Improved Topology of Quasi-Z-Source Inverter and Its Grid-Connected Control

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Abstract. In order to solve the problems of low voltage boost capability, high capacitance voltage stress, narrow voltage boost range and small gain of traditional z-source inverters, a new topology structure of quasi-Z source cascade H-bridge multilevel inverters is proposed. The simulation was verified by MATLAB/SIMULINK software and compared with other Z source topologies. The results show that the new topology makes up for the problems of insufficient voltage boost capacity and narrow voltage boost range of the traditional Z source inverter, and the output power is high when the inverter is connected to the grid.

1. Introduction

In recent years, the cascade multilevel inverter power devices will have wide applications in the future because of its low-pressure requirements, small switch stress, low output voltage harmonic content, obvious advantages in active power filter, static synchronous compensator, photovoltaic power generation systems, and many other areas [1-3]. In addition, the rapid development of electrified railway makes the cascade topology favoured in electrified traction power supply system [4]. Quasi Z source H type bridge cascade multilevel inverter QZSCMI is proposed and developed on the basis of the classic H-bridge cascaded multilevel inverter [5], since the DC link of the cascade unit contains a quasi-Z source network, the power supply properties have undergone fundamental changes, which are different from the voltage source inverter and the current source inverter, which is superior to the classic cascade H-bridge inverter.

However, the traditional cascade network has no significant boost capability, and in order to give full play to the advantages of QZSCMI, the topology structure needs to be improved on this basis. In the literature [6], an improved switching inductance Z-source inverter is proposed. It can make the input current continuous, increase the voltage variation range, avoid the formation of the start shock circuit, and reduce the damage to the device.

In this paper, a novel switched-inductive quasi-Z source inverter circuit is proposed. On the basis of the traditional quasi-Z source topology, one of the energy storage inductors is changed, and a new switching inductor unit is used instead, so that the entire topology is in the through state. More energy can be stored to achieve larger voltage gain and increase the output power quality under the condition of smaller duty cycle. Finally, the simulation is compared with the existing Z source topology at home and abroad to verify its performance.

2. Circuit Topology and Analysis

2.1. Circuit Topology
The proposed new quasi-Z-source inverter circuit topology is shown in Figure 1. The topology circuit consists of a large boost ratio quasi-Z source impedance network, a three-phase inverter bridge and a three-phase filter. One big step-up ratio impedance network composed of five energy storage inductors \( L_1 - L_5 \) \((L_1 = L_2 = L_3 = L_4 = L_5)\), two energy storage capacitor \( C_1 \) and \( C_2 \) \((C_1 = C_2)\), and 7 of the same diode, three-phase output damping resistance is similar to traditional Z source inverter, the new prospective Z source inverter is still working in direct and not through two kinds of conditions.

![Circuit topology of the new quasi-Z source inverter](image)

To simplify the analysis, it is assumed that all components work in an ideal state, and Figure 2 is a straight through state equivalent circuit diagram. In this state, the impedance circuit is disconnected due to the reverse voltage of diode \( D_1 \).

According to the circuit with the topological structure in the straight state, the equation can be obtained.

\[
\begin{align*}
U_{PV} & = U_{I_v} + U_{C_2} \\
U_{I_v} & = U_{I_a} = U_{I_b} = U_{C_1} / 2
\end{align*}
\]

(1)

The equivalent circuit diagram of the non-through state is shown in Figure 3. When the circuit is in a non-straight-through state, the diodes \( D_2, D_4, D_5 \) and \( D_7 \) in the circuit are in reverse disconnection and \( D_1, D_3 \) and \( D_6 \) are in direct connection, so that the inductance \( L_2, L_3, L_4 \) and \( L_5 \) are in series. At this time, inductance \( L_1 - L_5 \) to capacitor \( C_1, C_2 \) and load charging.

![Straight through state equivalent circuit diagram](image)

![Non-straight through state equivalent circuit diagram](image)

2.2. Comparison of various Z source inverters

2.2.1. A topology that reduces voltage stress in a circuit

Many Z source and quasi-Z source circuits can change or boost the voltage stress of components in the circuit by changing the relative position of diodes and energy storage elements in the circuit structure. The symmetric and asymmetric quasi-Z sources proposed by professor Peng reduce the voltage stress at both ends of the energy storage capacitor in the topological structure, as shown in Figure 4.
2.2.2. Topological structure for boost ratio

This kind of topological structure mainly replaces the energy storage inductance in Z source network with the deformation of switch inductance unit and similar switch inductance unit, or increases the boost factor by adding coupling inductance. Figure 5 shows the switching inductance topology structure, in which 2 switching inductance units are added, which greatly improves the boost capacity of Z-source network.

3. Mathematical model of a novel Z source in a parallel network

Compared with traditional inverters, QZSI introduces a quasi-Z source network and a pass-through working state. The energy storage capacitance and inductance in the quasi-Z source network can absorb or release energy through the change of pass-through state, so that the system has the boost characteristic. If \( L_1 = L_2 \) and \( C_1 = C_2 \) are assumed, in a switching cycle \( T_s \), a bridge arm is connected directly within the pass-through time \( T_0 \). Inductance stores energy and capacitor releases energy. The energy is released by inductance and stored by capacitance in the non-direct time. The operation mode of quasi-Z-source inverter is consistent with that of traditional inverter. \( D = D_0 / D_s \) is defined as the straight-through duty cycle, and \( B \) is the boost factor. According to the volts-second balance, the relationship between QZSI dc chain voltage \( U_{dc} \), capacitor voltage \( U_{c1} \) and \( U_{c2} \), straight-through duty cycle \( D \) and PV array output voltage \( U_{pv} \) in a steady state is obtained, as shown in equation 2.

\[
\begin{align*}
U_{c1} &= (1-D/1-2D)U_{pv} \\
U_{c2} &= (1-D/1-2D)U_{pv} \\
U_{dc} &= (1-D/1-2D)U_{pv} = BU_{pv}
\end{align*}
\]

4. The simulation verification

In order to verify the superiority of the quasi-Z source inverter proposed in this paper, it is compared with various common Z-source inverters by simulation. Specific simulation parameters are as follows: DC power supply voltage \( U_{pv} = 100V \), switching frequency \( f = 4kHz \), through duty cycle \( D = 0.21 \), inductance \( L_1 \) of Z source network is 0.012h, Z source network capacitance \( C_1 \) and \( C_2 \) are 0.001 μf, booster unit inductance \( L_2-L_6 \) is 1mH. Filter inductance is 20mH, load resistance is 5Ω. The simulation results are shown in Figure 6-8.
It can be clearly seen from the simulation results that, on the basis of the same duty cycle D, the bus voltage of the dc chain of all Z sources is lower when the output of the traditional quasi-Z source is stable. Other improved Z source topologies have been greatly improved, while the new quasi-Z source inverter proposed in this paper has obvious boost.

Similarly, under a small through-pass duty cycle D, the quasi-Z source topological structure proposed in this paper can obtain a larger boost factor. Load side voltage waveform is shown in Figure 9. As can be seen from the figure, the load voltage on the output side is stable, the waveform is relatively smooth and the output power quality is high.

5. Conclusion
In this paper, a new type of quasi-Z-source inverter is proposed. The new type of quasi-Z source inverter increases the cost by adding the inductance of switch on the structure, which is obviously better than other Z-source inverters. The quasi-Z source topological structure proposed in this paper has certain reference and application value when the environmental conditions are bad and the boost range fluctuates greatly, such as small new energy power plants and mine.

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