SPACE VECTOR MODULATION FOR FIVE-PHASE INDUCTION SPEED DRIVE CONTROL

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

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MAY 2014

I declare that this report entitle “Space Vector Modulation for Five-phase Induction Speed Drive Control" is the result of my own research except as cited I the reference. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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" I hereby declare that I have read through this report entitle " Space Vector Modulation for Five-phase Induction Speed Drive Control" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drive) "

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Date	: ………………………………

Dedicate to beloved parents and family.

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ABSTRACT

Multiphase motor drives considered for various applications. Utilization of AC machines with number higher than three can be enables using application of power electronic in electrical drives. The 5-phase motor drive has many advantages compared with the 3-phase motor such as reducing amplitude of torque and current pulsation. Aim of this project is to control the speed response of five-phase induction motor using a space vector modulation. Space vector modulation has chosen as the switching scheme due to its easiness of digital implementation. Space vector modulation gives effective control of multiphase VSI because of large numbers of space vectors. The elaborated aspects include advantages of multiphase induction machines, modeling of five-phase induction machines and five-phase voltage source inverter and control scheme of space vector modulation. . For this project, space vector modulation schemes for a 5-phase VSI generated to drive 5-phase induction motor in order to control the speed of the motor. The speed of the motor should follow the reference speed that give as input. The performance of the five-phase induction motor been analyzed.

ABSTRAK

Pemacu motor berbilang telah meluas penggunaannya. Penggunaan AC motor dengan bilangan fasa melebihi tiga boleh aplikasikan dengan menggunakan peranti elektronik kuasa dalam pemacu elektrik. Pemacu motor lima fasa mempunyai banyak kelebihan apabila dibandingkan dengan pemacu tiga fasa, contoh kelebihannya ialah amplitud tork dan denyutan arus dapat dikurangkan. Tujuan utama projek ini adalah untuk mengawal kelajuan motor aruhan lima fasa dengan menggunakan modulasi vektor ruang. Modulasi vektor ruang dipilih sebagai peralihan skim kerana pelaksanaan digitalnya yang mudah. Modulasi vektor ruang memberikan peralihan skim yang sangat berkesan untuk sumber penyongsang voltan lima fasa kerana modulasi vektor ruang mempunyai banyak ruang. Huraian didalam laporan ini termasuk kebaikan motor aruhan pelbagai fasa, pemodelan motor aruhan lima fasa, sumber penyongsang voltan lima fasa dan peralihan skim untuk modulasi vektor ruang. Untuk projek ini, peralihan skim untuk sumber penyongsang voltan dihasilkan bagi memacu motor aruhan lima fasa. Kelajuan motor mesti mengikut kemasukan yang diberikan. Prestasi motor dianalisa diakhir projek ini.

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d : direct axis

q : quadrature axis

s : stator variable

r : rotor variable

V_{qs}, V_{ds} : d and q-axis stator voltages

V_{qr}, V_{dr} : d and q-axis rotor voltages

I_{qr}, I_{dr} : d and q-axis rotor currents

I_{qr}, I_{dr} : d and q-axis rotor currents

$\emptyset_{qs}, \emptyset_{ds}$: d and q-axis magnetizing flux linkages

p : number of poles

J : moment of inertia

T_e : electrical output torque

ω_a : stator angular electrical frequency

ω_r : rotor angular electrical speed.

CHAPTER 1

INTRODUCTION

1.1 Project Overview

For this project, the speed of the motor has control by space vector modulation. The five-phase voltage source inverter (VSI) is use to run five-phase induction motor. Space vector modulation has chosen as the switching scheme due to its easiness of digital implementation. Space vector modulation gives effective control of multiphase VSI because of large numbers of space vectors. Voltage source inverter (VSI) implemented using ten Metal-oxide Semiconductor Field Effect Transistor (MOSFET). The speed of the motor should follow the reference speed that give as input.

1.2 Project Motivation

Nowadays, multiphase motor drives considered for various applications. Utilization of AC machines with number higher than three can be enables using application of power electronic in electrical drives. The five-phase motor drive has many advantages compared with the 3-phase motor such as reducing amplitude of torque and current pulsation.

Five-phase drives supplied from five-phase voltage source inverter (VSI) and adequate method for VSI pulse width modulation are therefore required. For this project, space vector modulation schemes for a five-phase VSI generated to drive five-phase induction motor in order to control the speed of the motor.

1.3 Problem Statement

A 5-phase machine has high fault tolerance. When one of the phase become fault, the machine can operate with three phase left. In order to run 5-phase machine, the drive system need to design and the space vector has chosen because it easy digital implementation.

1.4 Objectives

The research objectives are:

i. To design switching scheme for speed control of a five-phase induction motor and its drive.

ii. Simulate the five-phase speed drive control using a Matlab/Simulink.

iii. To analyze the performance of five-phase induction motor speed by space vector modulation.

1.5 Scope of Project

Scope of this project is running under the simulation environment. First, Matlab software will be use for simulation purposes. Then, the five-phase inverter and five-phase induction motor will stimulate in the Matlab/Simulink. After that, the switching scheme for five-phase inverter will program in Matlab/Simulink. Last, the five-phase induction motor will program in Matlab/Simulink. The drive will slowly design for induction motor and reference will be using space vector modulation.

1.6 Report Outlines

This report contains five chapters that explain in detail about the entire project to provide the understanding of the whole project.

Chapter 1- Introduction of the project

This chapter presents an overview of the project, objectives project, scope project and project outline.

Chapter 2- Literature Review

This chapter discuss about source and article that related to the project. This chapter also contains the theory of the components, equipments and programming software that used in the project. It helps more in understanding the concepts of the project.

Chapter 3- Design Methodology

This chapter covers up all the project implementation to achieve the objectives of the project. This chapter contains the method and procedure to finish the project. It also contains the step taken for the entire task to complete the project. All method and procedure to generate the expected results and the software technical details also explained in this chapter.

Chapter 4- Results and Discussion

This chapter contains the results and analysis of the project that been done. The results and the expected result also discuss in this chapter.

Chapter 5- Conclusion

This chapter contains the conclusion that can conclude from the project and the recommendations to improve the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Space Vector Modulation

Space vector modulation supplies AC machine with desired phase voltage. The space vector modulation method of generating the pulsed signals fit the requirement and minimizes the harmonic contents. Note that the harmonic content determines copper losses of the machine that account for a major portion of the machine losses [1].

Interest in multi phase drives has increased in recent years due to several advantages when compared to three-phase drives. Multi phase drive has some advantages that are less torque ripple, less acoustic noise and losses, reduced current per phase or increased reliability due to additional number of phases. Space vector modulation (SVM) is one of the most popular choices because it easy digital implementation and better utilization of the available dc bus voltage [2-3].

Power circuit topology for five-phase voltage source inverter with star-connected load presented. Five-phase space vector modulation can be developing as three phase space vector modulation for a period of the fundamental frequency. It shows the basic ten large and ten medium switching vectors for five-phase inverter.

Total voltage space vector in five-phase inverter is 32 vectors but only 22 vectors used, consists of ten large and ten medium active vectors and two zero vectors. This is to decrease number of switching in inverter and decrease switching losses.

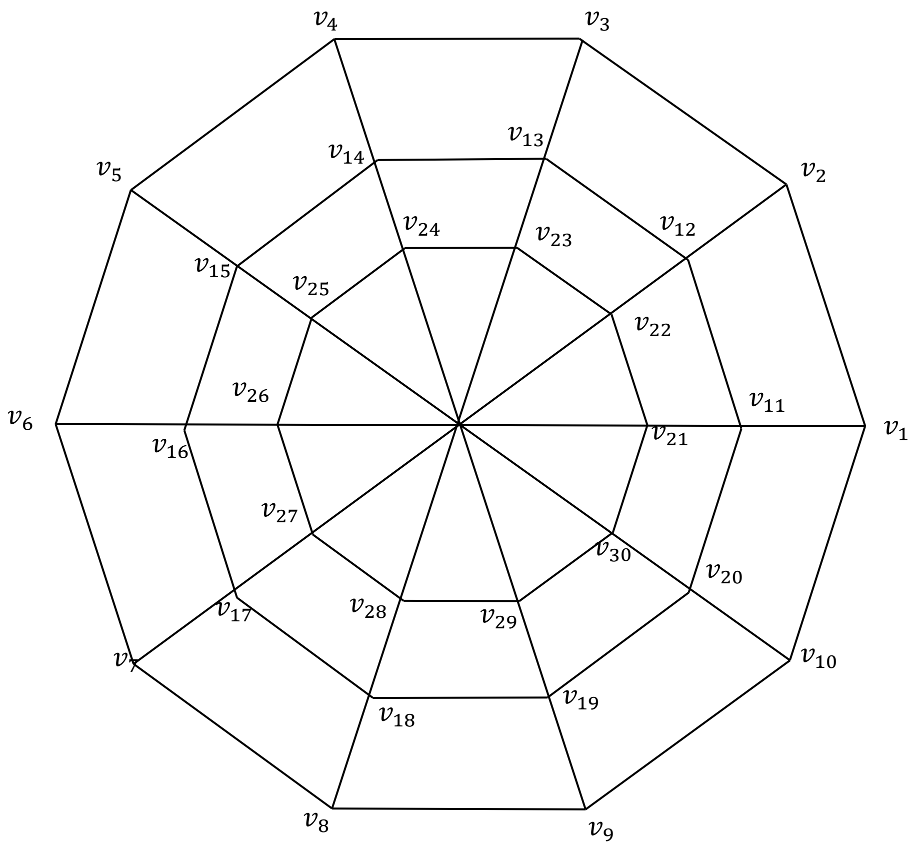

Figure 2.1: Phase to neutral voltage space vector in d-q plane.

When five-phase operated in PWM mode, there will be additional 22 switching states. 2^n is the general equation for number of possible switching states, where n is the number of inverter leg. The remaining twenty-two switching states encompass three possible situations. First, all the states when four switches from upper (or lower) half and one from the lower (or upper) half of the inverter are ‘on’ at state’s 11 until 20. Next, two states when either all the five upper (lower) switches are ‘on’ at state’s 31 and 32. Last, the remaining states with three switches from the upper (lower) half and two switches from the lower (upper) half are ‘on’ at state’s 21until 30.

2.2 Induction Motor

Induction motor is the one of the most common electrical motor use. This motor runs at speed lower than synchronous speed and it also known as a synchronous motor. The speed of rotation of the magnetic field in a rotary machine called as synchronous speed. Frequency and number of the machine influence synchronous speed of the motor. Flux generated in the rotor by the rotating magnetic field in the stator make the rotor to rotate.

There will be lag for the flux in the stator and rotor that makes the rotor cannot reach the synchronous speed. That why speed of the induction machine always less than synchronous speed. Induction process occurred in the induction motor.

The working principle of the induction motors are as follow. When give supply to the stator winding, flow of current in the coil will generate the flux in the coil. The arrangement of the rotor winding will make it becomes short circuit in the rotor itself. When the rotor coil are short circuit, current will flow in the coil of the rotor because flux of the stator cut the coil of the rotor. The flowing current will generated another flux in the rotor. There will be two fluxes that is stator, rotor flux, and the stator flux will leading the rotor flux. Due to this, rotor will produce torque that makes the rotor to rotate in the direction of rotating magnetic flux. Therefore, the speed of the rotor will be depending upon the ac supply and the speed can control by varying the input supply.

Fig 2.2 shows the equivalent per-phase electric circuit of an induction motor which consist of traditional parameters that is stator resistance, R_1, stator leakage reactance, X_1, magnetizing reactance, X_m, rotor leakage reactance, X_2 and rotor resistance, R_2.

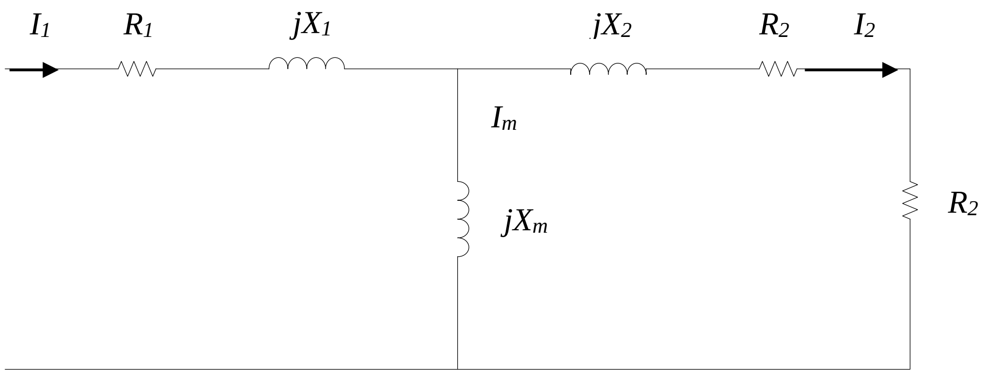

Figure 2.2: Per-phase equivalent circuit for induction motor.

2.3 Multiphase Induction Motor

Induction motor more than three-phase have same properties with three-phase induction motor that run without producing a twice line-frequency pulsating torque and accelerate theirs load from rest. Multiphase induction motors not connected directly to three-phase supplies. Three-phase supply connected to the power electronic converter that drive excitation for the multiphase induction motor. The output of the converter must have the same phase with the stator winding of the motor.

Multiphase machine have some advantages compare to three-phase machine. One of the advantage of multiphase machine is the efficiency of the multiphase machine is higher than three-phase machine because of the multiphase machine produces a field with lower space-harmonic content at the stator excitation. Second, multiphase machine have greater fault tolerance than three-phase machine [4-5].

Last, multiphase machine are less susceptible compare to three-phase machine to time harmonic components in the excitation waveform. Multiphase motor can reduce the required rating of power electronic components for the given motor output power. Important role of multiphase machine is to provide the concentrated stator winding rather than distributed stator winding. Injection of higher stator current harmonics can increase torque production [4-5].

Multiphase motor can reduce the stator current without increasing the stator voltage and it has greater fault tolerance [1]. For modeling of five-phase induction machine, assume that the same number of phases of stator and rotor winding with spatial displacement between any two phases of $\alpha = 2\pi/5$. Model of the machine transformed into a common reference frame, rotating at an arbitrary angular speed.

2.4 Voltage source inverter

Inverter in power electronic denotes a class of power conversion circuits that operates from dc voltage source or a dc current source and converts it into ac voltage or current. The inverter is the reverse of the as to dc converter. Primary source of input power may be utility ac voltage supply that converted to dc by an ac to dc converter and then been inverted back to ac using an inverter. The final ac output may have different frequency and magnitude compare to input ac of the utility supply.

Figure 2.3 shows the five-phase inverter that consist of ten MOSFET arranged in parallel. The capital letter is line voltage and the small letter is the phase voltage of the inverter. The relationship of line voltage and phase voltage are shows in equation 2.1.

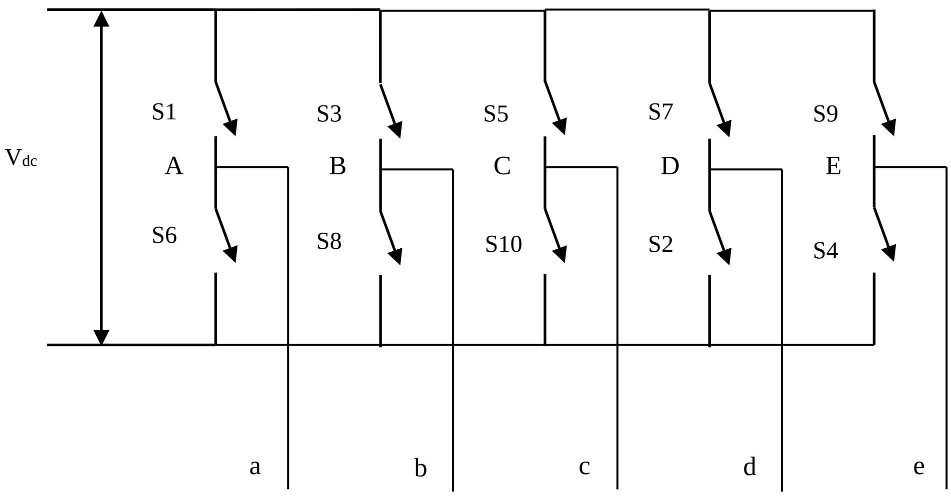

Figure 2.3: Power circuit of five-phase voltage source inverter.

$$v_a = \left(4/5\right)v_A - \left(1/5\right)(v_B + v_C + v_D + v_E)$$
$$v_b = \left(4/5\right)v_B - \left(1/5\right)(v_A + v_C + v_D + v_E)$$
$$v_c = \left(4/5\right)v_C - \left(1/5\right)(v_A + v_B + v_D + v_E) \qquad (2.4.1)$$
$$v_d = \left(4/5\right)v_D - \left(1/5\right)(v_A + v_B + v_C + v_E)$$
$$v_e = \left(4/5\right)v_E - \left(1/5\right)(v_A + v_B + v_C + v_D)$$