

High Performance Extended Switched Inductor Quasi Z-Source Inverter for Three Phase Loads

V.C.Elakya¹, Aarthi², V.V.Teresa³

Final year PG student, Department of Electrical and Electronics Engineering, Sri Eshwar College of Engineering, Coimbatore, Tamilnadu, India¹

Final year PG student, Department of Electrical and Electronics Engineering, Sri Eshwar College of Engineering, Coimbatore, Tamilnadu, India²

Assistant Professor, Department of Electrical and Electronics Engineering, Sri Eshwar College of Engineering, Coimbatore, Tamilnadu, India¹

ABSTRACT: This paper presents an extended switched inductor quasi Z-source inverter (ESL-qZSI) with the ability of high boost voltage inversion. This network combines the SL-qZSI with the boost converter hence improves the switched inductor cell performance and efficiency. The proposed system reduces the voltage stresses in a typical network caused by the capacitors, power devices and diodes when compared with the traditional qZSI without any variations in the output voltage. Further, the performance of the proposed topology is verified by simulations using MATLAB.

KEYWORDS: Quasi Z-source inverter(qZSI), Extended Switched inductor qZSI, switched inductor cell.

I. INTRODUCTION

The Z-source inverter (ZSI) has been reported suitable for residential PV system because of the capability of voltage boost and inversion in a single stage [1]. Figure 1.1 shows the general Z – source inverter. The network employs a unique impedance circuit to couple the converter main circuit to that of the power source in order to obtain the unique features that cannot be achieved using conventional VSI or CSI [3].The unique feature about Z- source inverter is that the output voltage can be anywhere from zero to infinity. The inverter can perform both buck and boost operation and provide a wide range of output voltage which is not possible in conventional voltage source and current source inverters..

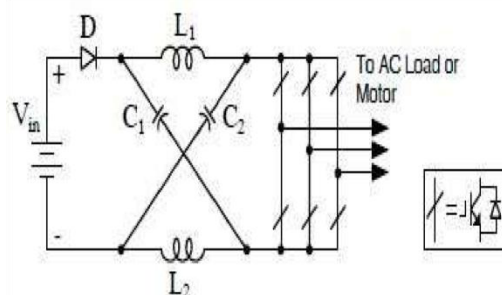


Figure 1: Z-source inverter topology

The Z-source inverter has nine permissible switching states which has an extra state compared to the conventional inverters. The extra switching state arises from the shoot through state of the network in which two switches of the same leg is switched ON and conduct simultaneously which is not possible in conventional inverters[2].

II. QZSI NETWORK

The QZSI circuit differs from that of a conventional ZSI in the LC impedance network interface between the source and inverter[6]. The unique LC and diode network connected to the inverter bridge modify the operation of the circuit, allowing the shoot-through state which is forbidden in traditional VSI [7]. This network will effectively protect the circuit from damage when the shoot through occurs and by using the shoot-through state, the (quasi-) Z-source network boosts the dc-link voltage.

III. EXTENDED SWITCHED INDUCTOR QZSI

To overcome the drawbacks of the QZSI and as well as to improve the performance of inverter, an extended switched-inductor quasi-Z-source inverter (ESL-qZSI) is proposed in this paper, which combines the new SL-qZSI with classic boost circuit[8],[9]. In addition, an improved SL cell derived from is used in the proposed topology to replace the original one. Although a few components are added, the proposed topology possesses much higher boost ability with the same shoot-through duty ratio than the other topologies to improve the output voltage profile. For the same input and output voltage, the proposed SL-qZSI achieves lower voltage stress on capacitors, diodes and power devices to increase the reliability. Furthermore, the conversion efficiency of the proposed topology is increased similar to the classic SL-qZSI and the operating state can also be simplified into two parts: shoot through state and non-shoot-through state. Figs. 3 and Fig. 4 shows the equivalent circuits of the ESL-qZSI under the two states, respectively.

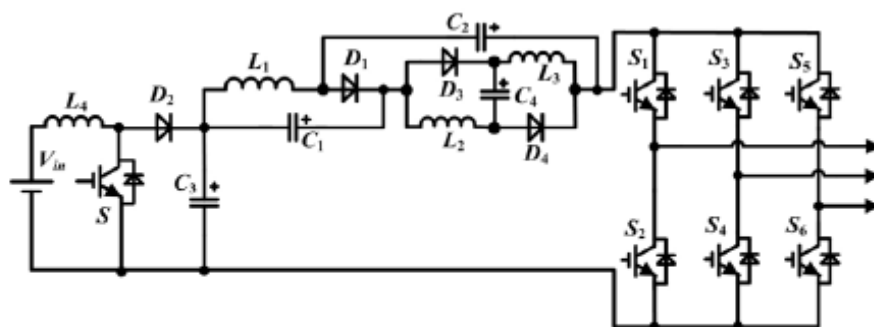


Fig. 2. Proposed ESL-qZSI

In order to simplify the analysis, this topology is analyzed under the assumption that all devices are ideal. During the shoot-through state, as shown in Fig. 3, the diodes D_3 and D_4 are on, while D_1 and D_2 are off. L_2 , L_3 and C_4 are connected in parallel, while L_1 and C_2 are connected in series. The capacitors C_1 , C_2 and C_3 are discharged, while C_4 is charged. All inductors store energy, and the corresponding voltages across L_1 , L_2 , L_3 and L_4 are V_{L1} , V_{L2} , V_{L3} and V_{L4} , respectively. The voltages across C_1 , C_2 , C_3 and C_4 are V_{C1} , V_{C2} , V_{C3} and V_{C4} , respectively. Thus, we can get,

$$\begin{cases} V_{in} = V_{L4} \\ V_{C1} + V_{C3} = V_{L3} \\ V_{C3} + V_{C2} = V_{L1} \\ V_{C4} = V_{L2} = V_{L3} \end{cases} \quad (1)$$

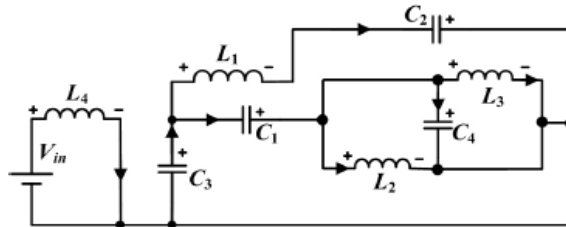


Fig. 3. Equivalent circuit of the proposed ESL-qZSI under shoot-through state

Similarly, in the non-shoot-through state, as shown in Fig. 4, the diodes $D3$ and $D4$ are off, while $D1$ and $D2$ are on. The capacitors $C1$, $C2$ and $C3$ are charged, while $C4$ is discharged. $L2$, $L3$ and $C4$ are connected in series. All Inductors $L1$, $L2$, $L3$ and $L4$ transfer energy from dc voltage source to the load.

$$\begin{cases} V_{in} + V_{L4} = V_{C3} \\ V_{C2} = V_{L2} + V_{C4} + V_{L3} \\ V_{C1} = V_{L1} \\ V_{PN} = V_{C1} + V_{C2} + V_{C3} \end{cases} \quad (2)$$

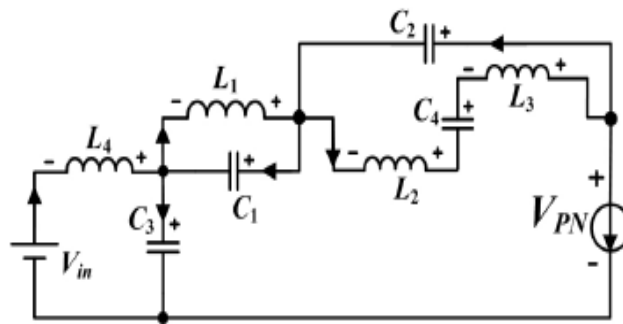


Fig. 4. Equivalent circuit of the proposed ESL-qZSI under non-shoot-through state

IV. DESIGN OF IMPEDANCE NETWORK

A. Inductor design

During traditional operation mode, the capacitor voltage is always equal to the input voltage [4]. So there is no voltage across the inductor. During shoot through mode, the inductor current increases linearly and the voltage across the inductor is equal to the voltage across the capacitor. The average current through the inductor is given by,

$$I_L = P/V_{dc} \quad (3.11)$$

Where P is the total power and V_{dc} is the input voltage.

The average current at 1kW and 150 V input is

$$I_L(\text{avg}) = 1000/150 = 6.67\text{A}$$

The maximum current occurs through the inductor when the maximum shoot-through happens, which causes maximum ripple current. In this design, 30% current ripple through the inductors during maximum power operation was chosen. Therefore the allowed ripple current was 4A and maximum current is 10.67A.

For a switching frequency of 10 kHz, the average capacitor voltage is

$$V_C = (1-T_O/T) * V_{dc} / (1-2T_O/T) \tag{3.12}$$

Substituting the values in the above equation 3.2 the average voltage is 300V. So the inductance must be no less than

$$L = 0.1 * 10 * 300 / 10.67 = 3\text{mH}$$

B. Capacitor Design

The purpose of the capacitor is to absorb the voltage ripple and maintain a fairly constant voltage [5]. During shoot-through the capacitor charges the inductors and the current through the capacitor equals the current in the inductor. Therefore the voltage ripple across the capacitor is

$$V_C = I_{L(\text{avg})} T_S / C \tag{3.13}$$

The capacitor voltage ripple is 0.17%. Substituting the above values in the equation the required capacitance was found to be

$$C = 6.67 * 0.1 * 10 (300 * 0.0017) = 1000\mu\text{F}$$

Hence the impedance network of the Quasi Z-Source inverter consists of a inductor of value 3mH and capacitor of 1000μF.

V. RESULTS

Input voltage is applied through the designed network as a result it is boosted with high performance. The corresponding output voltage and current graph is shown below

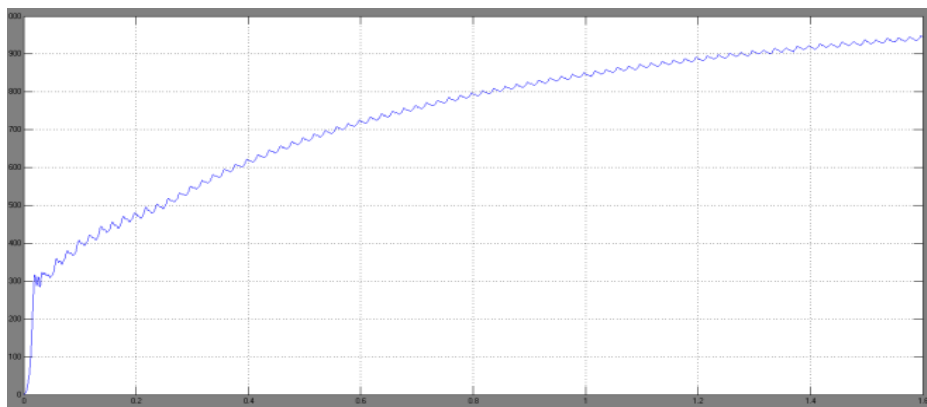


Figure 5: Output voltage graph

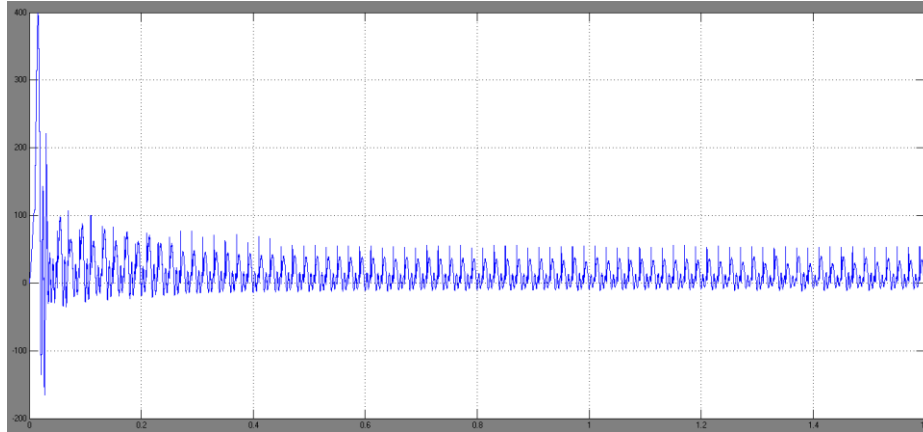


Figure 6: Output current graph

The speed curve of the induction motor is also shown below.

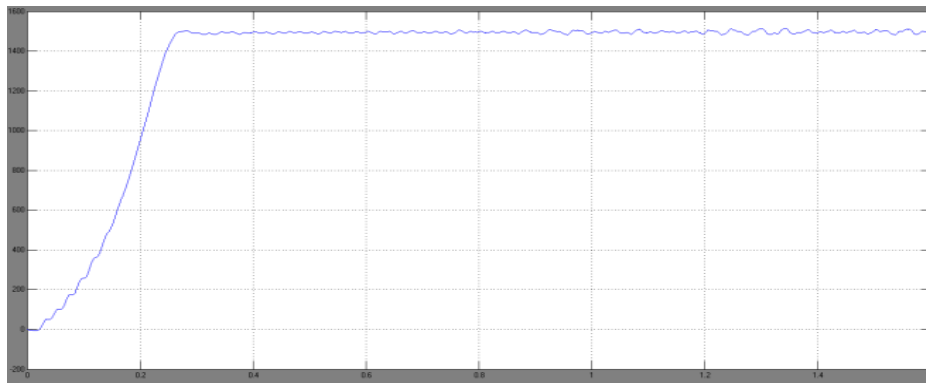


Figure 7: Output Speed Curve

VI. CONCLUSION

In this work, an ESL-qZSI by combining traditional SL-qZSI with boost converter as well as applying an improved SL cell. Compared with the original qZSIs, the proposed ESL-qZSI has the following main characteristics: obtains high boost ability with continuous input current; offers lower voltage stress across capacitor, switching devices as well as diodes for the same input and output voltage. Furthermore, the proposed topology will be able to achieve higher conversion efficiency. The effectiveness of the analysis for the proposed ESL-qZSI is verified by simulations. Hence we can conclude that the proposed ESL-qZSI is more applicable for the distributed generation applications with low voltage sources, such as fuel cells, photovoltaic and so on.

REFERENCES

- [1] F.Z. Peng, "Z-source inverter," *IEEE Transactions on Industry Applications*, vol. 39, no.2, pp. 504-510, March/April 2003.
- [2] F.Z. Peng, A. Joseph, J. Wang, M.S. Shen, L.H.Chen, Z.G. Pan, E. Ortiz-Rivera and Y. Huang, "Zsource inverter for motor drives," *IEEE Transactions on Power Electronics*, vol.20, no.4, pp.857-863, July 2005.
- [3] M.S. Shen, A. Joseph, J. Wang, F.Z. Peng and D.J.Adams, "Comparison of Traditional Inverters and Z -Source Inverter for Fuel Cell Vehicles," *IEEE Transactions on Power Electronics*, vol.22, no.4, pp.1453-1463, July 2007.
- [4] Y. Tang, S.J. Xie, and C.H. Zhang, "An Improved ZSource Inverter," *IEEE Transactions on Power Electronics*, vol. 26, no.12, pp. 3865-3868, December 2011.

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization,

Volume 4, Special Issue 4, April 2015

National Conference on Trends in Automotive Parts Systems and Applications (TAPSA-2015)

On 20th & 21st March

Organized by

Sri Krishna College of Engineering & Technology, Kuniathur, Coimbatore-641008, Tamilnadu, India

- [5] F. Gao, C. Loh, D. Li, and F. Blaabjerg, "Asymmetrical and symmetrical embedded Z-source inverters," *Power Electronics, IET*, vol. 4, no. 2, pp.181-193, February 2011.
- [6] C.J. Gajanayake, L.F. Lin, G. Hoay, S.P. Lam, and S.L. Kian, "Extended boost Z-source inverters," *IEEE Transactions on Power Electronics*, vol. 25, no.10, pp. 2642-2652, October 2010.
- [7] J. Anderson and F.Z. Peng, "Four quasi-Z-Source inverters," *Power Electronics Specialists Conference, PESC 2008, IEEE*, pp.2743-2749, 15-19 June 2008.
- [8] M.K. Nguyen, Y.C. Lim and G.B. Cho, "Switched-Inductor Quasi-Z-Source Inverter," *IEEE Transactions on Power Electronics*, vol.26, no.11, pp.3183-3191, November 2011.
- [9] M.K. Nguyen, Y.C. Lim and J.H. Choi, "Two switched-inductor quasi-Z-source inverters," *Power Electronics, IET*, vol. 5, no. 7, pp.1017-1025, August 2012.