IMPLEMENTATION OF SWITCHED INDUCTOR QUASI-Z-SOURCE INVERTER

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Abstract

This paper deals with a new family of high boostvoltage inverters, called switched-inductor quasi-Z-source inverters. The proposed switched-inductor quasi-Z-source inverter is based on the well-known quasi-Z-source inverter topology and adds only one inductor and three diodes. In comparison to the switched-inductor Z-source inverter, for the same input and output voltage, the proposed switched-inductor quasi-Z-source inverter provides: continuous input current, a common ground with the dc source, reduced the passive component count, reduced voltage stress on capacitors, lower shoot-through current, and lower current stress on inductors and diodes. In addition, the proposed switched-inductor quasi-Z-source inverter can suppress inrush current at startup, which might destroy the devices. This paper presents the operating principles, analysis and simulation results, and compares them with those of the switched-inductor Z-source inverter.

Keywords: Component; Z-source inverter; Switched inductor quasi Z-source inductor; Boost inversion ability.

1. Introduction

High performance voltage and current source inverter are widely required in various industrial applications such as servomotor driver, special power supplies, and distributed power system and hybrid electric vehicles. The traditional VSI and CSI have been seriously restricted due to their narrow obtainable output voltage range; shoot through problems caused by misgating and some other difficulties due to their bridge type structures. For the application where both buck and boost inverter, perform two stage power conversions with high cost and low efficiency. The topology of the Z-source inverter was proposed to overcome the problems in the traditional inverters in which the function of the traditional dc-dc boost converter with single stage power conversion and the bridge type inverter have been combined. Both power
switches in a leg can be turned on at the same time and dead time is eliminated. This significantly reduces the output waveform distortion and improves reliability. The conventional pulse width modulation strategies can be modified to switch a voltage type Z source inverter either continuously or discontinuously, while retaining all the unique harmonic performance features of these conventional modulation strategies. The VSI are considered here because it is more established and can constructed using low cost, high performance insulated gate bipolar transistor modules or intelligent power modules. The VSI inverter can assume all active and null switching states of VSI. Unlike the conventional VSI where dead time delays are inserted to the complementary switching of the two switches of a phase – leg to prevent short circuiting of the phase leg. With the fast development of modern technology, the disadvantage will limit the further application of Z-source inverter in some areas that need strong boost inversion ability for low voltage energy source such as fuel cell, batteries and PV systems.

The advanced dc-dc enhancement techniques such as switched inductor (SL) / switched capacitor (SC), hybrid SC/SL, and voltage multiplier cells have been greatly explored which are used to get high step up capacity in transformer less and cascaded structure. The main objective is to reach high efficiency, high power density and simple structure. So the combination with the Z source inverter with advanced dc-dc enhancement techniques could be a good solution for improving impedance type inverter.

In conventional method, the concept of SL techniques has been integrated into the classical Z source impedance network and a new SL Z source impedance network is proposed. In this conventional method the high power quality and high boost inversion ability has got an initial solution.

The boost inversion ability of the inverter is determined by the interaction of Z source impedance and the PWM control method applied to the main circuit. Two PWM control methods, termed as the simple boost method and maximum boost control method results the relation of the voltage boost inversion ability versus the modulation index M.

This project work focuses on the switched inductor quasi Z source inverter (SL-q ZSI) which is the combination of switched inductor Z source inverter and quasi Z source inverter. Compared with the SL-ZSI, the proposed (SL-q ZSI) improves the input current, reduces the passive component count and improves the reliability. Moreover the shoot through current, voltage stress on capacitors and current stress on inductors and diodes in the proposed SL-qZSI are lower than the conventional inverter.
2. Z Source Inverter

A. Over View: General Z source network (Fig.1) employs a unique impedance network (or circuit) to couple the converter main circuit to the power source, load, or another converter, for providing unique features that cannot be observed in the traditional V- and I-source converters where a capacitor anThe unique feature of the Z-source inverter is that the output ac voltage can be any value between zero and infinity regardless of the fuel-cell 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.

B. The three-phase Z-source inverter bridge has nine permissible switching states (vectors) unlike the traditional three-phase V-source inverter that has eight with six active vectors. However, shoot-through zero state (or vector) is forbidden in the traditional V-source inverter, because it would cause a short circuit. We call this third zero state (vector) the shoot-through zero state (or vector), which can be generated by seven different ways: shoot-through via any one phase leg, combinations of any two phase legs, and all three phase legs. The Z-source concept can be applied to all dc-to-ac, ac-to-dc, ac-to-ac, and dc-to-dc power conversion. The Z-source inverter intentionally utilizes the shoot through zero states to boost dc voltage and produces an output voltage greater than the original dc voltage. At the same time Z-source structure enhances the reliability of the inverter because the shoot through states might caused by EMI noise no longer destroy the inverter.

C. The zero state is produced when the upper three and lower three switches are turned on at the same time shorting the output terminals. The Z-source network is a combination of two inductors and two capacitors. This combined circuit, the Z-source network is the energy storage/filtering element for the Z-source inverter. The Z-source network provides a second-order filter and is more effective to suppress voltage and current ripples than capacitor or inductor used alone in the traditional inverters. Therefore, the inductor and capacitor requirement should be smaller than the traditional inverter.d inductor are used, respectively

B. Switched Inductor Z-source Inverter: In conventional method, the concept of SL techniques has been integrated into the classical Z source impedance network and a new SL Z source impedance network is proposed. In this method the high power quality and high boost inversion ability has got an initial solution. Only six diodes and two inductors are added compared to the classical Z source inverter. The boost factor ratio also increased from 1/ (1-2D) to (1+D)/ (1-3D).
The boost inversion ability of the inverter is determined by the interaction of Z source impedance and the PWM control method applied to the main circuit.

![Z-Source Inverter Network](image1)

**Fig.1 Z-Source Inverter Network**

Two PWM control methods, termed as the simple boost method and maximum boost control method result in the relation of the voltage boost inversion ability versus the modulation index M.

C. **Conventional circuit diagram**

In the Fig.2 the combination of $L_1$-$L_3$-$D_1$-$D_2$-$D_3$ and the combination of $L_2$-$L_4$-$D_4$-$D_5$-$D_6$ performs the function of the top SL cell and the bottom SL cell. Both of the SL cells are used to store and transfer the energy from the capacitors to the dc bus under the switching action of the main circuit.

![Conventional circuit diagram](image2)

**Fig.2 Conventional circuit diagram**

The SL–ZSI obtains high voltage conversion ratios with a very short shoot through state, which improves the main circuit output power quality. The increase in boost inversion, has several drawbacks as: it does not share a dc ground point between the source and converter, the input current is discontinuous, it does not suppress the inrush current and the resonance introduced by the Z-source inductor and capacitor at startup, resulting in current and voltage spikes.
3. Switched Inductor Quasi Z-Source Inverter

The proposed switched-inductor quasi-Z-source inverter (qZSI) is shown in Fig.3. It consists of three inductors (L1, L2 and L3), two capacitors (C1 and C2), and four diodes (Din, D1, D2 and D3). The combination of L2-L3-D1-D2-D3 acts as a switched-inductor cell.

![Fig.3. Proposed SLq ZSI circuit](image)

The proposed topology provides inrush current suppression, unlike the SL-ZSI topology, because no current flows to the main circuit at startup; however, the inductors and capacitors in the proposed switched-inductor qZSI still resonate. Compared with a conventional continuous current quasi-Z-source inverter, the proposed inverter adds only three diodes and one inductor and the boost factor increases from \(1/(1-2D)\) to \((1+D)/(1-2D-D^2)\).

A. Non shoot–through state

In the non-shoot-through state, as shown in Fig.4 (a) the proposed inverter has six active states and two zero states of the inverter main circuit.

During the non-shoot-through state, diode Din and D1 are on, while D2 and D3 are off. L2 and L3 are connected in series. The capacitors C1 and C2 are charged, while the inductors L1, L2, L3 transfer energy from the dc voltage source to the main circuit. The corresponding voltages across L2 and L3 in this state are \(V_{L2\_non}\) and \(V_{L3\_non}\), respectively. We get

\[ VL1 = VC1 - Vdc \]
\[ VL2 = VL2\_non = VC2 - VL3\_non \]
VL3 = VL3_non = VC2-VL2_non

VPN = VC1+VC2

B. Shoot through state

Fig. 4 (b) shows the shoot-through state, the inverter side is shorted by both the upper and lower switching devices of any phase leg. During the shoot-through state, D_in and D_1 are off, while D_2 and D_3 are on. L_2 and L_3 are connected in parallel. The capacitors C_1 and C_2 are discharged, while inductors L_1, L_2, and L_3 store energy, obtaining:

VL1 = -VC2 –Vdc

V_{L2} = V_{L3} = - V_{C1}

The boost factor of the proposed inverter B is defined by

$$B = \frac{1+D}{1-2D-D^2} = \frac{1+\frac{5}{2}}{1-2\frac{5}{2}}$$

4. Simulation Result

Simulations were performed by using MATLAB-Simulink to verify that the proposed Switched inductor quasi Z source inverter which can practically implemented with reduced passive component count. Both conventional and proposed circuit has a 110 V ac input voltage and output phase voltage be is 100 V that is the ac voltage is rectified through a single phase bridge rectifier and the resultant dc be given to the Z source network. It will boost the voltage and given to 3 phase inverter and to the motor load. Open Loop with disturbance occurs at 1 sec which may raise both voltage and current. Then to control this disturbance circuit a PI controller with set error voltage of 120 V be given.

A. Simulation circuit of SL-Z-Source Inverter

Fig.4 Simulation circuit of conventional method.  
Fig.5 Output voltage.
In this conventional method, with an input voltage of 110V the corresponding inverter output phase voltage and phase current are shown in Fig.5 & 6.

![Fig.6 Output current.](image)

B. Simulation circuit of SLQ-Z-SOURCE INVERTER

![Fig.7 simulation circuit of proposed method.](image)

In proposed method, the circuit with reduced component count can reduce the voltage stress on capacitors, current stress on inductors and can suppress inrush current at startup compared with the conventional circuit and the waveforms are shown in Fig 8 & 9.

![Fig.8 Output phase current.](image)

![Fig.9 Output voltage.](image)
C. Open loop circuit with disturbance

Open loop circuit with disturbance at an time of one sec. After one sec the voltage increases to 24V which will disturbs the circuit. This error voltage is given to circuit as shown in fig.10

![Fig.10 Simulation circuit of open loop with disturbance.](image)

![Fig.11 Input voltage and current.](image)

![Fig.12 Rectified voltage with disturbance.](image)

![Fig.13 Voltage after SLq-Z source inverter.](image)
D. Open loop circuit with PI controller

In Fig.17 the circuit with disturbance and controller in the input side with subsystem is shown. After one sec the voltage increases to 24V which will disturbs the circuit and a PI controller compares the set voltage value with capacitor voltage
and the error voltage. The error signal is given to the block where it compares the signal voltage with ramp signal. Then the pulsated dc pulses be given to the gate of the switching device. The corresponding voltage, current and speed of the machine are shown in Fig. 18.

**Fig. 18 Voltage after SLq-Z-source inverter.**

**Fig. 19 Output phase voltage.**

**Fig. 20 Output phase current.**

**Fig. 21. Motor speed.**

4. Conclusion

This project will introduces a new family of high boost voltage inverter called switched inductor quasi Z source inverters for high power applications. The proposed circuit will bring continuous input current, high voltage boost ability and it shares the dc source ground point compared with the traditional switched inductor Z source inverter circuit. The circuit is able to generate a new switching state called shoot through states in which switching devices of same leg is turn on.
Compared to the conventional circuit the shoot through current is low which increases the ability of the inverter. It will also avoid the inrush current at startup which may destroy the devices.

Under the phase-1 of this project the switched inductor quasi Z source inverter has been simulated using MATLAB software and its feasibility is checked with the simulated results of the conventional circuit. The prototype for this converter is yet to be developed and saved for phase-2.

5. References