signal. This resulting intersection points between this modulation and carrier signal become the switching instants of the PWM pulses. Derivation also based on two dispossition method that is Alternative phase opposition dispossion (APOD) and Phase opposition dispossion (POD). A cascaded multilevel inverter is selected as a topology for this project due to major advantages compare with other topology. The derived formula is analyzed by using MATLAB simulation software. It is found that the result that use the derived formula is almost identical to simulation result.

ABSTRAK

Struktur modular penyonsang pelbagai aras (MSMI) amat berguna untuk aplikasi elektrik terutamanya dalam penggunaan kuasa yang tinggi dan voltan tinggi. Fungsi utama penyongsang pelbagai aras ini adalah untuk menghasilkan pelbagai peringkat voltan keluaran AC dari beberapa sumber DC berasingan. Projek ini adalah untuk menerbitkan satu formula matematik yang baru bagi sudut peralihan penyongsang sumber voltan pelbagai aras. Kaedah yang dicadangkan untuk projek ini adalah berdasarkan persampelan semula jadi PWM sinusoidal (SPWM) dengan membandingkan beberapa isyarat modulasi diubahsuai dengan isyarat pembawa segi tiga. Titik persilangan yang terhasil antara isyarat modulasi dan isyarat pembawa menjadi sudut peralihan signal PWM. Penerbitan formula ini juga berdasarkan dua kaedah iaitu *Alternative phase opposition dispossion* (APOD) dan *Phase opposition dispossion* (POD). *Cascaded multilevel inverter* (CMI) dipilih sebagai topologi untuk projek ini kerana mempunyai kelebihan berbanding dengan topologi yang lain. Formula yang diterbitkan akan dianalisis dengan menggunakan perisian simulasi MATLAB. Ia didapati bahawa keputusan yang menggunakan formula yang diterbit adalah hampir sama dengan keputusan simulasi.

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LIST OF ABBREVIATIONS

PWM	-	Pulse Width Modulation
DC	-	Direct Current
AC	-	Alternating Current
I	-	Current
V	-	Voltage
VSI	-	Voltage Source Inverter
MVSI	-	Multilevel Voltage Source Inverter
APOD	-	Alternative Phase Opposition Disposition
POD	-	Phase Opposition Disposition
PD	-	Phase Disposition
SPWM	-	Sinusoidal pulse width modulation
DCMI	-	Diode-clamped Multilevel Inverter
FCMI	-	Flying-clamped Multilevel Inverter
CMI	-	Cascaded Multilevel Inverter

LIST OF SYMBOLS

ωc	-	The reference frequency
ωm	-	The carrier frequency,
Am	-	Reference signal amplitude, and
Ac	-	Carrier signal amplitude.

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CHAPTER 1

INTRODUCTION

1.1 Background

Usefulness of electrical supply has become bigger issues with the advancement of technology. People should not be limited to use electrical and electronic equipment at a fixed location due to power limitations. Overcoming this problem of having additional AC power source has led to the invention of DC to AC power inverters.

Inverter is one of the converter families which are called DC to AC converter. It converts DC power to AC power to a symmetric AC output voltage at desired magnitude and frequency. Inverter is widely used in industrial applications such as variable speed AC motor drives, induction heating, standby power supplies and uninterruptible power supplies. The DC power input of inverter is obtained from the existing power supply network. It can be a battery, photovoltaic, wind energy, fuel cell or other DC sources.

The output voltage that is AC output waveforms of an ideal inverter should be sinusoidal but for practical, inverters output waveform are non-sinusoidal and

certainly contain harmonics. Therefore, to obtain a quality output voltage waveform with a minimum amount of ripple or harmonic content, high-switching frequency is required along with various pulse-width modulation (PWM) strategies.

Multilevel Voltage Source Inverter (MVSI) topology is very useful in high power and high voltage application because it is easier to produce needed high voltage and high power output. This is because of the way in which device voltage stresses are controlled in the structure. By using multilevel structure, the stress on each switching device can be reduced proportional to the number of levels of the multilevel inverter. Thus, the inverter will neglect the using of an expensive and bulky step-up transformer in various applications. As the number of inverter output voltage levels is increased, harmonics content of the output voltage waveform decreases significantly enough to avoid the need of bulky filters.

1.2 Objective of the project

The objective of this project can be dividing into three main objectives that is:

i. To investigate the multilevel voltage source inverter switching technique and its topology
ii. To derive a new mathematical equation that defines the switching instants of sinusoidal pulse width modulation (SPWM) for multilevel voltage source inverter.
iii. To verify mathematical equation that defines the switching instants of sinusoidal pulse width modulation (SPWM) for multilevel voltage source inverter by using MATLAB simulation.

1.3 Scope of the project

The scopes of the project are highlighted as follows:

i. To investigate and study sinusoidal pulse width modulation switching technique for the multilevel voltage source inverter.
ii. To develop a new mathematical equation for multilevel voltage source inverter switching instants.
iii. To test, compare and analyze the output signal using MATLAB simulation

1.4 Problem Statement

An industries that involved in electrical and machinery have begun to demand for power converters in the range of several Megawatts to be connected to a medium voltage network. By using the multilevel voltage source inverter (MVSI) structure, it will provide the required output voltage.

Development of MVSI is usually implemented in various types of topology and switching technique such as Diode-clamped Multilevel Inverter (DCMI), Flying-clamped Multilevel Inverter (FCMI) and Cascaded Multilevel Inverter (CMI). Each type of topology has its own advantages and disadvantages. However, the disadvantage of FCMI and DCMI topology is more than the disadvantages of CMI topology. Based on major advantage, the topology of CMI is most useful. To make it more useful, MVSI also suitable implement for digital purpose by deriving mathematical formulation of MVSI switching instants.

1.5 Research Methodology

This project requires derivation of a new mathematical formulation of multilevel voltage source inverter that can be use for digital purpose. Extensive study on the switching technique and topology for the multilevel voltage source inverter are investigated before deriving the new mathematical equation.

Then, a new mathematical equation will be obtained. The derived equation will be tested by several tests using MATLAB simulation and also will be compared with other technique for verification the performance of that derived equation.

In this project, the task is divide into two; task for semester 1 and task for semester 2. Task for semester 1 consist of literature review that is prepare for project synopsis, derive equation and verify the derived equation using MATLAB simulation. For semester 2, verification of the result, troubleshoot it if has any problem, preparation on final report, paper writing and final presentation will be focused.

1.6 Thesis Outline

This report consists of five chapters, which are from this chapter to appendices. Chapter 1 introduces the background of the research, objective of this project, scope of project, problem statement, methodology and the overall thesis outline.

Chapter 2 focuses on literature reviews of this project based on journals and

other references.

Chapter 3 mainly discuss on the work progress of the project. Details on the progress of the project are explained in this chapter.

Chapter 4 presents the results of the project. The discussion focused on the result based on the simulation.

Chapter 5 concludes overall about the project.

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