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" I hereby declare that I have read this fully report entitled "*Modelling and simulation of 3-phase harmonic selection of voltage source inverter*" and found that it has comply the partial fulfilment for awarding the *Bachelor of Electrical Engineering (Power Electronic and Drives)*"

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Date : 1st JUNE 2015

MODELLING AND SIMULATION OF 3-PHASE HARMONIC SELECTION OF VOLTAGE SOURCE INVERTER

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A report submitted in partial fulfilment of the requirement for the degree of Bachelor of Electrical Engineering (Power Electronic and Drives)

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2015

DECLARATION

I declare that this report entitled "*Modelling and simulation of 3-phase harmonic selection of voltage source inverter*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and not concurrently submitted in candidature of any other degree.

Signature : ....

Name : AZRIN BIN BUYONG

Date : 1st JUNE 2015

Dedicated to my beloved family, friends and lecturers for their never-ending support, encouragement and understanding towards the completion of my work.

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ABSTRACT

Nowadays, voltage source inverter has been used widely in power electronic system due to their ability to supply source for medium and high power application. However, the harmonic that exist in the inverter has caused a major problem which is reducing the performance and increasing in losses of power. In order to overcome this problem, various types of control technique are applied to reduce the harmonic especially at the low frequency. This is because the harmonic at low frequency is not suitable for certain equipment because equipment have its own sensitivity. One of the control techniques that can eliminate the low frequency harmonic is the selective harmonic elimination pulse width modulation (SHE-PWM). This technique has been extensively studied compared to others because its ability to eliminate the low frequency harmonic from single or three-phase inverter and also controlling the fundamental of the system. This research focuses on the SHE-PWM and the model for three phase voltage source inverter is design according to theories collected. All the results gathered from the simulation is tabulated and shown in figures to ease the analysis. The simulation tool used in this research is MATLAB and this program is suitable for simulating the block diagram for the three-phase voltage source inverter as well as doing analysis for the output waveform. Based on the results, SHE-PWM has a lower total harmonic distortion (THD) and also eliminates the low order harmonics. Hence, SHE-PWM proved that it can eliminate harmonic at low frequency.

ABSTRAK

Pada masa kini, penyongsang sumber voltan telah digunakan secara meluas dalam sistem elektronik kuasa kerana kebolehan mereka membekalkan sumber untuk aplikasi kuasa sederhana dan tinggi. Namun, harmonik yang wujud dalam sistem penyongsang menjadi masalah utama kerana ianya mengurangkan prestasi peranti dan mesin serta meningkatkan kehilangan kuasa. Untuk menyelesaikan masalah ini, pelbagai jenis teknik kawalan telah digunakan untuk mengurangkan harmonik terutamanya pada frekuensi rendah. Hal ini kerana harmonik pada frekuensi rendah tidak sesuai untuk sesetengah peralatan di mana setiap peralatan ada sensitiviti tersendiri. Salah satu teknik kawalan yang mampu menghapuskan harmonik pada krekuensi rendah ialah Penghapusan Harmonik Terpilih Pemodulatan Denyut Lebar (PHT-PDL). Teknik ini telah dikaji secara menyeluruh berbanding teknik lain kerana kebolehannya menghapus harmonik pada frekuensi rendah tidak kira penyongsang satu fasa atau tiga fasa dan juga mengawal fundamental sistem. Kajian ini memfokus kepada PHT-PDL dan model untuk penyongsang sumber voltan tiga fasa telah di reka bentuk mengikut teori yang dikumpul dan dipelajari. Kesemua hasil kajian dikumpul dari simulasi direkodkan untuk memudahkan analisis. Alat simulasi yang digunakan dalam kajian ini adalah MATLAB dan program ini sangat sesuai untuk mensimulasi rajah blok untuk penyongsang sumber voltan tiga fasa dan juga melakukan analisis untuk gelombang keluaran. Dari hasil kajian yang dilakukan, PHT-PDL mempunyai jumlah herotan harmonik (JHH) yang rendah dan juga menghapus harmonik pada susunan yang rendah. Oleh yang demikina, PHT-PDL membuktikan bahawa ianya mampu menghapuskan harmonik pada frekuensi rendah.

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LIST OF ABBREVIATION

AC	-	Alternating Current
ASD	-	Adjustable Speed Drives
BJT	-	Bipolar Junction Transistor
CSI	-	Current Source Inverter
DC	-	Direct Current
FACTS	-	Flexible AC Transmission Systems
GTO	-	Gate turn-off Thyristors
IEEE	-	Institute of Electrical and Electronic Engineers
FFT	-	Fast Fourier Transform
IGBT	-	Insulated-Gate Bipolar Transistor
MATLAB	-	Matrix Laboratory
MOSFET	-	Metal-Oxide Semiconductor Field Effect Transistor
PWM	-	Pulse Width Modulation
R	-	Resistance
RC	-	Resistance-Capacitance
RL	-	Resistance-Inductance
SHE	-	Selective Harmonic Elimination
SPWM	-	Sinusoidal Pulse Width Modulation
SVM	-	Space Vector Modulation
THD	-	Total Harmonic Distortion
THDi	-	Total Harmonic Distortion of Current
THDv	-	Total Harmonic Distortion of Voltage
UPS	-	Uninterruptible Power Supplies
VSI	-	Voltage Source Inverter

CHAPTER 1

INTRODUCTION

1.1 Background

Selective harmonic elimination (SHE) is a famous control technique for generating PWM signals that used to eliminate a selected low-order harmonics from a voltage waveform generated by a voltage-source inverter (VSI). Although the technique has long been established, SHE is receiving new attention due to the fast development in digital signal processing tools that permit the implementation of such algorithms. In addition, SHE is a good option to other PWM techniques when the inverter frequency ratio is restricted to a small value, as in the case of high-speed ac drives. The chosen project is related to the modelling and simulation of 3 phase harmonic selection of voltage source inverter. The benefit of this research is to eliminate harmonics produced by Pulse Width Modulation (PWM) inverter using selective harmonic elimination (SHE). Selective Harmonic Elimination (SHE) technique is used to reduce the value of Total Harmonic Distortion (THD) in the existing system.

1.2 Research Motivation

DC-AC converters are power electronic circuits and also known as an inverter. Inverter is classified into two different types. Voltage source inverter is a one category of inverter. In such an inverter, the output voltage is able to increased or lessen as of the input voltage level by altering the duty ratio of its switch. The inverter rendition can be accomplish moreover using proscribed turn-on and turn-off devices (e.g. BJTs, MOSFETs, IGBTs, and

GTOs) or by forced commutated thyristors, depending on their applications. The projected work investigates the Selective Harmonic Elimination (SHE) to eliminate harmonics produced by Pulse Width Modulation (PWM) inverter by using simulation tool which is MATLAB/Simulink.

1.3 Objectives

The project's objectives are

1. To design the simulink block for 3 phase voltage source inverter
2. To simulate the simulink block of the Selective Harmonic Elimination control technique for three-phase voltage source inverter.
3. To examine and inquire the Total Harmonic Distortion of voltage source inverter by applying different load.

1.4 Scopes of Project

The scope of this project is mainly about developing the 3-phase voltage source inverter model and implementing SHE-PWM method into the system to eliminate certain harmonics. It will also focus on the sinusoidal pulse width modulation method for different type of loads. In addition, the THD of current and voltage for the 3-phase of the two switching technique are also covered. The different between these control techniques is compared.

1.5 Report Outline

A simple outline for the project report content is described as below:

Chapter 1 presents the project background. The problem statement and objective are also explain briefly. Lastly, it also delineates the scope of the research.

Chapter 2 elaborates the literature review related to the project. Each of the facts and analysis is reported based on the complete study of various reliable reading materials written by many researches. The materials are interpreted from IEEE journals, articles, books and technical papers.

Chapter 3 develops the flowchart of this project and the simulation of SHE-PWM for 3-phase voltage source inverter will be carried out. The milestone as well as the Gantt chart is briefly explained. Lastly, the method of the 3-phase Selective Harmonic Distortion is analyzed.

Chapter 4 highlights the results gathered from the MATLAB 2012a simulation. The current and voltage waveform of the SPWM and SHE-PWM technique are shown in this chapter. The total harmonic distortion of the system for both control technique is collected from the FT analysis. All results are discussed and compared.

Chapter 5 in this chapter, the overall of the research is concluded and recommendation is suggested.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Inverters are a circuit that changes direct current (DC) to alternating current (AC). It transfer power form a DC source to an AC load. A three-phase voltage source inverter is introduced which have came into view as a very important alternative that used for medium-voltage and high power range application.

2.2 Current Source Inverter

The ac output current waveform is produce by using static power converter which getting supply from dc current supply. The frequency, phase, and magnitude should be governable for the sinusoidal output. The generated load voltage which is nearly sinusoidal prove that these topologies are used. [1].

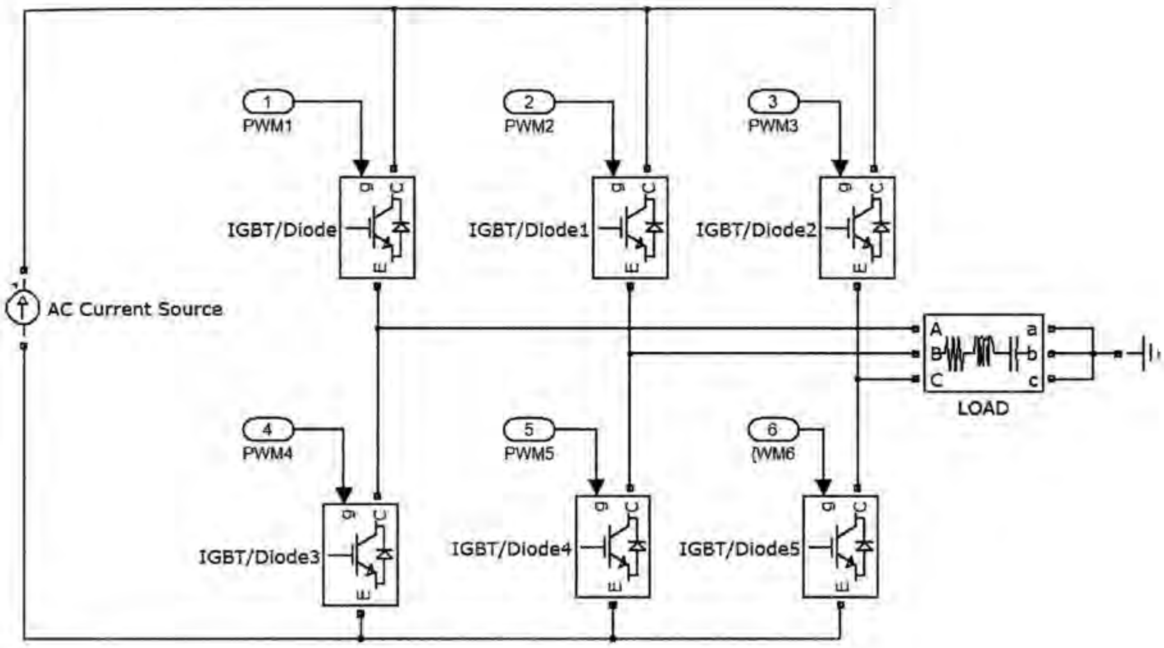

Figure 2.1: Three phase CSI topology

2.3 Voltage Source Inverter

The separately controlled output which is a voltage waveform is how the voltage source inverter got its name. As a static power converter, the transformations of DC/AC are resulting from the power switching device. Voltage source inverters have active uses in both single phase and three-phase applications. By determining the modulation technique controlling, near sinusoidal waveform is able to produce around the fundamental frequency.

2.3.1 Voltage Source Inverter Topology

The typical three-phase VSI topology is shown in Figure 2.2. On the other hand, the switch states are shown in Table 2.1. If all the inverter legs are switched on at the same time, a short circuit will occur in the dc link voltage supply. Same goes to switching off the all the inverter legs at the same time; an undefined states in voltage source inverter cannot be avoided Also, the voltage will be contingent to the respective line current polarity. The first to sixth state generate nonzero voltage while the seventh and eighth state generates zero voltage. The current freewheel from upper to lower part of the switch in this case. [1]

The switch used in this project is IGBT. There are diverse power switching that can be used for this inverter which is MOSFET and FET. MOSFET use for fast switching and have no thermal runaway. This power switch also have small on state resistance but high power dissipation. On the other hand, IGBT have the advantages of both power MOSFET and BJT. This switch is used for slower switching device. The reason for using IGBT is because having low on-state voltage drop. This is expected from the conductivity modulation. In addition, the control of the IGBT is easier [13].

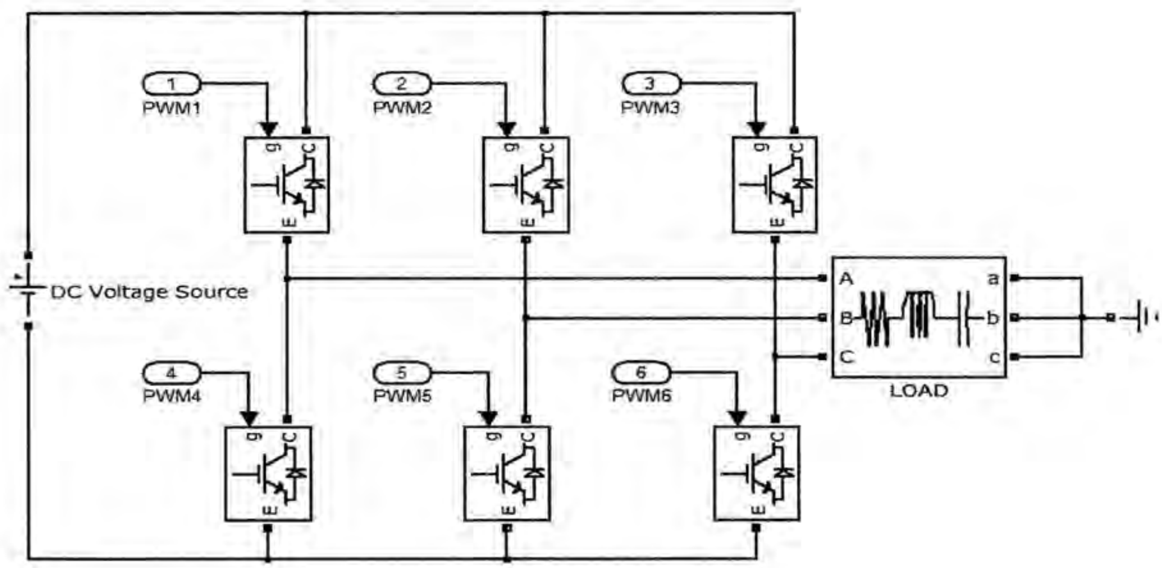

Figure 2.2: Three phase VSI topology

Table 2.1: Standard valid switch states for a three-phase VSI

Switch state						State	v_{ab}	v_{bc}	v_{ca}	Space vector
S1	S2	S3	S4	S5	S6					
1	1	0	0	0	1	1	v_i	0	$-v_i$	$\overrightarrow{V_1} = 1 + j0.577$
1	1	1	0	0	0	2	0	v_i	$-v_i$	$\overrightarrow{V_2} = j1.155$
0	1	1	1	0	0	3	$-v_i$	v_i	0	$\overrightarrow{V_3} = -1 + j0.577$
0	0	1	1	1	0	4	$-v_i$	0	v_i	$\overrightarrow{V_4} = -1 - j0.577$
0	0	0	1	1	1	5	0	$-v_i$	v_i	$\overrightarrow{V_5} = -j1.155$
1	0	0	0	1	1	6	v_i	$-v_i$	0	$\overrightarrow{V_6} = 1 - j0.577$
1	0	1	0	1	0	7	0	0	0	$\overrightarrow{V_7} = 0$
0	1	0	1	0	1	8	0	0	0	$\overrightarrow{V_8} = 0$

2.3.2 Application of Voltage Source Inverter

Voltage source inverter are used in the medium-voltage and high-power applications. The static power converters main aim is converting dc power supply to a ac output waveform. The waveforms are needed for the application for uninterruptible power supply, adjustable speed drives and flexible ac transmission system. Other common application included the static var compensator and active filter. The frequency, phase and magnitude are controllable for sinusoidal ac output. All of these can be considered VSI, which the voltage waveforms are independently controlled ac output. The topologies is used extensively because their natural conductivity which is as a voltage source wanted by so large industrial applications. [1]

For various applications, the energy is carried to the dc side from ac side of the inverter. For example, when the ASD slow down or braking, it transfers the kinetic energy to the voltage dc link. For a motoring mode, the dc link voltage is pre-determined so the dc link current is in reversed direction. If the system uses capacitor, the energy must be fed back to the system or degenerate or else the dc link voltage will augmented. In this case, the capacitor is connected with the resistor in parallel. Other alternative is feeding the energy to the system but the method need a reversible current topology. There are other kinds of approach to use the active rectifier for regeneration mode where it is the natural mode of the system.

2.4 Voltage Source Inverter Control Schemes

There are many types of control schemes for the voltage source inverter. It consist of sinusoidal pulse width modulation, square wave technique, space vector modulation, DC link current, load-phase voltage and lastly selective harmonic elimination [1]. In this project, only SPWM and SHE-PWM is discussed.

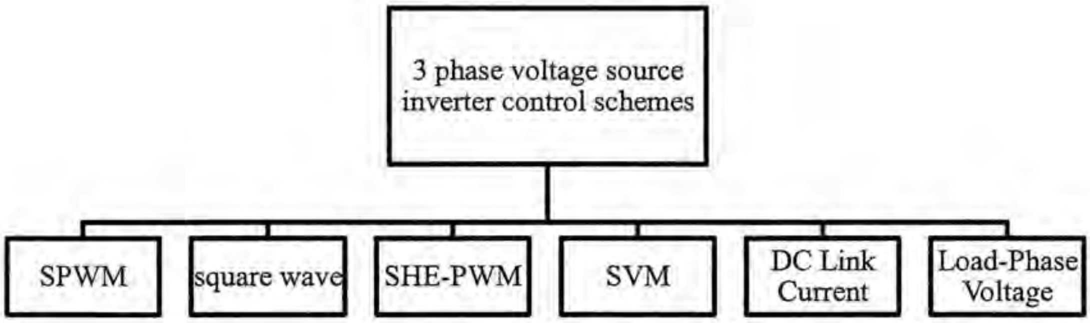

Figure 2.3: Voltage source inverter control schemes

2.4.1 Sinusoidal Pulse Width Modulation

Sinusoidal Pulse Width Modulation (SPWM) is widely used as a control technique of inverter. A sinusoidal waveform is compared with a triangular waveform to output a square waveform. The sinusoidal is set at the specific frequency. At switching frequency, *fs* the V_{tri} (triangular waveform) are turned-on and turn-off. The duty ratio is modulating using the frequency of the control signal. The switching frequency will contain harmonics because the switching frequency affects the output of inverter. The duty cycle of one of the inverter switches is amplitude modulation, m_a. [2]

The $V_{control}$ compared with V_{tri} are given as follows.

For $V_{control} > V_{tri}$,

$$V_A = \frac{V_{dc}}{2} \tag{2.1}$$

For $V_{control} < V_{tri}$,

$$V_A = -\frac{V_{dc}}{2} \tag{2.2}$$

The frequency modulation ratio, m_f and amplitude modulation ratio, m_a is deliberate using the formula below.

$$m_a = \frac{peak\ amplitude\ of\ V_{control}}{amplitude\ of\ V_{tri}} \tag{2.3}$$

$$m_f = \frac{PWM\ frequency, f_s}{fundamental\ frequency, f_1} \tag{2.4}$$

The m_f (frequency modulation) has to be an odd integer. The sub harmonics can exist if the m_f is not an integer. On the other hand, a dc component may exist in the output voltage if the frequency modulation is even number [3].

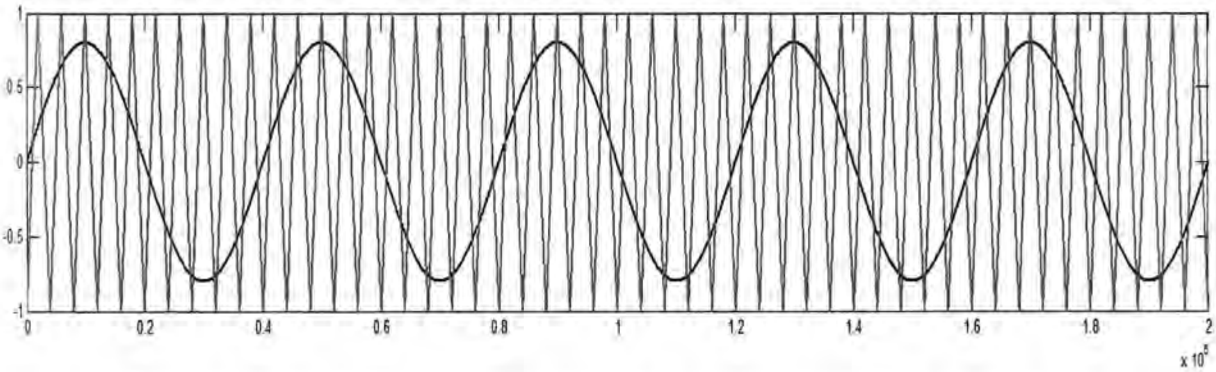

Figure 2.4: Comparison between triangular waveform and sine waveform