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**FINAL YEAR PROJECT  
TECHNICAL REPORT**

**IMPLEMENTATION OF SPACE VECTOR PULSE WIDTH MODULATION  
(SVPWM) FOR THREE PHASE VOLTAGE SOURCE INVERTER USING  
MATLAB/SIMULINK**

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## SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the awards of the Degree of **Bachelor of Electrical Engineering Industrial Power**

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**IMPLEMENTATION OF SPACE VECTOR PULSE WIDTH MODULATION  
(SVPWM) FOR THREE PHASE VOLTAGE SOURCE INVERTER USING  
MATLAB/SIMULINK**

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## STUDENT'S DECLARATION

I hereby declare that this thesis entitled "*Implementation Of Space Vector Pulse Width Modulation (Svpwm) For Three Phase Voltage Source Inverter Using Matlab/Simulink*" is the result of my own research except as cited in the references. This is project is adequate in terms of scope and quality for the award of the degree **Bachelor of Electrical Engineering Industrial Power**.

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## ABSTRACT

Space Vector Modulation (SVM) was originally developed as vector approach to Pulse Width Modulation (PWM) for three phase inverters. It is a more sophisticated technique for generating sine wave that provides a higher voltage to the motor with lower total harmonics distortion. Space Vector Pulse Width Modulation (SVPWM) is an advanced method which is a computation intensive PWM method and possibly the best technique to variable frequency drive application. This project focused on the development of MATLAB/SIMULINK model of SVPWM step by step. Firstly, model of a three phase Voltage Source Inverter (VSI) had investigated based on space vector concept which is developed by equation then create model based on these equation. The next step is simulation the model of SVPWM and SPWM using MATLAB/SIMULINK. The outcome of simulation results demonstrated. Finally, this paper also covered the comparison of the total harmonics distortion between SPWM and SPWM.

## ABSTRAK

Modulasi ruang vektor (SVM) pada asalnya dibangunkan sebagai pendekatan vektor kepada modulasi denyut lebar (PWM) untuk penyongsang tiga fasa. Ia adalah satu teknik yang lebih canggih untuk menjana gelombang sinus yang memberikan voltan lebih tinggi untuk motor dengan jumlah herotan harmonic yang lebih rendah. Modulasi denyut lebar ruang vektor (SVPWM) adalah satu kaedah yang maju di mana kaedah pengiraan intensif modulasi denyut lebar dan mungkin teknik terbaik untuk aplikasi pemacu pemboleh ubah frekuensi. Projek ini tertumpu kepada pembangunan model MATLAB / SIMULINK Modulasi denyut lebar ruang vektor secara berperingkat. Pertama model tiga fasa penyongsang sumber voltan (VSI) di kaji berdasarkan kepada konsep ruang vector, dimana ia dibangunkan oleh persamaan, kemudian model dibina berdasarkan persamaan yang terhasil. Langkah seterusnya adalah simulasi model Modulasi denyut lebar ruang vektor (SVPWM) dengan menggunakan MATLAB / SIMULINK dan hasil keputusan simulasi ditunjukkan. Akhir sekali, laporan ini juga merangkumi perbandingan jumlah gangguan harmonic diantara SPWM dan SVPWM.

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## CHAPTER 1

### INTRODUCTION

Section below focuses on what is expected to be done during the project period. It will also outline the general background, activities done and project goals. Furthermore, in order to give a more deeply concern, it will list out the key reasons for launch and what is the primary concerns that cause this project compulsory to be launched.

#### 1.1 Project Background

Nowadays, the demands for the electronic products are getting higher due to the rapid advances in technology. The usage of electronic appliances now is a part of our lives, where it covers 80% of the performance in our daily activities. For example, we require a computer to find the latest information on recent developments, mobile phones are used to communicate, machines and motors AC / DC are used by both small and large-scale industries to lift or move objects. Most of the electronic equipment is called distortion current also known as non-linear load. This non-linear load might be a single phase or three phase load. For example for the variable speed drives, the current production is called Harmonic distortion [14].

Harmonic distortion will produce a higher frequency where it will increase the current and damage the electrical equipment. Thus, to reduce these harmonic distortion, space vector Modulation techniques are used. This technique is used because it is an advanced method that involves computation intensive PWM method and possibly the best technique to the variable frequency drive application [15].

## 1.2 Problem Statement

As stated above, the largest problem in power quality is harmonic distortion. Harmonic distortion is divided into two of the harmonic which are voltage and current harmonics. Harmonic currents produced by the harmonics contained in the supply voltage depending on the types of loads such as resistive load, capacitive load and inductive load. These harmonics can be generated from the source side or load side. Harmonic at the load side is due to the nonlinear operation of electronic devices they include. This can cause magnetic core transformer and motor overheat thus, reduce the efficiency and lifetime of the equipment.

Induction motor drives are widely used in high performance drive system. It is due to the good power factor, high efficiency, extremely rugged and do not require starting motor. This function is to allow the adjustment of speed motor by using the frequency and amplitude of the stator voltage. However, the ratio of stator voltage to frequency should be kept constant [3].

In order to make the motor operates smoothly, there are several modulation technique that are used to cater the output variable that have maximum basic component with minimum harmonic and less switching losses. In this project, Space Vector PWM is used as a modulation technique. Actually, this technique was originally developed as a vector approach to pulse width modulation (PWM) for three phase inverter. [1] It is a more sophisticated technique for generating sine wave that provides a higher voltage to the motor with lower total harmonic distortion. SVPWM is a special switching scheme of the six Power transistor of a three phase power converter.

### 1.3 Project Objective

There are several objectives to be accomplished in this project including:

- i. To study and do analysis about the concept of inverter, sinusoidal pulse width modulation (SPWM) and space vector pulse width modulation (SVPWM).
- ii. To study and investigate model of a three phase voltage source inverter (VSI) based on space vector concept.
- iii. To design the suitable model SVPWM.
- iv. To develop step by step and do simulation model of SVPWM.

### 1.4 Project Scope

There are several types modulating technique that controls the amount of time and the sequence that uses to switch on and off. The most modulating techniques used are the carrier-based technique. For example the sinusoidal pulse width modulation (SPWM), the space-vector (SV) technique, and the selective-harmonic-elimination (SHE) technique. The scope of this project is focused on the implementation of SVPWM for three phase voltage source inverter using the software MATLAB/SIMULINK this includes:

- i. Focus on development of MATLAB/SIMULINK model of SVPWM step by step.
- ii. Investigated model of a three phase voltage source inverter (VSI) based on space vector.
- iii. Simulation model of SVPWM using MATLAB/SIMULINK.



## CHAPTER 2

### LITERATURE REVIEW

This chapter will discuss about the review done on several related article which includes the previous project and the method that use to solve the problem. The review will contain the theory that had been carried out by each article. The review is conducted among three (3) major articles which are:

- i. Project space vector PWM inverter [2].
- ii. Control of voltage source inverter using PWM/SVPWM for adjustable speed drive applications [1].
- iii. MATLAB/SIMULINK model of space vector PWM for three phase voltage source inverter [12].

#### 2.1 Pulse Width Modulation

PWM modulation is a technique developed by a combination of electronic components circuit to generate a variable analogue signal. It uses a simple concept where they open and close the switch at different intervals.

Pulse width modulation control within the inverter itself operates when a fixed dc input voltage is given to the inverter while a controlled ac output voltage obtained by adjusting the on and off periods of the inverter components. It is the most efficient method to adjust the output voltage from an inverter [1]. Nowadays, PWM application widely used to control the motor, current, voltage, and Uninterruptable Power Supply (UPS).

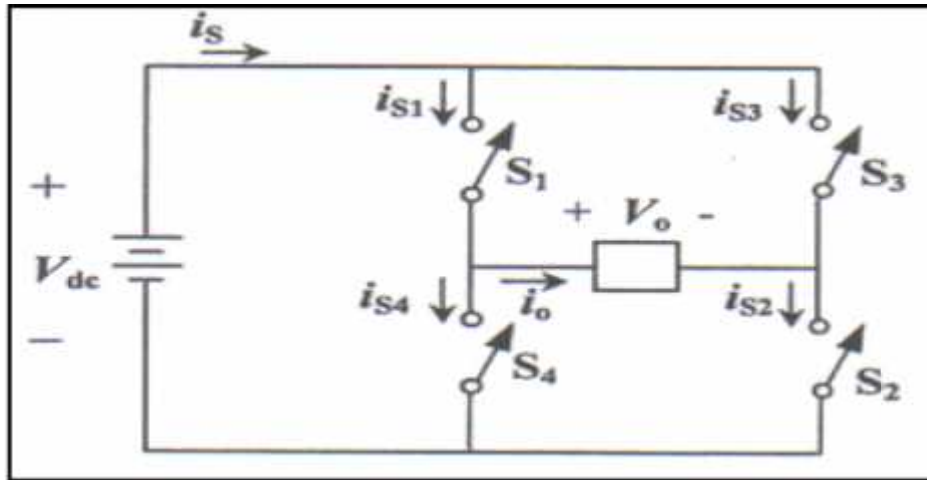


Figure 2.1.1: PWM Inverter [8].

Based on the Figure 2.1.1 above, on the positive cycle switch S1 and S2 will be ON while switch S3 and S4 are OFF. Different on the negative cycle where switch S3 and S4 now are ON and switch S1 and S2 will OFF. It will produce a full wave output.

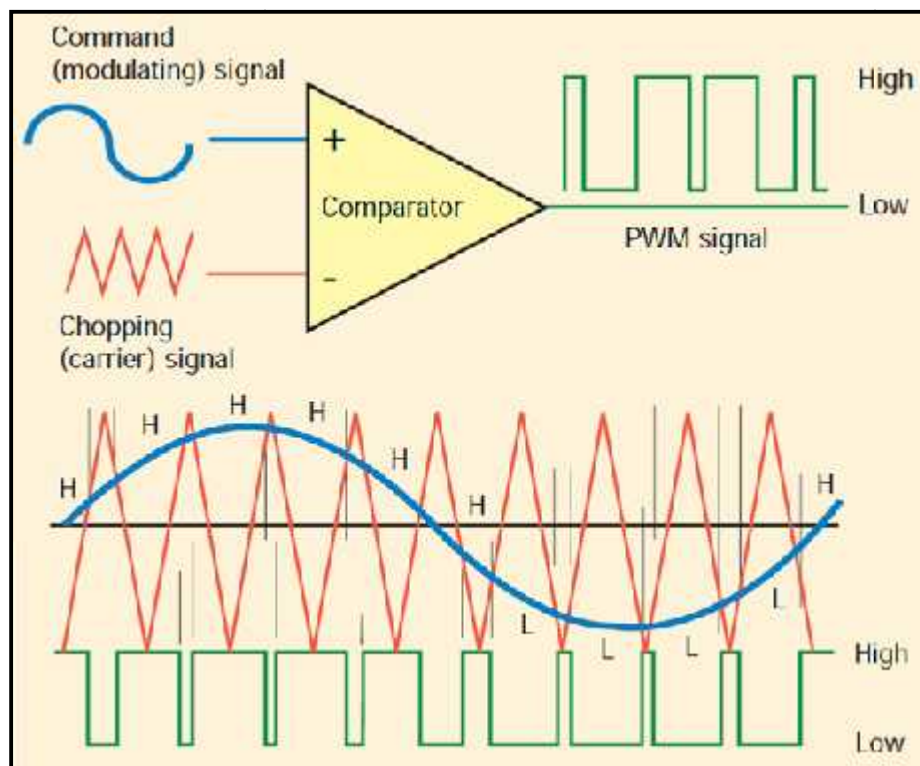
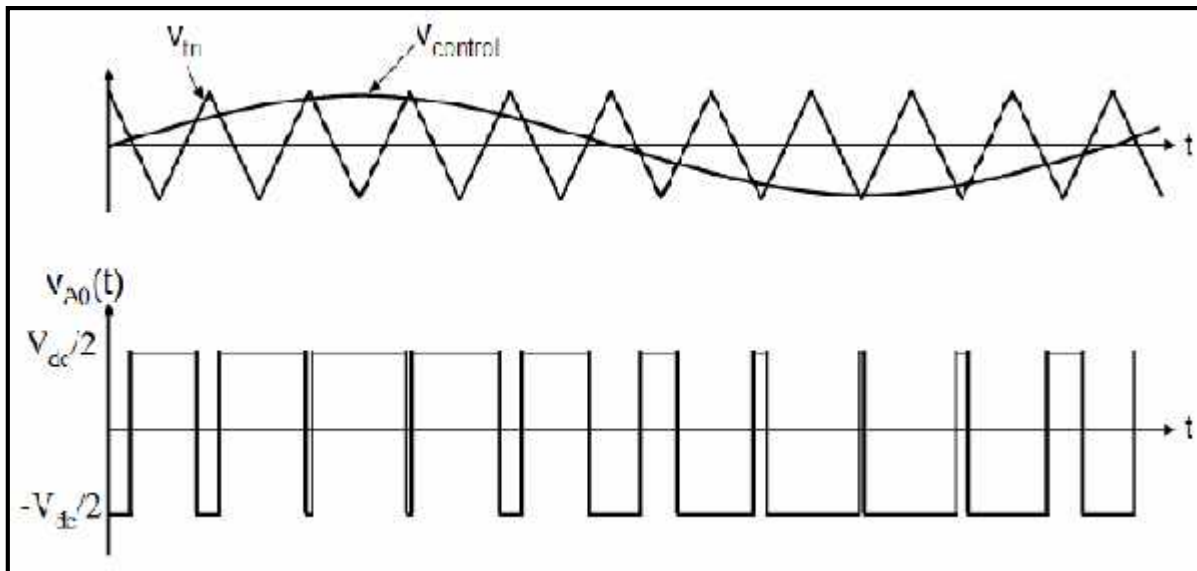


Figure 2.1.2: PWM Signal Produce and influence command signal to the wider of pulse [9].

The output of PWM signal is produce from the comparison between two different signal which are modulating signal (sinusoidal wave) and carrier signal (saw tooth wave). This comparison process is done by the comparator. The frequency size of PWM output signal is varying based on the size of intersection between carriers and modulating signal as Figure 2.1.2. Below will show the derivation of inverter output voltage:



**Figure 2.1.3: Pulse Width Modulation [8].**

When  $V_{control} > V_{tri}$ ,  $V_{AO} = V_{dc}/2$

When  $V_{control} < V_{tri}$ ,  $V_{AO} = -V_{dc}/2$

Modulation index (m) defined as:

$$m = \frac{V_{control}}{V_{tri}} = \frac{\text{peak of fundamental frequency component}}{\frac{V_{dc}}{2}}$$

The major advantages of Pulse Width Modulation Inverter:

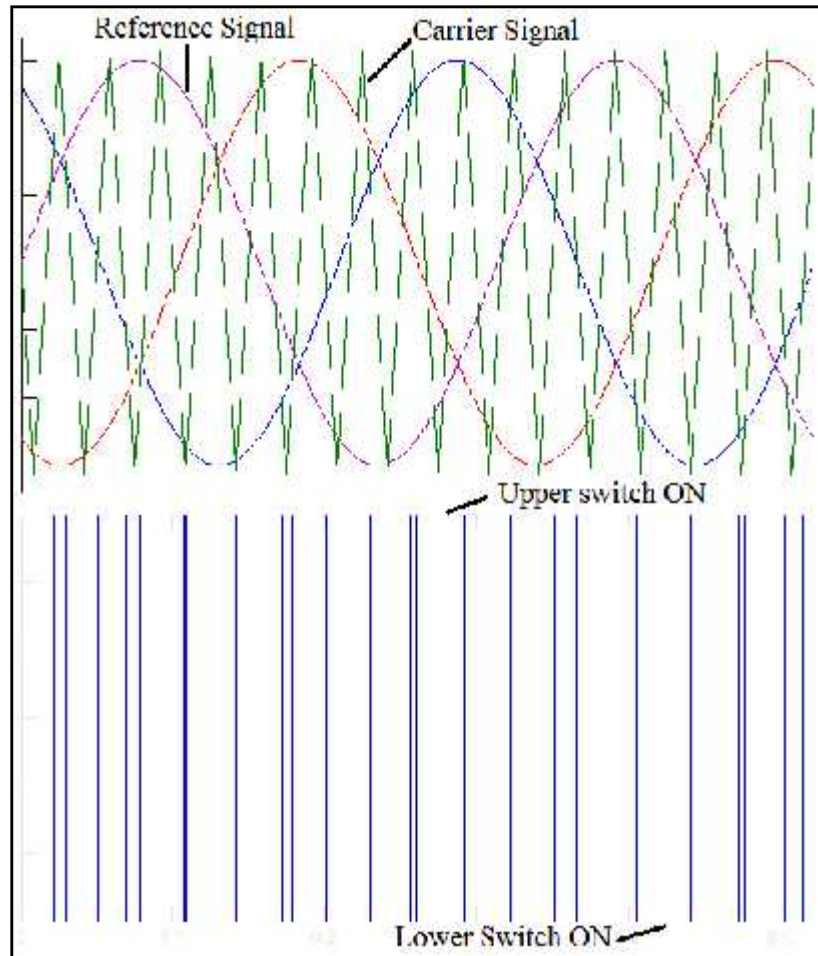
- i. Will make efficiency up to 90%. PWM will developed higher torque inside the motor in which use to overcome the internal motor resistance in simplest way.
- ii. Lower order harmonics can be eliminate or minimized along with its output voltage. Efficient when used to convert voltages or to dim light bulbs.
- iii. Low power consumption. PWM will reduce the harmonic distortion means that stabilize the frequency and current, so it will save the power.

The disadvantages of Pulse Width Modulation Inverter:

- i. Increase of switching losses due to high PWM frequency.
- ii. Electromagnetic interface problems due to high order harmonics.

## **2.2 Sinusoidal Pulse Width Modulation**

The most popular PWM approach is the Sinusoidal Pulse Width Modulation. In this method, carrier signal (triangular wave) is compared to a reference signal (sine wave). The relatives between these two signals are used to determine the pulse width and control the switching of devices in each phase leg of the inverter. The sinusoidal PWM is very easy to implement using analogue integrators and comparators for generation [4]. Otherwise it also very easy to implement the carrier and switching states too. However, due to the variation of the sine wave reference values during a PWM period, the relation between reference value and the carrier wave is not fixed [5]. In addition, SPWM have produced signal with a larger harmonic where is this harmonic will increase the frequency and disturb other equipment to provide 100% efficiency.



**Figure 2.2: Principle of three phases SPWM.**

The frequency of reference signal is used to determine the inverter output frequency, and its peak amplitude controls the modulation index,  $M_1$  and then in turn the output voltage. By varying the modulation index  $M_1$ , the output voltage can be varied [8].

$$\begin{aligned} \text{Modulation index, } M_1 &= \frac{\text{Amplitude of the modulating waveform}}{\text{Amplitude of the carrier waveform}} \\ &= \frac{A_m}{(n-1)A_c} \end{aligned}$$

Where:

$A_m$  = peak to peak amplitude modulation signal

$A_c$  = peak to peak amplitude carrier signal

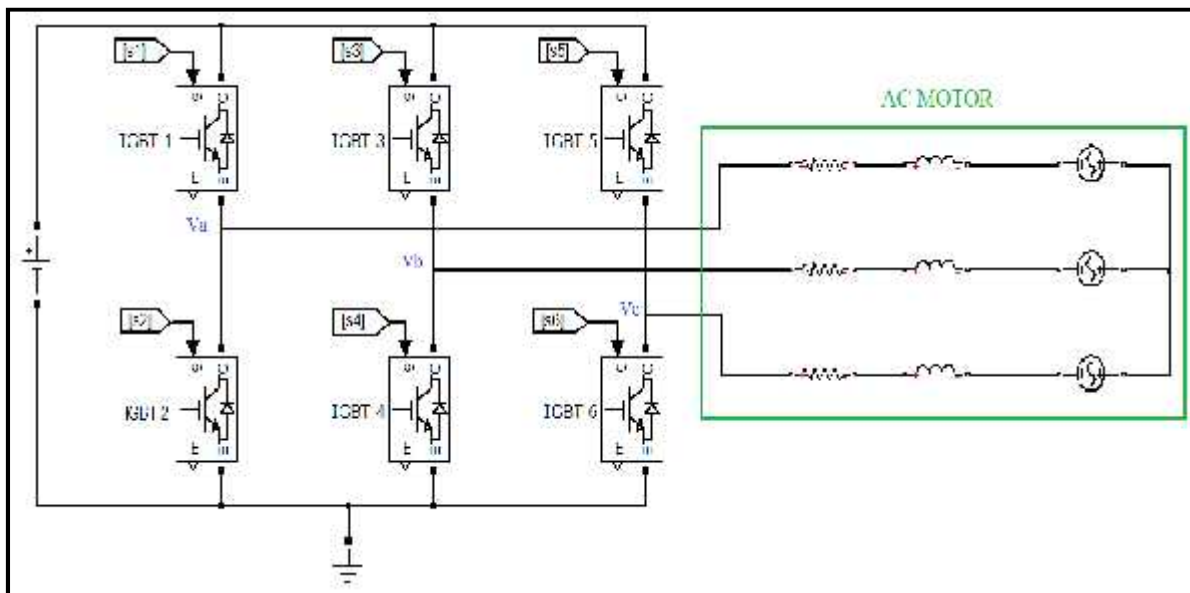
$n$  = number level of inverter

Output voltage,  $V_{out} = M_1 V_{in}$

$$\text{Modulation ratio, } M_r = \frac{\text{frequency of the carrier waveform}}{\text{frequency of the modulating waveform}}$$

### 2.3 Space Vector Pulse Width Modulation

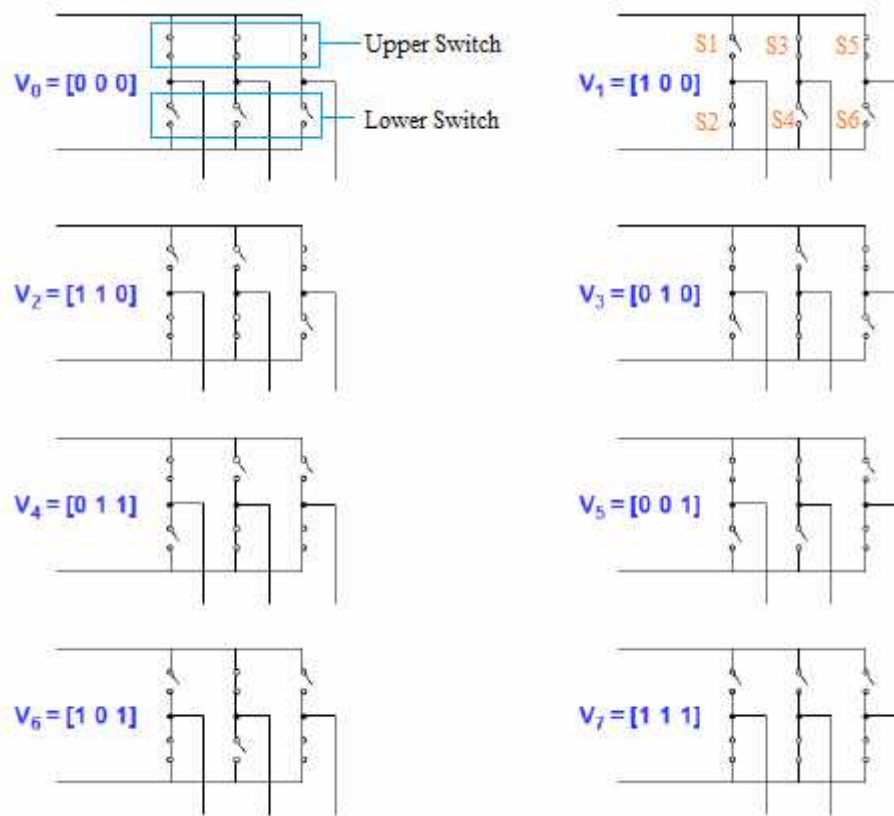
Space Vector PWM refers to a special switching sequence of the upper three power transistor of a three phase power inverter. It used to generate less harmonic distortion in the output voltages and current applied to the phases of an AC motor and to provide more efficient use of supply voltage compared with sinusoidal modulation technique [2]. The SVPWM circuit can be modelling by three phase voltage source PWM inverter as shown Figure 2.3.1.



**Figure 2.3.1: Three phase voltage source PWM inverter**

From the Figure 2.3.1, it will produce eight different topologies to obtain the continuous output circuit. There are another six non-zero switching states and two topology zero switching states or produce zero output voltage will be obtain from eight different

topologies. This topology is happen because of the switch controller at IGBT gate, which is switch, is ON and OFF condition during the certain time interval. Figure 2.3.2 show switching state of inverter.



**Figure 2.3.2: Eight switching state of inverter voltage vector. [2]**

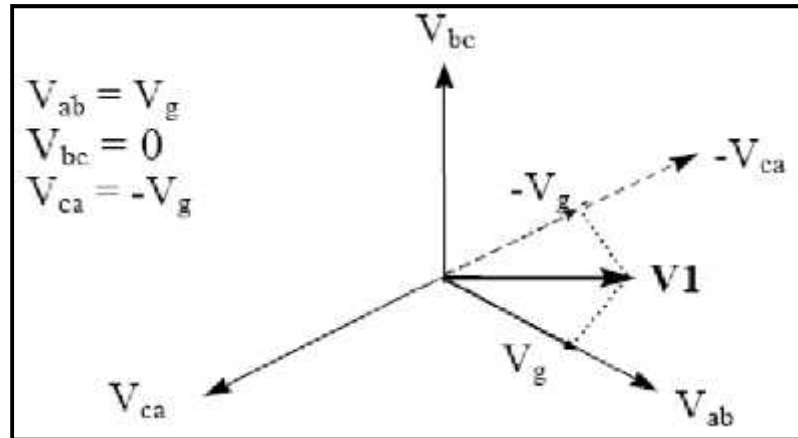
Zero switching state occurs at  $V_0$  and  $V_7$ , which the upper three switches (S1, S3, S5) are operate together or the three switch lower side (S2, S4, and S6) are operate at the same time. For non-zero switching state the upper side switch and lower side switch must move by alternate operate or interval to obtain the continuous output circuit (only one switch may be closed per phase leg in order to prevent a short circuit) [2].

From Figure 2.3.2 space vector modulation can be represent at plane - . For example from topology  $V_1$  the line voltages and are given:

$$V_{ab} = V_g$$

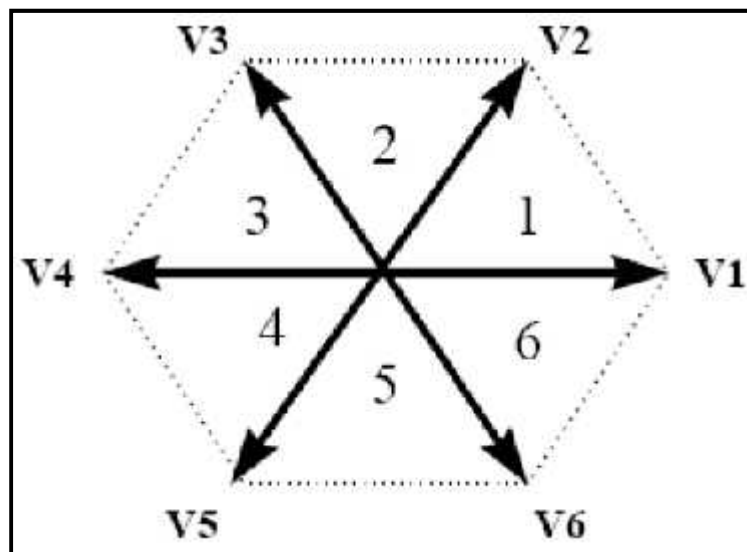
$$V_{bc} = 0$$

$$V_{ca} = -V_g$$



**Figure 2.3.3: Representation of topology 1 on plane - [2].**

From figure 2.3.3 the value of three line voltage vector plotted on plane - and the vector produce represented as,  $V_1$ . Proceeding on the similar plane the six non-zero voltages vector can be shown to assume the position of vector in regular hexagon (dotted line) as Figure 2.3.4 [1].



**Figure 2.3.4: Non-zero voltage vector on plane - [2].**

For zero voltage vectors, the vector represented as zero magnitude, it refer to the zero switching state. For example:

$$V_{ab} = 0$$

$$V_{bc} = 0$$

$$V_{ca} = 0$$