

Abstract

This thesis presents the comparative study of PI, Fuzzy and hybrid Fuzzy-PI controller for controlling the speed of brushless dc (BLDC) motor. The control structure of the proposed drive system is described. The simulation results of the drive system for different operation modes are evaluated and compared. Although conventional PI controllers are widely used in the industry due to their simple control structure and ease of implementation, these controllers pose difficulties when there are some control complexity such as nonlinearity, load disturbances and parametric variations. Moreover PI controllers require precise linear mathematical models.

A fuzzy controller offers better speed response for start-up while PI controller has good compliance over variation of load torque but has slow settling response. The Fuzzy Logic (FL) approach applied to speed control leads to an improved dynamic behaviour of the motor drive system and an immune to load perturbations and parameter variations

Hybrid controller has an advantage of integrating of these two controllers for better control performances. MATLAB/Simulink is used to carry out the simulation. BLDC motor can be modelled in the 3-phase abc variables which consist of two parts. One is an electrical part which calculates electromagnetic torque and current of the motor. The other is a mechanical part, which generates revolution of the motor.

Keywords- PI, Fuzzy, Hybrid Controller, BLDC Motor and Speed control.

List of Figure

Page No.

Fig.2.1.	Transverse section of BLDC	8
Fig.2.2.	Block diagram of BLDC.....	9
Fig.2.3.	Trapezoidal back E.M.F.....	10
Fig.2.4.	Three phase bridge inverter using IGBT.....	11
Fig.2.5.	Voltage waveform 120° conduction.....	12
Fig.2.6	Six step conduction.....	13
Fig.3.1.	PI speed controller structure.....	24
Fig.3.2.	BLDC motor model with PI.....	25
Fig.3.3.	BLDC motor model with Simulink.....	26
Fig.3.4.	Hall decoder circuit.....	28
Fig.3.5.	Gate logic circuit.....	29
Fig.3.6.	(a)Speed (b) Emf (c) torque(d) current with PI(at 2000rpm).....	30
Fig.3.7.	(a) speed (b) emf (c) torque (d) current ($T_L=4Nm$) with PI.....	32
Fig.3.8.	(a) speed (b) torque (2500rpm, no load).....	33
Fig3.9.	(a) speed (b) torque (2500rpm, load=4Nm).....	34
Fig.4.1.	FLC block diagram.....	37
Fig.4.2.	(a)Triangular, (b) Trapezoidal	39
Fig.4.3.	Membership function.....	42
Fig.4.4	(a) Triangular (b) Gaussian (c) Bell shaped(d) Trapezoidal.....	43
Fig.4.5.	FLC controller structure.....	46
Fig.4.6.	BLDC motor model in Simulink.....	46
Fig.4.7.	(a) Input error (b) Change in error (c) Output.....	47
Fig.4.8.	(a) speed(b)torque (c) emf (d) current(2000rpm, no load).....	49
Fig.4.9.	(a) speed (b) torque (c) emf (d) current (2000rpm, load=4nm).....	51
Fig.4.10.	(a) speed (b) torque (c) current (2500 rpm, load=0Nm).....	52
Fig.4.11.	(a) speed (b) torque (2500 rpm, load=4Nm).....	53
Fig.5.1.	Hybrid fuzzy model.....	54
Fig.5.2.	(a) speed (b) torque (c) emf (d) current(2000rpm, no load).....	55
Fig.5.3.	Speed response (2000rpm, $T_L=4Nm$).....	57
Fig.5.4.	Speed response (2500rpm, $T_L=0Nm$).....	57
Fig.5.5.	Speed response (2500rpm, $T_L=4Nm$).....	58

Fig.6.1.	Speed comparison graph (2000rpm, no load).....	59
Fig.6.2.	Speed comparison graph (2000rpm, $T_L=4Nm$).....	60
Fig.6.3.	Speed comparison graph (2500 rpm, no load).....	61
Fig.6.4.	Speed comparison at (2500rpm, $T_L= 4 Nm$).....	63

List Of Tables

Table No.		Page no.
3.1	switching sequence of emf using hall effect sensor.....	28
3.2	Transistor switching sequence using Gate logic.....	29
4.1	7X7 Fuzzy Rule Base	47

List of Acronyms

PMBLDCM	Permanent magnet brushless dc motor
PI	Proportional integral
FLC	Fuzzy logic controller
PMSM	Permanent magnet synchronous motor
PWM	Pulse width modulation
VSI -	Voltage source inverter
RPM	Revolution per minute
emf	Electromotive force
dc	Direct current

List of Symbols used

R_s -	Stator resistance per phase
L -	Stator inductance per phase
M -	Mutual inductance between phases
ω_m -	Angular speed of the motor
θ_r -	Angular position of the rotor
λ_m	Flux linkages
J	Moment of inertia
B	Damping constant
T_e	Electromagnetic torque
T_L	Load torque
K_P	Proportional constant
K_I	Integral constant
$e(t)$	Speed error
μ	Member ship function
i_a	Stator phase currents
e_a, e_b, e_c	Motor phase back emfs
v_{as}, v_{bs}, v_{cs}	Stator phase voltages
$\frac{d}{dt}$	derivative operator
$f_{as}(\theta_r), f_{bs}(\theta_r), f_{cs}(\theta_r)$	Trapezoidal unit functions
V	Volts

List of Contents

	Page no.
Abstract	i
List of Figures	ii
List of Tables	iv
List of Acronyms	v
List of Symbols	vi

1. Introduction

1. Background.....	1
2. Typical BLDC motor applications.....	1
3. A Comparison of BLDC with conventional DC motors.....	3
4. Review on brushless dc motor modelling.....	4
5. A brief on control of BLDC motor.....	5
6. Problem Statement.....	6
7. Thesis Organisation.....	7

2. Introduction to BLDC Motor Drive

1. BLDC motor Background.....	8
2. Permanent – Magnet motor structure.....	9
3. Principle operation of Brushless DC Motor.....	10
4. BLDC drives operation with inverter.....	12
5. Three Phase 120° Mode VSI.....	12
6. Mathematical Analysis of Inverter.....	17
7. Machine Dynamic Model.....	19
8. Conclusion.....	23

3. Design of a PI Speed Controller Scheme

1. PI speed controller design.....	24
2. PI speed control of the BLDC motor.....	26
3. Modeling of Back EMF using Rotor position.....	27
4. Switching algorithm for BLDC motor with Hall effect Sensor.....	28
5. Performance analysis with PI.....	31
9. Conclusion.....	36

4. Fuzzy Logic Control Scheme

1. Introduction to FLC.....	37
2. Motivations for choosing fuzzy logic controller (FLC).....	38
3. Fuzzy Logic Controller components.....	39
1. Fuzzification	
2. Fuzzy inference	
3. Defuzzification	
4. Membership function.....	43
5. Operation On fuzzy Sets.....	45
6. Fuzzy logic control of the BLDC motor.....	47
7. Performance analysis with FLC.....	50

5. Introduction to hybrid fuzzy PI controller

1. BLDC Motor model with hybrid fuzzy PI.....	56
2. Performance analysis with hybrid controller.....	57

6. Conclusion and further scope of work

1. Speed comparison analysis.....	61
2. Future work and scope.....	67
3. References.....	68

Appendix A	69
------------	----