Multicell Z Source Inverter For Adjustable Speed Drives

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***Abstract*—In this paper a Multicell Switched inductor Z-source inverter is proposed for adjustable speed drives (ASD). To increase the boosting flexibility a new topology is introduced by adding multiple cells of inductor and diode to the source side of the inverter, it results in the better performance than the conventional system. As the topological difference necessitates the change in switching control for the better performance SBC is employed. ZSI has the unique topological feature that it can act as a second order filter and there by reduces the harmonics and thus it achieves higher output profile.**

Keywords—*Adjustable speed drives (ASD),switched-inductor (SL) Simple boost control (SBC) Z source inverter(ZSI)*

INTRODUCTION

The main objective of inverter is to convert a dc power supply to an ac output waveform. Flexible ac transmission system (FACTS), active filters, adjustable speed drives, static var compensator and many more are some of the applications that require this type of waveform. Traditionally, there exist two types of inverters which are voltage source inverter and current source inverter

The inverter is the power electronic circuit, which converts the DC voltage into AC voltage. The DC source is normally a battery or output of the controlled rectifier. The output voltage waveform of the inverter can be square wave, quasi-square wave or low distorted sine wave. The output voltage can be controlled with the help of gate drives of the switches. The pulse width modulation techniques (PWM) are most commonly used to control the output voltage of inverters. Such inverters are called as PWM inverters. The output voltage of the inverter contain harmonics whenever it is not sinusoidal. These harmonics can be reduced by using proper control schemes and filters.

Converting DC input sources to AC output waveforms is important in most of electronic and electrical power applications. That is the main function of inverter circuit which is to convert DC input sources to AC output waveforms. Traditionally there are two types of inverters which are voltage source inverters (VSI) and current source inverters (CSI). Both of these types of inverters are differentiate by their type of DC input sources. Voltage Source Inverters are fed from DC voltage source or AC voltage source in parallel with the capacitor , Current source inverter is fed from current source ie, voltage source in series with the large inductor.The traditional inverters have a major setback, that is AC output can only be equal or less than the DC input values. This problem has limited the flexibility of the inverters. This means that if one wants to design a circuit that produces AC output larger than the DC input, one must design a two stage converter which is consists of boost converter and inverter, this directly affects the overall

.Thus, Z source inverters were introduced to overcome this barrier and improve the applications of inverters in electronic and electrical power fields. Z-source concept can be applied to all DC to AC, AC to DC, DC to DC ,and AC to AC conversions. Z- source inverter have been recently proposed as an alternative power conversion concept as they have both voltage buck and boost capabilities which cannot be achieved by the traditional inverters. To facilitate the study a detailed analysis of the impedance network, PWM technique and SBC PWM technique is made thus the limitations of the traditional inverters lead to necessitate the study and analyze the modified fashions of Z source inverter and its switching method.

Z- source inverter have been recently proposed as an alternative power conversion concept as they have both voltage buck and boost capabilities which cannot be achieved by the traditional inverters. Thus the new topology introduced are able to achieve higher output values from lower input values and are used for various renewable and drive applications.

II. Z SOURCE INVERTER

The Z-source inverter is analyzed using voltage source inverter. The unique feature of the Z-source inverter is that the output ac voltage can be any value between zero and infinity regardless of the input DC voltage. That is, the Z-source inverter is a buck–boost inverter that has a wide range of obtainable voltage. The traditional V- and I-source inverters cannot provide such feature. The main feature of the Z-source is implemented by providing gate pulses including the shoot-through pulses.[1] Here how to insert this shoot through state becomes the key point of the control methods. It is obvious that during the shoot-through state, the output terminals of the inverter are shorted and the output voltage to the load is zero. The output voltage of the shoot through state is zero, which is the same as the traditional zero.

The output voltage of the shoot through state is zero, which is the same as the traditional zero states, therefore the duty ratio of the active states has to be maintained to output a sinusoidal voltage, which means shoot-through only replaces some or all of the traditional zero states. The three-phase Z-source inverter bridge has nine permissible switching states (vectors) unlike the traditional three-phase V-source inverter that has eight. The traditional three-phase V-source inverter has six active vectors when the DC voltage is impressed across the load and two zero vectors when the load terminals are shorted through either the lower or upper three devices, respectively. However, three-phase Z-source inverter bridge has one extra zero state (or vector) when the load terminals are shorted through both the upper and lower devices of any one phase leg (i.e., both devices are gated on), any two phase legs, or all three phase legs.

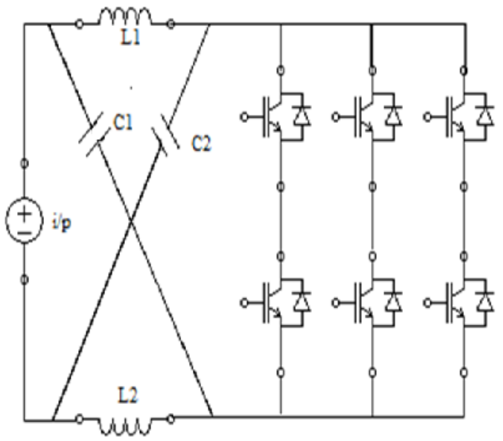

Fig 1 Z source inverter

II. GENERALIZED MULTICELL SL TOPOLOGY

A new Z-source inverter (ZSI) topology is developed to improve voltage boost ability. The proposed topology is modified from the switched inductor topology by adding some more inductors and diodes into inductor branch to the conventional Z-source network. The modulation methods developed for the conventional ZSI can be easily utilized in the proposed ZSI. The proposed ZSI has an ability to obtain a higher voltage boost ratio compared with the conventional ZSI under the same shoot-through duty ratio. Since a smaller shoot-through duty ratio is required for high voltage boost, the proposed ZSI is able to reduce the voltage stress on Z-source capacitor and inverter-bridge. In this chapter theoretical analysis and operating principle of the z source inverter are explicitly described. The PWM control method to achieve the topology is also well explained.

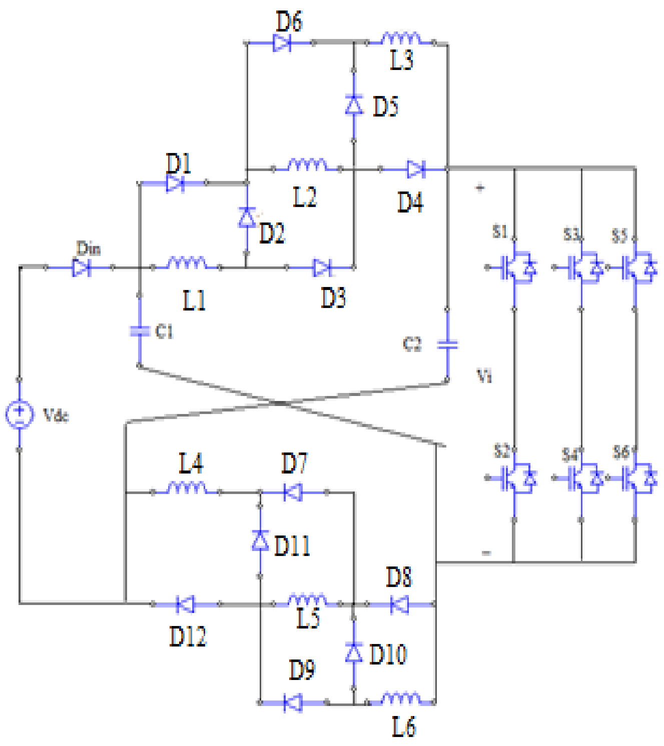

Fig 2 Proposed topology

The proposed new Z-source inverter topology as shown below. As compared with the conventional ZSI structure , the basic X shape structure of impedance circuit is maintained except that four inductors and twelve diodes are added. each group of components, i.e., L_1-L_2-L_3-D_1-D_2-D_3-D_4-D_5-D_6 in the upper branch or L_4-L_5-L_6-D_7-D_8-D_9-D_{10}-D_{11}-D_{12} in the lower branch of Z-source network replaces each single inductor in the conventional Z-source network. Owing to the combination of these components, the proposed topology is able to store and transfer a higher energy from the dc source to the inverter part compared with the conventional Z-source network.

A. Operating principle

The operation principles of the proposed impedance network are similar to those of the conventional Z-source network, which is classified into two states: shoot-through state and non-shoot-through state. For the sake of simplification,the equivalent circuit of the proposed topology viewed from the inverter-bridge side, where the three phase inverter bridge is replaced with a current source and a single switch S.

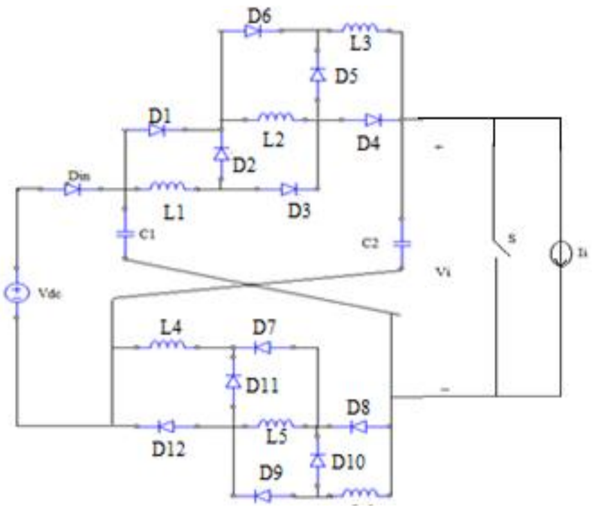

Fig 3 equivalent circuit

B. *Shoot through mode*

Firstly, consider the shoot-through state that is represented by the closed switch. During this state, Din is blocked. In the upper branch of Z-source network, four diodes D_1, D_3, D_4, and D_6 are conducted, while two diodes D_2 and D_5 are blocked. Three inductors L_1, L_2, and L_3 are connected in parallel and charged by capacitor C_1. Similarly for the lower branch, four diodes D_7, D_8, D_9, and D_{12} are conducted, while two diodes D_{11} and D_{10} are blocked. Three inductors L_4, L_5, and L_6 are connected in parallel and charged by capacitor C_2.

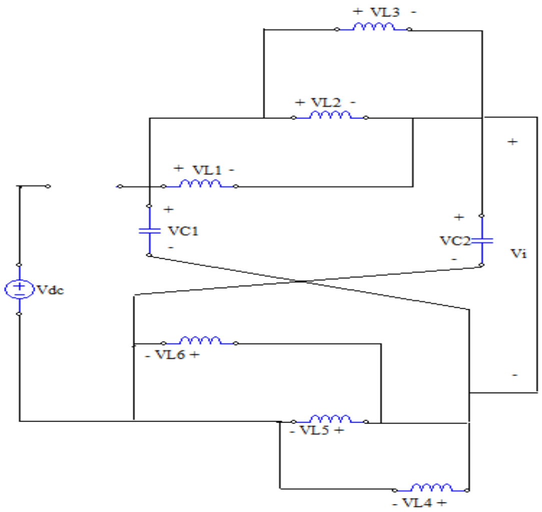

Fig 4 shoot through mode

C. *Non shoot through mode*

The equivalent circuit of the non-shoot-through state (include active and null state) is shown whrere the switch S is opened. During this state, Din is conducted.. In the upper branch of Z-source network, four diodes D_1, D_3, D_4, and D_6 are blocked, while two diodes D_2 and D_5 are conducted. Three inductors L_1, L_2, and L_3 are connected in series and the stored energy is transferred to inverter circuit. Likewise, in lower branch D_7, D_8, D_9, and D_{12} are blocked, while two diodes D_{11} and D_{10} are conducted. Three inductors L_4, L_5, and L_6, are connected in series and the stored energy is transferred to inverter circuit.

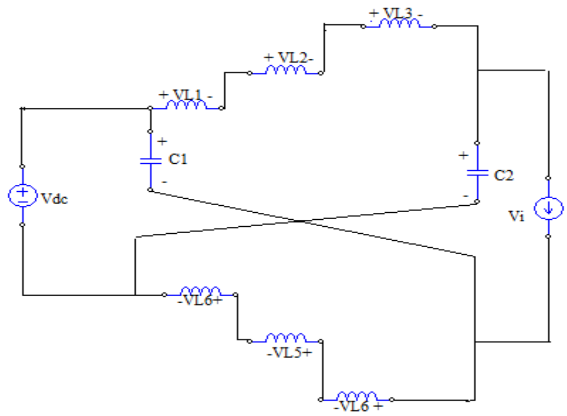

Fig 5 Non shoot through mode.

Here the four inductors (L1-L6) are having the same inductance and two capacitors (C1,C2) are having the same capacitance. There by the circuit become

$V_{L1}=V_{L2}=V_{L3}=V_{L4}=V_{L5}=V_{L6}=V_L$, Where V_L is the inductor voltage

$V_{C1}=V_{C2}=V_C$, Where V_C is the capacitor voltage

Voltage equations in shoot through state is derived as

$V_C = V_L$

$Vi = 0.$

Average inductor voltage can be obtained as;

$$V_L = (ToVc + (T - To)\ (Vdc - Vc)/3)/T$$

Average capacitor voltage is obtained as;

$$Vc = \frac{Vdc(1 - Do)}{1 - 4Do}$$

Peak dc link voltage across the inverter bridge is derived as

$$Vi = ((2 - 2Do - 1 + 4Do)/(1 - 4Do))Vdc.$$

Therefore the voltage boost factor is

$$B = \left(\frac{1 + 2Do}{1 - 4Do}\right)$$

Shoot through duty ratio can obtained as follows;The maximum voltage gain of the proposed system is

Gmax = M

$$G = \left(\frac{1 + 2Do}{1 - 4Do}\right)(-Do)$$

III SIMPLE BOOST CONTROL

After all the basic PWM pulses have been generated for each individual phase. All this pulses will be feed to a NOT gate to get another signal that will be feed to the switch. In the inverter circuit, each phase has two switches. One switch will be feed with the original pulses while the other switch will be feed with the pulses that gone through the NOT gate. Figure below shows the all the three phase PWM circuit together with its NOT gates.

Since all the PWM signals for all the three phases have been generated, now one proceed to the next part of the simple boost switching method. This part will generate the shoot through signal by comparing the straight lines with the carrier signal. For simple boost switching method control, the straight lines will be equal to the amplitudes of the reference signal. There are two straight lines which are and . The pulses will be high when the carrier signal is greater than or lower than . When the pulses is in high, that means shoot through state for the Z source inverter since on that moment all the switches will be turn on. This process will cause shoot through.

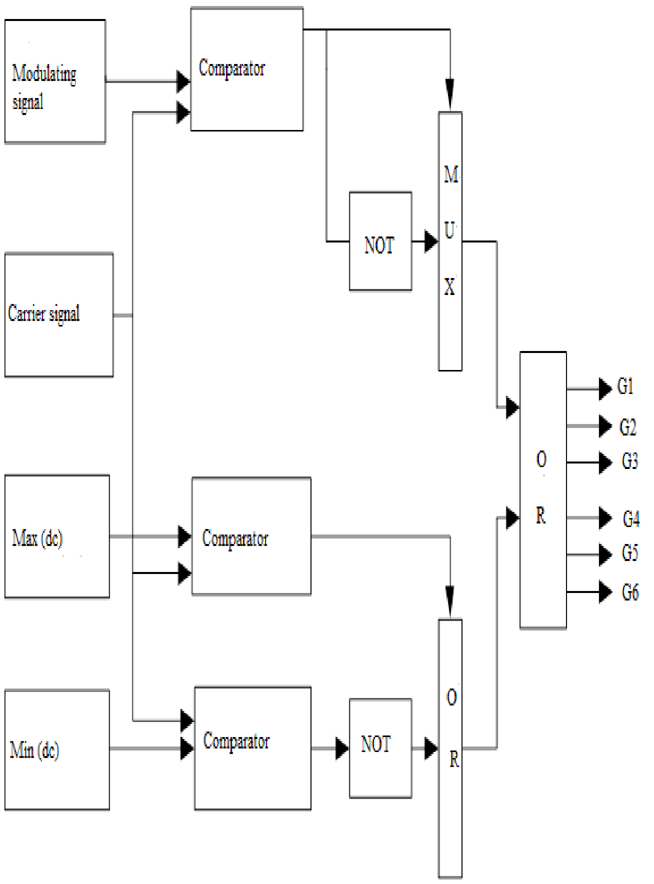

Fig 6 simple boost control

IV. SIMULATION RESULTS

The simulation is performed using Matlab/Simulink. Multicell switched inductor z source inverter of SBC method is simulated and the ZSI inverter fed induction motor is also simulated.

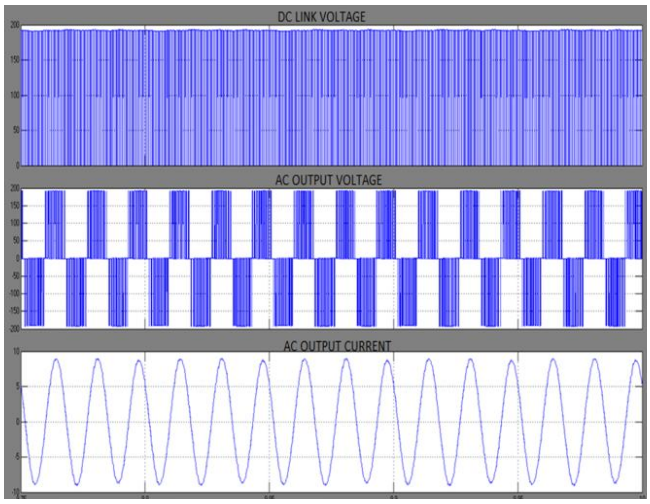

Fig. 7. Simulation results of multicell SL ZSI

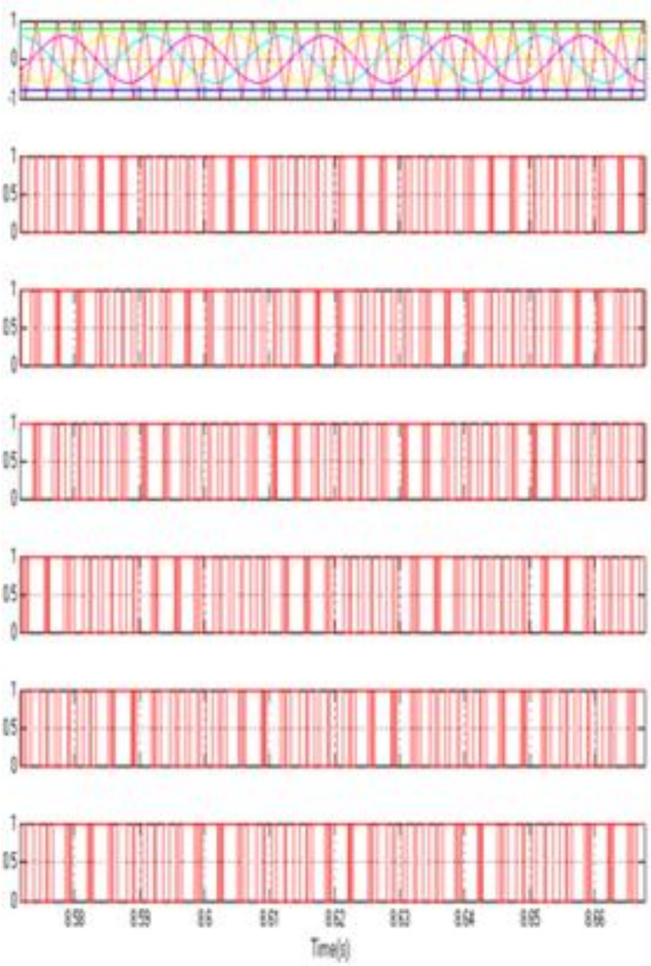

Fig .8.waveforms of simple boost technique

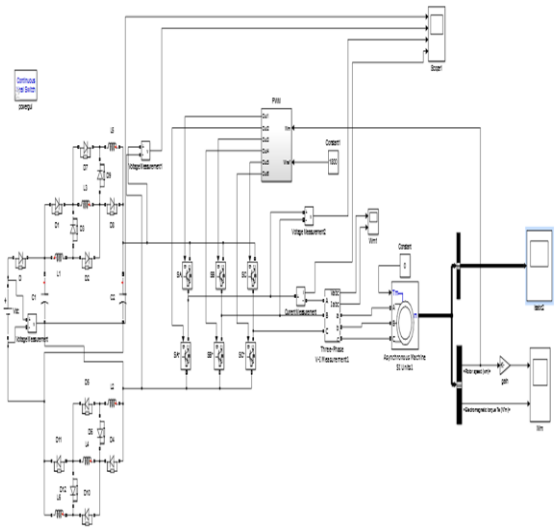

Fig .9.Simulink model of multicell SL ZSI fed induction motor

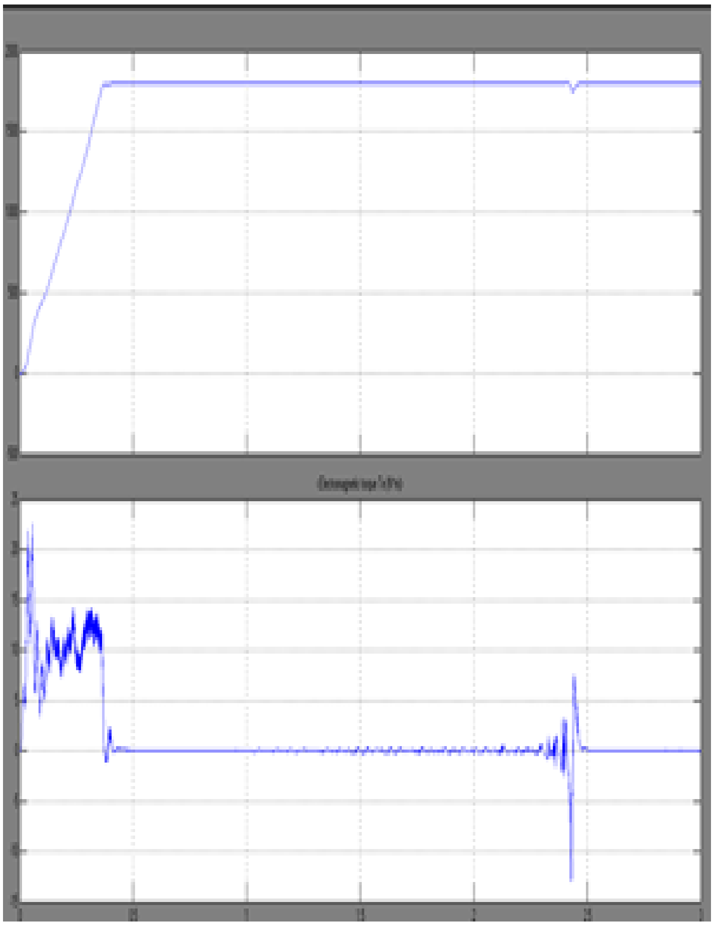

Fig .10.waveforms of rotor speed and electromagenetic torque

V. CONCLUSION

This paper mainly focuses on the study of Z source inverter and simple boost switching control method. The circuit has been designed based on the standard Z source inverter and simulated using MATLAB. The theoretical values have been calculated and the simulation results were gained through MATLAB simulations. The simulation results are almost similar to the calculated values both the output voltages and voltage stress. The output voltage also can be buck or boost depends on the requirement of the electronic or electrical power applications.. Thus, since the output voltage directly depending on the modulation index, the output voltage has been limited to a certain range for the Z source inverter instead of zero to infinity.

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