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# Mitigation of Torque Ripple & Detect Rotor Position of BLDC Motor

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## Abstract:

In the recent past, variable speed driving systems have sprouted in various small scale and large scale applications like automobile industries, domestic appliances etc. The usage of green and eco friendly electronics are greatly developed to save the energy consumption of various devices. This lead to the development in Brushless DC motor (BLDCM). The usage of BLDCM enhances various performance factors ranging from higher efficiency, higher torque in low-speed range, high power density ,low maintenance and less noise than other motors. The BLDCM can act as an alternative for traditional motors like induction and switched reluctance motors. In this paper hysteresis current controller is implemented with speed feedback loop and it is observe that torque ripples are minimized. Simulation is carried out using MATLAB / SIMULINK. The results show that the performance of BLDCM is quite satisfactory for various loading conditions.

***Keywords:*** Brushless DC (BLDC) motor, Fast Torque response, low-frequency torque ripples, RC network, , Hall effect Position-sensorlesscontrol,Torque Pulsation.

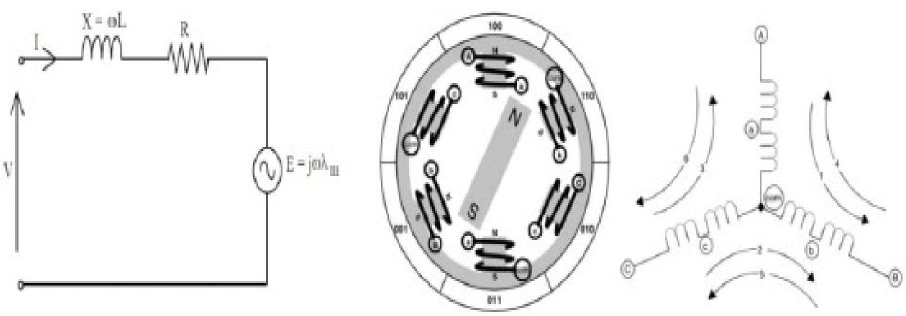
## 1. INTRODUCTION

In high performance applications like servos to traction drives BLDC motor drives are used extensively rather than permanent magnet synchronous motor (PMSM). Brushless DC Motor with trapezoidal BEMF has many advantages. It has high efficiency and high power density, reliability because the absence of field winding and brushes. So it has low maintenance, Simple frame and friction, high capability. Even though in a practical case BLDC drive have torque pulsations due to Back EMF desertion from the ideal. Torque ripple produces noise and problem of speed control. Because of Power electronic commutation, diode freewheeling of inactive phases and High frequency switching of power electronic devices, another problem is inverter output or input of the BLDC Motor have many harmonics that will produce Electromagnetic Interference. Brushless direct current (BLDC) motors have characteristics of high reliability, simple frame, and small friction. By comparing with PMSM, BLDC motor has the advantages of high speed adjusting performance and power density. The torque ripple reduction and the control show improvement of BLDC mainly focused on commutation torque ripple, the torque ripple produced by diode freewheeling of inactive phase, and the torque ripple caused by the non ideal back electromotive force (EMF).. BLDCs achieve commutation electronically by in corporating a feedback from the rotor-position into a control system instead of mechanical commutators found in brushed dc motors. Such a controller excites the stator coils of the motor in a specific order to rotate the magnetic field generated by the coils to be followed along by the rotor. In case of non-ideal motors , the distributed magneto motive force is not perfectly sinusoidal and hence sinusoidal commutation leads to torque ripple. With the suppression of torque ripple the performance of the motor drive performance can be improved by reducing speed fluctuations. By improving machine design such as increasing the number of motor poles the pulsating torque can be reduced in high-performance electric motors. But this may lead to increase in cost and bulkiness of the multiple coil windings. With the help of several current waveforms the torque –ripple harmonics have been reduced for brushless motors .This control approach produces accurate torque in electric motors and their underlying models. Torque ripple produced by non-ideal current waveform is minimized with the help of feed back controllers by adjusting the actual phase currents rather than using position sensors. During the commutation period the product of the instantaneous back EMF and current both in two-phase produces electromagnetic torque. With the help of mid precision position sensor the presto red phase back EMF can be obtained. As a result, torque pulsations due to the commutation are reduced. However, phase resistance is neglected and the torque estimation depends on parameters such as dc-link voltage and phase inductance. Moreover, instead of a simple voltage selection look-up table technique more sophisticated PWM method is used to drive the BLDC motor. Also, two phase conduction method instead of a three-phase one is used which is problematic in the high speed applications Complex control strategies (used for BLDC current/speed regulation) are sensitive to variation in parameters, magnetic saturation; unmodeled disturbances etc. and make the entire system less reliable. For domestic or simple industrial applications where the variation in operating parameters is not frequent, then the control strategies required for BLDC motor should also be simple. This simple control strategy will be available at low cost and uses simple structure and requires minor memory or processing capabilities.

## 2. Mathematical Model of the system

### *2*.1. Modelling of the BL DC motor

A BLDC motor has three stator phase windings connected in star fashion. Permanent Magnets (PMs) are mounted on the rotor. Fig.1 shows the equivalent circuit of a BLDC motor and Fig. 2 illustrates the relationship between the back EMF waveform of an ideal BLDC motor and the armature current, where E, I denotes the amplitude of back EMF and current respectively. The currents should have a rectangular waveform and must be in phase with the corresponding phase back EMF.



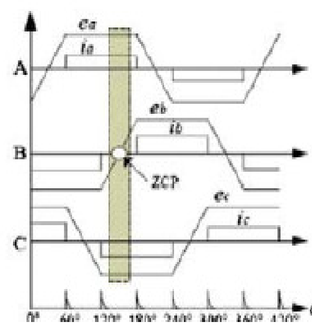




Fig.1 BLDC motor a) equivalent circuit and b) structure and star connected armature

Fig.2. Waveforms of ideal back EMF and phase current.

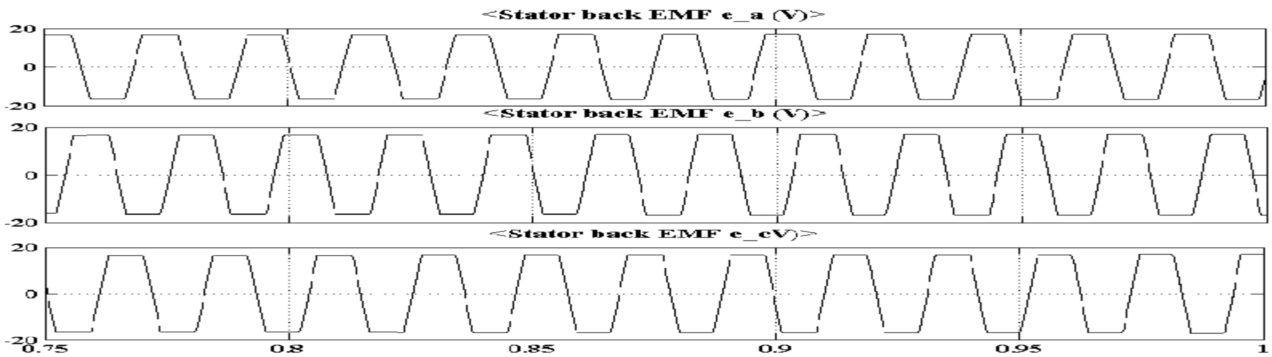
## 3.PROPOSED DIRECT BACK EMF SENSING

Brushless dc (BLDC) motors, with their trapezoidal electromotive force (EMF) profile, requires six discrete rotor positioninformations for the inverter operation. These are typically generated by Hall- effect switch sensors placed within the motor. However, it is a well-known fact that these sensors have a number of drawbacks. They increase the cost of the motor and need special mechanical arrangements to be mounted. Further, Hall sensors are temperature sensitive, and hence limit the operation of the motor. They could reduce system reliability because of the extra components and wiring. So sensor less method is the reliable method used in harsh environments. There are two independent methods for determining the Hall configuration. The selection of which method to use will depend on the information provided.

**1. Hall Based Commutation Sequence Provided.**
**2. Back EMF Waveforms.**

**Hall Based Commutation Sequence Provided:**

This method is the straight forward and requires the least amount of effort on the part of the user. This information is usually provided in the form of a diagram or table and may have different titles such as “Block Commutation” or“Brushless DC Motor Timing Diagram”.




This module implements the following true table

| ha | hb | hc | emf_a | emf_b | emf_c |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | -1 | +1 |
| 0 | 1 | 0 | -1 | +1 | 0 |
| 0 | 1 | 1 | -1 | 0 | +1 |
| 1 | 0 | 0 | +1 | 0 | -1 |
| 1 | 0 | 1 | +1 | -1 | 0 |
| 1 | 1 | 0 | 0 | +1 | -1 |
| 1 | 1 | 1 | 0 | 0 | 0 |

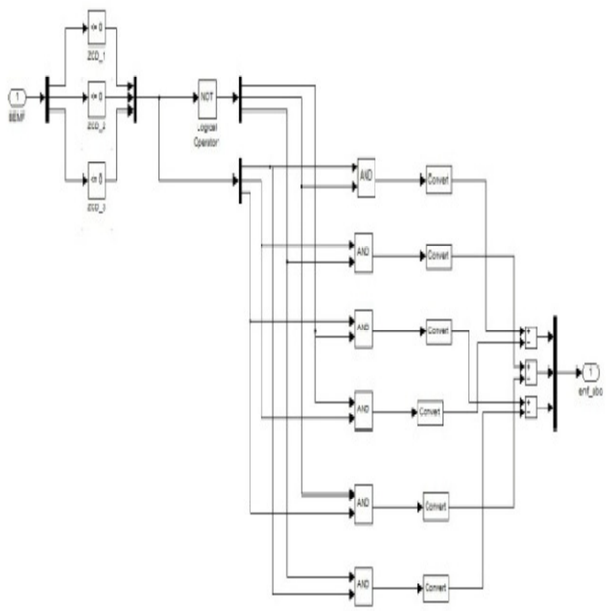


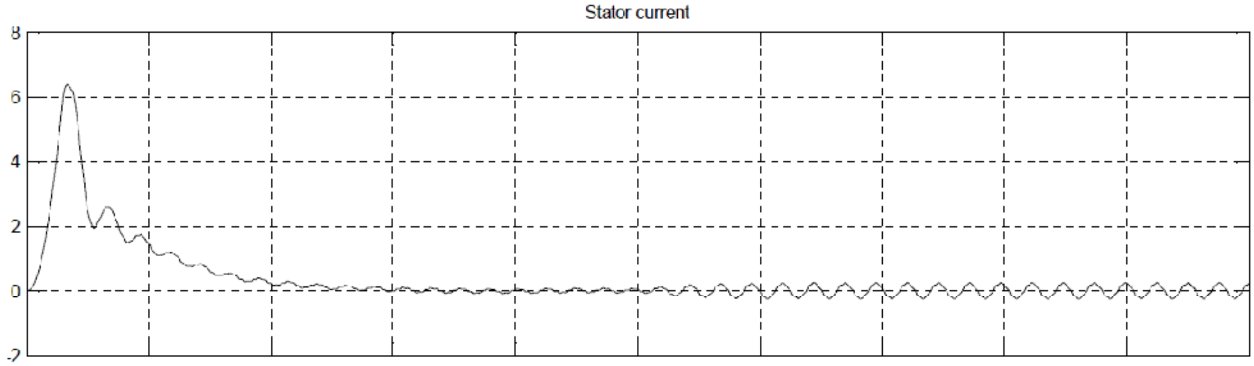
Fig.3 MATLAB/SIMULINK model of commutation logic & its table using zero crossing detector

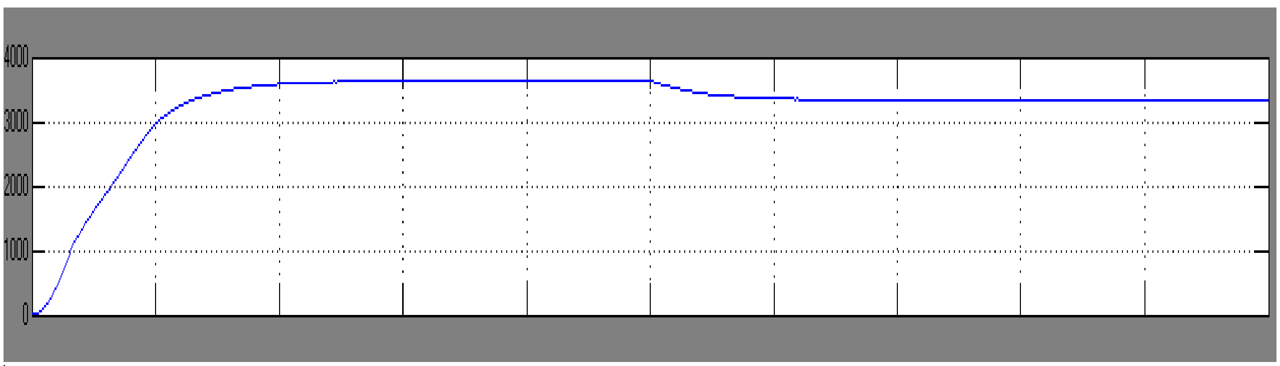
## 4. SIMULATION RESULTS

A three BLDC motor is fed to the to the inverter bridge and it is connected to controlled voltage source The inverter gates signals are produced by decoding hall effect signals. The three phase output of the inverter is applied to the motors stator windings. From the supply voltage divider is connected, with the RC low pass filter and a compare to zero circuit to produce the back emf for three phases. After simulating the circuit on the Matlab/Simulink, Motor rotor speed. Electromotive force, stator current and electromotive torque are shown in fig.

Let us take the above said values from the Fig. for one cycle.) we get the torque ripple value is 0.078%. Still further reduction in torque ripple can be achieved by selecting optimum value of PI controller constants also stator current ripple value is 0.38%.

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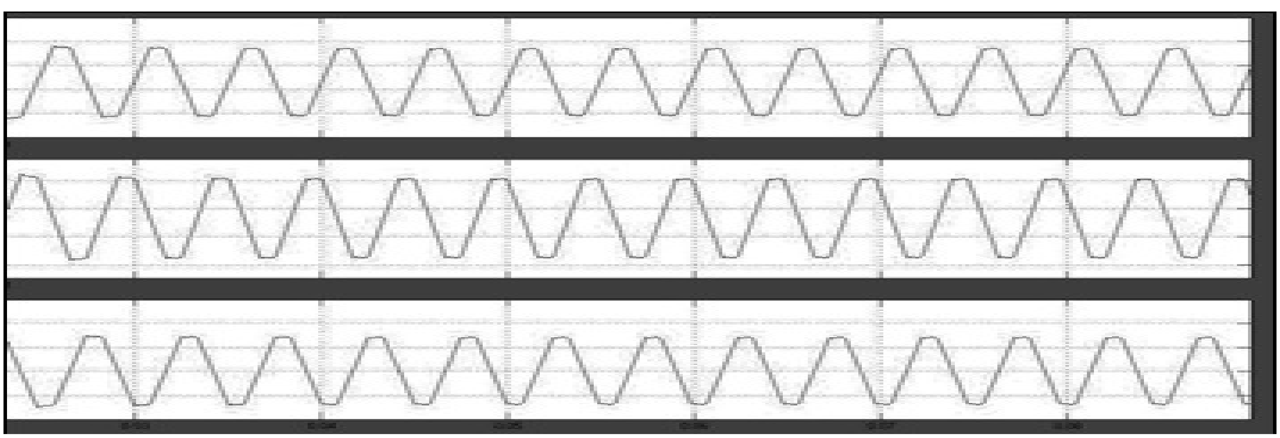
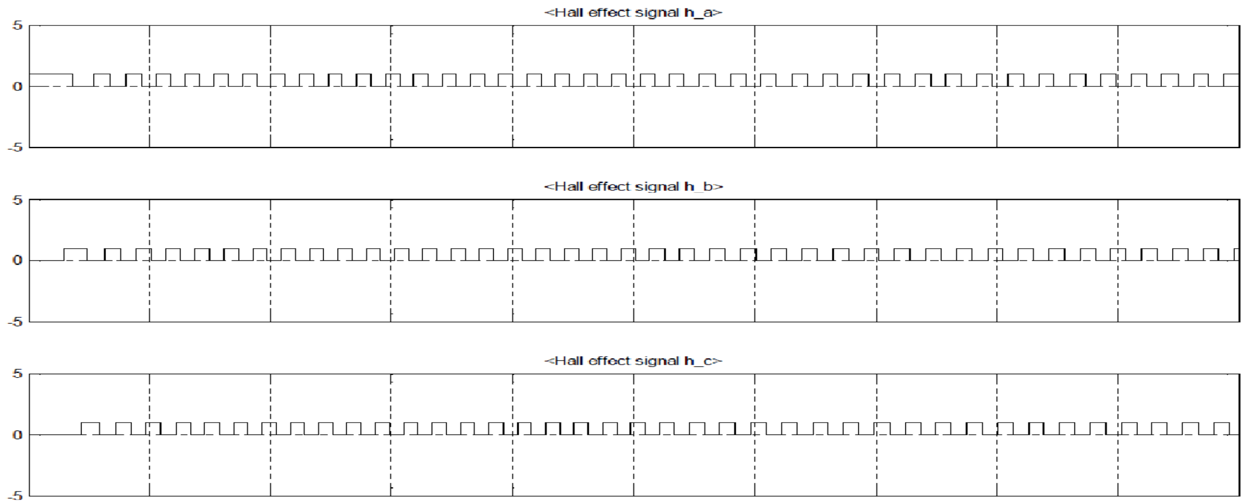
Rotor speed (RPM)



Improved back Electro motive force detected from proposed method




## 5. CONCLUSION

This paper presents the concept of torque produced by the BLDC motors with trapezoidal Back EMF is constant under ideal condition. Due to freewheeling torque ripples are produced which is reduced.In this paper rotor position is determined by the Zero Crossing Detection (ZCD) of back emf. Unlike old methods of calculating Back emf of the BLDC by creating a virtual neutral point, a complimentary method is used. This method provides a wide range of speed. A pre conditioning circuit is proposed to rectify the back emf at very low speed. In this paper improve the performance of BLDCM and reduce the torque ripples and harmonics, calculate the total harmonic distortion. The design of the inverter topology and phase shift pulse width modulating technique are carried out for five level cascade H bridge inverter fed BLDC motor drive and the simulation results are presented for the performance of the motor.. The power quality improvement at AC mains adds to the benefits of the drive in many applications. Investigations are being made in the direction of controller cost reduction using various topologies with and without position/speed sensors It is also understood that when torque ripple reduces the THD also reduces and there by performance of the machine is improved.reductionof Ripple Quantities Using With Current Controller in Closed Loop BLDC Drive should be 0.12 for Stator Current & 0.06 for Torque (Te)

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