Reduction of Harmonics and Torque Ripples of BLDC Motor by Cascaded H-Bridge Multi Level Inverter Using Current and Speed Control Techniques

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ABSTRACT

Considering the drive advantages of BLDC drive compared to other drive applications BLDC with phase switching inverter performance is improved with multilevel inverter(MLI)topologies employing current and speed control techniques which decrease the torque ripples and harmonic distortion in general three phase three level inverter which commutates the BLDCM and address the problems of harmonics and torque ripples for that by using a multilevel inverter topology of five level inverter with current and speed controller at lower switching levels which can improves the BLDC drive performance. This paper proposes a series connected five level inverter with phase shift modulation with current and speed control techniques to reduce the harmonic distortion and torque ripples. The simulation results are discussed with a comparative study in different operating strategies of BLDC drive. The simulation results based on Matlab/Simulink are discussed in detail in this paper.

Keywords: *Multilevel Inverter, Current and Speed Controller, Harmonics and Torque Ripples.*

I. INTRODUCTION

Power electronic inverters are widely used in various industrial drive applications. To overcome the problems of the limited voltage and current ratings of power semiconductors devices, some kinds of series and/or parallel connections are necessary. Recently, the multilevel inverters have received more attention in literature due to their ability to synthesize waveforms with a better harmonic spectrum and to attain higher voltages. They are applied in many industrial applications such as ac power supplies, static Var compensators, and drive System, etc.

Brushless DC motors (BLDC) with trapezoidal Back-EMF [3] 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 [5] may arise due to the back emf waveform Departing from the ideal. as well as commutation torque ripple, pulse width modulation (PWM)switching technique. Multilevel inverters have very important development for high power medium voltage AC drives. Nowadays researchers are trying to reduce the torque ripple and harmonic component in the BLDC motor. An active topology to reduce the torque ripple is synchronous motor presented in [1]. This paper discusses the hysteresis voltage Quite a lot of

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topologies have found industrial approval; Neutral Point Clamped, flying capacitor, H-bridge, cascaded with separated DC source, several control and modulation strategies have been developed Pulse Width Modulation (PWM) [6], Sinusoidal PWM, Space Vector PWM and Selective harmonic eliminations etc. One of the significant advantages of multilevel configuration is the harmonics reduction in the output waveform without increasing switching frequency or decreasing the inverter power output [2]. These multilevel inverters, in case of *m*-level, can increase the capacity by (*m*-1) times than that of two-level inverter through the series connection of power semiconductor devices without additional circuit to have uniform voltage sharing. Comparing with two level inverter system having the same capacity, multilevel inverters have the advantages that the harmonic components of line-to-line voltages fed to load, switching frequency of the devices and EMI problem could be decreased [1]. The output voltage waveform of a multilevel inverter is composed of a number of levels of voltages starting form three levels and reaching infinity depending upon the number of the dc sources. The main function of a multilevel inverter is to produce a desired ac voltage waveform from several levels of dc voltage sources. These dc voltages may or may not be equal to one another. These dc sources can be obtained from batteries, fuel cells, or solar cells.

Conventionally, each phase of a cascaded multilevel converter requires '*n*' dc sources for 2*n* + 1 levels in applications that involve real power transfer.

II. POWER-CONVERTER TOPOLOGY

2.1 Current Control

The proposed general configuration of three phase supply to the BLDC by current control technique as shown in Fig. 1.

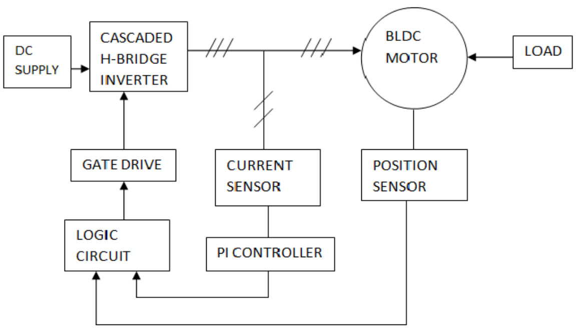

Fig. 1. Block Diagram of Five-Level Inverter Connected to BLDCM in Current Control Technique

Iref, and from this comparison, and error signal Ierr is obtained. This error is then passed through a PI control to The BLDC Motor requires [4] a power electronic drive circuit and a commutation system for its operation. The Fig.1 describes the functional units present in the drive circuit and the associated commutation controller for the BLDC 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 120degrees. These signals are decoded by a combinational logic to provide the firing signals for 120 degrees conduction on each of the three phases. The operation of the system is as follows: as the motor is of the brushless dc type, the waveforms of the armature currents are quasi square. 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, This dc signal is compared with a desired reference generate the PWM .for all the switches of the multi-level inverter which are sequentially activated by the shaft position sensor.

2.2 Speed Control

The proposed general configuration of three phase supply to the BLDC by current control technology as shown in Fig. 2. The speed control loop uses a proportional-integral controller to produce the quadrature-axis current reference iq* which controls the motor torque. The motor flux is controlled by the direct-axis current reference id*. Block DQ-ABC is used to convert id* and iq* into current references ia*, ib*, and ic* for the current regulator.

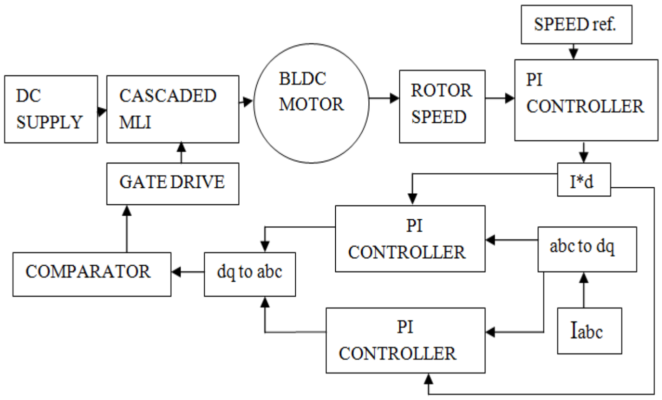

Fig. 2. Block Diagram of Five-Level Inverter Connected to BLDCM in Speed Control Technique

In speed control technique we give PWM gate signal by giving speed feedback to PI controller.
We compare actual rotor speed with its reference speed with PI controller and gives current command signal ,this signal is compared with Id and Iq currents with the help of PI controller, the PI controller signal is compared with carrier signal to produce PWM signal to the gate drive of cascaded H-Bridge five level inverter.

III. DESIGN OF INVERTER MODULES

Figure 3 shows the proposed five level cascade H bridge inverter fed BLDC motor drive. Figure 4 shows single phase structure of a multilevel cascade H bridge inverter. The N-level cascaded H-bridge, multilevel inverter comprises ½(N-1) series connected single phase H-bridges per phase, for which each H-bridge has its own isolated dc source. Three output voltages are possible, ±Vs, and zero.

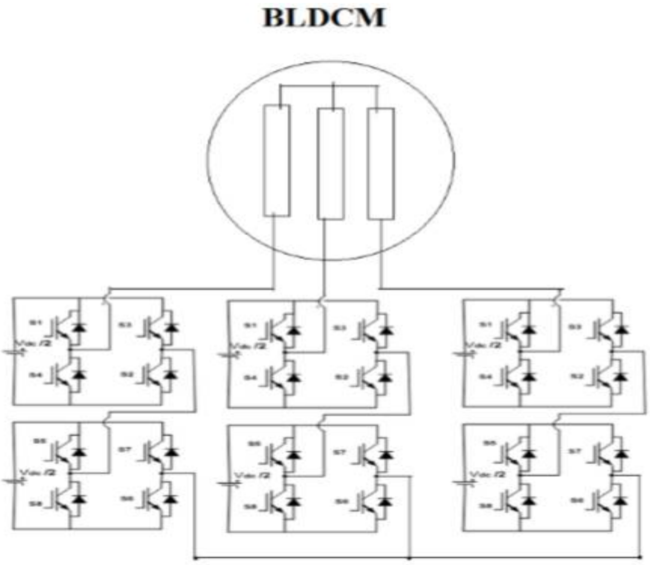

Figure 3: Proposed Five Level Cascade H Bridge Inverter Fed BLDC Motor Drive

The cascaded H-bridge multilevel inverter is based on multiple two level inverter outputs (each H-bridge), with the output of each phase shifted. Despite four diodes and switches, it achieves the greatest number of output voltage levels for the fewest switches. Its main limitation lies in its need for isolated power sources for each level and for each phase, although for VA compensation, capacitors replace the dc supplies, and the necessary capacitor energy is only to replace losses due to inverter losses. Its modular structure of identical H-bridges is a positive feature.

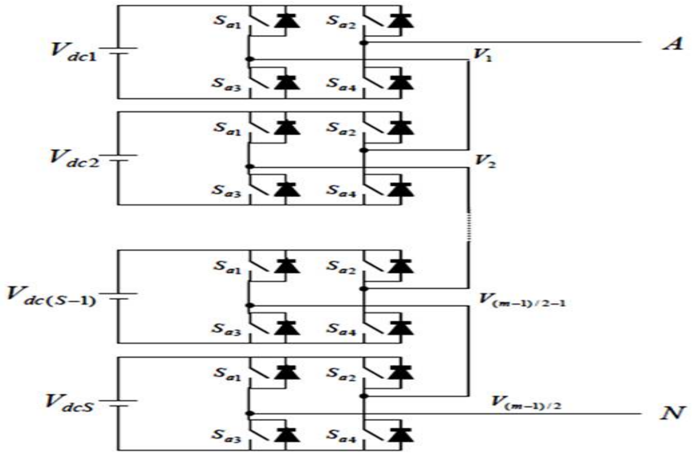

Figure 4: Single-Phase Structure of a Multilevel Cascaded H-Bridge Inverter

IV. THE BLDC MOTOR

The BLDC motor is an AC synchronous motor with permanent magnets on the rotor (moving part) and windings on the stator (fix part). Permanent magnets create the rotor flux. The energized stator windings create electromagnet poles. The rotor (equivalent to a bar magnet) is attracted by the energized stator phase, generating a rotation. By using the appropriate sequence to supply the stator phases, a rotating field on the stator is created and maintained. This action of the rotor - chasing after the electromagnet poles on the stator - is the fundamental action used in synchronous permanent magnet motors. The lead between the rotor and the rotating field must be controlled to produce torque. This synchronization implies knowledge of the rotor position.

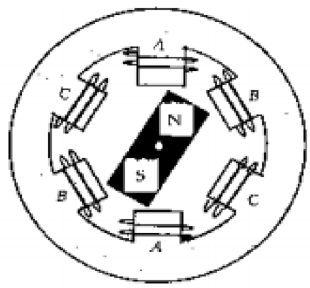

Fig.5: A 3-Phase Synchronous Motor [BLDC] with a Single Permanent Magnet Pair Pole Rotor

On the stator side, three phase motors are the most common. These offer a good compromise between precise control and the number of power electronic devices required to control the stator currents. For the rotor, a greater number of poles usually create a greater torque for the same level of current. On the other hand, by adding more magnets, a point is reached where, because of the space needed between magnets, the torque no longer increases. The manufacturing cost also increases with the number of poles. As a consequence, the number of poles is a compromise between cost, torque and volume.

V. MATLAB SIMULATION RESULTS

Implementation of current and speed control techniques to BLDC Machine Drive.

Fig. 6 Shows the Matlab/Simulink Model for speed and current control technique with cascasded H-bridge 5-level Inverter Topology Applied to BLDC Machine Drive

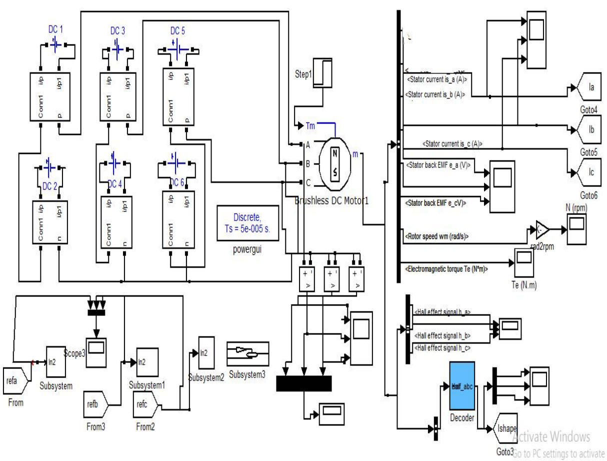

Fig. 6 Closed Loop Simulation Diagram of BLDC Motor with Current and Speed Control Techniques using Cascaded H-bridge MLI

Fig7 shows the current control block for BLDC motor.

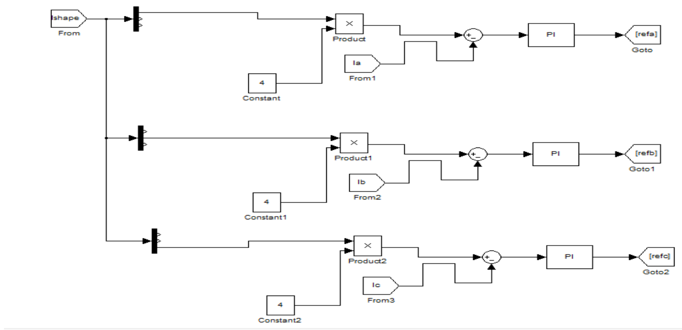

Fig.7: Current Control Block in Simulink

Fig8 Shows the speed control technique for BLDC motor.

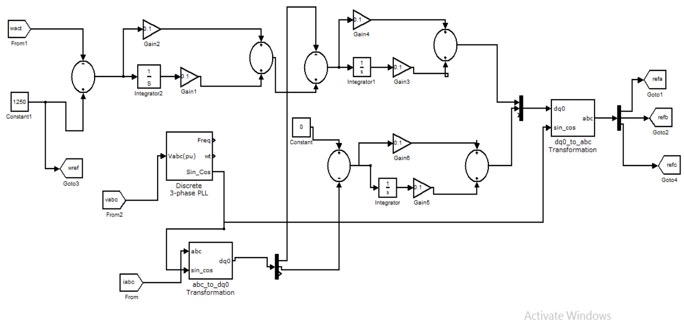

Fig.8: Speed Control Block in Simulink

Fig.9 shows the Output Voltage of proposed series connected multilevel inverter fed BLDC drive.

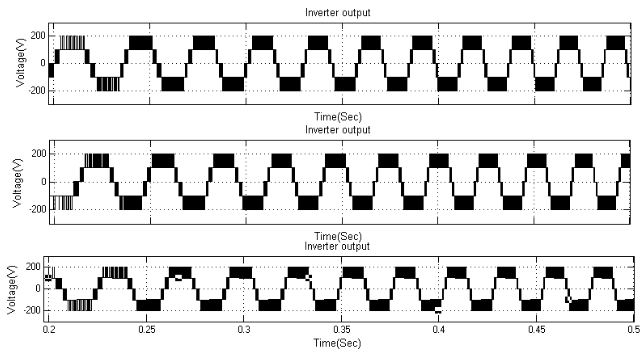

Fig. 9 Five Level Inverter Output Voltages

Fig.10 shows the waveforms represent the output voltage of the BLDCM.

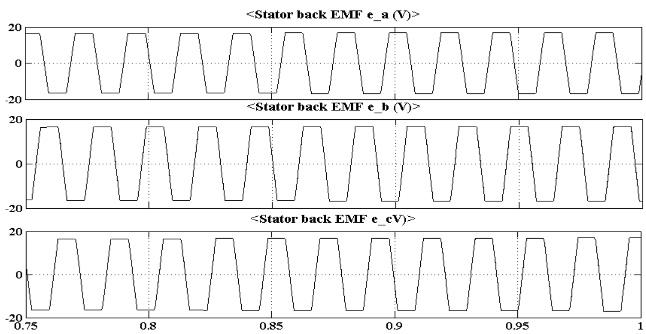

Fig : 10 Stator Individual Phase Back Emf

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Fig.11 shows the waveforms represent the output Current of the BLDCM

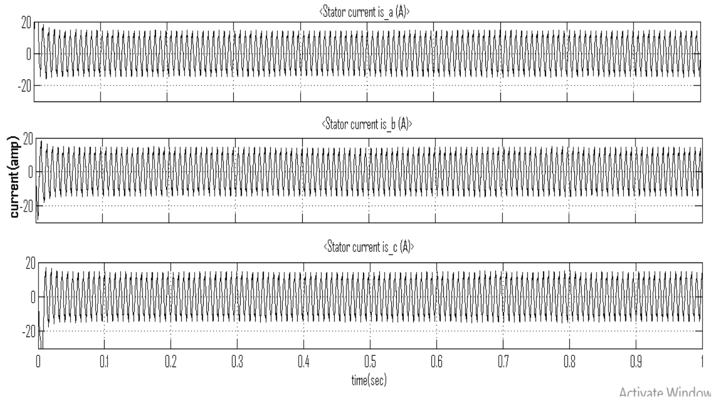

Fig: 11 Stator Individual Phase Currents

Fig.12 shows the Position sensor waveforms of the Back EMF of BLDCM

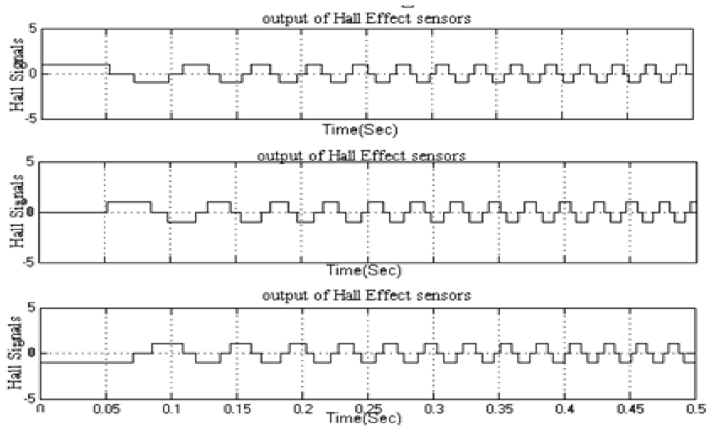

Fig: 12 Hall Effect Signals

Fig13 shows the speed waveform at full load in current control technique.

Fig14 shows the electromagnetic waveform in current control technique

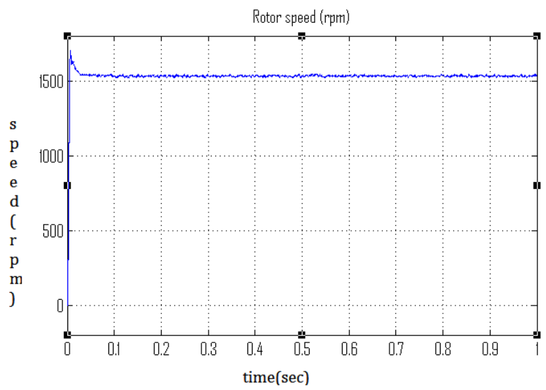

Fig: 13 Speed Waveform at Full Load in Current Control Technique

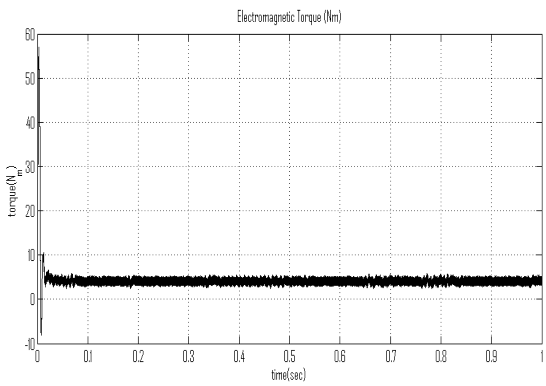

Fig 14 Electromagnetic Torque at Full Load in Current Control Technique

Fig15 shows the speed waveform at full load in Seed control technique

Fig16 shows the electromagnetic waveform in speed control technique

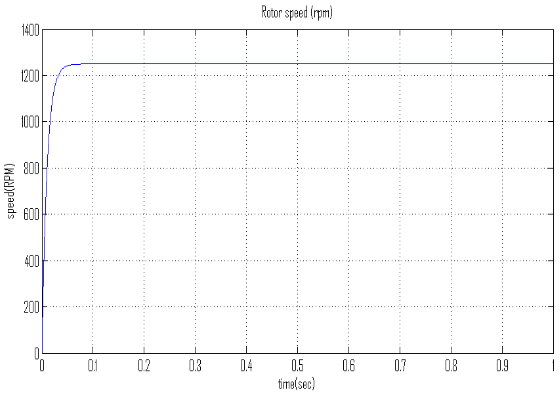

Fig: 15 Speed Waveform at Full Load in Speed Control Technique

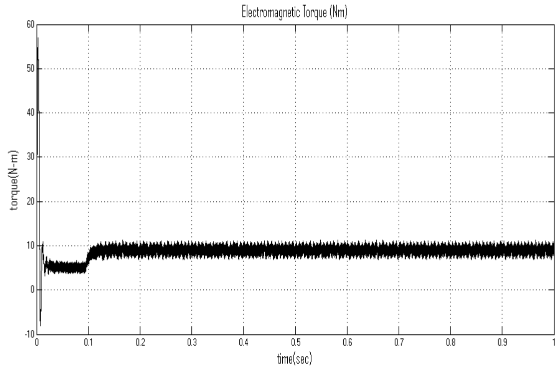

Fig: 16 Electromagnetic Torque at Full Load in Speed Control Technique

Fig: 17 and Fig:18 show the total harmonic distortion of the input voltage to the BLDCM in two operating conditions such as applying the current controller and speed controller techniques and analyze the total harmonic distortion.

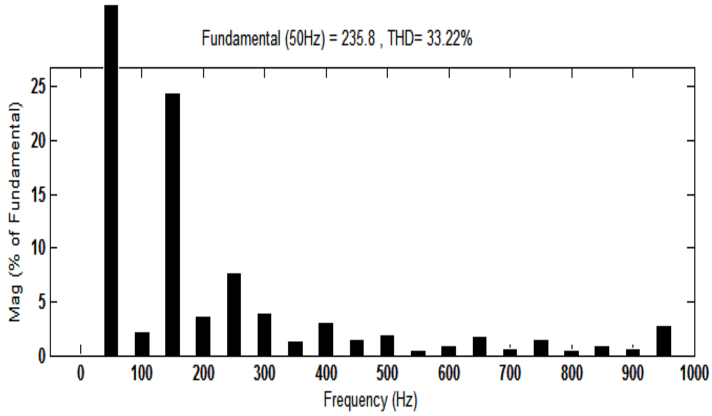

Fig: 17 THD of the Inverter Output Voltage in Current Controller

Figure 11 shows the THD of the phase to phase voltage after applying the current control method to BLDCM

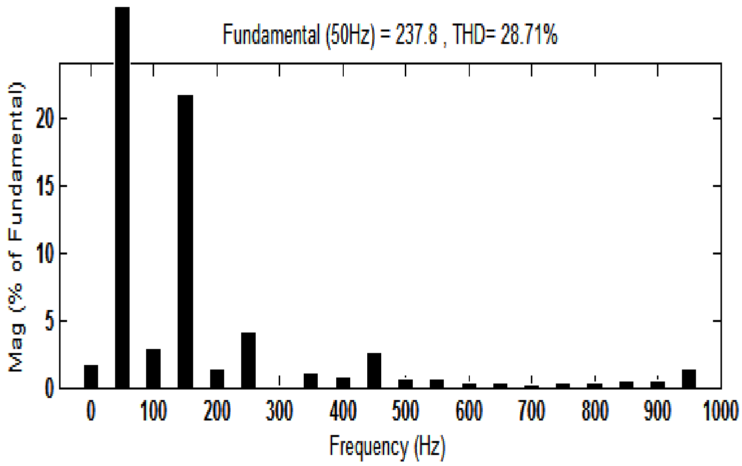

Fig: 18 THD of the Inverter Output Voltage in Speed Controller

Fig: 19 and Fig:20 show the total harmonic distortion of the phase currents of the BLDCM in two operating conditions such as current controller and speed controller techniques and analyze the total harmonic distortion.

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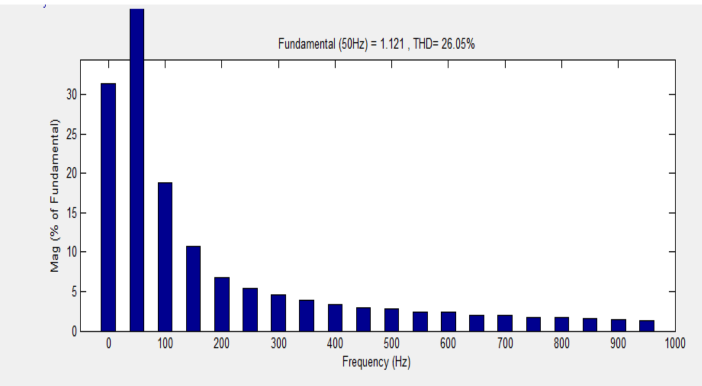

Fig: 19 THD for Phase Current of BLDC Motor in Current Controller

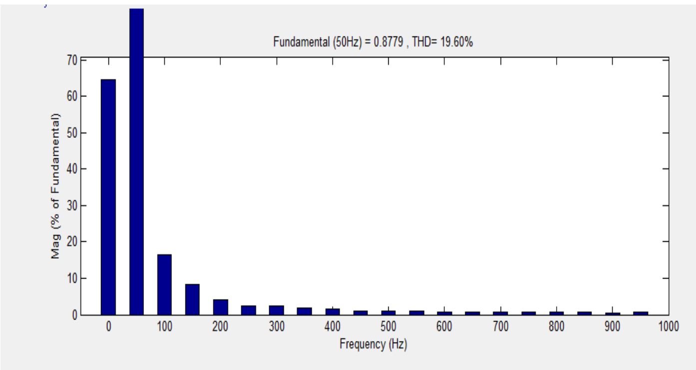

Fig: 20 THD for Phase Current of BLDC Motor in Speed Controller

VI. CONCLUSION

This paper presents the concept of Cascade H-Bridge multi 5-level inverter connected to three phase stator winding of BLDCM with current control and speed control techniques to 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. It is also understood that when torque ripple reduces the THD also reduces and there by performance of the machine is improved.

Table No.1Total Observation

S.NO	METHOD	SPEED (changing the load)	THD for inverter	THD for Stator current	Torque ripples
1	3-Phase inverter	changing	54%	40%	40%
2	Cascaded 5-level inverter in current feedback	changing	33.22%	26.06%	17%
3	Cascaded 5-level inverter in speed feedback	constant	28.71%	19.6%	15%

From above results we observe that the BLDC Motor can give a better performance in speed control technique than current control technique.

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