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Performance analysis of Impedance Source Inverter (ZSI) Controlled with Proposed Unipolar PWM Technique under Various Load Conditions

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Abstract: ***Power electronic converters are used for conversion of power from either AC to DC or DC to AC. Inverters convert DC power to AC power. A voltage source inverter (VSI) has been in use for power inversion but it suffers from few disadvantages. One of those drawbacks is, a VSI works as a buck converter only. So, in VSI, it is not possible to get an output which is more than the given input. To overcome this drawback, in this paper, Impedance source Inverter (ZSI) is presented. This inverter behaves as buck-boost inverter,i.e., using this inverter, we can get output either more or less than the given input. The PWM technique used to control the inverter is the proposed Unipolar PWM technique.***

Index Terms**:** ***Inverter, Voltage Source Inverter, Impedance Source Inverter, Modified Unipolar PWM Technique.***

I. INTRODUCTION

Power electronic converters are used in FACTS devices like STATCOM, UPFC, UPQC, etc., and also in uninterrupted power supplies, for having reliable power. These converters are used to convert power from either AC-DC, or DC-AC, or DC-DC, or AC to AC. The converter which converts DC power to AC power is called as Inverter. Inverters [1-2] are of two types, (i) Voltage source inverter (VSI) and (ii) Current source inverter (CSI). The drawback with these devices is that a VSI works as buck inverter alone and a CSI works as boost inverter alone. So, we are moving for Impedance source inverter (ZSI), which can either boost or buck the voltage.

II. IMPEDANCE SOURCE INVERTER (ZSI)

An Impedance source inverter is used to overcome the disadvantages with the traditional VSI and CSI. Insertion of shoot through state (shoot through state is the shorting of inverter leg/legs) is possible in ZSI [1]. By controlling the duty cycle of shoot through states, we can have control over the output of the inverter i.e., either increase or decrease the output [3] more than the given input.

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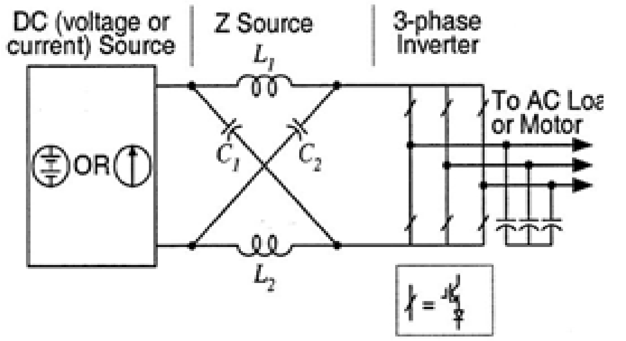

Fig 1: Structure of ZSI

Fig 1 shows the structure of an impedance source inverter. It comprises of an impedance network connected between the inverter bridge and source. The two port network, here, is made up of split inductors L1, L2 and capacitors C1, C2. These are connected in X-shape as shown in fig.1.Either a voltage source or a current source can be used as DC source.

Operation of ZSI [4] is carried out in two modes.

(i) Shoot through mode
(ii)Non shoot through mode

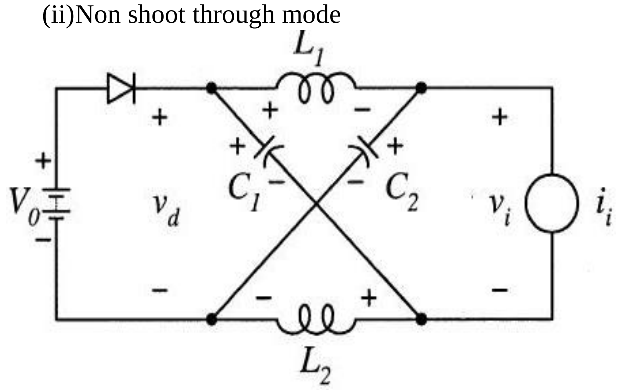

Fig 2: Equivalent Circuit of ZSI When Viewed from dc Link

A. Shoot Through Mode:

In shoot through mode, the inverter operates in one of the shoot through states. Shoot through state can be caused in totally seven ways for a three phase inverter bridge.

- Shorting of any one leg (which can be done in 3 ways)
- Shorting of any two legs(which can be done in 3 ways)
- Shorting of all the three legs (which can be done in 1 way)

Fig 2 shows the equivalent circuit of ZSI when viewed from the DC link. Fig 3 shows the equivalent circuit of ZSI in shoot through mode.

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It is viewed as a shoot circuit when the inverter is in shoot through mode. This shoot through mode provides the special buck-boost feature of ZSI. In this mode, the voltage of capacitor is boosted to the required value basing on the shoot through duty ratio.

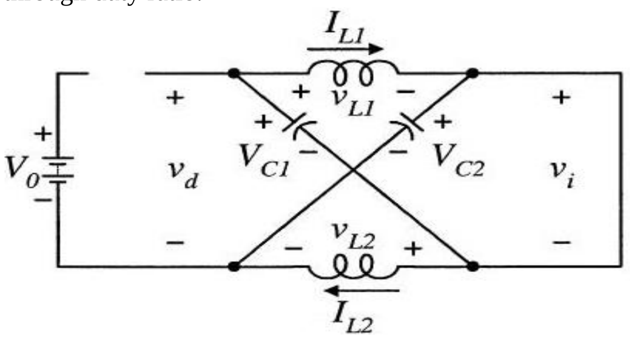

Fig 3: Equivalent Circuit of ZSI in Shoot-Through State

B. Non Shoot Through Mode:

The equivalent circuit of ZSI in non shoot through mode is as shown in fig 4.The inverter is operating in either one of the six active states or the two zero states. When the inverter is operating in one of the six active states, then the inverter bridge is viewed as a current source from the DC link. The DC voltage appears across the inductor and capacitor network. The capacitor gets charged and the path for energy flow is to the load via inductor. When the inverter operates in one of the zero states, then the inverter bridge can be viewed as an open circuit from the DC link. The DC voltage appears across inductor and capacitor, but no current flows through the load.

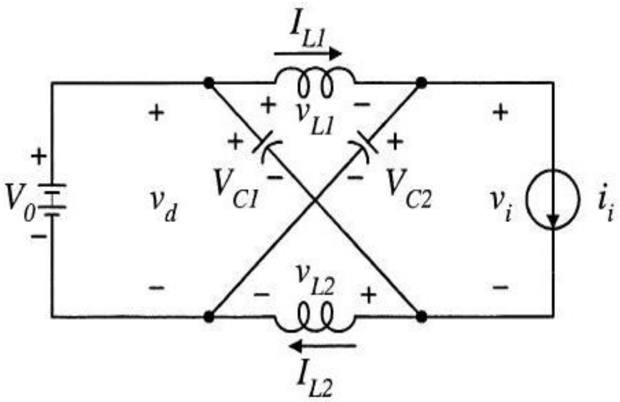

Fig 4: Equivalent Circuit of ZSI in Active State

III. CONTROL TECHNIQUE

The PWM technique used here is the proposed Unipolar PWM technique. To understand this technique, we consider a single phase inverter bridge shown in fig 5.

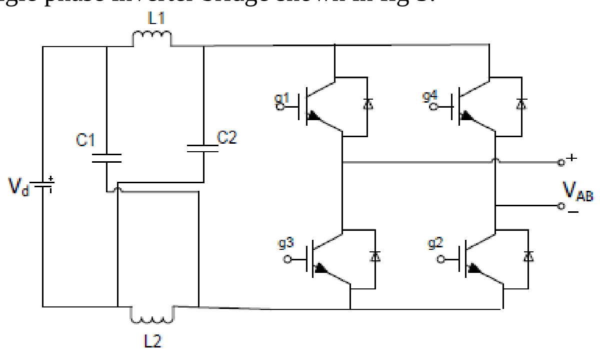

Fig 5: Single Phase H-bridge Inverter

In the traditional Unipolar PWM technique, the drawback is that, we cannot insert shoot through states. The switching pulses to the two switches in any particular leg complement each other i.e., when one switch of the inverter leg is turned ON, then the other switch will be turned OFF and vice versa. In this method, we use two sinusoidal signals (V_m and V_{-m}) as reference waves and a triangular signal as carrier wave (V_{Cr}). Any one of the reference waves and the carrier wave are compared with each other to generate pulses [5-6] for the switches of any one inverter leg. Whenever the reference wave is greater than the carrier wave, upper switch of one inverter leg is turned ON and whenever the reference wave is lesser than the carrier wave, lower switch of the same inverter leg is switched ON. So, from this we understand that, insertion of shoot through state is not possible.

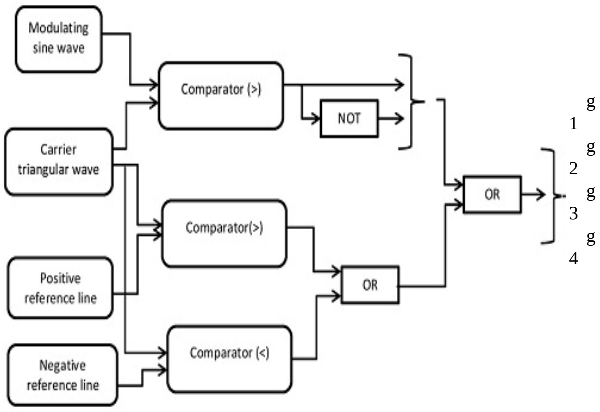

Fig 6: Proposed Unipolar PWM Technique

Hence, we modify the existing method by adding two reference lines, which are positive and negative reference lines, as shown in fig 6. They are equal in magnitude and opposite in sign. The magnitude of these reference lines is equal to or slightly greater than the peak value of the reference wave taken but lesser than the peak value of triangular wave. Whenever the triangular wave is greater than the positive reference line or smaller than the negative reference line, then all the switches will be switched ON, inserting a shoot through in the inverter. The inverter operates in normal manner during rest of the time interval. In this way, the existing technique is modified for applying it to the Impedance source inverter.

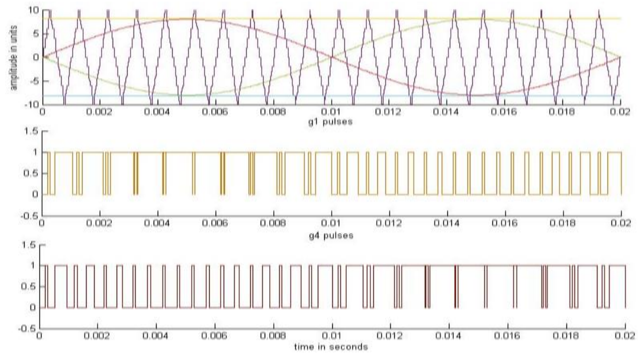

Fig 7. Unipolar Waveforms (i) Carrier Wave, Sine Wave, Positive Reference Line and Negative Reference Line, (ii) Gate Pulses g1, (iii) Gate Pulses g4

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IV. PERFORMANCE OF ZSI FOR DIFFERENT LOADS

The output of ZSI is tested for various load conditions. The waveforms of ZSI with different loads are as shown in the following figures.

Parameters taken are:

- Input voltage V_{DC} = 400V
- Impedance network of ZSI: L= 19.055mH, C= 3.88µF
- Modulation index= 0.8
- Carrier wave frequency=1000Hz

Waveforms of ZSI at different load conditions:

R Load:

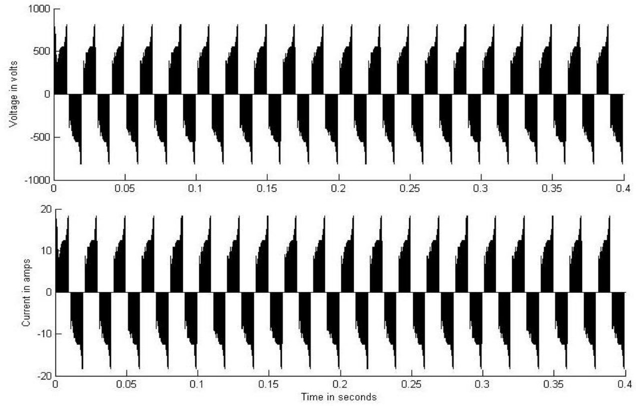

Fig 8: Voltage and Current Waveform of ZSI with R load, R= 44.5Ω

L Load:

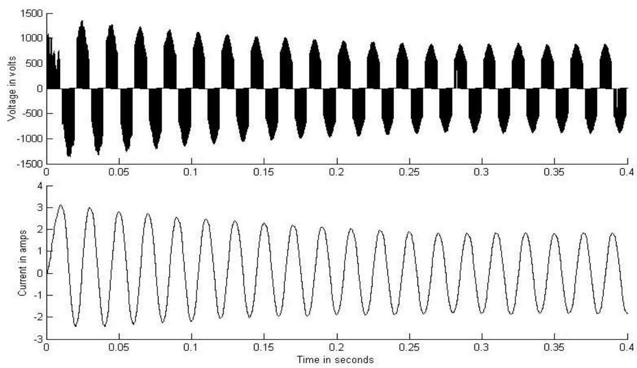

Fig 9: Voltage and Current Waveform of ZSI with L load, L= 1000mH

RL Load:

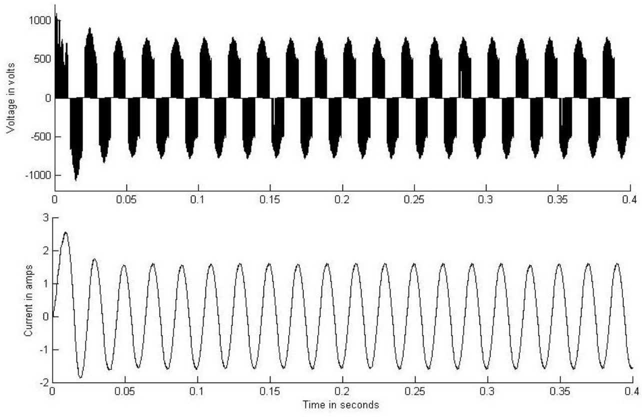

Fig 10: Voltage and Current Waveform of ZSI with RL load, R= 44.5Ω and L= 1000mH

RC Load:

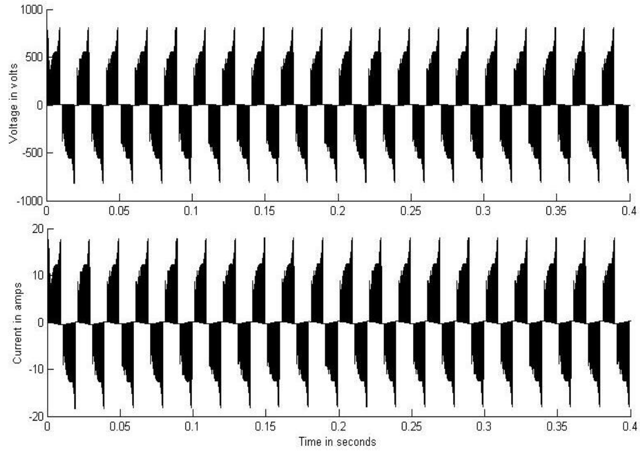

Fig 11: Voltage and Current Waveform of ZSI with RC load, R= 44.5Ω and C= 2.5mH

LC Load:

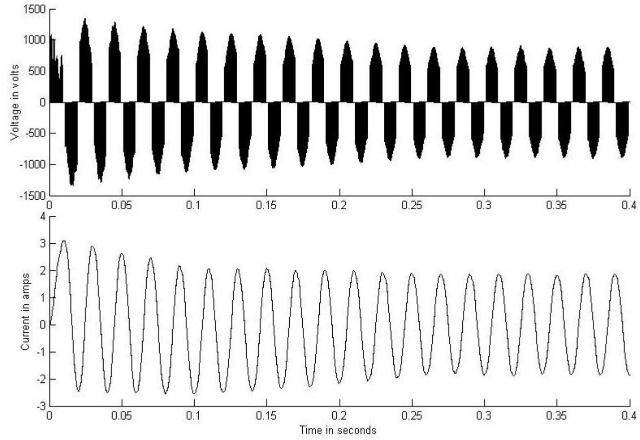

Fig 12: Voltage and Current Waveform of ZSI with LC load, L= 1000mH and C= 2.5mF

RLC Load:

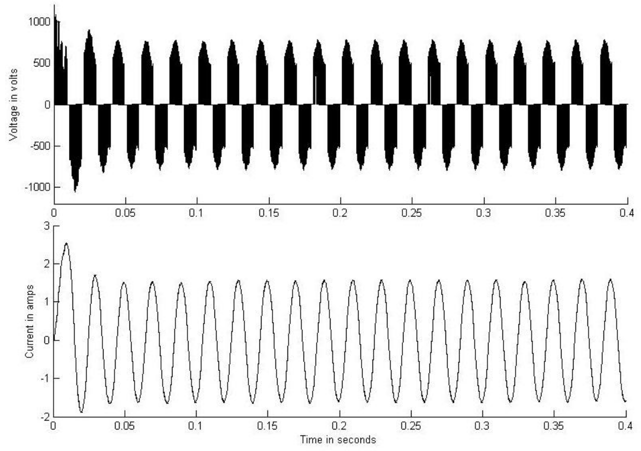

Fig 13: Voltage and Current Waveform of ZSI with RLC load, R= 44.5Ω, L= 1000mH and C= 2.5mF

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V. CONCLUSION

In this paper, Impedance source inverter (ZSI) is tested for various load conditions and the proposed Unipolar PWM technique is applied for ZSI. Using ZSI, the output of the inverter is increased more than the input taken. The existing Unipolar PWM technique is modified and using this proposed technique, insertion of shoot through states in the ZSI is made possible. The outputs of ZSI at various loads are plotted. From the results, it is clearly seen that the output voltage is boosted by using the proposed Unipolar PWM technique applied to ZSI.

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