A Survey on Modified PWM Techniques for Z-Source Inverter

Penchalababu.V, Chandrakala.B, Gopal Krishna

Abstract: The proposed work presents a Z-source inverter which can be proposed as an alternative power conversion concept for variable speed AC drives. It has both buck and boost capabilities as they allow operation of the inverter in the shoot through state. It uses an exclusive Z-source network (LC component) to DC-link in between inverter and the DC source. By controlling the shoot-through duty cycle of IGBTs in inverter system, reduces the line harmonics, improves power factor, and extends output voltage range..This Paper presents different switching techniques such as Simple boost pwm, Constant boost pwm, Maximum boost pwm, Sine carrier pwm and Modified SVPWM.

Keywords: pulse width modulation, Modified SVPWM, z-source inverter

I. INTRODUCTION:

Traditional voltage-source inverter (VSI) and current source inverter (CSI) are either a buck or a boost converter and not a buck-boost converter. That is, their obtainable output voltage range is limited to either more or less than the input voltage. Z –source inverter has the following advantages: Immune to EMI noise, less inrush current compared with the voltage source inverter and low common mode noise. Figure-1 shows the circuit of the Z-source inverter. It uses an exclusive impedance network coupled between the source and the converter circuit which consists of inductors and capacitors (L_1, L_2 and C_1, C_2) connected in X shape. The X-arms connects the inverter to a DC voltage source. The voltage source can be a battery, a diode rectifier or a fuel cell. This unique impedance network allows the Z-source inverter to boost or buck its output voltage.

Many pulse-width modulation (PWM) control methods have been developed and used for the traditional three phase voltage source inverter [2]. When the dc voltage is impressed across the load the traditional VSI has six active vectors and two zero vectors when the load terminals are shorted. The total eight switching states and their combinations have spawned many PWM control schemes. Along with the eight vectors Z-source inverter has additional zero vectors or shoot-through switching states that are not allowed in the traditional VSI, both switches of any phase leg can never be switched on at the same time or a short circuit (shoot through) would occur and destroy the inverter. The new Z-source inverter (ZSI) advantageously uses the shoot through state to boost the dc voltage by gating on both lower and upper switches of a leg to produce a desired output voltage that is more than the available dc voltage. The reliability of the inverter also greatly improved because the shoot-through.Therfore it can provide a low-cost, reliable, and high efficiency single stage structure for buck and boost power conversion. The operating principle and the shoot through duty cycle control using Simple boost, Constant boost pwm, Maximum boost pwm, Sine carrier pwm and Modified SVPWM have been described in detail.

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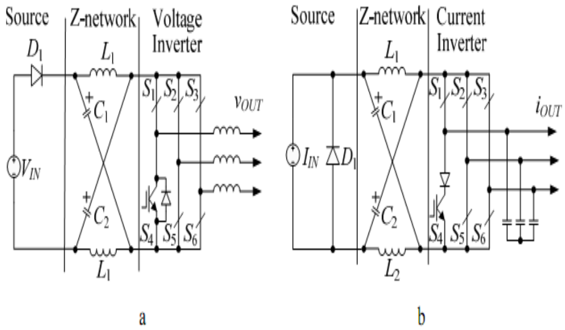

Figure 1.1: General structure of z-source converter; (a) Inverter type with voltage feed, (b) Inverter type with current feed.

II. PWM CONTROLS FOR Z-SOURCE INVERTER (ZSI)

A uniqueness of PWM control in ZSI is the ability of the shoot-through state to boost to a desired output voltage (greater than available dc-link voltage) and under single stage process.

It is done by gating on both the upper and the lower of the power devices of a phase leg. PWM controls generating the shoot-through period are Simple Boost PWM, Maximum Boost PWM, Maximum Constant PWM, Modified Space Vector PWM and Sine Carrier PWM

A. Simple boost control

To control the shoot through states, Simple boost control utilises two straight lines as shown in Figure 2 (a). When the triangular carrier waveform is greater than the upper envelope, *V1*, or lowers than the bottom envelope, *V2*, the circuit turns into shoot-through state. Otherwise it operates just as traditional carrier-based PWM. Figure 2 (a) shows the pulse generation of the three phase leg switches (S1, S3 and S5-positive group/upper switch and S2 , S4 and S6-negative group/lower switch).This method is very uncomplicated; however, the resulting voltage stress across the device is relatively high because some traditional zero states are not utilized either partially or fully.

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In order to produce an output voltage that requires a high voltage gain, a small modulation index (*ma)* has to be used. However, greater voltage stress on the devices is due to small modulation indices. As the modulation index is raises, the switching frequency of the inverter also raises and hence the switching losses.

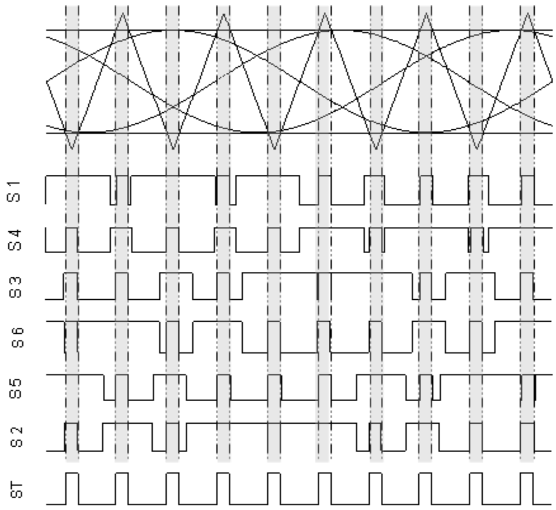

Figure 2.1:Modulation using Simple boost control

B. Maximum boost control

Maximum boost control utilises all traditional zero states into shoot-through state, as shown in Figure 2 (b). The voltage stress across the switching devices is greatly reduced by fully utilizing the zero states. Indeed, turning all zero states into shoot-through state can minimize the voltage stress; however, doing so also causes a shoot-through duty ratio varying in a line cycle, which causes inductor current ripple. This will require a high inductance for low-frequency or variable-frequency applications. Maximum boost control method maintains the six active states unchanged and turns all zero states into shoot-through zero states. As can be seen from Figure 2 (b), the circuit is in shoot through state when the triangular carrier wave is either greater than the maximum curve of the references (*Va,Vb andVc*) or smaller than the minimum of the references. The shoot-through duty cycle varies each cycle. Maximum boost control method introduces a low frequency current ripple associated with the output frequency in the inductor current and the capacitor voltage. Maximum boost control with third harmonic injection method is shown in Figure 3 (a). This method of control produces the output voltage and current with better harmonic profile.

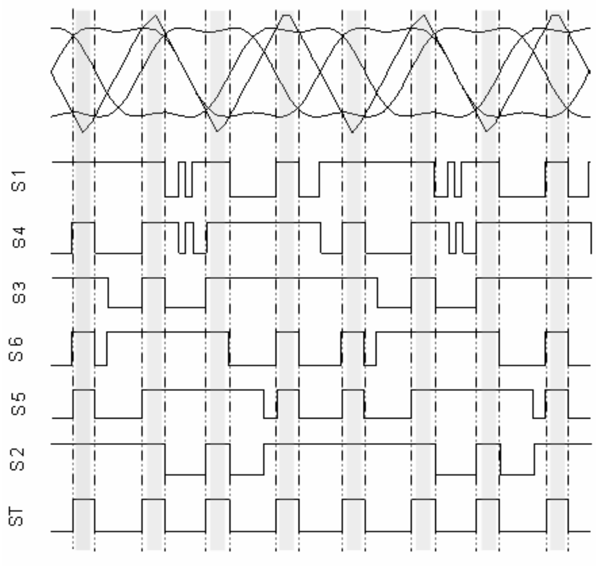

Figure 2.2: Modulation using maximum boost control with third harmonic injection

C. Constant boost control

To reduce the volume and cost, always it is important to keep the shoot-through duty ratio constant. At the same time, to reduce the voltage stress across the switches, a greater voltage boost for any given modulation index is desired. Figure 3 (b) shows the generation of switching pulses by maximum constant boost control method, which achieves the maximum voltage gain while always keeping the shoot-through duty ratio constant.

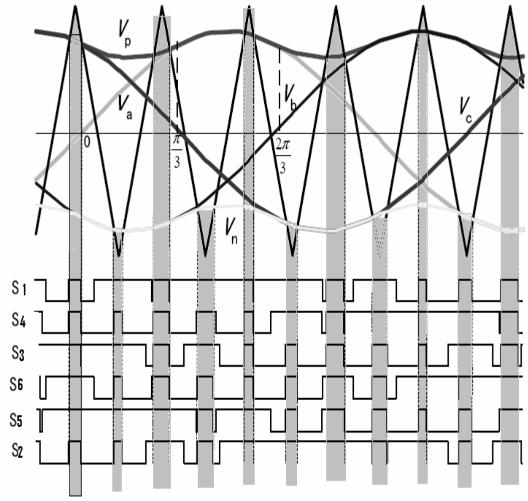

Figure 2.3: Modulation using constant boost control

There are five modulation curves in this control method: three reference signals, *Va*, *Vb*, and *Vc*, and two shoot-through envelope signals, *Vp* and *Vn*. When the carrier triangle wave is greater than the upper shoot-through envelope, *Vp*, or lower than the lower shoot-through envelope, *Vn*, the inverter is turned to a shoot-through zero state. In between, the inverter switches in the same way as in traditional carrier-based PWM control. The sketch map of maximum constant boost control is shown in Figure 3 (b).

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This method achieves maximum boost while keeping the shoot-through duty ratio always constant; thus it results in low line frequency current ripple through the inductors. With this method, the inverter can buck and boost the voltage from zero to any desired value smoothly within the limit of the device voltage.

D.Sine carrier PWM

The idea behind modified carrier signal was for improvement simple boost PWM control. In simple boost PWM, to get the high output voltage, it is necessary to increase the shoot-through duty ratio. This can be done by reducing the Mi but will cause the voltage stress become higher. Revision by recommended that for a particular Mi, carrier signal's high frequency can maximize output voltage. Under same value Mi with simple boost PWM, the modified carrier signal was found to give higher shoot-through duty ratio and higher boost factor, both increasing the peak output voltage. Figure 11 shows the sine carrier PWM signal for a three-phase ZSI; three reference signals Va, Vb and Vc, one upper signal Vp, and one lower signal Vn.The signals were compared with the sine carrier signal, to generate gating pulses.

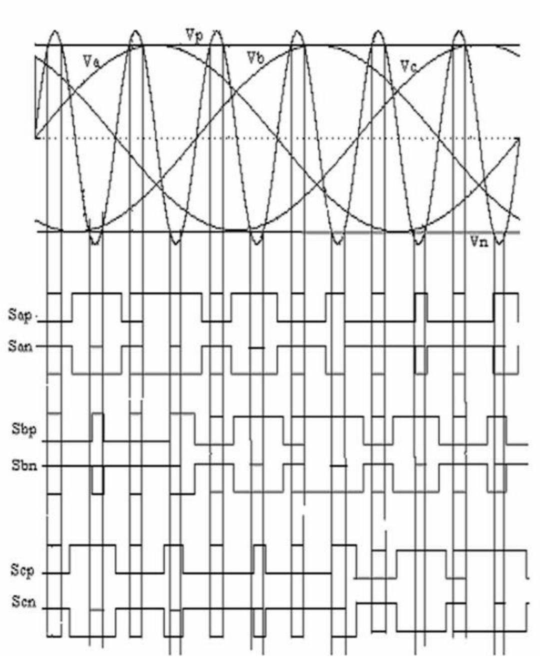

Figure 2.4: Modulation using constant boost control

E. Modified Space Vector PWM (MSVPWM)

Space vector PWM control are commonly used incurrent-regulated PWM inverters for its relatively low current harmonics and relatively high Mi. Traditional SVPWM's eight space-vectors (active vectors V1 till V6 and zero vectors Vo and V7 are still used in MSVPWM, but with additional shoot-through period added to traditional SVPWM's switching time. The addition can boost the dclink voltage and generate sinusoid ac output voltage. The zero voltage periods *T0* should be diminished for generating a shoot-through time *Tsh*, while the active state times *T1*, *T2* are unchanged. During the shoot-through period, both switches of the phase leg are conducted simultaneously for boosting the dc capacitor voltage. The six PWM pulses in the MSVPWM should be controlled independently. Figure shows SVPWM's switching pattern in Sector 1, whose similar concept is used by other sectors, who mimic traditional SVPWM; sectors 2, 3, 4, 5, and 6 are used according to their switching times.

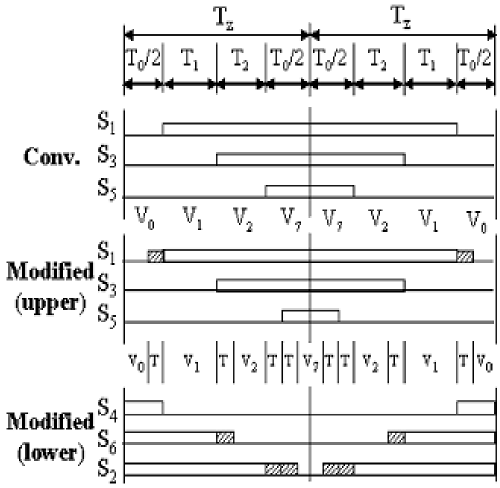

Figure: Switching pattern of modified SVPWM (MSVPWM), for Sector1. (Upper: Conventional SVPWM). (Middle and Lower: MSVPWM)

Table I shows the switching time of the upper and the lower power devices in a three-phase ZSI, for Sector 1 only.

TABLE I. Switching Time Duration At Sector 1

Sector	Upper (S1,S3, S5)	Lower (S4, S6,S2)
1	S1 = T1+T2+T0/2+T	S4 = T0/2
2	S3 = T2 + T0/2	S6 = T1 + T0/2+T
3	S5 = T0/2 - T	S2 = T1+T2+T0/2 +2T

III RESULTS AND DISCUSSION

A. simple boost control

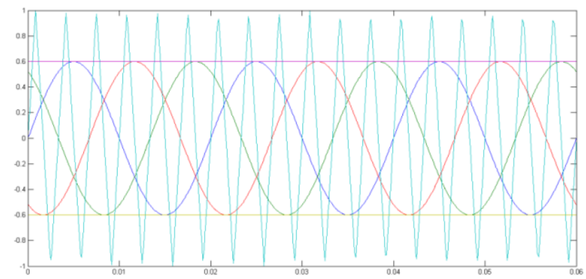

Figure 3.1(a) Modulation in simple boost control

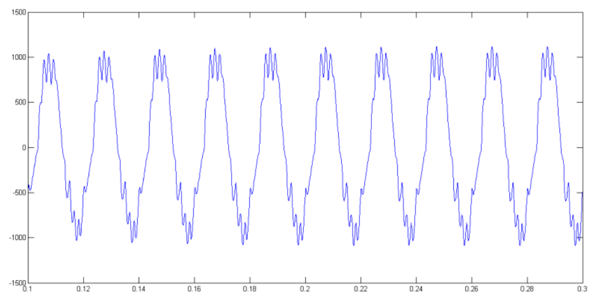

Figure 3.1(b) Output voltage of IM load

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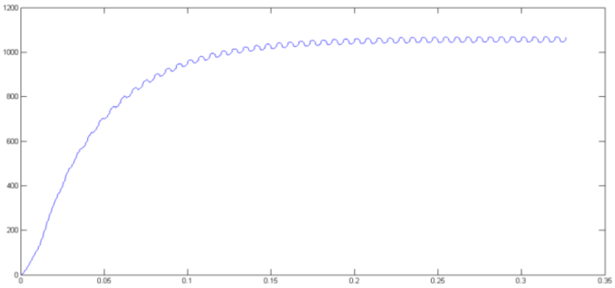

Figure 3.1(c) DC link voltage

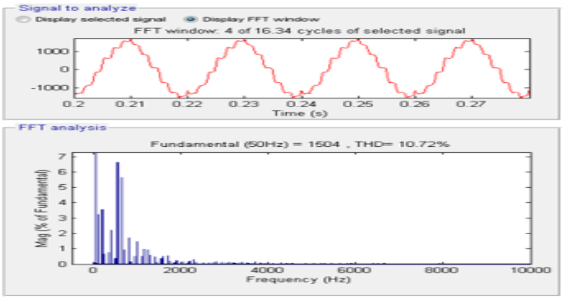

Figure 3.1(d) FFT analysis of ZSI output voltage

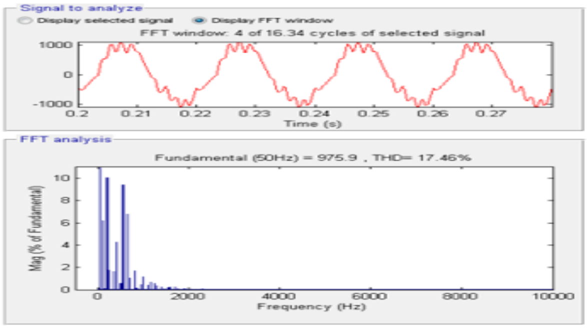

Figure 3.1(e) FFT analysis of Load voltage

B. constant boost control

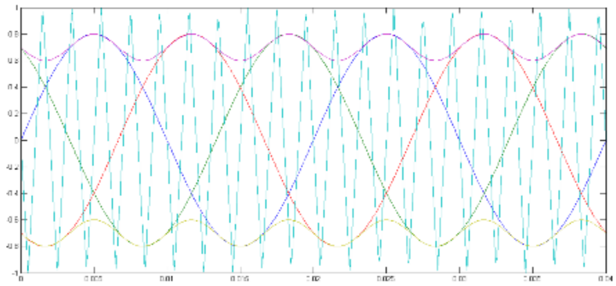

Figure 3.2(a) Modulation in constant boost control

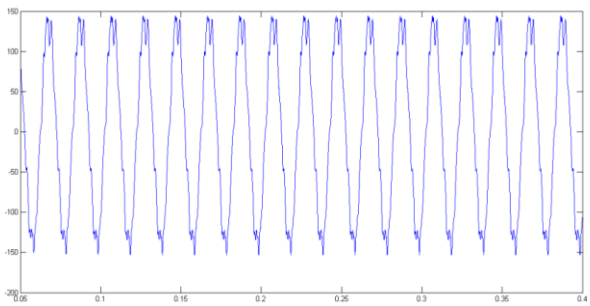

Figure 3.2(b) Output voltage of IM load

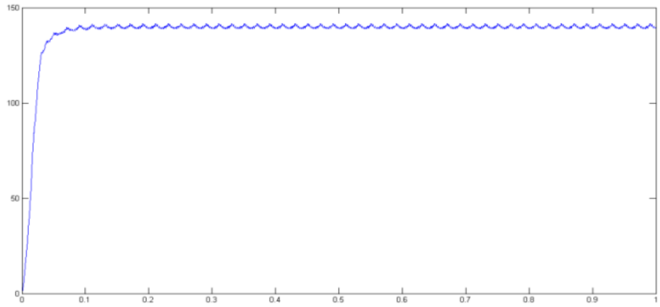

Figure 3.2(c) DC link voltage

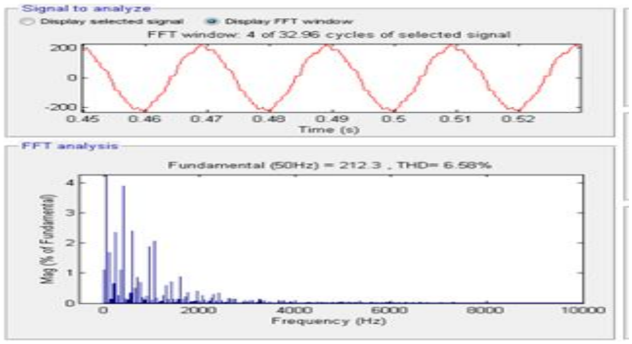

Figure 3.2(d) FFT analysis of ZSI output voltage

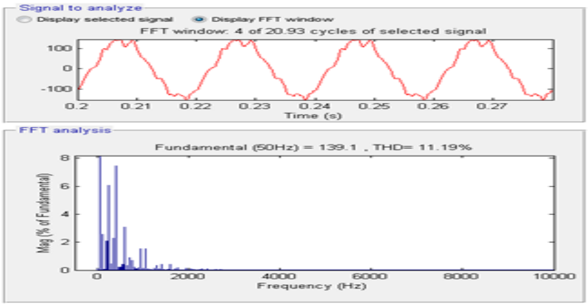

Figure 3.2(e) FFT analysis of Load voltage

C .Maximum boost control

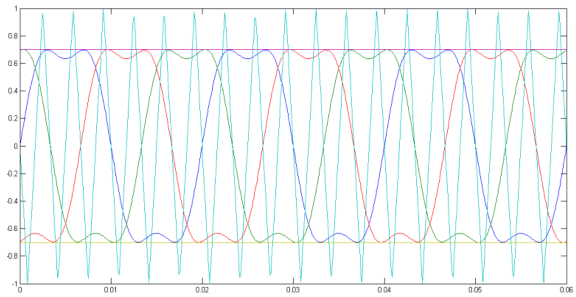

Figure 3.3(a) Modulation in maximum boost control

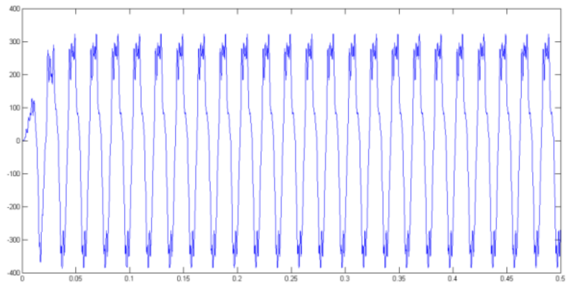

Figure 3.3(b) Output voltage of IM load

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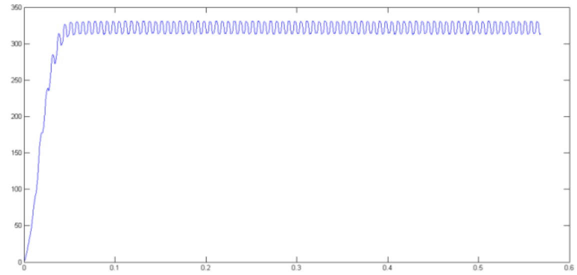

Figure 3.3(c) DC link voltage

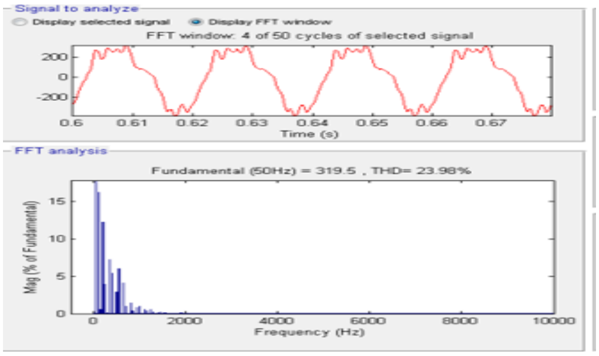

Figure 3.3(d) FFT analysis of Load voltage

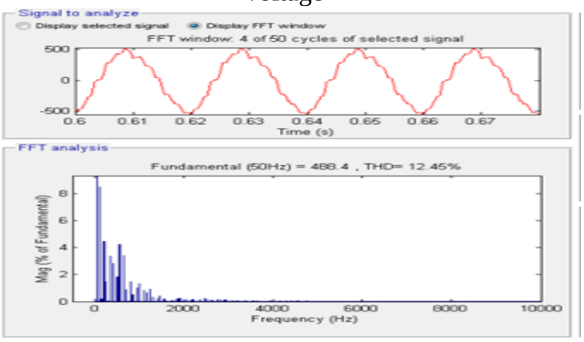

Figure 3.3(e) FFT analysis of ZSI output voltage

D. sine carrier PWM

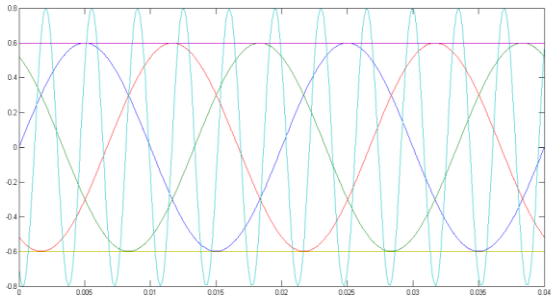

Figure 3.4(a) Modulation in sin carrier control

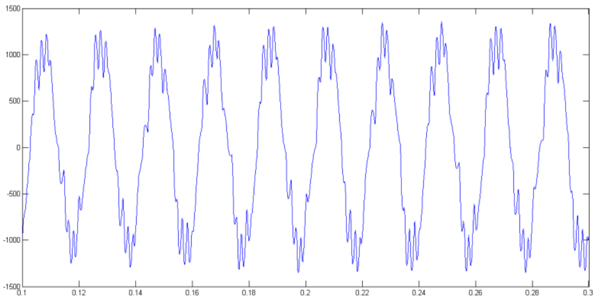

Figure 3.4(b) Output voltage of IM Load

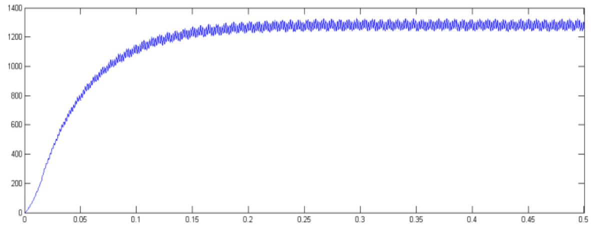

Figure 3.4(c) DC link voltage

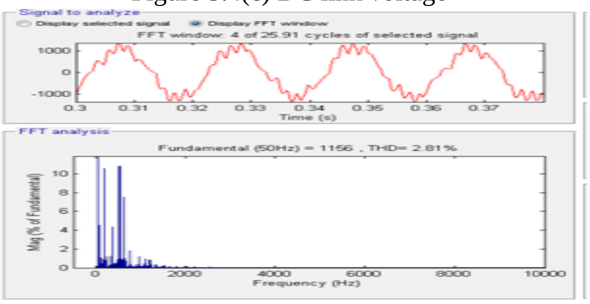

Figure 3.4(d) FFT analysis of Load voltage

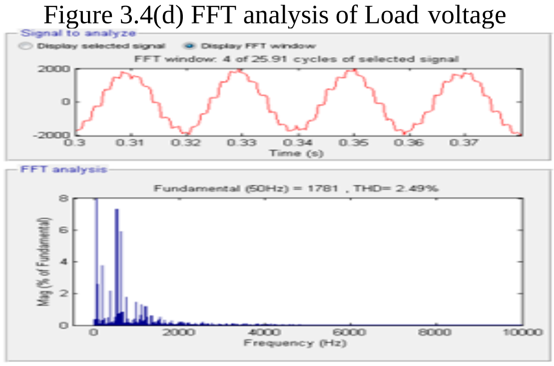

Figure 3.4(e) FFT analysis of ZSI output voltage

E. MODIFIED SVPWM

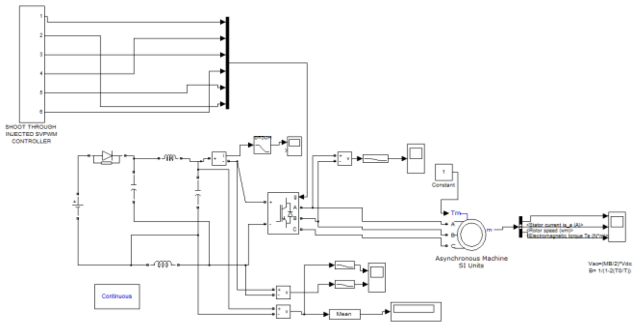

Figure 3.5(a) MATLAB/Simulink model for modified SVPWM based z-source inverter with IM load.

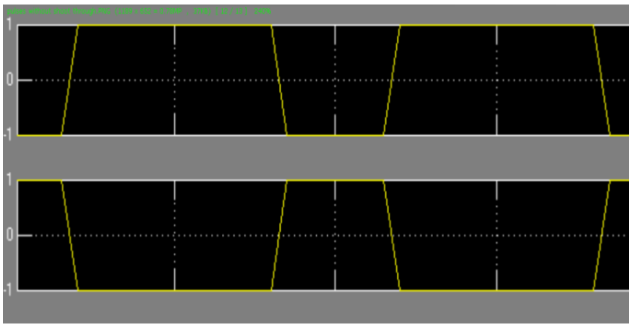

Fig 3.5(b) The gate pulses given to both the switches in a leg without shoot through state (Traditional SVPWM)

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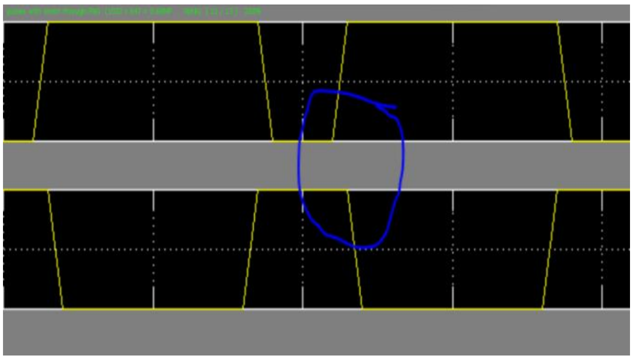

Fig 3.5(c) The gate pulses given to both the switches in a leg with shoot through state (Modified SVPWM)

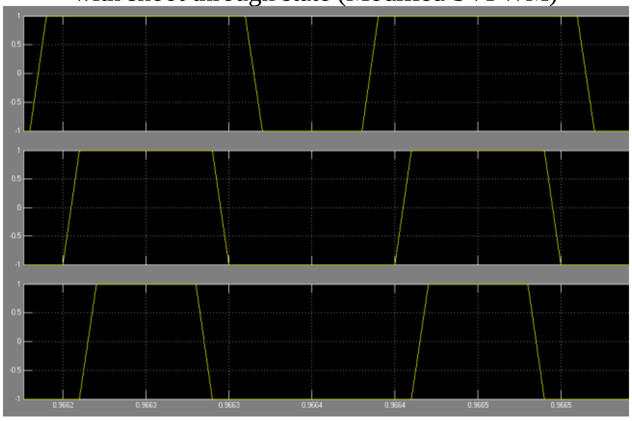

Fig 3.5(d) the plot of gate pulses for all the three legs

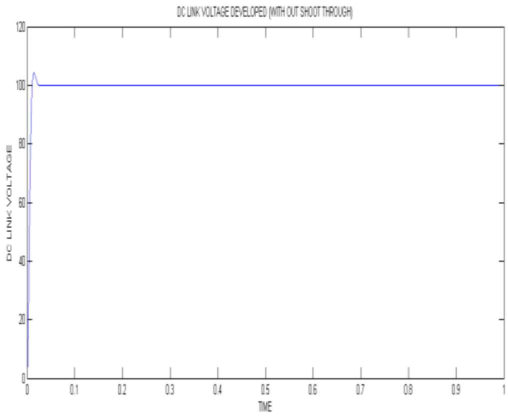

Fig 3.5(e) The Dc Link Voltage Plot For A ZSI With Modified SVPWM

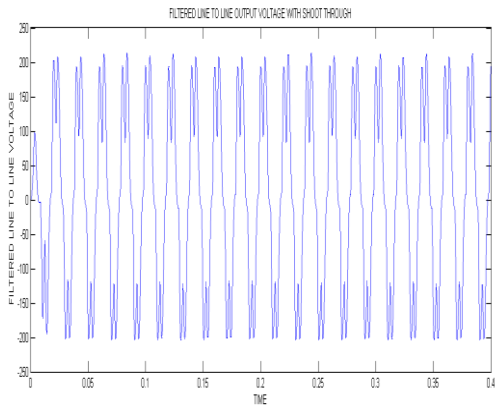

Figure 3.5(f) Output voltage of ZSI with Modified SVPWM

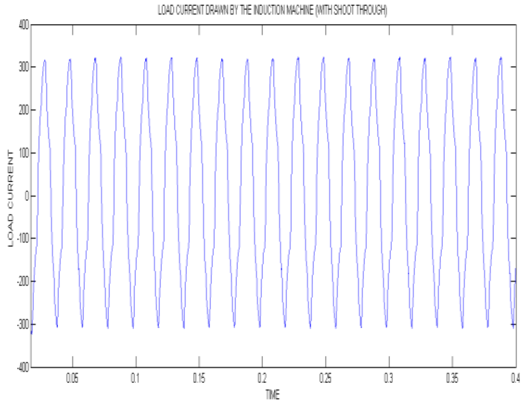

Figure 3.5(g) Output voltage of IM load with Modified SVPWM

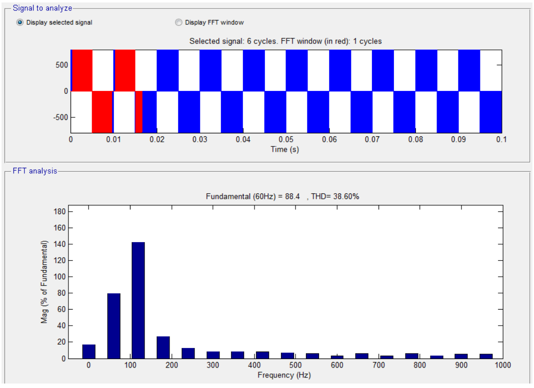

Figure 3.5(h) FFT analysis of ZSI output voltage

V. CONCLUSION

This paper reviewed five PWM controls, The results shows dc-link voltage stress to be the design parameter needing main consideration in ZSI performance. A factor common to the PWM controls is the boosting of the dc link voltage via use of shoot-through state. A modified Space vector Pulse Width Modulation (SVPWM) Z-source inverter based approach presented shows that the Output AC voltage obtained from ZSI is no longer limited and can be boosted beyond the limit imposed by conventional VSI. Possibly, it is the best among all the PWM techniques for variable speed applications

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