DESIGN AND IMPLEMENTATION OF ACCELERATION AND SPEED CONTROL UNIT FOR ECO VEHICLE (SOLAR)

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Abstract - *This paper explores the different ways to control speed by using simple PI control and Fuzzy logic control of permanent magnet brushless DC motor (BLDC). There are many effective ways to control the speed of a BLDC motor. That can be achieved by using simple PI logic control or Fuzzy logic control. By using PI logic control we can control the motor speed by closed-loop control method. But in that way, we cannot control the speed of the motor accurately because of less number of logic we are using. This can be rectified by using simple Fuzzy logic control. By using fuzzy logic control the motor speed can be controlled accurately with high response time. So in this paper, we are going to study about a comparative study of simple PI control and Fuzzy logic control.*

Key Words*: *Permanent Magnet Brushless DC Motor (PMBLDC); simple PI Logic control; Fuzzy logic control; Microcontroller;

1. INTRODUCTION

The rapid requirement of electric drives with the new technology in the various industries are increases day by day. There is great demand for efficient variable speed, long term stability and good transient performance of motor drives. The dc motor may be categorized according to the commutation circuit. One is traditionally DC motor which is mechanically commutated and other is Permanent Magnet Brushless DC motor (BLDC) having an electronically commutated with sensor or sensor-less system. The BLDC motor has a rotating permanent magnet and stationary armature [1]. It has many advantages such as simple structure, high reliability, small size, high torque and simple structure. It is mainly applicable for high performance drives. Generally the performance of motor is affected by sudden change in unknown load or speed. But as the BLDC motor drive are non-linear in nature, they require an improved or modified controller that can adapt a non-linear condition and achieve the desired performance [2]. So to encounter this problem controller is required. Because of the simplicity in tuning, the PI controller are until now are mostly useful controller in industries. The PI controller is carried out from the input and feedback signal [3]. But this controller is fails to operate in dynamic conditions. While comparing with the Fuzzy logic controller, PI controller takes large number of peak overshoot that affects the system performance. The hybrid Fuzzy tuned with conventional PI controller improves the dynamic as well as steady state behavior and also it improves the system performance. The proposed system are analyzed with the help of MATLAB and compared with PI controller and simple FLC.

2. MATHEMATICAL MODELLING OF BLDC MOTOR

The BLDC motor is working as same as the traditional DC motor, but it is construction wise different from it. It is a self-rotating synchronous machine whose stator is similar to that of an induction motor and the rotor has permanent magnet which is rotating part. BLDC has no brushes and commuters, instead of this it is replaced by electronically commutated system. Current polarity can be reversed by switches like MOSFET or IGBT for the three phase inverter circuit in synchronization with rotor position. This rotor position can be sensed using Hall Effect sensor encapsulated in the stator. The drive can be controlled in sensor or sensor-less mode. The sensor-less mode can be reduced its cost and sizes but its performance is poor. So in this paper we use Hall Effect sensor. The schematic representation of equivalent BLDC motor dive is as shown in fig 1.

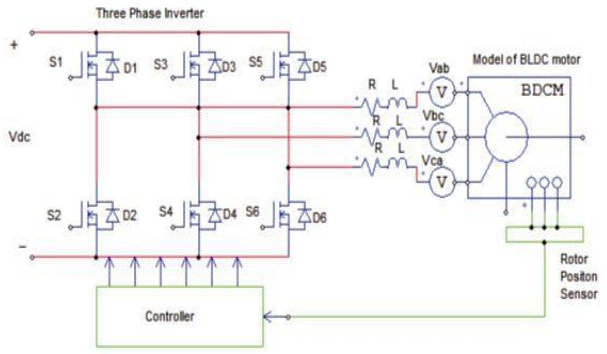

Fig. 1. Equivalent circuit of BLDC motor drive [5]

Where V_{ab}, V_{bc}, V_{ca} are the phase voltages,

$$V_{ab} = R\,(i_a - i_b) + (L - M)\, d/dt\,(i_a - i_b) + e_{ab} \quad (1)$$

$$V_{bc} = R\,(i_b - i_c) + (L - M)\, d/dt\,(i_b - i_c) + e_{bc} \quad (2)$$

$$V_{ca} = R\,(i_c - i_a) + (L - M)\, d/dt\,(i_c - i_a) + e_{ac} \quad (3)$$

and i_a, i_b, i_c are the stator phase currents, R is the stator resistance, L is the self- inductance and M is the mutual inductance.

The condition for the stator current to be balance is,

$$i_a + i_b + i_c = 0 \quad (4)$$

The developed torque, load torque and output power is related as follows:

$$T_e - T_L = j\ G_m /dt +\ _m ù \quad (5)$$

Where km is the rotor speed, Ke is the back emf constant.

3. BLDC MOTOR WORKING

Permanent Magnet Synchronous Motor (PMSM) has two types of excitation model; sinusoidal and another one is trapezoidal. PMSM having a trapezoidal excitation is called as the Permanent Magnet Brushless DC Motor (PMBDCM). In a BLDC motor, stator contains three phase windings and the rotor segment is made up of permanent magnet and consist of 2 to 8 pole pairs with alternate pairs of North (N) and South (S) poles. In a conventional DC motor, the commutation of a BLDC motor is carried out using electronic switches. To operate BLDC motor, sequential excitation must be provided. For this, details of the rotor position are required so that the coils will be excited. Hall based sensors placed in the stator. Generally BLDC motor consists of Hall sensors placed on the stator providing positioning of rotor and it is also connected at the off-driving end of the motor. As the magnetic poles of the rotor crosses the Hall sensors, they give out a high or low signal, corresponding to the North or South Pole close to the sensors, these two fields are orthogonal to each other and reduces gradually as the fields stay together. Unidirectional torque can be produced by the flux produced by the windings should catch up with the rotor. BLDC motors mostly finds application with the operation at medium and very high speeds. As these kind of motors shows less inertia with high peak torque characteristics, the motor matches for quick acceleration and deceleration of drives. BLDC With the help of speed feedback (speed sensor) or by a sensor less mode (without a speed feedback) motors can be controlled. During the normal speed control of such type of drives, an encoder measures the speed and compares it with a reference speed in-turn controlling the PWM switching process.

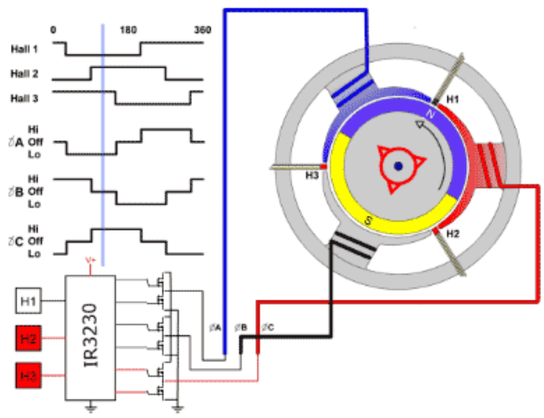

Figure.2 BLDC Motor[6]

PWM technique is a most commonly used technique for the power control to an electrical device, made practical by modern electronic power switches. The average value of voltage (and current) given to the load is controlled by turning on and off the switch between supply and load. Longer the switch is in ON condition compared to that of the OFF periods, the higher will be the power supplied to the load. The PWM switching frequency should be as faster as it can, than what would affect the load.

4. Fuzzy – PI controller

The simple FLC is though it better than a conventional PI controller but it is not used in industries everywhere because it is auto tuning controller. Also it has disadvantage as it takes more memory and time consuming controller to simulate it. So this drawback obtained from the simple FLC are overcomed by Fuzzy – PI controller. The proposed controller in this paper is a Mamdani fuzzy controller which works on the principle of two input and single output.

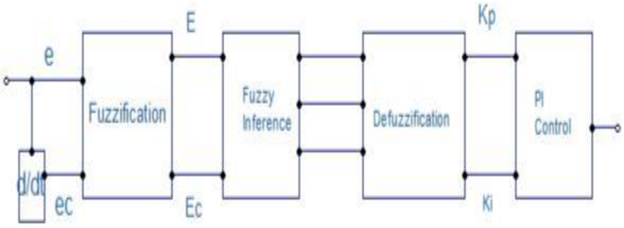

Fig. 3. Structure of Fuzzy tuned PI controller

It is used to calculate the speed controller is more quickly and hence it does not take a more time to computation and so that the memory. The design algorithm of proposed system is just to adjust the K_P and K_I parameter used on the speed error e and rate of change speed error to control the speed in static and dynamic condition.

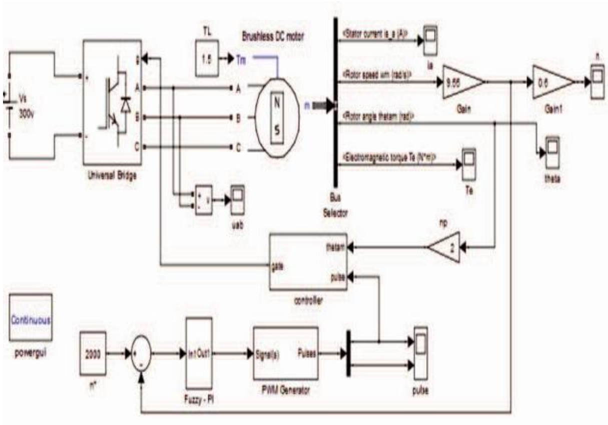

Fig. 4. Simulink model of BLDC motor using Fuzzy–PI controller

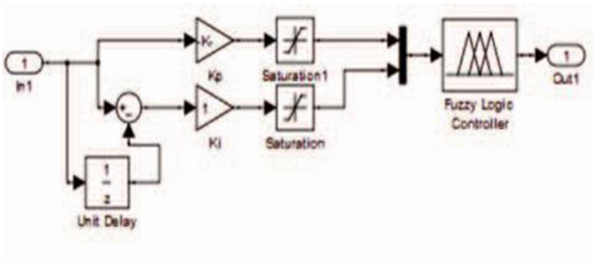

Fig. 5. Subsystem of Fig. 4

The graphical representation of above simulink model is shown in following diagram. The Speed Vs time for Fuzzy – PI controller is shown in Fig 4. This shows that it has rising time is 0.002 sec and it settle down at 0.015 sec by maintaining the overshoot 6.6 % which is less as compared to simple FLC and conventional PI controller.

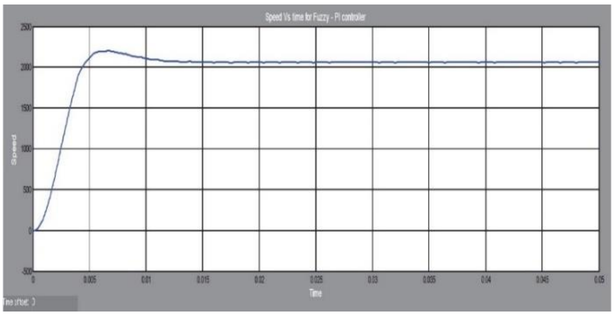

Fig. 6. Speed Vs time for Fuzzy – PI controller

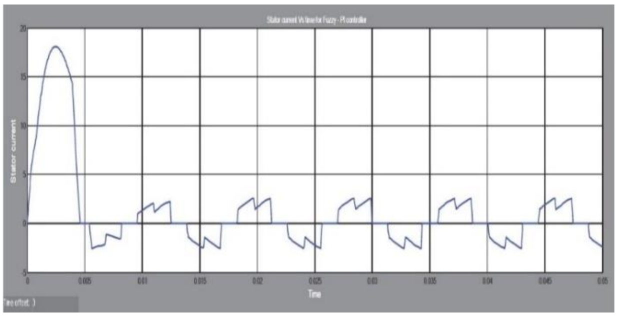

Fig. 7. Stator current Vs Time for Fuzzy – PI controller.

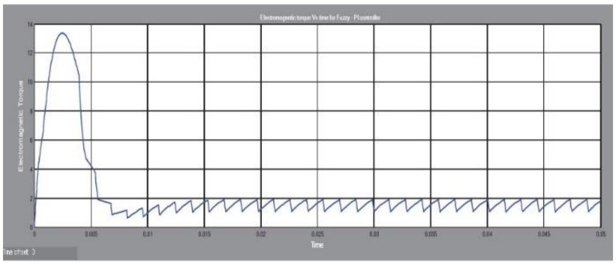

Fig. 8. Electromagnetic torque Vs time for Fuzzy – PI controller.

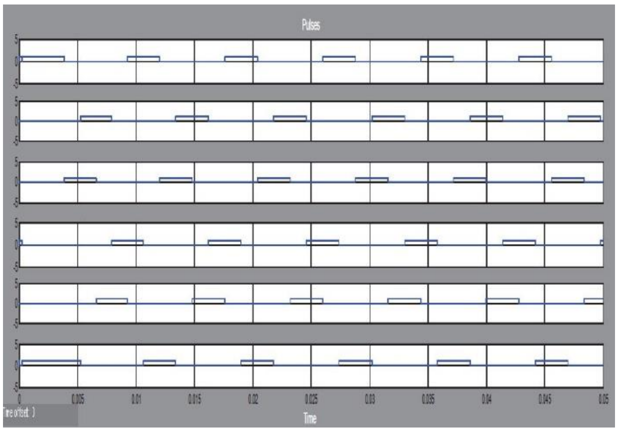

Fig. 9. Gate signal

5. CHARACTERISTICS OF SPEED RESPONSE

TABLE I. CHARACTERISTICS OF SPEED RESPONSE

Controller	Rise time T_R (Sec)	Settling Time T_s (Sec)	% peak Overshoot (%)
PI	0.0091	0.053	12.1
Simple FLC	0.0015	0.012	11.2
Fuzzy – PI controller	0.002	0.015	6.6

6. HARDWARE SETUP

The hardware setup of closed loop speed control of BLDC motor drive is shown in Figures. The waveforms are obtained when the motor was programmed to run at rated speed.

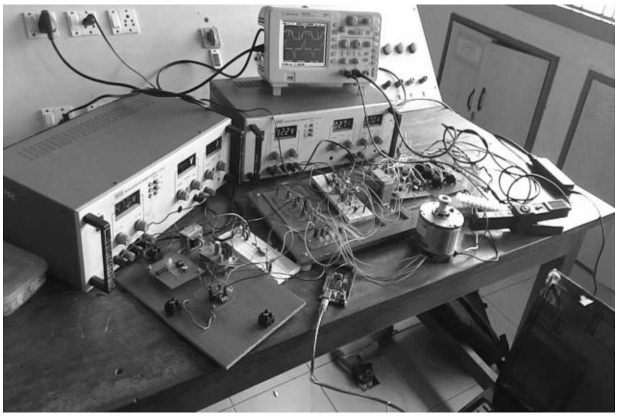

Fig 10. Hardware setup

7. CONCLUSION

The main problems occurred in controlling the BLDC motor is on their characteristic and hence it is very important to solve the problem, as use of BLDC motor is quite large. The proposed system is improving the operating characteristic such as its percentage overshoot rise time and settling time etc. It is obtained during the analysis near about 6.6% which is good with the help of only 21 linguistics rules so as to reduce memory.

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