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FLC based Speed Control of Brushless DC Motor using C2000

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***Abstract*: Brushless DC (BLDC) motors are coming high energy permanent magnet materials, power semiconductor and digital integrated circuits. In any application requiring an electric motor where the space and weight are at a premium, the BLDC motors becomes the ideal choice. A BLDC motor has high power to mass ratio, good dissipation characteristics and high speed capabilities. Limitations of brushed DC motors overcome by BLDC motors include lower efficiency, susceptibility of the commutator assembly to mechanical wear, consequent need for servicing, less ruggedness and requirement for more expensive control electronics. Due to their favorable electrical and mechanical properties, BLDC motors are widely used in servo applications such as automotive, aerospace, medical field, instrumentation areas, electro mechanical actuation systems and industrial automation requirements. Many control schemes have been developed for improving the performance of BLDC Motor Drives. In this paper, a novel controller for brushless DC (BLDC) motor has been presented. The proposed controller is based on Fuzzy logic controller and the rigorous analysis through simulation is performed using simulink tool box in MATLAB environment. The performance of the motor is analyzed using simulation results obtained. The dynamic characteristics of the brushless DC motor is observed and analyzed using the developed MATLAB model. Implementation of hardware is done using C2000 controller and the results were compared with simulation.**

***Keywords*: BLDC, Fuzzy logic, speed control, C2000**

1. Introduction

There is an increased requirement on electrical systems today. The system should have better efficiency and reduced electromagnetic. It should be flexible to meet market modification and to reduce development time. Even then, it should be economical satisfying all these constraints. The only motor which have these properties is Brushless DC Motor. Such motors combine high reliability with high efficiency, and for a lower cost in comparison with brush motors. The BLDC Motor is a permanent dc motor fed with rectangular currents and we get trapezoidal back-emf. The brushless characteristic can be applied to several kinds of motors, the AC synchronous motors, stepper motors, switched reluctance motors, AC induction motors. Because of trapezoidal back-emf, it has the following advantages, firstly commutation process is accurate, the mechanical torque developed by the motor is constant. Secondly, the brushless DC drives show a very high mechanical power density.

2. Literature review

Back-emf is sensed without using neutral point of the motor, is applicable for wide speed range but still have accuracy problem at low speed [1], [4], [13], of dynamic performance of the Modelling is very essential in studying high performance drive before evaluating the concept motor. Modelling helps further to use the drive in high performance applications [3]. A Simple method to implement and improved motor efficiency. In this method, access to motor winding neutral point is required, this will complicate the motor structure and increase the cost [2]. More uniform current waveform, better torque performance but low pass filters are required so that the back-emf difference can be detected with lower sensor diode [6] [7]. Implementation of Fuzzy and it is compared with PID controller which show the superiority of fuzzy to be used for controlling drives [5].

3. Brushless DC motor-overview

The two important parts of BLDC Motor are as follows.
1) Stator
2) Rotor

A. Stator

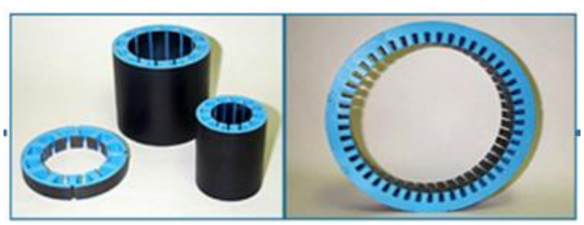

Fig. 1. Laminated steel Stampings-Stator

B. Rotor

Fig. 2. 4-pole and 8-pole permanent magnet rotor

4. BLDC control

It is based on two phase ON operation to control the inverter. In this control, torque production follows the principle that current should flow in two of three phases at a time and there should be no torque production in the region of back-emf zero crossings.

5. Fuzzy logic control of the BLDC motor

The fuzzy logic controlled BDCM drive system block diagram is shown in Fig.4.The input variables to the fuzzy logic controller are speed error (E), and change in speed error (CE).The output variable is the torque component of the reference (i_{ref}) where $i_{ref}$is obtained at the output of the controller by using the change in the reference current.

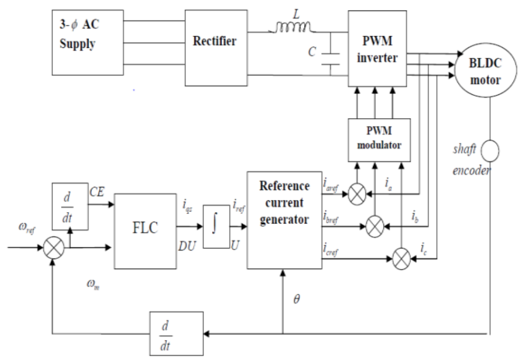

Fig. 3. Fuzzy speed control block diagram of the BLDC motor

The controller observes the input pattern and correspondingly updates the output DU and so that the actual speed ω_m matches the command speed ω_{ref}. There are two inputs signals to the fuzzy controller, the error E $=\omega_{ref} - \omega_m$ and the change in error CE. The controller output DU in brushless dc motor drive is current ΔI^*_{qs}. The signal is summed or integrated to generate the actual control signal U or current I^*_{qs}, where $K_1$and K_2 are nonlinear coefficients or gain factors including the summation process shown in Fig. 3.

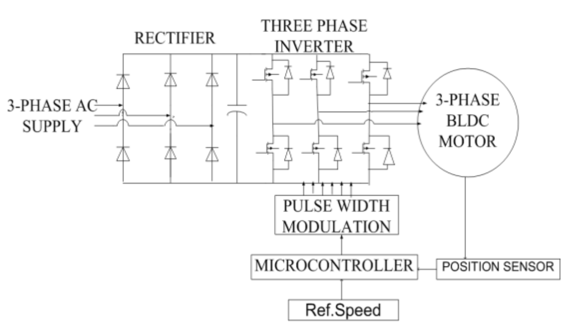

Fig. 4. Circuit Diagram

A. Membership functions

The seven fuzzy member's ship functions defined for both inputs to control the speed of BLDC Motor are as follows:

1) Positive Big: PB
2) Negative Big: NB
3) Positive Medium: PM
4) Negative Medium: N
5) Positive Small: PS
6) Negative Small: NS
7) Zero Error: ZE

The input variable speed error and change in speed error is defined in the range of $-1\leq \omega_e \leq +1$ and $-1\leq \omega_{ce} \leq +1$ and the output variable torque reference current change Δi_{qs} is define in the range of $-1\leq \Delta i_{qs} \leq +1$.

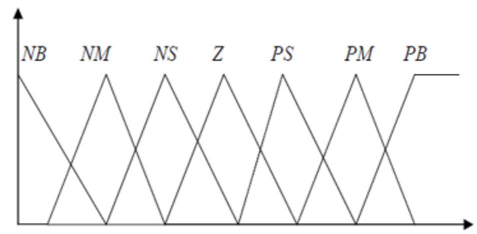

Fig. 5. Seven levels of fuzzy membership function

The triangular shaped functions as shown in the fig.6 are chosen as the membership functions due to the resulting best control performance and simplicity. The membership function for the speed error and the change in speed error and the change in torque reference current are shown in figure 6.

B. Fuzzy rule table

For all variables seven levels of fuzzy membership function are used. Table 1 shows the 7*7 rule base table that was used in the system.

Table 1
Fuzzy Rule Table

e/ce	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

6. Simulink model for the proposed system

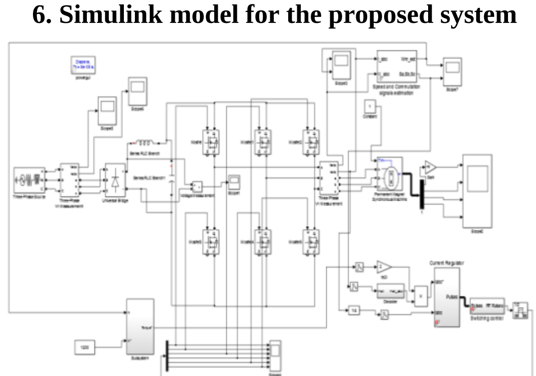
Fig. 6. Simulink Model

The current control block computes the three reference motor line currents in phase with back-emf, corresponding to torque reference and then feeds the motor with these currents using a three phase current regulators. Current regulator controls the current by delivering current pulses to the switches in order to keep the current inside a user-defined hysteresis band. Motor speed and position are estimated from terminal voltages and current using back-emf observer. The commutation signals are generated from the rotor position every sixty degree electrical. The speed control loop uses a PI regulator to produce the torque reference for the current control block.

7. Specification of the motor

The table represents the specification of the motor.

Table 2
Specification of the motor

Parameters	Ratings
Power	60W
DC Voltage	460V
Stator Resistance(R_s)	0.2Ω
Stator Inductance(L_{ls})	8.5e-3H
Flux linkage	0.175 V.s
Back EMF flat area	120 degrees
Viscous damping	0.005 F (N.m.s)
Inertia	0.089 J(kg.m^2)
Pole	4

8. Results

The following are the waveforms obtained during simulation.

A. Speed waveform

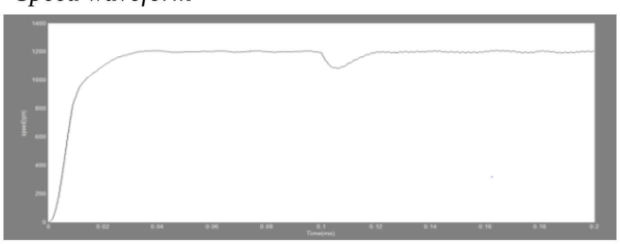

Fig. 7. Output-Speed

Reference speed – 1200rpm.
Motor speed after controlling – 1205rpm.

B. Current waveform

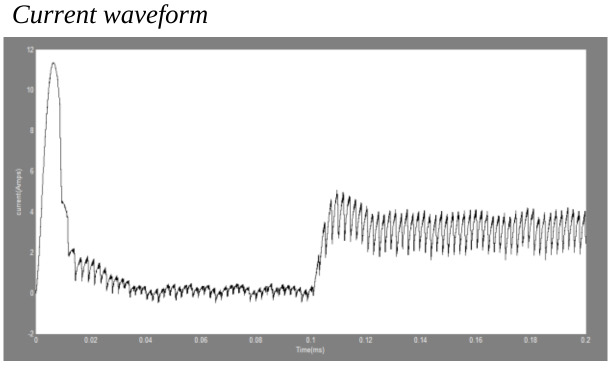

Fig. 8. Output-Current

C. Torque waveform

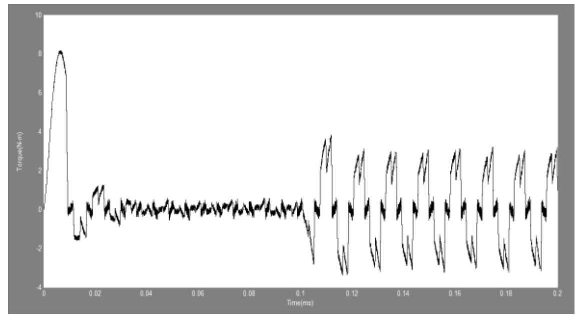

Fig. 9. Output – Torque

D. Trapezoidal back-emf

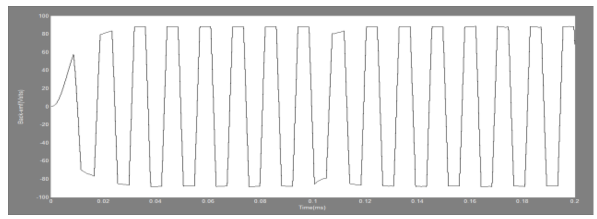

Fig. 10. Output-Back-emf

From the above results obtained during simulation, it is shown that the speed of BLDC Motor has been controlled using fuzzy logic controller.

9. Hardware implementation

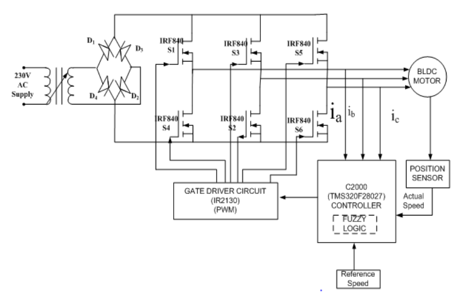

Fig. 11. Circuit Diagram

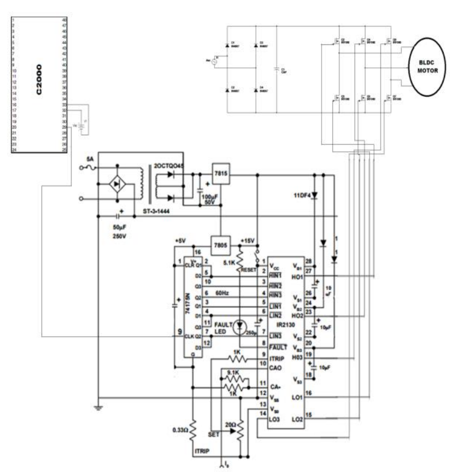

Fig. 12. Wiring Diagram

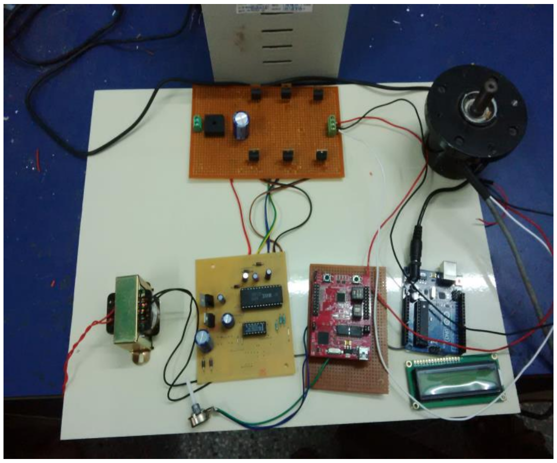

Fig. 13. Hardware setup

10. Hardware results

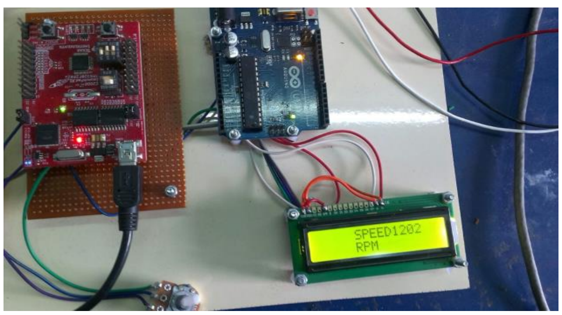

Fig. 14. Output

11. Conclusion and future scope

The modelling and simulation of the complete drive system is described in this presentation. Simulation runs confirming the validity and superiority of the fuzzy logic controller over conventional controller. This will be also helpful in solving problems associated with sensored control and conventional controllers in order to reduce cost and complexity of the drive system without compromising the performance.

The hardware implementation is also explained using C2000 (TMS320F28027) controllers. In future, this can be implemented using Artificial Neural Network (ANN) which results in better performance in the sensor less control area. This method will be more cost effective and have good dynamic response.

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