Fuzzy Logic Based Speed Control of BLDC Motor

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Abstract— *It is possible to control speed of the BLDC motor without using Hall sensors and position sensors. Sensorless control has advantages like cost reduction, reliability, elimination of difficulty in maintaining the sensor etc. Sensorless control is highly advantageous when the motor is operated in dusty or oily environment, where cleaning and maintaining of Hall Sensors is required for proper sensing of rotor position. Sensorless method is preferred when the motor is in less accessible location. Accommodation of position sensor in motor used in compact unit such as computer hard disk may not be possible. This paper demonstrates a hardware implementation of sensorless control of Permanent Magnet Brushless DC motor and controlling the speed of the PMBLDC motor using fuzzy logic controller.*

Keywords—**Speed Control, BLDC Motor, Sensorless, Sensors, Fuzzy Logic Controller, Rotor Position.**

I. INTRODUCTION

Brushless dc (BLDC) motors have been desired for small horsepower control motors due to their high efficiency, silent operation, compact form, reliability, and low maintenance. However, the control complexity for variable speed control and the high cost of the electric drive hold back the widespread use of brushless dc motor. Over the last decade, continuing technology development in power semiconductors, microprocessors/logic ICs, adjustable speed drivers (ASDs) control schemes and permanent-magnet brushless electric motor production have combined to enable reliable, cost-effective solution for a broad range of adjustable speed applications.

The BLDC motor that are utilized in the proposed control design is star connected BLDC motor. The power distribution is achieved by the intelligent electronic controller. The electronic controller requires rotor position information for proper commutation of currents in the respective stator windings. The rotor position can be sensed using Hall Effect sensors embedded in the stator and thus stator windings are energized accordingly.

BLDC motor drive control can be done in sensor or sensor less mode. Though the sensor less control offers the advantage of reduced cost, the sensor less control offers low performance at transients or low speed range with increase in complexity of the control electronics and algorithms makes the use of Hall sensors more efficient. Embedded control of BLDC motors using dsPIC30f4013 generates a PWM signal that controls the inverter topology there by controlling the drive. High flexibility of control can be obtained by implementing efficient control algorithm in the controller. These classic motors typically are operated at constant-speed directly from main AC power without regarding the efficiency. Consumers now demand for lower energy costs, better performance, reduced acoustic noise, and more convenience features. Those traditional technologies cannot provide the solutions.

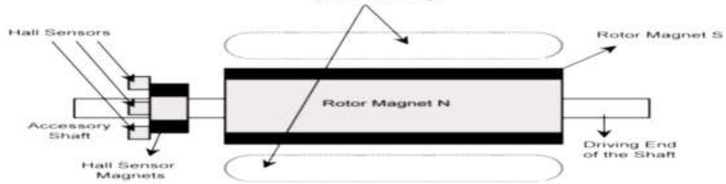


Fig. 1 BLDC Motor Transverse Section with Hall Sensors

The rotor position is sensed which enables commutation logic for the three phase inverter circuits that contain MOSFET switches.

TABLE I
CLOCKWISE HALL SENSOR SIGNALS AND DRIVE SIGNALS

Ha	*Hb*	*Hc*	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*
0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	1	1	0
0	1	0	0	1	1	0	0	0
0	1	1	0	1	0	0	1	0
1	0	0	1	0	0	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	0	0	1	0	0	1
1	1	1	0	0	0	0	0	0

II. MATHEMATICAL MODEL

The principle of operation and the dynamic model of BLDC motor can be explained as follows. The circuit equations of the stator windings in terms of electrical constants is given by equations (1)-(6)

$$v_a = R_a i_a + L_a \frac{di_a}{dt} + M_{ab}\frac{di_b}{dt} + M_{ac}\frac{di_c}{dt} + e_a \quad (1)$$

$$v_b = R_b i_b + L_b \frac{di_b}{dt} + M_{ba}\frac{di_a}{dt} + M_{bc}\frac{di_c}{dt} + e_b \quad (2)$$

$$v_c = R_c i_c + L_c \frac{di_c}{dt} + M_{ca}\frac{di_a}{dt} + M_{cb}\frac{di_b}{dt} + e_c \quad (3)$$

R: Stator resistance per phase, assumed to be equal for all phases
L: Stator inductance per phase, assumed to be equal for all phases.
M: Mutual inductance between the phases.
ia, ib, ic: Stator current/phase.
Va, Vb, Vc: are the respective phase voltage of the winding
Neglecting mutual inductance

$$v_a = Ri_a + L\frac{di_a}{dt} + e_a \quad (4)$$

$$v_b = Ri_b + L\frac{di_b}{dt} + e_b \quad (5)$$

$$v_c = Ri_c + L\frac{di_c}{dt} + e_c \quad (6)$$

III. PROPOSED MODEL

In Figure, ω ref. is the reference speed (rad/sec), ωa is the actual rotor speed (rad/sec), θ is the rotor position (degree), u is the control signal used to reference moment (N-m), ia , ib , ic are the actual phase currents (Ampere), $i_a$ref, $i_b$ref, $i_c$ref are the reference phase currents (Ampere), $S1 - S6$ are switches of the inverter and Vdc is the supply voltage of the inverter (Volt).In speed control loop as shown in the block diagram, the reference speed and the actual motor speed is compared and the error signal is obtained. These signals are employed in fuzzy controller and reference current is produced for control system. The current control loop regulates the BLDC motor current to the reference current value generated by the speed controller. The current control loop consists of reference current generator, PWM current control unit and a three phase voltage source inverter (VSI). Position of the BLDC motor can be obtained by employing direct back Emf detection methods eliminating position sensor requirement.

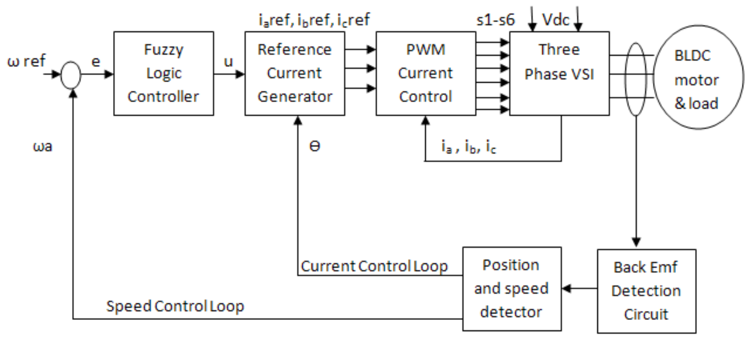


Figure 2: Block diagram of proposed method

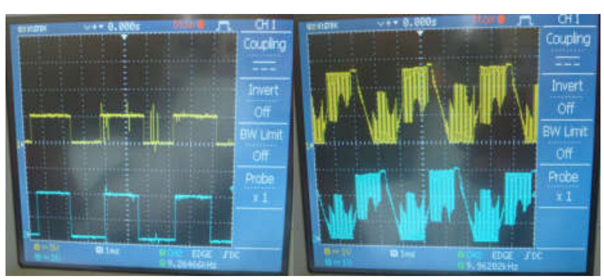
IV. Hardware Implementation and Experimental Setup of the Proposed Back EMF Detection Scheme

The Experimental or Hardware Setup of the project work is shown in figure 3.The experimental system consist of a brushless DC motor, a voltage source, a voltage regular circuitry ,a motor driver circuit, back-emf detector circuit, optocoupler circuit and a dsPIC30F4011 microcontroller board.

Figure 3: Experimental Set-up

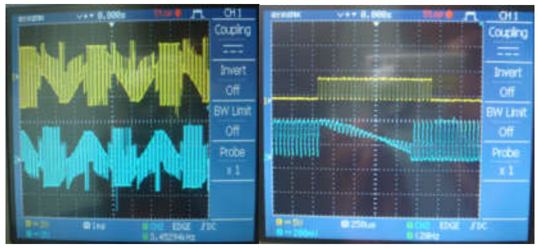
V. Results

The proposed sensorless BLDC drive has been successfully implemented using dsPIC30F. The following waveforms show some key operating waveforms of a sensorless BLDC drive system. Fig.7.9 Output of One phase by microcontroller using Back Emf and HALL sensor signals.



(a) (b)

Figure 4: (a) Output of One phase using Back Emf and HALL sensor (b) Back Emf Waveform RN and YN phase through back Emf Detection Circuit



(a) (b)

Figure 5: (a) Back Emf Waveform RY and YB phase directly from Motor terminals (b) PWM pulse with the zero-crossing point

Figure 4.a shows the output monitored at one phase of the motor through microcontroller circuit and another signal is taken from the output of the hall sensor. Figure shows the relationship between the hall sensor signals and the back Emf signals. Figure 4.b shows Back Emf Waveform of R phase with respect to neutral point N and Y phase with respect to neutral point N through back Emf Detection Circuit. The motor windings produce trapezoidal back Emf. The back Emf generated in the windings are at 120 degrees out of phase to each other. Figure 7.11 shows Back Emf Waveform RY and YB phase directly from Motor terminals i.e without using back Emf detection circuit and it is clear that it is difficult to identify the zero crossing at these terminals. PWM pulse applied to MOSFETs of driver circuit. Which provide the control action for turning on and off of electronic switches for proper commutation of motor. Change in PWM duty cycle for different speed variations. Motor speed is directly proportional to applied voltage, so varying the PWM duty cycle linearly from 0% to 100% will result in a linear speed control from 0% to 100% of maximum RPM. Figure 5.b shows PWM pulse and the zero-crossing point of back Emf waveform and the zero-crossing point and DC bus.

VI. Conclusion

Electric machines are used to generate electrical power in power plants and provide mechanical work in industries. The Permanent Magnet Brushless DC (PMBLDC) motors are one of the electrical drives that are rapidly gaining popularity, due to their high efficiency, good dynamic response and low maintenance. The brushless DC (BLDC) motors and drives have grown significantly in recent years in the appliance industry and the automotive industry. BLDC drives are very preferable for compact, low cost, low maintenance, and high reliability system. It is obvious that the control for BLDC motors using position sensors, such as shaft encoders, resolvers or Hall-effect probes, can be improved by means of the elimination of these sensors to further reduce cost and increase reliability. Furthermore, sensorless control is the only choice for some applications where those sensors cannot function reliably due to harsh environmental conditions and a higher performance is required.

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