IMPLEMENTATION OF SPACE VECTOR MODULATION FOR THREE PHASE INVERTER UTILIZING FIELD-PROGRAMMING GATE ARRAY

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“ I hereby declare that I have read through this report entitle “*Implementation Of Space Vector Modulation For Three Phase Inverter Utilizing Field-Programming Gate Array*” and found that it complies the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering”

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A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering

Faculty of Electrical Engineering

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I declare that this report entitle "*Implementation Of Space Vector Modulation For Three Phase Inverter Utilizing Field-Programming Gate Array*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : HALIMAHANI BINTI ROSLI

Date : ....

Special dedication to my parent Murdiati binti Darwis and Rosli bin Saat which give me a lot of love and support to complete my final year project 1. As well as my sibling, Hamidahsyahri, Yahamzah and Yabahalif which give me strength and happiness.

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ABSTRACT

Industries that used ac drives are growing rapidly to become more advanced because of high performances drive technology. In industry different there are different type of motor and variable speed. As for that, the three-phase inverters will give a variable voltage and variable frequency supply to the machines. As for that, using Space Vector Modulation (SVM) with Field-Programmable Gate Array (FPGA) can increase the performance of the three-phase inverter. The problem occurs within the SPWM technique and the existing SVM works. The SPWM techniques are difficult to control three-phase quantities such as amplitudes, frequencies and phase angle of three-phase voltage and depending to the torque and flux demands in vector control. This method also has a constrain for output voltage such as it cannot fully utilize the DC link voltage. Next, the problem with the existing SVM works because it totally implement the complex calculation of SVM algorithm and vector control in DSP which can increase the computational burden and hence reduce AC drive performance as the sampling time increase. The main objectives to be achieved in this task is to design and implement a space vector modulator utilizing Field-Programmable Gate Array (FPGA) which produce appropriate switching states, according to the inputs of d- and q- axis of space vector for measuring the output voltage and Fast Fourier Transform (FFT) Analysis. This modulator is suitable to be employed for any type of AC motor controls. Second objective is to verify the effectiveness of the design of SVM modulator through simulation and experiment. The scope of the project is to study various PWM and SVM techniques, especially for AC motor drives. Next, to develop simulation models of SVM using MATLAB or SIMULINK. Besides, implement SVM modulator using FPGA. As well as, performing the simulation and the experiment results to verify the effectiveness of SVM. The simulating and experimental designing the Space Vector Pulse Width Modulation (SVPWM) technique for three phase Voltage Source Inverter (VSI) using MATLAB/Simulink software for simulation as well as to develop the experimental result using FPGA. SVM can operated in high voltage and high frequency. The results that produce by SVM is high quality because it can managed to read in nanosecond.

ABSTRAK

Industri yang menggunakan pemacu ac berkembang pesat untuk menjadi lebih maju kerana prestasi yang tinggi memacu teknologi. Oleh itu, inverter tiga fasa akan memberikan pemboleh ubah voltan dan pemboleh ubah frekuensi kepada mesin. Untuk itu, menggunakan Modulasi Vektor Ruang (SVM) dengan Field-Programmable Gate Array (FPGA) boleh meningkatkan prestasi inverter tiga fasa. Masalah yang berlaku dalam teknik SPWM dan kerja-kerja SVM sedia ada. Teknik SPWM sukar untuk mengawal kuantiti tiga fasa seperti amplitud, frekuensi dan sudut fasa voltan tiga fasa dan bergantung kepada tork dan permintaan fluks dalam kawalan vektor. Kaedah ini juga mempunyai kekangan untuk voltan keluaran seperti tidak dapat menggunakan sepenuhnya voltan pautan DC. Seterusnya, masalah dengan SVM yang sedia ada berfungsi kerana ia benar-benar melaksanakan pengiraan kompleks algoritma dan kawalan vektor SVM di DSP yang boleh meningkatkan beban pengiraan dan dengan itu mengurangkan prestasi pemacu AC apabila peningkatan masa pensampelan. Objektif utama yang akan dicapai dalam tugas ini adalah untuk mereka bentuk dan melaksanakan modulator vektor ruang yang menggunakan litar Field-Programmable Gate Array (FPGA) yang menghasilkan litar bersesuaian sesuai dengan input d- dan q - paksi vektor ruang untuk mengukur voltan keluaran dan Analisis Fast Fourier Transform (FFT). Modulator ini sesuai digunakan untuk sebarang jenis kawalan motor AC. Objektif kedua adalah untuk mengesahkan keberkesanan reka bentuk modulator SVM melalui simulasi dan eksperimen. Skop projek ini adalah untuk mengkaji pelbagai teknik PWM dan SVM, terutamanya untuk pemacu motor AC. Seterusnya, untuk membangunkan model simulasi SVM menggunakan MATLAB atau SIMULINK. Selain itu, melaksanakan modulator SVM menggunakan litar FPGA. Serta, melaksanakan simulasi dan hasil percubaan untuk mengesahkan keberkesanan SVM. Simulasi dan eksperimen merancang teknik Modulasi Lebar Pulse Vector Space (SVPWM) untuk tiga fasa Voltage Source Inverter (VSI) menggunakan perisian MATLAB / Simulink untuk simulasi serta untuk membangunkan hasil eksperimen menggunakan FPGA. SVM boleh dikendalikan dalam voltan tinggi dan frekuensi tinggi. Hasil yang dihasilkan oleh SVM adalah berkualiti tinggi kerana ia dapat dibaca dalam nanosecond.

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LIST OF ABBREVIATIONS

PWM	-	Pulse width modulation
SPWM	-	Sinusoidal pulse width modulation
SVPWM	-	Space vector pulse width modulation
SVM	-	Space vector modulation
AC	-	Alternating current
DC	-	Direct current
DTC	-	Direct torque control
FPGA	-	Field-programmable gate array
VHDL	-	VHSIC hardware description language
VHSIC	-	Very high speed integrated circuit
FFT	-	Fast fourier transform
VSI	-	Voltage source inverter
CSI	-	Current source inverter
ASD	-	Adjustable speed drives
VSD	-	Variable speed drives
UPS	-	Uninterruptible power supplies
HVDC	-	High voltage direct current
BJT	-	Bipolar junction transistor
MOSFET	-	Metal oxide semiconductor field effect transistor

IGBT	-	Insulated gate bipolar transistor
GTO	-	Gate turn off
DSP	-	Digital signal processor
MIPS	-	Measurement in millions of instruction per second
HDL	-	Hardware description language
IC	-	Integrated circuit
RAM	-	Random Access Memory
HDMI	-	High Defination Multimedia Interface
USB	-	Universal Serial Bus
PC	-	Personal Computer
LED	-	Light Emitting Diode
SOPC	-	System-on-a-programmable-chip
MATLAB	-	MATrix LABoratory
RMS	-	Root mean square
TNB	-	Tenaga Nasional Berhad

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CHAPTER 1

INTRODUCTION

1.1 Research Background

A conventional Sinusoidal Pulse Width Modulation (SPWM) technique is not practical to be adapted in Alternating Current (AC) motor drives due to inflexibility control of three-phase quantities and lower output voltages. Space Vector Modulator Width Modulation (SVPWM) or known as Space Vector Modulator (SVM) technique was intensively used for obtaining high performances of AC motor drives such as produce a constant switching frequency in Direct Torque Control (DTC), fast dynamic torque control with over modulation strategy adopted in SVM and improved torque control capability for a wide-speed range. SVM is one of the approached to improve the SPWM technic for a better performance.

1.2 Motivation

The development of high performance drive technology is a center in the industry because technologies become more advanced from time to time. Industries that used AC drives, mostly are necessary to be conducted at different speed because in industries used different types of drives and machines. As for that, to get a variable speed, this machine is fed from inverters with variable voltage and variable frequency supply. So, using SVM with Field-Programmable Gate Array (FPGA) can increase the performance of the three-phase inverter. This is because FPGA used very high speed integrated circuit VHSIC Hardware Description Language (VHDL), where it is capable to perform Pulse Width Modulation (PWM) control algorithm especially SVM at high speed calculation.

1.3 Problem Statement

The problem is divided into two which is the SPWM technique and the existing SVM works. The SPWM techniques are inflexible control because difficult to control three-phase quantities such as amplitudes, frequencies and phase angle of three-phase voltage. It is according to the torque and flux demands in vector control of induction motor. This technique also has a limit for output voltage such as it cannot fully utilize the DC link voltage. Next, the problem with the existing SVM works because it totally implement the complex calculation of SVM algorithm and vector control in DSP which can increase the computational burden and hence reduce AC drive performance as the sampling time increase.

1.4 Objectives

In that respect are various objectives to be achieved in this task which include:

i. To design and implement a space vector modulator utilizing FPGA which produce appropriate switching states, according to the inputs of d- and q- axis of space vector for measuring the output voltage and Fast Fourier Transform (FFT) Analysis. This modulator is suitable to be employed for any type of AC motor controls.
ii. To verify the effectiveness of the design of the SVM modulator through simulation and experiment

1.5 Scopes of Project

The scope of the project is to study various PWM and SVM techniques, especially for AC motor drives. The scope of work is more to the investigate the performance of SVM for two levels with three-phase inverter. Next, to develop simulation models of SVM using MATLAB or SIMULINK. Besides, implement SVM modulator using FPGA. As well as, performing and comparing the results of simulation and experiment to validate the effectiveness of SVM.

1.6 Report Outline

Chapter 1 Introduction

This chapter will brief explains the main idea of this project is discussed in the overview. The idea is then elaborated in research background, objectives and scopes of work.

Chapter 2 Literature Review

The review of basic inverter and principle PWM method that will used in this project. Besides, this chapter summed up the research information in related previous work and journals.

Chapter 3 Methodology

The overall of this chapter is discussed the principle of SVPWM switching technique for three-phase Voltage Source Inverter (VSI). The flow of the project is explained and illustrated in flow chart. Besides, in this chapter also will this discuss the simulation of the MATLAB/Simulink. In this chapter, the hardware setup will concisely explain.

Chapter 4 Result and Discussion

The software and hardware is used for simulation and experimental is described. This chapter will discuss the comparison result between SPWM and SVM. Besides, this chapter discusses about the switching result and the SVM result from the simulation and hardware, which is the output voltage and FFT Analysis.

Chapter 5 Conclusion and recommendation

This chapter will summarize the idea about this report and there will be recommended for the future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses about the study from the journal or technical paper that related to the three-phase inverter which contain Voltage Source Inverter (VSI) and Current Source Inverter (CSI). This review also includes the Pulse Width Modulation (PWM) such as Sinusoidal Pulse Width Modulation (SPWM), SPWM with third harmonic injection and Space Vector Modulation (SVM). This review will briefly explained about the two levels of three-phase inverter to justify the main topic in this report. Besides, this review also discusses about the connection of Field-Programmable Gate Arrays (FPGA).

2.2 Inverter

An inverter is used to convert Direct Current (DC) to Alternating Current (AC) at desired output voltage and frequency. The application that will be used inverter is grid-connected system, Uninterruptible Power Supplies (UPS), High Voltage Direct Current (HVDC) power transmission and adjustable speed motor drive. An inverter function to supply an induction motor and need a switching device capable of being turned off and on through the gate. The output voltage can be controlled with the help of drives and the switches.

Three phase inverter is a large application in the industry. Adjustable Speed Drives (ASD) or known as Variable Speed Drives (VSD) where the motor's supplied voltage and frequency of power is changing by hold at the speed of an AC induction motor. Using this approach the energy can save because the speed of motor can vary according to the situation. Figure 2.1 shows the example application of ASD.

Figure 2.1 : Adjustable Speed Drives (ASD)

Next, three phase inverter can act as an Uninterruptible Power Supply (UPS) or known as a backup power supply. When the main power from the supplier is discontinuous, it is function to provide and supply the energy from the battery stored while protecting the hardware. Figure 2.2 shows the example application of UPS.

Figure 2.2 : Uninterruptible Power Supply (UPS)

High Voltage Direct Current (HVDC) gives permission between unsynchronized AC transmission systems for power transmission. This system can stabilize a network against disturbances due to rapid changes in power using the force flow over an HVDC link. Besides, it also can go through independently of the phase angle between source and load. Figure 2.3 shows the illustration application of UPS.

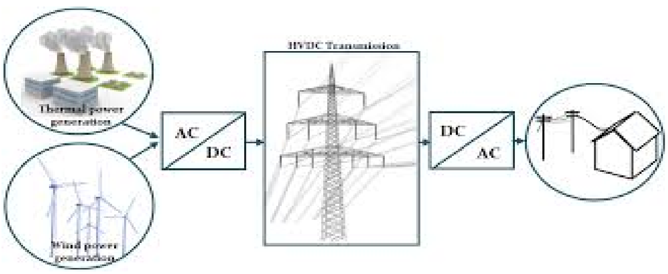

Figure 2.3 : Illustration of High Voltage Direct Current (HVDC)