Investigation on PV System based Z Source Inverters

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Abstract. This paper presents a comparison between PV system using Z source inverters and Quazi Z source inverters. The Z-source inverter employs a unique LC network to couple the inverter power circuit to the diode front end and can be shoot through to boost the DC link voltage. By controlling the shoot-through duty cycle, the PV array output voltage is controlled and the maximum power point tracking (MPPT) is realized. The quasi-Z-source inverter (QZSI) is similar to the ZSI. It has got several advantages such as lower component ratings, reduced source stress, reduced component count, and simplified control strategies.

Keywords: Photovoltaic, Maximum Power Point Tracking, Z Source Inverters, Quazi Z Source Inverters

I. INTRODUCTION

The use of the renewable-energy generating system in India has increased dramatically due to the exhaustion of fossil fuel and the influence of the environment. The major renewable-energy sources are photovoltaic energy, wind power, and fuel cell. The unregulated output power of renewable energy sources should be regulated through the power converters, and the power system reliability can be guaranteed depending on the performance of the converters.

Conventional configuration for connecting a PV array to grid is a combination of a DC/DC converter and an inverter. DC-DC converter can act as a buck or boost converter. Two functions should be considered in the control system, tracking the maximum power point and providing constant voltage for inverter. The function of inverter is delivering power to grid. This conventional configuration has got some drawbacks such as increased price, reduced efficiency and complicated control system.

ZSI (Z-source inverter) has been proposed to overcome the disadvantage of the conventional scheme with a unique impedance network. Z-source inverter is a single stage converter suitable for photovoltaic applications since it is capable of boosting voltage and delivering power in a single stage structure. ZSI can buck or boost the input voltage using the shoot-through state and the modulation index in a single stage. Besides, no dead time is needed, thus the output voltage is free from voltage distortion [1].

The quasi-Z-source inverter (QZSI) is similar to the ZSI, but has several advantages including in some combination; lower component ratings, reduced source stress, reduced component count, and simplified control strategies. Another advantage of this configuration is current drawn from the DC supply will be continuous [2].

In this paper, a PV system with topologies using Z source inverter and Quazi Z Source inverters are made and the results of both are compared.

II. Z SOURCE INVERTER

This topology contains a PV array, Z-source bridge inverter, filter and control circuit. This system produces high quality sine wave output current with the same phase and direction with the grid voltage. The whole control system consists of two loops namely MPPT control loop, Z-source capacitor voltage control loop and voltage-current compensation loop.

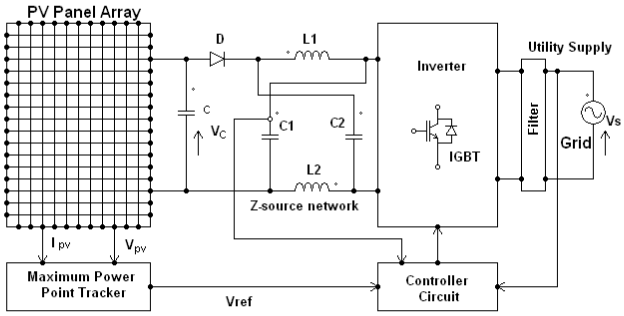

Fig 1. Diagram of Z Source Inverter

2.1 Operating Principle of Z Source Inverter

Z-source network parameters are selected as $L_1 = L_2 = L$ and $C_1 = C_2 = C$ which make the Z-source network symmetrical. Accordingly, the capacitor and inductor voltages of the Z-source network become

$$V_{L1}=V_{L2}=V_L$$

$$V_{C1}=V_{C2}=V_C \qquad (1)$$

V_C is the capacitor voltage and V_L is the inductor voltage.

Consider the converter in the shoot-through state for an interval of To during a switching cycle T.

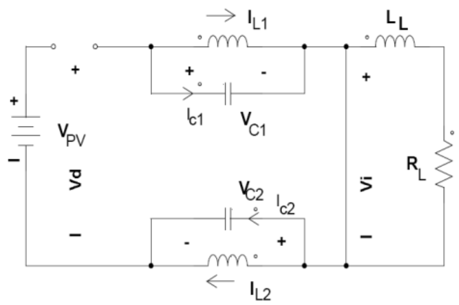

Fig 2. Shoot through state of ZSI

In shoot-through states, the circuit can be described by the following equations

$$V_i=0$$

$$V_L=V_C$$

$$V_d=2V_C=V_{C1}+V_{C2}>V_{PV} \quad (2)$$

where VPV is the output voltage of PV array, Vi is Z-source network dc link voltage.

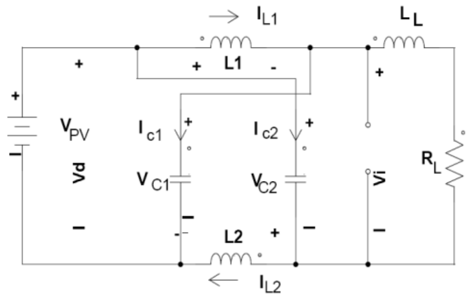

Fig 3. Active state of ZSI

For the active states, the output side of the ZSI can be represented by an equivalent current source. So the equations obtained will be

$$V_d=V_{PV}=V_L+V_C$$

$$V_i=V_C-V_L=2V_C-V_{PV} \quad (3)$$

The total duration of shoot through time and total active time are denoted by T0 and T1, the average voltage VL1 over a switching period T should be zero in steady state which gives the equation

$$V_CT_0+ (V_{PV}-V_C)T_1=0$$

$$T_0+T_1=T \quad (4)$$

From (4) the boost factor B can be derived as

$$B=V_i/V_{PV}=T/T_1-T_0=1/ (1-2T_0/T_1)>=1 \quad (5)$$

For active states the peak dc link voltage is

$$V_i=(T/(T_1-T_0))\ V_{PV}=BV_{PV} \quad (6)$$

The AC output of ZSI can be written as

$$V_{ac}=V_im=mV_{PV}\ (1/1-2T_0/T_1) =Bm\ V_{PV} \quad (7)$$

$$D_0=T_0/T \quad (8)$$

Where m is the modulation index and D_0 is shoot through duty ratio.

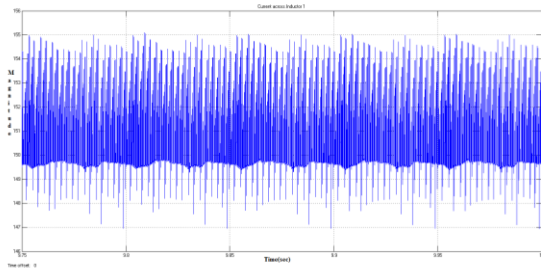

Fig 4. Inductor Current I_{L1}

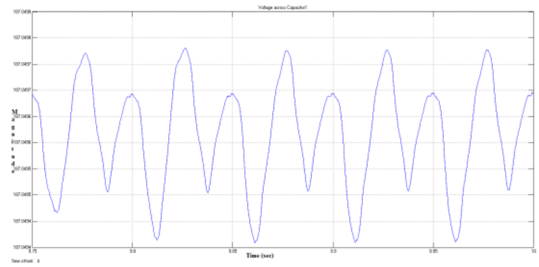

Fig 5. Voltage across Capacitor V_{C1}

The Z-source inverter is simulated in the MATLAB / simulink, the inductor current (I_{L1}) and voltage across capacitor (V_{C1}) is shown in fig 4 and fig 5. The purpose of the inductors is to limit the current ripple through the devices during boost mode with shoot-through state. During shoot through mode, the purpose of the inductors is to limit the current ripple through the devices. Similarly the inductor current increases linearly and the voltage across the inductor is equal to the voltage across the capacitor. During non-shoot through modes, the inductor current decreases linearly and the voltage across the inductor is the difference between the input voltage and the capacitor voltage but the capacitor voltage is always equal to the input voltage. Therefore, there is no voltage across the inductor and only a pure dc current goes through the inductors. The purpose of the capacitor is to absorb the current ripple and maintain a fairly constant voltage so as to keep the output voltage sinusoidal. During shoot-through, the capacitor charges the inductors, and the current through the capacitor equals the current through the inductor.

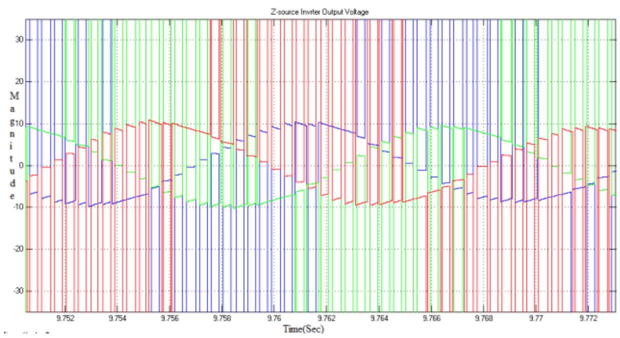

Fig 6. Inverter Output Voltage of ZSI

III. QUAZI Z SOURCE INVERTERS

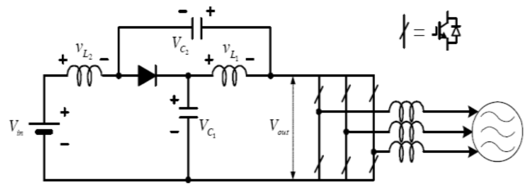

Fig 7. Diagram of Quazi Z Source Inverter

The operation of QZSI can be broken down into two states; the active state and the shoot through state. During the active state, the inverter is operated by the same manner as a standard voltage source inverter (VSI). But, the shoot through state occurs when both switches in at least one phase conduction. The voltage across the inverter, *Vpn* , during this state is zero. When the inverter is in the shoot-through state for the interval of *To* during a switching cycle of *T* , the following voltage equations can be derived from fig 6.

$V_{C1}=v_{L1};\ V_{C2}+V_{in}=v_{L2};\ V_{out}=0$ (9)

When the inverter is in the active state for an interval of *T*1 , during a switching cycle of *T* .

$v_{L1}=V_{C1}-v_{out}=-V_{C2}$

$v_{L2}=V_{in}-V_{C1}=V_{in}-v_{out}+V_{C2}$ (10)

The average voltage of the inductors, *vL*1 , over one switching period of *T* should be zero in steady state, and from (9) and (10), we have

$$V_{L_1}=\bar{v}_{L_1}=\frac{T_0\cdot V_{C_1}+T_1\cdot(-V_{C_2})}{T}=\frac{T_0\cdot V_{C_1}+T_1\cdot(V_{C_1}-\hat{v}_{out})}{T}=0$$

$$T_0\cdot V_{C_1}=T_1\cdot V_{C_2},\quad V_{C_1}=\frac{T_1}{T}\cdot\hat{v}_{out} \qquad (11)$$

The average voltage of the inductors *vL*2 over one switching period of *T* should be zero in steady state

$$\hat{v}_{out}=\frac{T}{T_1-T_0}\cdot V_{in},\quad V_{in}=V_{C_1}-V_{C_2} \qquad (12)$$

Similarly, the average dc-link voltage across the inverter bridge can be found as follows:

$$V_{out}=\bar{v}_{out}=\frac{T_0\cdot 0+T_1\cdot(V_{C_1}-v_{L_1})}{T}=\frac{T_1\cdot(V_{C_1}+V_{C_2})}{T}=V_{C_1} \qquad (13)$$

And from these we can find out

$V_{out}=V_{C1}=(T_1/(T_1-T_0)).\ V_{in}$ (14)

From this equation it is shown that the input voltage of QZSI can be boosted by using the shoot through ratio.

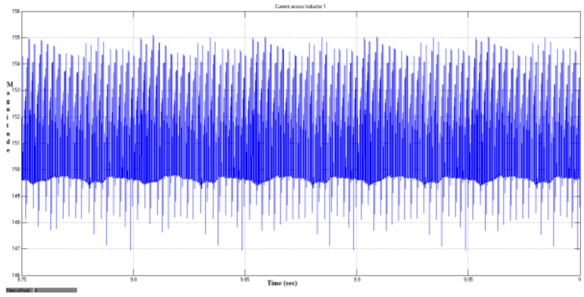

Fig 8. Inductor Current I_{L1}

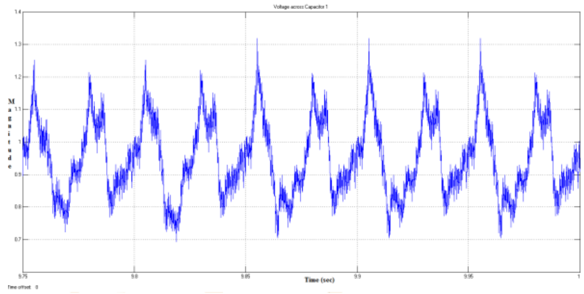

Fig 9. Voltage across Capacitor V_{C1}

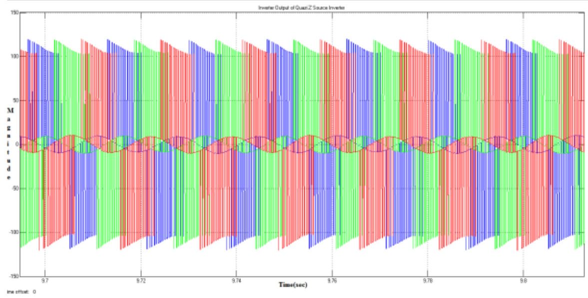

Fig10. Inverter output voltage of QZSI

IV. COMPARISON BETWEEN ZSI AND QZSI

If the shoot-through ratio is not controlled well, the system can be affected by this. During the shoot-through state, in case of ZSI, the input current is zero due to the blocking diode. But this current is the output current of PV array and so, it should be continuous for the MPPT control. In case of the QZSI, the input current is continuous.

The output voltage of ZSI and QZSI is zero during the shoot-through time interval. If the shoot-through time interval is in the switching state, the output voltage is affected. Thus the shoot-through time interval should be located within the zero state in order not to affect the output voltage.

V. CONCLUSIONS

The PV system using Z Source inverter and Quazi Z Source inverter is described in this paper. The single stage Z-source inverter has both voltage-buck and boost capabilities due to its unique LC impedance network. In addition, it needs no dead time so the control accuracy and THD levels can be improved. From the graphs, it is clear that the output voltage of Quazi Z Source Inverter is better than Z Source Inverter. And also the capacitor voltage is V_{c1} is also reduced.

REFERENCES

[1] Sebastian Strache, Ralf Wunderlich and Stefan Heinen, “A Comprehensive, Quantitative Comparison of Inverter Architectures for Various PV Systems, PV Cells, and Irradiance Profiles”IEEE Transactions on Sustainable Energy, vol. 5, no. 3, July 2014.

[2] Rupesh G. Wandhare, and Vivek Agarwal, “Reactive Power Capacity Enhancement of a PV-Grid System to Increase PV Penetration Level in Smart Grid Scenario”IEEE Transactions on Smart Grid, vol. 5, no. 4, July 2014.

[3] M. J. Hossain, Hemanshu Roy Pota, M. Apel Mahmud and Mohammad Aldeen, " Robust Control for Power Sharing in Microgrids With Low-Inertia Wind and PV Generators”, V IEEE Transactions on Sustainable Energy, vol. 5, July 2014.

[4] Sungjin Lee, Beom Kwon and Sanghoon Lee, "Joint Energy Management System of Electric Supply and Demand in Houses and Buildings”, IEEE Transactions on Power Systems, vol. 5, July 2014.

[5] Kyriaki-Nefeli D. Malamaki and Charis S. Demoulias, "Analytical Calculation of the Electrical Energy Losses on Fixed-Mounted PV Plants”, IEEE Transactions on Sustainable Energy, vol. 5, June 2014.

[6] Duong Quoc Hung, Nadarajah Mithulananthan and Kwang Y. Lee, " Determining PV Penetration for Distribution Systems with Time-Varying Load Models”, IEEE Transactions on Power Systems, vol. 5, June 2014.

[7] M. Santhosh Rani and Parul Thakur, “Performance Analysis of Modified LLC Resonant Converter”, Advanced Electrical and Computer Engineering, Volume -1, Issue -1, pp. 24-27, 2014

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