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A REVIEW PAPER ON CLOSED LOOP CONTROL OF BLDC MOTOR USING FUZZY LOGIC

Jayesh S. Sawai[1], Akash V. Rathod[2], Prof. Apurva A. Bhalerao[3]

[1]Student,Department of Electrical Engineering
[2]Student, Department of Electrical Engineering
[3]Prof. Apurva A. Bhalerao, Department of Electrical Engineering, DES's college, Maharastra, India

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Abstract –
In this paper, a fuzzy logic controller for the Closed loop control of BLDC motor is used. The fuzzy logic controller is used from a fuzzy logic toolbox in MATLAB. A single current sensor technique is used for closed loop current control. For closed loop current control of BLDC motor, the motor phase currents are measured using current sensors. These sensors are expensive and the use of different current sensors can cause undesirable imbalance in phase currents due to differences in current sensor sensitivities. These drawbacks can be avoided by using a single current sensor placed on the DC link. Here an algorithm is presented to obtain the phase current values from the DC link current. The proposed system was simulated using MATLAB/Simulink, with PI and fuzzy logic speed controllers. The simulation result shows that, the fuzzy logic controller gives better performance than PI controller.

Keywords: *Brushless DC (BLDC) motor, fuzzy logic, current sensor, DC link, closed loop control*

1. INTRODUCTION

There is wide application of BLDC motor in industry because of their high power density and it is easy for controlling. The BLDC motor are used in a servo, robotics and domestic application because of its high efficiency, low maintenance, good speed torque characteristics and its low rotor inertia. Because of permanent magnet are on the rotor and winding on the stator, the BLDC motor are also known as AC synchronous motor. Permanent magnet creates a rotor flux and the energized stator winding create a electromagnetic poles. The energized stator phase attracts the rotor by using the appropriate sequence to supply the stator phases. This action is a fundamental action in a permanent magnet BLDC motor. The rotor position information is necessary for the successful operation of BLDC motor. The phase windings are switched in a sequence to obtain the rotation according to the rotor position. A current control loop is used in a BLDC drives to maintain the load current at some desired level, this is done by switching the constant DC link voltage across the motor windings. The current control loop is provided by direct measurement of the winding current by using separate current sensor. But the current sensor are costly But the current sensors are expensive and the use of different sensors can cause undesirable imbalance in phase currents. These drawback can be removed by using the single current source on DC link.

For developing sophisticated control system fuzzy logic is one of the best technology in today Several studies show, both in simulations and experimental results that fuzzy logic control yields superior results with respect to those obtained by conventional control algorithms. Thus in industrial electronics the fuzzy logic are used to control the electric motor drive.in this paper, simulation by using Fuzzy logic controller is presented The fuzzy logic toolbox in MATLAB is used to design fuzzy logic controller, which is integrated into simulations with Simulink. The hardware implementation of the fuzzy logic controller is done using PIC16F877A. The hardware results show that the fuzzy logic controller gives a smooth speed control.

2. TECHNIQUES USED TO CONTROL BLDC MOTOR

2.1. Fuzzy Logic Controller

Fuzzy logic control (FLC) is a control algorithm based on a linguistic control strategy which tries to account the human knowledge about how to control a system without requiring a
mathematical model. Input and output are non-fuzzy values. The block diagram of the FLC is shown in Fig. 1.

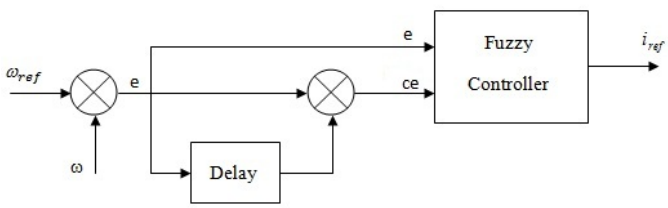

Fig. 1. Block diagram of fuzzy control system

Here Mamdani type of fuzzy logic is used for speed controller. Speed error (e) and change of speed error (ce) are the inputs to fuzzy controller. The speed error is calculated by comparing the reference speed (*ref* ω) with the actual speed (ω). The output of the controller is considered as a reference current (*ref i*). The triangular shaped functions are chosen as the membership functions due to the resulting best control performance and simplicity. The membership function for speed error, change in speed error and the reference current. For all variables seven levels of fuzzy membership function are used. Table I shows the 7�7 rule base table that was used in the system.

TABLE I. Rule base table used in the system

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

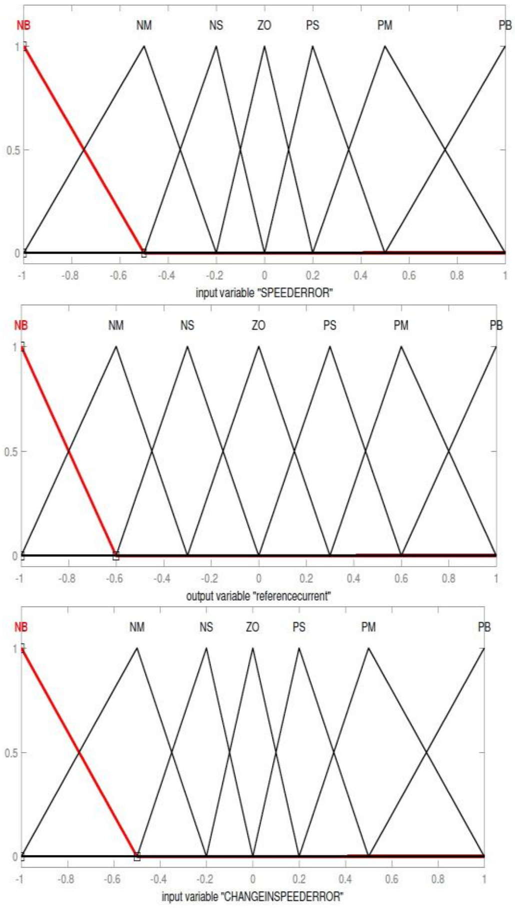

Fig. 2: Fuzzy membership functions for (a) speed error (b) change in speed
error (c) reference current

2.2. The Single DC link Current Sensor Technique

The BLDC motor is supplied from a DC source through an inverter. The back emf and phase current waveforms for one complete cycle is shown in Fig. 3. For closed-loop current control of brushless DC motors, instantaneous phase currents are measured using current sensors. Such sensors are often expensive. In single DC link current sensor technique, a single current sensor is placed in the DC link. From the measured DC link current, the phase currents can be estimated.

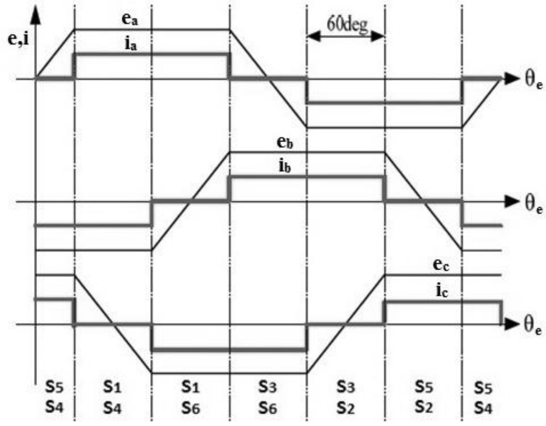

Fig. 3: Back emf and phase current waveforms

In a BLDC motor two stator phases are energized at a time. So two switches of the inverter are conducting (one upper and one lower) at any instant. Since two phases of the motor are energized at any instant and the motor is star connected, the same current flows through them. Also this current is same as the DC link current, measured by the single DC link current sensor. From the DC link current, the phase currents are estimated according to the phase current waveforms in Fig. 3.

3. BLDC MOTOR DRIVE SCHEME

The block diagram of the proposed BLDC motor drive is shown in Fig. 4.

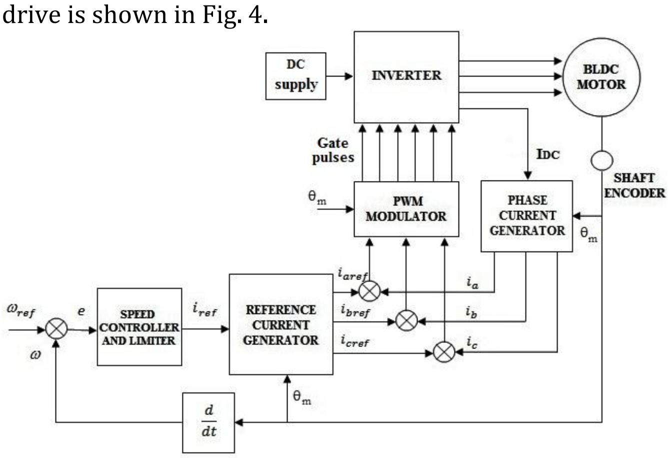

Fig.4: Block diagram of proposed BLDC motor drive

In a BLDC motor drive, usually hall sensors are used to obtain the rotor position information. The drive control system consists of an outer speed loop for speed control and an inner current loop for current control. Conventionally three separate current sensors are used to measure the phase currents. But here only one current sensor is used, which is placed on the DC link.

3.1. Speed controller

The speed control is achieved by using a fuzzy logic or PI controller. The fuzzy logic controller is used to produce an adaptive control so that the motor speed can accurately track the reference speed. The input to the controller is the speed error. The output of the controller is considered as a reference current. A limit is put on the speed controller output depending on permissible maximum winding currents.

3.2. Current controller

For current control, the actual phase currents are compared with reference phase currents and the error is given to PWM modulator to produce the switching signals for the inverter switches. Depending on the rotor position, the reference current generator block generates three phase reference currents by taking the value of reference current magnitude as *ref i* . The rotor position and phase reference currents are shown in Table II.

TABLE II. Rotor position and reference currents

Rotor position (θe)	i_{aref}	i_{bref}	i_{cref}
0 - 30	0	$-i_{ref}$	i_{ref}
30 - 90	i_{ref}	$-i_{ref}$	0
90 - 150	i_{ref}	0	$-i_{ref}$
150 - 210	0	i_{ref}	$-i_{ref}$
210 - 270	$-i_{ref}$	i_{ref}	0
270 - 330	$-i_{ref}$	0	i_{ref}
330 - 360	0	$-i_{ref}$	i_{ref}

The PWM modulator can be a PI controller or a hysteresis controller. Here a hysteresis controller is used. A hysteresis controller is designed to control the stator current, hence the output electromagnetic torque of the motor. It provides a fast response compared to the PI controller. The controller maintains the stator current within the predefined hysteresis band about the reference current value. Here the current error is given to hysteresis controller to obtain the gating signals.

CONCLUSION

A fuzzy logic controller is used for the speed control of BLDC motor. The performance of the drive with PI and fuzzy logic controllers was studied through simulation. Simulation result shows that, fuzzy logic controller gives better speed control than PI controller. Here a single current sensor technique is proposed which obtains the actual phase current values by using a single DC link current sensor, thus reducing the cost and the size of the drive. The hardware implementation of the fuzzy logic controller is done using PIC16F877A. The hardware results show that the fuzzy logic controller gives a smooth speed control.

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