High Performance MLI Based BLDC Motor Drive with PFC for reduced torque Ripples

[1] S Nafisa Tabassum, [2] D Chinna Dastagiri,[3] V Pratapa Rao
[1]M.Tech Student, Department of EEE, Sri Sai Institute of Technology and Science
JNTUA University, Anantapuram, AP, India[1]
[2]Assistant professor, Department of EEE, Sri Sai Institute Of Technology And Science
JNTUA University, Anantapuram, AP, India[2]
[3]Assistant professor &HOD, Department of EEE , Sri Sai Institute of technology and science
JNTUA University, Anantapuram, AP, India[3]

***Abstract*— In this paper the performance of the Brushless Direct current (BLDC) Motor drive with multi level inverter are analyzed by increasing power factor up to 0.998 and reducing the torque ripples. The use of multilevel inverter can improve application of BLDC motor in medium and high power applications The bridgeless (BL) Buck-Boost converter is used for power factor correction. The bridgeless topology used in this system can reduced the conduction looses associated with the Diode Bridge Rectifier (DBR). As the power factor increases cost will be reduced. The Power quality can be maintained within the acceptable limits at load side. The torque ripples can be reduced by increasing the levels of Multi level inverter. By using this multi level inverter topology harmonics will be reduced in the system. The performance of proposed system is evaluated in MATLAB/SIMULINK environment.**

***Index Terms*—Brushless Direct current (BLDC) motor, Cascaded multilevel inverter, Bridgeless (BL),Buck-Boost converter, Power Factor Correction(PFC), Power Quality.**

I. INTRODUCTION

Brushless DC Motor introduces advancement in its materials and design with which the cost of it is reduces. Now a days BLDC motor is used in various applications like Instrumentation, aerospace, medical, appliances, military etc., BLDC motors is becoming more popular in high-performance variable-speed drives. As it requires relatively little maintenance and has lower inertia, larger power-to-volume ratio, lesser friction, and lesser noise than a conventional permanent-magnet DC servo motor of similar output rating. However, these advantages are costly, and the controller of a BLDC motor is more complex than that of a conventional motor. Good armature current response is also necessary to drive a BLDC motor satisfactorily. BLDC motors have higher power density than other motors (e.g., induction motors) because no loss of rotor copper and no commutation occur. The structure is compact and robust, which contributes to the popularity of BLDC motors in efficiency-critical applications or where commutation-induced spikes (which are unwanted) exist. Commutation necessitates using an inverter and a rotor position sensor

Multilevel inverter (MLI) topologies have been widely used in the motor drive industry to run induction machines for high-power and high-voltage configurations. Traditional multilevel converter topologies, such as neutral point clamped (NPC) MLI, flying capacitor (FC) MLI, and cascaded H-bridge (CHB) MLI, have catered to a wide variety of applications. The CHB MLI might be the only type of MLI where the energy sources (capacitors, batteries, etc.) can completely be the isolated DC sources. Induction motors have been traditionally used for mostly all types of commercial, industrial, and vehicular applications. However, studies in the last decade have shown that vehicular applications demand high performances that are delivered by certain special machines, which include BLDC machines, switched reluctance machines, and permanent magnet synchronous machines The obvious reasons for traditionally using induction motor is that the motor technology and control methodologies are understood by both the academia and the industry. The paradigm shift toward using permanent magnet synchronous machines and BLDC machines is the result of the increased demand in high performance, faster torque response, and enhanced speed and efficiency from vehicles BLDC motors offer numerous advantages including high efficiency, low maintenance, greater longevity, reduced weight, and more compact construction. They have been widely used for various industrial applications based on inherent advantages. They are the most suitable motors in application fields that require fast dynamic response of speed because they are highly efficient and can be easily controlled in a wide speed range

The power quality is major problem at load side due to the power quality problems the various losses are occurred in the system .according to the International electrical commission the power quality standards should be maintained the power quality should be with in its acceptable limits. The PFC can operated in two modes of operation that is continuous current mode(CCM) and discontinuous current mode (DCIM) .If it is operated in CCM two sensors will be required so in this paper PFC will be operated in DCIM.

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***S Nafisa Tabassum, M.Tech(PE),** EEE(dept), SSITS, JNTUA University , Rayachoty,India,9030262886,*
***D Chinna Dastagiri (Assit. professor),** dept of EEE, JNTUA University. Rayachoty, India, 9966386195*
***V.Prathap Rao(HOD),**dept of EEE, JNTUA University., Rayachoty, india,9441433911.*

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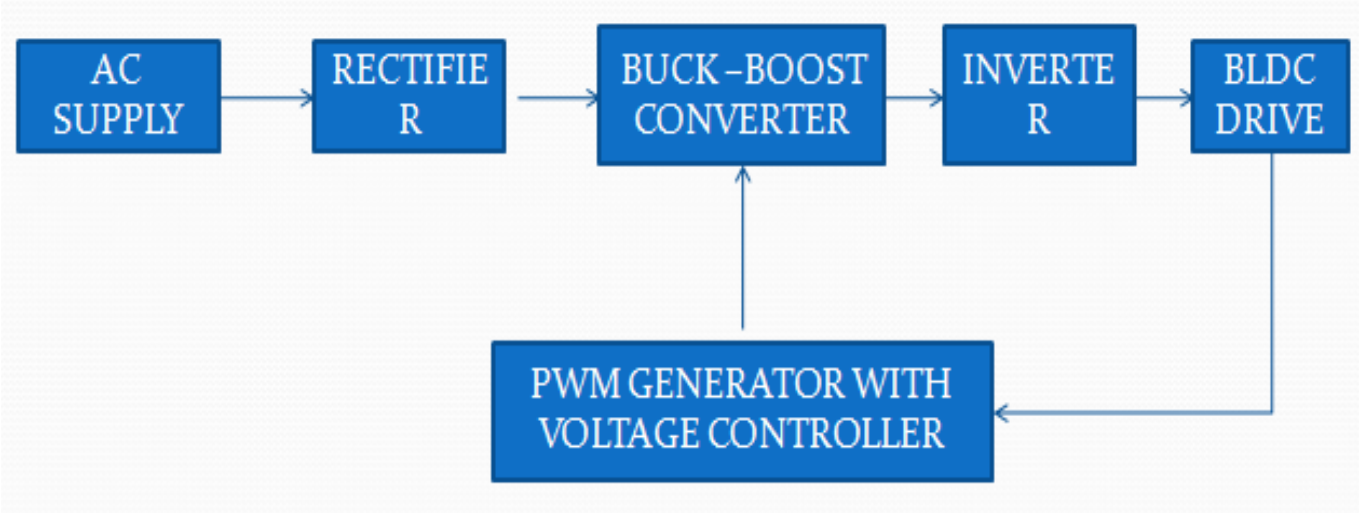
II BLOCK DIAGRAM OF BLDC MOTOR



Fig(1) Basic Block diagram of BLDC Motor

The block diagram of proposed Brushless DC motor with Multilevel inverter is as shown in fig(1)

1 AC SUPPLY:

The single phase ac supply of 230v is given to the supply voltage

2 RECTIFIER:

The rectifier rectifies ac to dc coming from the ac supply. Normally the ripple content can be reduced by using LC Filters

3 BUCK-BOOST CONVERTER:

In these we are using power factor corrected bridgeless buck-boost converter in order to maintain its inherent PFC at the ac mains. The BL Buck-Boost converter is set to operated in discontinuous inductor current mode so that the single voltage sensor will be used. Fig(2) shows circuit diagram of PFC

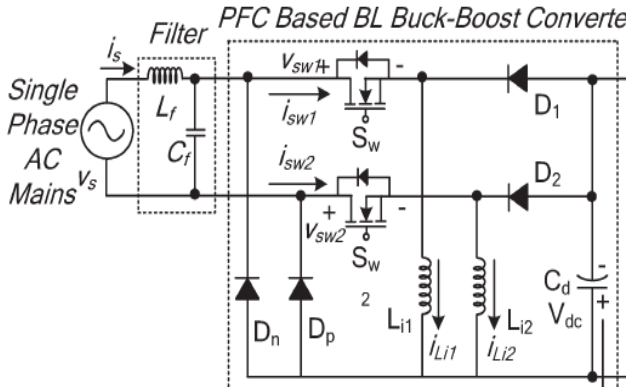


Fig (2) : PFC Buck-boost converter

It can be operated in two modes during positive half cycle switch s1,L1, and diodes D1and Dp are operated similarly for negative half cycle s2,L2 and diodes D2,Dn are operated

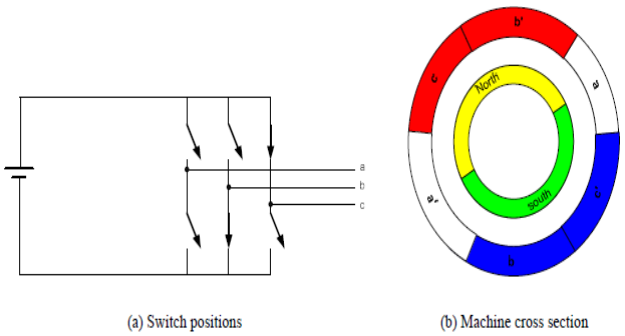
4 INVERTER:

The traditional two or three level inverters doesn't eliminate the unwanted signals presents in the system completely Cascaded Multi level inverter is used to fed the BLDC motor drive. The typical cascaded H-Bridge inverter uses IGBT swithes. The cascaded H-bridge inverter uses separate dc source in its topology

BLDC MOTOR:

The windings of the stator in a brushless DC machine are distributed concentrated form , each occupying one third of the pole pitch. The flux density on the magnet surface and in the air gap is also concentrated distributed over the magnet but almost uniform in the air gap. The torque is developed when the flux coming from the magnet interacts with the stator current. From these it shows that the same direction of flux, results opposite forces from opposite current directions. Therefore, it results in reduction in total torque. This in turn makes it necessary that all the current in the stator above the rotor is in the same direction.

The direction of flux coming from the rotor, is sense by the sensors on the stator. As determined by the direction of flux, A fast supply that will provide currents to the appropriate stator windings. Figures(3) and (4) shows the rotor positions, the stator currents and the switches of the supply inverter for two rotor positions.



Fig(3) Energizing the windings in a brushless DC motor

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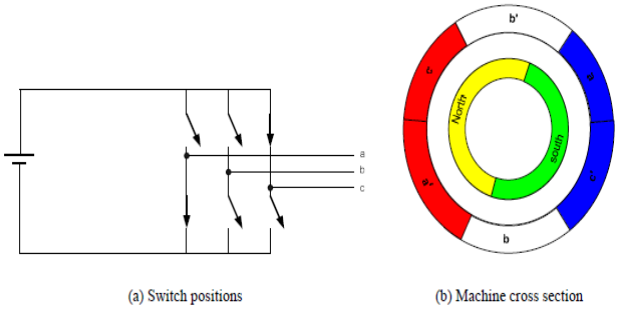

Fig (4) A little later Energizing the windings in a brushless DC motor

The formulae that describe the operation of the system are quite simple.
The developed torque is proportional to the stator currents:

$$T = k\,¢\,I_s$$

At the same time, the rotating flux induces a voltage in the energized windings:

$$E = k\,¢$$

Finally the terminal voltage differs from the induced voltage by a resistive voltage drop:

$$V_{term} = E + I_s R$$

SIMULATED PERFORMANCE OF BLDC MOTOR WITH CASCADED MLI

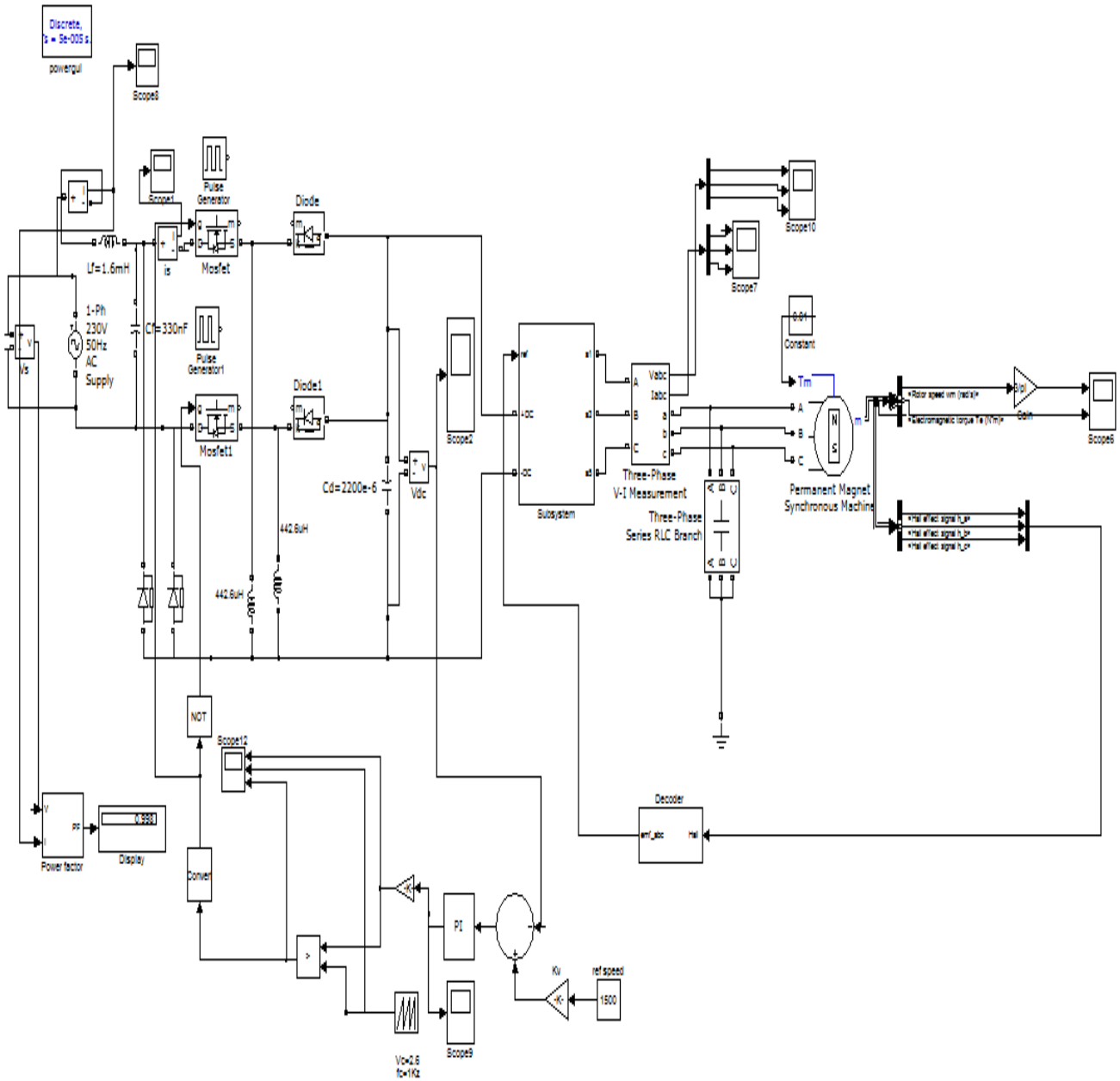

Fig (5) simulation diagram of proposed BLDC motor with MLI

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The brushless dc motor with multilevel inverter is as shown in fig(5) the single phase ac is given at the source side the LC filter will filter out the harmonics present in the source voltage. The Power factor corrected buck-boost converter will operated in discontinuous current mode to obtain the inherent PFC at the ac mains. The dc output from the buck-boost converter is fed to the capacitance c_d. The dc link capacitive voltage is given to the multilevel inverter. The output from the multilevel inverter is fed to brushless dc motor stator winding .the flux coming from the rotor magnet interacts with stator current to produce torque.

HALL EFFECT SENSOR:

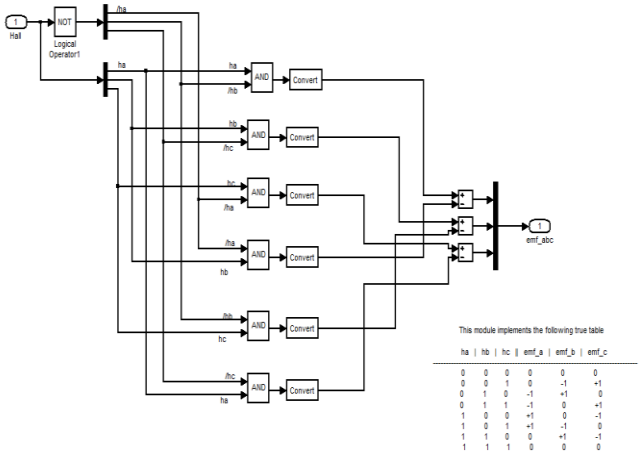
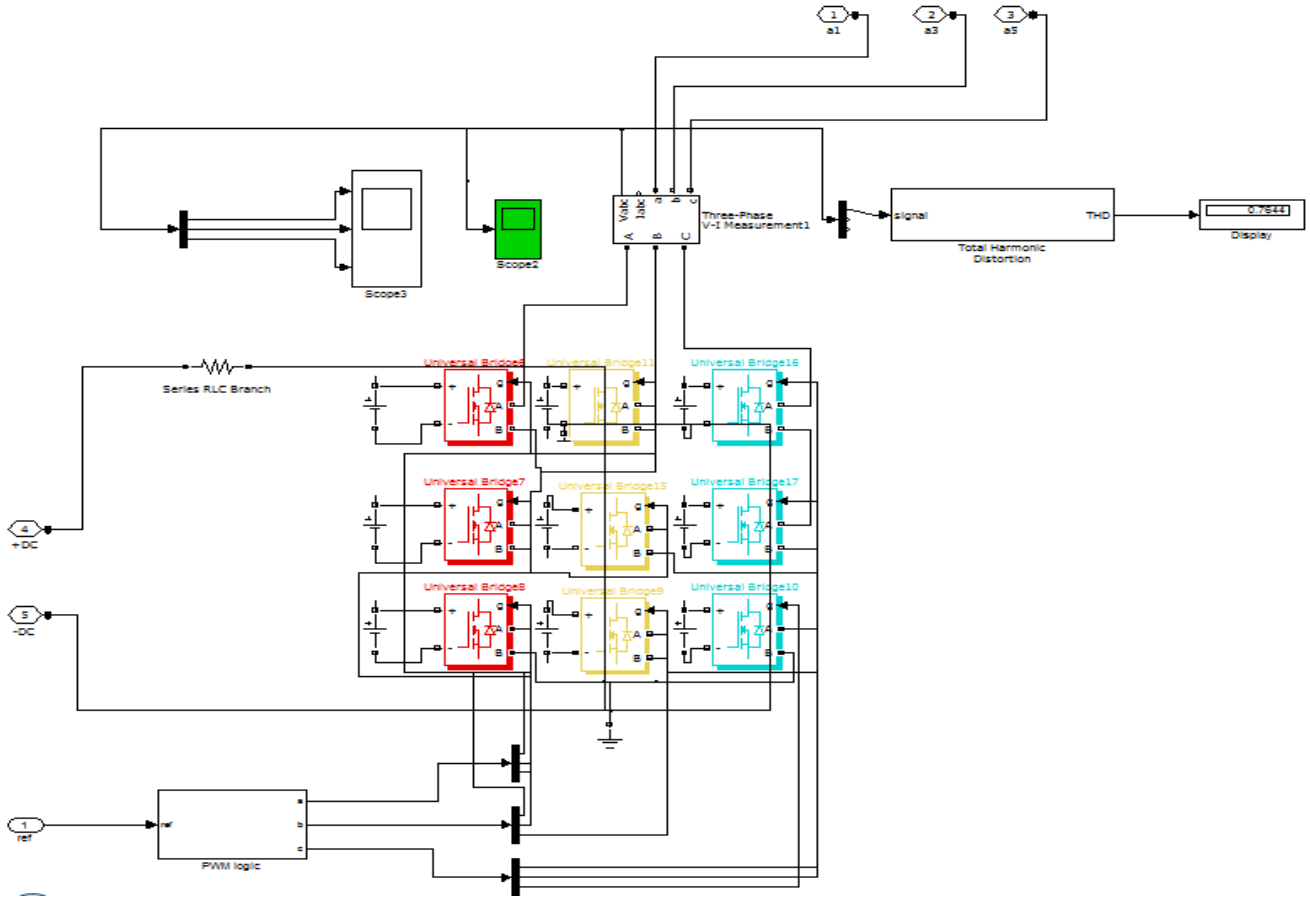


Fig (6) operation of Hall effect sensor

The hall effect sensors senses the rotor position as shown in fig and sends signals to produce back emf for example when the hall sensor senses ha-1,hb-0 and hc-1, the emf _a will be positive and emf_b will be negative the table in below figure shows the sensing pattern and produced phase emf's. the electronic commutation is given to the switches of cascaded multi level inverter as shown in figure. The reference speed is given to the reference voltage generator. The error signal compares the reference voltage and the dc-link voltage. The error voltage is given to the PI controller. From the voltage controller it is given to the PWM generator. The PWM generator will compare the output signal from voltage controller and saw tooth generator. the switching signals are given buck-boost converter switches from the PWM generator

CASCADED H-BRIDGE MLI:

The three phase seven level cascaded H-bridge inverter with separate dc source is as is as shown in figure. The three single phases is connected in star connectionThe synthesis seven level phase voltage requires three firing angles. These three switching angles can be used in all these three phases with delaying 0,120 and 240 electrical degree for phase A,B and C respectively. The formula for calculating the output phase voltage can be given as 2N+1. where N is the number of cells or dc link voltages. In this topology, each cell has separate dc link capacitor and the voltage across the capacitor might differ among the cells. So, each power circuit needs just one dc voltage source



Fig(7) Cascaded H-Bridge Multi level inverter

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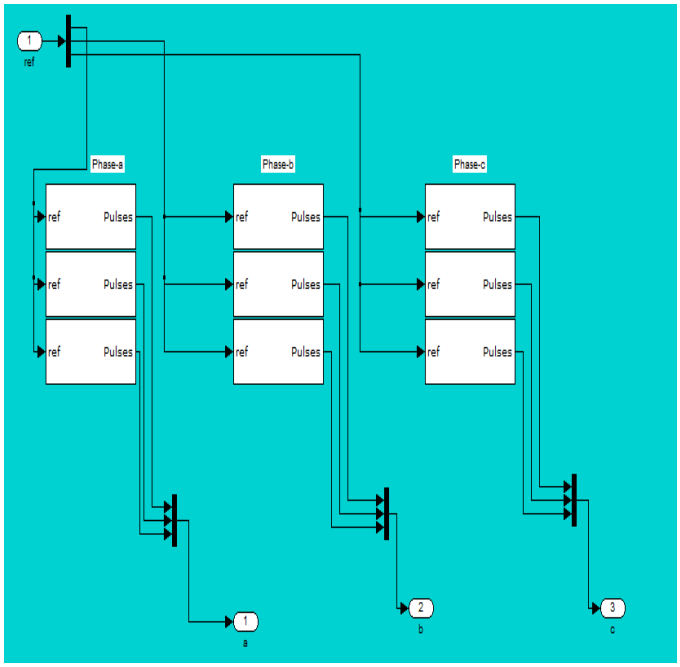
The figure (8) shows firing angle sequence of three phase 7-level cascaded H-bridge inverter. These gives the gating signals for the MLI switches by providing proper phase shift



Fig(8) PWM logic for gating sequence

Figure(9) shows the seven level output voltage of each phase from this figure assuming the positive sequence of three phase system, output voltage of phase C lags output voltage of phase A by 120 electrical degree. Similarly phase B by 240 electrical degree.

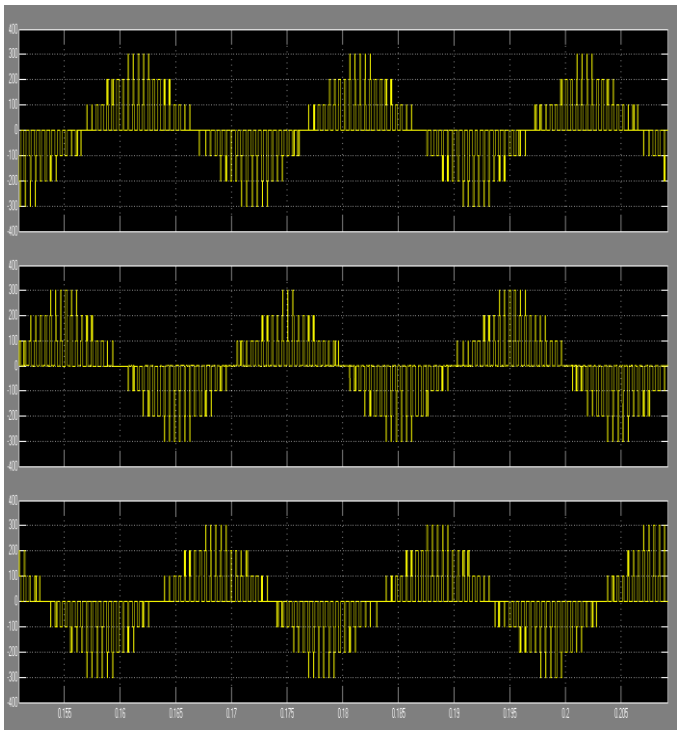


Fig (9) 7-level output voltage

The figure(10) shows that speed and torque characteristics. By using Brushless dc motor fed with voltage source inverter has high torque ripples and switching looses. In order to reduce the torque ripples the voltage source inverter is replaced with three phase cascaded multi level inverter to fed the BLDC motor. The advantages of using three phases cascaded system is we can eliminate the triplen harmonic components in the line voltage by one third cycle phase shift feature

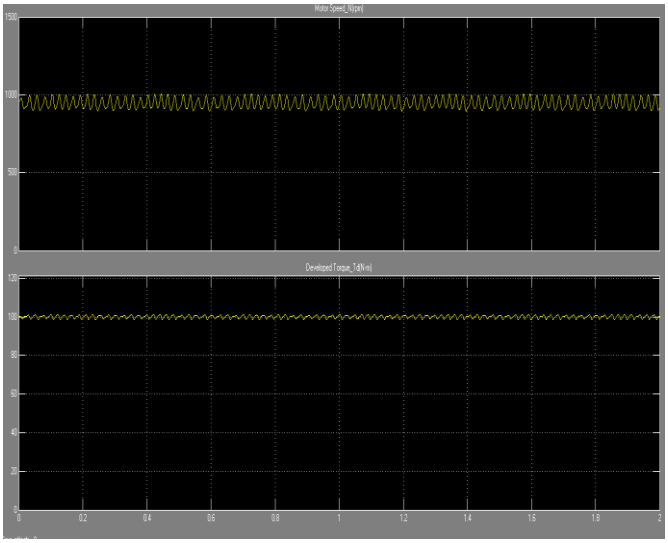


Fig (10) : speed and torque characteristics with reduced harmonics

CONCLUSION

The BLDC motor with voltage source inverter is cost effective in low power applications. The inherent PFC is obtained at the ac mains by operating power factor corrected bridgeless buck-boost converter in discontinuous inductor current mode. The total harmonic distortions are obtained satisfactorily with in the acceptable limits of power quality standards of IEC-61000-3-2 by achieving speed control and voltage variations. The BLDC Motor with MLI is used to obtain the reduced torque ripples. By using MLI we can also increase the power factor at at the ac mains to 0.998. although the cost of MLI is greater than VSI by small amount but the performance of Multilevel inverter is very high compared to voltage source inverter

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First Author

S Nafisa Tabassum currently pursuing M.Tech in POWER ELECTRONICS from SRI SAI INSTITUTE OF TECHNOLOGY AND SCIENCE affiliated JNTUA . She has done her B.Tech degree from SRI SAI INSTITUTE OF TECHNOLOGY AND SCIENCE affiliated JNTUA in 2013 and her field of interest includes POWER ELECTRONICS.
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Second Author

D Chinna Dastagiri has completed his B.Tech ELECTRICAL & ELECTRONICS ENGINEERING in 2006 from SRI SAI INSTITUTE OF TECHNOLOGY AND SCIENCE affiliated JNTUA, M.Tech in power systems NIE Mysore 2009. working as a Assist. Professor at SRI SAI INSTITUTE OF TECHNOLOGY AND SCIENCE affiliated JNTUA .Rayachoty, kadapa(dist).Andhra Pradesh, INDIA. His areas of interest includes Power Systems.

Third Author

V. Pratapa Rao has completed his B.Tech ELECTRICAL & ELECTRONICS ENGINEERING in 2003 from R.G.M college of engineering and technology affiliated JNTUH M.Tech in power system from AITS Rajampet, affiliated JNTUA, and presently he is interested to reach topics includes power system especially in Electrical Distribution System ,working as HOD of EEE department of SRI SAI INSTITUTE OF TECHNOLOGY AND SCIENCE affiliated JNTUA .Rayachoty, kadapa(dist).Andhra Pradesh,INDIA

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