



STUDY, MODELLING & SIMULATION OF Z SOURCE INVERTER WITH DIFFERENT CONTROL METHODS

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ABSTRACT:

This paper presents a comparative study between different control methods of ZSI (Z-source inverter). Z source inverter has a unique feature so that it can overcome the limitation of traditional voltage and current source inverter. The different control methods are simple boost control method, maximum boost control method with third harmonic injection control. The relationship between voltage gain versus modulation index and THD are analyzed in detail. Simulation results are obtained by using MATLAB/SIMULINK.

KEYWORDS: *Boost Factor, Current Source Inverter, Impedance Source, Modulation Index, Voltage Source Inverter.*

1. INTRODUCTION

The z-source inverters are having the single stage buck-boost conversion facility. The network is having a unique impedance circuit which couples the main circuit of converter with source for obtaining a particular characteristic which cannot be achieved by traditional voltage source inverter (VSI) and current source inverter (CSI).

Both the V-source converter and the I-source converter have the following common problems.

- Their main circuits cannot be interchangeable.
- They are sensitive to EMI noise in terms of reliability.
- They can be either a buck converter or boost converter, they cannot be a buck-boost converter at the same time.

These limitations can be overcome by the z source inverter. 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. Thus, it provides a low-cost, reliable, and highly efficient for buck and boost power conversion. The reliability of the ZSI can be improved.

Many control methods have been developed by controlling the duty ratio of shoot through. The simple boost control is presented in [11]. Maximum control method is explained in [12].



There are two parameters to be changed in order to get desired output AC voltage in Z source inverter. The first one is the modulation index, which also exists in traditional voltage source inverters. The second one is the Boosting factor, which depends on the shoot through time. Theoretically, modulation index can take values from zero to one, while the Boosting factor can take values from one to infinity. So the multiplication gives desired voltage at the output. These two parameters are considered while designing three phase Z source inverter and their control strategies. In this paper, a comparative study of different control strategy of z source inverter is held.

Power electronics has been widely used in various applications since it was born. It plays a vital role in efficient power control and conversion but each converter has its own unique drawbacks. So in order to improve power control capability, power quality, harmonic spectrum, we decided to work in the field of power converters, hence we selected the topic of Z source inverter. Then we started searching IEEE papers regarding basics of Z source inverter, it's control strategies and practical applications.[1]

The single phase inverter which converts DC voltage / current into single phase AC voltage / current is one of the most important and popular power electronics converter. It has been widely used in uninterruptable power supplies, used in AC motor control, grid connected PV system etc. The Z-source converter employs a unique impedance network (or circuit) to couple the converter main circuit to the power source, thus providing unique features that cannot be obtained in the traditional voltage-source (or voltage-fed) and current-source (or current-fed) converters where a capacitor and inductor are used, respectively. The Z-source concept can be applied to all dc-to-ac, ac-to-dc, ac-to-ac, and dc-to-dc power conversion. Control methods for the Z-source inverter and their relationships of voltage boost versus modulation index is studied. A maximum boost control is presented to produce the maximum voltage boost (or voltage gain) under a given modulation index. The control method, relationship of voltage gain versus modulation index and voltage stress versus voltage gain are analyzed in detail.

In electrical engineering power conversion has a specific meaning, namely converting power from one form to another. Power conversion systems often incorporate redundancy and voltage regulation.

2 INTRODUCTION OF INVERTER

The increased power capabilities, ease of control, and reduced cost of modern power semiconductor devices have made converter affordable in a large number of applications and have opened a host of new converter topologies for power electronic applications. An inverter is an electrical device that converts DC power or direct current into AC power or alternating current. The converted output alternating current can be at any required voltage and frequency with the use of appropriate transformer, switching and control circuits. An inverter allow you to run electrical equipments, computers, emergency equipments, uninterruptable power supplies (UPS) in medical facilities, life supporting systems, data centers, telecommunications, industrial processing, online management system, automation applications and AC appliances for houses . when used as ups , providing uninterruptable, reliable and high quality power for vital loads become critical. They in fact add an extra layer of protection for essential loads against power outage, as well as over voltage and over current conditions.[2]

2.1.1 Introduction to Traditional Voltage Source Inverter

Figure 2.1 shows the traditional single phase voltage source inverter structure. A dc voltage source supported by a relatively large capacitor feeds the main converter circuit, a single phase bridge.

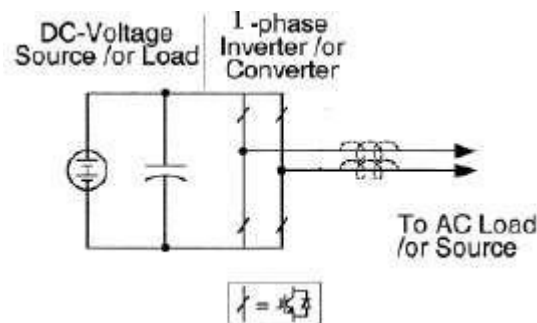
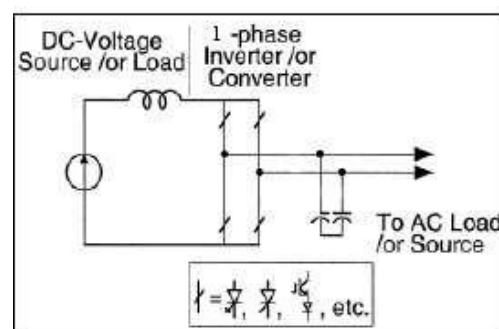


Figure 2.1.1 Traditional Voltage Source Inverter

2.1.2 Introduction of Traditional Current Source Inverter

Figure 2.1.2 shows the traditional single phase current source converter structure. DC current source feeds the main the converter circuit, a single phase bridge. [5] Each is traditionally composed of a semiconductor switching device with reverse block capability such as a gate turn off thyristor (GTO) & silicon controlled rectifier (SCR) or a power transistor with a series diode to provide unidirectional current flow and bidirectional voltage



blocking.

Fig.2.1.2 Traditional Current Source Inverter

2.1.3 Introduction of Z Source Inverter

Fig. 2.1.3 shows the general Z-source converter structure proposed. It employs a impedance network (or circuit) to couple the converter circuit to the power source, load, or another converter, for providing unique features that cannot be observed in the traditional V- and I-source converters where a capacitor and inductor are used, respectively.[6] The Z-source converter overcomes the above-mentioned conceptual and theoretical barriers and limitations of the traditional V-source converter and I-source converter and provides a novel power conversion concept.

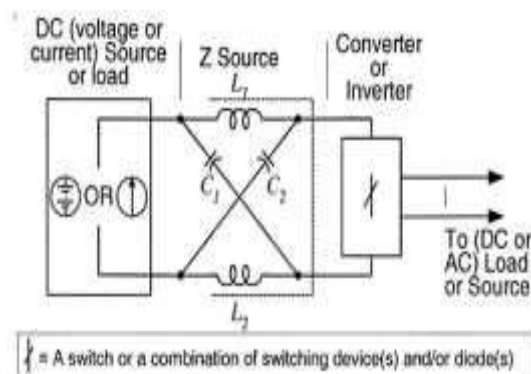


Fig. 2.1.3 General structure of Z source inverter

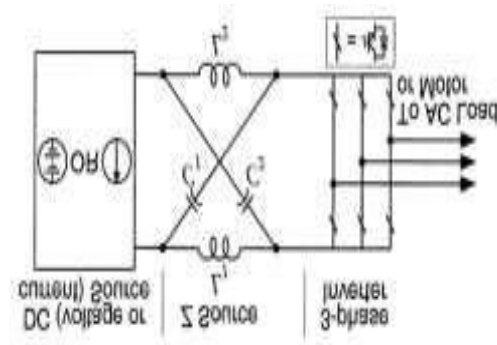


Fig.2.1.4 Z-source converter structure using the Anti-parallel combination of switching device and diode.

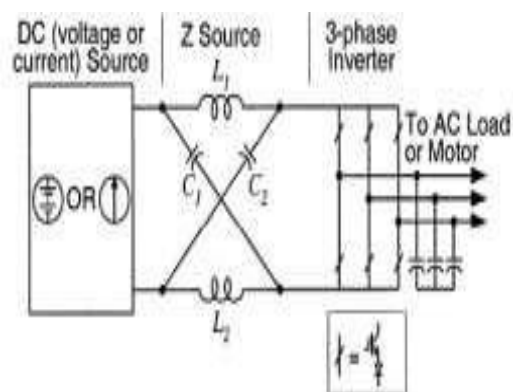


Fig. 2.1.5 Z-source converter structure using the series combination of switching device and diode

2.2 Comparison Between CSI, VSI & ZSI

Sr. no.	Current source inverter (CSI)	Voltage source inverter (VSI)	Z source inverter (ZSI)
1.	As inductor is used in the DC link, the source impedance is high. It acts as a Constant current source	As capacitor is used in the dc link, it acts as a low impedance voltage source.	As capacitor and inductor is used in the dc link, it acts as a constant high impedance voltage source.
2.	This is used in only boost operation of inverter	This is also used in only a buck operation of inverter.	This is used in both buck and boost operation of inverter.
3.	Lower efficiency because of high power loss	Lower efficiency because of high power loss	Higher efficiency because of less power loss
4.	A current source inverter is capable of withstanding short circuit across any two of its output terminals. Hence momentary short circuit on load and misfiring of switches are acceptable	A VSI is more dangerous situation as the parallel capacitor feeds more power to the fault	In ZSI misfiring of the switches sometimes are also acceptable.

Table.2.1 comparison between CSI, VSI, & ZSI

3 CONTROL STRATEGY

3.1 SIMPLE BOOST CONTROL

Following fig.(3.1.1) shows simple boost control waveform;

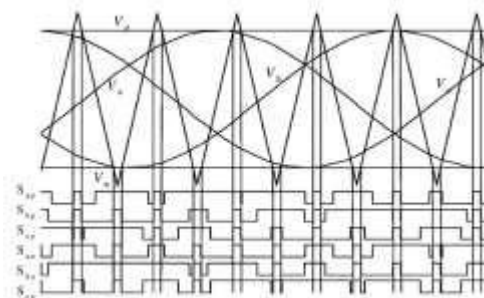


Fig.3.1.1 simple boost control waveform

The voltage gain of the Z-source inverter can be expressed as; [2]

$$\frac{V_{ac}}{V_0/2} = MB \quad (3.1.1)$$

where V_{ac} is the output peak phase voltage, V_0 is the input dc voltage, M is the modulation index, and B is the boost factor, which is determined by

$$B = \frac{1}{1 - 2\frac{T_0}{T}} \quad (3.1.2)$$

$$\frac{T_0}{T} = 0$$

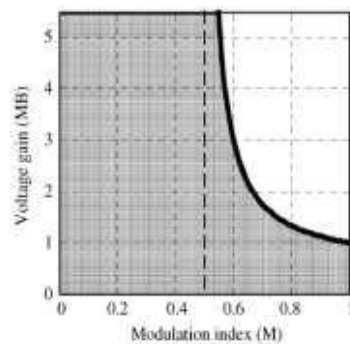


Fig.3.1.2 Voltage gain of the simple boost control

The thick curve in Fig. 3.1.2 shows the maximum obtainable voltage gain, versus, which indicates no voltage boost and no voltage gain at 1. The shaded area is the possible operation region under the simple control. In order to produce an output voltage that requires a high voltage gain, a small modulation index has to be used. However, small modulation indexes result in greater voltage stress on the devices.

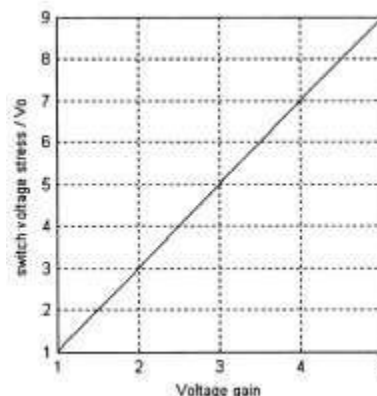


Fig.3.1.3 Switch voltage stress versus voltage gain

Using this control method, the voltage stress across the switches is quite high, which will restrict the obtainable voltage gain because of the limitation of device voltage rating. [6]

3.2 MAXIMUM BOOST CONTROL

We should maximize B for any given modulation index to achieve the maximum voltage gain.

Consequently, from (3.1.2), we have to make the shoot through duty ratio as large as possible.

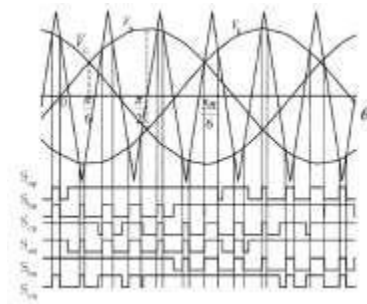


Fig.3.2.1 maximum boost control waveform

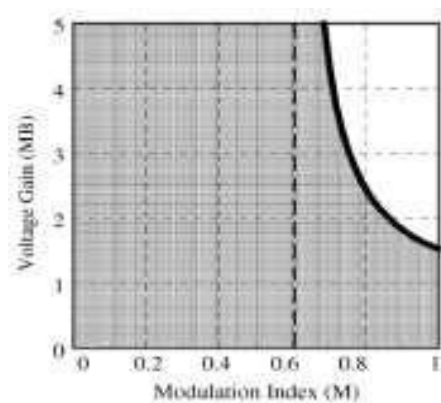


Fig. 3.2.2 voltage gain of maximum boost control

Compared with the simple control method, shown in Fig. 3.1.3, the voltage stress in the proposed control method is much lower, which means that for given devices, the inverter can be operated to obtain a higher voltage gain.

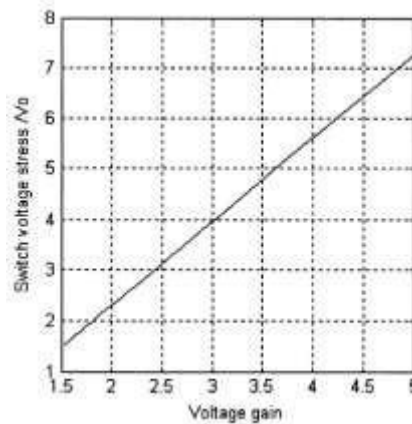


Fig. 3.2.3 Switch voltage stress versus voltage gain.

3.3MODIFIED PWM CONTROL FOR SHOOT THROUGH

From Fig. 3.3.1, the inverter with maximum constant boost control with third harmonic injection shoots through twice in one cycle (triangular waveform cycle); the equivalent frequency to the inductor is doubled, thus reducing the requirement to the inductors.

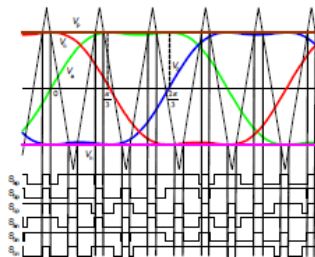


Fig.3.3.1 Maximum Constant Boost with Third Harmonic Injection

However, it is obvious from Fig. 3.3.1 that the real switching frequency of the device also doubles, which increases the switching loss. In traditional PWM control, there is always a zero state after two active states, as shown in Fig. 3.3.2. There are two types of zero states, Zero 1 and Zero 2, Zero 1 occurs when all upper three switches are turned on, and Zero 2 occurs when all lower three switches are turned on. [8]

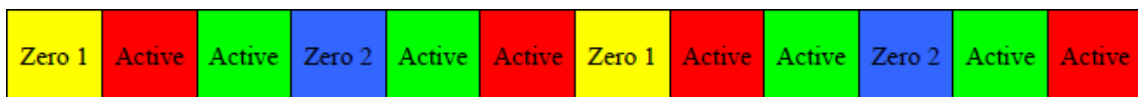


Fig. 3.3.2 Switching states sequence of traditional PWM control.

The control of the Z-source inverter maintains the active states unchanged and shoots through some or all of the zero states. The key point of the modified PWM control is to turn half of the zero states (Zero 1 or Zero 2) into shoot-through state and leave the active states unchanged. The duty ratio of that shoot-through state equals the shoot-through duty ratio of maximum constant boost control. [3]

2. HARMONIC COMPARISON BETWEEN VARIOUS CONTROL STRATEGIES

Sr No	Type of converter	Control strategy	Fundamental	Harmonic order						
				3 rd	5 th	7 th	9 th	11 th	13 th	THD
1.	VSI	PWM control	397.5	4.715	11.25	10.33	4.729	10.65	10.32	0.9309
2.	ZSI	Simple boost control	495.9	0.2915	7.224	2.017	0.374	1.068	1.606	0.9773
3.	ZSI	Third harmonic injection	476.5	138.9	22.05	12.49	8.38	2.818	1.672	1.1

Fig.4.1 Table of Harmonic Comparison for Various Control Strategies.

4.1SIMULATION MODEL

Fig. 4.1.1 shows complete simulation model in MATLAB SIMULINK.

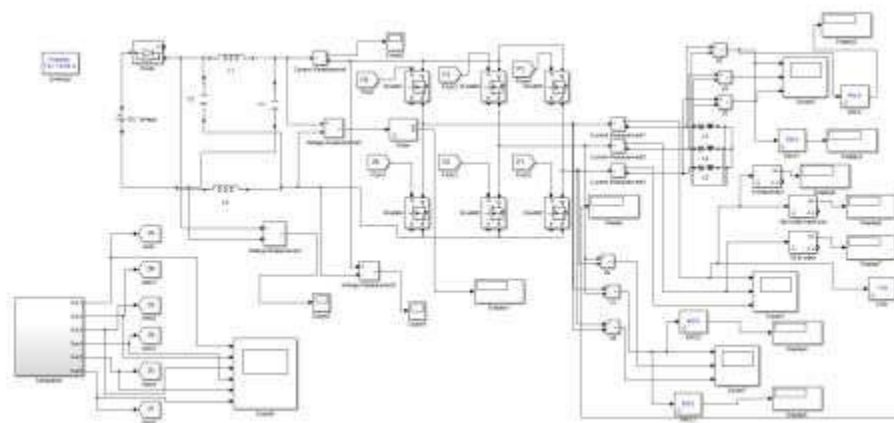


Fig.4.1.1 simulation model of Z source inverter with RL load.

4.2 GENERATION OF GATING PULSES

4.2.1 Basic Comparator Circuit

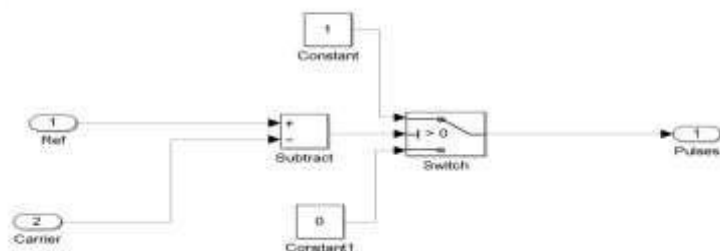


Fig 4.2.1 Basic Comparator Circuit

4.2.2 Generation Of Gate Pulses For One Phase

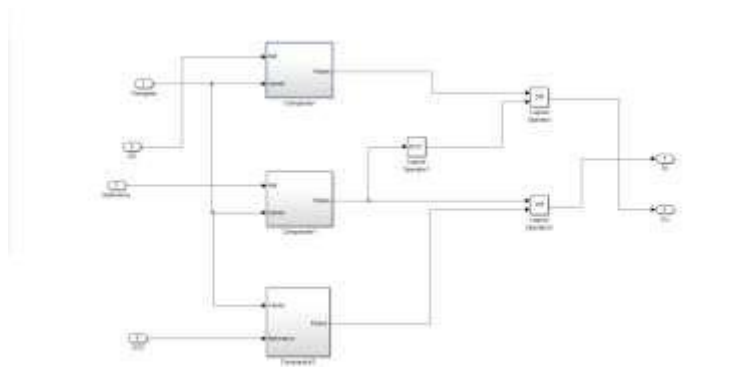


Fig 4.2.2 Generation Of Gate Pulses For One Phase

4.2.3 Generation of Gate Pulses For All Three Phases

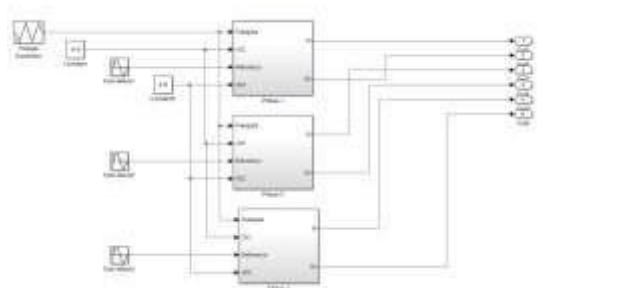


Fig.4.2.3 Generation of Gate Pulses For All Three Phases



3. CONCLUSIONS

A Z-Source Inverter is a buck boost inverter that has a wide range of obtainable value of output voltage, which is verified through MATLAB/SIMULINK model. The various control strategies such as simple boost control, maximum boost control and third harmonic injection control are studied and results are verified through simulations and it is observed that third harmonic injection control method is more advantageous than other methods. The performance of the scheme has been evaluated on the basis of THD & load voltage, load current and found that the output voltage quality is good.

As per the results obtained from various simulations, following conclusions are obtained

1. For constant Z source inductance and modulation index, if Z source capacitance decreases then output voltage increases.
2. For constant Z source capacitance and modulation index, if Z source inductance decreases then output voltage increases.
3. For constant modulation index, if Z source capacitance and inductance decreases then output voltage increases.
4. For constant Z source inductance & capacitance, if modulation index increases then output voltage decreases.
5. For constant Z source capacitance and inductance if load resistance decreases then output voltage decreases.

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