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Modeling and Design of Hybrid Controller for BLDC Motor

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Abstract: **- The BLDC motors are widely used in aerospace, instrumentation, system space vehicles, robotics, electric vehicles, and industrial control applications. In such applications, the conventional controllers such as P, PI, PID are being used along with the BLDC servomotor drive system. These conventional controllers have reasonable transient and steady state response under changing parameter. The problem with these controller sis they do not have superior transient and steady state effect at different operating conditions which includes variation in parameters and disturbance in load. This paper presents design of the hybrid fuzzy PID controller for achieving improved performance of the brushless dc (BLDC) servomotor drive. The hybrid controller will have the advantages of both fuzzy and PID controller. The modeling, control and simulation of the BLDC motor is been done using MATLAB SIMULINK software.**

Index Terms—Brushless DC (BLDC) servomotor drive, PID (proportional integral derivative) controller, Fuzzy controller.

I. INTRODUCTION

The BLDC motors have attained an extremely significant place in electric drives finding its application in wide range of areas such as industrial controls, automation and robotics etc. The BLDC motor is electrically commutated by the power switches. Electronic commutation in these types of motors is achieved by sensing the rotor position and switching the inverter switches accordingly so that the flux rotates in the required direction. Compared with the brushed DC motor or an induction motor, the BLDC motor has following advantages.

- Higher efficiency and reliability
- Lower acoustic noise
- Smaller and lighter
- Greater dynamic response
- Better speed versus torque characteristics
- Higher speed range
- Long life

For BLDC motor the controlling part plays a very important role in enhancing its performance for applications concerning the load variations. Thus the need for having intelligent controllers has increased.

The proportional integral derivative (PID) controller is used widely in many of the control applications because of its simplicity and effectiveness. In practice the design of BLDCM drive has a complex process such as modeling, control scheme solution, simulation and parameters tuning etc. Expert knowledge of the system is basically required to get optimal performance.

Recently, numbers of modern control solutions were proposed for the speed control of BLDC motor [1] [2] [3]. The conventional PID controller algorithm is to simpler, easily adjustable and has high reliability. Tuning of PID control parameters is quite difficult hence it is difficult to achieve the optimal state under the field condition in actual production.

Fuzzy logic control (FLC) has proven very effective for the complex, non-liner and imprecisely defined process for which the standard model based control techniques are impractical. The fuzzy logic deals with the problems that have vagueness, uncertainty and uses membership function with varying values. It therefore means that if the reliable knowledge expert is not available or if the system is very complex to derive or make the necessary decision rules the development of fuzzy logic controller cannot be achieved by using trial and error.

The objective of this paper is that it shows the response of the speed along with the design of fuzzy logic controller for controlling the speed of motor.This paper also introduces a hybrid fuzzy PID controller which has the advantages of both fuzzy as well as controller and helpsto achieve faster speed response.

II. SPEED CONTROL SYSTEM OF THE BLDC MOTOR

The complete block diagram of speed control of BLDC motor is given in fig.1

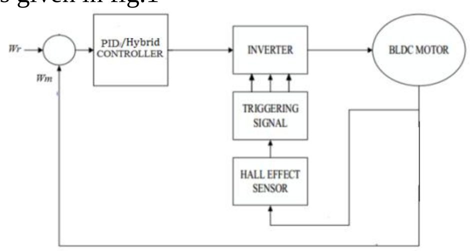

Fig-1: Speed control of BLDC motor

There are two closed loops, which are used to control the BLDC motor. With the inner loop the inverter gate signals are synchronized with the electromotive forces by varying DC bus voltage.

III. INVERTER

A DC to Ac converter is defined as inverter. The operation of this drive, along with the motor, it consists of an inverter which requires 3phase DC to AC converter. In the self-systematized form, converter is like an electronic ON/OFF device where in it receives the logical pulses of switching from the set position sensors. The position, determines the switching sequence of the IGBT's, is detected with help of the 3 hall sensors. Using the hall sensors information, decoder block generates signal vector of the back emf. Table 1 is for calculating back emf. Table 2 describes the gate logic for transforming electromagnetic forces to six signals on the gates.

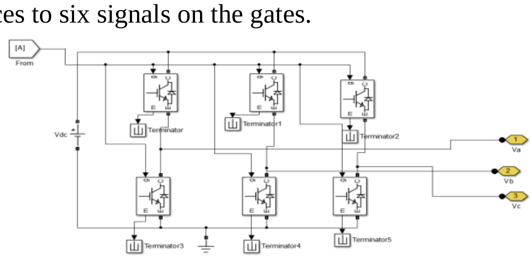

Fig -2:Simulink model of the inverter

TABLE -1: CLOCKWISE ROTATION

Hall sensor A	Hall sensor B	Hall sensor c	EMF A	EMF B	EMF C
0	0	0	0	0	0
0	0	1	0	-1	1
0	1	0	-1	1	0
0	1	1	-1	0	1
1	0	0	1	0	-1
1	0	1	1	-1	0
1	1	0	0	1	-1
1	1	1	0	0	0

TABLE -2: GATE LOGIC

EMF A	EMF B	EMF C	Q1	Q2	Q3	Q4	Q5	Q6
0	0	0	0	0	0	0	0	0
0	-1	1	0	0	0	1	1	0
-1	1	0	0	1	1	0	0	0
-1	0	1	0	1	0	0	1	0
1	0	-1	1	0	0	0	0	1
1	-1	0	1	0	0	1	0	0
0	1	-1	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0

IV. CONTROLLER CIRCUIT

a. PID controller

Proportional integral derivate controllers are used widely in industrial control systems as they require few parameters to be tuned. Fig.2 shows the PID controller block diagram [5]. Proportional controller stabilizes gain but produces steady state error. Integral controller where in reduces the steady state error, and the derivate controller reduces the rate of change of the error. Ziegler-Nichols method is used widely for tuning of the PID controllers. Consider the characteristics parameters of proportional (P), integral (I), derivative (D) controls applied to the Fig 3.

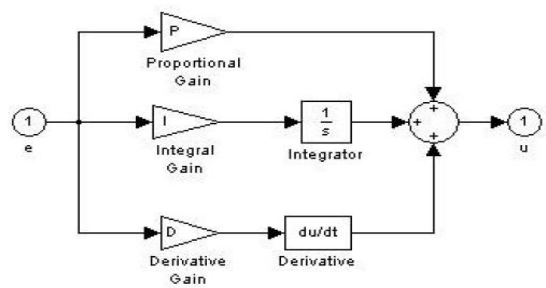

Fig -3: Simulation model of PID controller

The transfer function of the most basic form of the PID controller is,

$$C(s)=K_p+\frac{K_i}{s}+K_d s$$

Where Kp is proportional gain, Ki is integral gain and Kd is derivative gain.

Steps for designing the PID controller,

1) Determine which characteristics of the system need to be improved
2) Use proportional gain (kp) to decrease the rise time
3) Use derivative gain (kd) to reduce overshoots and settling time
4) Use integral gain (ki) for eliminating the steady-state error.

b. Hybrid Fuzzy PID controller

In the drive operation, by controlling the voltage source inverter the speed can be controller. Here the speed has been controlled by the Fuzzy logic controller whose output is inner dc voltage. By varying the dc voltage the voltage is controlled.
Fuzzy PID controller that is used in this paper is based on two input FLC structure. The overall structure of Fuzzy PID controller is shown in fig.3

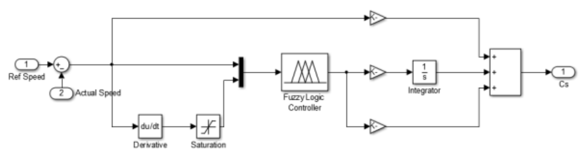

Fig-4:Simulation model of the hybrid Fuzzy PID controller.

The inputs and the outputs which are selected for the fuzzy logic controller plays an important role. With the help of the control detail analysis of the PID controller based system the inputs are taken as the error in speed and the change in error in that speed and the output is selected to be the control signal for the generation of the voltage. The mentioned FLC based system is designed using MATLAB tool for the fuzzy inference system (fis).
The main objective while designing a FLC is framing less number of rules and obtaining good control characteristics. The rules are framed with the help of defined input variables "E" and "CE" which are further quantized.
The fuzzy inference output variable is "ΔV".
The surface view after framing the rules is given in fig.5

TABLE -3: The 3x3 fuzzy associated matrix

CE/E	NE	ZE	PE
NCE	D	I	I
NCE	D	NC	I
PCE	I	I	I

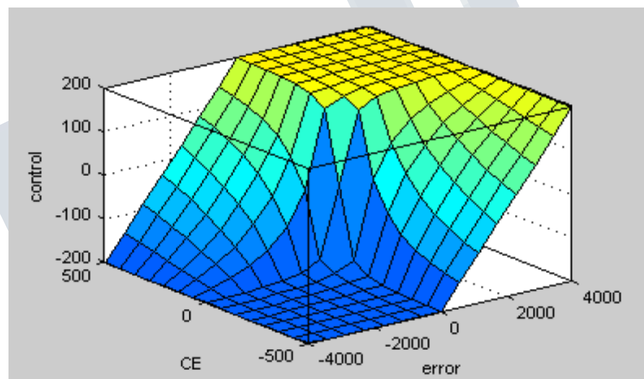

Fig-5: Surface view of the rules designed

c. Simulation and discussion

To validate the control strategies, simulation was carried out on BLDC motor system by using MATLAB/SIMULINK. The motor parameters are given in the following table.

Table-4: Motor parameters

Rated Voltage	36 V
Rated Current	5 A
No. of Poles	4
No. of Phases	3
Rated Speed	4000 RPM
Rated Torque	0.42 N.m
Torque Constant	0.082 N.m/A
Mass	1.25 kg
Inertia	23e-06 kg-m^2
Resistance per phase	0.57Ω
Inductance per phase	1.5 mH

The generated emf and the stator current for the change in load from no load to full load (0.42Nm) at 0.1 sec are shown below in fig.6 and fig.8

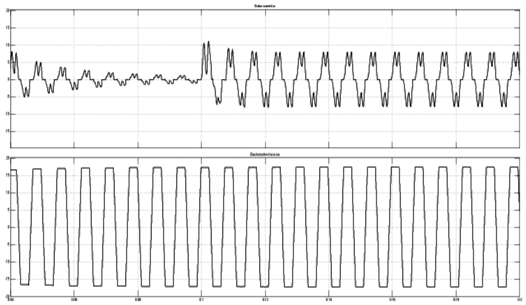

Fig -6:Generated emf and stator current

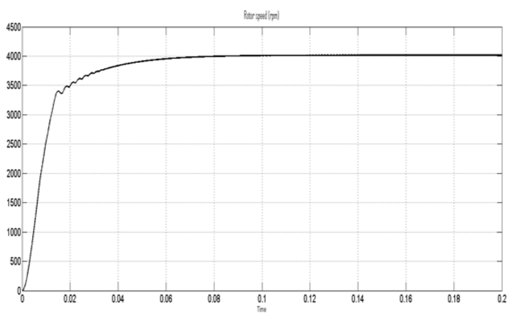

Fig-7:Full load response of PID controller

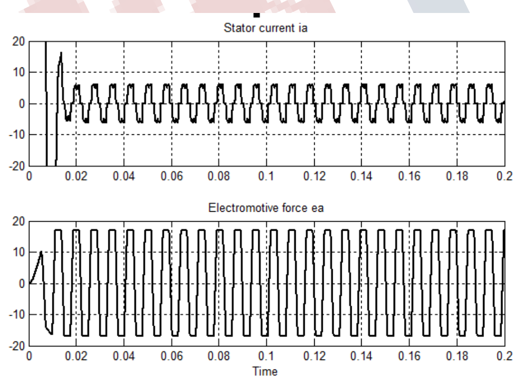

Fig-8:Generated emf and stator current

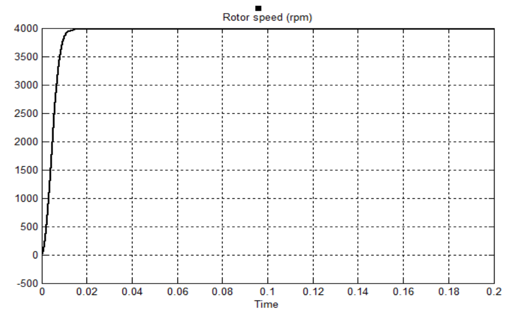

Fig-9: Full load response of Hybrid controller

The simulation has been carried out using PID and Hybrid controller for the BLDC motor drive with the load torque of 0.42 Nm. fig.6 and fig.8 shows the stator current and back emf. As predicted the back emf is trapezoidal in shape.

fig.7and fig.9 shows the full load response using PID and Hybrid controller respectively. It is evident from the fig.7 that themotor speed settles down at the reference value of 4000rpm at 0.1 sec with little oscillations, and from fig.9 that speed settles down with minimal oscillations at 0.02 secs. The PID and hybrid controller is found to maintain the actual speed close to the reference speed. But the speed response time of the hybrid controller is better than that of the PID as it has better speed response

V. CONCLUSION

The speed control for the BLDC motor is designed, simulated and implemented in this paper. Initially the whole drive system is simulated with the use of MATLAB/Simulink. The model for machine has been developed in Simulink, as well as for inverter and different controllers. The result of the simulation shows the good response of the model when tracking a command speed.
The results show that the hybrid based system is having better response time as compared to the PID controller. As the hybrid controller has better performance they can replace PID based system for various control, industrial, automation, robotics and various other applications where the conventional controllers are used

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