DESIGN AND SIMULATION OF BLDC MOTOR DRIVE USING PID CONTROLLER AND HALL SENSORS

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Abstract : This paper exhibits a speed control technique for brushless dc motor (BLDC) drives by estimating speed using the hall sensor signals. Conventionally, the speed is measured using precision speed encoders. As these encoders cost is high and almost half of the entire drive system. As the sensorless method has algorithm complexity and catastrophic, there arises need of cost effective speed estimation technique. This is proposed by measuring the speed and position from hall sensors. Here a closed loop speed controller is proposed using PID controller and current controlled pulse width modulation (PWM) technique since BLDC motor is electronically commutated machine, the commutation period is determined by switching table that shows hall signal status. The entire system is simulated in MATLAB/simulink and the performance of the system is analyzed for different speed and references

IndexTerms* - *Brushless DC motor(BLDC); Current sensing controllers; hall sensors; PID controller; current controlled PWM; Inverter;

I. INTRODUCTION

Replacement of a BLDC motor by a BLDC motor places higher demands on a control algorithm. The torque of BLDC motor is mainly influenced by the waveform of back EMF. The development of low cost motor drive system has gained importance. The speed and position estimation of BLDC motor is done by Kalman filter algorithm [1].this algorithm is better for low speed applications. To improve this algorithm micro-angle control scheme is used for low speed applications[2]. In addition to this comparison study of 3 different sensors has done with use of MC73110 micro control chip; and found that hall sensors have low algorithm complexity[3&4]. Now to drew a BLDC motor a voltage source inverter, several current control (cc) techniques are studied and special emphasis on various approaches of the hysteresis current controllers has been observed[5]. To compare with hall sensors a permanent magnet synchronous motor with an incremental encoder but it is not cost effective[6]. To study different control methods with DSP and DSPIC33FJMC804 but it has design complexity and requires large memory[7&8] . To know the difference between former and later method an estimation of electromagnetic torque using direct torque controller(DTC) but it leads to low efficiency[9&10].

The objective of this paper is building a BLDC motor drive with Trapezoidal motor excitation system and analyzing the speed-torque characteristic for different input torques. And also comparing it with permanent magnet synchronous motor where the power density, speed variation is observed. hall sensors are used for speed estimation as well as to help in controlling so that it removes the cost of precision speed encoders and algorithm complexity of sensorless methods And the conventional PI controller is replaced with PID controller to control the system.

II. ANALYSIS OF BLDC MOTOR DRIVE SYSTEM

- Modelling of three phase BLDC motor
- BLDC MOTOR

The BLDC motor is an AC synchronous motor with permanent magnets on the rotor (moving part) and windings on the stator (fixed part).

- THREE PHASE INVERTER(IGBT)

The BLDC motor control consists of generating DC currents in the motor phases. Commutation of BLDC motor is done using Voltage Source Inverter.

This control is subdivided into two independent operations: stator and rotor flux synchronization and control of the current value. Both operations are realized through the three phase inverter

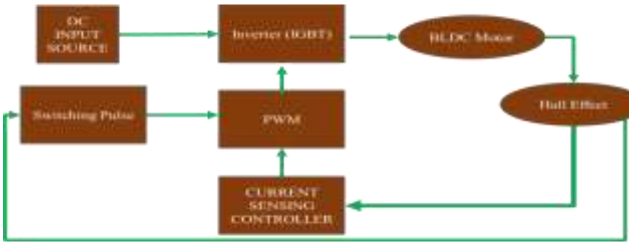

Fig.1 Block diagram of BLDC motors

- HALL SENSORS

Hall sensors is a sensing switch that outputs a logic level based on magnetic field detected as shown in fig.2. Combining the outputs of all hall sensors gives 8 status from 000 to 111 because of hardware constraints signal 000 and 111 don't exist. Table.1 shows the other 6 status can divide the one electrical of position in to six areas and determined by equation (1)

$$\theta_m = \frac{2}{p}\,\theta_e \qquad (1)$$

Where

P = number of poles

$\theta_m = mechanical\ angle$

$\theta_e = electrical\ angle$

Consider a BLDC motor with a north and south pole permanent magnet attached to the rotor and attached Hall sensors at 120° from each other to measure the orientation of the magnet. This will yield that the Hall sensors will give six states for one full revolution, that is 360°/6 = 60° for each state, as shown in fig.2 The process of continually switching current to different motor coils to produce torque on the rotor is called *commutation*.

Table.1 Truth table of hall effect sensor

Time	Hall Input			Phase A		Phase B		Phase C	
	A	B	C	Q1	Q2	Q3	Q4	Q5	Q6
1	0	0	1	0	0	0	1	1	0
2	0	1	0	0	1	1	0	0	0
3	0	1	1	0	1	0	0	1	0
4	1	0	0	1	0	0	0	0	1
5	1	0	1	1	0	0	1	0	0
6	1	1	0	0	0	1	0	0	1

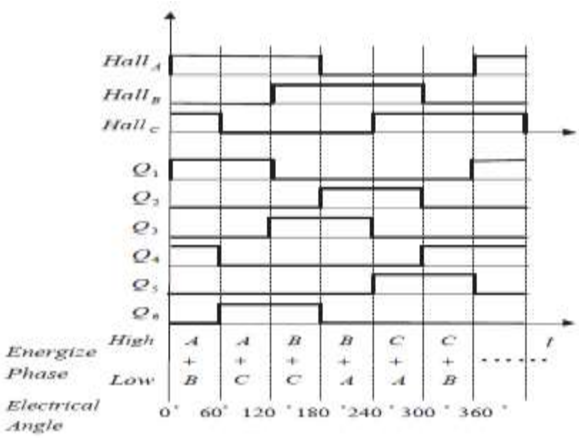

Fig.2 Switch sequence of hall signal and PWM pulses

According to table.1 the rotor position at Hall state 100. The south pole turns Hall 1 on. The north pole turns off Hall 2 and Hall 3. The Hall state, therefore, is 100. (Hall 1 = ON, Hall 2 = OFF, Hall 3 = OFF)

- PULSE WIDTH MODULATION MODE

The supply voltage is chopped at a fixed frequency with a duty cycle depending on the current error. Therefore, both the current and the rate of change of current can be controlled. The two phase supply duration is limited by the two phase commutation angles. The main advantage of the PWM strategy is that the chopping frequency is a fixed parameter; hence, acoustic and electromagnetic noises are relatively easy to filter.

- CURRENT SENSING CONTROLLER

Characteristic of the BLDC control is to have only one current at a time in the motor (two phases ON).Consequently, it is not necessary to put a current sensor on each phase of the motor; one sensor placed in the line inverter input makes it possible to control the current of each phase. Moreover, using this sensor on the ground line, insulated systems are not necessary, and a low cost resistor can be used. Its value is set such that it activates the integrated over-current protection when the maximum current permitted by the power board has been reached.

III. SIMULATION MODEL OF BLDC MOTOR DRIVE SYSTEM

Fig.4 shows the overall system configuration of the three-phase BLDC motor drive. The inverter topology is a six-switch voltage-source configuration with constant DC link voltage (Vdc). The PWM three phase inverter operations can be stated as shown in Fig.1. BLDC motor model is composed of two parts. One is an electrical part, which calculates electromagnetic torque and current of motor.

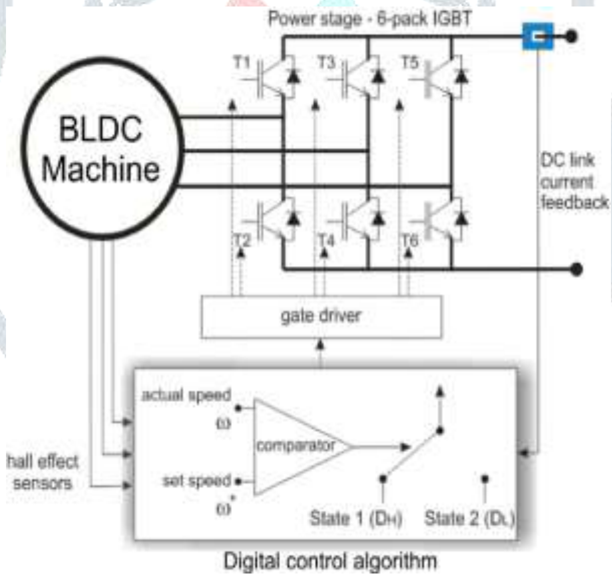

Fig.3 Schematic Diagram of Trapezoidal BLDC motor drive

The three phase currents are controlled to take a form of quasi-square waveform. For this motor, at each time only two phases are through the conduction operating modes and the third phase is silent. So, we can use just one current sensor as shown in fig.1. The reference and actual speed are compared and the speed error is given to current sensing controller. Current sensing controller is explained in Fig.1.the Hall sensor block is used to extract the BEMF information from the Hall effect signals. The outputs, three-level signals (−1, 0, 1), represent the normalized ideal phase currents to be injected in the motor phases. These type of currents will produce a constant torque. The following figure shows the BEMF of phase A and the output of the Hall sensor for the phase A.

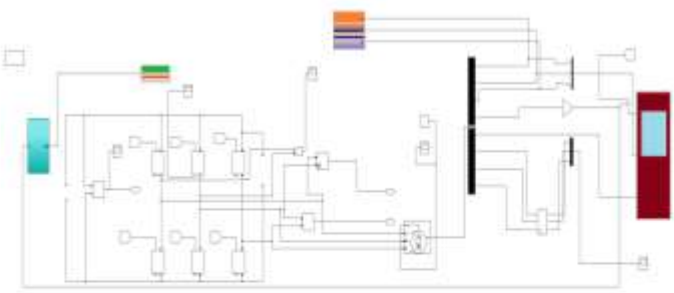

Fig.4 Simulation model of BLDC motor

BLDC motor is same as conventional DC motor but it has no brushes and commutator so it requires, an inverter to commutate and in later methods SVPWM controlled inverter is used. But current controlled voltage source inverter is efficient for former method.

IV. SIMULATION RESULTS

A. INVERTER (120°)

Fig.5 shows simulation model of voltage source inverter. In Hysteresis-type current regulator, the IGBT are switched off and on according to whether the current is greater or less than a reference current. The error is used directly to control the states of IGBT.

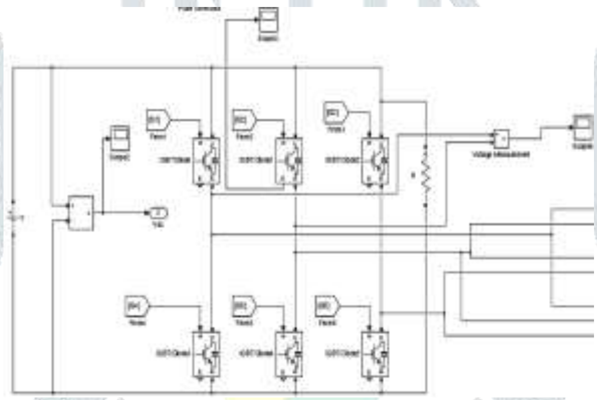

Fig.5 Voltage source inverter model

B. ELECTRICAL SYSTEM

The outputs of the VSI is fed through the stator windings of the BLDC motor, then a rotating magnetic field is produced. This rotating magnetic field interacts with the permanent magnetic field then an electromagnetic torque is developed in the rotor.

Fig.6 electrical model

$$V_{an} = R_a i_a + L_a \frac{di_a}{dt} + e_{an} \quad (2)$$

$$V_{bn} = R_b i_b + L_b \frac{di_b}{dt} + e_{bn} \quad (3)$$

$$V_{cn} = R_c i_c + L_c \frac{di_c}{dt} + e_{cn} \quad (4)$$

where Van , Vbn , Vcn are phase voltages, Ra , Rb , Rc are stator resistances, ia , ib , ic are the stator currents, La , Lb , Lc are the phase inductances, ean , ebn , ecn are the phase back-EMFs. The Electro-magnetic torque developed by the machine at steady state is given by equation (5).

$$T = k\, \emptyset\, Ia \quad (5)$$

where T is the torque (electromagnetic), k is the EMF constant, ϕ is the flux, Ia is the stator current.

C. MECHANICAL SYSTEM

The mechanical system of BLDC motor contains the moment of inertia(J), damping constant(B), friction(F) and the governing equation of the system is as follows

$T_m - T_l$= Bωm+ J (dωm/dt) (6)

ea = kaωmcosθt (7)

eb = kbωmcos(θt-120) (8)

ec = kcωmcos(θt+120) (9)

Back-EMF waveforms are generated by using the mechanical system equations speed and mechanical angle (θ).

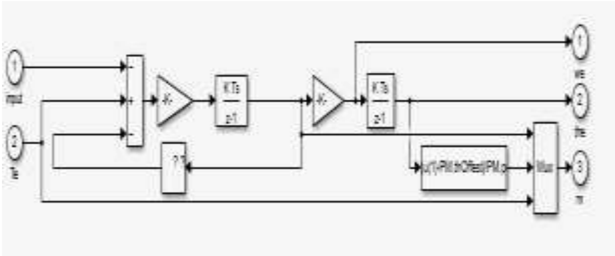

Fig.7 mechanical model

D. CURRENT CONTROLLER

Conventional PID controller is used as a current controller for recovering the actual motor torque to the reference. The reference and the measured current are the input signals to the PID controller. The Kp Ki and Kd values of the controller are determined by trail and error method for each set of currents. Then comparator is compares the output signal with repetitive reference signal then a pulses is produced as the output. This pulses is given to the switches of the inverter with help of decoder signals and hall signals. As shown in Fig.7

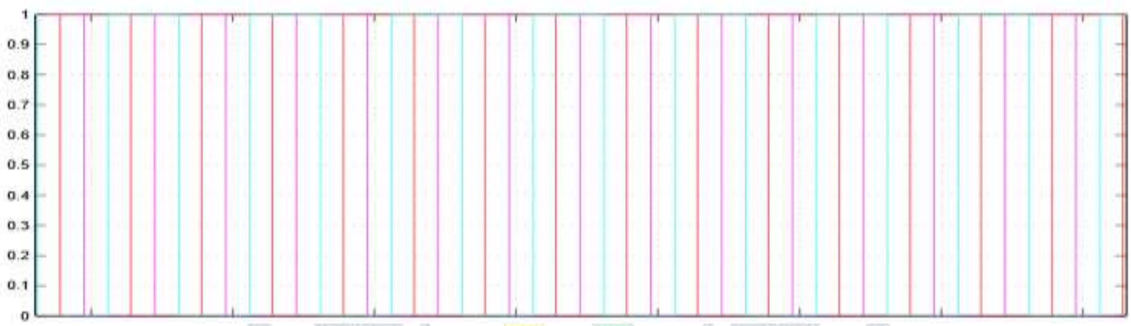

Fig.7 hall signals

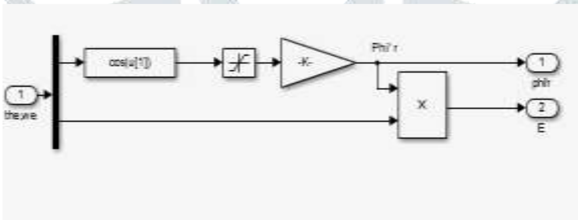

Fig.8 Back EMF generator of phase A

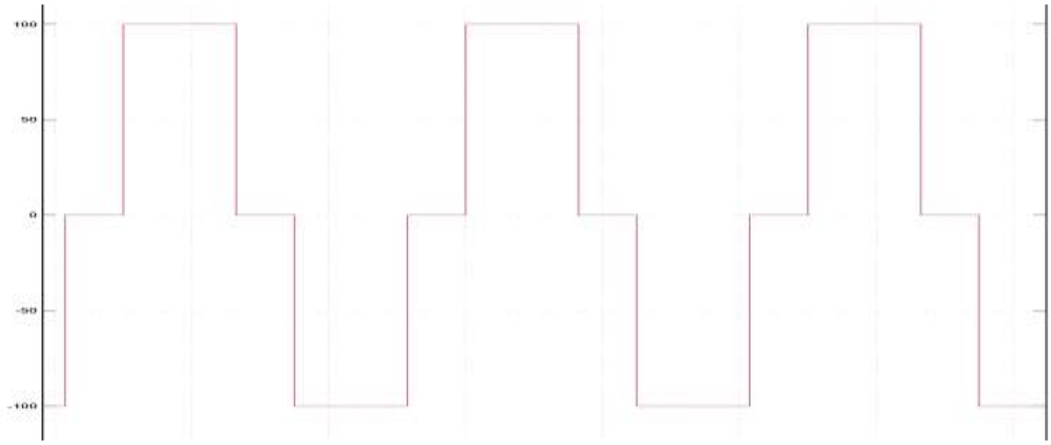

Fig.9 Three phase back EMFs

By using AND gates we are going to develop the six independent pulses for the six inverter switches. Pulses from the decoder circuit is shown in the Fig.10

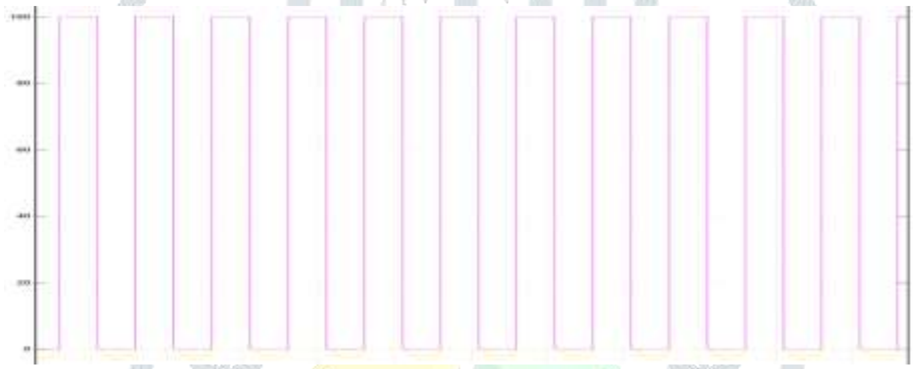

Fig.10 Gate Pulses

The inverter are used for getting three level output as shown in fig.10 which we are giving pulses for the gate using PWM signals for all six switches to get three level output.

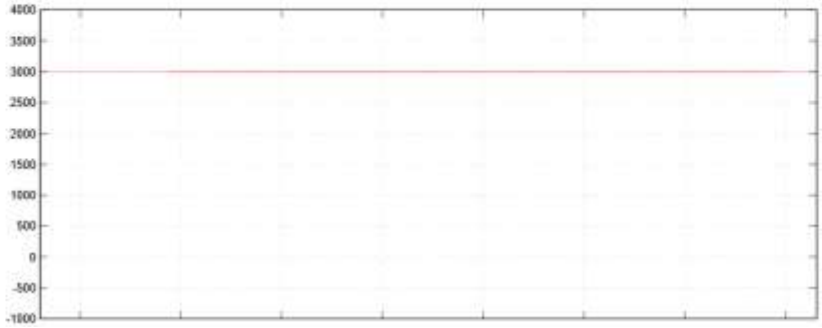

Fig.11 motor speed with torque

The entire closed loop system was simulated using a 440W, 48V, 3000rpm, 1.2Nm rated machine. The system was initially run with a reference speed of 3000rpm and a starting torque of 1Nm. As shown in fig. 11

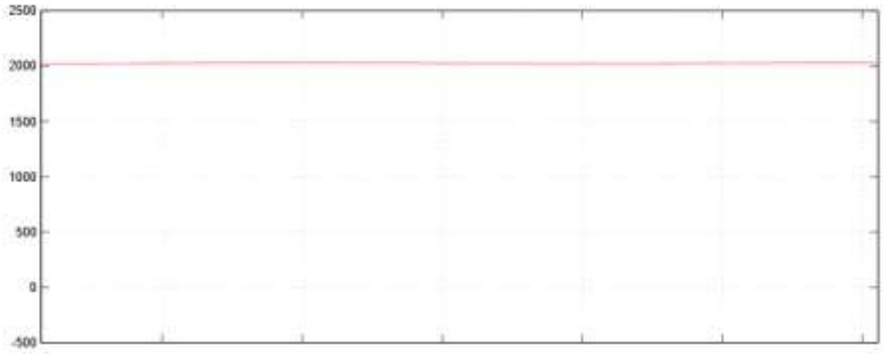

Fig.12 motor speed at torque of 0.5Nm

The BLDC motor model is tested for different torque values. The speed is 2000rpm for the value of torque 0.5Nm sa shown in fig.11 and fig.12

Fig.13 three phase stator current

The fig.11 and fig.13 shows reference speed and measured speed is fed to PID controller .Then PID controller is tuned with kp kd ki constants .By Using PID controller we are achiving the speed of about 3000 rpm, and 3-phase stator output.

IV.CONCLUSION

This paper proposes cost effective speed estimation technique for BLDC motor drive. This method is found to be working for the entire range of speeds below the rated speed. The performance of the system is comparable with that of the conventional speed encoder based control technique. As well as with that of permanent magnet synchronous motor with sinusoidal excitation, Actual speed is found to maintain the reference speed for different values of load torques. This is verified successfully by using MATLAB/Simulink. Since the proposed speed estimation technique does not require the motor parameters like resistance, inductance etc., the system is suitable for robust applications, especially in industries.

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V. ACKNOWLEDGMENT

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