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Quasi –Z- Source Inverter for Photovoltaic Power Generation

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Abstract: Quasi Z-source inverter is a recently developed topology derived from Z-source inverter (ZSI) which is capable of boosting action along with inversion. QZSI is a one-stage power conditioner that employs a capacitor-inductor network for connecting inverter to photovoltaic module. By means of controlling shoot-through duty cycle, the objective of tracking maximum power point can be accomplished. In comparison with ZSI, QZSI benefits some prominent privileges such as lower component ratings and source constant dc current. In this paper, through introducing an appropriate control structure, QZSI is used for connecting photovoltaic system to single phase grid. In the control structure, maximum power with unity power factor and low THD current is delivered to grid by controlling modulation index via PI controller. The proposed system is verified by using MATLAB/Simulink.

Keywords: Quasi Z Source inverter, Shoot –through duty ratio, Maximum power point tracking, Grid connected inverter.

I. INTRODUCTION

Among the renewable sources, solar energy consistently shows its great potential to serve as a clean and inexhaustible energy source [1-3]. The electricity generated by the solar panel will be a DC quantity. It should be converted to AC for feeding the power grid. So the inverter plays an important role in the energy conversion [4-13]. Inverters can be broadly classified into two types. They are voltage source inverter (VSI) [14] and current source inverter (CSI) [15]. When the DC voltage remains constant, then it is called voltage source inverter or voltage fed inverter. When input current is maintained constant then it is called current Source inverter or current fed inverter. Typical inverters have few disadvantages like they behave in a boost or buck operation only. Thus the obtainable output voltage range is limited, either smaller or greater than the input voltage. Vulnerable to EMI noise and the devices gets damaged in either open or short circuit conditions.

Impedance (Z) source networks provide an efficient means of power conversion between source and load in a wide range of electric power conversion applications6 [16-20]. Z source related research has grown rapidly since it was first proposed in 2002 by Prof. F. Z. Peng. In traditional voltage-source inverter, the two switches of the same phase leg can never be gated on at the same time because doing so would cause a short circuit (shoot through) to occur, which would destroy the inverter. In addition the maximum output voltage obtainable can never exceed the dc bus voltage. These limitations can be overcome by the Z source inverter. This uses an impedance network (Z network) to replace the traditional dc link. The Z source inverter advantageously utilizes the shoot through states to boost the dc-bus voltage by gating on both the upper and lower switches of a phase leg. Therefore the Z source inverter can buck and boost voltage to a desired output voltage that is greater than the available dc bus voltage. In addition, the reliability of the inverter is greatly improved because the shoot through caused by electromagnetic interference (EMI) noise can no longer destroy the circuit. Quasi Z-source inverter [21-24] is a recently developed topology derived from Z-source inverter (ZSI). In the same manner as the traditional ZSI, the quasi ZSI has two types of operational states at the dc side, the non shoot-through states (six active states and two conventional zero states of the traditional VSI) and the shoot-through state (both switches in at least one phase conduct simultaneously). In the non shoot through states, the inverter bridge viewed from the dc side is equivalent to a current source. Non shoot through state consist of six active and two zero state. The shoot-through state is forbidden in the traditional VSI, because it will cause a short circuit of the voltage source and damage the devices. With the quasi ZSI and ZSI, the unique LC and diode network connected to the inverter bridge modify the operation of the circuit, allowing the shoot-through state. This network will effectively protect the circuit from damage when the shoot-through occurs and by using the shoot-though state, the quasi- Z-source network boosts the dc-link voltage.

II. QUASI –Z- SOURCE INVERTER

In this paper a QZSI is used for connecting photovoltaic system to grid. With proper control structure QZSI inject current at unity power factor to the grid.

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The same as conventional ZSI, QZSI operates in two modes at the dc-side:
i) shoot-through state.
ii) non-shoot-through state.

During shoot through state two switches in the same leg is gated at same time. Inverter bridge is equivalent to a short circuit during shoot through. During non shoot through inverter bridge is equivalent to a current source. During non shoot through Switching vectors are of a typical VSI consisting of two active and two zero vectors.

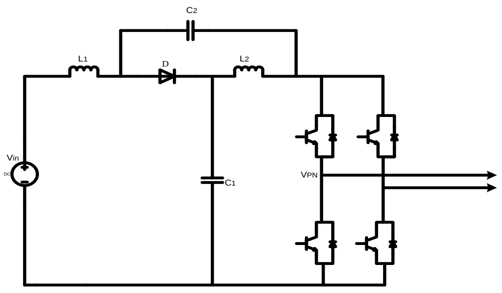

Fig. 1. QZSI.

Shoot through vector provides the inverter with voltage boost capability and makes it feasible to generate a desired ac output even in the presence of DC bus variation [25].
Assuming that during one switching cycle T, the interval of the shoot through state is T0. The interval of non-shoot-through states is T1; thus one has T= T0+T1and the shoot-through duty ratio D= T0/T.

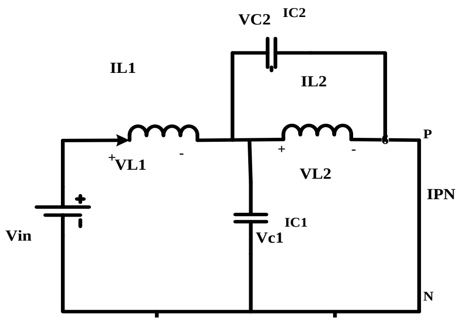

Fig.2 Equivalent Circuit of the quasi ZSI in Shoot-through States.

Fig. 2 and 3 shows the equivalent circuit of QZSI during shoot through and non shoot through state respectively. From state space analysis steady state capacitor voltage can be calculated.

$$V_{C1} = \frac{T_1}{T_1 - T_0} V_{in} \tag{1}$$

$$V_{C2} = \frac{T_0}{T_1 - T_0} V_{in} \tag{2}$$

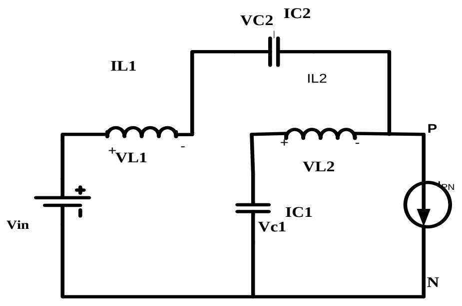

Fig.3 Equivalent Circuit of the quasi ZSI in non Shoot-through States.

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The peak dc-link voltage across the inverter bridge is given by the following equation.

$$V_{PN} = V_{c1} + V_{C2} = \frac{T}{T_1 - T_0} V_{in} = \frac{1}{1 - \frac{2T_0}{T}} V_{in} = BV_{in} \quad (3)$$

Where B is the boost factor of the QZSI. Output amplitude of a single phase inverter can be calculated using equation.

$$V_{ac} = B.M.V_{in} \quad (4)$$

Where M is the modulation index.

III.CONTROL

In QZSI, the ac output voltage may be controlled by regulating modulation index along with shoot-through duty ratio control. Sinusoidal PWM control [26-28] is used for pulse generation.

A.MPPT

There are several Maximum power point tracking (MPPT) control for grid tied system. Perturb and observe and incremental conductance are the two algorithms common in use. Perturb and observe method have a disadvantage of oscillating operating point around maximum power point. For accurate maximum power point calculation incremental conductance algorithm is used. Incremental conductance method is simple and easy to implement. In incremental conductance method the array terminal voltage is always adjusted according to the MPP voltage and it is based on the incremental and instantaneous conductance of the PV module.

Fig. 4 shows that the slope of the P-V array power curve is zero at The MPP, increasing on the left of the MPP and decreasing on the Right hand side of the MPP. The basic equations of this method are as follows.

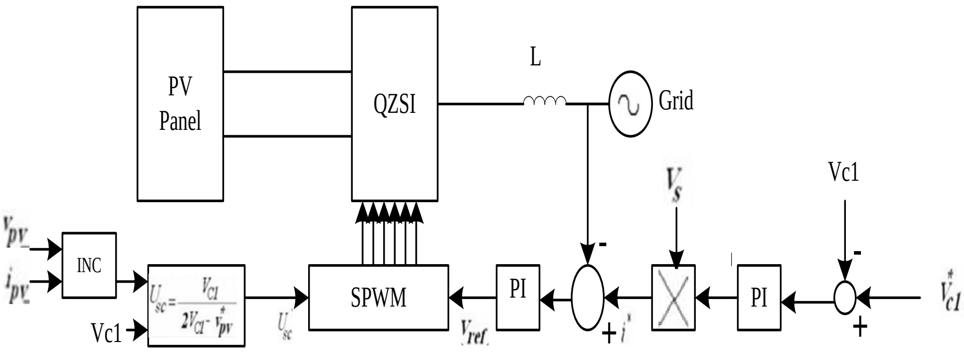

Fig. 2. Control block diagram.

$$\frac{dI}{dV} = -\frac{I}{V} \quad \text{; At MPP} \quad (5)$$

$$\frac{dI}{dV} > -\frac{I}{V} \quad \text{; Left of MPP} \quad (6)$$

$$\frac{dI}{dV} < -\frac{I}{V} \quad \text{; Right of MPP} \quad (7)$$

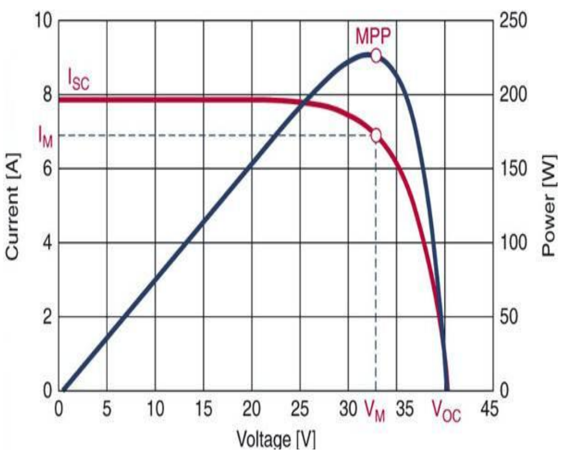

Fig. 4. PV Characteristics.

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Fig. 5 shows the flow chart of incremental conductance algorithm. Duty ratio is varied according to instantaneous and incremental conductance. Instantaneous conductance equal to incremental conductance is the condition for maximum power point. According to equation 6 and 7 duty ratio is varied.

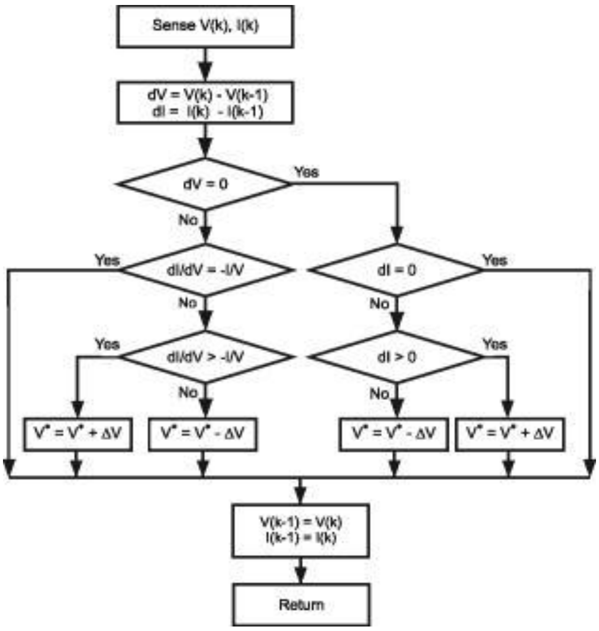

Fig. 5. Incremental conductance algorithm

B. QZSI –PWM

Fig. 6 describes a straightforward method for controlling boost factor in QZSI. In this method U_{sc} and $-U_{sc}$ are used as short circuit references. When the carrier signal is higher than U_{sc} or lower than $-U_{sc}$, a short circuit vector will be produced.

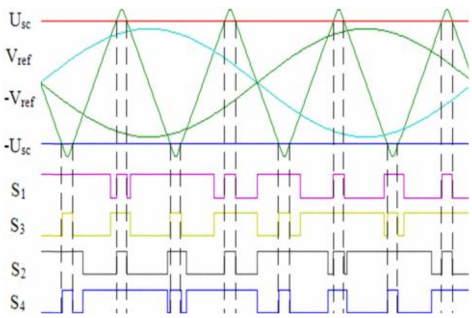

Fig. 6. Switching states.

IV.SIMULATION

To verify the proposed system, a PV array connected through a 1mH inductor to a grid is simulated. Input voltage selected is 180V to get 230V as output rms value.

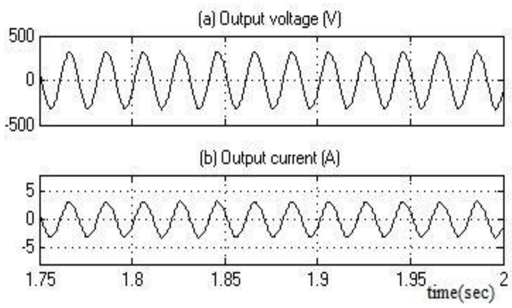

Fig. 7. Output voltage and current.

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Fig. 7 shows the output voltage and current. Peak of the output voltage is 325V. Output current peak is about 4.1A. Input current is in phase with voltage thus unity power factor is obtained.

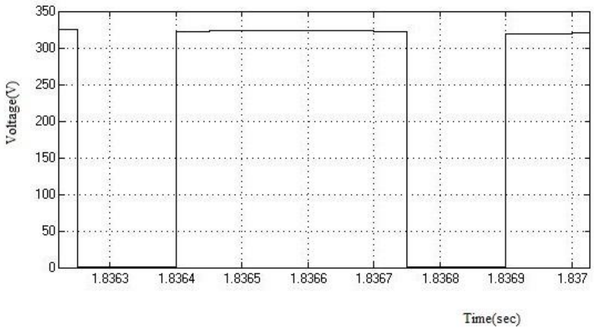

Fig. 8. DC link voltage

Fig. 8 shows the dc link voltage. During shoot through dc link voltage become zero and in other cases the dc link voltage is about 325V. During shoot through output voltage will be zero and in active states dc link voltage will be 325V.

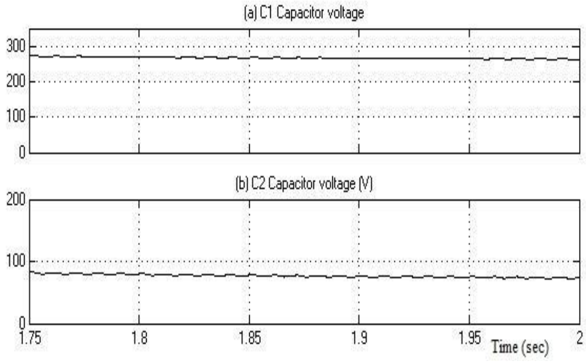

Fig. 8. Capacitor voltage (a) C_1 (b)C_2

Fig. 8 shows the capacitor voltage C_1 and C_2 respectively. C_2 voltage is less than C_1. We can select lower voltage rating capacitor C_2.

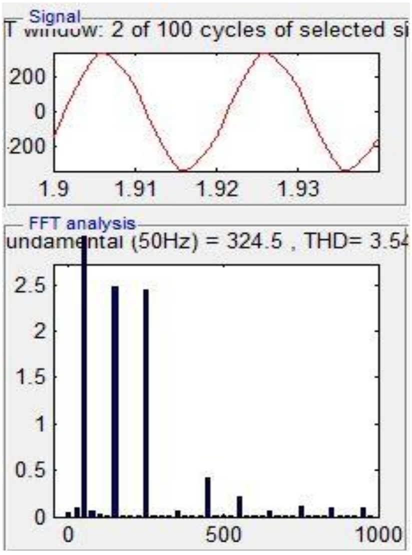

Fig. 9. FFT analysis of output voltage.

Fig. 9 shows the FFT analysis of output voltage. THD is found to be 3.5%.

V. CONCLUSION

A photovoltaic system based on quasi Z source inverter (QZSI) connected to a single phase grid is introduced. An appropriate control structure was suggested for application of QZSI connected to the single phase grid.
This system injects the PV power to the grid with a single Stage. Quasi-Z- Source inverter inject current in phase with voltage, thus unity power factor is obtained. Single stage conversion reduces cost and the efficiency is improved. Capacitor C_2 in QZSI require lower rating compared with ZSI capacitor C_2.

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BIOGRAPHIES

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