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Simulation of PV Powered Impedance Source Inverter (ZSI)

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Introduction

Generally, the PV panel outputs low DC voltage, in order to boost the DC voltage and to convert DC voltage into AC voltage, converters are required. The impedance source inverter can perform both buck and boost operation and provide single stage power conversion. The traditional voltage source converters (VSI) or inverters (VSI) and current source inverters (CSI) have the following limitations and problems:

- They are either a boost or buck converter and cannot be a buck-boost converter, their output voltage is limited to either greater (or) smaller than the input voltage.
- Their main circuits cannot be interchangeable.
- They are vulnerable to EMI noise in terms of reliability.

The Z-Source converter presented by F.Z .Peng (2003), the above mentioned conceptual and limitations of VSI and CSI and provides single stage power conversion.

This chapter deals with analysis and modeling of impedance source inverter. This chapter also evaluates the performance of PV powered impedance source inverter through simulation using Mat lab/Simulink. The ZSI is simulated for different solar irradiation levels. The objective of the work is to obtain higher output voltage and minimize the THD content in the output current.

3.2 ZSI

The circuit diagram of three-phase ZSI is shown in Figure.1. Equivalent circuit of Z source inverter viewed from the dc link is delineated in Fig.2. Equivalent circuit of Z source inverter viewed from the dc link when the inverter bridge is in the shoot through zero stage is delineated in Fig.3. Equivalent circuit of Z source inverter viewed from the dc link when the inverter bridge is one of the eight non shoot through zero switching state is delineated in Fig.4. Two inductors and two capacitors form the LC impedance network. This network can perform both buck and boost operation. The VSI has eight switching states, six active states and two non-shoot through states. Non-shoot though state exist when the inverter load terminals are shorted by either upper or lower three switches and its circuit shown in figure. But the ZSI has nine switching states, one extra state known as shoot through zero state exist when the load terminals are shorted by both upper and lower switches, any one of the phases or any two of the phases or all the three phases and its circuit shown in figure.

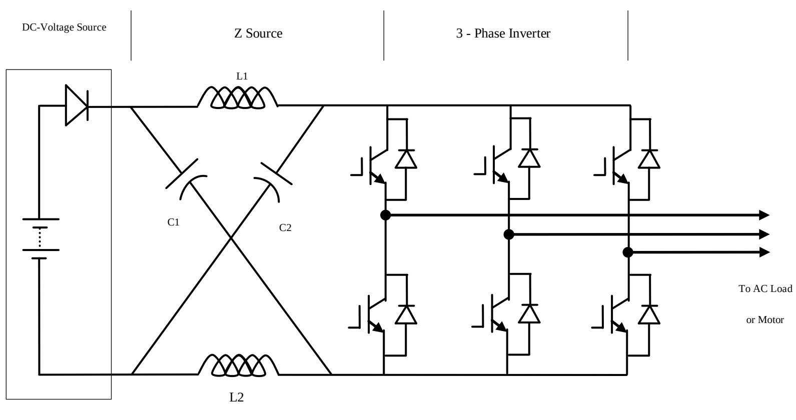

Fig.1. Circuit diagram of three phase ZSI

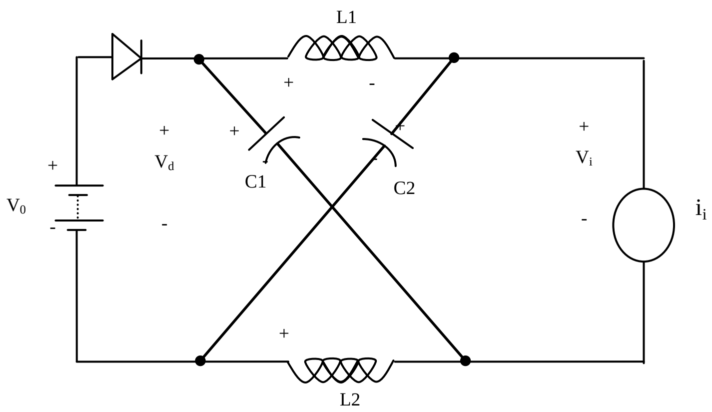

Fig.2. Equivalent Circuit of the Z Source Inverter viewed from the dc link

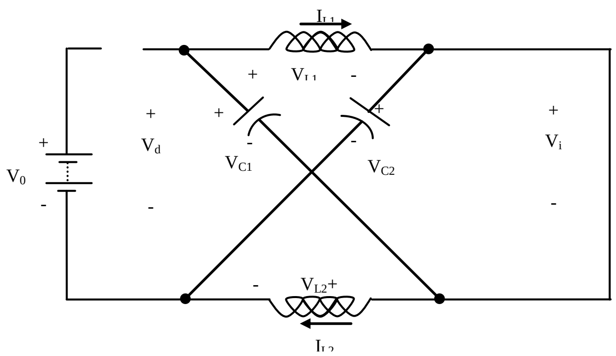

Fig.3. Equivalent Circuit of the Z Source Inverter viewed from the dc link when the inverter bridge is in the shoot-through zero state.

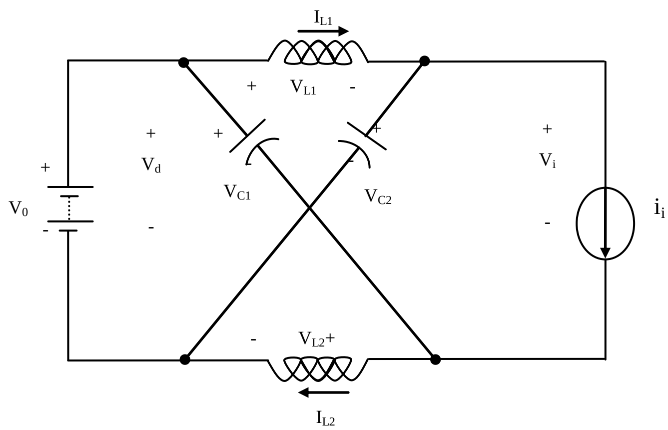

Fig.4. Equivalent Circuit of the Z Source Inverter viewed from the dc link when the inverter bridge is in one of the eight non-shoot-through zero switching state.

Three-phase ZSI -Circuit Analysis

The Z-network is designed by assuming $L_1 = L_2 = L$ and $C_1 = C_2 = C$, so that the network performs as a symmetrical network. Therefore, from the equivalent circuit we can write,

$$V_{C1} = V_{C2} = V_C$$

$$v_{L1} = v_{L2} = v_L \text{……….……………..(3.1)}$$

During the shoot-through zero state for an interval of T_0, the inverter bridge is equivalent to a short circuit and no voltage impressed across the load, the inductors present in the network are charged by the capacitors. This shoot through zero state provides the unique buck-boost capability. By adjusting the time period for shoot through state, the buck-boost operation is performed. PWM technique used to control the output voltage of VSI is modified by allocating shoot through zero states without changing the total zero-time interval to control the output voltage of ZSI.

$$v_L = V_C$$

$$v_d = 2V_C$$

$$v_i = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.2)}$$

The inverter bridge is equivalent to the current source, during its six active states and the stored energy of the inductors and DC source voltage are transferred to the load, thus performing the boost operation. During the non-shoot through zero state, the inverter bridge is equivalent to a current source with zero value. The expression for Voltage across the inductors and capacitors are given as,

$$v_L = V_0 - V_C$$

$$v_d = V_0$$

$$v_i = V_C - v_L = 2V_C - V_0 \ldots\ldots\ldots\ldots \text{(3.3)}$$

$$V_L = \overline{v_L} = \frac{T_0.V_C + T_1.(V_0 - V_C)}{T} = 0 \ldots\text{..(3.4)}$$

$$\frac{V_C}{V_0} = \frac{T_1}{T_1 - T_0} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.5)}$$

The peak value of dc-link voltage is written as,

$$\widehat{v_i} = V_C - v_L = 2V_C - V_0 = \frac{T}{T_1 - T_0} V_0 = B.V_0 \ldots\ldots\ldots\ldots\ldots\ldots \text{(3.7)}$$

Where B is the boost factor, T_0/T is the shoot-through duty ratio

$$B = \frac{T}{T_1 - T_0} = \frac{1}{1 - 2\frac{T_0}{T}} \geq 1, \ldots\ldots\ldots\ldots \text{(3.8)}$$

The output peak phase voltage of the inverter is given by

$$\widehat{v_{ac}} = M.\frac{\widehat{v_i}}{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.9)}$$

$$\widehat{v_{ac}} = M.B.\frac{V_0}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.10)}$$

Where M is the modulation index and Buck-boost factor is given by the following expression.

$$B_B = M.B = (0 \sim \infty) \quad \ldots\ldots\ldots\ldots\text{.... (3.11)}$$

Voltage across the capacitors can be expressed as,

$$V_{C1} = V_{C2} = V_C = \frac{1 - \frac{T_0}{T}}{1 - 2\frac{T_0}{T}} V_0 \ldots\ldots\ldots\ldots \text{(3.12)}$$

4.Simulation results of ZSI

Z-source inverter with motor load for Different Solar irradiation is shown in Figure .5. The output voltage of PV system is shown in Figure .6. and its value is 47.5 Volts, this voltage is applied to ZSI. The value of inductors present in the Z-network are L1= L2= 2mH and the capacitors C1= C2= 2μF. Output voltage of Z-Source network is shown in Figure .7. Output-voltage network of Z-source inverter is shown in Figure.8. The inverter current waveforms is shown in Figure .9.and its peak value is 8 Amperes.

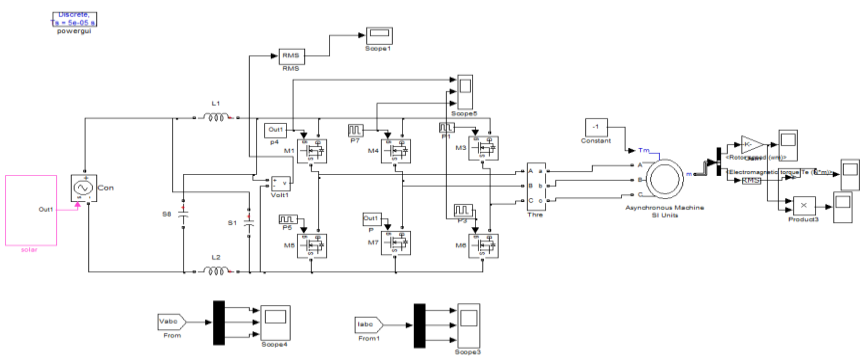

Fig.5. Simulation circuit of Three phase Impedance Source Inverter.

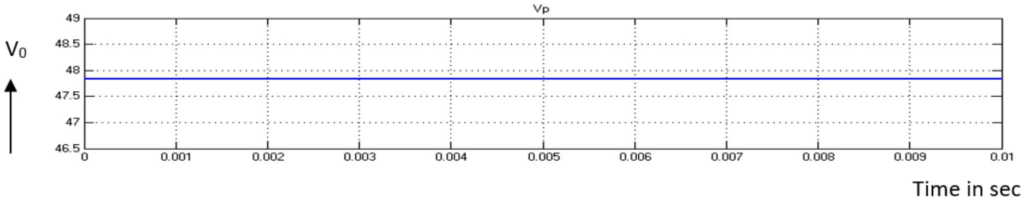

Figure .6. Output voltage of solar system

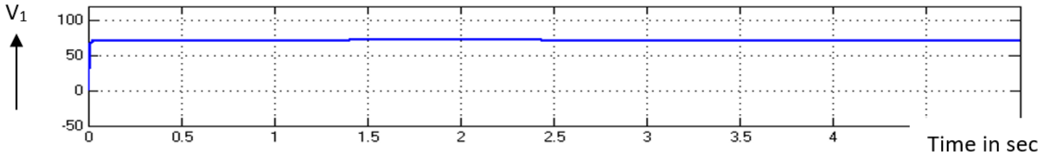

Figure .7. Output voltage of Z-Source network

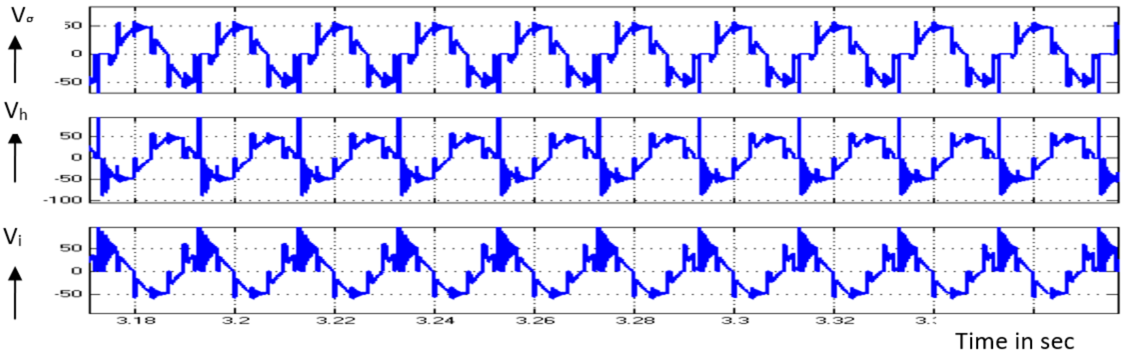

Figure .8. Output voltage waveforms of inverter

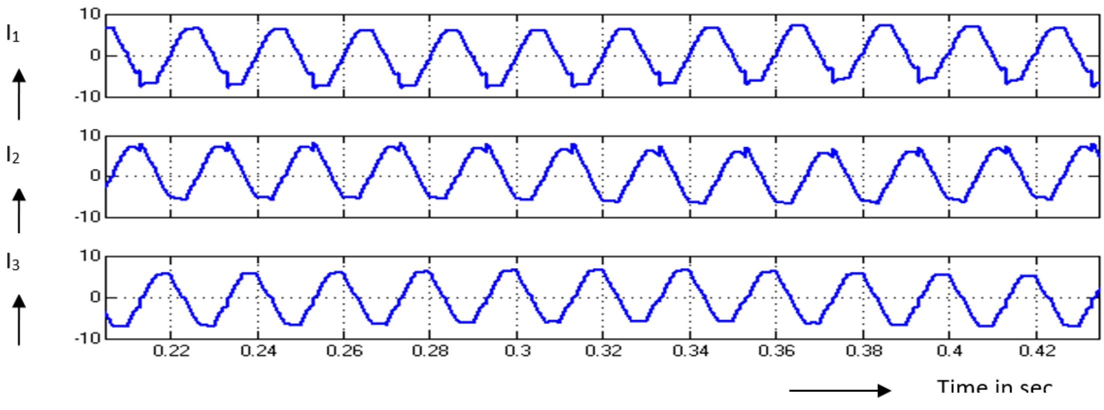

Figure .9. Output current waveforms

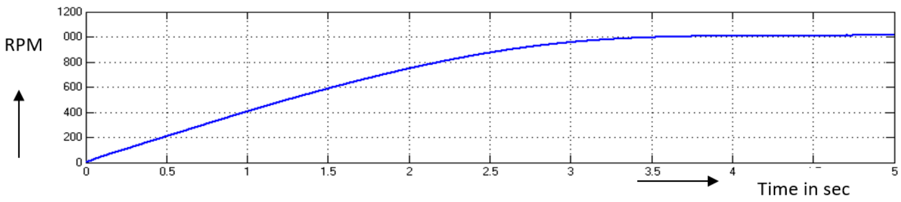

Figure .10. Motor speed

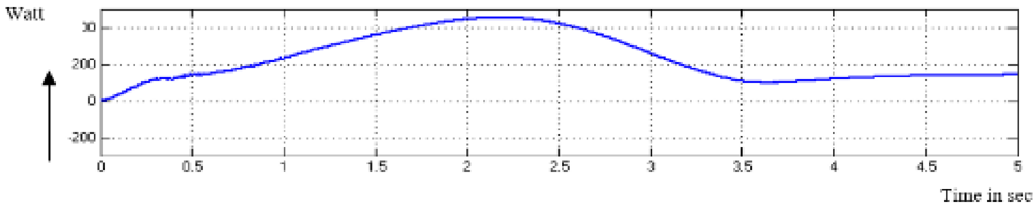

Figure .11. Output Power

he motor speed is shown in Figure .10. The speed settles at 1000 RPM. The output power developed is shown in Figure 3.15. The Power settles at 180 watts. The frequency spectrum for output current is shown in Figure 3.16 and THD is 8.75%.

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