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“I hereby declared that I have read through this report entitle “Speed Control of Permanent Magnet Synchronous Motor Drive Using Fuzzy Logic Controller” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drive).”

Signature :

Supervisor Name : Associates Professor Dr. Zulkifilie Bin Ibrahim

Date :

**SPEED CONTROL OF PERMANENT MAGNET
SYNCHRONOUS MOTOR DRIVE USING FUZZY LOGIC CONTROLLER**

CHANG TING WEI

**A report submitted in partial fulfillment of the requirements for the degree of
Bachelor in Electrical Engineering**

**Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

2015

DECLARATION

I declared that this report entitle “Speed Control of Permanent Magnet Synchronous Motor Drive Using Fuzzy Logic Controller” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Chang Ting Wei

Date :

DEDICATION

To my beloved father, mother, my brothers and family

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I would like to take this opportunity to express my gratitude toward those authorities who support and give a helping hand to me for accomplish this final year project.

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ABSTRACT

The aim of this project is to utilize the fuzzy logic controller (FLC) in controlling the speed of a sinusoidal permanent magnet synchronous motor (PMSM) drive. The fixed controlled parameter of SPMSM drive with fuzzy logic control are studied during the nominal phase and load disturbance phase and will be compared with the reference parameters to see the degrade of the speed performance. Besides, the study of re-tuning of membership function for difference speed command will be perform in this project to observe the changes in speed response. Other than that, several operating condition such as the forward and reverse speed operation, load disturbance and step reduction of various speed command are implemented to study the speed performance of the driver system in term of overshoot, undershoot, rise-time, settling time, speed and recovery time. Lastly, this project will be separated into two part, which is the simulation part and experimental part. Simulation part will be on the design of a Simulink model for the purpose of study the speed behavior of the motor drive. Whereas for the experimental part, hardware will be implemented and collaborated with SIMULINK and dSPACE to see the synchronization level of the speed response between the simulations part result and experimental part result. The result will be explained and shown in graph form by using the Matlab/Simulink software.

ABSTRAK

Tujuan projek ini adalah untuk menggunakan pengawal logik kabur (FLC) dalam mengawal kelajuan pemacu motor segerak magnet kekal (PMSM). Parameter tetap yang dikawal dengan kawalan logik kabur dalam pemacu motor segerak magnet kekal akan dikaji semasa fasa pemulaan dan fasa gangguan dan seterusnya akan dibandingkan dengan parameter rujukan untuk memperhatikan prestasi penurunan kelajuan motor. Selain itu, kajian untuk membuat penalaan fungsi keahlian untuk kelajuan yang berbeza akan dilaksanakan dalam projek ini bagi memerhati tindak balas perubahan dalam kelajuan. Selain daripada itu, beberapa operasi seperti operasi kelajuan depan-belakang, gangguan beban dan pengurangan langkah dari pelbagai perintah kelajuan akan dilaksanakan untuk mengkaji prestasi kelajuan sistem pemandu dari segi lajak, lajak bawah, masa naik, masa penganapan, kelajuan dan masa pemulihan. Akhir sekali, projek ini akan dibahagikan kepada dua bahagian, iaitu bahagian simulasi dan bahagian eksperimen. Bahagian simulasi adalah pada reka bentuk bagi model SIMULINK bertujuan mengkaji tingkah laku kelajuan pemacu motor. Manakala bahagian eksperimen, perlaksanaan perkakasan dan kerjasama dengan SIMULINK dan dSPACE untuk melihat tahap penyegerakan tindak balas kelajuan antara hasil bahagian simulasi dan hasil bahagian eksperimen. Hasilnya akan diterangkan dan ditunjukkan dalam bentuk graf dengan menggunakan perisian MATLAB/SIMULINK.

TABLE OF CONTENT

CHAPTER	TITLE	PAGE
	ACKNOWLEDGEMENT	v
	ABSTRACT	vi
	ABSTRAK	vii
	TABLE OF CONTENT	viii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
	LIST OF ABBREVIATIONS	xviii
	LIST OF APPENDICES	xix
1	INTRODUCTION	1
	1.1 Research Background	1
	1.2 Problem Statement	4
	1.3 Objectives	5
	1.4 Scope	5
	1.5 Expected Outcome	6
	1.6 Report Outline	6
2	LITERATURE REVIEW	8
	2.1 Introduction	8
	2.2 Permanent Magnet Synchronous Motor (PMSM) Drive	8
	2.3 Conventional Speed Controllers	9
	2.4 Fuzzy Logic Controller (FLC)	11
	2.4.1 Membership Function	14
	2.5 Pulse Width Modulation	17
	2.5.1 Hysteresis Current Control	18

	2.6 Summary	19
3	METHODOLOGY	20
	3.1 Introduction	20
	3.2 Simulations	21
	3.2.1 Permanent Magnet Synchronous Motor (PMSM) Drive	21
	3.2.1.1 Mathematical Modelling for PMSM Drive	22
	3.2.1.2 Electrical Modelling for PMSM Drive	23
	3.2.1.3 Mechanical Modelling for PMSM Drive	24
	3.2.2 Fuzzy Logic Controller (FLC)	25
	3.2.2.1 Membership Function of Fuzzy Logic Controller	27
	3.2.2.2 Rule Base of Fuzzy Logic Controller (FLC)	30
	3.2.3 Simulink Model	34
	3.2.3.1 The Fuzzy Logic (FL) Speed Controller	36
	3.2.3.2 Vector Transformation	38
	3.2.3.3 Pulse Width Modulation (PWM) Inverter	39
	3.2.3.4 Hysteresis Current Control	40
	3.3 Experimental Investigation	40
	3.3.1 Simulation Procedure	41
	3.3.1.1 MATLAB	42
	3.3.1.2 FLC Implementation in dSPACE and ControlDesk Environment	45
	3.3.1.3 Fuzzy Logic Speed Controller in Experimental Investigation	46
	3.3.1.4 Inverse Park Transformation in Experimental Investigation	47
	3.3.1.5 Three Phase Actual Current of Experimental Motor	47
	3.3.1.6 Function Block of Motor Speed and Motor Rotor Angle	48
	3.3.1.7 ControlDesk	49
	3.3.2 Hardware Implementation	49
	3.3.2.1 Personal Computer (PC)	50
	3.3.2.2 Digital Signal Processor (DSP)	51

	3.3.2.3 Opto-coupler	51
	3.3.2.4 Three Phase IGBT Gate Driver	52
	3.3.2.5 Three Phase Voltage Source Inverter	53
	3.3.2.6 Resolver-to-linear DC (R/LDC) Converter	53
	3.3.2.7 Current Sensor	54
	3.3.2.8 Permanent Magnet Synchronous Motor Drive	55
	3.4 Procedure of Experiment	55
	3.5 Flow Chart	58
	3.6 Gantt Chart	59
4	RESULT AND DISCUSSION	60
	4.1 Introduction	60
	4.2 Simulation Procedure	61
	4.2.1 Forward and Reverse Operation	61
	4.2.2 Load Disturbance	64
	4.2.3 Step Reduction in Speed Command	67
	4.2.3.1 20% Step Reduction from 1000rpm	67
	4.2.3.2 50% Step Reduction from 800rpm	69
	4.2.3.3 50% Step Reduction from 400rpm	70
	4.2.4 Change of Area of Membership Function	72
	4.2.5 Change of Initial Speed Command	74
	4.2.5.1 Medium Speed Operation	75
	4.2.5.2 Low Speed Operation	78
	4.3 Hardware Implementation	80
	4.3.1 Signal Testing	81
	4.3.1.1 Signal Testing at Opto-coupler	81
	4.3.1.2 Signal Testing At Three Phase IGBT Gate Driver	83
	4.3.1.3 Signal Testing At Three Phase Voltage Source Inverter (VSI)	84
	4.3.2 Scalar Control	87
5	CONCLUSION	91
	5.1 Conclusion	91

5.2 Future Work	92
REFERENCES	93
APPENDICES	96

LIST OF TABLES

TABLE	TITLE	PAGE
3.0	The fuzzy rule table for output.	31
3.1	The value of G_e , G_{e1} and G_{ce} .	37
3.2	The values of the speed errors and change of speed error	46
3.3	Gantt chart showing the activities for this project.	59
4.0	Experimental value of V/f ratio.	87

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.0	Basic scheme of permanent magnet synchronous motor	2
1.1	Basic structure of fuzzy logic controller (FLC)	3
2.0	Block diagram for a Proportional Integral (PI) controller system	10
2.1	Block diagram for a Proportional Integral Derivative (PID) controller system	10
2.2	A fuzzy logic controller implementation circuit on DSRV model	11
2.3	Block diagram of a fuzzy logic controller (FLC) system.	13
2.4	Block diagram of hybrid proportional integral- fuzzy logic controller	13
2.5	A 3×3 partition membership function for input	14
2.6	A 5×5 partition membership function for input	14
2.7	A 7×7 partition membership function for input	15
2.8	Different shape of membership functions	17
2.9	The waveform of the carrier, modulation and the output signal	18
2.10	Pulse which produce by the hysteresis band.	19
3.0	Block diagram of FLC for speed control of PMSM drive.	21
3.1	The structure of a PMSM Drive	22
3.2	The electrical model of PMSM drive	23
3.3	The mechanical model of PMSM drive	25
3.4	Block diagram of Fuzzy Logic Controller (FLC) system	27
3.5	The Fuzzy Inference System (FIS) Editor layout	28
3.6	The membership function for speed error, e	29
3.7	The membership function for change of speed error, Δe	29
3.8	The membership function for output torque	29
3.9	The rule viewer of Fuzzy Logic Controller (FLC)	32

3.10	The surface viewer of the Fuzzy Logic Controller (FLC)	33
3.11	The block diagram for the PMSM drive	34
3.12	The internal component of PMSM drive	35
3.13	The internal structure of the speed controller	36
3.14	The phasor diagram for the dq vector transformation	38
3.15	The d-q vector transformation mathematical model of the motor drive	38
3.16	A PWM inverter structure	39
3.17	The hysteresis current control structure	40
3.18	Configuration for the experimental setup	41
3.19	Block diagram of speed control of SPMSM drive using fuzzy logic controlled	43
3.20	Circuit diagram for speed control of SPMSM drive using fuzzy logic controller in experimental investigation	44
3.21	FLC implementation in dSPACE and ControlDesk environment	45
3.22	The circuit diagram of the fuzzy logic controller in experimental investigation	46
3.23	The circuit diagram of inverse park transformation in experimental investigation	47
3.24	The circuit diagram of three phase actual current of experimental motor	47
3.25	The circuit diagram for speed and angle of experimental motor	48
3.26	The ControlDesk layout	49
3.27	The personal computer in the laboratory	50
3.28	The DSP control board	51
3.29	The Opto-coupler	52
3.30	The three phase IGBT gate driver	52
3.31	The three phase inverter	53
3.32	The resolver-to-linear DC converter	54
3.33	The current sensor	54
3.34	The PMSM drive with DC generator	55
3.35	The hardware configuration for the speed control of PMSM using FLC	57

3.36	Flow chat	58
4.0	Speed performance during forward and reverse operation	62
4.1	Enlarge scale of forward operation during transient state	62
4.2	Enlarge scale of reverse operation during transient state	62
4.3	Three phase current during forward and reverse operation	63
4.4	i_d and i_q current during forward and reverse operation	63
4.5	Torque during forward and reverse operation	63
4.6	Speed response during load disturbance	64
4.7	Enlarge scale of speed response during load disturbance	65
4.8	Three phase current during load disturbance	65
4.9	Enlarge scale of the three phase current during load disturbance	65
4.10	i_d and i_q current during load disturbance	66
4.11	Torque during load disturbance	66
4.12	Speed response during 20% step reduction from 1000rpm	67
4.13	Enlarge scale of speed response during 20% step reduction from 1000rpm	67
4.14	Three phase current during 20% step reduction from 1000rpm	68
4.15	i_d and i_q current during 20% step reduction from 1000rpm	68
4.16	Speed response during 50% step reduction from 800rpm	69
4.17	Enlarge scale of speed response during 50% step reduction from 800rpm	69
4.18	Three phase current during 50% step reduction from 800rpm	69
4.19	i_d and i_q current during 50% step reduction from 800rpm	70
4.20	Speed response during 50% step reduction from 400rpm	70
4.21	Enlarge scale of speed response during 50% step reduction from 400rpm	71
4.22	Three phase current during 50% step reduction from 400rpm	71
4.23	i_d and i_q current during 50% step reduction from 400rpm	71
4.24	The new membership function for output torque	72
4.25	Speed response during change of area of membership function	72
4.26	Enlarge scale of speed response during change of area of membership function	73

4.27	Three phase current during change of area of membership function	73
4.28	i_d and i_q current during change of area of membership function	73
4.29	Torque during change of area of membership function	74
4.30	Speed response during change of initial condition with load at medium speed	75
4.31	Enlarge scale of speed response during forward condition with load at medium speed.	75
4.32	Enlarge scale of speed response during reverse condition with load at medium speed.	76
4.33	Enlarge scale of speed response during load condition at medium speed	76
4.34	Three phase current with load disturbance at medium speed	76
4.35	Enlarge scale of three phase current during forward to reverse condition at medium speed	77
4.36	Enlarge scale of three phase current during reverse to loaded condition at medium speed	77
4.37	Speed response during change of initial condition with load at low speed	78
4.38	Enlarge scale of speed response during forward condition with load at low speed	78
4.39	Enlarge scale of speed response during reverse condition with load at low speed	78
4.40	Enlarge scale of speed response during load condition at low speed	79
4.41	Three phase current with load disturbance at low speed	79
4.42	Enlarge scale of three phase current during forward to reverse condition at low speed	79
4.43	Enlarge scale of three phase current during reverse to loaded condition at low speed	80
4.44	Output voltage of Phase A	82
4.45	Output voltage of Phase \bar{A}	82
4.46	Output voltage of Phase B	82

4.47	Output voltage of Phase \bar{B}	82
4.48	Output voltage of Phase C	82
4.49	Output voltage of Phase \bar{C}	82
4.50	Output voltage of Phase A	83
4.51	Output voltage of Phase \bar{A}	83
4.52	Output voltage of Phase B	84
4.53	Output voltage of Phase \bar{B}	84
4.54	Output voltage of Phase C	84
4.55	Output voltage of Phase \bar{C}	84
4.56	Output of Phase A at VSI	85
4.57	Output of Phase \bar{A} at VSI	85
4.58	Output of Phase B at VSI	86
4.59	Output of Phase \bar{B} at VSI	86
4.60	Output of Phase C at VSI	86
4.61	Output of Phase \bar{C} at VSI	86
4.62	Speed response during 10V of voltage supply	88
4.63	Three phase current during 10V of voltage supply	88
4.64	Speed response during 10V of voltage supply at different angle	88
4.65	Three phase current during 10V of voltage supply at different angle	89
4.66	Speed response during 10V of power supply from standstill to stop	89
4.67	Speed response during 10V of power supply from standstill to stop	89

LIST OF ABBREVIATIONS

AC	-	Alternate Current
DC	-	Direct Current
DSP	-	Digital Signal Processor
FL	-	Fuzzy Logic
FLC	-	Fuzzy Logic Controller
IGBT	-	Insulated Gate Bipolar Transistor
PMSM	-	Permanent Magnet Synchronous Motor
PWM	-	Pulse Width Modulation
RPM	-	Revolution per Minutes
VSI	-	Voltage Source Inverter

LIST OF APPENDICES

APPENDICES	TITLE	PAGE
A	49 If_Then rule	96
B	Opto-coupler Specification	97
C	Three Phase IGBT Gate Driver Circuit Diagram and Component Specification	98
D	Three Phase Voltage Source Inverter Specification	99
E	Resolver-to-digital Converter Specification	100
F	Hall Effect Current Sensor Specification	101
G	BALDOR Motor Specification	102

CHAPTER 1

INTRODUCTION

1.1 Research Background

In concern with the advancement of technology and application in this era, high performance of motor drive are needed to scope this requirement. Therefore, a lot of motor drive have been introduced by the professional to the society so that the requirement of high performance motor drive can be fulfill.

Nowadays, Permanent Magnet Synchronous Motor (PMSM) Drive is very popular in high performance variable speed drive due to its high power density, high efficiency, high power factor and low inertia characteristic. Besides, permanent magnet synchronous motor (PMSM) drive are also good in conserve energy compare to other nonlinear motor drive. Permanent magnet synchronous motor (PMSM) drive can be categorized into two types depending in the control strategy with the inverter supply system. The two types are the rectangular wave electronically commutated permanent magnet synchronous motor which is also known as Brushless DC (BLDC) motor and the sinusoidal wave fed Permanent Magnet Synchronous Motor (PMSM) which is known as permanent magnet synchronous motor.

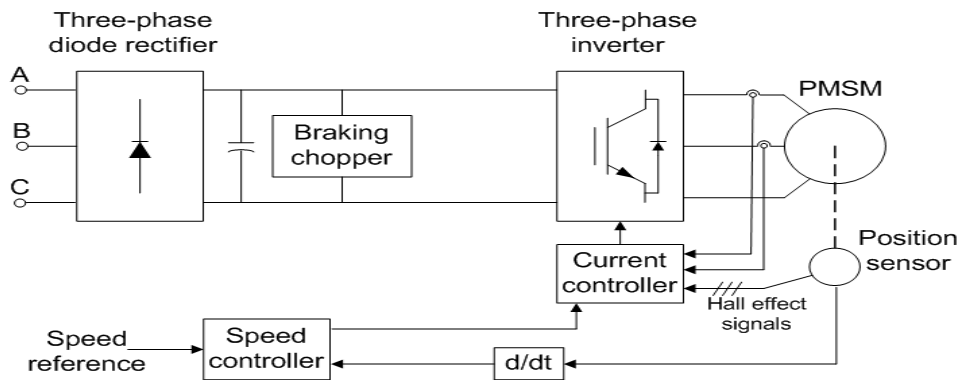


Figure 1.0: Basic scheme of permanent magnet synchronous motor

The speed controller used in the speed control system plays an important role as it needs to meet the criteria of the high performance drive. Conventional controllers such as the Proportional (P) controller, Proportional Integral (PI) controller, and Proportional Integral Derivative (PID) controller can't achieve the high performance in the speed control as there are a lot of aspects that need to be taken into consideration. The aspects are the changes in transient response, error integral, unknown dynamics and other factors such as noise and temperature. These changes of factors will cause the output to be shattering from the required output.

Besides, these conventional controllers require an accurate mathematical model to describe the dynamics of the system under control and require fine tuning for the parameter variations. Lastly, the conventional controller design depends only on the exact system with accurate motor parameters and its fixed gain controllers are sensitive to system disturbances.

Therefore, Fuzzy Logic Controller (FLC) controllers are recommended to be used in this speed control system. This is because FLCs are simpler than the other controller schemes since they don't need complicated mathematical manipulations and they only have 3 stages for the conversion of output torque from the speed error and the rate of change of speed error. The three stages are the fuzzification, rule execution and defuzzification. These three stages are important as they will produce the desired output for the speed controlling command.

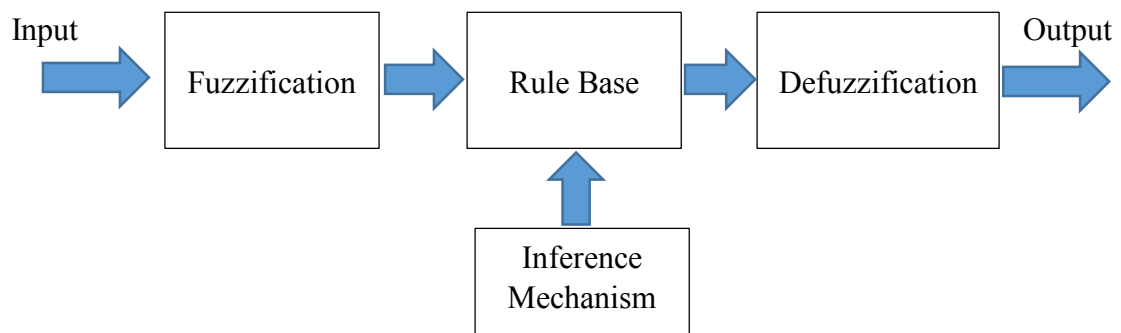


Figure 1.1: Basic structure of fuzzy logic controller (FLC)

Other than that, FLC have high robust ability, low cost and less complex compared with other conventional controller. The biggest difference of this controller with conventional controller is that it execute a set of control rule by following a rule base. The rule base is the IF X AND Y, THEN Z rules. Membership function also play an important roles in FLC, it need to be chosen such that it cover the whole universe of discourse. Other than that, the membership function should also overlapping with each other so to avoid any kind of discontinuity with respect to the minor changes in the inputs.

Besides, several technique such as the adaptive control, neural network control, robust control and variable structure control are introduced to overcome the nonlinearity problem and improve the dynamic response of the sinusoidal permanent magnet synchronous motor drive (PMSM) with fuzzy logic control system.

Fuzzy logic controller (FLC) solves the problem of nonlinearities and parameter variations of sinusoidal permanent magnet synchronous motor (PMSM) drive. Addition, it can achieves high dynamic performance and accurate speed control with good steady-state characteristics. The control performance can be seen in the MATLAB SIMULINK simulation with various operating with it.

1.2 Problem Statement

Over the decade, the usage of fuzzy logic controller have been increase in the power electronic and automotive field. This is mainly because of the easy tuning features of the fuzzy logic and the simple structure of the fuzzy logic controller which ease the implementation of the controller to the machine or system. Fuzzy logic controller is easy to implement compared to other current controller such as the Proportional Integral (PI) Controller and Proportional Integral Derivative (PID) Controller. The fixed controlled parameter of fuzzy logic controller will degrade the speed performance for different speed command. Therefore, the fixed controlled parameter need to be keep constant so that the speed performance behaviour will be constant. However, the re-tuning and designing of membership function in FLC for difference speed command is one of the problem facing in this project since there is a lot of way to design the membership function [1]. It is hard to decide which range and shape of the membership function should use for this project. Besides, it is also difficult in changing and tuning the fuzzy logic controller (FLC) in order to obtain good speed response since FLC have variation of rule [2]. The designing and tuning of the fuzzy logic controller are all by trial and error method, which mean that the process are time consuming and depend on the knowledge and experience of the user to design and utilize the fuzzy logic controller.

As a summary, the problem statement are:

- I. The fixed controlled parameter which will degrade the speed performance for different speed command.
- II. The re-tuning and designing of membership function in fuzzy logic controller (FLC) for difference speed command.
- III. The difficulty in changing and tuning the fuzzy logic controller (FLC) in order to obtain good speed response since FLC have variation of rule

1.3 Objective

The objective of this project are:

- I. To design and develop a fuzzy logic controller using Matlab Simulink.
- II. To investigate and analyze the speed response behavior of the drive which vary with the constant parameter of fuzzy logic.
- III. To study the correlation between rule base and membership function in speed response behavior.
- IV. To implement the fuzzy logic speed controller to the PMSM drive.

1.4 Scope

The project mainly focuses on:

- i. The mathematical model of vector control of permanent magnet synchronous motor (PMSM) drive.
- ii. The control of fixed controller parameter of a sinusoidal permanent magnet synchronous motor (PMSM) drive by using fuzzy logic controller.
- iii. The modelling and simulation of Fuzzy Logic Controller (FLC) for permanent magnet synchronous motor (PMSM) drive using Matlab or Simulink.
- iv. The experimental evaluation on the performances of Fuzzy Logic Controller (FLC) in permanent magnet synchronous motor (PMSM) drive in terms of switching frequency and current control.