"I admit that I have read this report and in my opinion, this report is adequate from the scope and quality for awarding the Degree of Bachelor in Electrical Engineering (Industrial Power)"

Signature : .....

Supervisor's Name : En. Auzani Bin Jidin

Date : 4/05/2006

COMPARATIVE STUDY BETWEEN SINUSOIDAL PULSE WIDTH MODULATION TECHNIQUE AND SIX-STEP TECHNIQUE FOR VOLTAGE SOURCE INVERTER

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4 MAY 2006

I hereby declared that this report is a result of my own work except for the works that have been cited clearly in the references."

Signature : .....

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Date : 4th MAY 2006

Special dedicated to my beloved parents, family and fellow friends, who had strongly encouraged and supported me in my entire journey of learning…

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Assalamualaikum Wbt.

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Thank you!

ABSTRACT

This project discuss about inverters that transfers power from a DC source to an AC load. Inverters are widely used in motor drives, uninterruptible power supplies (ups), appliances run from an automobile battery and photovoltaic utility grid interface. This project presents a comparative study of performance between Sinusoidal Pulse Width Modulation (SPWM) and SIX STEP technique for voltage source inverter. The circuit of these techniques has been designed and analyzed using simulations software packages such as MATLAB 6.5 and ORCAD 9.1. The performance comparison of both techniques presented in terms of the appropriate Total Harmonic Distortion (THD), Fast Fourier Transformed (FFT) and Spectrum Analysis of the output waveforms. Basically, Total Harmonic Distortion describes the quality of the output waveform. Fast Fourier Transformed shows the selected signal wave and the analysis of voltage or current relative to fundamental or DC. While, Spectrum analysis explains a filter requirement in eliminating higher harmonic and unwanted noise. This project is divided into three importance stages of study. Firstly, to study on how to generate the switching SPWM signals to drive the power switches (i.e MOSFETs , IGBTs) and to construct the topologies using Simulink-MATLAB 6.5 for SPWM and SIX-STEP inverters. Secondly, involves the discussion and performance comparison in terms of THD, FFT and Harmonic Spectrum for SIX-STEP and SPWM. Finally, this project presents the construction of schematics of the SIX-STEP and SPWM inverters using ORCAD 9.1 where the schematics can be represented as real practical experimental set-up. Simulation results using ORCAD 9.1 are in close agreement with simulation results using Simulink.

ABSTRAK

Projek ini membincangkan mengenai penyongsang yang menukarkan arus terus kepada arus ulangalik. Penyongsang digunakan secara meluasnya dalam motor pemacu, bekalan kuasa tak terganggu and aplikasi dalam utiliti grid antaramuka bagi voltan photo. Projek ini menghuraikan kajian perbandingan perlaksanaan antara dua teknik dalam penyongsang sumber voltan iaitu teknik Lebar Denyut Modulasi Sinusoidal dan teknik Enam Langkah. Litar bagi kedua-dua teknik direkacipta dan dianalisa menggunakan pakej perisian seperti MATLAB 6.5 and ORCAD 9..1. Perlaksanaan perbandingan kedua-dua teknik dipersembahkan dalam bentuk Jumlah Herotan Harmonik yang bersesuaian, Pertukaran Pantas Fourier dan analisis spektrum berdasarkan gelombang keluaran yang diperolehi daripada keputusan simulasi. Umumnya, Jumlah Herotan Harmonik menjelaskan mengenai kualiti gelombang keluaran manakala Pertukaran Fourier Pantas menjelaskan mengenai analisis bagi voltan dan arus secara relatif kepada frekuensi asas. Sementara itu, analisis spektrum pula menerangkan keperluan menggunakan penapis untuk menghapuskan harmonik tinggi dan bunyi yang tidak diperlukan. Projek ini dibahagikan kepada tiga bahagian penting dalam pengkajian. Bahagian pertama adalah mengenai penghasilkan isyarat yang dapat memacu suis kuasa seperti MOSFETs dan IGBTs serta membina topologi menggunakan Simulink-MATLAB bagi kedua dua teknik. Bahagian kedua pula merupakan perbincangan dan perbandingan antara kedua-dua teknik. Manakala, bahagian ketiga membincangkan tentang penggunaan perisian ORCAD 9.1 sebagai pembinaan skematik yang lebih praktikal dan keputusan simulasi menggunakan 9.1 adalah sama dengan keputusan simulasi menggunakan Simulink-MATLAB 6.5.

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CHAPTER 1

INTRODUCTION

This project will presents an overall description of Voltage Source Inverter. This chapter includes the project overview, project objectives, project scopes, method of analysis and report summary. Roughly, flow of work from the beginning until the fulfillment of this project will be described in this chapter.

1.1 PROJECT OVERVIEW

Voltage Source inverters (VSI's) are utilized in ac motor drive, utility interface, and uninterruptible power supply (UPS) applications as a means for dc ac electric energy conversion. The classical VSI generates a low-frequency output voltage with controllable magnitude and frequency by programming high-frequency voltage pulses. Inverters can be broadly classified into two types, voltage source and current source inverters. A voltage–fed inverter (VFI) or more generally a voltage–source inverter (VSI) is one in which the dc source has small or negligible impedance. The voltage at the input terminals is constant. A current–source inverter (CSI) is fed with adjustable

current from the dc source of high impedance that is from a constant dc source. This project will be only focusing on Voltage Source Inverter part. A voltage source inverter employing thyristors as switches, some type of forced commutation is required, while the VSIs made up of using GTOs, power transistors, power MOSFETs or IGBTs, self commutation with base or gate drive signals for their controlled turn-on and turn-off .In this project, three-phase inverters and their operating principles are analyzed in detail. The concept of Sinusoidal Pulse Width Modulation (SPWM) and SIX STEP technique for inverters is described with performance analysis of waveforms. Finally the simulation results along with all analysis for three phase inverter using the SPWM and SIX STEP are presented. [4]

1.2 PROBLEM STATEMENT

Higher harmonics distortion appears mostly when using SIX-STEP technique. As one of the objectives of this project is to describe the advantage of SPWM technique in reducing power losses and heat dissipated in the output stage, it is necessary to know on how SPWM technique method solves this problem. Basically, SPWM technique control strategies involving either unipolar or bipolar switching. These switching are quite common since the harmonics of significant amplitude are pushed into high frequency range near the carrier frequency.

As the switching frequency is increased, a high quality output voltage waveform can be more easily recovered by low-pass filtering. During a typical turn-on or turn-off operation, however, the voltage across each power device remains near to the DC bus voltage for a significant portion of the switching transient, while a relatively large current is being commutated. Consequently, the devices (motor, heater or etc) undergo high power losses which increase linearly with the switching frequency. This not only

impairs the power transfer efficiency of the inverter, but also increase the size and cost of heat sinks required for efficiency radiating heat loss to avoid device failure.

A conventional linear output stage also applies a continuous voltage to load. This can waste plenty of power. So, as a method of solution for this problem, it is proposed to use SPWM technique which can applies a pulse train of fixed amplitude and frequency where only the width is varied in proportion to an input voltage. The end result is that, the average voltage at the load is the same as the input voltage but with less wasted power in output stage. [2]

1.3 PROJECT OBJECTIVES

The objectives of the project are:

i. To compare and study the performance of analysis for SIX-STEP & SPWM inverter based on their characteristics, output waveforms and switching..

ii. To design a circuit and obtain computer simulation results using Simulink-MATLAB 6.5 and ORCAD 9.1.

iii. To implement the hardware of generation of the PWM signals using IC analogue such as Operational Amplifier LM741 and Comparator LM339.

1.4 PROJECT SCOPES

The scope of work need to be done in this project will be more to analysis of performance for both techniques using Simulink-MATLAB 6.5 and ORCAD 9.1. These two technique will be compared based on their performance such as the existence of higher harmonic in SPWM technique, the switching transition in SIX STEP, their characteristic and the quality of output waveforms of both technique. Since the computer simulation involving two kinds of software packages, my supervisor had narrowed the using of ORCAD 9.1 simulation into SPWM simulation only. But, using Simulink-MATLAB 6.5, both SPWM and SIX-STEP simulation results will presented and analyzed.

The development of hardware is done to get all the results that can prove the simulation results. But, there is a problem of getting the MOSFET's part which is used as a switches. Therefore, the implementation of the components on the project board has limited to the available components only. Even though the hardware results is not well obtained, the best commitment of finding and searching for the components that are needed to build the hardware has been done.

1.5 METHOD OF ANALYSIS

This project performed in two stages. The first stage deals with the designing and simulation process to get proved the expected result of SPWM and SIX-STEP technique theoretically. This involves the using of Simulink-MATLAB 6.5 and ORCAD 9.1 to design SPWM and SIX-STEP schematics which will obtained all the results in terms of output waveform such as voltage line to line, voltage phase, load current and simple Fourier analysis. Then, the results for both technique will be analyzed and compared based on their performance such as the appropriate Total Harmonic Distortion (THD), Fast Fourier Transformed (FFT) and Spectrum Analysis of the output waveforms.

For the second stage, an implementation of hardware that hoped to get the same result obtained from the theoretical/simulation results is performed. Before the hardware implemented, the simulation using ORCAD 9.1 must be done as this software provides practical set-up where simulation can be done cycle by cycle compared to Simulink-MATLAB which only represent all components in block diagram. Some of the information in the process of expanding the idea of analysis and comparison performance of the results are referred from the research journal of related website, power electronic reference books and from my supervisor who had contributes greatly in guiding me for the entire project.

1.6 PROJECT REPORT SUMMARY

This project report contains of five chapters which will describe this project in details. The first chapter is the introduction part where in this chapter, the overall descriptions of the project are highlighted. The objectives of this project, the scopes and the methodology are described.

Second chapter of this report will be discussing about the research and analysis of this project. Each of the facts and the information from the analysis will be explained.

The third chapter will describe the method used in implement the project task. The techniques and methodology of this project is split into two major parts that is the hardware and software. In this chapter, each part will be described in depth.

The fourth chapter is the result and analysis of the project. In this chapter, all of the final results and the analysis that had been done will be stated clearly. The analysis is done by using computer simulation which are Simulink-MATLAB 6.5 and ORCAD 9.1.

The final chapter is the conclusion and suggestion. A conclusion about the achievement of the project objectives and the knowledge gained while doing this project is being stated in this chapter. The suggestion and future work is highlighted to improve the study of the project for the next reference.

CHAPTER II

LITERATURE REVIEW AND PROJECT BACKGROUND

This chapter will described about the background of this project and literature review which includes the previous related project and the development made by people in Electronic Engineering field all over the world.

2.1 PROJECT BACKGROUND

For the project background, the basic concept, characteristic and application of SPWM and SIX-STEP technique will be explained. While for the literature review, the people who responsible of proposing and developing the three phase Voltage Source Inverter PWM schemes and discontinuous modulation in three phase Voltage Source Inverter will be exposed.

2.1.1 SIX STEP TECHNIQUE

SIX-STEP three phase inverter circuit used widely in the speed of induction motors where the output frequency is varied. The three phase load connected to this output voltage may be connected in delta or ungrounded-neutral wye. For a wye-connected load, which is the more common load connection, the voltage each phase of the load is a line-neutral voltage. Figure 2.0 below shows an ungrounded-neutral wye switching scheme for SIX -STEP Inverter. Note that, switches S_1 and S_4 close and open opposite each other, as do pairs (S_2 and S_5) and (S_3 and S_6).

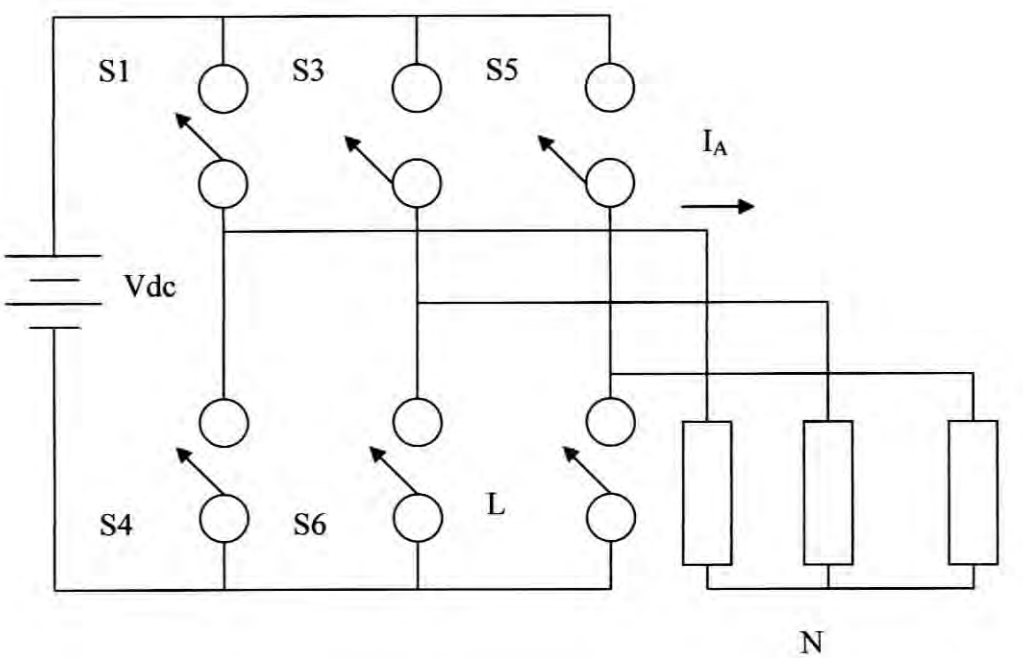

Figure 2.0: SIX-STEP three-phase inverter

Figure 2.1 below shows the switching transition for SIX-STEP inverter. The Switching sequence from (a) will produce the output voltage shown in voltage line to line (b). The output frequency can be controlled by changing the switching frequency. The magnitude of the output voltage depends on the value of the DC supply voltage. So, to control the output voltage of SIX-STEP inverter, DC input voltage must be adjusted. The switching scheme for voltage line to line can be summarized as follows:

For V_{A-B}, S_1 and S_6 are closed - the other will opened
For V_{B-C}, S_3 and S_2 are closed - the other will opened
For V_{C-A}, S_5 and S_4 are closed - the other will opened

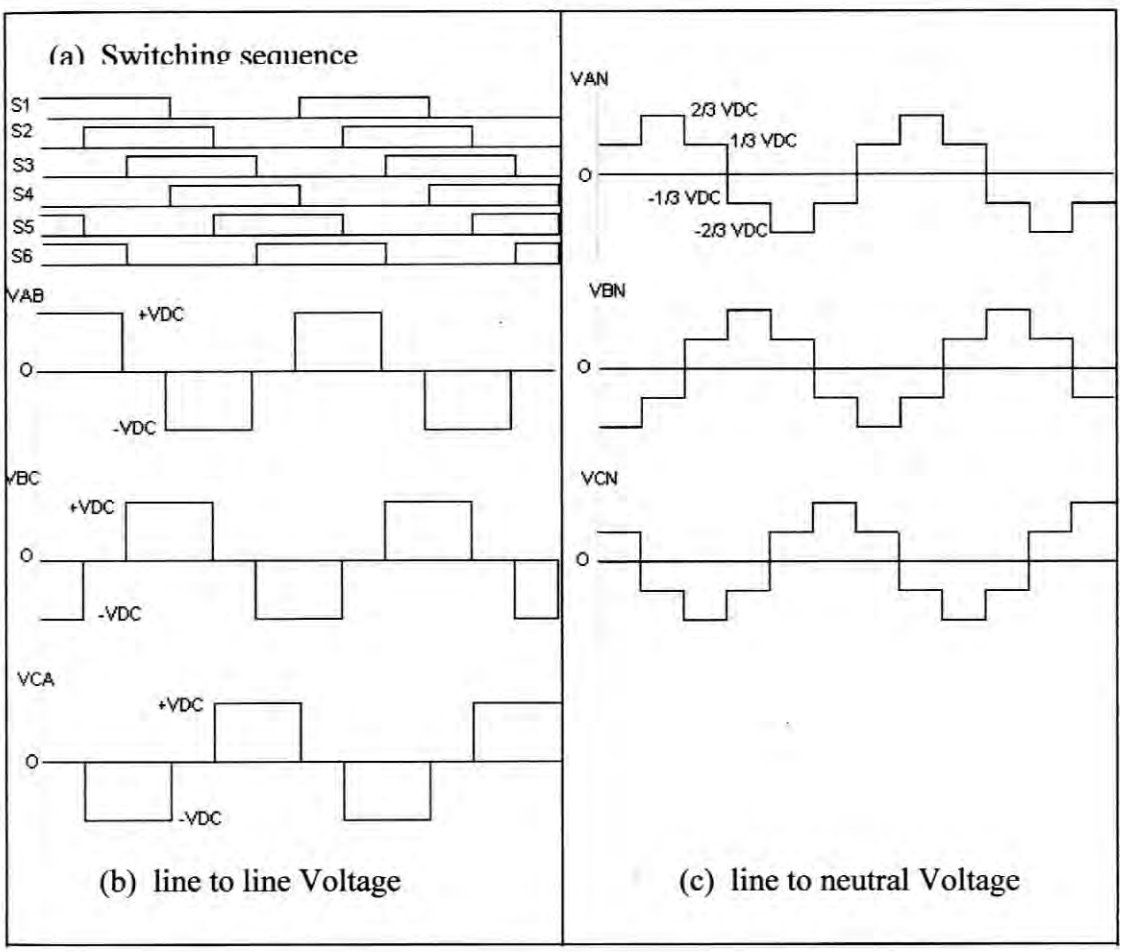

Figure 2.1: Switching transitions for SIX-STEP inverter

Figure 2.2 below shows waveforms of line to neutral (phase) voltages and line to line voltages for SIX-STEP voltage source inverter. The waveforms shows how the switching transitions of figure 2.1 represented mathematically in terms of line to line voltages and phase voltages..

Line to line voltages

$V_{AB} = V_{AN} - V_{BN}$

$V_{BC} = V_{BN} - V_{CN}$

$V_{CA} = V_{CN} - V_{AN}$

Phase voltages

$Van = 2/3V_{AN} - 1/3V_{BN} - 1/3V_{CN}$

$V\,b\,n = -1/3V_{AN} + 2/3V_{BN} - 1/3V_{CN}$

$V\,c\,n = -1/3V_{AN} - 1/3V_{BN} + 2/3V_{CN}$

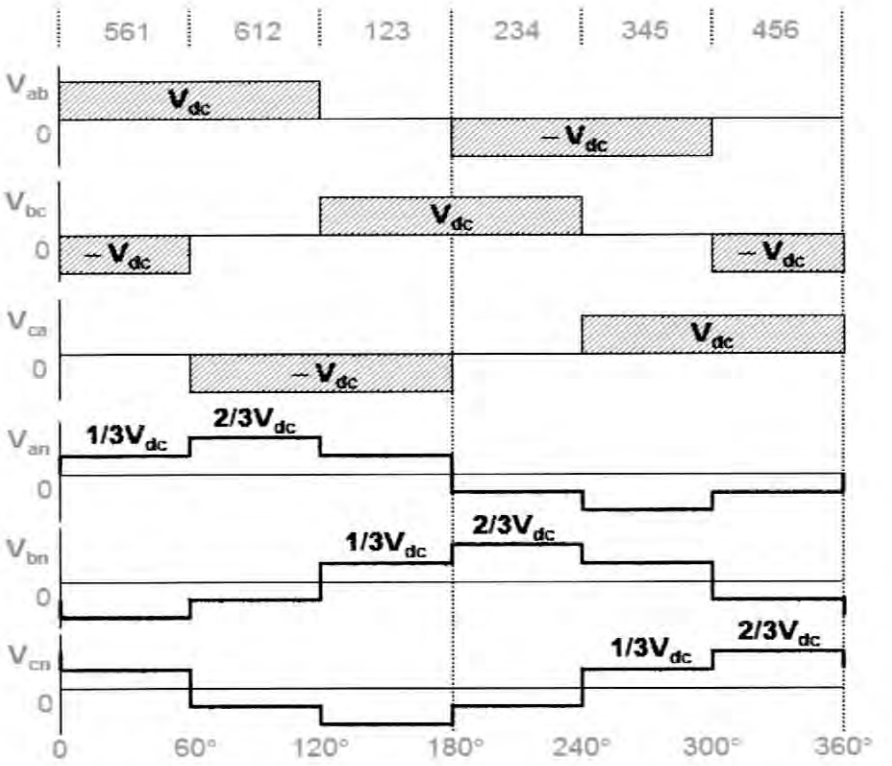

Figure 2.2 : Waveforms of line to neutral (phase) voltages and line to line voltages for SIX-STEP voltage source inverter