International Journal Of Engineering Research And Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 14, Issue 4 (April Ver. I 2018), PP.23-28

Performance Comparison of Different Control Methods Applied To Switched Inductor Z Source Inverter

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ABSTRACT:- On the basis of boost inversion ability this paper compare the performance of different control methods applied on Switched Inductor Z-Source Inverter (SLZSI) .Control methods : Simple Boost , Maximum Boost and Maximum Constant Boost are generated for same value of modulation index. The operating principle and analysis of inverter are presented. To verify the performance of the circuit, SLZSI is simulated on SIMULINK/MATLAB environment.
KEYWORDS:- Z Source Inverter (ZSI), Shoot through, Pulse Width Modulation(PWM), Boost Inversion, Switched Inductor.

Date of Submission: 22 -03-2018 Date of acceptance: 05-04 2018

I. INTRODUCTION

Voltage Source Inverter (VSI) [1] and Current Source Inverter (CSI) have a huge demand in power system, hybrid electric vehicle adjustable speed drives and other applications. But these inverters introduce number of drawbacks. VSI can only step down the input voltage and CSI can only step up the input voltage. Applications where both step up and step down is required these inverters uses an additional circuit. By adding an extra circuit increases the system volume as well as the cost. The shoot through condition doesn't work on these inverters hence results in damage of the switching devices. The dead time introduces to prevent the shoot through condition gives waveform distortion.

Peng [2] introduces a special converter system shown in Fig. 1to overcome all the limitations of VSI and CSI and provide step up and step down conversion in a single stage. This system is known as Z Source Inverter (ZSI). It uses shoot through condition as its special feature and boost the voltage in this state. Thus dead time is not required and waveform quality increased [3].

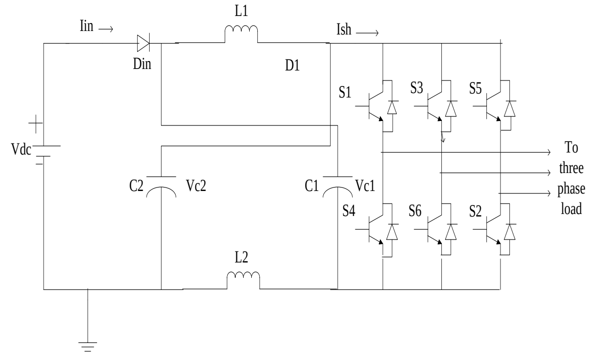

Fig. 1. Z-source inverter

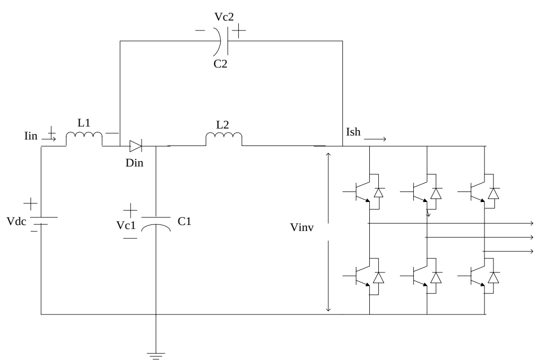

Fig. 2. Quasi Z-source inverter

In [4] another Z source inverter technique known as Quasi Z source inverter (Fig. 2) is proposed. It has several advantages over ZSI. This inverter provides common ground between the Inverter Bridge and DC voltage source and thus produces continuous input current. This improves the input profile of inverter. It also reduces the voltage stress across the inverter bridge. Despite its advantages the boost ability of QZSI is similar to ZSI and not suitable for the application where high boost inversion is required. In 2010 Zhu [5] presents a developed inverter with high voltage inversion ability named as Switched inductor Z-source inverter. It exhibits the quality of high boost inversion at low input DC voltage.

Modified Pulse Width modulation techniques support the ZSI topologies. Initially Simple boost control method [2] is used to control the operation of ZSI. This limits the performance of ZSI .Research has been made for control methods and results in the form of Maximum boost control [6]. This provide a high boost under a given modulation index. To minimize the voltage stress and produce low frequency ripple with maximum voltage gain Constant boost control method [7],[8] is introduced.

This paper compares the performance of Switched Inductor ZSI based on boost inversion ability. All three control techniques are used at constant modulation index to determine the suitable control for high boost inversion.

II. SWITCHED INDUCTOR Z-SOURCE INVERTER

The circuit of SL Z-source inverter is shown in Fig. 3. It consists of two capacitors (C1 and C2), four inductors (L1 , L2 , L3 , and L4), and six diodes (D1 , D2 , D3 , D4 , D5 , and D6). The L1 –L3 –D1 –D3 –D5 act as top switched Inductor (SL) cell and the L2 –L4 –D2 –D4 –D6 as bottom SL cell.

A. Operating Principle

The operation principle of Switched Inductor Z-source inverter is similar to Z-source inverter. Therefore, it works in two states: the shoot-through state and the non- shoot-through state. Assuming all the inductor and capacitor has the same inductance and capacitance respectively.

$$V_{L_1} = V_{L_2} = V_{L_3} = V_{L_4} = V_L \quad (1)$$

$$V_{C_1} = V_{C_2} = V_C \quad (2)$$

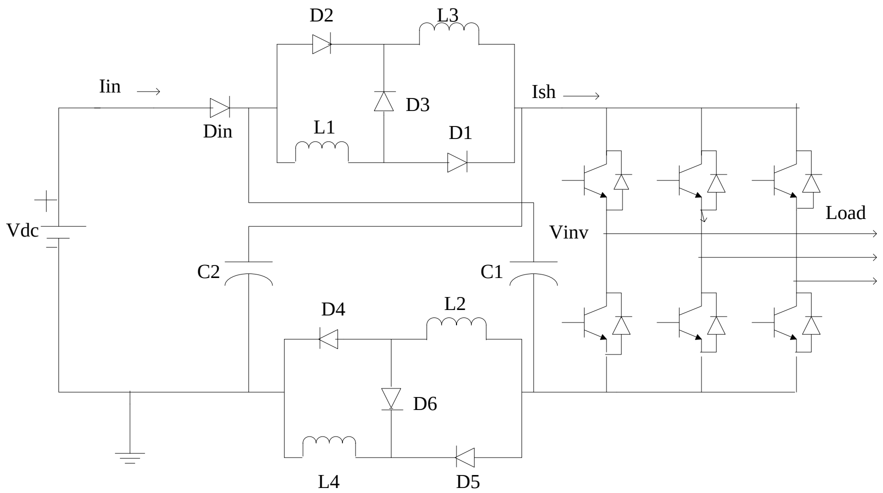

Fig. 3. Switched Inductor Z-source inverter

*1) **Shoot Through State***: Fig. 4 show the circuit of SLZSI in shoot through state. During this state the diode Din, D3 and D6 are OFF while D4 and D5 are ON. Inductor L1 and L3 are connected in parallel and charged by C1. Similarly L2 and L4 are connected in parallel and charged by C2.

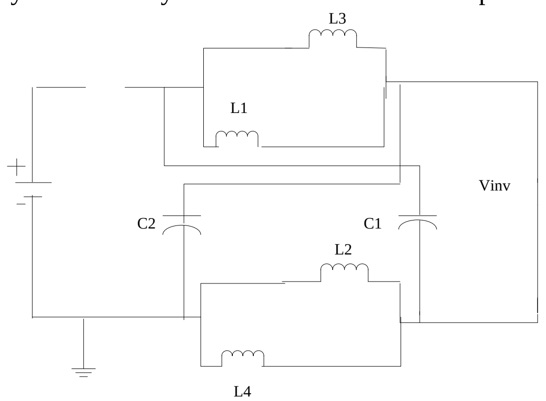

Fig. 4: Non Shoot Through State

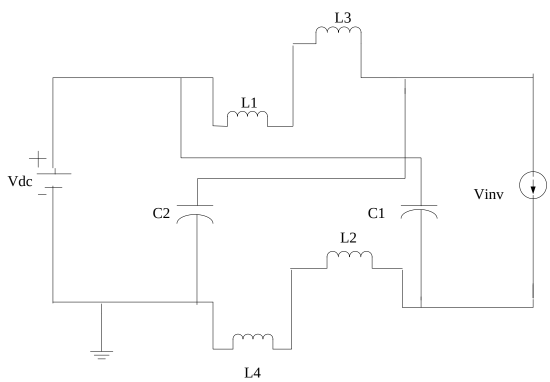

Fig. 5. Shoot Through State

*2) **Non Shoot- Through State:*** During this state diode Din, D3 and D6 are ON while diode D4 and D5 are OFF. Inductor L1 and L3 are connected in series and transfer energy to the main circuit. Similarly energy is transferred to the main circuit via inductors L2 and L4. Capacitors C1 and C2 are charged by input voltage via top and bottom cell respectively.

B. Analysis

The inductor current iL1 decreases during switching OFF and increases during switching ON

$$V_{L_{1(ON)}} = V_C \quad (3)$$

Applying the volt–second balance principle to L1,

$$V_{L_{1(OFF)}} = -\frac{D}{1-D}V_C = V_{L_{3(OFF)}} \quad (4)$$

Here D defines the duty cycle. The inductor current iL3 decreases during switching OFF and increases during switching ON.

$$V_{L_{3(ON)}} = V_{C_1} \quad (5)$$

$$V_{L_{3(OFF)}} = -(V_{C_2} - V_{dc} + V_{L_{1(OFF)}}) \quad (6)$$

Applying the volt–second balance principle to L3,

$$DTC_1 = (1-D)T(V_{C_2} - V_{dc} + V_{L_{1(OFF)}}) \quad (7)$$

$$DTV_{dc} = (1-D)T(V_{C_2} - V_{dc} + -\frac{D}{1-D}V_C) \quad (8)$$

Therefore

$$V_C = \frac{1-D}{1-3D}V_{dc} = V_{C_1} = V_{C_2} \quad (9)$$

During switching OFF condition

$$V_C = V_{inv} + V_{L_{1(OFF)}} + V_{L_{3(OFF)}} \quad (10)$$

Hence peak dc link voltage

$$V_{inv} = \frac{1+D}{1-3D}V_{dc} = BV_{dc} \quad (11)$$

Here B is known as the boost factor of SL Z-Source Inverter and expressed as

$$B = \frac{1+D}{1-3D} \quad (12)$$

The output peak phase voltage of the inverter

$$V_{ac} = \frac{MV_{inv}}{2} = \frac{MBV_{dc}}{2} \quad (13)$$

$$V_{ac} = \frac{GV_{dc}}{2} \quad (14)$$

Where G is the gain of SLZSI and depends upon the modulation index and boost factor.

III. CONTROL METHODS

The output voltage of Switched inductor Z source inverter depends upon the shoot through insertion .Basically there are three ways to insert this shoot through condition.

A. Simple Boost Control

The Simple boost control is the basic control technique for ZSI topologies. In this a triangular wave is compared with two straight lines. These straight lines are of the maximum and minimum peak value of the sinusoidal reference. The inverter operates in shoot through condition when the triangular wave is greater than the maximum peak line and smaller than the minimum peak line.

B. Maximum Boost Control

For this method all the zero states convert into the shoot through state. This makes the duty ratio as large as possible so as to increase the boost capability of inverter. With the maximum boost this control method provides lower voltage stress. In this the triangular wave compared the minimum and maximum curve of references.

C. Maximum Constant Boost Control

To provide a constant shoot through duty ratio with maximum boost a maximum constant boost control method is used. It reduces the voltage stress and also provides the lower frequency ripple at any modulation index. Hence it is the combination of first two control methods .In this method the triangular wave is compared with the three reference signal as well as the shoot through envelope signal.

Table I: Summary of Different Control Method Parameters

Control Method/ parameter	**Simple Boost**	**Maximum Boost**	**Maximum constant Boost**
Duty Ratio (D_0)	$1-M$	$\frac{2\pi-3\sqrt{3}M}{2\pi}$	$1-\frac{\sqrt{3}M}{2}$
Boost factor (B)	$\frac{2-M}{3M-2}$	$\frac{4\pi-3\sqrt{3}M}{9\sqrt{3}M-4\pi}$	$\frac{4-\sqrt{3}M}{3\sqrt{M}-4}$
Voltage Gain (G)	$\frac{M(2-M)}{3M-2}$	$\frac{4\pi M-3\sqrt{3}M^2}{9\sqrt{3}M-4\pi}$	$\frac{4M-\sqrt{3}M^2}{3\sqrt{M}-4}$
Voltage Stress (Vs)	$\frac{2-M}{3M-2}V_{dc}$	$\frac{4\pi-3\sqrt{3}M}{9\sqrt{3}M-4\pi}V_{dc}$	$\frac{4-\sqrt{3}M}{3\sqrt{M}-4}V_{dc}$

Table I shows the different parameter for these control methods. All the values are depending upon the Modulation index used in control techniques and the input voltage.

IV. SIMULATION RESULTS

Parameter used for the Simulation of SLZSI are shown in Table II

Table II: Simulation parameters

Input DC voltage	40V
$L_1=L_2=L_3=L_4$	10mH
$C_1=C_2$	300 µF
Carrier frequency	10KHz
L_f	10mH
C_f	20µF
Resistive Load	10Ω

First the simulation done for the Simple Boost, Maximum Boost and Maximum Constant Boost and then applied to Switched inductor Z Source Inverter. Performance comparison is based on the implementation of different control methods on SLZSI at a constant modulation index 0.72.

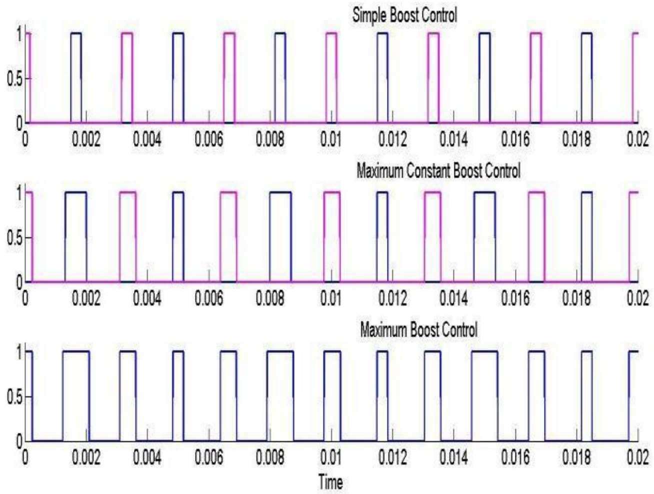

Fig. 6. Shoot-through states in different control methods

From the above results it is clear that for simple boost control the shoot-through duty ratio is constant but it is applied in only the half cycle. In maximum constant shoot- through applied in all and there is a variation in the shoot-through duty ratio. In maximum constant shoot-through duty ratio is constant and boost factor is also improved.

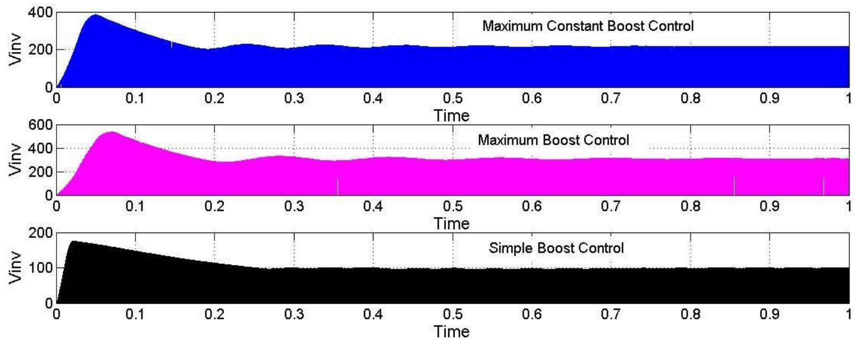

Fig. 7. Voltage across the inverter input in different control methods.

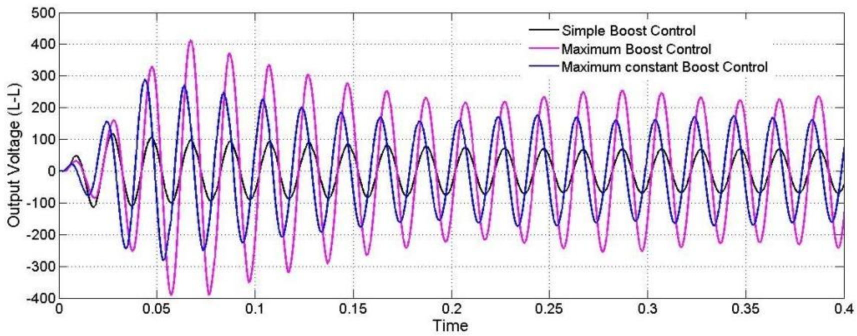

Fig. 8. Output line-line voltages in different control methods

On applying the three control method on Switched Inductor Z Source Inverter at given modulation index the voltage across the inverter (Fig. 7) and output line to line voltages are obtained. From Fig. 8 it is clear that for a constant modulation index the boost inversion ability of Switched Inductor Z Source Inverter is increased with maximum boost control.

V. CONCLUSION

In the application where high boost inversion is required for low input voltage Switched Inductor Z Source Inverter is used. By using maximum boost control with this topology of Z Source Inverter we can use SLZSI in those area where a high output is required with a very low input dc voltage .Hence this topology with the maximum boost is very suitable for photovoltaic applications.

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Saloni Mishra."Performance Comparison of Different Control Methods Applied To Switched Inductor Z Source Inverter." International Journal Of Engineering Research And Development , vol. 14, no. 04, 2018, pp. 23–28.