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Controlling speed of BLDC Motor by using PID and Fuzzy PI Controller

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Abstract— *This paper presents the modeling and controlling of PID controller and fuzzy logic controller (FLC) for achieving better dynamic performance of the Brushless DC (BLDC) motor. The performance of fuzzy and PID based BLDC motor is investigated under the load varying conditions. BLDC motors are used in industrial control, automation and instrumentation system applications. Based on other applications the conventional controllers like P, PI and PID controllers are used in the BLDC motor drive control systems to get the desired level of transient and steady state responses. In this paper, the modeling and controlling of fuzzy logic controller is presented its performance and it compared with the PID Controller shows the error capability and usefulness of the fuzzy controller in the control applications.*

Keywords: *Brushless dc motors (BLDC), PID logic controller, Fuzzy logic controller (FLC), Pulse width modulation (PWM).*

I. INTRODUCTION

Recently the Brushless dc motors are preferred as small horsepower control motors due to their high efficiency, reliability and low maintenance [1]. Speed control is an important part of brushless dc motor for precise speed and position control applications. For the boosting of brushless dc motor performance, different controllers have been developed. The conventional controllers are being used for some control applications. The responses of the system are found to be complex and nonlinear form [2]. Because brushless DC motor servo system is a multivariate, nonlinear, strong-coupled time-varying system, traditional PID control does not meet the requirements of high precision control. Advanced control strategies, such as fuzzy control [3].

The aim of this paper is that it shows the dynamics response of speed with design the fuzzy logic controller to control a speed of motor for keeping the motor speed to be constant when the load varies.

II. SPEED CONTROL SYSTEM OF BLDC MOTOR

The block diagram of speed control of three phases BLDC Motor is shown in Fig. 1. Two control loops are used to control BLDC motor. The inner loop synchronizes the inverter gates signals with the electromotive forces [3]. The outer loop is used for controlling the speed of the BLDC motor by controlling the dc bus voltage through PWM inverter. Actual speed is compared with reference speed through feedback from the motor and generates speed error. Based upon error, controller provides the control signal to the switching logic circuit. The switching logic circuit provides the PWM signal for the inverter gate with respect to rotor position of the motor and the control signal output obtained from controller.

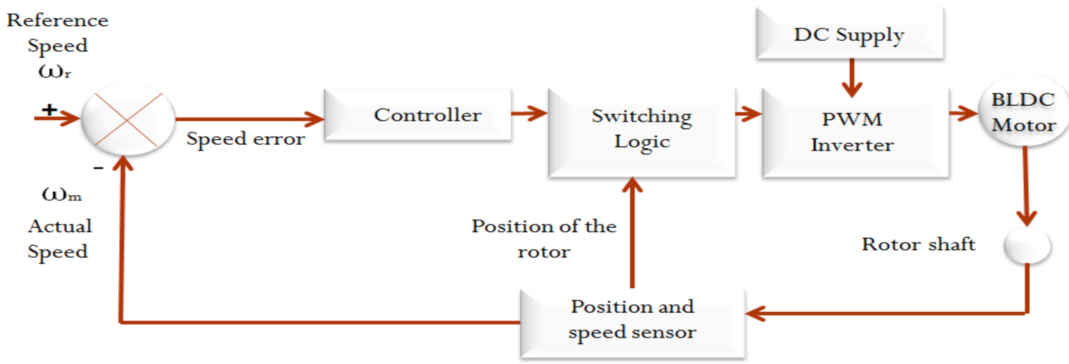

Figure 1 Block Diagram of Close Loop Speed Control Technique [5]

Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low signal, indicating the N or S pole is passing near the sensors. Based on the combination of these three Hall sensor signals, the exact sequence of commutation can be determined.

Sequence	Hall Sensor Input			Active Switches	
	A	B	C	-	-
1	0	0	1	S1	S6
2	0	0	0	S1	S4
3	1	0	0	S5	S4
4	1	1	0	S5	S2
5	1	1	1	S3	S2
6	0	1	1	S3	S6

Table 1 Drive Pattern for CW Direction [3]

III. CONTROLLER

To control the speed of BLDC motor by reducing the errors like overshoot, undershoot, steady state error, settling time and peak time, two controllers are proposed which are listed below.

- PID Controller
- Fuzzy PI Controller

3.1 Tuning of PID Controller [6]

One of the most powerful but complex controller mode operations combines the proportional, integral, and derivative modes. This mode eliminates the offset of the proportional mode and still provides fast response for changing loads.

$$C(S) = K_p+K_I/s+K_Ds \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where KP = Proportional gain, KI = Integral gain and KD= Derivative gain.

The Values of Kp, Ki and Kd of PID Controller is shown in below which are obtained by using trial and error method.

$K_p = 0.2$
$K_i = 2$
$K_d = 0.0003$

3.2 Fuzzy Logic Controller [7]

The controller is represented as a set of rules, which accepts/gives the inputs/outputs in the form of linguistic variables. FLCs are rule-based systems that use fuzzy linguistic variables to model human rule-of-thumb approaches to problem solving, and thus overcoming the limitations that classical expert systems may face because of their inflexible representation of human decision making. Two inputs are given to the fuzzy system: one is speed error and second is rate of change speed error which are shown in Fig. 2 & 3

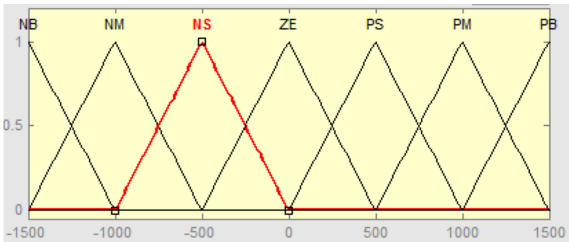

Figure 2 Input variable for error

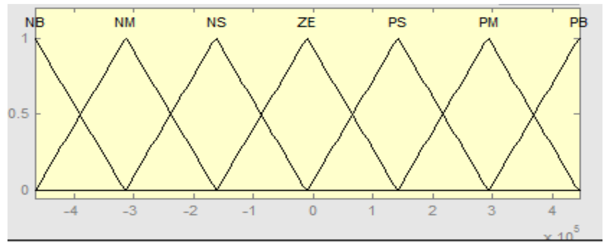

Figure 3 Input variables for rate of change of error

The input range for error and rate of change error are from 1500 to1500 and -4.65e+005 to 4.45e+005.

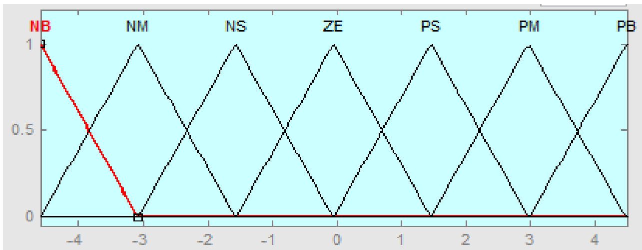

Figure 4 Output variable

Similarly output is distributed with seven triangle shaped membership function. The range is -4.6 to 4.5. Totally 49 rules are set created for fuzzy logic controller.

Δe / E	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NM	NM	NS	NS	ZE
NM	NB	NM	NM	NS	NS	ZE	PS
NS	NM	NM	NS	NS	ZE	PS	PS
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NS	NS	ZE	PS	PS	PM	PM
PM	NS	ZE	PS	PS	PM	PM	PB
PB	ZE	PS	PS	PM	PM	PB	PB

Table 2 Rule Table

IV. SIMULATION OF CLOSE LOOP SPEED CONTROL

For speed control of BLDC Motor, below motor parameters are used in Close Loop Control System simulation.

Parameters	**Rating**
Voltage	470 Volt
Current	50 Amp
Rated Speed	1500 RPM
Stator phase resistance	3 Ohm
Stator phase inductance	0.001 H
Pole pairs	4

Table 3 Motor Specification Parameter [4]

4.1 Simulation circuit for close loop controller using PID Controller

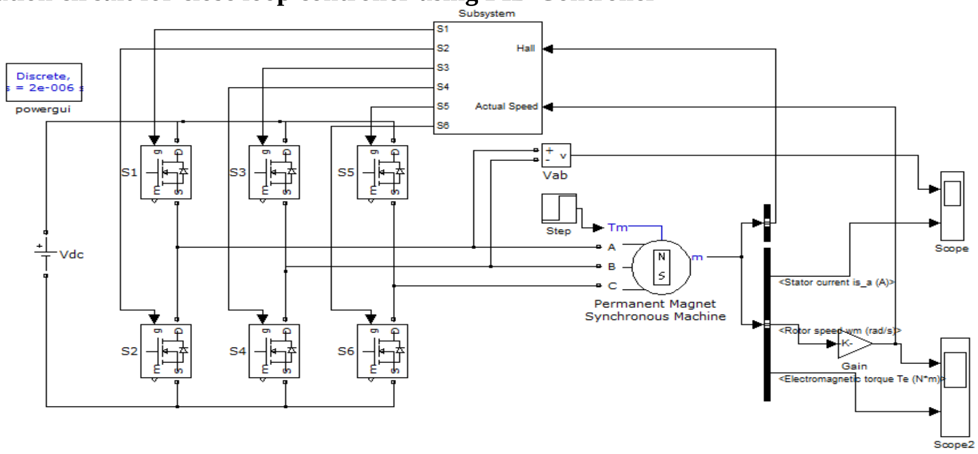

Figure 5 Simulation Circuit of close loop control System

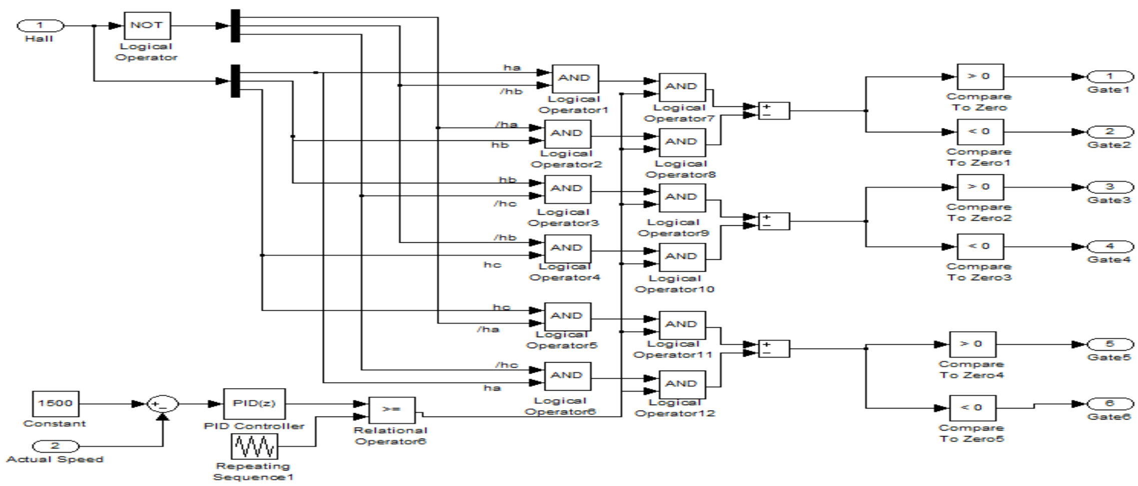

Figure 6 Subsystem circuit of close loop control system

Simulation results for PID controller

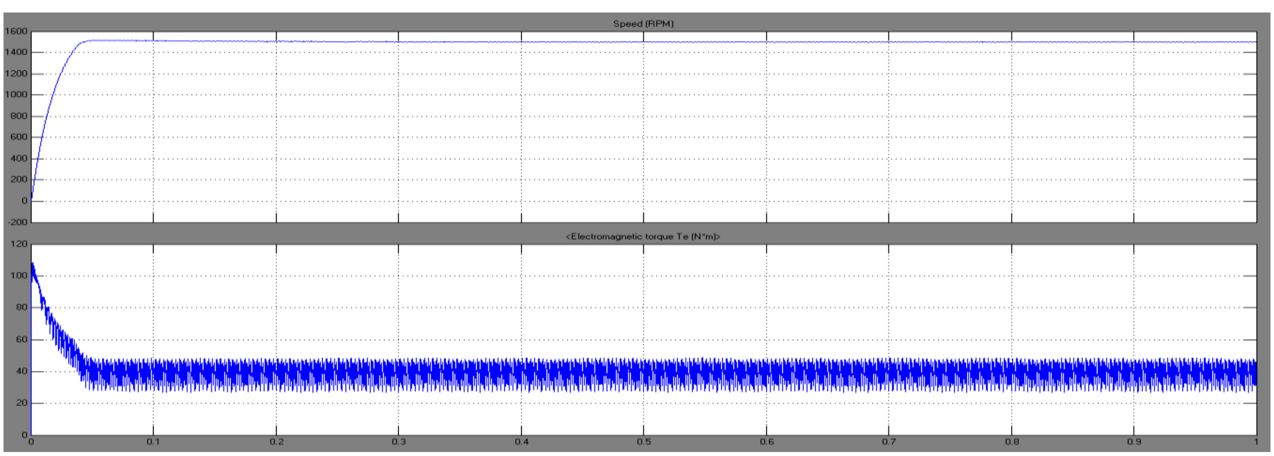

Figure 7 Simulation result for speed at 39.4 N.m load (PID Controller)

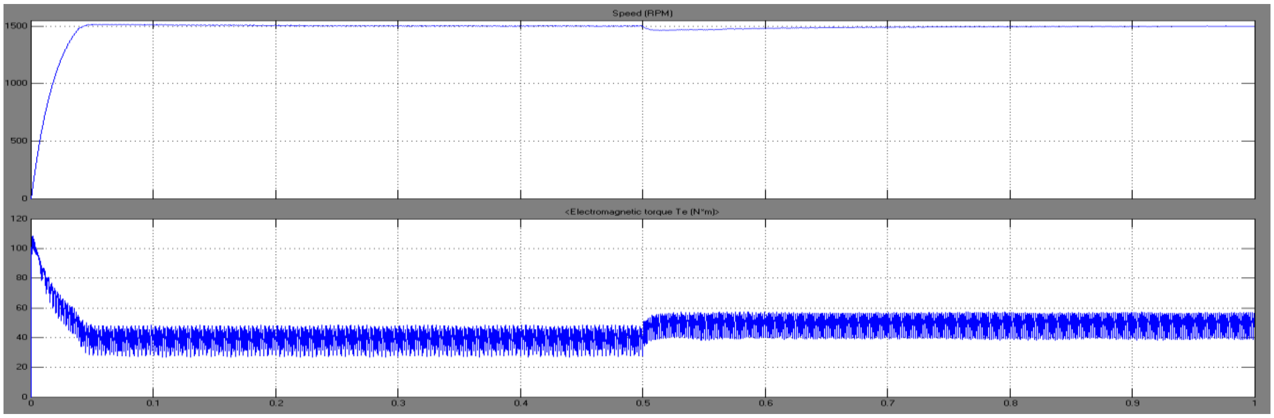

Figure 8 Simulation result for speed at Load variation from 39.4 to 49.4 N.m (PID Controller)

Simulation Analysis

Sr No.	Load (N.m)	Overshoot (RPM)	Undershoot (RPM)	Settling time(Sec)	Recovery time(Sec)	Steady state error(RPM)
1.	39.4	1505	1498	0.106	-	0
2.	39.4 to 49.4	1505	1496	0.106	0.55	0
3.	39.4 to 29.4	1505	1497.5	0.106	0.65	0

Table 4 Simulation Analysis of close loop control system (PID controller)

4.2 Simulation circuit for Close Loop Controller using Fuzzy PI

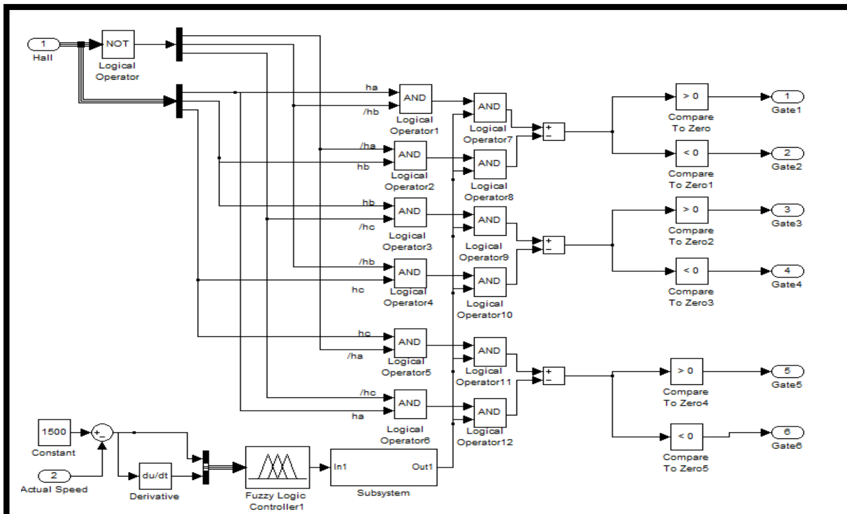

Figure 9 Subsystem1 Circuit of close loop control System

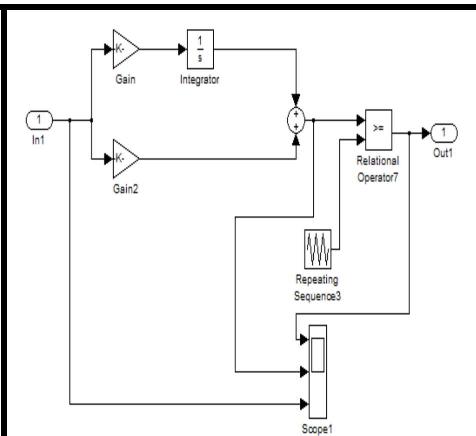

Figure 10 Subsystem2 Circuit of close loop control System

Using Trial and error method, the values of Kp and Ki are calculated.

Kp = 1.78

Ki = 18.15

Simulation result for Close Loop Controller using Fuzzy PI

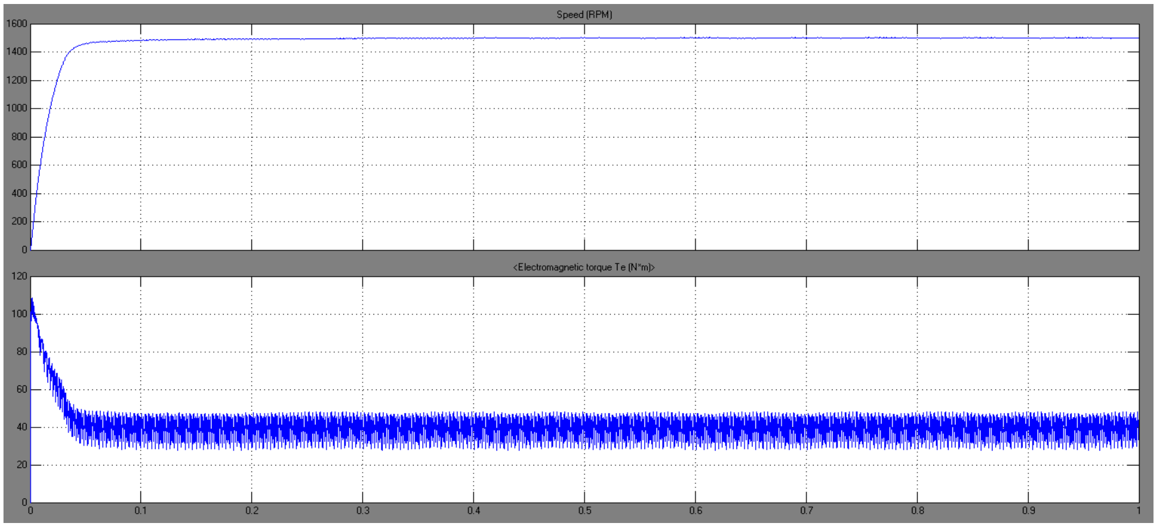

Figure 11 Simulation result for speed at 39.4 N.m load

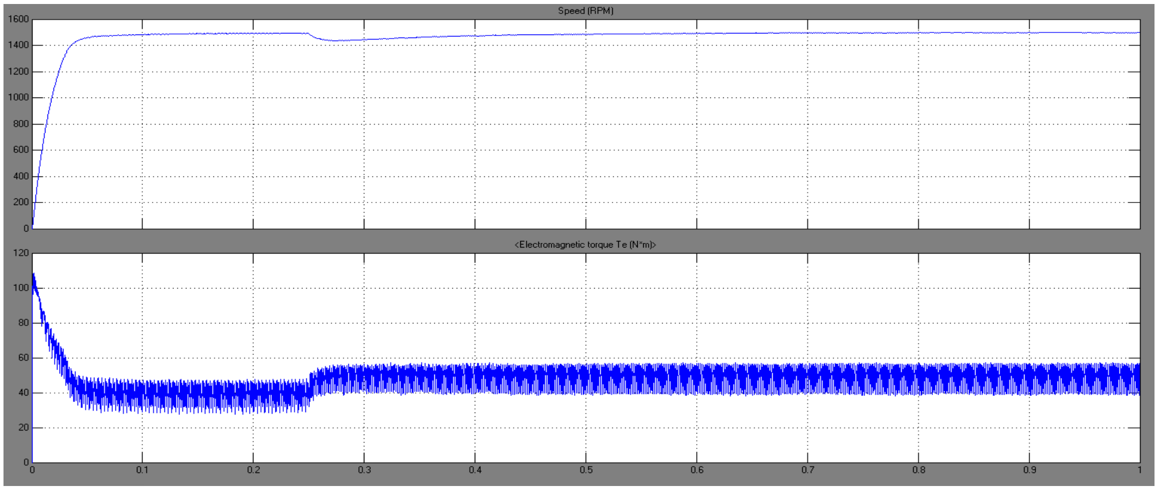

Figure 12 Simulation result for speed at 39.4 N.m to 49.4 N.m load

Simulation Analysis of Fuzzy PI

Sr. No.	Load (N.m)	Rise Time (Sec)	Settling Time (Sec)	Recovery time (Sec)	Overshoot	Undershoot
1.	39.4	0.075	0.098	-	0	0
2.	39.4 to 49.4	0.075	0.098	0.65	0	0
3.	39.4 to 29.4	0.075	0.098	0.50	0	0

Table 5 Simulation Analysis for constant load and variable load

The simulation was carried out using Matlab/Simulink with Fuzzy Logic Toolbox as a platform. The Fuzzy PI speed control was designed to achieve the following objectives:

i. Good speed tracking
ii. Fast transient response (short rise time)
iii. Zero overshoot
iv. Zero steady state error.

IV. COMPARISON ANALYSIS

Load (N.m)	Close Loop Control System (PID)	Close Loop Control System (Fuzzy PI)
49.4	1500	1500
39.4	1500	1500
29.4	1500	1500

Table 6 Simulation Analysis for speed

Load (N.m)	Close Loop Control System (PID)	Close Loop Control System (Fuzzy PI)
49.4	0.116	0.107
39.4	0.109	0.098
29.4	0.102	0.087

Table 7 Simulation Analysis for settling time

V. CONCLUSION

The simulation for speed control of BLDC Motor is carried out for PID Controller and Fuzzy PI controller. By comparing these two controllers it is clear that PID Controller gives the problem of overshoot and undershoot. To reduce those errors, fuzzy PI is developed and it reduces those errors to zero.

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