PI CONTROLLER BASED COMMUTATION TUNING ON SENSORLESS BLDC MOTOR

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Abstract

Brushless DC Motor are widely used in aerospace, automotive, appliance, industrial controls, automation, aviation because their high power to wait ratio, cost effective, high efficiency and reliable operation over long periods of time. These advantages also make them preferred over brushless DC motors. But the requirement of a sensor for rotor position detection makes brushless DC motors a costly affair. Because of the above drawback, sensor less position and speed control of brushless DC motor is proposed in this project. The rotor position can be estimated from the back EMF detection for commutation tuning of bldc motor. One of the methods is the DSP-based sensor less scheme contingent on a disturbance observer for back-EMF estimation. Also speed of a BLDC motor is controlled using PI controller. This project is implement in Matlab Simulink.

Keywords: Brushless dc motor, PI controller, Back EMF sensorless drive.

I. INTRODUCTION

Recently the increase in energy prices spurs higher demands of variable speed Permanent Magnet (PM) motors drives. Also, recent rapid proliferation of motor drives into the automobile industry, based on hybrid drives, generates a serious demand for high efficient PM motor drives. The Brushless dc motor (BLDC) is a Permanent Magnet DC Synchronous motors. These are used in great amount of industrial sectors because their architecture is suitable for any safety critical applications, from a modelling perspective looks exactly like a DC motor and having linear relationship between current and torque, voltage and rpm [4,5]. The electromagnets do not move, the permanent magnets rotate and the armature remains static, the position sensor and intelligent electronic controller are required to transfer current to a moving armature, which performs the same power distribution as a brushed DC motor. Regular uses of cheap induction motor drives, which have around 10% lower efficiency than adjustable PM motor drives for energy saving applications [10]. BLDC motor have many advantages over brushed DC motors and induction motors, such as a better speed versus torque characteristics, high dynamic response, high efficiency and reliability, long operating life (no brush erosion), noiseless operation, higher speed ranges and reduction of electromagnetic interference (EMI). In addition, the ratio of delivered torque to the size of the motor is higher, making it useful in application where space and weight are critical factors, PM motors have been widely used in automotive (hybrid vehicles), computers, household products and especially in aerospace application [1].

However, the PM BLDC motors are inherently electronically controlled and require rotor position information for proper commutation of currents in its stator windings. But it is not desirable to use the Hall sensors for high temperature applications where reliability is of utmost importance because a sensor failure may cause instability in the control system [11]. Another major problem is associated with the conventional controllers that are widely used in the industry due to its simple control structure and ease of implementation. But these controllers pose difficulties under the conditions of nonlinearity, load disturbances and parametric variations [3]. Traditional control systems are based on mathematical models in which the control system described using one or more differential equations that define the system response to its inputs. In many cases, the mathematical model of the control process may not exist or may be too expensive in terms of computer processing power and memory and a system based on empirical rules may be more effective for closed loop speed control.

This paper develops to remove the drawbacks associated with sensored control and use of traditional controllers by using zero crossing point (ZCP) based on Back electromotive force (Back-EMF) sensorless control with fuzzy logic controller. The sensorless control requires good reliability and various speed ranges with the high starting torque for BLDC motor drive system. To satisfy these requirements, this paper proposes an efficient sensorless speed control to avoid high energy prices.

II. PRINCIPLES OF SENSORLESS BLDC MOTOR CONTROL

Brushless DC motor drives have need of rotor position information for appropriate operation to execute phase commutation. Position sensors are generally used to provide the position information for the driver. So this type of position sensors is not used in sensorless drives. The advantage of sensorless drives comprises of less hardware cost, increased system reliability, decreased system size and reduced feedback units. And also they are free from mechanical and environmental constraints [2].

Various control methods arises for sensorless drive, in which a back EMF is the most cost effective method to obtain the commutation sequence in the star wound motors and current sensing provides enough information to estimate with sufficient rotor position to drive the motor with synchronous phase currents. BLDC motor drives that do not require position sensors but it contains electrical dimensions are called a sensorless drive. The BLDC motor provides sensorless operation based on the nature of its excitation intrinsically suggest a low-cost way to take out rotor position information from motor-terminal voltages. In the excitation of a 3 phase BLDC motor, apart from the phase-commutation periods, two of the three phase windings are functioning at a time and no conducting phase carries in the back-EMF. Since back-EMF is zero at standstill and proportional to speed, the measured terminal voltage that has large signal-to-noise ratio cannot detect zero crossing at low speeds. That is the reason why in all back-EMF-based sensorless methods the low-speed performance is limited, and an open-loop starting strategy is required [7,8].

In BLDC motor the stator iron has a non-linear magnetic saturation features that is the fundamental from which it is feasible to find out the initial position of the rotor. When a stator winding is energized, then DC voltage is applied for a particular time and a magnetic field with a fixed direction will be recognized. Then, the stator current responses are changed owing to the inductance variation and this variation of the stator current responses which comprises of the information of the rotor position.

Back-emf zero crossing detection method:

The zero-crossing detection method is an easiest method of back-EMF sensing approach and it is based on finding the instantaneous at which unexcited phase crosses zero due to back-EMF [4]. This zero crossing activates a timer that might be as easy as an RC time constant; accordingly the next sequential inverter commutation take place at the end of timing interval.

For a distinctive operation of a BLDC motor, the back- EMF and phase current should be associated to generate constant torque. Fig. 2 shows the waveform for current commutation point which can be attained by the zero crossing point of back-EMFs and a six-step inverter commutation design for driving the BLDC motor [5,7].

As a result the interval for every phase of a BLDC motor is conducted at 120 electrical degrees. Hence, in BLDC motor only two phases conduct current at whichever time. The third phase is called floating phase. In order to produce greatest torque, the inverter is to be commutated at every 60° by calculating zero crossing of back-EMF on the floating phase of the motor, therefore the current is in phase with the back- EMF.

III. MATHEMATICAL MODELLING OF BLDC MOTOR

BLDC motor modelling is similar to three-phase synchronous machine modelling.

The model is developed, in which the permanent magnet enclosed with the rotor and it contains different dynamic characteristics. Fig. 1 shows the Inverter BLDC motor-drive model. The BLDC motor is fed to a three-phase voltage source is not necessary to be sinusoidal or square wave can be applied. The peak voltage produced over there should not exceed the maximum voltage of the motor.

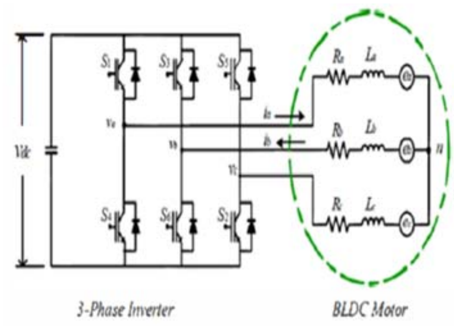

Fig:1 Inverter with BLDC Motor drive model

Phase A and B are conducting and phase C is floating. The motor three phase voltages equation is given by.

$$V_{an} = I_a Z + e_a + V_n$$
$$V_{bn} = I_b Z + e_b + V_n$$
$$V_{cn} = e_c + V_n$$

Where, V_{an}, V_{bn}, V_{cn}-three phase voltages, R_S-resistance of winding, I_a, I_b, I_c-three phase currents, e_a, e_b, e_b-three phase back EMF and Z-impedance of circuit.

Stator resistance of all winding are assumed to be equal and there is no change in the rotor reluctance with angle. Then the phase voltage equation are given as,

$$\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} = \begin{bmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} L & M & M \\ M & L & M \\ M & M & L \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix}$$

$$\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} = \begin{bmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} L_S - M & 0 & 0 \\ 0 & L_S - M & 0 \\ 0 & 0 & L_S - M \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix}$$

$$L = L_S - M$$

Where L is the equivalent induction in each stator windings, L_s is the self inductance of the stator winding, M is the inductance of stator winding.

If the self-inductance and mutual inductance around the air gap are constant, there will be a direct relation between the applied source voltage to the phase terminals (V) and the induced back EMF (E).

$$E \infty V$$

According to the working principle of BLDC motor, only two phases are conducting at a time while the third phase is floating in running mode so Eq. reduces to the following.

$$\begin{bmatrix} V_{an} \\ V_{bn} \end{bmatrix} = \begin{bmatrix} R_s & 0 \\ 0 & R_s \end{bmatrix} \begin{bmatrix} I_a \\ I_b \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} L_S - M & 0 & 0 \\ 0 & L_S - M & 0 \end{bmatrix} \begin{bmatrix} I_a \\ I_b \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \end{bmatrix}$$

This equation is the electrical transfer function of BLDC motor.

IV. PROPOSED SENSORLESS CONTROL OF BLDC MOTOR

The proposed method is based on the fact that rotor position can be detected by using a trapezoidal Back-EMF of BLDC motors. Since Back-EMF of the BLDC motor is not measured directly, it is estimated by the comparator with zero crossing detection technique and PI controller is used for efficient speed control.

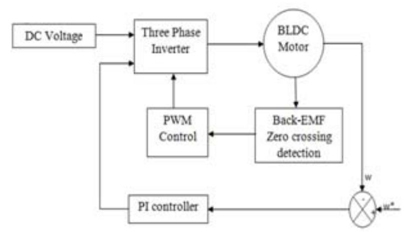

Fig:2 Proposed block diagram of sensorless control of BLDC motor

In proposed method, the comparators are used for generating the gating signals, by comparing ,V_a,V_b and V_c toV_n . If V_a, is greater than V_n , then the comparator outputs high level, else the comparator outputs low level, which is expressed as Z_a. At the rising edge of Z_a , the MOSFET S_1should be ON, and the MOSFET S_5 should be OFF, at the falling edge of Z_a , the MOSFET S_4 should be ON, and the MOSFET S_2 should be OFF. Similarly, according to the rising and falling edge of Z_b and Z_c respectively, the other commutation instants should be obtained. The gating signals Z_a, Z_b and Z_c are generated from the every commutation instants. Consequently, the BLDC motor could work normally on the prior state.

PI SPEED CONTROLLER:

A proportional integral derivative is control loop feedback used in industrial control system. The PI controller calculation involves two separate modes the proportional mode, integral mode. The proportional mode determine the reactive to the current error, integral mode determines the reaction based recent error. The weight sum of the two modes output as corrective action to the control element. PI controller algorithm can be implemented as

$$\mathrm{output(t)} = \mathrm{K_p e(t)} + \mathrm{K_I} \int_0^t \mathrm{e(\tau)d\tau}$$

SIMULINK SENSOR LESS BLDC MOTOR:

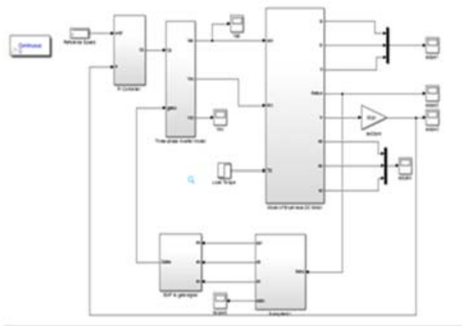

Fig:3 simulation diagram of proposed sensorless control of BLDC motor

V.SIMULATION RESULTS AND DISCUSSIONS

In order to validate the control strategies as described, digital simulations were carried out on a converter for the BLDC motor drive system using MATLAB/SIMULINK . Simulation studies were carried out to evaluate the performance of both sensored and sensorless based speed control of BLDC motor. The output waveform of back EMF and stator current are shown in figure. The speed response for sensored drive using Proportional integral controller and sensorless drive using PI controller are observed. Also, electromagnetic of the PI controllers analysed under comparator with zero crossing back EMF sensorless drive technique.

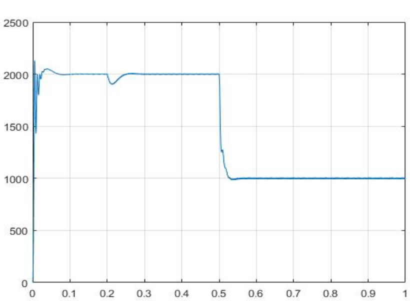

Fig:4 Speed controller

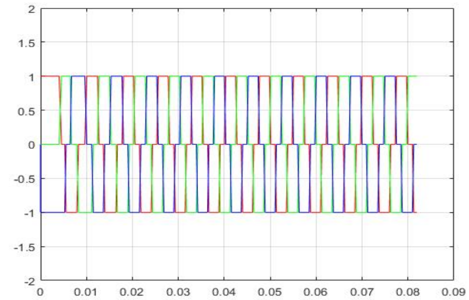

Fig:5 PWM pulses to inverter

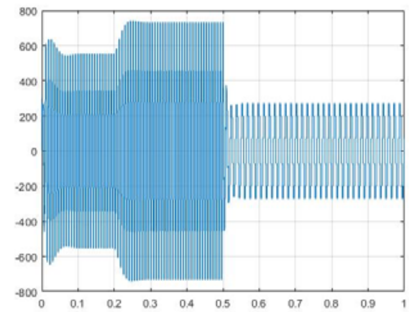

Fig :6 Phase current

VI.CONCLUSION

In this project sensor less method of BLDC Motor control using back EMF difference estimation method is introduced. This method does not require any phase delay circuit thereby reduce the phase error correction. The zero crossing point of the back EMF difference was adopted to commutate the motor and simple circuit. A sensor less drive without phase compensation and stating procedure is implemented. The close loop speed control is achieved by PI controller.

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