Pak. J. Biotechnol. Vol. 13 (special issue on Innovations in information Embedded and Communication Systems)
Pp. 203- 207 (2016)

HARMONIC REDUCTION IN BLDC MOTOR USING SEVENLEVEL CASCADED MULTILEVEL INVERTER

G.Nandini[1] and A.Senthilnathan[2]

Department of EEE, Dr. N.G.P. Institute of Technology Coimbatore, India
[1]nandipriyaelec@gmail.com; [2]senthilnathanme@gmail.com

ABSTRACT

Brush Less DC (BLDC) motor is widely used in many industrial and household applications due to its high reliability, simple frame, speed precision, fast dynamic response etc. In this paper, a cascaded multilevel inverter using Sinusoidal Pulse Width Modulation (SPWM) is proposed for BLDC drive. As it is an electronically commutated motor, the commutation can be done by conventional PWM inverters. The torque ripple and harmonics are generated due to high voltage stress in BLDC motor. This problem can be avoided by using a cascaded multilevel inverter with SPWM switching. The proposed seven-level cascaded multilevel inverter using SPWM for BLDC drive is implemented using MATLAB/Simulink and the simulation results are presented. The reduced Total Harmonic Distortion is analyzed using FFT analysis.

Keywords: Brush Less DC Motor (BLDC), Multilevel Inverter (MLI), Total Harmonic Distortion (THD), Sinusoidal Pulse Width Modulation (SPWM).

I.INTRODUCTION

The power electronic inverters are mostly used in the power industry application. As power semi-conductor devices has limited voltage and current ratings, the series and parallel connection of devices are required to increase the power ratings [1,3,4]. The multilevel inverters have fabulous interest in power industries due to their features(1) Staircase waveform quality (2) Common-mode (CM) voltage (3) Input current (4) Switching frequency- it can operate in both, fundamental and high switching frequency PWM [7]. They have different topologies such as diode clamped, flying capacitor, Cascaded H-bridge inverter. The multilevel inverter produces stepped output voltage waveforms due to array of semiconductors, capacitor voltage and selection of switching techniques [1,4,11]. Several modulation techniques generally used in multilevel inverters are Pulse Width Modulation (PWM), Sinusoidal PWM and Space Vector PWM etc. Harmonics reduction in multilevel inverter has been achieved without increasing the switching frequency or decreasing the power output. The multilevel inverter having m-level, in case of increasing the level by (m-1) times than that of two level inverter through the series connection of H-bridge inverter without additional circuit to have the uniform voltage sharing [1,3]. A BLDC motor has permanent magnet as rotor and windings in its stator. The position of permanent magnet is varied depending on the applications, either surface mounted or buried magnet. The stator winding are stacked steel laminated and the generated Back EMF (Electro Motive Force) waveform is either trapezoidal or sinusoidal depending on the conFiguration of stator [1,2,10].

The trapezoidal Back-EMF of Brushless DC motor offers more advantages such as high efficiency, high power density because the absence of field winding, high reliability due to the absence of brushes [1,2]. The practical BLDC motor has torque pulsations due to the back EMF waveform departing from its ideal. Torque ripples due to current commutation is caused by mismatches between the applied electro-motive force and the phase currents with the motor electrical dynamics [1,7].

II.CASACDED MULTILEVEL INVERTER

Multilevel inverters are used in many industries for medium voltage high power applications. Out of the different types of multilevel inverter topologies, the cascaded multilevel inverter topology has more advantages such as it does not require any extra clamping diode, flying capacitors, and also has less circuit complexity [7].

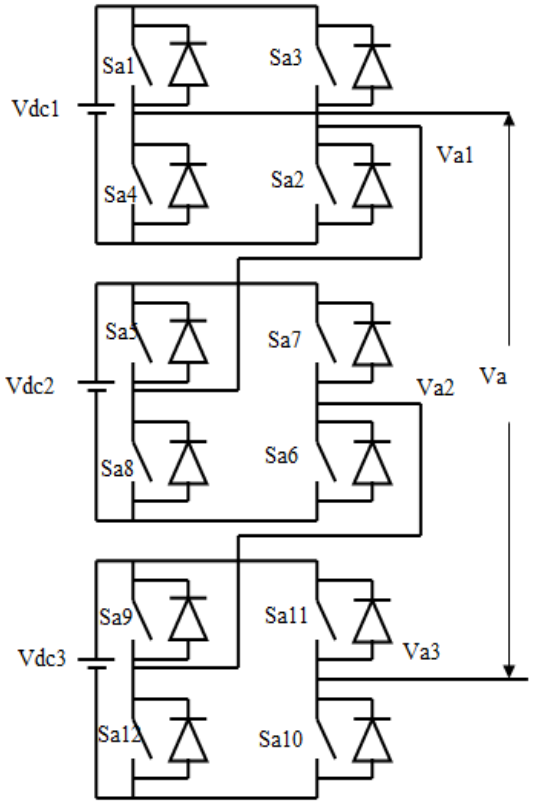

Figure 1: Single-Phase Seven Level Cascaded Multilevel Inverter

Cascaded H-bridge inverter has series connection of H-bridge inverter. Each bridge has four solid states switches S1, S2, S3, S4 and DC source [3,6]. The seven level cascaded multilevel inverter for single

phase is shown in Fig. 1. By increasing the level of inverter the harmonic content can be reduced and it synthesizes sinusoidal waveform. Unique structure of CMLI gives high voltage with low harmonics. The output power quality depends on the method of switching [2,13]. Various switching methods are available for multilevel inverter to reduce the THD.

Depending on switching configuration each H-bridge generates three possible output voltages, i.e. $\pm V_{dc}$ and zero. The total output voltage of CMLI is sum of the all H-bridge output voltages, which is given in equation (1) [3].

$$V_a = V_{a1} + V_{a2} + V_{a3} \quad (1)$$

The Fig. 1 shows the single phase seven level cascaded Multilevel inverter circuit, series connection of the same circuit gives three phase seven level cascaded Multilevel inverter.

III. BLDC MOTOR

The Brushless DC Motor will have better efficiency and power factor compared to conventional DC motor due to the absence of commutator and brushes. The Fig.2 shows the cross section view of BLDC motor. In BLDC the stator is made up of silicon steel stampings with slots in its interior surface. These slots are either closed or opened distributed armature winding. This winding is suitably connected to a dc supply through a power electronic switching circuitry [2].

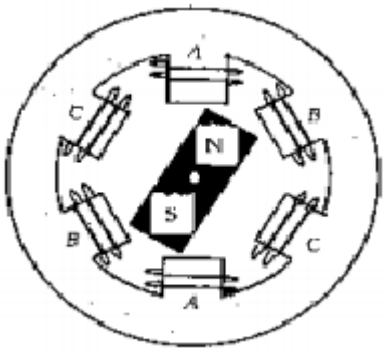

Figure 2: Cross Section View of Brushless DC Motor

Rotor is made up of forged steel. Rotor accommodates permanent magnet. Number of poles of the rotor is same as the number of poles of the stator. The rotor shaft carries a rotor position sensor. This position sensor provides information about the position of the shaft at any instant to the controller which sends suitable signals to the electronic commutator.

IV. CARRIER BASED SINUSOIDAL PULSE WIDTH MODULATION

Carrier based PWM method is the most popular in decades. In motor control and inverter aplications the SPWM is used nowadays[9].The modulated pulse width signals are used to obtain controlled output voltage and reduced harmonics. SPWM generates constant amplitude and different pulse width modulated signals. The Fig.3 shows the method of SPWM signal generation by comparing Sine wave (reference) signal having frequency (f_r) with carrier trianguler wave having frequency (f_c) and produce trigger signal with frequency (f_o) for power electronic switches. The principle of CBPWM is similar to SPWM generation but only difference is it uses multiple carrier wave instead of single carrier wave[3]. The number of carrier waves required to compare depends on the level of inverter.

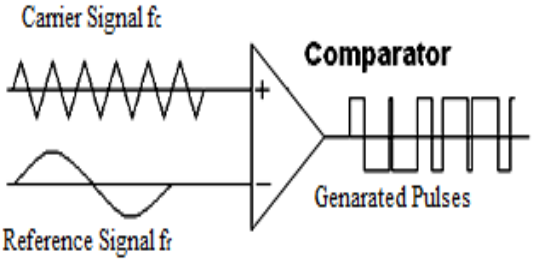

Figure 3: SPWM Generation Method

Figure 4: Comparison of Reference with Carrier Wave

A m-level inverter requires (m-1) number of carrier wave with same frequency f_c and same amplitude A_c. The reference wave having amplitude of (A_r) and frequency of (f_r) and its zero is centered at the middle of carrier set. Amplitude modulation ratio A_m and frequency modulation ratio F_m are important parameters in modulation to produce quality output [12]. These parameters are calculated by the following equation (2 & 3)

$$\mathbf{A_m = A_r / A_c} \quad (2)$$

Where,

A_m = Amplitude modulation ratio,
A_r & A_c = Amplitude of reference & carrier Wave respectively,

$$\mathbf{F_m = f_r / f_c} \quad (3)$$

Where,

F_m = Frequency modulation ratio,
f_r & f_c = Frequency of reference & carrier wave respectively,

Modulation ratio or index offers ripple free voltage and current in inverter outputs. The reference wave is compared with six carrier waves for seven

level MLI is shown in Fig. 4. The pulse signal is produced by the principle, when the reference signal is greater than the carrier signal, then the corresponding device for that carrier is switched off [3].

V.SIMULATION OF SEVEN LEVEL CASCDED MULILEVEL INVERTER FED BLDC

The MATLAB/Simulink model for three-phase seven-level cascaded Multilevel inverter using Carrier Based Sinusoidal Pulse Width modulation (CBSPWM) for three phase BLDC motor is shown in Fig.5

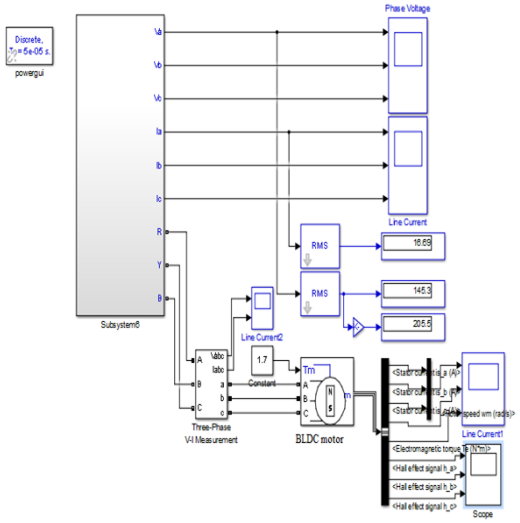

Figure 5: Simulink Model Sevenlevel Cascaded Multilevel Inverter fed BLDC

In Fig.5 the sevenlevel CMLI output is fed to the BLDC motor. To simulate the drive, torque value is taken as constant 1.7 N/m. Then the output value of stator current is 20A with speed of 150 rad/sec has peak overshoot of 230 rad/sec and settling time of 0.05 ms. The output waveforms are shown in Fig.6 a) stator current, b) speed and c) torque

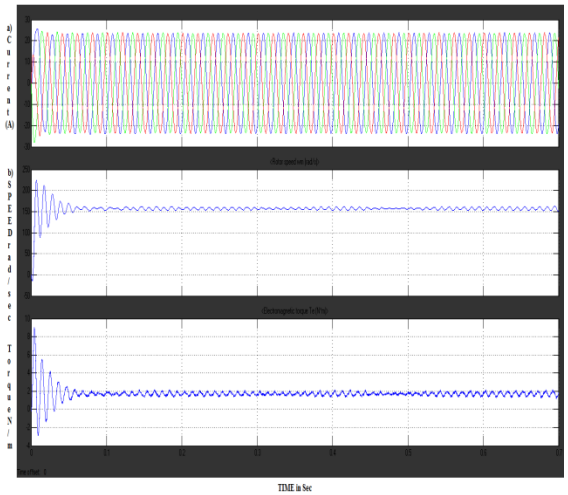

Figure 6: a) stator current, b) speed, c) torque

The subsystem model seven level CMLI for single phase is shown in Fig.7. Inverter has input voltage of 200V per phase which produces the output voltage of 145.6V per phase depending on the pulse. Pulse signals for inverters are generated using pulse generation circuit which as shown in Fig.8.

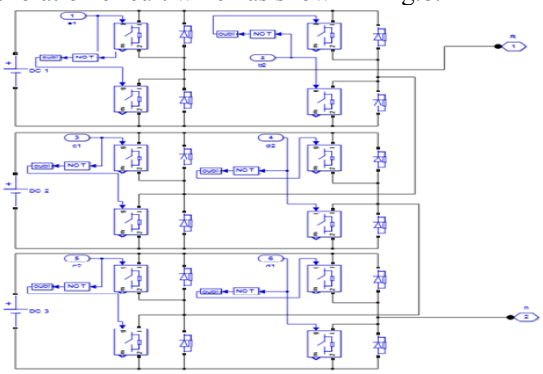

Figure 7: Seven Level Cascaded Multilevel Inverter per Phase

Fig. 8 shows the Carrier based Sinusoidal pulse Width Modulation (CBSPWM) generation circuit. The single reference wave having amplitude of 1V and frequency of 50Hz is compared with six carrier waves with constant amplitude 0.3V. The pulses are generated under amplitude modulation index of 0.9 and switching frequency of 3000Hz.

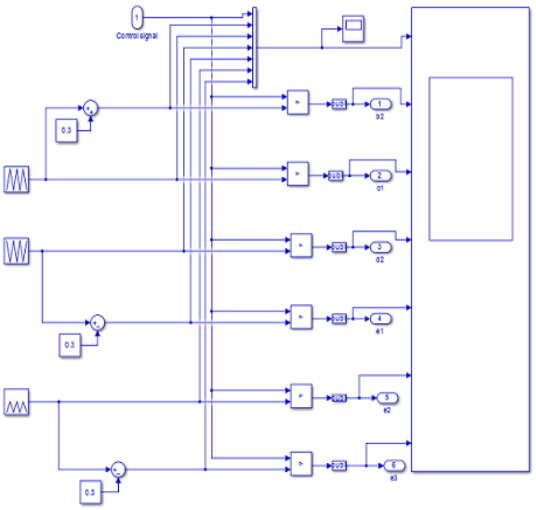

Figure 8: CBSPWM pulse generation circuit

The comparison between the reference and carrier wave is shown in Fig.4. The compared output produced pulse signal for inverter which is shown in Fig.9.

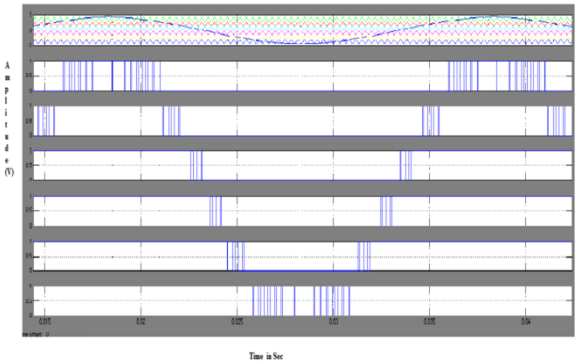

Figure 9: Generated Pulse Signal

In Three phase inverter obtains a phase to ground voltage 200V, phase to ground current 20A which is shown in the Fig.10 Phase voltage, Fig.11 phase current

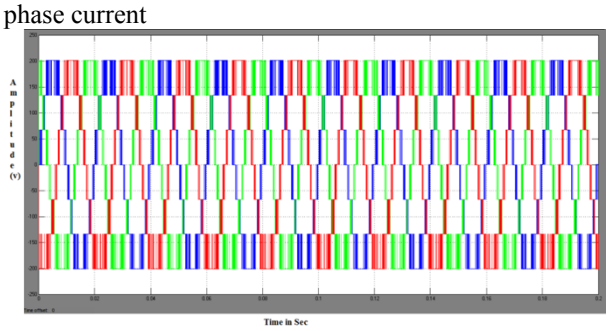

Figure 10: Phase Voltage of Three Phase Inverter

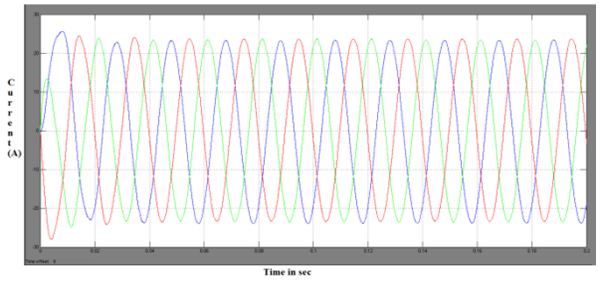

Figure 11: Phase Current of Three Phase Inverter

Three phase, phase to phase voltage and current of inverter is shown in Fig.12.

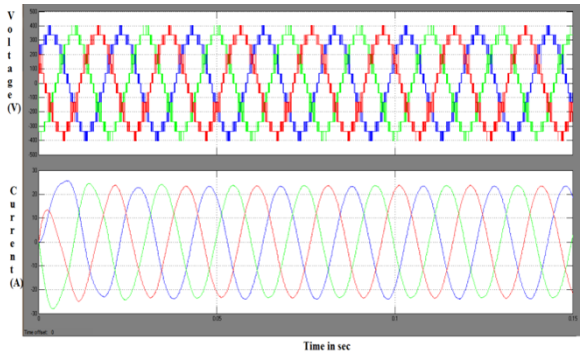

Figure 12: Phase to Phase Voltage and Current

V. RESULTS OF FFT ANALYSIS

FFT analysis is used to analyze the harmonics present in motor output. The FFT analysis gives the magnitude of voltage and current and percentage (%) of Total Harmonic Distortion (THD).

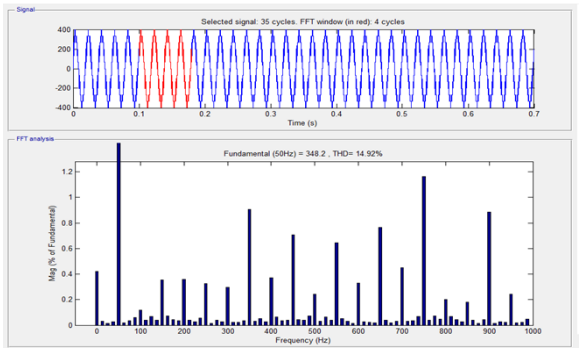

Figure 13: FFT Analysis of Output Voltage

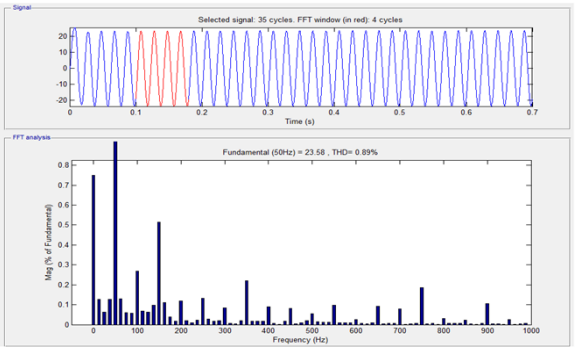

Figure 14: FFT Analysis of Output Current

FFT analysis of output voltage and current of seven level CMLI is shown in Fig.13 & Fig.14.

The THD of output voltage and current at fundamental frequency of 50Hz, is 14.92% and 0.89% respectively and magnitude of voltage and current is 300V and 20A respectively.

VI. CONCLUSION

In this paper, seven level cascaded MLI fed BLDC motor is simulated in MATLAB/Simulink. Inverter and BLDC output characteristics are discussed using simulation results. In simulation, Carrier Based SPWM switching reduces the THD compare to normal SPWM switching. In the proposed system we obtain voltage THD as 14.92% and the current THD of 0.89%. The motor gives constant speed and torque ripples are greatly reduced.

VII.REFERENCES

[1] Anugu Sneha, and R.Somanatham, Reduction of harmonics & torque ripples of BLDC motor by cascaded H-Bridge multi-level inverter using current & speed control techniques. International Journal Of Engineering And Technical Research (IJETR) 3(4):479-483 (2015)

[2] Arunkumar and Thangavel, A Review paper on torque ripple reduction and improvement in brushless DC motor drives. International Electrical Engineering Journal (IEEJ) 5(10): 1567-1575 (2014).

[3] Bambang Sujanarko, Simulation development of carrier based pulse width modulation for cascaded multilevel inverter. International Journal of Computer Applications 104(5): 36-41 (2014).

[4] Gomathi C. Nayanagath, S.V.Purnima and V. Veerakumar, Comparison of PWM methods for multilevel inverter. International Journal of Advanced Research in Electrical, Electronics And Instrumentation Engineering 2(12): 6106-6114 (2013)

[5] Jose Rodriguez, Jorge Pontt, Samir Kouro and Pablo Correa, Direct torque control with imposed switching frequency in an 11-level cascaded inverter", IEEE Transactions on Industrial Electronics 51(4): 827-833 (2004)

[6] Kalaivani, S., K.Kavinelavu, G.Jegadeeswari and S. Kanimozhi, Comparison of THD reduction for asymmetrical cascaded H-bridge inverter, International Journal Of Engineering And Technology 3(5): 242-247 (2014)

[7] Krishana Reddy K, and D.V.Kiran, Torque ripple and harmonics reduction in BLDC drive using multilevel inverter.International Journal of Advanced Technology and Innovative Research 7(3): 367-373 (2015)

[8] Pankaj H Zope, Pravin G. Bhangale, Prashant Sonare, and S.R.Suralkar, Design and implementation of carrier based sinusoidal PWM inverter", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering 1(4): October (2012).

[9] Savyasachi, G.K, R.Avinash, P.Rakshith and G.K. Apoorva, Comparison of three sinusoidal pulse width modulation technique for five level cascaded inverter using simulink. International Journal of Engineering Research & Technology 4(5): 1294-1298 (2015)

[10] Sushmita Ravella, Priyanka Buragadda, Praveen Kumar Kannam and Krishna Swayampu, BLDC motor fed by cascaded MLI. International Journal of Advanced Research In Electrical, Electronics and Instrumentation Engineering 2(11): (2013)

[11] Tejas M. Panchal, Rakesh A. Patel and Hiren S. Darji, Simulation of cascaded and modified cascaded H-bridge multilevel inverter for 3-phase asynchronous motor. International Journal of Recent Trends In Engineering & Technology 11: 404- (2014)

[12] Uma Devi G., P.Manikandan, A. Thimo Theu and S. Prabakaran, Implementation of multilevel inverter using sinusoidal pulse width modulation technique. International Journal Of Science, Engineering and Technology 2(7): 1433-1436 (2013)

[13] Venumadhav M. and K.S.Ravi Kumar, MATLAB based analysis and simulation of multilevel inverters. International Journal of Computer Applications 39(4): 20-22 (2013)

[14] Viswanathan V. and S.Jeevanthan, A Novel current controlled space vector modulation based control scheme for reducing torque ripple in bushless DC drives. International Journal of Computer Applications 28(2): 25-31 (2011)