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PV Connected Z-source Inverter for Grid

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ABSTRACT
This paper presents a proposed model of Impedance-Sourced Inverter (ZSI) for the Three-Phase PV System which is further connected to the grid. ZSI implements shoot-through mode for controlling output voltage which differs from conventional VSI. Shoot through mode is implementing in ZSI for performing the buck-boost operation on Input Voltage by modification of the conventional PWM Technique. Power Conversion of Single Stage is achieved by the Z-source circuitry. This paper recaps the design of Capacitors and Inductors used in the circuit. Validation of designed parameters is achieved by simulating the PV module in the MATLAB/Simulink platform.

Keywords - PV Module, Z-source Inverter (ZSI), Shoot-through Boost Control

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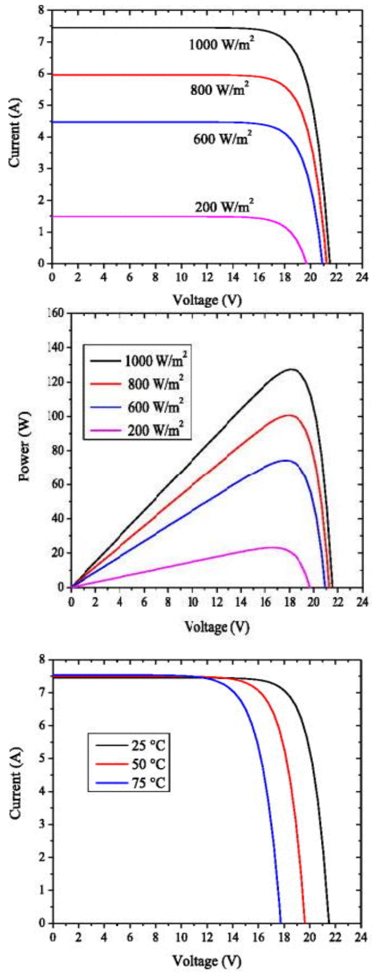
I. INTRODUCTION

Now a day, Distributed Generation is on trending way for micro-grid development. One kind of Distribution Generation can be obtained from DC power through Photovoltaic panels. This paper presents a proposed model of Three-Phase ZSI for the conversion of DC power output from the Photovoltaic Panel to AC Power. For modification in conventional PWM technique Simple Boost Control method is utilized. Many papers present the methods of achieving the value of maximum output power from the photovoltaic (PV) panel. Various methods are there for tracking up the output of maximum power from the solar panel.

II. PV Panel

The photovoltaic panel is made up of series or parallel combinational string of Photovoltaic (PV) array consisting of PV cells made up of Semiconductor material. For achieving required voltage level, required current, and required power of load these PV modules are combined in series or parallel combination.

The Solar Insolation and temperature required for PV cells are continuously varied. Therefore, the power getting from the PV panel is of fluctuating nature. So, the Current-Voltage (IV) curve and Power Voltage (PV) curve of the PV array appears in non-linear nature. The fluctuations in Solar Insolation and temperature are creating changes in the IV and PV curve of Solar panel which are as shown in fig. (1)



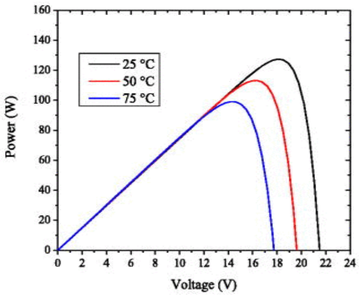


Fig (1) Effect of insolation and temperature on IV and PV curve of solar cell

On this both IV and PV curve, there exists one specific point at which power getting from Solar Panel is in the maximum amount. That point is called the Maximum Power Point of the Solar Photovoltaic module (MPP).

Many processes are carried out on the output Power from Solar PV panel of dc form before feeding into the Grid. For this purpose, the Power Conditioning Unit (PCU) is used. This PCU is Boost up the DC voltage from the PV Panel and convert it into fixed frequency AC Voltage. Maximum Power getting from PV Panel is also extracted by PCU.

III. Z-SOURCE INVERTER.

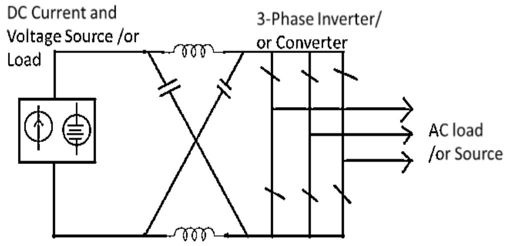
The Common Disadvantage of VSI and CSI are:

1) They cannot act as a Buck and Boost Converter at a time. Therefore, the voltage at the output is confined to more or lesser than the voltage fed at the input.

2) The circuits of VSC and CSC cannot be alternate because the main circuit of the Voltage Source Converter (VSC) cannot be utilized for the Current-Source converter (CSI).

3) The working of Conventional VSI and CSI is get affected due to Electromagnetic Interference (EMI).

The above disadvantages are overcome by using the Impedance Source Inverter (ZSI). The Structure of Impedance source Inverter is sectionalized into three parts. The first part is of DC Input Source. DC Supply can be achieved from Battery, Fuel Cell, Renewable Energy Sources like Solar. The second part consists of the Impedance circuitry. The Impedance Circuitry is formed by connecting L and C Pair in Cross-Shape (X-Shape). This Impedance Network Provides Buck and Boost operation of Input DC Voltage. The third part Comprises of Three leg bridge circuit where sinusoidal ac voltage is achieved at the Secondary Side.



F Impedance Circuitry of ZSI

As Input Source DC Voltage is passing through Impedance network before feeding up to the Three leg bridge circuit, This Inverter is known as Impedance Source Inverter.

IV. OPERATION OF ZSI

The working of ZSI is based on the following 3 modes:

1) Active state: Similar to the traditional inverter system, ZSI consists of Six active states. During these active states, a dc voltage is given as input to the circuit, and ac voltage is achieved across the load.

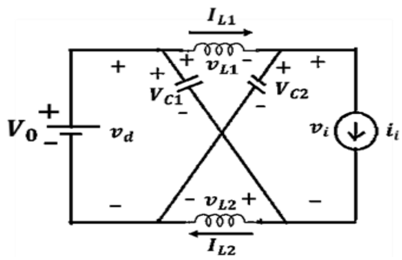


Fig (3) Active State of ZSI

2) Zero state: ZSI can be operated in Two zero states. During these zero states, the load terminals are short by a positive upper group and negative lower group switches respectively.

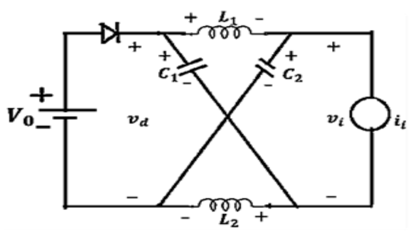


Fig (4) Zero State of ZSI

3) Shoot-through zero state: ZSI operates one shoot-through state. For these shoot-through states, there are seven ways of shorting the load terminal by using an upper switch and lower switch pairs of similar phase leg turning on at a time.

These shoot-through zero states provide a special feature of Boosting the Voltage Level. Therefore, it is called a shoot-through state.

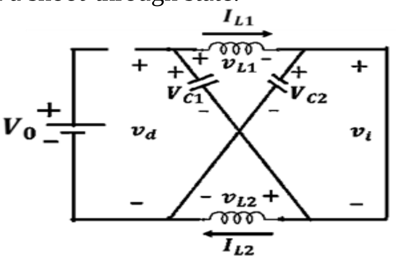


Fig (5) the Shoot-through State of ZSI

V. EXPRESSIONS FOR ANALYSIS OF ZSI CIRCUITRY AND OUTPUT VOLTAGE

Consider two inductors L1 and L2 of equal inductance ratings and capacitors C1 and C2 of equal capacitance ratings. Thus, the impedance-sourced network appears to be symmetrical. So, from the equivalent circuit and according to symmetry, we have

$$V_{C1} = V_{C2} = V_C;\ V_{L1} = V_{L2} = V_L \quad (1)$$

During the shoot-through zero states, from the equivalent circuit

$$V_L{=}V_C V_d{=}2V_C V_i{=}0 \quad (2)$$

Now, Suppose that the bridge inverter system is in one of the non-shoot-through states out of the eight non-shoot-through states. From the equivalent circuit

$$V_L = V_o - V_C V_d = V_o V_i = V_C - V_L = 2V_C - V_o \quad (3)$$

Where V_o is noted as a dc voltage of the source

Total time, $T = T_o + T_1$

In steady-state condition, the mean value of voltage appearing across the inductors is to be zero, from (2) and (3), thus

$$V_L = \frac{T_0.V_C + T_1.(V_0 - V_C)}{T} = 0 \quad (4)$$

Or

$$\frac{V_C}{V_O} = \frac{T_1}{T_1 - T_0} \quad (5)$$

Also, the mean value of voltage appearing across dc-link and the bridge of inverter is given out by expression:

$$V_i = \frac{T_0.0 + T_1.(2V_C - V_0)}{T} = \frac{T_1}{T_1 - T_0} V_O = V_C \quad (6)$$

So, by implementing equation (6) in equation (3), and can be rewritten as

$$V_i = V_C - V_L = 2V_C - V_O = \frac{T}{T_1 - T_0} V_O = \text{B}.V_O \quad (7)$$

Where,

$$\text{B} = \frac{T}{T_1 - T_0} = \frac{1}{1 - 2\frac{T_0}{T}} \geq 1 \quad (8)$$

B is noted as a boosting factor which can be obtained from switching of shoot-through zero states. On another side, maximum phase voltage from the inverter at the output side can be provided as,

$$v_{ac} = M.\frac{V_0}{2} \quad (9)$$

Where M is noted as a modulation index. From equation (7), and equation (9) it can be written as,

$$v_{ac} = M.B.\frac{V_0}{2} \quad (10)$$

In Conventional PWM Voltage-Source Inverter (VSI), there is one common expression

$$v_{ac} = M.\frac{V_0}{2}$$

From Equation (10) it is getting that the voltage at the output side can be raised (Boost) or stepped down (Buck) by selecting a proper buck-boost factor B_B,

$$B_B = M.B = (0\sim\infty) \quad (11)$$

The voltage appearing across the z-source network capacitor from equations (1), (5), and (8), can be obtained by an expression,

$$V_{C1} = V_{C2} = V_C = \frac{1 - \frac{T_0}{T}}{1 - 2\frac{T_0}{T}} V_O \quad (12)$$

The bucking factor or boosting factor is to find out from the modulation index. By controlling the duty cycle provided for shoot-through zero states, the Boost factor in equation (8) can be controlled. Main Point here is that the PWM controlling of an inverter cannot be affected by Shoot- through zero state, due to there is an equal production of zero voltage across the load side terminal. Limitation on the shoot-through switching period is provided from the period for zero states which can find out from modulating index value.

VI. SHOOT-THROUGH CONTROL METHOD

For controlling the operational characteristics of Z-source Inverter, controlling methods for Shoot through the state are implemented. This shoot-through control it has four different methods.

1. Simple-Boost Control (SBC)
2. Maximum-Boost Control (MBC)
3. Maximum Constant Boost Control (MCBC)
4. Modified Space vector modulation Boost Control

The Amplitude Modulation ratio (Modulation Index M) is the main control factor and it is expressed as a ratio of the maximum peak value of the Reference wave signal to the maximum peak value of the carrier wave signal.

$$\text{M} = \frac{V_{ref}}{V_{car}}$$

The control on output result voltage is achieving by using the Modulation Index (M <1).

Here, the Simple Boost Control method is used to boost up the voltage level. In the Simple Boost Control method, Two straight lines mark the Shoot-though Duty Ratio Do. The value of the first line is the same as the value of the positive peak of the Reference Sinewave voltage signal and the value of another line is the same as the negative peak of the Reference Sinewave voltage signal. When the amplitude of the triangular wave is more than first-line and lesser than the second line, then the shoot-through state is implemented in the Circuit.

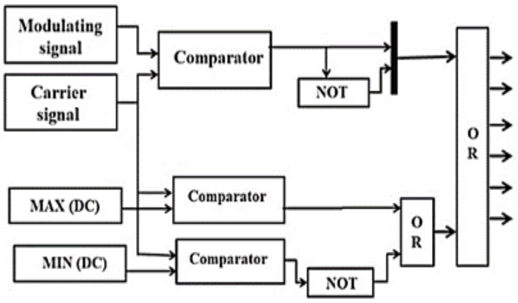


Fig (6) Block Diagram of Simple-Boost Control (SBC)

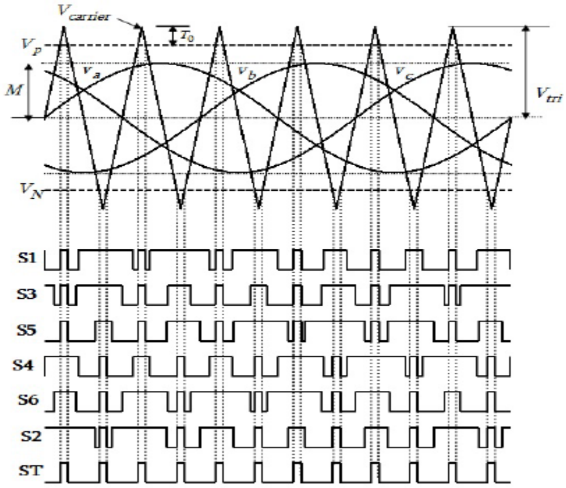


Fig (7) Simple-Boost Control (SBC) Pulses

VII. SIMULATION AND RESULTS:

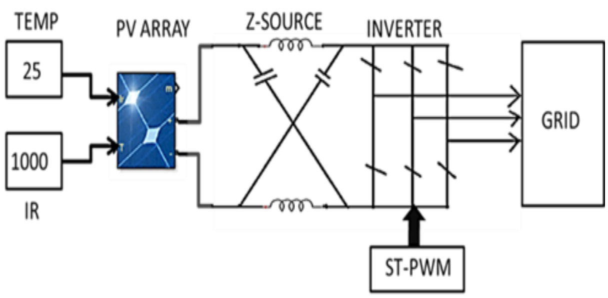


Fig (8) Simulink model of PV Connected ZSI

For validation of results, PV System and Z-source converter are modeled in MATLAB/Simulink. PV module gives output voltage Vdc ≈ 180V.

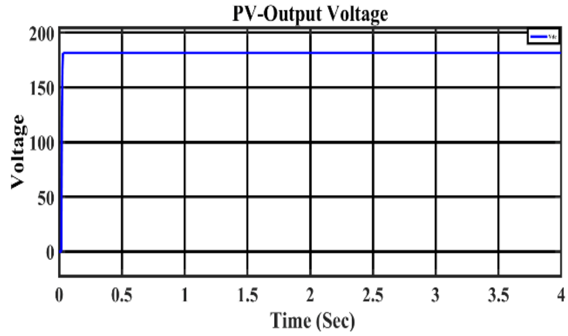


Fig (9) Output Voltage of PV Module

The parameters used for this model are as follows: L1=10mH, L2=10mH, C1=100µF, C2=100µF. The motto to be achieved behind this system is a generation of 3ph, 415V, 50Hz Voltage from PV System by using Boost factor Control in Impedance Source Inverter (ZSI).

The resultant voltage appearing across the capacitor of the Z-source network is as shown in fig (10). This Voltage level is boosted up to 614V. The Modulation Index used for Boost control is 0.8 and the switching frequency is 10 kHz.

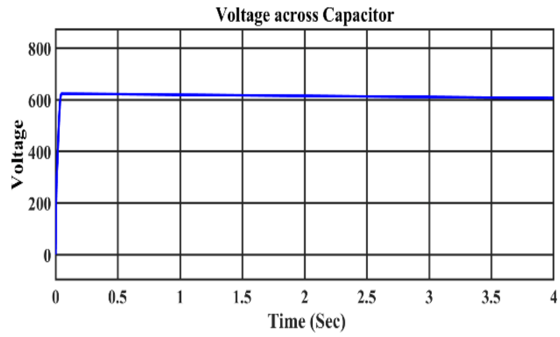


Fig (10) Voltage across Capacitor

From the inverter system, 415V RMS ac voltage is get between two phases. The three combinations of line voltage waveforms are as shown below:

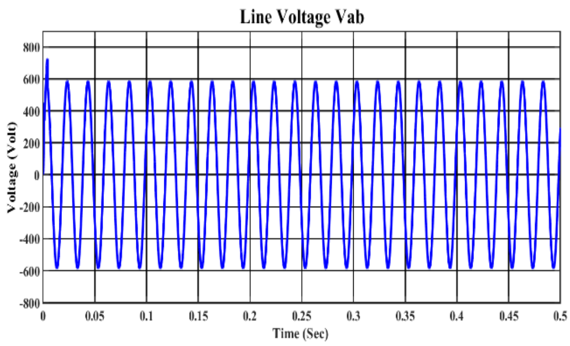


Fig (11) Line Voltage Vab

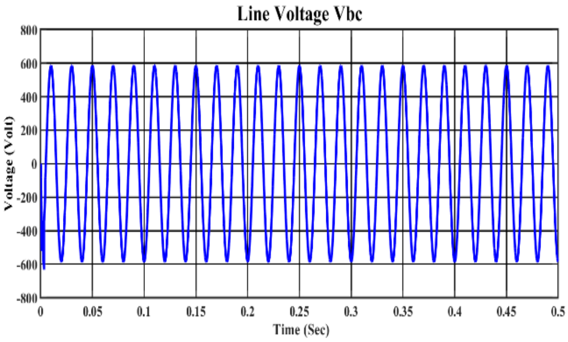


Fig (12) Line Voltage Vbc

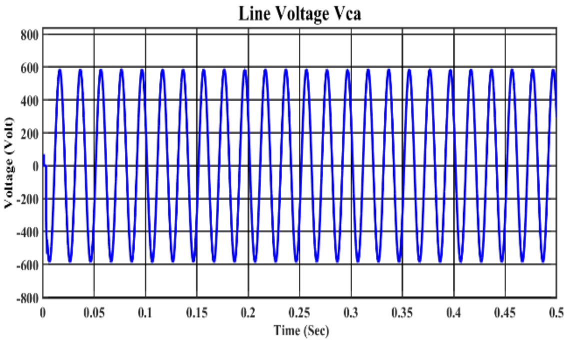


Fig (13) Line Voltage Vca

The output voltage got from the Inverter system is further provided to a step-up transformer of 415V/11kV rating. This stepped-up voltage is injected into an 11kV grid. The Grid Voltage waveform is as follows:

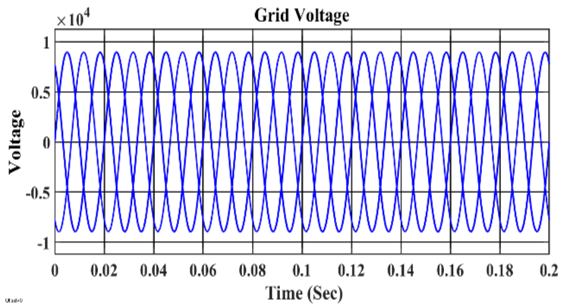


Fig (14) Grid Voltage

VIII. CONCLUSION

Z-source Inverter faded by Solar PV array is Proposed in this work. From this work, it is concluded that the Overall system is Simple and Sophisticated in an arrangement. It provides easier control arrangement for controlling output voltage and Operational Characteristics. As ZSI Circuitry gives Boosting up Voltage Level so One more Power Stage of Boost Chopper is Avoided. Sine Wave Output is achieved at Inverter Secondary Side which can be injected into the Grid. All the Output Waves are validated on MATLAB Simulink Platform.

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