PERFORMANCE ANALYSIS ON MULTIPHASE VOLTAGE SOURCE INVERTER

Mohd Hafizzudin bin Ismail

Bachelor of Power Electronic and Drives

2012

PERFORMANCE ANALYSIS ON MULTIPHASE VOLTAGE SOURCE INVERTER

MOHD HAFIZZUDIN BIN ISMAIL

A report submitte in partial fulfillment of the requirements for the degree of

Power Electronic and Drives

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTeM)

JUNE 2012

SUPERVISOR DECLARATION

"I hereby declare that I have read through this report entitle "**Performance Analysis On Multiphase Voltage Source Inverter**" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronics and drives)"

Signature : .....

Supervisor‟s Name : DR AUZANI BIN JIDIN

Date : 26 JUNE 2012

STUDENT DECLARATION

"I declare that this report entitle "**Performance Analysis On Multiphase Voltage Source Inverter**" is the result of my own research except as cited in the references. The report has not been accepted for my any degree and is not concurrently submitted in the candidature of any other degree"

Signature : .....

Student"s Name : MOHD HAFIZZUDIN BIN ISMAIL

Date : 26 JUNE 2012

DEDICATION

Especially dedication is to my beloved mother Puan Hamimah bt Abdul Majid, my beloved father En Ismail bin Hassan, my sister and brothers beloved

For taking care of me and educating me all these while. Also thank for their continuous prayers until I became what I‟m now.

Also for my family

Dr Auzani Bin Jidin

Thank you very much

And not forgetting to all my relatives

Especially Electrical Engineering (Power Electronics and Drives) batch 2009-2012

The success belongs to us all

May God bless all of us…..Amin

ACKNOWLEDGEMENT

Assalamualaikum……

First of all, thanks to The Almighty ALLAH S.W.T in giving me extremely strength to face this final project for this semester. In the process of completing this project, there are many problems that I have to face in order to achieve the goal of this project. This makes me closer to the Creator and is testing my patience level. Here, I would like to thank to all those who have helped me in preparing this report. I wish to thank to Dr. Auzani b Jidin as a my project coordinator that has helped me a lot to run the project. I wish to thank my parents who have given me a strength to finish this final report. Once again, I would grateful to Allah for giving me the strength to complete this project.

ABSTRACT

Application of power electronic in electric drives enables utilization of ac machine with a phase number higher than three. Such multiphase motor drives are nowadays considered for various applications. Multiphase inverter is invariably supplied from multiphase voltage source inverters (VSIs) and adequate method for VSIs pulse width modulation (PWM) are therefore required. This project deals with sinusoidal pulse width modulation, which enables an improvement in the DC source utilization as well as power output. The viability of the proposed concept is proved by simulating taking 5 phase VSI as an example. Voltage source inverter were implemented using five pairs of IGBT‟s. Implementation of 5-phase SPWM utilizing Ezdsp F28335 and IQ math component is used to model the SPWM in Matlab/Simulink. To generate the SPWM, sine waveform and triangular waveform is needed to get the SPWM. Sine and triangular waveform have their own frequency 50Hz and 2000Hz respectively.Multiphase inverter can improved the current ripple and load that connected with the multiphase inverter were run smoothly. In this experiment, 5-phase voltage source inverter was tested on passive load, resistive-inductive load.

ABSTRAK

Penggunaan elektronik kuasa dalam pemacu mesin elektrik membolehkan penggunaan mesin arus ulang alik dengan bilangan fasa yang lebih tinggi daripada tiga. Pemacu motor berbilang seperti hari ini mula diaplikasikan untuk pelbagai kegunaan. Voltan pengubah berbilang fasa lazimnya dibekalkan dari penyongsang sumber voltan berbilang (VSIs) dan kaedah yang digunakan oleh VSIs selalunya dengan menghasilkan modulasi lebar denyut (PWM). Projek ini mengaplikasikan penggunaan modulasi lebar denyut sinus untuk mengeluarkan output kepada beban. Daya maju konsep yang dicadangkan dibuktikan dengan simulasi mengambil 5 fasa VSI sebagai contoh. Penyongsang sumber voltan telah dilaksanakan menggunakan lima pasang IGBT itu. Pelaksanaan 5-fasa SPWM menggunakan Ezdsp F28335 dan komponen IQMATH digunakan untuk memodelkan SPWM di dalam Matlab / Simulink. Untuk menjana SPWM, gelombang sinus dan gelombang segi tiga diperlukan untuk mendapatkan SPWM. Gelombang sinus dan gelombang segi tiga masing-masing mempunyai frekuensi 50Hz dan 2000Hz. Pengubah voltan berbilang fasa dapat memperbaiki riak arus keluaran dan beban yang bersambung dengan penyongsang berbilang dapat berfungsi dengan lancar. Dalam eksperimen ini, penyongsang sumber voltan 5-fasa telah diuji kepada beban pasif iaitu beban perintang dan pengaruh.

TABLE OF CONTANT

LIST OF FIGURES

LIST OF TABLE

CHAPTER 1

INTRODUCTION

1.1 Project Background.

The electric motor is important to our lives. Many machinery uses an electric motor in it operation no matter on high operation, medium operation and low operation. Nowadays, many motors use an inverter to convert the DC voltage and enter the inverter to convert the DC voltage into an AC source and supply to the motor. An inverter, the switching of the motor is to make the AC motor run with AC source. For this project, the multilevel voltage source inverter is used to run the motor. From the previous study, multilevel inverter has many advantages on voltage/current ripple, total harmonic distortion (THD) and low power dissipation on power switches. The important thing on multilevel inverter is a the switching scheme. Sinusoidal Pulse Width Modulation (SPWM) is chosen to make the switching scheme for this multilevel inverter.

The SPWM is created by comparing the sine wave form with the triangular waveform and the triangular waveform must be higher than the frequency of the sinusoidal waveform. Many types of industrial fields drive nowadays run a variety task for variety application, where the difference on speed is needed. Nevertheless, not all of these drives like a pump and conveyer, require a highly dynamic performance. The main objective of multiphase inverter static power converters is to produce an AC output waveform from a DC power supply. These are the types of waveforms required in adjustable speed drives

(ASDs), uninterruptible power supplies (UPS), static var compensators, active filters, flexible AC transmission systems (FACTS), and voltage compensators, which are only a few applications. For sinusoidal AC outputs, the magnitude, frequency, and phase should be controllable.

According to the type of ac output waveform, these topologies can be considered as voltage source inverters (VSIs), where the independently controlled AC output is a voltage waveform. These structures are the most widely used because they naturally behave as voltage sources as required by many industrial applications, such as adjustable speed drives (ASDs), which are the most popular application of inverters. Similarly, these topologies can be found as current source inverters (CSIs), where the independently controlled ac output is a current waveform. These structures are still widely used in medium-voltage industrial applications, where high-quality voltage waveforms are required. Static power converters, specifically inverters, are constructed from power switches and the ac output waveforms are therefore made up of discrete values. This leads to the generation of waveforms that feature fast transitions rather than smooth ones.

For instance, the ac output voltage produced by the VSI of a standard ASD is a three-level waveform. Although this waveform is not sinusoidal as expected, its fundamental component behaves as such. This behavior should be ensured by a modulating technique that controls the amount of time and the sequence used to switch the power valves on and off. The modulating techniques most used are the carrier-based technique (e.g. sinusoidal pulse width modulation, SPWM), the space-vector (SV) technique, and the selective-harmonic-elimination (SHE) technique.

Pulse width modulation with variable speed drives are increasingly applied in many new industrial applications that require higher performance. Recently, the development of strength electronics and semiconductor technology have led to the improvement of electronic energy. Thus, different circuit configurations multilevel inverter have become popular and it is considerable interest by researcher to find the advantage of the multilevel

inverter. Variable number of pulse width modulation systems are used to generate a variable voltage and frequency.

1.2 Problem Statement.

Many types of inverter nowadays only changing the DC source to a 3 phase system and to the load. In this project, dc source will be converted into five phase AC source and supply to the load. In this modern world, many researchers make a researcher on making a new inverter like a multiphase source inverter using the additional phase like a 5 phase voltage source inverter. If the motor runs with 3 phase source, it becomes normal but if 1 of the 3 phase supply broken, motor will run with unbalance load. After a few times the motor will trip because the motor overheating. Researcher gets an idea to make a multiphase voltage source inverter to run an induction motor because when motor using multiphase voltage source inverter, the motor also can run if 1 phase of the source broken. In this project, the 5 phase RL load will drive with 5 phase voltage source inverter. It will show what will effect to the load voltage and current when increasing the phase to the load and voltage source inverter.

Multi-phase (more than 3 phase) drives possess several advantages over conventional three-phase drives such as reducing the amplitude and increasing the frequency of torque pulsations, reducing the rotor harmonic currents, reducing the current per phase without increasing the voltage per phase, lowering the dc link current harmonics and higher reliability. By increasing the number of phases it is also possible to increase the power/torque per RMS ampere for the same volume machine. Today‟s world, many kinds of motor use 1 inverter to control the behavior of the motor but with multiphase voltage source inverter, we can run two same types of induction motor with parallel connection by control only one of the motor. The behavior of the two motors is same in term of speed and torque. It can save money by reducing the inverter construction.

1.3 Objective

The main objective of the project is

1) To analyze the performance of multilevel inverter in term of current ripple and total harmonic distortion (THD).
2) To construct the switching scheme of the multiphase inverter using a Matlab/Simulink and Ezdsp.

1.4 Scope

In order to achieve this objective, several scopes had been outlined.

i. Matlab/Simulink software and Ezdsp software will be performed on computer and also Ezdsp platform device is used.
ii. The switching sinusoidal pulse width modulation (SPWM) for the multiphase inverter were programed in Matlab/Simulink software.
iii. The difference between 3 phase and multiphase inverter were simulated in Matlab/Simulink.
iv. The performance of 5-phase SPWM for balanced passive loads like a resistive-inductive load will be analyzed to highlight the advantages of multiphase system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss overall of the previous research about this project and what is the opinion from previous research can use for this project. In this chapter also will discuss about the theory of 3 phase and 5 phase system.

2.2 Generalized Sinusoidal PWM With Harmonic Injection For Multi-Phase Vsis

Many kinds of machine that use motor have a variable speed and that machine almost all use three phase machine. When a power electronics is occurred on controlling the VSI, the 3 legs of phase cannot be a suitable phase to running a load. Converter has make a different in term of control a motor‟s speed and converter was proven can give a lot of advantage on motor controller. Nowadays, many researcher making a research on how to get the suitable switching for a multiphase voltage source inverter [1]. Many kind of PWM available on controlling the gate switching. The most popular switching PWM for a voltage source inverter are sinusoidal pulse width modulation (SPWM) and space vector modulation (SVPWM). This two technique will discussed in literature. There have a lot of way to control the switching using multiphase voltage source inverter. That is happen because too many vector can be controlled in electrical system and this make a lot of

research based on motor controller. In space vector modulation, the voltage reference is a most important because that kind of reference is use to make decision on vector choosing. Multiphase voltage source inverter also have a problem when running a motor and that is called low order voltage harmonic, this kind of harmonic will make the stator current harmonic increase [1].

That is why the switching for multiphase inverter always different and keep on researching. When a multiphase inverter supplied with a sinusoidal PWM switching, we must mind that the output of the voltage source inverter do not have a low order stator harmonic [1]. The sinusoidal pulse width modulation and space vector modulation become a famous technique on control the speed of ac motor.

2.3 Modelling Of Multiphase Voltage Source Inverter

Power circuit of multiphase voltage inverter is shown in figure above and the dc link input is considered constant. For figure above, the load will connect with star connection. The multiphase inverter is simulated in vector transformation and the voltage drop is neglected. When a space vector modulation apply on multiphase voltage inverter, each sector represented with a d and q transformation just like x and y axis on three phase inverter. Generally, number of vector for multiphase voltage source inverter represented 2^n. Thus, for a five phase voltage source inverter, there have 32 vector including 2 zero vector [2]. The important thing on multiphase inverter, the pairing of the switching device must ON or OFF for one time. Second things must be remind, the rms voltage output must same with a d and q for a reference voltage for a space vector modulation technique.

When using a large vector technique, the harmonic of the output voltage did not give a good result because only two active voltages is use on running a load. That is meant more active voltage is need to make a harmonic of output voltage become perfect. This research try to combine large active voltage with a medium active voltage to run a ac motor by make a switching more than usual. This research prove that only the large vector

make a high on harmonic on output voltage for multiphase voltage inverter [2]. So, this two technique is apply to make the output voltage of voltage source inverter similarly like a sinusoidal in addition to make a switching scheme for a multiphase voltage source inverter. However, output voltage of voltage source inverter cannot be produce 100% because the switching of gate make a losses for the system.

2.4 Realization Of A Spwm Inverter For Multiphase Induction Motor Drive

Conventional three phase motor usually use a three phase source from a three phase voltage source inverter. Development on many type of power converter make a new idea to develop a converter that have more than three phase. Example of advantage of multiphase power converter is a produce a high voltage from a low DC source. For a decade researching is make to settle a problem that occurred in high voltage application. For a multiphase inverter, there a many type of switching technique can be apply for an example sinusoidal pulse width modulation and space vector modulation. The objective for all studied on multiphase voltage inverter is to generate a output voltage of inverter similarly sinusoidal wave and increasing the performance on total harmonic distortion (THD). Today, the multiphase inverter become more popular when the inverter come out with many advantage on performance of the load that the inverter drive [3]. The multiphase voltage source inverter have 25% improvement on produce a sinusoidal output voltage [3]. For 3 phase inverter drive, the space vector is a popular technique, but when space vector and sine PWM applied on multiphase inverter, the result almost same on all parameter like a voltage output, total harmonic distortion.

For a multiphase inverter in this paper, sine pwm is choose to drive a motor. Sinusoidal pulse width modulation is more easy to simulate better than a space vector modulation. The performance of the load is nearly same when this two technique was applied. That is the reason why the SPWM technique is choose but researcher continue their research on space vector because the space vector is more efficient on controlling the motor speed. For nine phase voltage source inverter, space vector must have $2^9 = 512$ space of vector on $360°$ plane [3]. This type of technique is not practical for a multiphase

voltage source inverter. For a 360° plane, 512 of vector becomes a problem on divide a degree for each vector [3]. Many problem will occurred when space vector applied on multiphase voltage source inverter especially on complexity of space vector algorithm. When a inverter changing on phase, the old space vector algorithm cannot be use and new algorithm must create. For SPWM, the switching algorithm cannot be a problem when the inverter phase is changing. The original algorithm can be use when a inverter phase is changing [3]. SPWM technique is most easy technique to generate a PWM.

2.5 Theory Of 3 Phase And 5 Phase System

Five phase system is not much different than a three phase system. Theoretically, a five phase system differ only in term of phase with other phases. Phase shift of five phase system was 72 degree and 120 degree for three phase system. This difference will be more clearly seen when the process to produce a sinusoidal pulse width modulation (SPWM) in which each phase in the system will be contrasted with a triangular wave. For three phase system, this process will be easier because the phase difference is large. Figure below shows SPWM for three phase and five phase that have been simulated in matlab/simulink software. For a 3 phase system, this instantaneous voltage is followed.

$$V_a = V_m \sin \omega t$$
$$V_b = V_m \sin(\omega t + 120)$$
$$V_c = V_m \sin(\omega t - 120)$$

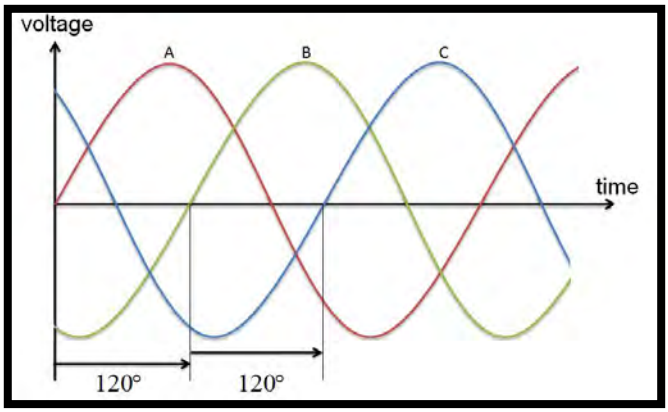

Figure 2.1 : 3 Phase System