International Journal of Research in Advent Technology, Special Issue, March 2019
E-ISSN: 2321-9637
International Conference on Technological Emerging Challenges (ICTEC-2019)
Available online at www.ijrat.org

Harmonics and Torque Ripple Reduction of Brushless DC Motor (BLDCM) Using Cascaded H-Bridge Multilevel Inverter

[1]Shaik A Johny Begam, [2]Hothri Ravikindi, [3]G.Naveen Kumar
[1,2,3]Asst professor
[1,2]Tirumala engineering college, Narasaraopet ,India
[3]Narasaraopet engineering college, Narasaraopet, India
Jani.eee215@gmail.com, hothri.ravikindi@gmail.com, gubba.naveen213@gmail.com

Abstract: Brushless DC motors with trapezoidal Back-e.m.f have several inherent advantages. Most prominent among them are high efficiency and high power density due to the absence of field winding, in addition the absence of brushes leads to high reliability, low maintenance and high capability. However in a practical BLDC drive, significant torque pulsations may arise due to the back e.m.f waveform departing from the ideal .as well a commutation torque ripple, pulse width modulation (PWM) switching. Torque ripple due to the current commutation is caused by them is matches between the applied electromotive force and the phase currents with the motor electrical dynamics. It is one of the main drawbacks of BLDC drives. These torque ripples produces noise and degrade speed control characteristics especially at low speed. Due the power electronic commutation, the usage of high frequency switching of power devices, Imperfections in the stator and the associate control system. The input supply voltage to the motor contains various harmonics components. During its operation, high frequency component present in the input voltage will cause Electromagnetic Interference (EMI) problem. Nowadays researchers are trying to reduce the torque ripple and harmonic component in the BLDC motor. In this paper the current controller method is used for reducing the torque ripple and harmonics. This method is based upon the generation of the quasi-square wave armature current. To reduce torque ripple the indirect position detection is used and, it is based on the detection of the zero crossing points of the line voltage measured at the terminal of the motor. The harmonics and torque ripple reduced by using the L-C filter proposed. The proposed method based upon the current controlled technique. The armature current is measured and compared with the reference value to produce the gate pulses for the multilevel inverter.

Key words: Multilevel inverter, current and speed controller, harmonics and torque ripples.

1. INTRODUCTION

Brushless DC motor has the characteristic of simple structure, large torque, don't need to change phase based on the brush, and has long use time, good speed regulation. For the advantages mentioned above now electric vehicles and micro electric motor cars in the market mostly adopt BLDCM. The traditional BLDC controlling system requires hall sensor signals to drive the motor. When disturbance on the hall sensor exists, the wrong actions on the main circuit prompts the BLDCM action unsteady, the reliability of the whole controlling system is greatly reduced, also the cost of controller is increased. In recent years, some of these developments like Proportional-Integral (PI) controllers have been implemented for the speed control of B LDC motors. Different advanced control theories like the optimal and adaptive strategies have been used. Neural network control has also been used to control BLDC motors but its performance under load disturbance and parameter uncertainty due to the non linearity is not satisfactory. Sliding control is a technique that originated in Soviet literature, in the early 1950's initiated by S. V. Emel'yanov, with advantages like order reduction, disturbance rejection and invariance to parametric variations has now become very popular for designing of robust system performance. Speed and current control of different motor drives is amongst many of its other areas of application. The sliding surface can be reached quickly and the system chattering can be reduced at the same time, facilitating the design of variable-structure control. Brushless dc motors have only decades of history. Permanent magnet brushless dc (PMBLDC) motors could become serious competitors to the induction motor for servo applications. The PMBLDC motor is becoming popular in various applications because of its high efficiency, high power factor, high torque, simple control and lower maintenance. The major disadvantage with permanent magnet motors is their higher cost and relatively higher complexity introduced by the power electronic converter used to drive them. The added complexity is evident in the development of a torque/speed regulator. High efficiency, high power density and wide range speed controllability of BLDC motors make them suitable in various drive applications. In particular the spindle motors used in computer hard disk drives are to possess high speed characteristics for fast data access. Brushless Direct Current (BLDC) motors are one of the motor types rapidly gaining popularity. BLDC motors are used in industries such as Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation equipment and Instrumentation. As the name implies, BLDC motors do not use brushes for commutation;

instead, they are electronically com-mutated. BLDC motors have many advantages over brushed DC motors and induction motors. A few of these are:

- Better speed versus torque characteristics
- High dynamic response
- High efficiency

1.1 Main Characteristics Of BLDC Motor

- Brushless DC motors consist of two coaxial Magnetic armatures separated by an air gap. In certain types of motor, the external armature, the stator, is fixed. The internal armature, the rotor, is mobile
- The stator is the induced part of the machine.
- The rotor is the inductor of the machine
- In brushless DC motors, the internal armature, the rotor, is a permanent magnet. This armature is supplied by a constant current (DC).

2. LITERATURE SURVEY

BLDC **m**otor is a permanent magnet synchronous that uses position detectors and an inverter to control the armature currents. The BLDC motor is sometimes referred to as an inside out dc motor because its armature is in the stator and the magnets are on the rotor and its operating characteristics resemble those of a dc motor. Instead of using a mechanical commutator as in the conventional dc motor, the BLDC motor employs electronic commutation which makes it a virtually maintenance free motor. There are two main types of BLDC motors trapezoidal type and sinusoidal type. In the trapezoidal motor the back-E.M.F induced in the stator windings has a trapezoidal shape and its phases must be supplied with quasi-square currents for ripple free operation. The sinusoidal motor on the other hand has a sinusoidally shaped back – emf and requires sinusoidal phase currents for ripple free torque operation. The shape of the back – emf is determined by the shape of rotor magnets and the stator winding distribution. The sinusoidal motor needs high resolution position sensors because the rotor position must be known at every time instant for optimal operation. It also requires more complex software and hardware. The trapezoidal motor is a more attractive alternative for most applications due to simplicity, lower price and higher efficiency. BLDC motors exist in many different configurations but the three phase motor is most common type due to efficiency and low torque ripple. This type of motor also offers a good compromise between precise control and number of power electronic devices needed to control stator currents. Fig.1 shows a transverse section of a BLDC motor. Position detection is usually implemented using three Hall - an effect sensor that detects the presence of small magnets that are attached to the motor shaft.

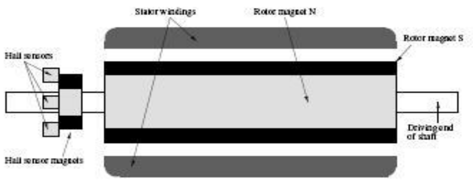

Fig.1 BLDC motor transverse section.

Typically, a Brushless dc motor is driven by a three-phase inverter with, what is called, six-step commutation. The conducting interval for each phase is 120^o by electrical angle. The commutation timing is determined by the rotor position, which can be detected by Hall sensors as shown in the figure 2 (H1, H2, H3).The figure also shows ideal currents and back e.m.f waveforms. Figure 2.shows a cross section of a three phase star connected motor along with its phase energizing sequence. Each interval starts with the rotor and stator field lines 120^0 apart and ends when they are 60^0 apart. The switches are shown as bipolar junction transistors but MOSFET switches are more common.

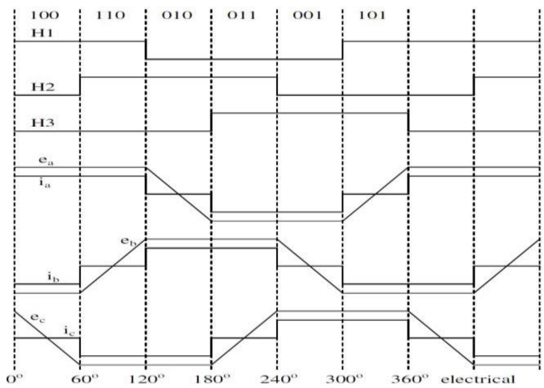

Fig. 2 Ideal back-emf's phase currents, and position sensor signals.

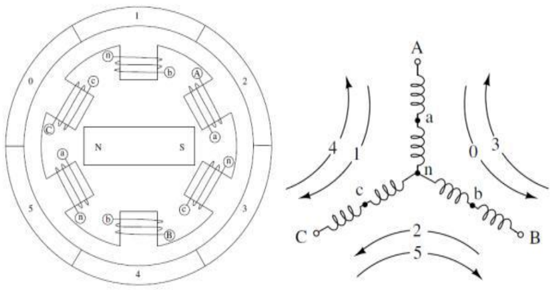

Fig. 3 BLDC motor cross section and phase energizing sequence

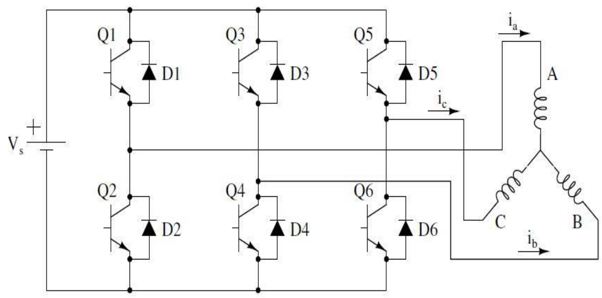

Fig. 4 Simplified BLDC drive

2.1 Applications

- Consumer electronics
- Transport
- Heating and ventilation
- Industrial engineering
- Model engineering

3. PROPOSED CONCEPT

Brushless DC motors with trapezoidal Back-EMF have several inherent advantages. Most prominent among them are high efficiency and high power density due to the absence of field winding, in addition the absence of brushes leads to high reliability, low maintenance and high capability. However in a practical BLDC drive, significant torque pulsations may arise due to the back e.m.f waveform departing from the ideal, as well as commutation torque ripple, pulse width modulation (PWM) switching. These torque ripples produces noise and degrade speed-control characteristics especially at low speed. Due the power electronic commutation, the usage of high frequency switching of power devices, Imperfections in the stator and the associated control system.. An active topology to reduce the torque ripple is synchronous motor presented. This paper discusses the hysteresis voltage control method. The torque ripple is minimized using PWM switching is presented in paper this scheme has been implemented using a PIC microcontroller to generate modified pulse width modulation (PWM) signals for driving power inverter bridge. In this paper the current controller method is used for reducing the torque ripple and harmonics. This method is based upon the generation of the quasi-square wave armature current. To reduce torque ripple the indirect position detection is used, it is based on the detection of the zero crossing points of the line voltage measured at the terminal of the motor. The harmonics and torque ripple reduced by using the L-C filter proposed. The proposed method based upon the current controlled technique. The armature current is measured and compared with the reference value to produce the gate pulses for the multilevel inverter

3.1 Functional Units

The BLDC Motor requires a power electronic drive circuit and a commutation system for its operation. The Fig.5 describes the functional units present in the drive circuit and the associated commutation controller for the BLD.

Motor. A 4 pole BLDC motor is driven by the inverter for 120 degree commutation. The rotor position can be sensed by a hall-effect sensor, providing three square wave signals with phase shift of 120^o. These currents are sensed through current sensors, and converted to voltage signals. These signals are then rectified, and a dc component, with the value of the ceiling of the currents, Imax, is activated by the shaft position sensor .

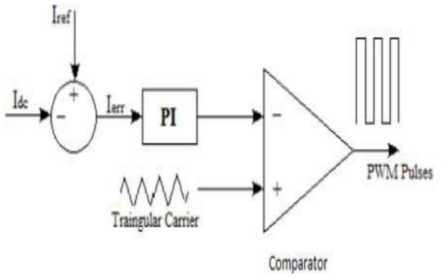

Fig. 5 Current Controller of BLDC Motor with MLI

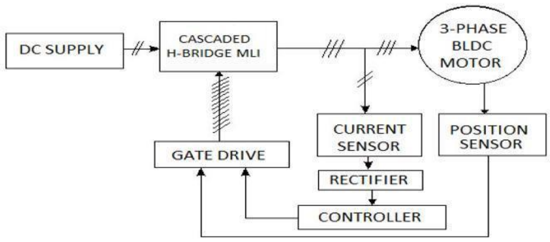

Fig. 6 Current Controller Block

3.2 Cascaded H-Bridge Multilevel Inverter

Each phase leg of the three level converters has two pairs of switching devices in series. The waveform obtained from the three level converters is a quasi-square wave output. The Switching sequence of three phase five level MLI is represented in Fig7

S_{11}	S_{12}	S_{13}	S_{14}	S_{21}	S_{22}	S_{23}	S_{24}	V_1	V_2	$V=V_1+V_2$
OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	0	0	0
ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	V	0	V
ON	ON	OFF	OFF	ON	ON	OFF	OFF	V	V	2V
OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	0	V	V
OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	0	0	0
OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	-V	0	-V
OFF	OFF	ON	ON	OFF	OFF	ON	ON	-V	-V	-2V
OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	0	-V	-V
OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	0	0	0

Fig.7 switching sequence of three phase five level MLI

4. MATLAB/SIMULATION RESULTS

This section presents the MATLAB / Simulink implementation of the Cascaded H- Bridge (CHB) multilevel inverter fed BLDC motor.

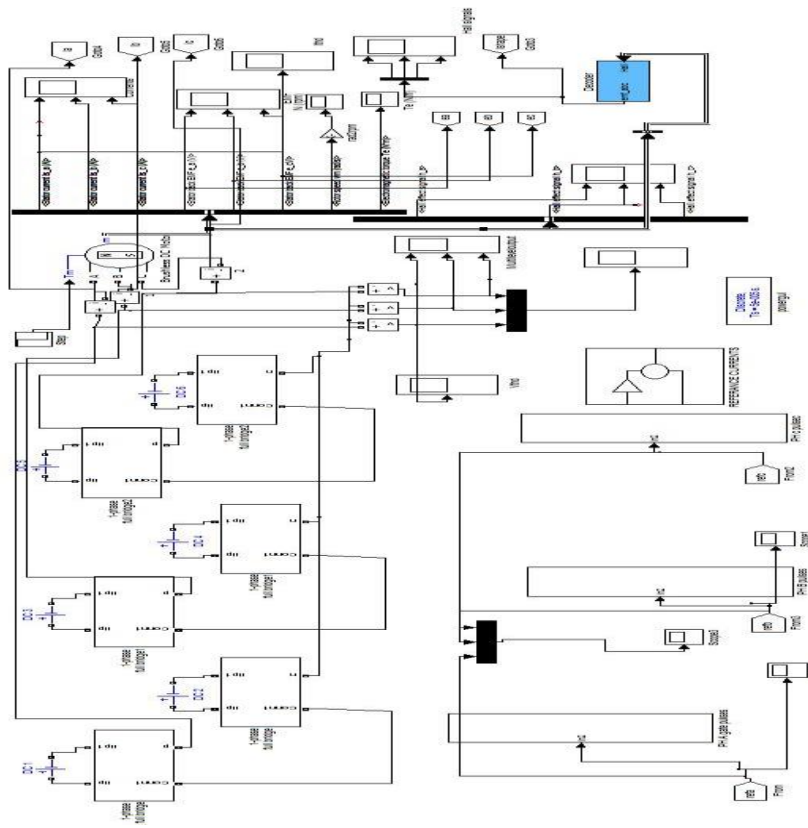

Fig.8 Simulink diagram of BLDC Motor with current controller using MLI

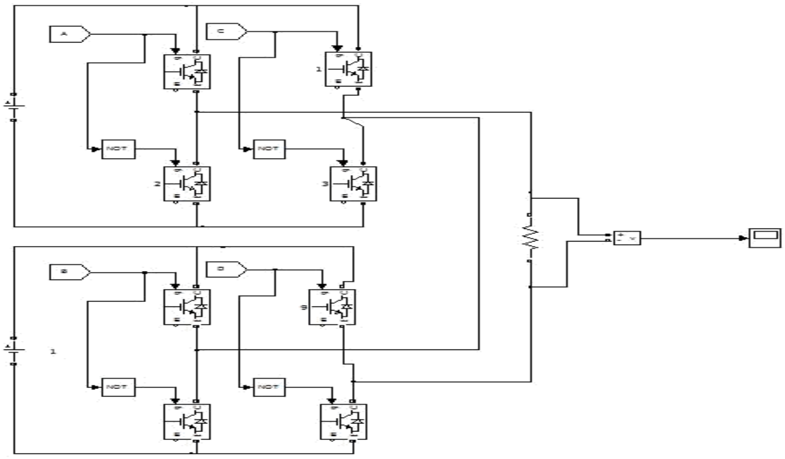

Fig. 9 Signal phase cascaded H-Bridge multilevel inverter

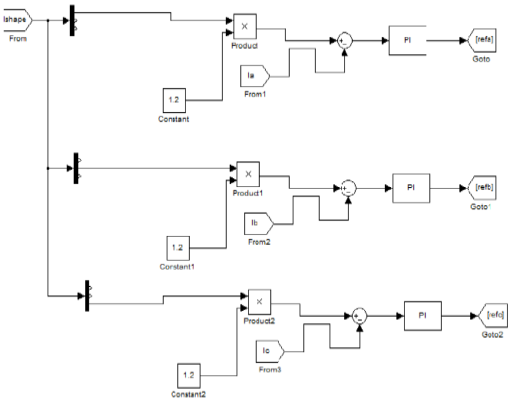

Fig. 10 reference currents generation

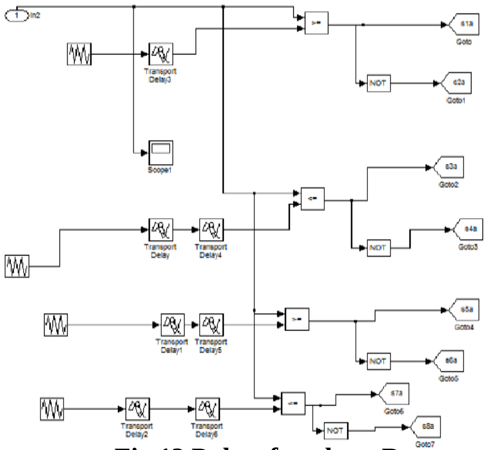

Fig.12 Pulses for phase B

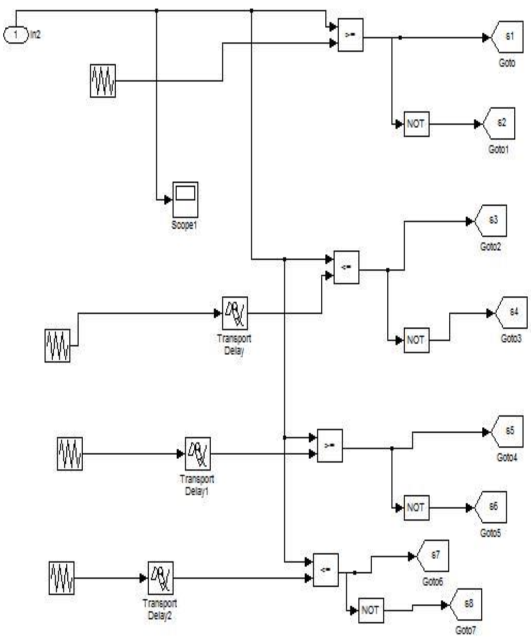

Fig .11 Pulses for phase A

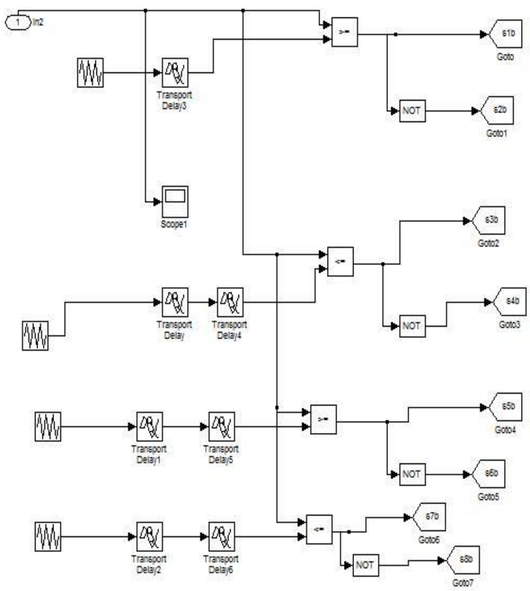

Fig. 13 Pulses for phase C

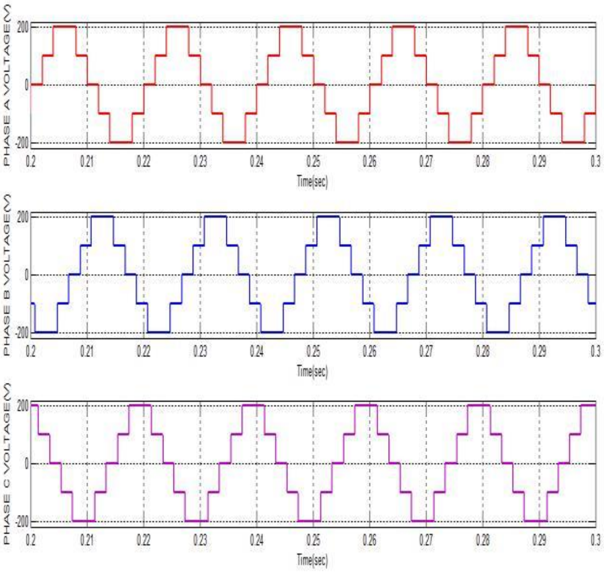

Fig.14 Phase to Phase voltage of BLDC motor

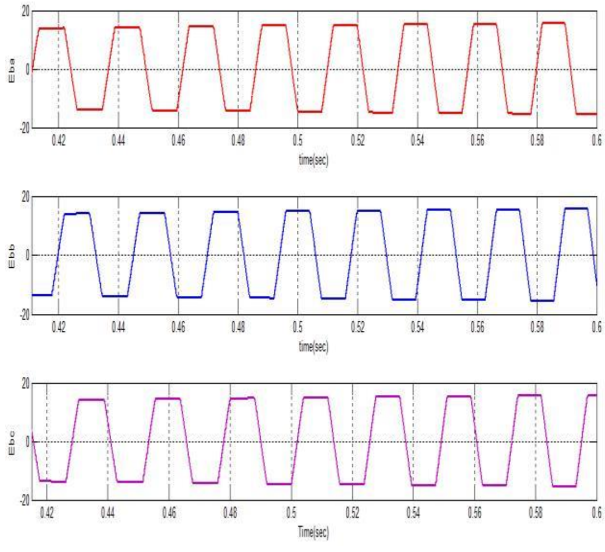

Fig .16 Back EMF of the BLDC motor

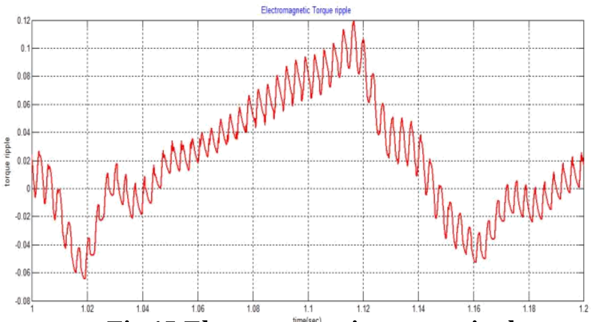

Fig.15 Electromagnetic torque ripple

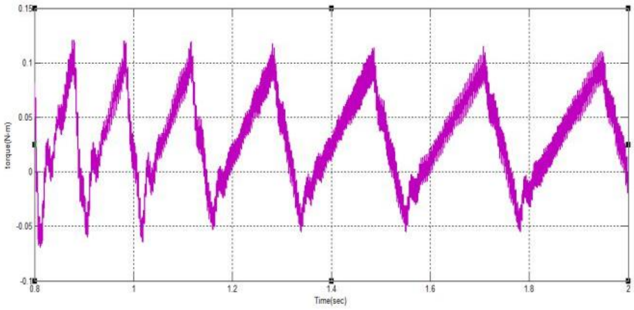

Fig.17 Torque waveform of BLDC motor

The harmonics content of the voltage and Current for a BLDC motor is analyzed and the amount of torque ripple and the THD also calculated. From the simulated results it is evident that the harmonics Components at the switching frequency and multiples of switching frequency are reduced also the torque ripples are reduced.

5. CONCLUSION

This paper has proposed harmonics and torque ripples have been reduced using multilevel inverter with the current controlled technique. The harmonics content of the voltage and Current for a BLDC motor is analyzed and the amount of torque ripple and the THD also calculated. From the simulated results it is evident that the harmonics Components at the switching frequency and multiples of switching frequency are reduced also the torque ripples are reduced. The main advantage of this method is it uses one current controller for the three phases

REFERENCES

[1] Kayhan.Gulez, Ali Ahmed Adam, and Halit.Pastaci, "*Torque Ripple and EMI Noise Minimization in PMSM Using Active Filter Topology and Field-Oriented Control*,"IEEE Trans,Industrial Electronics, Vol. 55, No. 1, pp. 251-256, Jan 2008.

[2] WaelA.Salah, DahamanIshak, Khaleel and J.Hammadi" *PWM switching strategy for torque ripple minimization in BLDC motor*" Journal of *electrical engineering, Vol*. 62, No. 3, 2011, 141–146.

[3] J.Karthikeyan,Dr.R.Dhanasekaran."*simulation and implementation of current control of BLDC motor based on a common dc signal*". International Journal of Engineering Science and Technology, Vol. 2(6), 2010, 1632-163.

[4] VanisriA, DevarajanN."*Torque ripple minimization in indirect position detection of permanent magnet DC motor"* European journal of scientific research, Vol No:65 No.4(2011) .

[5] A.AlbertRajan,Dr.S.Vasantharathna."*Harmonics and Torque Ripple Minimization using L-C Filter for Brushless DC Motors*" .International Journal of Recent Trends in Engineering, Vol 2, No. 5, November 2009.

[6] Kwang-Woon Lee, Dae-Kyong Kim, Tae-Duck Kim, and JaeYoung Choi."*Commutation Torque Ripple Reduction in a Position Sensor less Brushless DC Motor Drive*". 2004.35rh Annul IEEE Power Electronics Specialists Conference.