

الآية

﴿بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ﴾1

الْحَمْدُ لِلَّهِ رَبِّ الْعَالَمِينَ﴿2﴾ الرَّحْمَنِ الرَّحِيمِ

﴿3﴾ مَالِكِ يَوْمِ الدِّينِ ﴿4﴾ إِيَّاكَ نَعْبُدُ وَإِيَّاكَ

نَسْتَعِينُ ﴿5﴾ أَهْدِنَا الصِّرَاطَ الْمُسْتَقِيمَ

﴿6﴾ صِرَاطَ الَّذِينَ أَنْعَمْتَ عَلَيْهِمْ غَيْرِ الْمَغْضُوبِ

عَلَيْهِمْ وَلَا الضَّالِّينَ﴿7﴾

سورة الفاتحة (1-7)

DEDICATIONS

The words and measures can never express my deepest gratitude to my parents. They have been a force of strength all along, and without them it would have been an uphill task for me to complete this work.

Last but not the least, I am deeply indebted to my brothers, sisters and my friends; their incessant support made me achieve new heights in life and built my character and career.

ACKNOWLEDGEMENT

I wish to express my profound gratitude to my Supervisor Dr.AwadAlla Taifour, for his valuable guidance, continuous encouragement, worthwhile suggestions and constructive ideas throughout this research. His support, pragmatic analysis and understanding made this study a success and knowledgeable experience for me.

ABSTRACT

The goal of adaptive control is to adjust unknown or changing plant parameters. This is accomplished by either changing parameters in the controller to minimize error, or using plant parameter estimates to change the control signal. Therefore, there are many different approaches to adaptive control such as self-tuning and model reference adaptive control (MRAC).

Use of variable speed control to improve DC motor performance and efficiency has become the core of recent developments in industry. Among adaptive control methods the MRAC has earned wide respect since its effectiveness is sufficiently illustrated in real time applications.

In this study the idea is for a further perfection to the MRAC method. This is examined when combining the MRAC method with the fuzzy logic control (MRAFC). The choice of the fuzzy logic is based on its main feature; that its logic flow approaches real time situations more than most of the other known algorithms. The idea of perfection is to provide an even more smooth control to the DC motor and to minimize deficiencies of the traditional MRAC method.

This study deals with the conventional MRAC and replaces it with MRAFC. The performance of the drive system obtained, formed a set of test conditions with MRAFC. The performance of the drive is tested for load disturbances along with reference model. This study also compares the performance of MRAFC over conventional MRAC. To achieve these objectives the simulation environment is provided in the MATLAB Simulink.

المستخلص

هدف السيطرة التكيفية تعديل معاملات النظام المجهولة أو المتغيرة، وهذا التعديل يتم إما بواسطة تغيير المعاملات في جهاز التحكم لتقليل الخطأ، أو استعمال تخمينات لثوابت النظام من أجل تغيير إشارة التحكم. لذا، هناك العديد من الطرق المختلفة للتحكم التكيفي مثل التحكم الذاتي أو التحكم النموذجي المرجعي التكيفي.

استخدام تحكم السرعة المتغيرة لتحسين الأداء والكفاءة لمحركات التيار المستمر أصبح من صميم التطورات الحديثة في الصناعة. ومن بين تقنيات التحكم التقليدية تقنية النموذج المرجعي التحكمي التكيفي التقليدي MRAC الذي كسب شهرة وثقة واسعة لفعاليته في تطبيقات الزمن الحقيقي في بعض الأنظمة.

هذا الدراسة تسعى لتحسين تقنية النموذج المرجعي التحكمي التكيفي التقليدي، الاختبار تم بالجمع بين نظامي تقنية النموذج المرجعي التحكمي التكيفي والتحكم الغامض (MRAFC). إن اختيار المنطق الغامض كان بسبب الميزة الأساسية لهذا النظام، وهي أن طريقة التدفق المنطقي تكون في حالة الزمن الحقيقي أكثر من أنظمة التحكم المعروفة الأخرى. والسعي لتحسين نظام التحكم من أجل توفير عنصر تحكم أكثر كفاءة وسلاسة لمحركات التيار المستمر والحد من أوجه القصور في طريقة تقنية النموذج المرجعي التحكمي التكيفي التقليدي MRAC .

في هذا الدراسة سوف يتم تحسين هذه التقنية، باستبدال تقنية النموذج المرجعي التحكمي التكيفي التقليدي MRAC بتقنية المخطط المرجعي التحكمي التكيفي باستخدام المتحكم الخطي الغامض MRAFC، حيث يختبر ويقارن مع حالة اضطرابات الحمل والاضطرابات الخارجية سوية مع النموذج التقليدي. تُستعمل بيئة المحاكاة المدرجة في Matlab Simulink لأداء تحليل تجريبي.

TABLE OF CONTENTS

	PAGE
الآية.....	i
DEDICATIONS.....	ii
ACKNOWLEDGEMENT.....	iii
ABSTRACT.....	iv
المستخلص.....	v
TABLE OF CONTENTS.....	vi
LIST OF FIGURES.....	ix
LIST OF TABLES.....	xiii
LIST OF ABBREVIATIONS.....	xiv
LIST OF SYMBOLS.....	xv
CHAPTER ONE: INTRODUCTION	
1.1 General.....	1
1.2 Objective of Research.....	2
1.3 Problem Statement	3
1.4 Methodology.....	3
1.5 Layout	4
CHAPTER TWO: LITERATURE REVIEW AND BACKGROUND	
2.1 Introduction.....	5
2.2 Construction of a DC motor.....	6
2.3 Principles of operation	9
2.4 Types of DC motors.....	9
2.5 Adaptive System.....	12
2.5.1 Model reference adaptive system (MRAS).....	12

2.5.1.1	Classifications of model reference adaptive control (MRAC).....	13
2.5.2	Adaptive laws.....	15
2.5.2.1	Sensitivity methods.....	15
2.5.2.2	Gradient and least squares methods	16
2.5.2.3	Lyapunov and positivity design approach.....	16
2.6	Fuzzy Logic and Fuzzy Controller.....	17
2.6.1	Fuzzy Sets, membership functions and logical operators.....	18
2.6.2	Linguistic variable and rules bases.....	19
2.6.3	Fuzzy logic models	21
2.6.3.1	Mamdani modeling.....	22
2.6.3.2	Sugeno modeling.....	25
2.3.4	Types of fuzzy controller.....	26

CHAPTER THREE: MATHEMATICAL AND SIMULINK MODELING OF DC MOTOR

3.1	Introduction.....	32
3.2	Model Design of DC Motor.....	32
3.2.1	Physical system.....	32
3.2.2	Electrical characteristics.....	33
3.2.3	Mechanical characteristics.....	34
3.2.4	Transfer function and block diagram.....	34
3.2.5	Simulink model of DC motor.....	36

CHAPTER FOUR: DC MOTOR CONTROL DESIGN

4.1	Introduction.....	39
4.2	Model Reference Adaptive Control (MRAC).....	39
4.2.1	Design MRAC technique for DC motor system.....	41
4.3	Model Reference Adaptive Control with Fuzzy Controller(MRAFC)	45

4.3.1	Design of fuzzy adaptive controller.....	46
4.3.1.1	Fuzzy Inference System (FIS) editor.....	48
4.3.1.2	Rule editor.....	49
4.3.1.3	Membership function editor.....	51
4.3.1.4	Rule viewer.....	53
4.3.1.5	Surface viewer.....	54
4.4	Matlab Simulation.....	55
<p style="text-align: center;">CHAPTER FIVE: SIMULATION RESULTS AND DISCUSSIONS</p>		
5.1	Introduction.....	59
5.2	MRAC Technique Results.....	60
5.3	MRAFC Technique Results.....	64
5.4	Comparison and Discussion.....	65
<p style="text-align: center;">CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS</p>		
6.1	Conclusions	67
6.2	Recommendations.....	68
	REFERENCES\.....	69

LIST OF FIGURES

Figure	Title	Page
(2.1)	Electromechanical energy conversion	5
(2.2)	DC motor construction	6
(2.3)	DC motor stator construction	7
(2.4)	DC motor rotor construction	8
(2.5)	Equivalent circuit of series DC motor	10
(2.6)	Equivalent circuit of a shunt motor separately excited and common source	11
(2.7)	Equivalent circuit of compound motors	11
(2.8)	Equivalent circuit of a separately excited DC motor	12
(2.9)	Model reference adaptive control system	13
(2.10)	Indirect MRAC	14
(2.11)	Direct MRAC	14
(2.12)	Fuzzy logic	17
(2.13)	Boolean logic	17
(2.14)	Example fuzzy set. S small, MS, medium small, Medium, ML medium	18
(2.15)	Sample Gaussian shaped MF	19

(2.16)	Mapping of input space to output space	21
(2.17)	Mamdani Fuzzy Control System	23
(2.18)	Diagram showing aggregation and defuzzification	24
(2.19)	Implementation of Sugeno model	26
(2.20)	Fuzzy controller for a plant	26
(2.21)	A block diagram of a PD-like fuzzy control system	28
(2.22)	A block diagram of a PI-like fuzzy control system (version1)	29
(2.23)	A block diagram of a PI-like fuzzy control system (version2)	30
(2.24)	The structure for a PID-like fuzzy controller	31
(3.1)	Schematic representation of the DC motor	32
(3.2)	Block diagram of DC motor	35
(3.3)	Building the block DC motor by SIMULINK	37
(3.4)	Create subsystem of DC motor	37
(3.5)	Simulation result of the model DC motor	38
(4.1)	Structure of model reference adaptive control	40
(4.2)	Structure of MRAC system	41
(4.3)	Block diagram for PID controller parameter adaptation using the MIT rule	45

(4.4)	Basic control diagram for model reference fuzzy adaptive control scheme	46
(4.5)	Model following characteristics in Model Reference Fuzzy Adaptive Control	47
(4.6)	Design of fuzzy system in Matlab	49
(4.7)	Rule editor	50
(4.8)	Membership function editor for error (e)	52
(4.9)	Membership function editor for change of error (ce)	52
(4.10)	Membership function editor for controller output	53
(4.11)	Rule viewer	54
(4.12)	Surface viewer	55
(4.13)	Block diagram layout of MRAC of DC motor	56
(4.14)	Sample from results of MRAC technique using MIT rule	56
(4.15)	Block diagram layout of MRAFC of DC motor	57
(4.16)	The results of the MRAFC techniques.	57
(5.1)	Reference input and desired trajectory for the DC motor ω_M	60
(5.2)	Step unit response of the DC motor	60
(5.3)	Step unit response of MRAC without load with adaptive gain= 0.5	61
(5.4)	Step unit response of MRAC DC motor speed without disturbance and load with adaptive gain= 2.5	61
(5.5)	Step unit response of MRAC DC motor speed without disturbance and load with adaptive gain= 5	61
(5.6)	Adaptation of controller parameters for MRAC with adaptive gain =0.5	62

(5.7)	Adaptation of controller parameters for MRAC with adaptive gain= 2.5	62
(5.8)	Adaptation of controller parameters for MRAC with adaptive gain= 5	62
(5.9)	Step unit response of MRAC DC motor speed with disturbance and load with adaptive gain= 0.5	63
(5.10)	Step unit response of MRAC DC motor speed with disturbance and load with adaptive gain= 2.5	63
(5.11)	Step unit response of MRAC DC motor speed with disturbance and load with adaptive gain= 5	63
(5.12)	Step unit response of MRAFC DC motor speed without load and disturbances	64
(5.13)	Step unit response of MRAFC DC motor speed with load and disturbances	64
(5.14)	adaptation of output control signal of fuzzy controller	65

LIST OF TABLES

Table	Title	Page
(4.1)	The linguistic rule table	49
(5.1)	Characteristic values for techniques with no load & disturbances	66
(5.2)	Characteristic values for techniques with load & disturbances	66

LIST OF ABBREVIATIONS

DC	Direct current
DS	Degree of stability
FIS	A Fuzzy inference system
FL	Fuzzy logic
FLC	Fuzzy logic control
GUI	The graphical user interface
MF	A membership function
MIT	Massachusetts Institute of Technology
MRAC	Model reference adaptive control
MRAFC	Model reference adaptive fuzzy control
MRAS	Model reference adaptive system
PD-FZ	Proportional- Derivative like fuzzy controller
PID	proportional integral Derivative controller
PID-FZ	Proportional- integral- Derivative like fuzzy controller
PI-FZ	Proportional- integral like fuzzy controller
RM	Reference model

LIST OF SYMBOLS

ω_d	The actual speed of DC motor
ω	Ideal speed of DC motor
ω_m	Desired speed of DC motor
Φ_f	Field flux
I_f	Field current
$C(\theta)$	General controller
K_p	Proportional gain
K_i	Integration gain
K_d	Derivative gain
$u(t)$	Control output
$\Delta u(t)$	Change of control
Σe	Sum of errors
V	Voltage across the coil of the armature
E_b	Back emf electrical motion force
I_a	Current passes through
R_a	Armature resistant
L_a	Armature inductance
K_M, K_b	velocity constant and back electromotive force constant
T_w'	A torque dye to rotational acceleration of the rotor
T_w	The torque produced from the velocity of the rotor
T_L	The torque of mechanical load
T_M	The electromagnetic torque
J	moment of inertia of the rotor

B	damping (friction) of the mechanical system
d_L	Output disturbances due torque load
d_u	Output disturbances due to uncertainties
$J(\theta)$	Cost function
θ	The controller parameter vector
γ	The adaptation gain
G_P, G_M	Transfer function of DC motor and reference model
u_C, u_M	Reference model input
Y_p	The process output
Y_M	The reference model output
e, ε	The model error, difference between process output and reference model output
e^\wedge	Closed loop error difference between process output and reference input
$C_e, \Delta e$	Error change
ω_n	Undamped natural frequency
ζ	Damping ratio
t_r	Rise time
t_s	Settling time
M_P	Maximum Overshoot