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Simulation Modelling on Switched-Inductor Z-Source Inverter Based BLDC Drive

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Abstract*:* The main objective of this paper is to minimize the high component stresses, poor spectral performances and increase the boosting gain of voltage-type SL Z-Source inverter. These are achieved by their modulation ratios can be set higher to better utilize their dc links and keep their component stresses lower. This is achieved by generalized SL topology for voltage type SL Z-source inverters. The generalized SL topology is adding extra SL cells for increasing the boosting gain. BLDC motor is connected at the output side which acts as a load. The closed loop control regulates the speed of the BLDC motor for different load conditions and also maintains regulated voltage and current. The simulation model is developed by using MATLAB software.

Keywords: switched-inductor (SL), Brushless DC Drive (BLDC), Z-source inverter (ZSI), shoot-through (ST).

I. INDRODUCTION

The Z-source inverter (ZSI) is an emerging topology for power electronics dc-ac converters [1], Z-sources the presence of an X-shaped LC impedance network and far-left diode D. it can utilize the shoot-through (ST) state to boost the input voltage, which improves the inverter reliability and enlarges its application field. It provides an attractive single-stage dc-ac conversion with buck-boost capability, reduced cost. These additions give boosting abilities and robustness to the z-source inverters, which can now tolerate shoot-through and open-circuit states without causing the damages. There for the ZSI is a very promising and competitive topology for renewable energy sources, such as fuel cells, photovoltaic arrays and wind turbines, and new power electronics applications, such as electric and hybrid vehicles. Indeed, research in Z-source inverter has progressively actively with their modulation, control, component sizing,and applications. Recently, another interest has surfaced, that is conversion gain of the Z-source inverter is limited due to the higher Semiconductor losses and poorer spectral performance.

These constrains are linked to the tradeoff between modulation ratio shoot through duration experienced by the z-source inverters .To address concern, number of improvements have been proposed in the literature,which are switched-inductor(SL)[3],tapped-inductor[5],T-source[2],andtransz-source[5] configurations in. Each technique have drawbacks that are high gain of these traditional Z-source inverters have high component stresses which cause higher semiconductor switching losses and other resistive lossless. In this paper, interest directed to the generalized switched-inductor Z-source inverter. To overcome the above limitations of the traditional voltage type SL Z-source inverters, this thesis deals the generalized voltage type SL Z-source inverter with higher boosting gain and better utilize of the DC link and keep their component stresses are lower than the traditional voltage type SL Z-source inverters. In this paper interest is directed to the generalized SL topology of Z- source inverter, which improved the boosting gain in renewable energy industry. Voltage stability is improved in renewable energy sources. The resultant output voltage is fed to the BLDC drive. The three phase inverter gates signals are produced by decoding the Hall signals of the motor into EMF.

II.EXISTING SYSTEM ANALYSIS

Conventional z-source inverter is limited due to the higher semiconductor losses and poorer spectral performance. These constrains are linked to the tradeoff between modulation ratio shoot through duration experienced by the z-source inverters. The earlier z-inverters performance gives the switch stress experienced by the inverter bridge. That causes switching losses in inverter According to this parameter should more appropriately be normalized with the minimum dc-link Vdc demanded by a traditional VSI for producing the same ac output voltage at high modulation ratio, where the SL and TL inverter are clearly having lower switch stresses than the tran-z-source inverter and alternate cascaded inverters. For that, it is important to note that for the trans-Z-source inverter, although only one capacitor, its capacitance is two times bigger than each capacitance used for the SL and TL inverters. That causes its total capacitor stress to be higher. Combining the understanding gained so far, it is appropriate to comment that the SL and alternate

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cascaded inverters are attractive topologies for spreading stresses if higher rated components are not available. Their combined stresses are however not necessarily lower. To overcome the above limittions generalized switched-inductor cell topology has been introduced. The generalized switched-inductor cell topology offers several advantages over the conventional Z-source inverter such as reduced component stresses, higher boosting gain of inverter, higher reliability, and better utilization of dc link. This topology of the inverter is identified as one of the most suitable power conditioning interface between the PV generation system and the grid. This paper presents a generalized topology of voltage type switched-inductor z-source inverter where adding the extra SL cells to increase boosting gain that allows a higher modulation ratio can be achieved.

III. EMF BASED CONTROL OF BLDC

In the proposed generalized SL topology Z source inverter is used to run the BLDC drive with back emf control method. This closed loop control method is achieved by using PIC so that speed of the BLDC motor can be maintained constant even under load changing condition.

A. BLOCK DIAGRAM OF PROPOSED CONTROL SCHEME

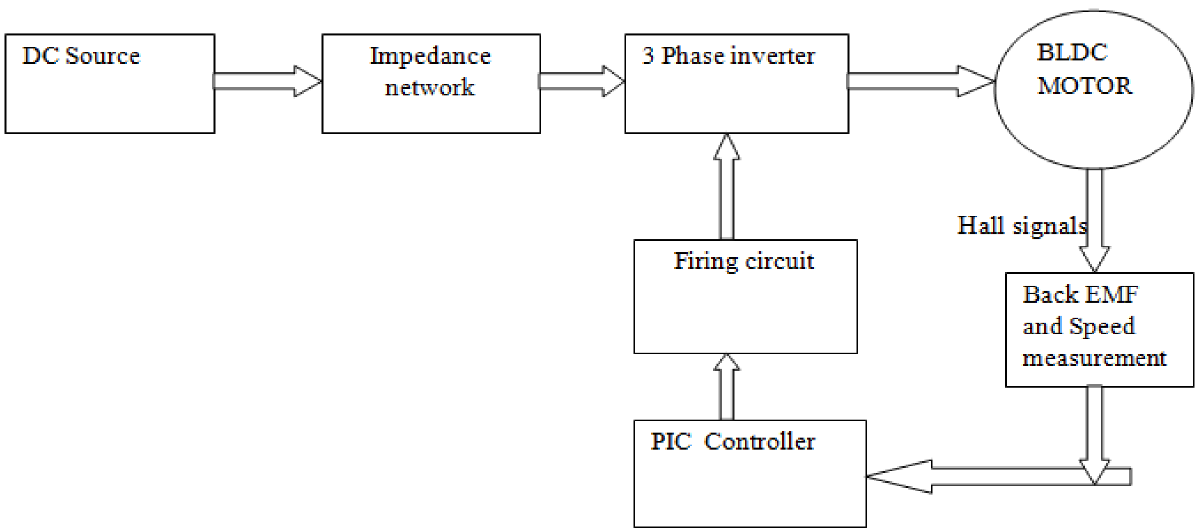

Fig. 1. Block diagram of proposed system

It consist of dc source from battery or solar panel, impedance network which consists of capacitors and switched-inductor cells, three phase inverter, BLDC with hall sensor and pulse generator to control the operation of BLDC motor as shown in the Fig.2.where SL cells is major roll to boosting the voltage gain of inverter and reduce the higher component stresses in switching devices in the three phase inverter. By generalized SL topology switched-inductor cells are adding extra in impedance network which reduce the shoot-duration that allows a higher modulation ratio to be used. High value of modulation ratio M linked to dc

2. Boost-buck function by the one-stage conversion.
3. Better utilization of DC link
4. Lower stresses in switching devices of inverter
5. .High value of boosting factor.
6. Continuous input current (input current never drops to zero, thus featuring the reduced stress of the input voltage source, which is especially topical in such

link and lower component stresses . inverter output voltage is fed to the BLDC drive. DC output from the battery is given the generalized SL topology of z-source inverter is likely to find applications in renewable or other clean energy industry, where high boosting gain for grid interfacing is usually needed. A probable example is grid-tied photovoltaic (PV) system, whose implementation will usually involve the sensing of vi directly or indirectly through measuring capacitor voltage Vc. This control arrangement is standard for PV systems. This paper presents a generalized SL topology of z-source inverter its advantages are

1. Boost-buck function by the one-stage conversion.

demanding applications as power conditioners for fuel cells and solar panels).

7. Low or no in-rush current during start up.

A.BRUSHLESS DC MOTOR

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In the brushless DC motor, polarity reversal is performed by power transistors switching in synchronization with the rotor position. Therefore, BLDC motors often incorporate either internal or external position sensors to sense the actual rotor position, or the position can be detected without sensors. Commutation provides the creation of a rotation field. It is necessary to keep the angle between stator and rotor flux close to 90° for a BLDC motor to operate properly. Six-step control creates a total of six possible stator flux vectors. The stator flux vector must be changed at a certain rotor position. The rotor position is usually sensed by Hall sensors. The Hall sensors generate three signals that also comprise six states. Each of Hall sensors' states corresponds to a certain stator flux vector. All Hall sensor states with corresponding stator flux vectors. The switching states of inverter is shown in the table.

TABLE I

Emf generation according to the hall signal

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

As seen from Fig. 3. the output stage consists of a three-phase inverter composed of switches that could be MOSFETs or IGBTs. Here IGBTs are used. Brushless-dc machine operation requires rotor position information to allow for appropriate solid state switch firing. For sensored control, three leading technologies are commonly used to fulfil the position information requirement. These technologies are hall-effect sensors, resolvers, and optical encoders. The most commonly used sensor type is a Hall Effect sensor. They are low cost and provide position

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emf-a	emf-b	emf-c	Q1	Q2	Q3	Q4	Q5	Q6
0	0	0	0	0	0	0	0	0
0	-1	+1	0	0	0	1	1	0
-1	+1	0	0	1	1	0	0	0
-1	0	+1	0	1	0	0	1	0
+1	0	-1	1	0	0	0	0	1
+1	-1	0	1	0	0	1	0	0
0	+1	-1	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0

Since a permanent magnet rotor is used in a BLDC the speed control can be implemented by varying the average voltage across the stator windings. This tends to change the value of the average stator current. However for a given load torque the average stator current has to be ideally fixed. Hence the back EMF induced in the stator windings has to change such that the stator current remains constant. For a constant field the speed will be changed. Thus increasing the applied stator voltage increases the motor speed and vice-versa. Here sensor control is used with the use of hall sensor. Usage of semiconductor switches is preferred due to their low loss, high frequency operation and the allowance for electronic control. This is apart from the other advantages like space and cost saving. The typical inverter drive system for a BLDC motor is shown in Fig. 3

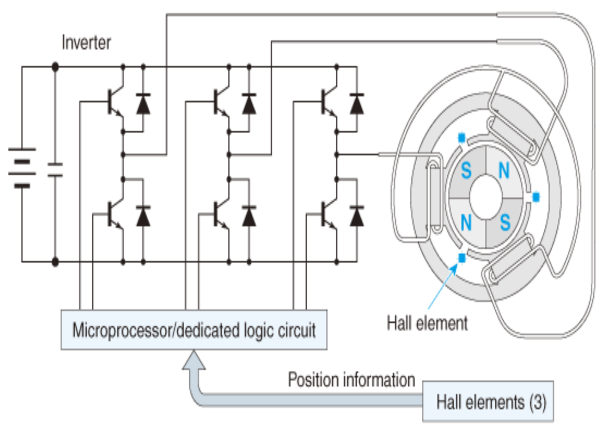

Fig. 2. Typical inverter drive system for a BLDC motor

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resolution to within thirty electrical degrees, which is sufficient to operate a BLDC machine. The major advantages of BLDC motor are

1. It has 3 times longer life than brushed motor
2. Spark free operation is possible with safe and less radio interference
3. Electronic and frictional noise are absent
4. No brush friction, so power consumed is 28% less than brushed motors, based on the same output
5. No commutator or brushes to wear out.

C. PROPOSED CIRCUIT

The circuit diagram of generalized switched-inductor z-source inverter fed BLDC motor with back emf method Here the SL switched inductor cells places a major part, where output from inverter is effectively utilized for driving a BLDC motor, and further control of motor is done with the help of gate pulse generation by pulse generator accordingly, through hall sensor placed at the rotor side. It effectively senses the rotor position and hall signals are converted to emf by decoder. According to the value of emf fed, the gating signal produced by pulse generator differs and hence speed of the motor can be controlled. This topology of the inverter is one of the most suitable power conditioning interface between the PV generation system and the load.

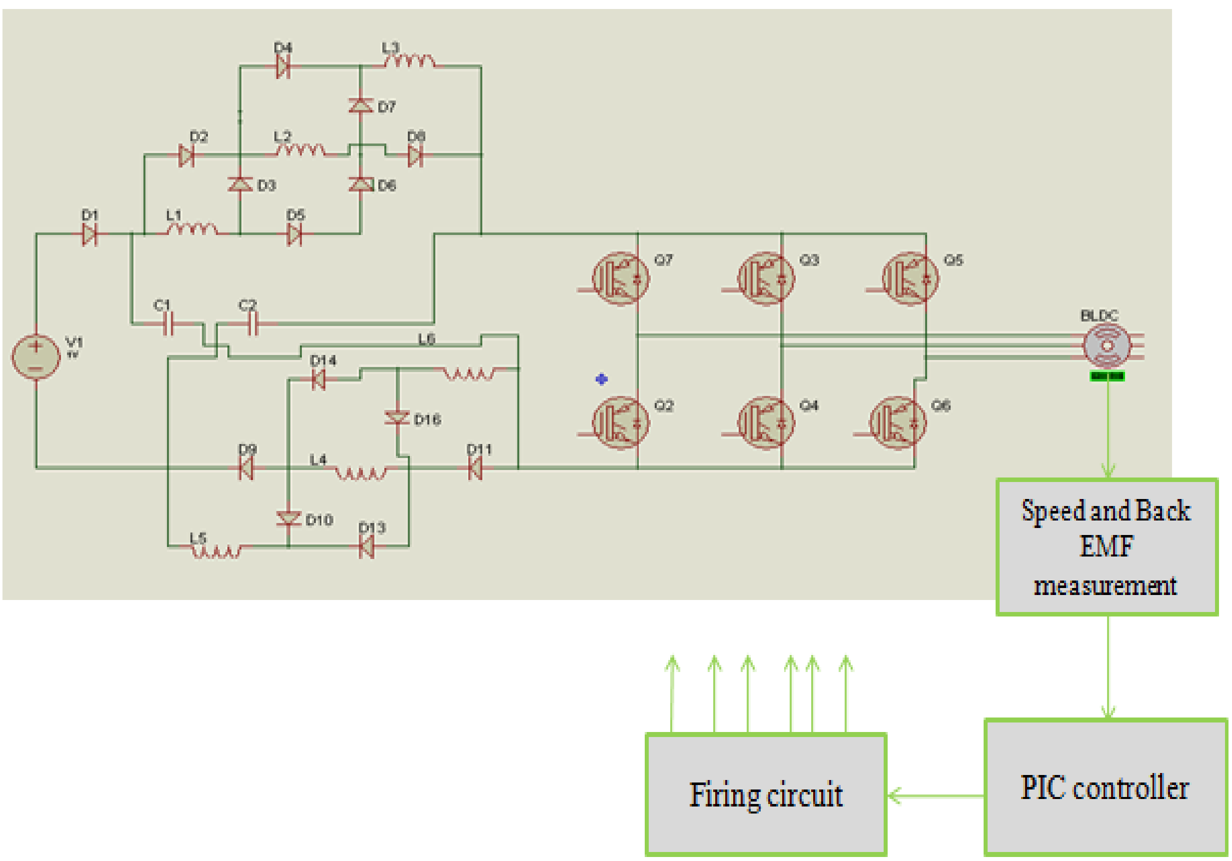

Fig.3.Generalized SL voltage-type Z-source inverter based BLDC drive

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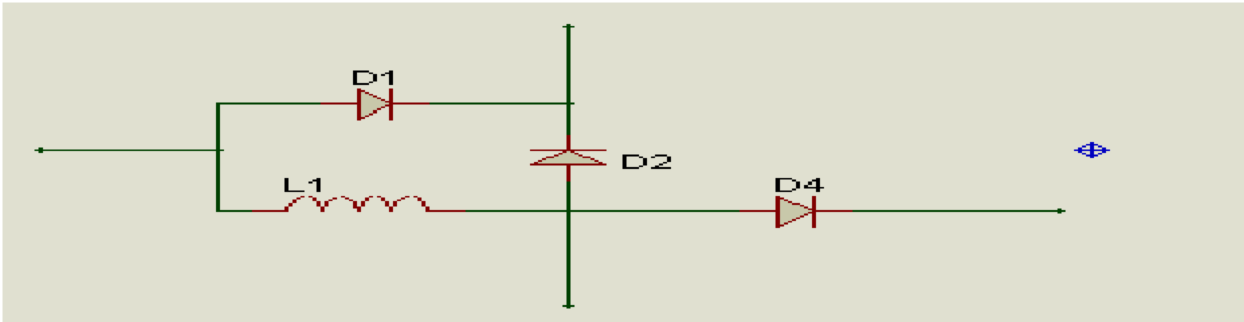

Fig.4. Switched Inductor (SL) Cell

IV PRINCIPLE OF OPERATION

The generalized topology is generalized in fig 3, where the generic cell is shown in fig 4. it consists of One inductor L_n and three diodes D3n-1,D3n-1 and D3n for nth cell. this cell can be duplicated 2N times, divided equally between the upper and lower dc rails and connected as in the fig 2a. note that inductors L2n and L2n+1 in the generic cells are not included in the generic cells. In which the forming the generic cells allows the generalized SL topology to be viewed as adding the extra cells to increase the boosting gain. These cells introduce the additional inductors in cells are parallel during shoot-through state for charging and more inductors are in series in non shoot through state for discharging. Feature for these two operations as follows.

1) *Shoot-through state:* supply is given, turning on the two switches in same phase leg of the VSI bridge . That causes the diodes D and D3n are turnoff, while D3n-1 and D3n-2 conduct. All the inductors in the cells are parallel to rise the common inductive voltage of vL=Vc

2) nonshoot-through state: Null states in VSI Bridge. In this state, diodes D and D3n conduct, while diodes D3n-2 and D3n-2 block. All the inductors in the cells are discharge in series to the external ac load, whose common inductive voltage is vL = (Vdc-Vc) / (N+1), where N+1 is the number of inductors in the cascaded block. A generic expression for the generalized Z-source inverter is:

$$Vc = \frac{1-dST}{1-(N+2)dST} Vdc \qquad (1)$$

$$vi = \frac{1+NdST}{1-(N+2)dST} Vdc \qquad (2)$$

$$vac = \frac{M(1+NdST)}{1-(N+2)dST} \frac{Vdc}{2} \qquad (3)$$

The boost factor is given by

$$B = \frac{1+NdST}{1-(N+2)dST} \qquad (4)$$

Equation (4) can be higher than the traditional Z-source inverters by adding the more generic cells. The desired gain also reduced the shoot-through duration. That allows a higher modulation ratio to be used since better utilization of dc link, lower component stresses, and better spectral performance are achieved this is depended the higher modulation ratio M. In BLDC drive speed and back EMF are measured by hall sensor and decoded to gate signals. This is given to the switching devices of the three phase inverter

V. SIMULATION AND RESULTS

To validate the proposed control scheme, the simulated model is developed in Matlab/Simulink for the whole system A BLDC motor is fed by a generalized switched-inductor z-source inverter. The inverter is a IGBT bridge of the SimPowerSystems™ library. The inverter gates signals are produced by decoding the Hall effect signals of the motor. The three-phase output of the inverter is applied to the BLDC block's stator windings. The constant load torque applied to the machine's shaft is 2.5 (N.m).The closed loop synchronizes the inverter gates signals with the electromotive forces. This control loop controls the motor's speed by varying the inverter output voltage.

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The simulation circuit diagram is shown in figure5

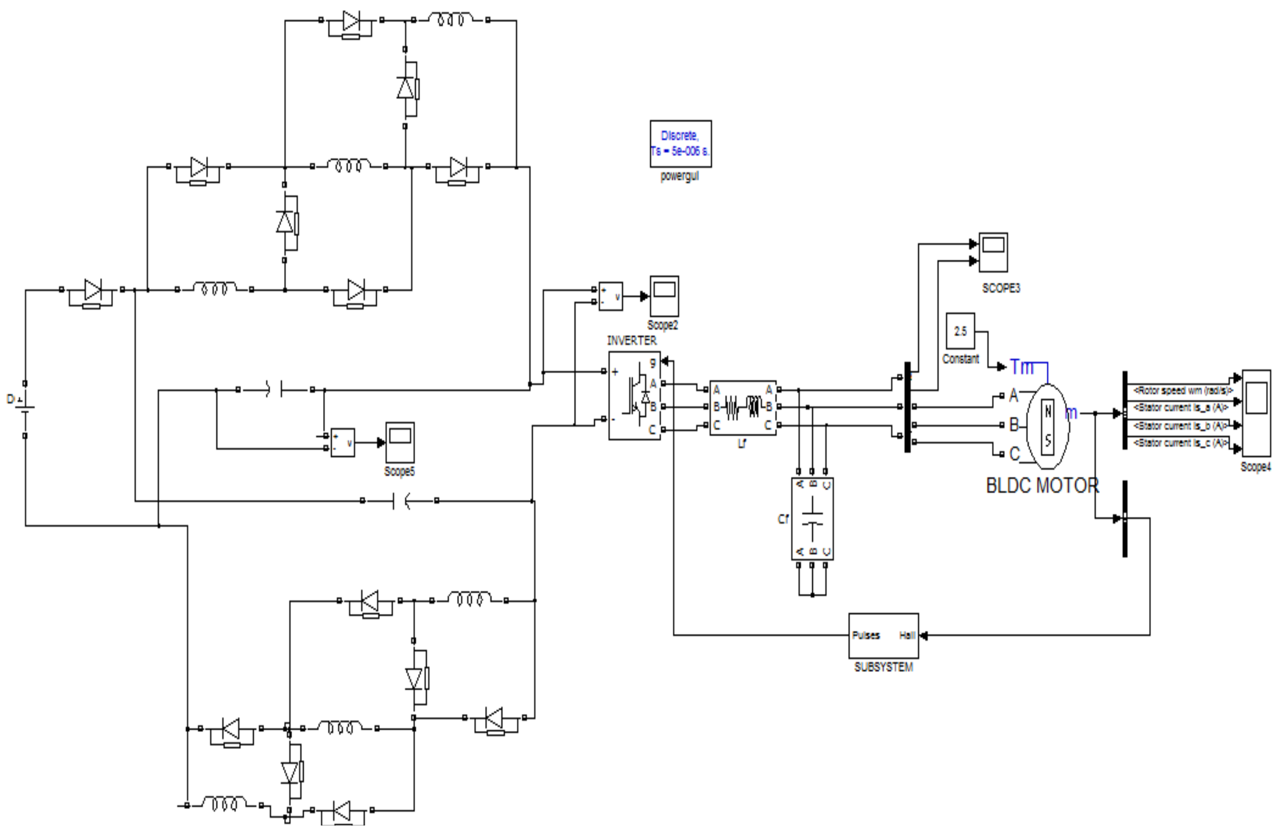

Fig.5. simulation circuit diagram

The capacitor voltage waveform is shown in figure 6

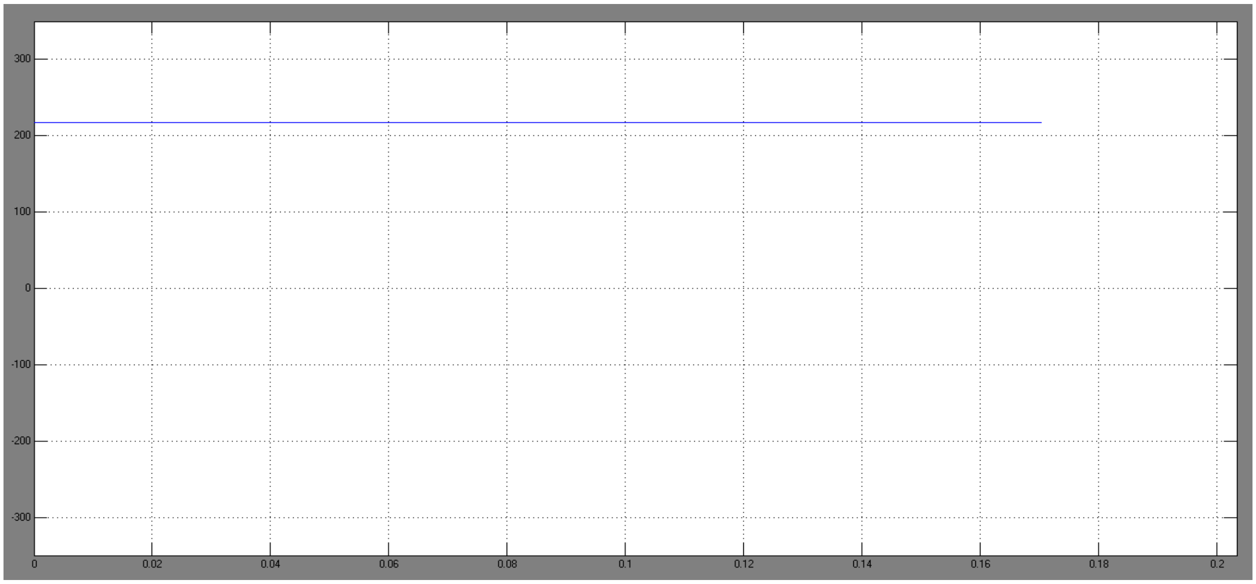

Fig.6.capacitor voltage waveform

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The DC link voltage (vi) waveform is shown in figure.7.

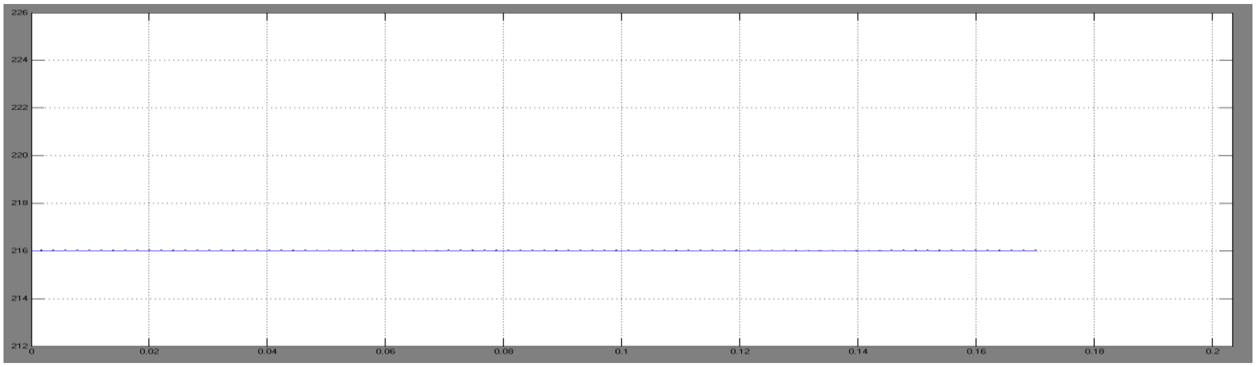

Fig.7.DC link voltage waveform

The inverter output voltage waveform is shown in figure.8.

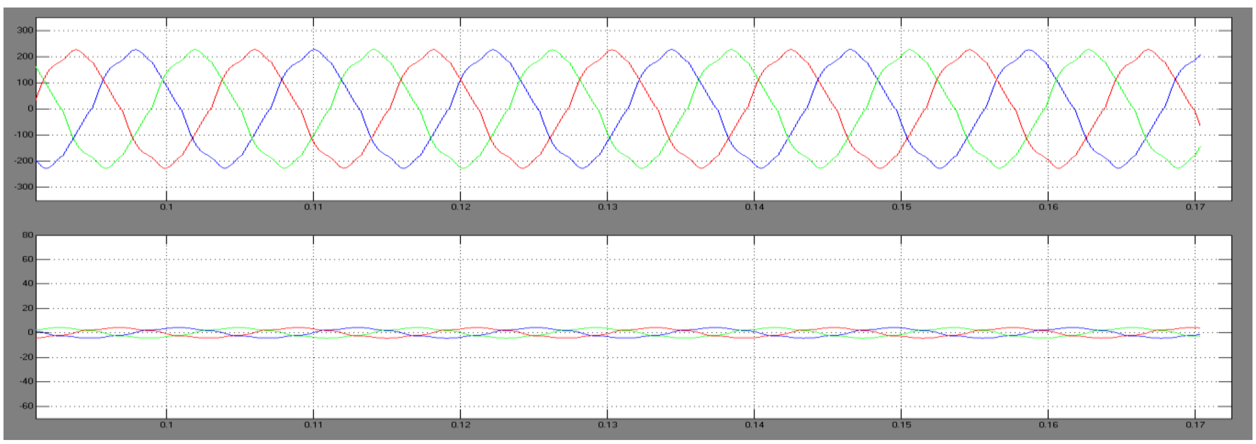

Fig.8. Inverter output voltage waveform.

The motor speed versus time waveform is shown in figure 9.

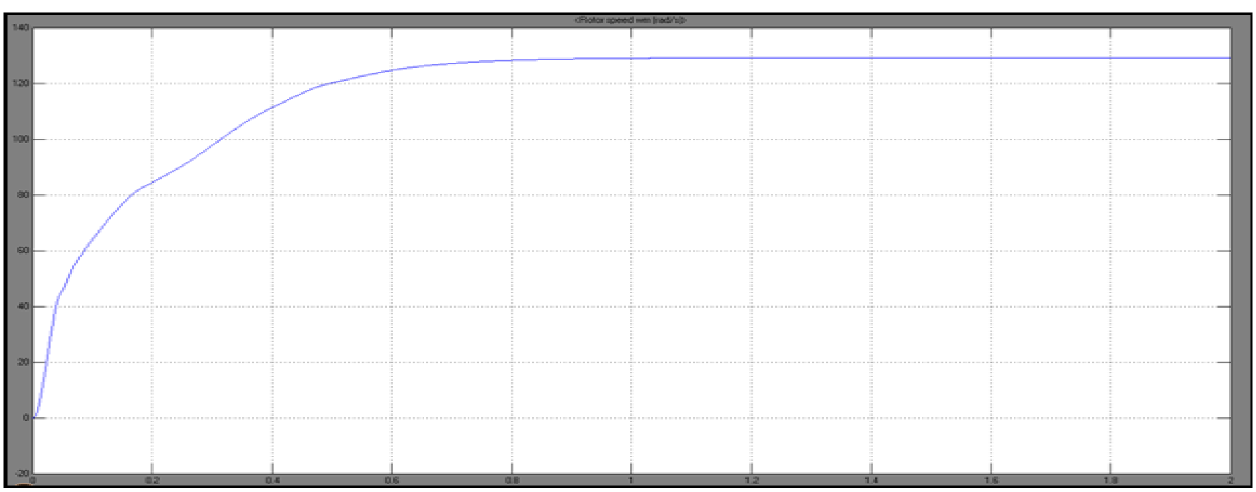

Fig.9. Motor speed waveform

The stator current waveform is shown in figure10

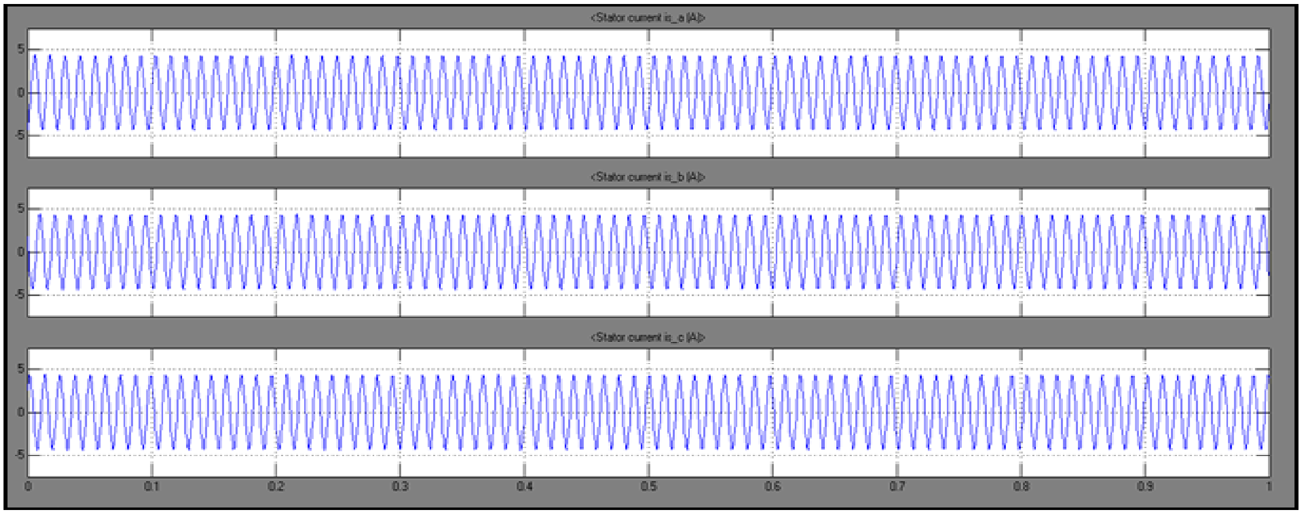

Fig.10. stator current

V. CONCLUSION

This paper proposes a minimized the high component stress, poor spectral performances and increase the boosting gain of voltage type SL Z-source inverter. This achieved by adding more generic cells that allows a modulation ratios can be set higher to better utilize of their DC links, and keep their component stress lower. This paper is implemented in the generalized voltage type SL Z-source inverter for BLDC drive with hall sensor. The inner speed control loop of drive is achieved by decoding the hall signals to EMF. The simulation model is developed using MATLAB software. The simulation result shows the better boosting gain than the traditional Z-source inverters.

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BIOGRAPHY

Dr.Govindaraj Thangavel born in Tiruppur , India , in 1964. He received the B.E. degree from Coimbatore Institute of Technology, M.E. degree from PSG College of Technology and Ph.D. from Jadavpur University, Kolkatta, India in 1987, 1993 and 2010 respectively. His Biography is included in Who's Who in Science and Engineering 2011-2012 (11th Edition). Scientific Award of Excellence 2011 from American Biographical Institute (ABI). Outstanding Scientist of The 21st century by International Biographical centre of Cambridge, England 2011.

Since July 2009 he has been Professor and Head of the Department of Electrical and Electronics Engineering, Muthayammal Engineering College affiliated to Anna University, Chennai, India. His Current research interests includes Permanent magnet machines, Axial flux Linear oscillating Motor, Advanced Embedded power electronics controllers,finite element analysis of special electrical machines,Power system Engineering and Intelligent controllers.He is a Fellow of Institution of Engineers India(FIE) and Chartered Engineer (India).Senior Member of International Association of Computer Science and Information. Technology (IACSIT). Member of International Association of Engineers(IAENG), Life Member of Indian Society for Technical Education(MISTE). Ph.D. Recognized Research Supervisor for Anna University and Satyabama University Chennai Editorial Board Member for journals like International Journal of Computer and Electrical Engineering,International Journal of Engineering and Technology,International Journal of Engineering and Advanced Technology (IJEAT).International Journal Peer Reviewer for Taylor &Francis International Journal "Electrical Power Components & System"United Kingdom,Journal of Electrical and Electronics Engineering Research,Journal of Engineering and Technology Research (JETR),International Journal of the Physical Sciences,Association for the Advancement of Modelling and Simulation Techniques in Enterprises,International Journal of Engineering & Computer Science (IJECS),Scientific Research and Essays,Journal of Engineering and Computer Innovation,E3 Journal of Energy Oil and Gas Research,World Academy of Science, Engineering and Technology,Journal of Electrical and Control Engineering（JECE),Applied Computational Electromagnetics Society etc.. He has published 132 research papers in International/National Conferences and Journals. Organized 40 National / International Conferences/Seminars/Workshops. Received Best paper award for ICEESPEEE 09 conference paper. Coordinator for AICTE Sponsored SDP on Soft Computing Techniques In Advanced Special Electric Drives, 2011. Coordinator for AICTE Sponsored National Seminar on Computational Intelligence Techniques in Green Energy, 2011.Chief Coordinator and Investigator for AICTE sponsored MODROBS - Modernization of Electrical Machines Laboratory. Coordinator for AICTE Sponsored International Seminar on "Power Quality Issues in Renewable Energy Sources and Hybrid Generating System", July 2013.