Various topologies used for Resonant Inverter

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***Abstract*-There has been several research leading to the development of the new topologies that overcomes the existing drawbacks of the 3-phase Voltage source Inverters. Z-source Inverters has an aided advantage over the traditional VSIs. Apart from the advantages, there has been certain concerns regarding the Z-source Inverter, which, has been handled by the improved Z-source inverter topology. Realization of the Improved Z-source Inverter shall be conducted with the implementation of the various control methods with the different PWM techniques so as to enhance and maximize the efficiency of the topology and to reduce the voltage stress and minimize the inrush current at start-up. This paper will give an insight of the proposed work that has to be done during the course of the time.**

Keywords: ZSI, IZSI, boost control

I. INTRODUCTION

Due to the limitations of the Voltage and Current Fed Inverter topologies, Z-source Inverters has come to existence. As described and shown in fig 1, the Voltage Source or a Voltage fed Inverters uses a parallelly connected Capacitor along with a constant Voltage Source. Whereas the Current source or Current fed Inverter uses a power source that has a constant current which is filtered by a series inductor as shown in fig 2.

Considering the voltage fed Inverters, each switch has to able to withstand the unidirectional voltage generated and has to permit the bidirectional current flow and hence an antiparallel combination of transistor and diode is commonly implemented which has been illustrated in the fig 1. And in case of Current fed Inverters, each switch has to withstand the Bidirectional Voltage generated and permit the unidirectional current and for this purpose, a reverse blocking switch or a series combination of transistor and diode can be implemented as shown in fig 2.

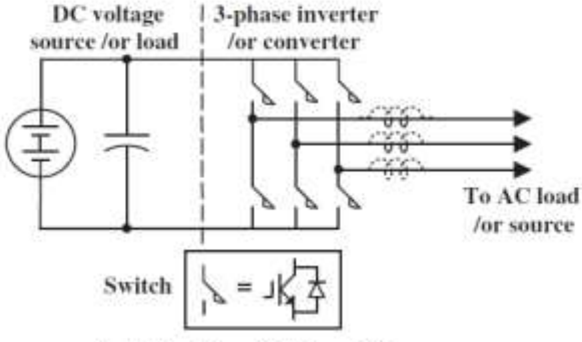

fig 1: Traditional 3-Phase VSI

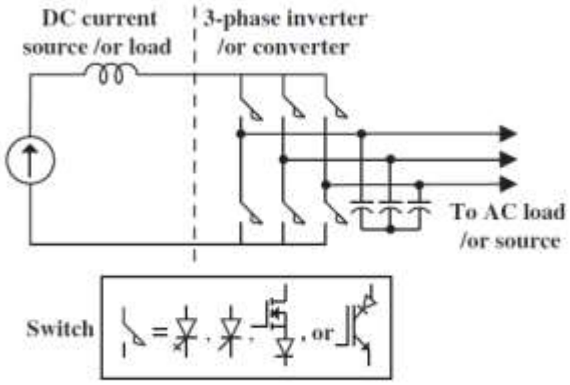

fig 2: Traditional 3-Phase CSI

On the basis of the Analysis, it is imperative to notice that both these topologies of Inverters has failed to achieve certain parameters such as their intolerance towards Electromagnetic Interference (EMI)

A generalized Z-source inverter has been shown in fig 3., which has been introduced to the field of power electronics which is able to eradicate the major drawbacks of the traditional VSIs and CSIs and can operate for both Buck-Boost Operations so thereby making the system more reliable.

These resonant converters are actually result of choosing the proper switching arrangement with the defined parameters and synchronizing them with a converter topology that gives a ZVS/ZVC switching.[2] Following is a broader way of categorizing the inverter:

A. Load Resonant Converter

In this case, resonant capacitor Cr and resonant inductor Or are connected in along the load side .The electrical and magnetic energy oscillates between the two elements (L and C) providing us zero current/voltage switching .In these converter circuit ,the power flow to the load is controlled by the resonant tank impedance ,which in turn is controlled by the switching frequency f_s in comparison to the resonant frequency of the tank f_o.

Series resonant converter (SRC): For a half bridge and full bridge topology of a SLR the basic working principle and waveforms of current and waveform are same Whenever the normalized frequency fn i.e. fs/fo is between .9090 to .7692 the circuit becomes a capacitive impedance at the load side and switches and diodes undergoes ZCS .Low frequency switches like SCR's are used. For high frequency switches BJT's and MOSFET's the circuit changes into an inductive impedance where the fs>fo. SRC find themselves in high switching appliances, not only due to the usage of high frequency switches but also due to the combination of parasites of leakage inductance and switches are added to SRC. The area under the curve gives the region of operation of SRC. The negative slope where fs>fo gives the region where operation is done under ZVS, and for fo>fs the operation is done for ZCS. Because switches like MOSFET's are used for higher frequency applications, ZVS operation is done mostly in these converters.

B. Resonant Link PWM Inverters: With the conventional resonant PWM converters , we achieve ac voltage by using high frequency switches and reduced conduction and switching losses, while conduction loss are due to the structure of a switch and switching losses are due to high frequency of current ,voltage and switching device.[14].What we saw in the previous configuration was the power transfers takes place through resistive part of the resonant tank which requires continuous undampenened oscillations. As a result, large VA rating of LC components and of the switches are required. As a result resonant tank is shifted on dc side as it gets minimally involved in the power transfer[15] and provides a link current or link voltage depending on the configuration of the inverter. Not only the losses gets reduced but the power density is also increased. It is categorized in two:

a. The ZSI bridge will have one extra zero state when the load terminals are shorted through both upper as well as lower switches of phase branches. This third null state is called the shoot-through zero state, which may be achieved by seven unique methods:
   i. Short circuit any one phase branch,
   ii. any two-phase branches, and
   iii. all three-phase branches.
b. In the traditional voltage-source inverter, the shoot-through zero state is taken into consideration because it would cause a shoot-through and damage the switches, but in case of the Z-source Inverter configuration, the shoot-through zero state is possible for use, which providesthe additional buck–boost feature to the inverter.

When the ZSI bridge is in the third null state, it's equivalent configuration can be depicted as shown in Figure 5, whereas when the ZSI bridge operates in any other switching states rather than the shoot-through state, the configuration can be depicted as shown in Figure 6.

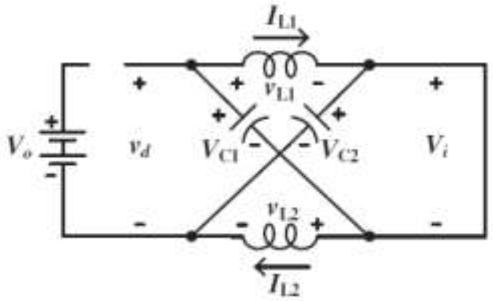

fig 5: Equivalent circuit of the Z-source inverter viewed from the DC side when the inverter bridge is in the shoot-through zero state.

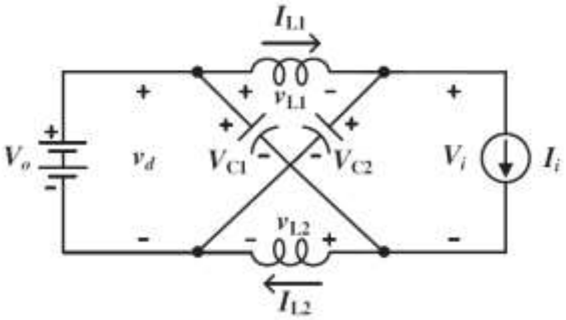

fig 6: Equivalent circuit of the Z-source inverter viewed from the DC side when the inverter bridge is in one of the eight traditional (nonshoot-through) switching states.

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Pulse width modulation (PWM) switching methods can be implemented to control the Z-source inverter as implemented over traditional VSI and input output correlation remains the same.

With the passage of time, certain modifications have been made to enhance the overall quality, cost and efficiency of the Z-source Inverters. And this report will show the enhancements and modifications and an effort will be made to determine the most efficient and cost effective model till date, and finally sorting the enhancements that can be done on the model for further upholding of the model.[21-32]

II. OVERVIEW OF TOPOLOGIES

1. **Fang Zheng Peng**, in his paper "Z-Source Inverters" describes about all the different types of control methods of Z-Source Inverters along with some of the practical implementations of this Inverters, along with the implementation of Quasi-Z-Source Inverter and its implementations.[1]

2. **Fang Zheng Peng**, in his paper "*Maximum Boost Control of the Z source Inverter*" discusses the maximum Boost control scheme for the Voltage fed Z-source Inverter and compares the variations of voltage boost with respect to modulation index and voltage stress versus voltage gain are analysed and verified. He varied the modulation index from 0.88 to 1.1(attained by using Third harmonic injection) with the input voltage from 170V to 250V and the observations were made during the period π/6 to π/2 as the shoot through state was repeating periodically every π/3.[2]

3. **Miaosen Shen**, in his paper " *Constant Boost Control of the Z source Inverter to minimize Current Ripple and Voltage stress*" introduces the Maximum constant boost control method, by which one can achieve maximum voltage boost at any modulation index without any introduction of low-frequency disturbances in the configuration and in turn reduces the voltage stress on the switches as well as the capacitors. The requirement of lesser number of passive elements is also one of the major advantages of the Constant Boost control Method.[3]

4. **Yuan Li**, in his paper "*Quasi Z-source Inverter for Photovoltaic Power Generation Systems*" discusses implementation of qZSI for the photovoltaic Systems due to its lower component ratings and constant dc current from the source. As per the control topologies, qZSI can be triggered similarly to the ZSI. qZSI can operate both buck-boost operation working as an inverter, and power conditioning can be done in its single stage with higher reliability. [4]

5. **Yu Tang,** in his paper *Improved ZSource Inverter with reduced Z-source Voltage Stress and Soft start Capability* introduces a new topology which can minimize the Z-source capacitor voltage stress as well limit the inrush current at start-up, for the same voltage boost.Even a soft-starting strategy has been proposed to limit inrush current and the resonance of Zsource capacitors and inductors without not much further changes in the operating principles and modulation techniques, which is exactly the same with the traditional ZSI.[5]

6. **Yu Tang,** in his paper "Pulse width Modulation Z-source Inverters with minimum Inductor Current ripple" introduces the PWM technique implemented to the Z-source inverters which holds the minimal inductor current transients. The shoot-through time period of three phase branches are calculated in the technique and accordingly, they are rearranged to obtain the

7. minimal current transients across the Z-source inductor, without affecting the total shoot-through time interval.[6]

8. **Himanshu Sharma,** in his paper "*Comparative analysis of a novel topology for single-phase Z-source inverter with reduced number of switches*" proposed a new topology for the Z-source Inverter so as to reduce the number of passive elements and active switches in order to achieve a low cost and compact size of the ZSI.

9. **Aman Sharma,** in his paper "*Buck-Boost Operation Using a Z-Source Inverter*" explains the Buck-Boost operation of the Z-source Inverter.

10. **Quang-Vinh Tran,** in his paper *Algorithms for Controlling Both the DC-Boost and AC Output Voltage of ZSource Inverter* introduces an algorithm that is implemented to linearly control the Zsource capacitor voltage in turn to the overall transient response

Type of topology	Number of passive elements and switches	Remarks
Z-source Inverter	2L,2C,1D,6S	Better voltage regulation and reduced voltage stress compared to the Traditional Multilevel Inverters
Improved Z-source Inverter	2L,2C,1D,6S	Improved reliability and low inrush inductor current at startup due to the specific change in the configuration.
Quasi Z-source Inverter	2L,2C,1D,6S	Has continuous input current, reduced source stress, and lower component ratings and hence the cost
Novel topology of Single phase Z-source Inverter	2L,1C, 2S	Due to the lesser number of components the topology is cost effective

where L, C, D and S denotes Inductor, Capacitor, Diode and switch respectively

III. COMPARISION OF THE CONTROL METHODOLOGIES

The control methodologies that are implemented for the control of the switching in the ZSI topologies are Simple-boost Control, Maximum-boost Control and Maximum-constant Boost Control Method.

1. **Simple Boost Control:**It uses two references whose magnitudes is either greater than or at par with the maximum value of three phase reference for controlling shoot-through duty ratio in a sinusoidal PWM. The simple boost control waveforms can be depicted by:

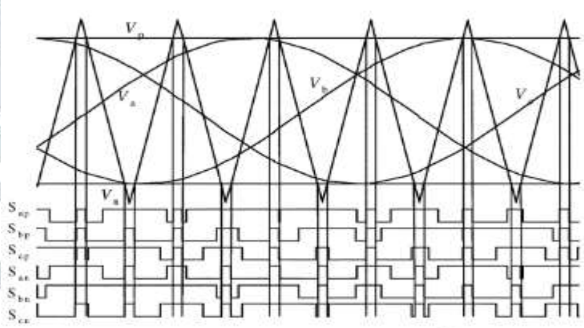


fig 7: simple boost control waveforms

2. **Maximum Boost Control:** In this method of control, all active states remain unchanged while the null states get altered into shoot-through zero states. The waveforms for this control can be depicted by:

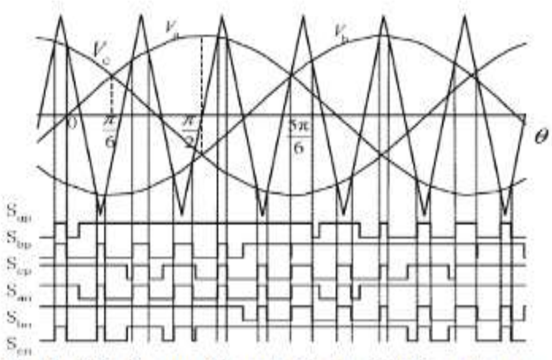


fig 8: Maximum Boost Control Waveforms

3. **Maximum Constant Boost Control:** This control method implements the use of three reference signals along with two shoot-through envelope signals. The waveforms relating the Maximum constant boost control method can be depicted in figure 9.

The Voltage boost vs. Modulation index curves for the control methods implemented for the ZSI is depicted in the figure 10.

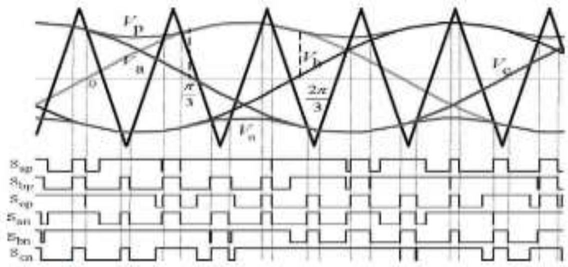


fig 9: Maximum constant boost control waveforms

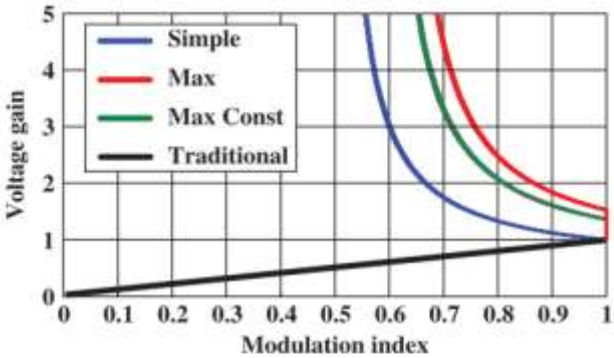
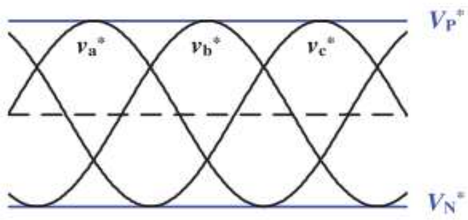
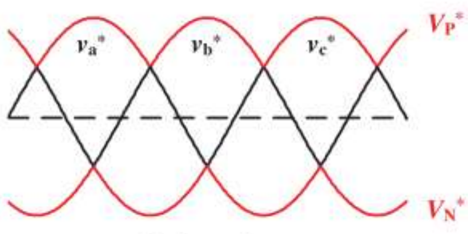
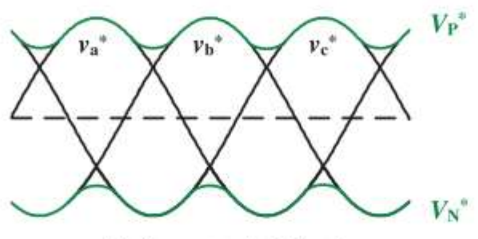


fig 10: comparision of Voltage gain vs. Modulation Index curves for the different topologies of ZSI

The comparison of the control methods can be tabulated as

Control Method	No. of reference signals	Reference signals used in the method	Modulation Index at 50% shoot-throughout state
Simple Boost Control	Two constant reference signals whose magnitude is either greater than or at par with the peak values of the voltage references		0.50
Maximum Boost Control	It uses the peak envelope of the three phase voltage references, which, results in the short circuit of the entire zero-states to achieve the maximum voltage boost corresponding to every modulation index.		sqrt(3)π/9= 0.605

Maximum Constant Boost Control	It uses two envelope signals to produce the maximum and constant shoot-through duty cycle.	 Maximum constant boost	sqrt(3)/3=0.577

IV. FUTURE ASPECTS OF RESEARCH

It is evident to check out all the advantages and disadvantages of the several topologies that are proposed for the Z-source Inverter. Even with all the research on this topic, there has been lacking of research on certain sections of the topologies, its implementation.

The implementation of the simple boost control has only been implemented over the improved Z-Source Inverter and the outcomes almost up to the content provided by the traditional Z-Source with minimal cost and reliability in accordance with minimal voltage stress, for the same boost capability.

There is a possibility of further research on

a. decreasing the voltage stress on the switches by implementing the maximum boost control method and maximum constant boost control methods with the improved Z-source Inverter topology.
b. Enhancing the reliability of the improved Z-source Inverter by using the PWM modulation technique to minimize the inductor current and thereby accompanied by the several control methods to enhance the overall performance of the topologies, in terms of economics, switch count and reliability.

V. CONCLUSION

Implementations of the Improved Z-source Inverters has been implemented over the MATLAB simulation software to understand Traditional Zsourcedinverter and the Improved Z-source inverter with the various control methods:

a. Simple-boost control Method
b. Maximum-boost control Method
c. Constant-boost control Method

Apart from this Quasi Z-source Inverters topologies, were also implemented to, so, as to check the significant changes and modifications that can be either the topologies so as to make a change to the for achieving the certain Goals:

a. Higher Reliability of the Z-source Inverter.
b. Minimum inrush inductor current at start-up.
c. Minimize the overall cost of the Inverter.

Moreover, it can be concluded that Improved Z-source Inverter, can be preferred for the overall cost effectiveness, but certain progress can be made by the implementation of the various control methods as cited above.

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