MODELING OF SENSORLESS CONTROL OF PMBLDC MOTOR

P.MANIKANDAN, K.ANAND, J.RAJESH, J.PRANESH JONATHAN

Abstract— **A model of BLDC motor is done using MATLAB. This simulated model is based on the dynamic mathematical equations of the BLDC motor. The different blocks associated with BLDC motor such as the inverter, speed and current controllers which are necessary for controlling the motor is also simulated using MATLAB. Based on this model a sensor less control technique is implemented. For this purpose a zero crossing position (ZCP) method is proposed. The simulation results indicate that the established model based on the method proposed in this study has a good response to the rotor speed. This can be used for the future work of control design of BLDC motors. The hardware implementation is also possible because of satisfied simulated output results.**

Index Terms— Brushless DC motor, MATLAB, modeling, zero crossing position (ZCP)

I. INTRODUCTION

In recent years there has been significant development of permanent magnet (PM) motors of various kinds. Improvements in the properties of permanent magnet materials have increased the viability of related types of motor, such as the permanent magnet synchronous motor (PMSM) and brushless dc motor (BLDC). Both motors require alternating stator current to produce the constant torque, and to control them the rotor flux position has to be identified[1]. The rotor position information is used to manage the switching of the supply to the phases of the stator in correct sequence by a control circuit. The motor drive system requires a rotor position sensor to provide the proper commutation sequence. The position sensors such as resolvers, absolute position encoders and hall sensors increase the cost and size of the motor [2-4]. These sensors, practically hall sensors are temperature sensitive. Absolute position sensors are generally speed limited to -600rev/min. Resolvers need special external circuit to obtain the correct position information. In some compact applications, e.g. Computer hard disk drives, it may not be possible to mount any position sensor to the motor. Also in motors rated below 1W the power consumption by position sensor can substantially reduce the motor efficiency. Owing to these limitations of the motor operation with position sensor, the sensorless operation of a brushless motor is receiving wide attention [5]. The sensorless approach has several advantages: 1) only electrical connections to the machine are the main phase windings, so installation costs are minimized; 2) position-sensing function can be located with the other control electronics: it does not need to be sited adjacent to the machine, and therefore does not inhibit the operating temperature range; 3) absence of connecting leads prevents corruption of position data by electromagnetic interference; and 4) cost of a position-encoding device is avoided. The idea of position-sensorless operation of brushless machines was first advanced by Frus and Kuo [6] using a technique known as “waveform detection” for deducing rotor position in voltage-fed variable-reluctance stepping motors by analysis of current waveforms. This paper discusses some of the position sensorless methods to get an insight of the methods used, and then the zero crossing position method is discussed along the modeling of the BLDC motor after which the simulink MATLAB simulated results are given.

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II. POSITION SENSORLESS METHODS

In back EMF detection method the instantaneous magnitude of the EMF is the function of rotor position relative to the winding, information about the winding is contained in the Back EMF waveform [7].But it is not possible to directly extract the information from the waveform. And the back EMF is directly proportional to speed of the machine. So in such cases it is difficult to detect the rotor position at low and zero speeds. For that reason the machine is accelerated under open loop condition after which the rotor position can estimated. Based on the zero crossing value of the back EMF in each phase winding used for sensing, commutation logic is provided so that the phase gets excited. Some of the limitations of this method are Sensing at low speeds is not possible. It is assumed that there is a very rapid decay of current when the phase is switched off, so the voltage appearing across terminals is back EMF. This is not true for speeds approaching base speeds.

Third Harmonics of back EMF method utilizes the third harmonic component in the EMF waveform of a trapezoidal machine and thus reduces phase shifting problem in the zero crossing back EMF detection method [8]. Here, there is a reduced filtering requirement because of integration function is performed on a signal which has frequency three times the fundamental frequency. Operation at higher speeds is possible. Some of its limitations are the assumption that the inductance is equal in all phases. This is valid for surface mounted machine and not for others machines because it can exhibit significant saliency and error in estimation could occur.

A mathematical model of the converter/machine combination is supplied with the same inputs and produces estimates of the outputs. These estimated outputs are compared with the measured outputs to yield an estimation error, which is fed back to the model to assist in correcting the estimates. If the estimation error is small, the model replicates the behavior of the real converter and machine. Some of its limitation, there is a lower limit on rotor velocity for good estimation performance because the amplitude of the back EMF is proportional to rotor velocity. The starting problem remained, and for consistent starting, a separate technique is needed.

The rate of current change depends on the inductance of the winding, and this inductance is a function of rotor position and winding current, then rotor position can be deduced from winding current and its rate of change [9]. Its major limitations are, sensing of rotor position by inductance variation in the brushless DC machine is complicated as there is no saliency, rotor position arises from magnetic saturation .the rate of change of current in the machine is dominated by the back EMF .the variation of incremental inductance with rotor position undergoes two cycles per single electrical cycle of the machine causing ambiguity in sensed position.

The implementation of flux linkage variation is possible in recent years because the emergence of the devices [10]-[13]. By subtracting the voltage drop from the phase voltage and integrating, and then a continuous estimate of phase flux linkage can be produced. But it should be emphasized that flux linkage estimation does not access any position information than is available from the combination of back EMF and position sensing, so for certain machine types it becomes extremely difficult to do sensor less operation.

III.PROPOSED SENSORLESS METHOD

A.MODELLING OF BLDC MOTOR:

Assuming phase resistances, R_a, R_b, R_c equal to R and phase inductances L_a, L_b, L_c equal to L, the voltage equation of BLDC motor from Fig (1) can be derived as

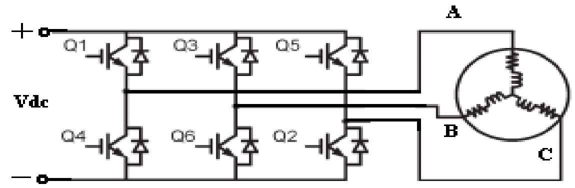

Fig. 1 BLDC motor equivalent

$$V_a = RI_a + (L - M)\frac{dI_a}{dt} + E_a \quad .... (1)$$

$$V_b = RI'_b + (L - M)\frac{dI_b}{dt} + E_b \quad .... (2)$$

$$V_c = RI_c + (L - M)\frac{dI_c}{dt} + E_c \quad .... (3)$$

The above equations can be represented in matrix form by,

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} R & 0 & 0 \\ 0 & R & 0 \\ 0 & 0 & R \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + \begin{bmatrix} L & M & M \\ M & L & M \\ M & M & L \end{bmatrix} \frac{d}{dt} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + \begin{bmatrix} E_a \\ E_b \\ E_c \end{bmatrix} ... (4)$$

Where,

R =stator resistance per phase

L =stator inductance per phase

M=mutual inductance per phase

I_a, I_b And I_c =stator phase currents

V_a , V_b and V_c =stator phase voltages

E_a, E_b And E_c =represent the back EMFs in the respective phases.

The back-EMF is depending on magnetic flux in rotor because of permanent magnet with speed of rotor, given by

$$\begin{bmatrix} E_a \\ E_b \\ E_c \end{bmatrix} = \omega\psi \begin{bmatrix} \mathrm{trapez}(\theta_r) \\ \mathrm{trapez}(\theta_r - (2\pi/3)) \\ \mathrm{trapez}(\theta_r + (2\pi/3)) \end{bmatrix} \quad .... (6)$$

ω = rotor speed

ψ = magnitude of flux linkage

θ_r − rctor positon

The line to line voltages can be written as,

$$V_{ab} = RI_{ab} + (L - M)\frac{dI_{ab}}{dt} + E_{ab} \quad .... (7)$$

$$V_{bc} = RI_{bc} + (L - M)\frac{dI_{bc}}{dt} + E_{bc} \quad .... (8)$$

$$V_{ca} = RI_{ca} + (L - M)\frac{dI_{ca}}{dt} + E_{ca} \quad .... (9)$$

The generated electromagnetic torque is given by

$$T_e = \frac{v}{2\omega}[E_a I_a + E_b I_b + E_c I_c] \qquad .... (10)$$

The load dynamics becomes

$$T_e - T_l = J\frac{d\omega}{dt} + B\omega \qquad .... (11)$$

Where,
J =moment of inertia
B = friction coefficient
T_l = load torque.

B. ZERO CROSSING POSITION (ZCP)

From the zero crossing point of the back EMF, a virtual hall signal is created. The point at which it becomes zero and thereafter is taken as a low signal and the point at which it crosses the zero and goes increasingly is taken as high signal. For the starting the motor is run in the method [14], after which the motor attains certain amount of speed for producing the required back EMF for zero crossing detection, from the fig(2) we can see the exact ZCP.

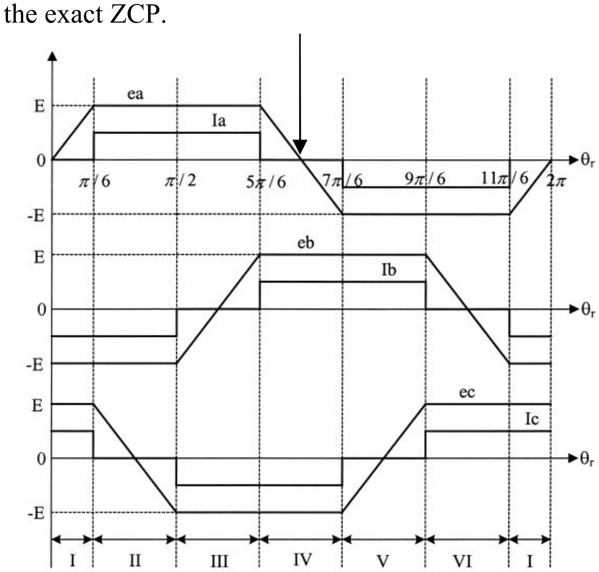

Fig. 2 back EMF along with currents.

IV.SIMULATION RESULTS

A BLDC motor is modeled from its dynamic equations using simulink MATLAB. The simulator used is ode45. Figures (3-7) shows the hall signal, zero crossing position signal, back EMF, current, and the speed of the BLDC motor which is simulated using simulink. In figures (5-7) a load is being introduced at 0.04sec and the variation in waveform is also seen clearly

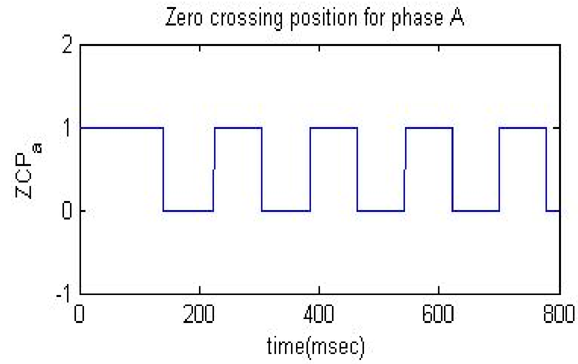

Fig.3 Zero Crossing Position signal

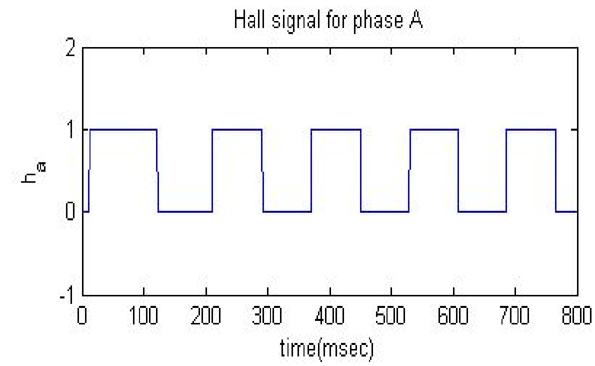

Fig. 4 Hall signal

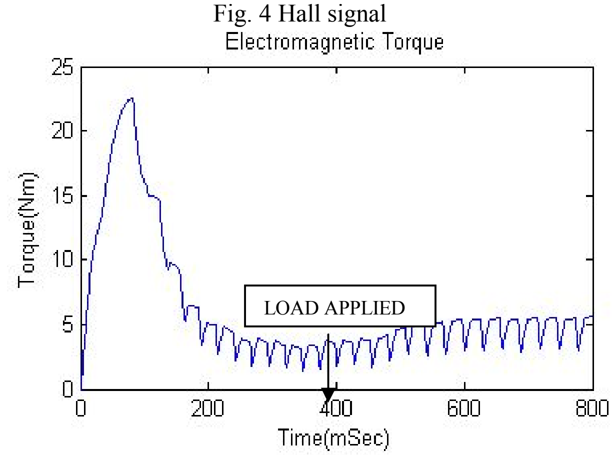

Fig 5 Torque Produced

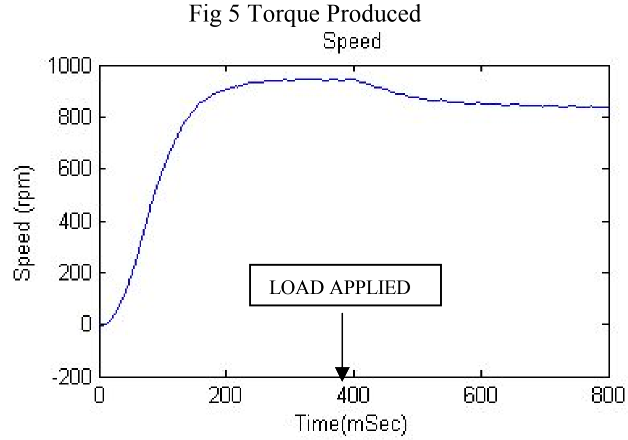

Fig. 6 Speed Of the motor

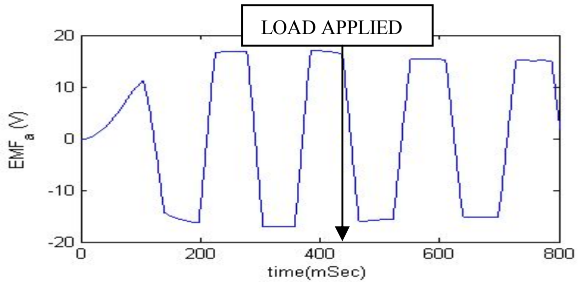

Fig. 7 Back EMF of the motor

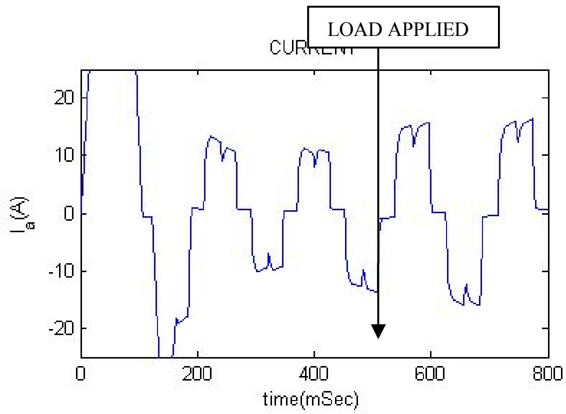

Fig.8 Current Waveform of the motor

CONCLUSION

Sensorless technology for PM machines has been researched extensively with a surge of recent interest being prompted by the availability of more powerful digital signal processing devices. In this paper based on the motor dynamic equations of the BLDC motor, a BLDC motor model is modeled. From the motor model a simple sensorless control based on the zero crossing position is designed and simulated.

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