Indian Journal of Science and Technology, *Vol 9(26), DOI: 10.17485/ijst/2016/v9i26/92210, July 2016*

ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Comparative Analysis of PWM Controlling Techniques of Single Phase Z-Source Inverter

R. Sivapriyan* and S. Umashankar

SELECT, Vellore Institute of Technology, Near Katpadi Road, Vellore – India; sivapriyan@gmail.com, umashankar.s@vit.ac.in

Abstract

Background/Objectives: This paper analysis the various PWM controlling Techniques of Single Phase Z-Source Inverter (ZSI) and suggest the most suitable controlling technique for renewable power conversion applications. **Methods/Statistical Analysis**: This ZSI is the Buck-Boost Inverter. The boost in the output voltage can be controlled by Shoot-Through (ST) zero state. This ST zero state can be controlled by Simple Boost Control (SBC), Maximum Boost Control (MBC) and Constant Boost Control (CBC) methods. The performances of the controlling techniques are investigated against the simplicity in control technique, harmonic content and the peak value of output voltage. The controlling techniques are validated by simulation of the circuits in Simulink. **Findings:** The MBC method is the simplest one to implement but voltage stress across the switches is high. The CBC method gives a higher voltage gain but implementing the Shoot-Through envelope is difficult. In SBC method Voltage stress across the switches is less but voltage gain is less. The Photo Voltaic Energy conversion system requires high voltage gain with reduced harmonic content in the output. Therefore, the CBC method is suitable for the Solar PV system to provide higher voltage gain with less harmonic content in the output voltage. **Application/Improvements:** The CBC method gives higher voltage gain with less harmonic content in the output voltage, therefore it is most suitable for the standalone Solar PV system.

Keywords: PWM, Shoot-Through, Voltage Gain, ZSI

1. Introduction

The Voltage Source Inverter (VSI) is the buck inverter, where output voltage will be always less than the input voltage. The Current Source Inverter (CSI) is the boost inverter, where output voltage will be always greater than the input[1]. The Z-Source Inverter (ZSI) is the buck-boost inverter, where the output voltage can be varied from zero to infinite[2]. This Single phase ZSI consists of a normal two leg inverter with an impedance source connected between the input DC voltage and the inverter main circuit. This impedance source consists of a split inductor and a split capacitor connected in X-shape.

The buck-boost in the output voltage is achieved by introducing a non-active state called Shoot-Through (ST) zero state. Without ST zero state the Z-Source inverter will act as a normal VSI. The ST zero state can be achieved by triggering the switches present in the same leg. During this ST zero state periods, the impedance source will store the energy and during normal active state the stored energy will be released, so that the output voltage across the load will be increased. The output voltage gain is controlled by controlling the ST zero state. The reverse power flow from Z-Source to DC source will be avoided by placing a diode between the input DC voltage and the Z-Source. The ST zero state can be produced by using three techniques, namely Simple Boost Control (SBC), Maximum Boost Control (MBC) and Constant Boost Control (CBC) method[2-4].

2. Voltage Gain

The output voltage of the Single phase ZSI can be expressed as

*Author for correspondence

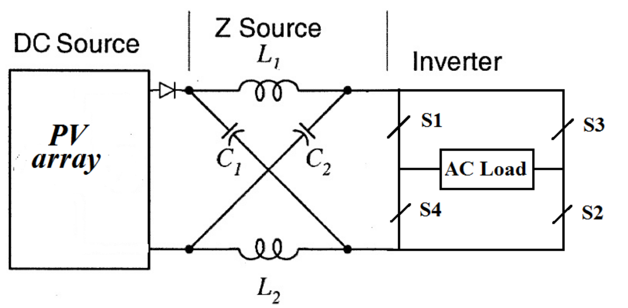


Figure 1. Single Phase ZSI.

$$V_{ac} = MB\frac{V_{dc}}{2} \tag{1}$$

Where, V_{ac} is the output ac voltage, V_{dc} is the input dc voltage, M is the modulation index and B is the boost factor[2]. This boost factor can be determined by

$$B = \frac{1}{1-2\frac{To}{T}} \tag{2}$$

Where T is switching cycle and T_o is the Shoot-Through time interval. By using the above two formula, the voltage gain (G) of the ZSI can be determined as

$$G = MB = \frac{V_{ac}}{\left(V_{dc}/2\right)} = \frac{M}{2M-1} \tag{3}$$

3. PWM Controlling Techniques

The Single Phase ZSI can be controlled by using three techniques, namely Simple Boost Control (SBC), Maximum Boost Control (MBC) and Constant Boost Control (CBC) method.

3.1. Simple Boost Control (SBC)

In SBC method a carrier wave is compared with sine wave to produce the active and non-active state; and again the same carrier wave is compared against a constant reference line to produce ST zero state. Whenever the carrier wave is greater than the constant reference line switches in the same leg will be turned ON to get ST zero state. By moving the constant reference line up and down, the ST time will be increased or decreased.

3.2 Maximum Boost Control

In MBC method a carrier wave is compared with a sine wave to produce the active and ST zero state. Whenever the carrier wave is greater than the sine wave then the switches in the same leg will be turned ON to get ST zero state. If the carrier wave is less than the sine wave then it will produce pulse like normal Sine PWM. In this method ST zero state intervals will be large enough to produce maximum voltage gain. In MBC method the non-active state is absent. This method is simple to implement.

3.3. Constant Boost Control (CBC)

In CBC method a carrier signal is compared with sine wave to produce the active and non-active state and also the same carrier wave is compared with ST envelope signal to produce the ST zero state. Whenever the carrier wave is less than the sine wave then normal Sine PWM pulses will be produced. But if the carrier wave is greater than the ST envelope signal the switches in the same leg will be turned ON to get ST zero state. This method is difficult to implement since the generation of ST envelope signal is quite difficult.

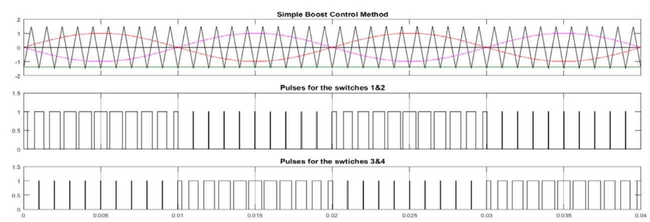


Figure 2. Simple Boost Control.

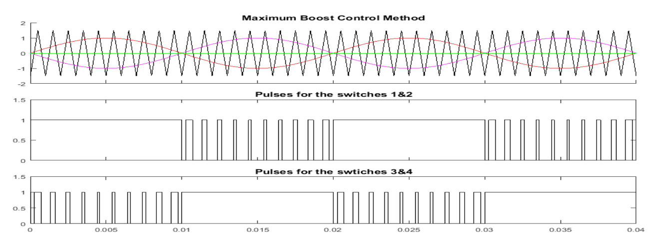


Figure 3. Maximum Boost Control.

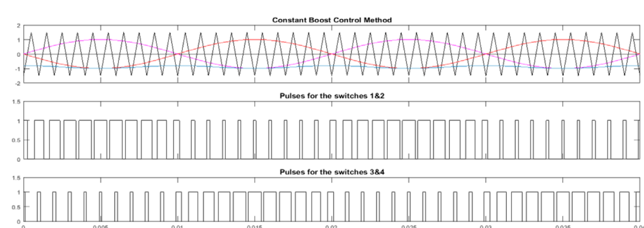


Figure 4. Constant Boost Control.

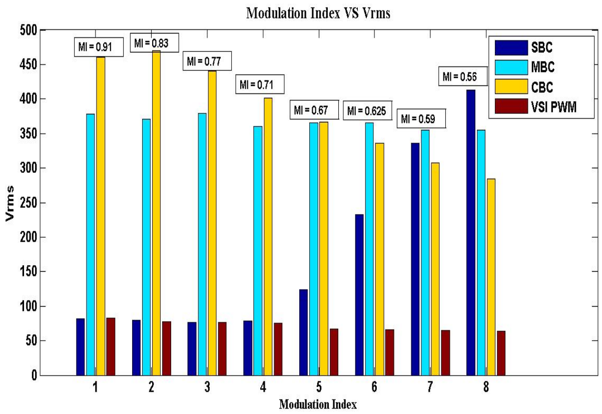


Figure 5. Modulation Index (M.I) vs. Vrms.

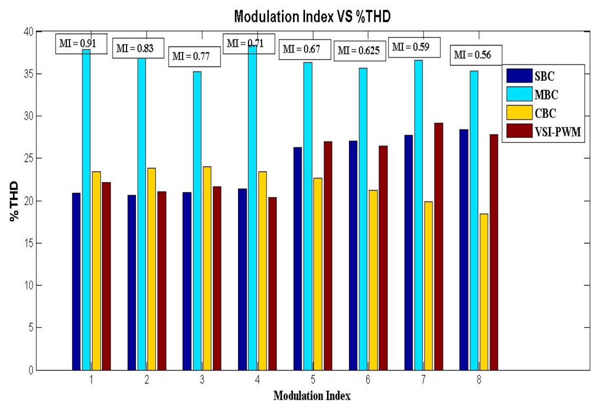


Figure 6. Modulation Index vs. %THD.

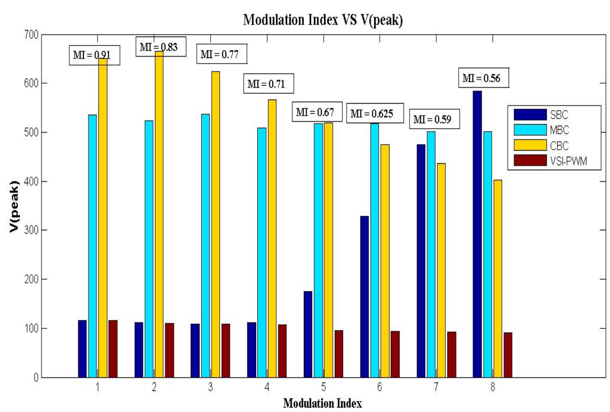


Figure 7. Modulation Index vs. Vpeak.

The three modulation concepts SBC, MBC, CBC has been verified in Matlab/Simulink simulation for the impedance source values of L1=L2=160μH and C1=C2=1000μF. The input DC voltage is fixed at 100V for different Modulation Index. In each method the Modulation Index is varied and correspondingly the rms value, peak value and the %THD content of output voltage. The outcome of the simulation is plotted for different values of Modulation Index along with the normal Voltage Source Inverter (VSI).

4. Conclusions

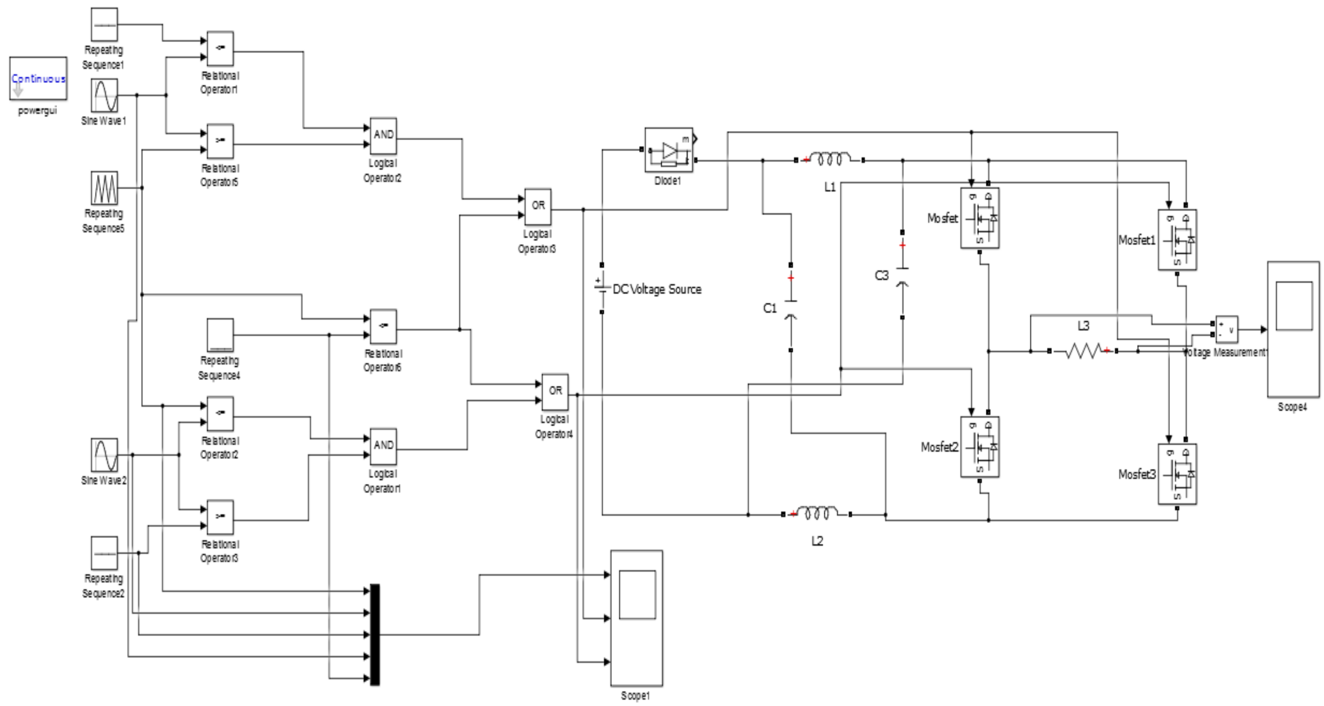
The three modulation concepts SBC, MBC, CBC have been verified in Matlab/Simulink simulation. The CBC method gives a higher voltage gain but the peak voltage is very high which results in very high voltage stress across the switches. The SBC gives moderate voltage gain. The MBC achieves higher voltage gain with reduced peak voltage which results in a less voltage stress across the switches compare with MBC and good voltage gain when compare with SBC method. Harmonic content in the MBC method is higher when compare with the other two methods. The Photo Voltaic Energy conversion system requires high voltage gain with reduced harmonic content in the output. Therefore, the CBC method is suitable for the Solar PV system to provide higher voltage gain with less harmonic content in the output voltage.

5. References

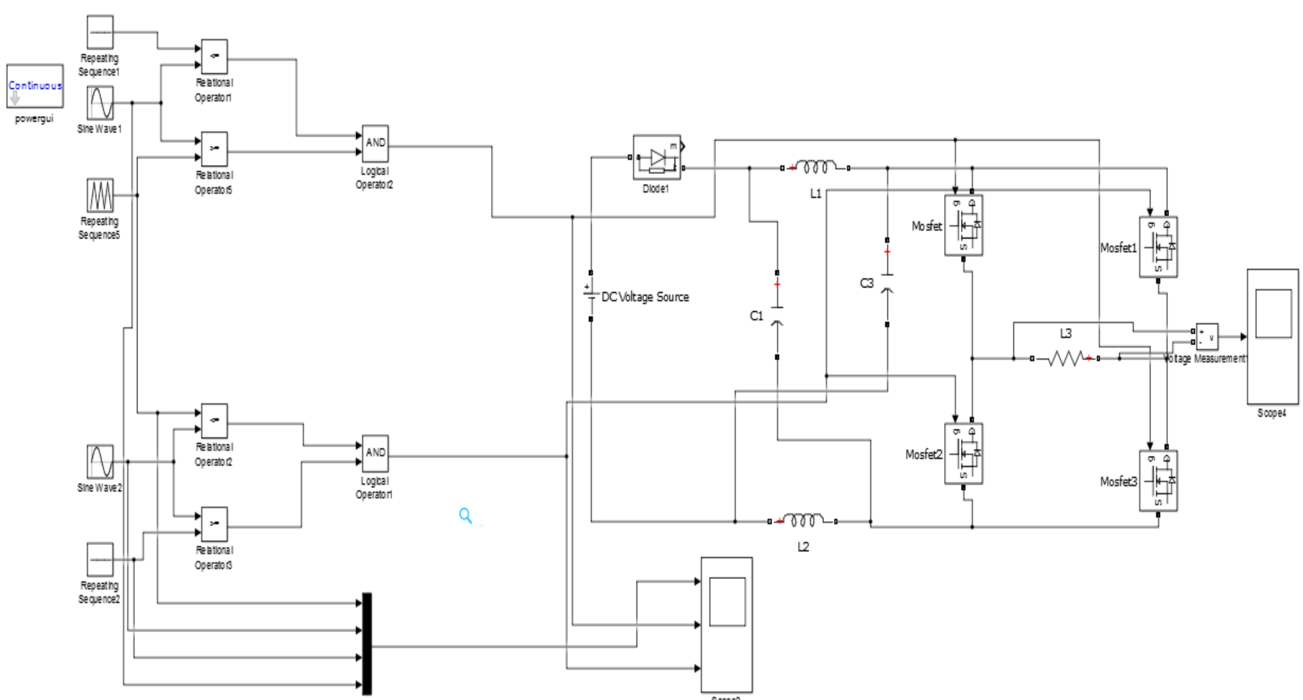
1. Rashid MH. Englewood Cliffs, NJ: Printice-Hall: Power Electronics, 2nd ed. 1993.
2 Peng FZ. Z-source inverter. IEEE Trans. Ind. Application. 2003; 39(2):504-10.
3. Peng FZ, Shen M, Qian Z. Maximum boost control of the Z-source inverter. IEEE Trans. Power Electronics. 2005 July; 20(4):833-38.
4. Shen M, Wang J, Joseph A, Peng FZ, Tolbert LM, Adams DJ. Constant boost control of the Z-source inverter to minimize current ripple and voltage stress. IEEE Transaction on Industrial Applications. 2006 May/June; 42(3):770-78.

Appendix

Appendix 1.Matlab/Simulink Simulation of Simple Boost Control (SBC).



Appendix 2.Matlab/Simulink Simulation of Maximum Boost Control (MBC).



Appendix 3.Matlab/Simulink Simulation f Constant Boost Control (CBC).