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Improvement of Back EMF & Minimization of Torque Ripple of BLDC Motor

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Abstract- **In Brushless DC (BLDC) motor minimized the torque ripple with the help of electronically based commutators. When torque ripple is minimizes then copper loss is also minimizes. In this paper, our main aspect to decrease the torque ripples & improved the back emf of brushless dc (BLDC) motor. This paper shows that the 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. The rotor position can be determined even in stand still condition to minimize the torque ripple and designed to overcome the disadvantages from other torque ripple decrease methods.**

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

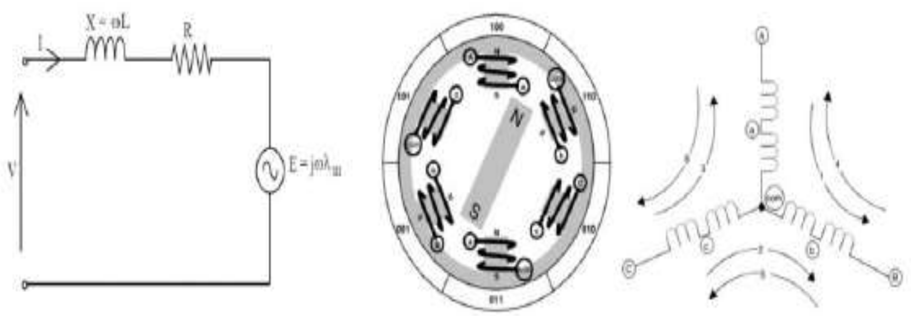
1. INTRODUCTION

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.



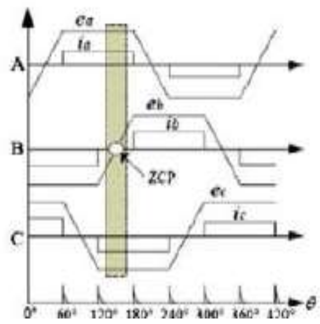


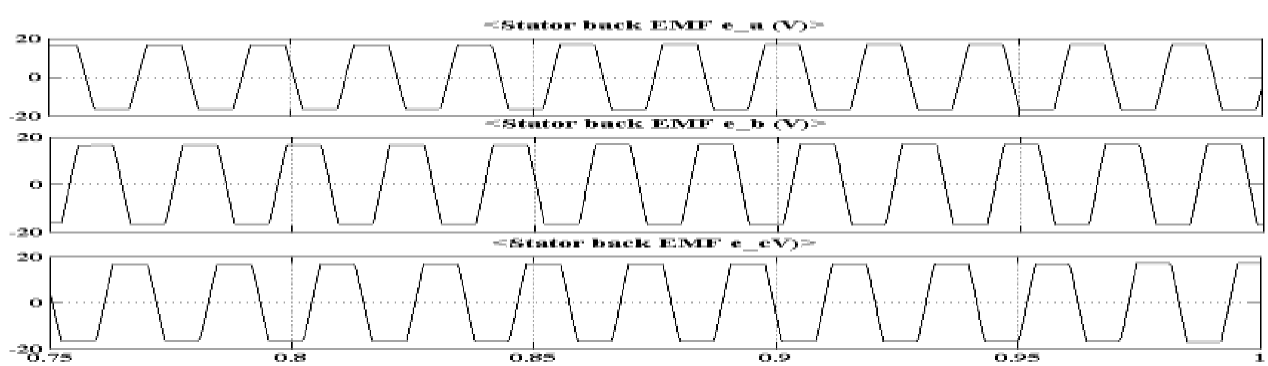
Fig.1 BLDC motor a) equivalent circuit and b) structure and star connected armature Fig.2. Waveforms of ideal back EMF and phase current.

3.PROPOSED DIRECT BACK EMF SENSING

Brushless dc (BLDC) motors, with their trapezoidal electromotive force (EMF) profile, requires six discrete rotor position informations 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

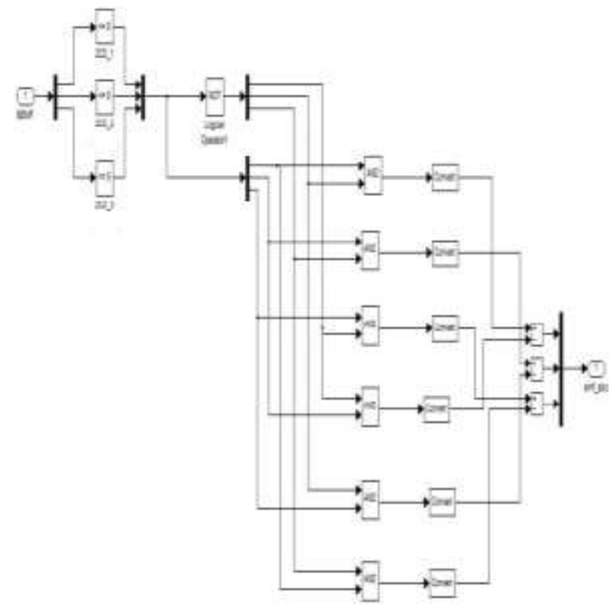


Fig.3 MATLAB/SIMULINK model of commutation logic & its table using zero crossing detector

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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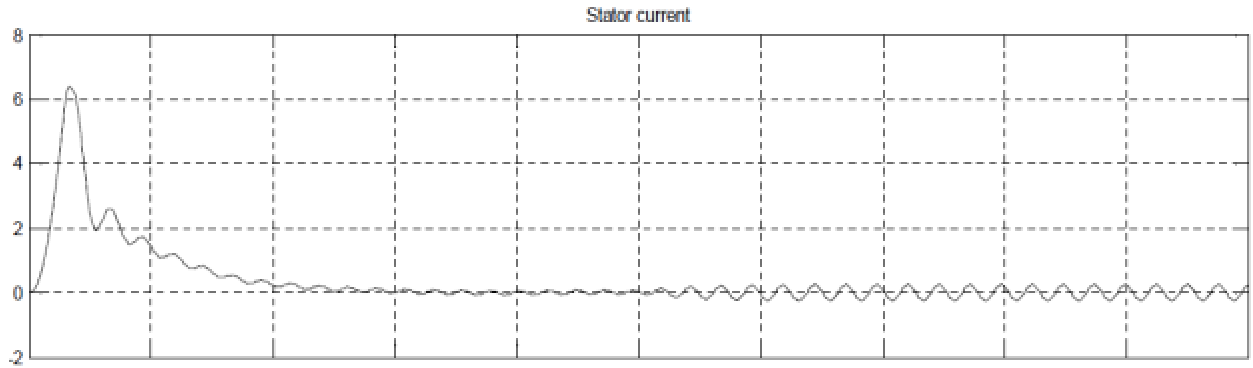

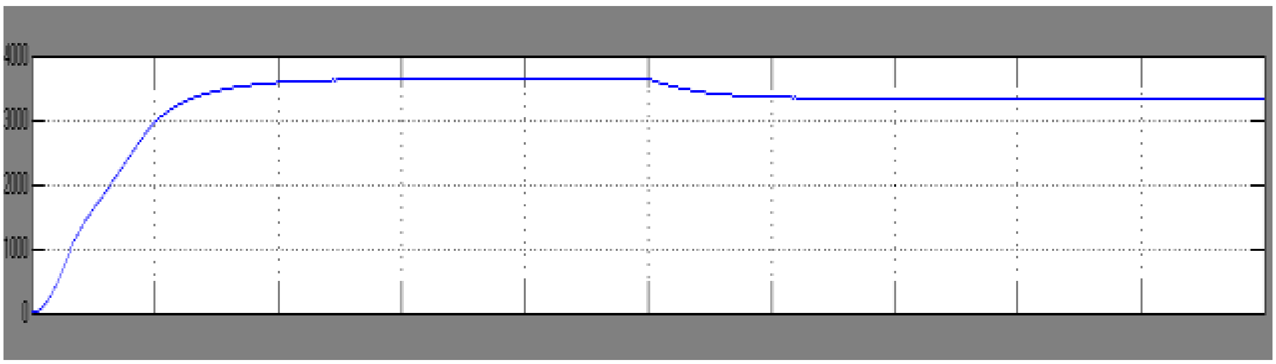

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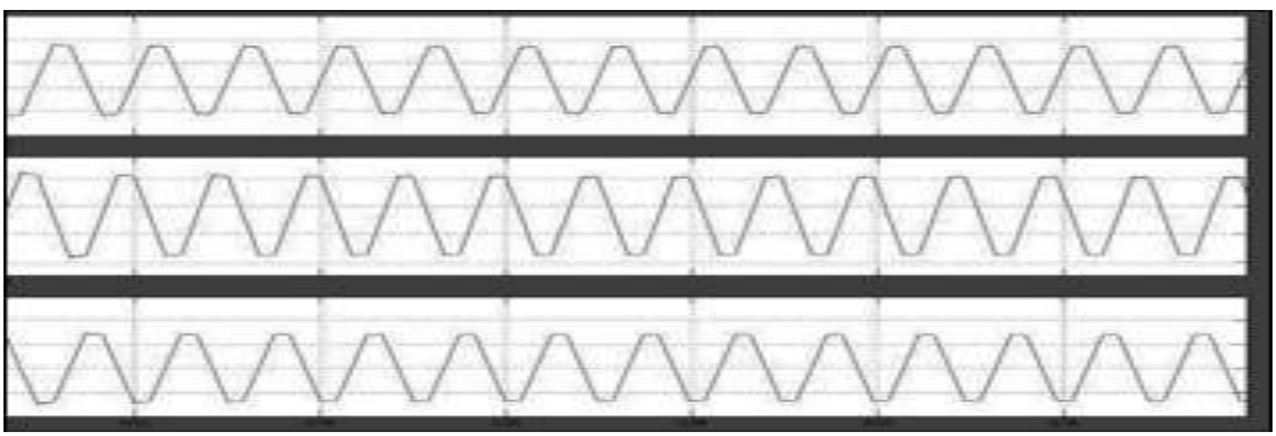
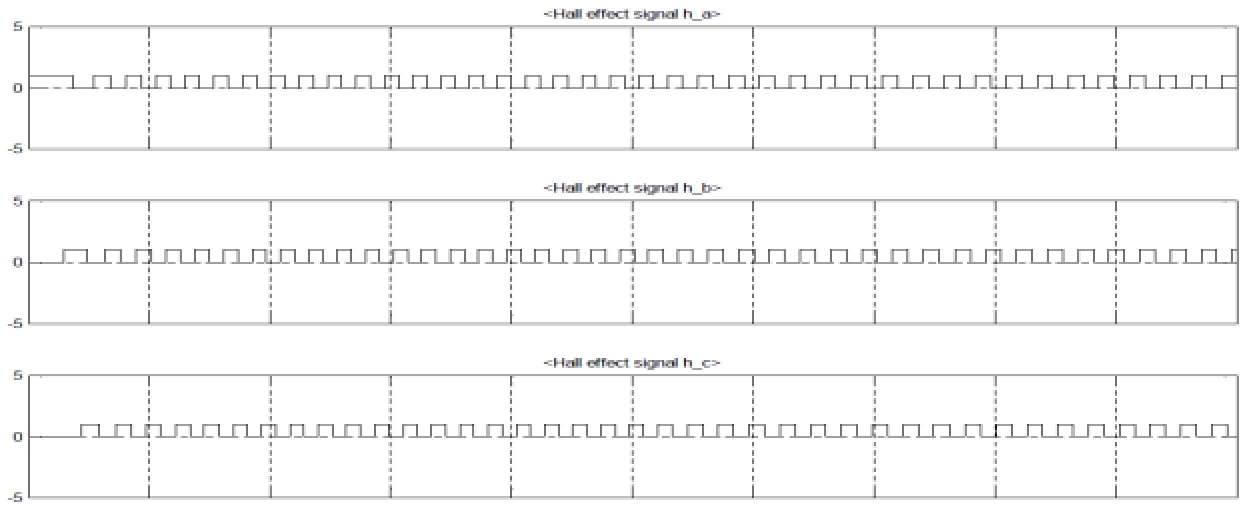
Rotor speed (RPM)



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.reduction of Ripple Quantities Using With Current Controller in Closed Loop BLDC Drive should be 0.12 for Stator Current & 0.06 for Torque (Te)

REFERENCES

[1] C. Delecluse and D. Grenier, “A measurement method of the exact variations of the self and mutual inductances of a buried permanent magnet synchronous motor and its application to the reduction of torque ripples,”in *Proc. 5th Int. Workshop Adv. Motion Control*, Coimbra, 1998, pp. 191–197.

[2] R. S. Wallace and D. G. Taylor, “Low-torque-ripple switched reluctance motors for direct-drive robotics,” *IEEE Trans. Robot. Autom.*, Vol. 7, No. 6, pp. 733–742, Dec. 1991.

[3] W. S. Newman and J. J. Patel, “Experiments in torque control of the Adept One robot,” in *Proc. IEEE Int. Conf. Robot. Autom.*, Sacramento, CA, Apr. 1991, pp. 1867–1872.

[4] F. Filicori, C. G. L. Bianco, and A. Tonielli, “Modeling and control strategies for a variable reluctance direct-drive motor,” *IEEE Trans. Ind. Electron.*, Vol. 40, No. 1, pp. 105–115, Jan. 1993.

[5] N. Matsui, T. Makino, and H. Satoh, “Auto compensation of torque ripple of direct drive motor by torque observer,” *IEEE Trans. Ind. Appl.*, Vol. 29, No. 1, pp. 187–194, Jan.–Feb. 1993.

[6] S. Ogasawara and H. Akagi, “An approach to position sensorless drive for brushless dc motors,” *IEEE Trans. Ind. Applicat.*, Vol. 27, pp.928–933, Sept./Oct. 1991.

[7] A. Consoli, S. Musumeci, A. Raciti, and A. Testa, “Sensorless vector and speed control of brushless motor drives,” *IEEE Trans. Ind. Electron.*, Vol. 41, pp. 91–96, Feb. 1994.

[8] J. P. Johnson, M. Ehsani, and Y. Guzelgunler, “Review of sensorless methods for brushless dc,” in *Proc. IEEE IAS’99 Conf.*, Vol. 1, 1999, pp.143–150.

[9] M. Tomita, M. Satoh, H. Yamaguchi, S. Doki, and S. Okuma, “Sensorless estimation of rotor position of cylindrical brushless dc motors using eddy current,” in *Proc. IEEE International Workshop on Advanced Motion Control*, Vol. 1, 1996, pp. 24–28.

[10] T. Kim and M. Ehsani, “Advanced sensorless drive techniques for brushless dc motors,” U.S. Patent 60/438,949, 2004.

[11] P. P. Carney and J. F Watson, “Review of position-sensor less operation of permanent-magnet machines,” *IEEE Trans. Ind. Electron.*, Vol. 53, No2, pp. 352–362, Apr. 2006.

[12] C.-H. Chen and M.-Y. Cheng, “New cost effective sensor less commutation method for brushless dc motors without phase shift circuit and neutral Voltage,” *IEEE* Trans. *Power Electron.*, Vol. 22, No. 2, pp. 644–653, Mar.2007

[13] C.-G. Kim, J.-H.Lee, H.-W.Kim, and M.-J. You, “Study on maximum torque generation for sensor less controlled brushless DC motor with trapezoidal back EMF,” *IEE Proc.-Electro. Power Appl.*, Vol. 152, No. 2, pp. 277–291, Mar. 2005

[14] J.X. She and S. Iwasaki, “Sensor less control of ultrahigh-speed PM brushless motor using PLL and third harmonic back EMF,” *IEEE Trans. Ind. Electron.*, Vol. 53, No. 2, pp. 421–428, Apr. 2006.

[15] P. Damodharan, R. Sandeep, and K. Vasudevan, “Simple position sensor less starting method for brushless DC motor,” *IEEE Electro. Power Appl.*, Vol. 2, No. 1, pp. 49–55, Jan. 2008.

[16] J.E.MURALIDHAR, and Dr.P.VARANASI, “Torque Ripple Minimization & Closed Loop Speed Control of BLDC Motor with Hysteresis Current Controller,” *IEEE* 2014 2nd International Conference on Devices, Circuits and Systems (ICDCS).