Rotor Positions Control of BLDC Motor Drive

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Abstract:

Controlled motion of the electrical machines via a system is called an electrical drive. Precise control of the speed of rotation of an electrical machine can be done by implementing the concept of drive. Optimization is easily possible for motion control via drive. A motor drive consists of electrical machine with power electronic converter and the associated controllers. Recent advancement in power semiconductor technologies have paved the way to the development of reliable, efficient, and compact, AC and DC electric motor drives. According to the early research work the most popular method for determining rotor position of BLDC motor is (Zero cross detector)Back EMF method thatworks well for BLDC motor with speed controller being a PID controller.

In this paper the outputanalysis of a sensor-less operation of BLDC motor is done by using ZCD Back EMF method and the simulation model done on MATLAB 14.0(R2014b) version.Control of the BLDC motor drive system is still one of the ubiquitous research problems.

Keywords:

BLDC – Brushless D.C. Motor, PMSM- Permanent Magnet synchronous motor, EMF- Electro Magnetic force, ZCD- Zero Cross Detector, BEMF- Back Electro Magnetic force.

1. Introduction:

BLDC Motor drive systemsare more efficient, fault tolerant, smoother in operation, smaller and matched to the applications. Modeling and design tools are developed to aid the machine design and development of the drive. Particular research emphasis is on permanent magnet and reluctance type machine based drives.

These motors are used in very popular industrial sectors because their structure is suitable for any safety required applications.

BLDC motors are generally powered by a traditional 3-ϕ voltage source inverter (VSI) or current source inverter (CSI) which is controlled. The traditional techniques used for rotor position senseare Hall sensors, resolvers, or optical encoders. These rotor position sensors increase cost, size and complexity of control thereby reducing the reliability and acceptability of these drives. Due to the high cost of the motor and controller, very few commercial applications of BLDC motor.

In this paper firstly rotor position estimation is described. In the second section conventional method using sensors is discussed, in further part of the paper many sensor-less control methods for BLDC motor have been briefed. In the latter section of the paper, modeling of sensor-less zero back-EMF technique is discussed. Along with simulation results is presented. Last section is the conclusion drawn upon the simulation results. In this paper, sensor-less performance of BLDC motor is analyzed by using zero cross back-EMF method and the simulation is done on MATLAB version – 14.00(R2014b). The problem of designing drive system is still one of the ubiquitous research problems.

2. Rotor Position Evaluation

The evaluation of rotor position is very crucial step in controlling BLDC motors. A small error in rotor position evaluation for BLDC motor can result in very poor operation and in some cases it may result in a complete motor failure. The measurement of rotor position can be sense by with sensor and sensor-less approaches. In with sensor approach some type of additional sensors are attached with the stator of the motor, but sensor-less approaches there are no sensors attached to stator of the motor [2].

3. Back-EMF Sensing Techniques-

The BLDC motor, back-EMF sensing technique is based on detecting the instant at whichthe back-EMF in the unexcited phase crosses zero. This zero crossing initiates thenext sequential inverter commutation to occur at the end of at triggered timing interval equal to RC time constant[3]. One of the most cost efficient sensorless control methods of BLDC motors is sensing the back-EMF of an unused phase. It requires a virtual neutral point which brings an extra error in this method. Though, the back-EMF integration and third harmonic voltage integration have the advantage of reduced switching noise sensitivity; they have the drawback of low accuracy at low speed. The flux estimation needs no neutral voltage, but suffers from disadvantages like complex circuit and long sample time. As a consequence, these techniques used to have medium speed range and poor startup characteristics. These technique based on line back-EMF was proposed to reduce those limitation[6].

In PM brushless D.C. machines, the magnitude of the back-EMF is dependent on instantaneous rotor position and having a trapezoidal variation with 120º flat duration. It is difficult to evaluate the back-EMF, because ofsuddenly changing currents in motor windings and also owing to the voltages induced due to electronicphase switching. Initially magnitude of back-EMF is not adequate enough until rotor reaches at some speed, thereforetypical procedure is to make the starting acceleration under open loop control via ramped frequency signal in order that the back-EMF can be measured [9].

The third-harmonic approach assumes equal inductance in each three phases, though this applies for surface-mounted magnet motors only, but in the case of rotors with saliency, error occurs in rotor position estimation due to quickly changing phase currents. It is necessary to have the machine's star neutral terminal availableto evaluate the back-EMF across the terminals of a star-connected machine. The back-EMF technique is mostly applied on low cost applications (fans and pumps)[7].

4. Modeling of Hall Sensor and Sensor-less Zero crossing Back EMF Technique:

In sensorless technique, the motor parameter i.e. stator back-EMF is used to identify the instant position of rotor. Back-EMF detection technique has been proved as a significant improvement of the conventional with sensor methods. BLDC motors exhibit two different types of back-EMF waveforms:

a) Trapezoidal

b) Sinusoidal.

The back-EMF waveform changes its phase every time when the rotor of the motor crosses the stator coil in front of it. The back-EMF waveforms thus produce from the motor stator is made become a zero crossing detector (ZCD). The output of ZCD is a square wave pulses and it is created every time when the back-EMF pulse revise its phase. These square wave pulses hence generated are similar to a hall sensors output and so are used to commute the motor. Square wave pulses from each of the stator windings are fed back to the control logic from motor to achieve commutation [6].

5. Current Controller

The electronic commutation of the Brushless DC motor is becomes necessary to sense the phase currents and the current sensing is sense with the help of Zero Cross detectormethod comes under zero BEMF.

The electronic commutation of the Brushless DC motor is becomes necessary to sense phase currents and current sensing is sense with the help of additional device hall sensors.

The sensing sections are divided in two parts: (a) Position Sensor System and (b) Current Sensor System. The first section is based on three Zero Cross detector cell placed inside the motor winding, and a magnetic disc in the rotor, with the same number of poles as the motor. The second sensing section is based on the current sensors.

The large and small signal speed response is the same whether PWM or Hysteresis current controller are used. The current controller is implemented as a(ZCD) BEMF based. The torque is output of the speed controller will be input torque of the current controller. The output of the current controller will control the current regulator by switching control of RF pulses is fed to the gate, and gate is input of three phase inverter. Therefore current controller is controlled by three phase inverter is fed to the BLDC machine.

To rotate the BLDC motor the stator windings should be energized in a sequence. The rotor position understand to order of stator winding will be energized following the energizing sequence. Rotor position is sensed Back EMF of motor by ZCD embedded into the stator.

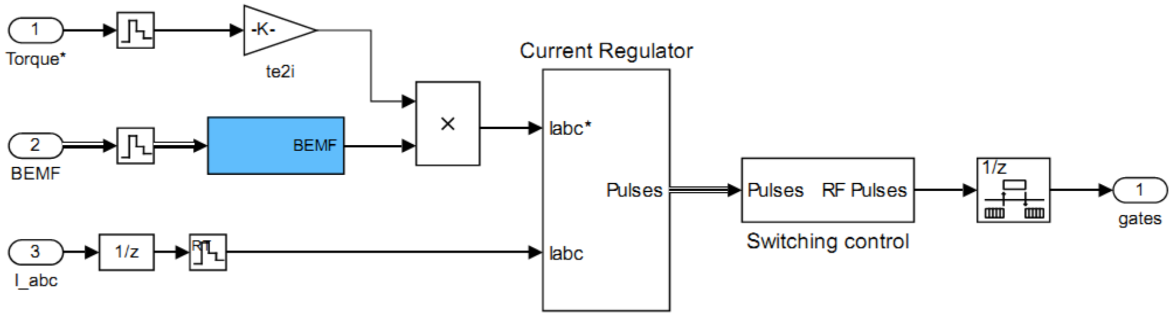

Fig. 1(a) MATLAB/SIMULINK model of current controller by zero crossing Back EMF technique

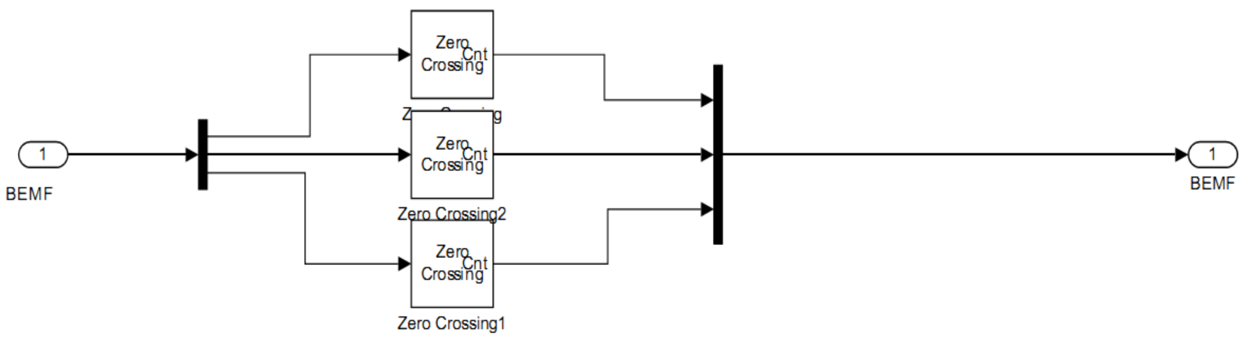

Fig. 1(b)MATLAB/SIMULINK model of current controller/decoder by zero crossing Back EMF technique

6. BLDC Motor Drive parameter representations

The parameters of a three phase permanent Magnet Synchronous Machine are given in Table-1. The stator windings are connected in wye to an internal neutral point.

Table –1 BLDC Motor Model Parameters

S.no.	Parameters of BLDC Motor Drive	Symbols	Value
1.	Stator resistance	r_s	2 Ω
2.	Phase inductance of stator	L_s	10mH
3.	Flux linkage		0.175 V.s
4.	Voltage Constant ($V_{peak\ LL/krpm}$)		146.6 Volt
5.	Torque Constant (Nm/Apeak)		1.4 Nm
6.	Viscous friction	B	0.005 N.m.s
7.	Rotor inertia	J	0.095 $kg.m^2$
8.	Back EMF flat area (degree)		150^0
9.	No. Of pole pairs	P	2

7. Simulation Results:

The circuit has been simulated using Sim Power System library. The permanent magnet synchronous motor (with trapezoidal back-EMF) is fed by a 3-phase inverter, which is made by using a Universal Bridge Block. In this BLDC drive is modeled by manipulating, current controller/decoder.

The PM synchronous motor parameters are specified in the PMSM tab. The braking chopper, the diode rectifier and the inverter switches parameters are specified in the Converters and DC bus tab. Current controller and speed controller parameters are specified in the controller tab.

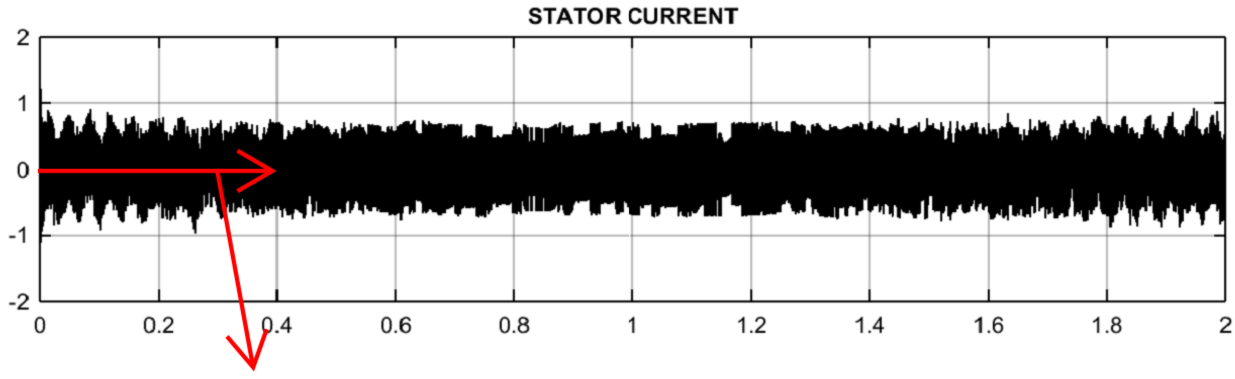

Fig.2a- Stator Current of BLDC Motor by using BEMF method

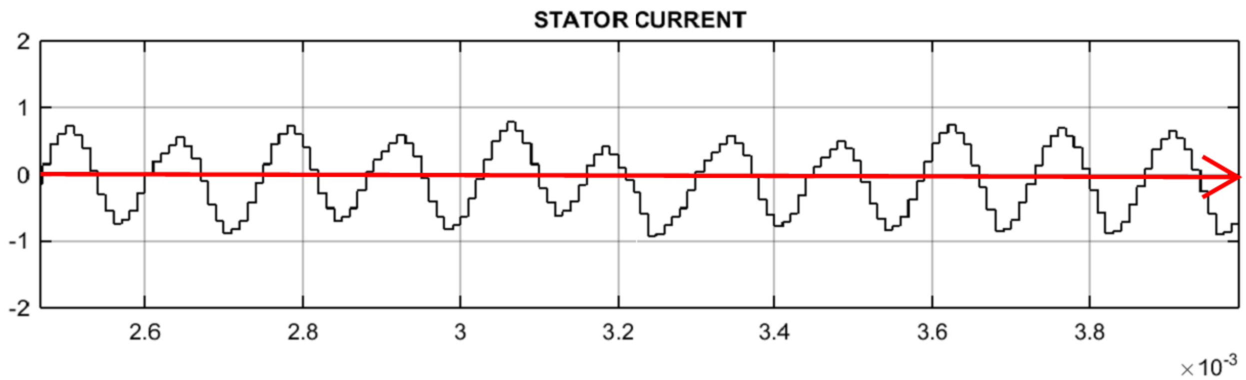

Fig.2b–Zoom out Stator Current wave of BLDC Motor by using BEMF method

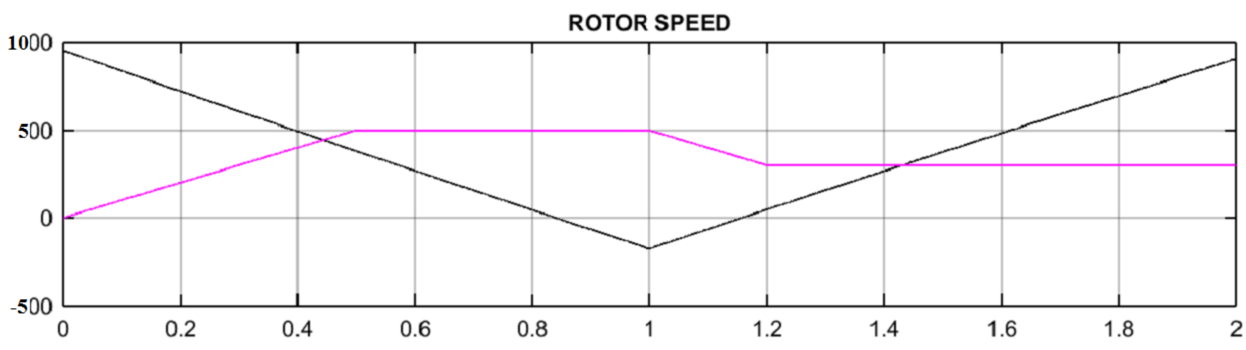

Fig.3 - Rotor Speed of BLDC Motor by using BEMF method

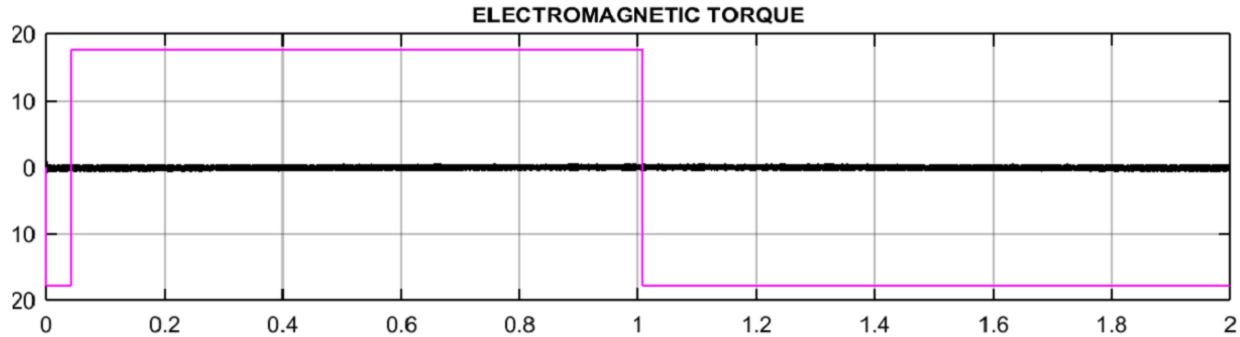

Fig.4- Electromagnetic Torque of BLDC motor by using BEMF method

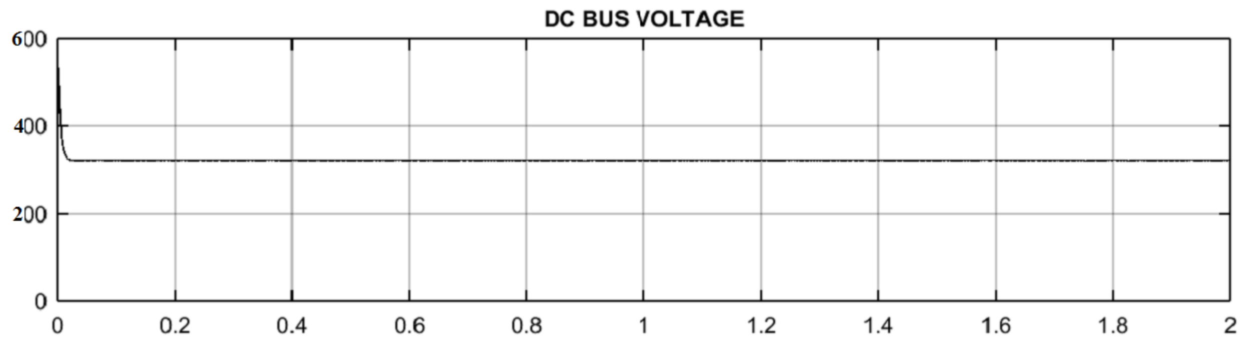

Fig.5-DC Bus voltage of BLDC Motor by using BEMF method

In the graph of Figure 2 (a) and (b),has been shown, the stator current (I_a in Amp) Vs time (in sec.) of Brushless DC Motor by using BEMF method.

The graph in Fig. 3shows the rotor speed (in rpm) Vs time (in sec) of BLDC Motor.

Speed of the motor is variedbetween Rated Speed 500 rad/sec. at 0.4 sec and 300 rad/sec at 1.2 sec but load torque is varied 11 to -11Nm in square form.

Speed N = (120*frequency) / Numbers of poles.

$\omega_m = 2\pi N$

Figure 4and Figure 5 respectively showElectromagnetic Torque (in Nm) Vs time (sec.)and variation of dc bus voltage (in volts) with respect to time (in sec.) of BLDC Motor.

D.C. bus voltage is obtained from 3- phase rectifier circuits. Rectifier circuit maintains D.C. bus voltage always constant at 300 V.

8. Conclusions

This paper shows the estimation of rotor position using back EMF (Zero cross detection) based sensor-less control. The following parameters can be obtained like stator current, rotor speed, Back EMF and DC Bus voltage and their performance are shown in results. According to simulation results obtained using MATLAB/Simulink it can be concluded, that Zero BEMF (ZCD) method is able to estimate the rotor position and speed regulation with PID controller with high precision specially when high speed is considered and the results show the fast operation, robustness, reliability, smooth operation, noiseless operation and excellent dynamic performance for high speed BLDC motor drive.

According to the applied method, sensor-less method can avoid Hall sensors and it's related installation cost. So the sensor-less method is normally adapted for fan, pump applications which do not have big torque variety at start-up and normal running. Also sensor-less method could produce little reverse running at startup.

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