Switched Inductor Z-Source Inverter fed Induction Motor

M. Sudhakaran[1], G. Muthuselvi[2], A. Bharathi[3], S. Subathra[4] and M. Shanmugasundaram[5]

[1,2,3]*Department of EEE, Ganadipathy Tulsi's Jain Engineering Collège, Kaniyambadi, Tamilnadu, India*

[4]*Department of ECE, C.Abdul Hakeem College of Engineering and Technology, Melvisharam, Tamilnadu, India*

[5]*School of Electronics Engineering, VIT University, Vellore, Tamilnadu, India*

Abstract - Now a day's three phase locomotives consist of converter inverter technology for controlling the traction motors which are squirrel cage induction motors fed by voltage source inverter. This paper presents a developed impedance-type power inverter which is known as switched inductor (SL) Z-source inverter. To expand voltage adjustability, the switched inductor Z-source inverter employs a unique switched inductor impedance network to couple the main circuit and the power source. The voltage buck inversion capability is also provided in the proposed inverter for those applications that need low ac voltages. The proposed concepts of switched-inductor Z-source inverter can be applied to various applications of dc-ac, ac-ac, dc-dc and ac-dc power conversion. Matlab/Simulink software is used to validate the analysis.

Keywords - Converter, switched-inductor, voltage conversion ratio, boost ability, Z-source inverter.

1. INTRODUCTION

Three phase locomotives which are in service today uses AC-DC-AC conversion technology for its speed control. The voltage and current source inverters are broadly used in various industrial applications such as servomotor drives, special power supplies, distributed power systems, hybrid electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV), for fuel cell hybrid electric vehicles (FCHEV).

However, the traditional VSI and CSI have been seriously restricted due to their narrow obtainable output voltage range. To overcome the problems in the traditional inverters, in which the function of the traditional dc-dc boost converter has been successfully introduced into the inverter by a unique X-shape impedance network.

The advanced dc-dc conversion development techniques such as switched capacitor (SC), switched inductor (SL), hybrid SC/SL, voltage lift (VL) and voltage multiplier cells techniques have been really explored, which are used to get the high step up capacity in transformer less and cascaded structures. Therefore, the combination with the Z source inverter and advanced dc-dc enhancement techniques could be a good solution for improving impedance-type inverters performance and promoting their further industrial applications.

The main characteristics are summarized as follows:

- The basic X-shape structure is utilized.
- Only six diodes and two inductors are added compared with the classical Z-source inverter.
- The boost factor has been increased.
- The new structure is extensible for the further development using the coupled-inductor techniques.

2. SWITCHED INDUCTOR Z-SOURCE INVERTER

In Fig. 1, the proposed SL Z-source inverter consists of four inductors such as L1, L2, L3 and L4, two capacitors such as C1and C2, and six diodes such as D1, D2, D3, D4, D5 and D6.

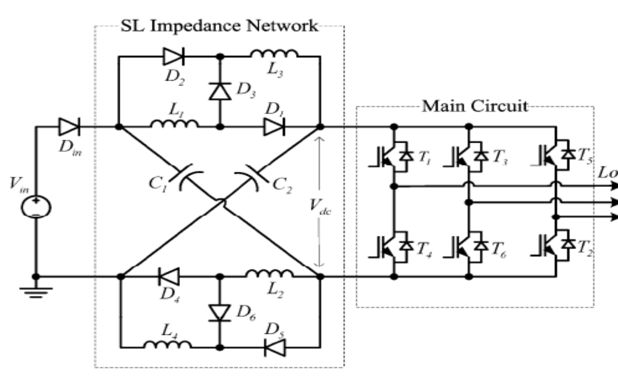

Fig.1. Proposed SL Z-source inverter.

The combination of L1-L3-D1-D3-D5 and the combination of L2-L4-D2-D4-D6 perform the function of the top switched inductor cell and the bottom switched inductor cell respectively. Both of these two cells are used to store and transfer the energy from the capacitors to the dc bus below the switching action of the main circuit.

The sub-states of the proposed impedance network are classified as (i) shoot-through state and (ii) non-shoot-through state, respectively.

Shoot-through state

This state correspond to additional zero state produced

by the shoot-through actions of the top and bottom arms of the main circuit. Its equivalent circuit is shown in Fig. 2. During this sub-state, *S* is on, while both *Din* and *Do* are off. For the top SL cell, *D1* and *D2* are on, and *D3* is off. *L1* and *L3*are charged by *C1* in parallel. For the bottom SL cell, *D4* and *D5*are on, and *D6* is off. *L2* and *L4* are charged by *C2* in parallel. It is seen that both the top and bottom SL cells carry out the same function to absorb the energy stored in the capacitors.

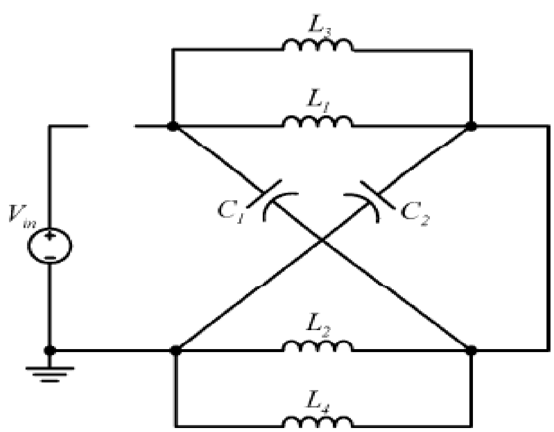

Fig.2. Equivalent circuits: Shoot-through zero state (switching-on).

Non-shoot-through state

This state correspond to six active states and two zero

states of main circuit and the equivalent circuit is shown in Fig. 3. During this sub-state, *S* is off, while both *Din* and *Do* are on. For the top SL cell, *D1* and *D3* are off, and *D5* is on. *L1* and *L2* are connected in series, and the stored energy is transferred to the main circuit. For the bottom SL cell, *D4* and *D5* are off, and *D5* is on. *L3* and *L4* are connected in series, and the stored energy is transferred to the main circuit. At the same moment, to supplement the consumed energy of *C1* and *C2* during the shoot-through state, *C1* is charged by *Vin* via the bottom SL cell and *C2* is charged by *Vin* via the top SL cell.

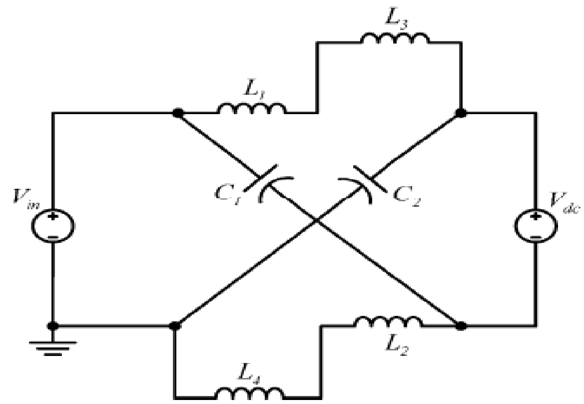

Fig.3. Equivalent circuits: Non-shoot-through states (switching-off).

3. SIMULATION RESULTS

To verify the above theoretical results, a simulation is carried out through MATLAB/SIMULINK software.

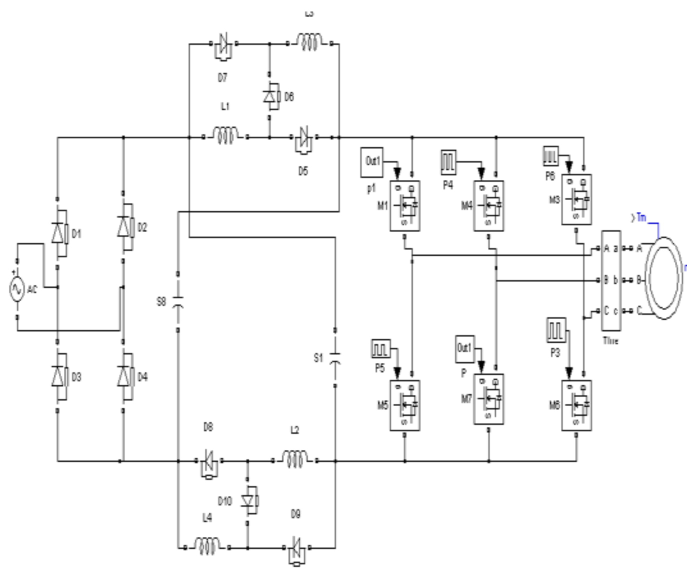

Fig.4. Proposed SL Z-source inverter fed Induction Motor.

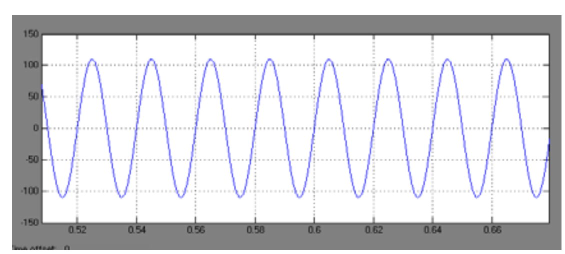

Fig.5. AC Input Voltage.

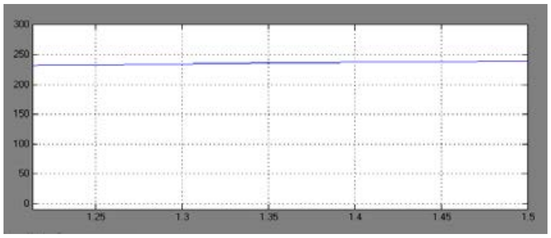

Fig.6. Rectifier Output Voltage.

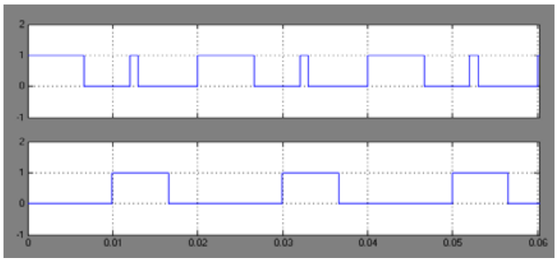

Fig.7. Driving Pulses for first leg.

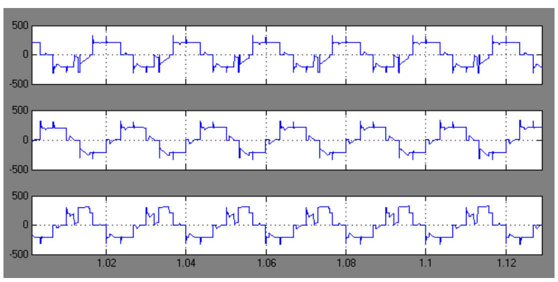

Fig.8. Phase to Phase Output Voltage.

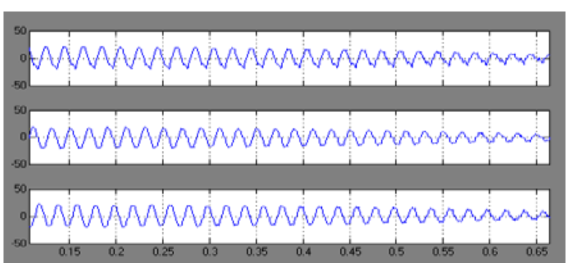

Fig.9. Inverter Output Phase Current.

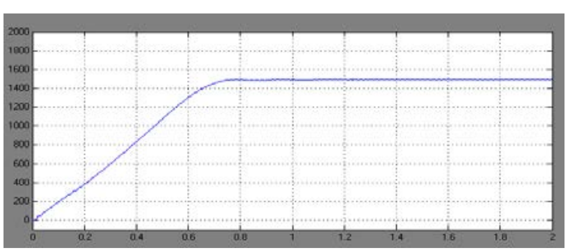

Fig.10. Rotor Speed.

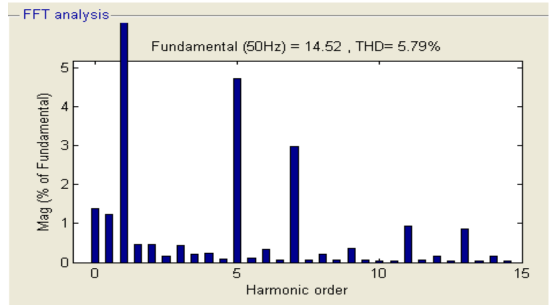

Fig.11. THD Analysis.

4. CONCLUSION

Compared with the classical Z-source inverter, the proposed inverter increases the voltage boost inversion ability appreciably. The proposed inverter employs a unique SL Z-source impedance network to combine the low dc voltage energy source to the main circuit of the inverter. The proposed inverter could be widely used in the distributed renewable energy power systems. Furthermore, the concepts of SL Z-source impedance network can be applied to all areas of dc-ac, ac-dc, ac-ac, and dc-dc power conversion.

REFERENCES

[1] F.Z. Peng, “Z-source inverter,” in Proc. IEEE/IAS Annu. Meeting, 2002, pp. 775–781.

[2] F.Z. Peng, M. Shen, and Z. Qian, “Maximum boost control of the Zsource inverter,” IEEE Trans. Power Electron., vol. 20, no. 4, pp.833- 838, Jul. 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 Trans. Power Electron., vol. 22, no. 4, pp. 1453-1463, Jul. 2007.

[4] J.B. Liu, J.G. Hu, and L.Y. Xu, “Dynamic modeling and analysis of Z source converter-derivation of ac small signal model and design-oriented analysis,” IEEE Trans. Power Electron., vol. 22, no. 5, pp.1786-1796, Sept. 2007.

[5] A. Ioinovici, “Switched-capacitor power electronics circuits,” IEEE Circuits and Systems Magazine, vol. 1, no. 4, pp. 37-42, 2001.

[6] O. Abutbul, A. Gherlitz, Y. Berkovich, and A. Ioinovici, “Step-up switching mode converter with high voltage gain using a switched capacitor circuit,” IEEE Trans. Circuits and Systems I: Fundamental Theory and Applications, vol. 50, no. 8, pp. 1098-1102, 2003.

[7] M. Prudente, L.L. Pfitscher, G. Emmendoerfer, E.F. Romaneli, and R. Gules, “Voltage multiplier cells applied to non-isolated dc-dc converters,” IEEE Trans. Power Electron., vol. 23, no. 2, pp. 871-887, Mar. 2008.

[8] M. Zhu, F.L. Luo and Y. He, “Remaining inductor current phenomena of complex dc-dc converters in discontinuous conduction mode: general concepts and case study,” IEEE

Trans. Power Electron., vol. 23, no. 2, pp. 1014-1019, Mar. 2008.

[9] M. Zhu and F.L. Luo, “Series SEPIC implementing voltage lift technique for dc-dc power conversion,” IET Power Electron., vol. 1, no. 1, pp. 109-121, Mar. 2008.

[10] M. Zhu and F.L. Luo, “Voltage-lift-type Cûk converters: topology and analysis,” IET Power Electron., vol. 2, no. 2, pp. 178-191, Mar. 2009.

[11] M. Zhu and F.L. Luo, “Super-lift dc-dc converters: graphical analysis modelling,” J. of Power Electron., vol. 9, no. 6, pp. 854-864, Nov. 2009.