

Speed Control System for BLDC Motor by using Direct Back EMF Detection Method

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Usually the BLDC motor has trapezoidal back EMF waveform and stator is fed by rectangular stator current and theoretically it gives a constant torque but the torque ripple exists due to EMF waveform imperfection, current ripple and phase current commutation. BLDC motor also need position information for torque producing and this information is obtained by using hall sensors or sensorless techniques [5] [6].

BLDC motors are required rotor position information for the proper commutation of currents in its stator windings, this information can be obtained using hall sensors mounted on a rotor. This results in a high cost as well as poor reliability. These limitations of using sensors have spurred the development of sensorless control technology. Basically, two types of sensorless control technique are there. The first method is the position sensing using back EMF of the motor and the other one is position approximation using terminal voltages, currents and other motor parameters. The back EMF voltage in the unenergized winding can be measured to maintain a switching sequence for commutation in the three phase inverter. In conventional back EMF detection method, a virtual neutral point is built and senses the difference between the virtual neutral and the voltage at the floating terminal.

II. Principle of sensorless control for BLDC Motor

BLDC motor drives that do not require position sensors but it contains electrical dimensions are called a sensorless

ABSTRACT

BLDC motors are used in many industrial and traction applications due to high efficiency, low maintenance and high torque. For good performance of BLDC motors, the accurate knowledge of the rotor position is required. The need for the rotor position information in BLDC motors have been satisfied by use of some form of rotor position sensors. But to reduce cost, complexity and also to improve reliability of the system, sensor less drive system is preferred. In this paper, the development of sensor less control system for BLDC motor using a direct back EMF detection method is presented and simulation for proposed system is done with the help of MATLAB/SIMULINK.

KEYWORDS: Sensorless BLDC motor, direct back EMF detection, sensorless control system

I. INTRODUCTION

In variable-speed control of AC motor drives, utilization of BLDC motor has been widely used because the BLDC motor has simpler structure and lower cost than the other AC motors [1]-[2]. They have better speed versus torque characteristics, high efficiency and better dynamic response and also the torque delivered to the motor size is higher making it useful where space and weight are critical factor.

A three phase BLDC Motor has three phase stator winding on stator and permanent magnet rotor. The torque developed in BLDCM is affected by the waveform of back EMF waveform.

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 three 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 the back EMF. Among various sensorless control methods, the zero-crossing detection of back-EMF is the easiest method and it is based on finding the instantaneous at which unexcited phase crosses zero due to back-EMF.[3]

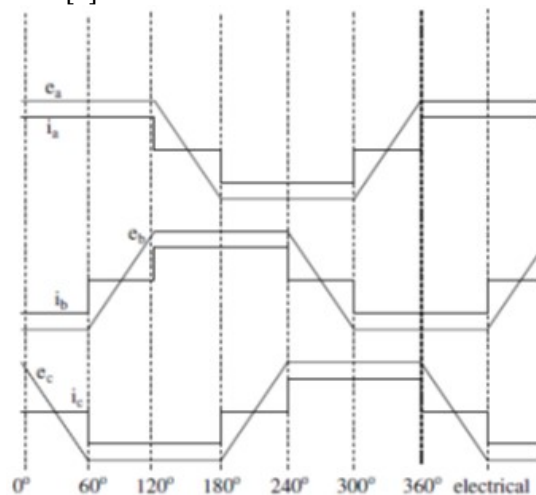


Figure.1 Phase currents and back EMFs of a three phase BLDC motor

In BLDC motor for its distinctive operation, the back-EMF and phase current should be associated to generate constant torque. As a result, the interval for every phase 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 electrical degrees 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. Direct Back EMF Detection

Three phase brushless DC motors are operated in the six-step 120° commutation mode. That means, at any certain time, only two of the three phases are conducting and the other phase is un-energized. For instance, if phases A and B are conducting current, phase C will be floating and unexcited. The conduction interval takes 60 electrical degrees and referred to as a step, and hence the name six-step. Commutation means the transition from one state to another during operation. The first step is called AB, then AC, BC, BA, CA, CB and then repeating. It is important to note that the step names are made from phases having positive to negative states.[5]

Rotor position determines when to commutate the current. In a sensorless control method, no physical sensor can be used for position detection, so other means have to be implemented for rotor position detection. Since the shape of the back EMF changes depending on the rotor position, it is quite possible to determine the commutation by having a back EMF detection circuitry. [5]. It is evident that if the zero crossing of the back EMF can be determined, we can find when to commutate the current exactly. Since one of the three phases does not conduct any current at a certain time, this gives a chance to measure the zero crossing of the back EMF.

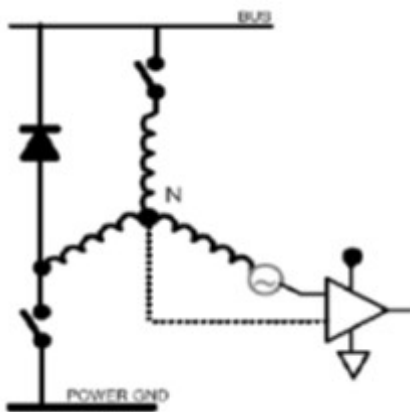


Figure.2 Phase voltage measurement with respect to motor neutral point

The voltage of the un-energized phase has to be measured which the motor neutral needs point to be identified because phase voltage is basically the voltage of the phase with respect to the neutral point, which is usually not the inverter ground. Since most Y-connected motors have their neutral point unexposed, it is physically not possible to identify the motor neutral and measure the phase voltage. Hence, in practice, a method of creating a virtual neutral point is most commonly used. Theoretically, the virtual neutral point will have the same potential as of the actual neutral point if the

motor is perfectly balanced [5] The virtual neutral point is created by three identical resistors as shown in figure 3.[6]

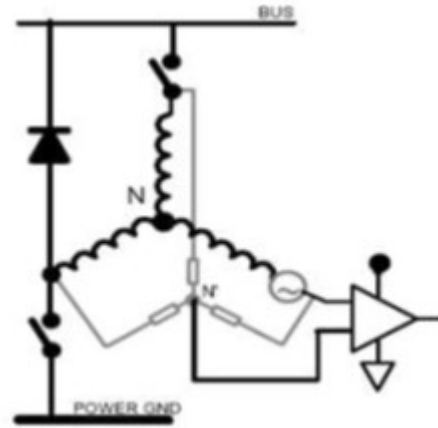


Figure.3 Zero crossing detection scheme with virtual neutral point

IV. Mathematical Model of BLDC Motor Based Back EMF Detection Method

The equivalent circuit of a star connected BLDC motor and the inverter topology is shown in figure 4. The BLDC motor is fed to a three phase voltage source through inverter, which is not necessary to be sinusoidal or square wave can be applied.

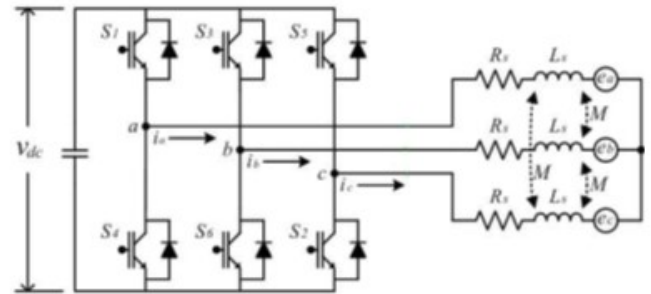


Figure.4 Power circuit of a BLDC motor drive system

$$V_{an} = i_a R_s + L \frac{d}{dt} i_a + e_{an} \tag{1}$$

$$V_{bn} = i_b R_s + L \frac{d}{dt} i_b + e_{bn} \tag{2}$$

$$V_{cn} = i_c R_s + L \frac{d}{dt} i_c + e_{cn} \tag{3}$$

Where, R is the stator resistance, L is the combined inductance, and V_{an}, V_{bn}, V_{cn} are the applied phase voltages.

$$V_{ab} = V_{an} - V_{bn} = (i_a - i_b)R_s + L \frac{d}{dt} (i_a - i_b) + (e_{an} - e_{bn}) \tag{4}$$

$$(e_{an} - e_{bn}) = V_{an} - V_{bn} - (i_a - i_b)R_s - L \frac{d}{dt} (i_a - i_b) \tag{5}$$

$$(e_{bn} - e_{cn}) = V_{bn} - V_{cn} - (i_b - i_c)R_s - L \frac{d}{dt} (i_b - i_c) \tag{6}$$

$$e_{ab} = V_{ab} - (i_a - i_b)R_s - L \frac{d}{dt} (i_a - i_b) \tag{7}$$

$$e_{bc} = V_{bc} - (i_b - i_c)R_s - L \frac{d}{dt} (i_b - i_c) \tag{8}$$

$$e_{an} = K_e \times \omega_e \times f_a(\theta) \tag{9}$$

$$e_{bn} = K_e \times \omega_e \times f_b(\theta) \tag{10}$$

$$e_{cn} = K_e \times \omega_e \times f_c(\theta) \quad (11)$$

where, k_e refers to motor back EMF constant, ω_e is the electrical speed of the rotor and $f(\theta)$ is the rotor position function which has the same shape as the motor back EMF of the corresponding with a maximum magnitude of 1.

V. Modeling of Sensorless BLDC Motor Using Direct Back EMF Detection

For the sensorless BLDC motor control, the modeling and simulation is carried out with MATLAB/SIMULINK software. For the modeling 5kW, 72V_{dc} BLDC motor is used and parameters of BLDC are shown in table 1.

Table.1 Parameters of BLDC motor

Rated Power, kW	5
Rated Voltage, V	72
Rated Torque, Nm	15.9
Rated Speed, rpm	2000
Rotor Inductance, mH	2.08
Resistance, Ω	1.2
EMF constant, V/krpm	25.3
No. of pole	4

The simulink model for sensorless BLDC motor control system is shown in figure 5. The speed control is done by PI controller. The reference speed is compared with actual speed and the error is fed to controlled voltage source. Then the DC output voltage from the controlled voltage source is applied to the inverter. The inverter is controlled by the gate pulses signals supplied from the hysteresis controller. Figure 6 and 7 show simulated the output stator phase current and gate pulse signals. Figure 8 shows the zero crossing output waveform. Torque response and speed response of BLDC motor are shown in figure 9 and 10.

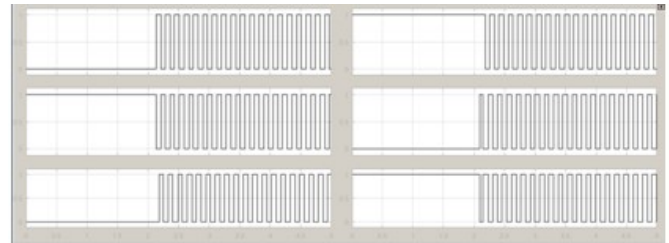


Figure7. Gate pulse signal

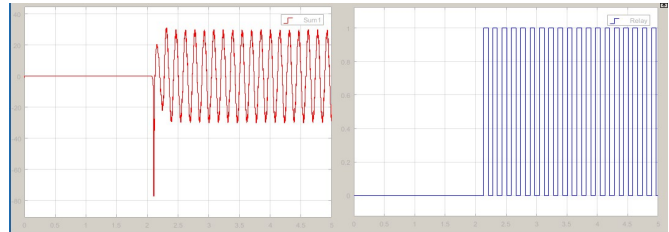


Figure8. Zero-cross output

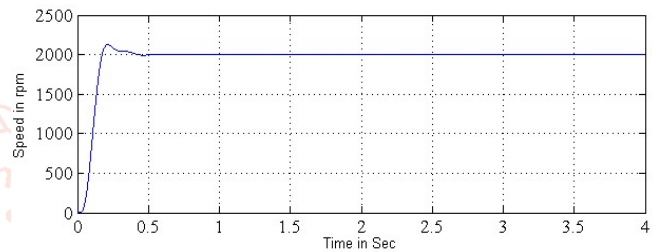


Figure9. Torque response of BLDC motor

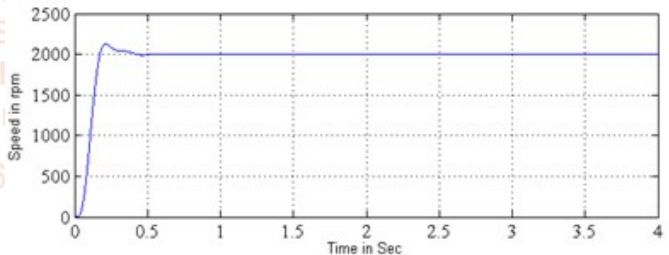


Figure10. Speed response of BLDC motor

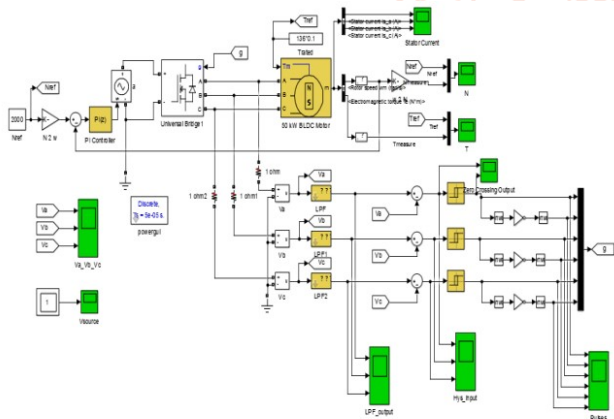


Figure5. Simulink model for sensorless BLDC motor control system

VI. Result

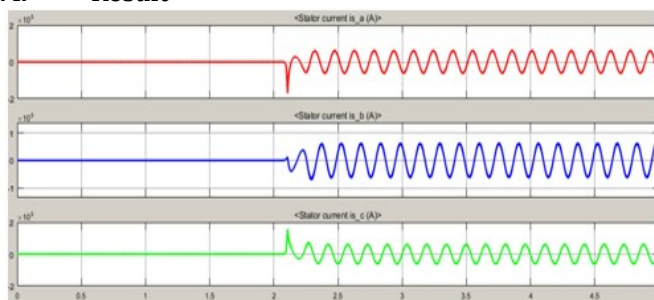


Figure6. Stator current waveform

VII. Conclusion

This paper presents the speed control of BLDC motor using direct back EMF detection method with PI controller was implemented using MATLAB/SIMULINK. In sensorless speed control system, a closed loop speed control technique is used for the BLDC motor. In simulation results with PI controller, the speeds of BLDC motor are stable 2000rpm at 0.3s.

The sensorless speed control system based on the back EMF zero crossing detection method with PI controller produces the best speed error and no steady state error. Therefore, the results of sensorless speed control system with PI controller are able to perfect the stability of the speed variation and less error speed. Therefore, it can be concluded that the simulation of sensorless BLDC motor speed control system is one of the most important applications in electrical engineering field.

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