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Design and Analysis for Various Controlling Methods of a Z-Source Inverter

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Abstract

In this paper three diverse control strategies of z-source inverter are proposed. The ZSI overcomes the restrictions and conceptual boundaries of the VSI (voltage source snverter) and CSI (current source inverter). The ZSI has a separate LC network used to combine the converter network to the source and thus gives unique features as compared to traditional VSI and CSI. This inverter performs as both buck operation as well as boost operation in a one stage structure. The unwavering quality of the inverter has enhanced on the grounds that the shoot through caused by EMI (electromagnetic interface) noise cannot any more pulverize the circuit. The simple boost constant boost and maximum boost control strategies are examined and the correlation of voltage gain to modulation index (MI) are additionally dissect in detail and confirmed by the Matlab Simulation results.

Keywords: VSI, CSI, ZSI, controlling methods of ZSI.

1. INTRODUCTION

Voltage source, current source (VS and CS) inverters are the two conventional inverters, depending upon power flow directions.

1.1. Voltage source inverter

The fundamental converter circuit of VSI, is feeded by DC voltage source with a large capacitor which makes the info DC voltage is steady. The DC voltage source is a battery, diode rectifier &fuel-cell. In this circuit six switches are utilized, and each having one diode is connected anti parallel, which gives the two directional current stream and one directional voltage blocking limit. The VSI can be acts as pulse width inverter.fig.1.1. Demonstrates the conventional three stages VSI is a buck converter.

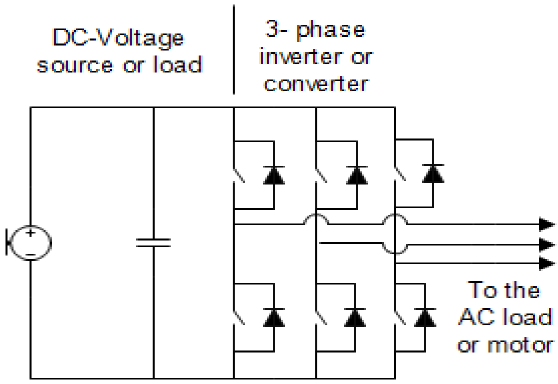


Fig 1.1 Voltage source inverter

The demerits of the VSI are

- Output voltage is finite and cannot transcend the Dc input voltage.
- External devices are needed to boost the voltage, which increases the cost and decrease the overall system efficiency.
- Occurrence of shoot through will destroy the devices.
- LC filter output is needed which causes losses and control is more complex.

1.2. Current Source Inverter

The CSI is shown in fig.1.2. The input to the inverter is a current source or voltage source with an inductor in series. This inverter having six switches and each switch is having one series diode which provides a one directional flow of current and two directional voltage blocking capacity.

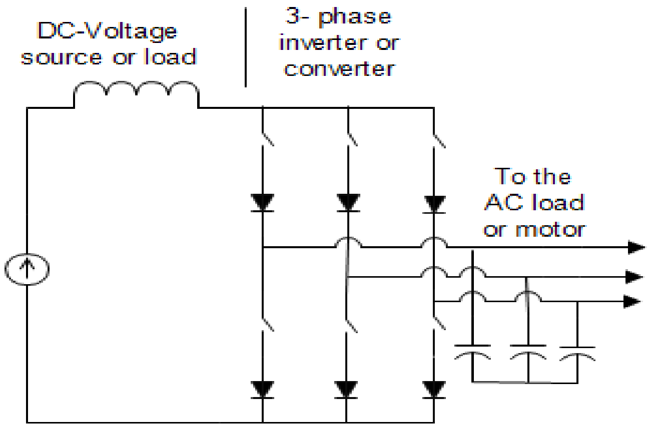


Fig 1.2 Current source inverter

The inverter consists of three capacitors is connected at output of the inverter to gives a load power factor is leading.

The demerits of the CSI are

- It is a boost inverter.
- The CSI is more economic.
- The operating power factor is low on line side.
- CSI is sensitive to EMI noise in terms of reliability.

2. Z-SOURCE INVERTER

To defeats the demerits of the conventional VSI and CSI converters, this paper introduces an impedance source control converter (Z-Source). The setup of three stage Z-Source inverter is appeared in fig.2. It comprises of the two indistinguishable inductors and capacitors which are made to frame a one of a kind impedance system to avoid the short circuit when devices are in ST mode, one diode is used to block the reverse current and three Phase Bridge as in traditional inverter.

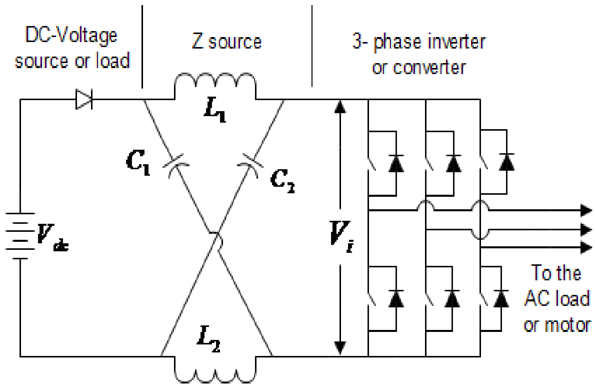
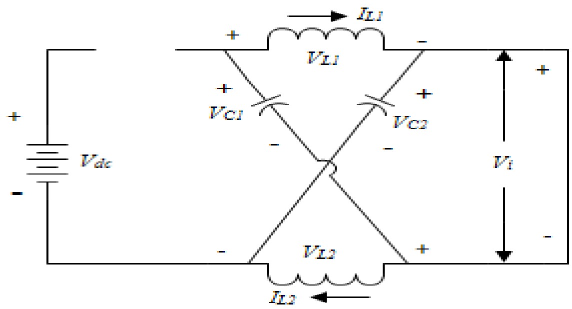
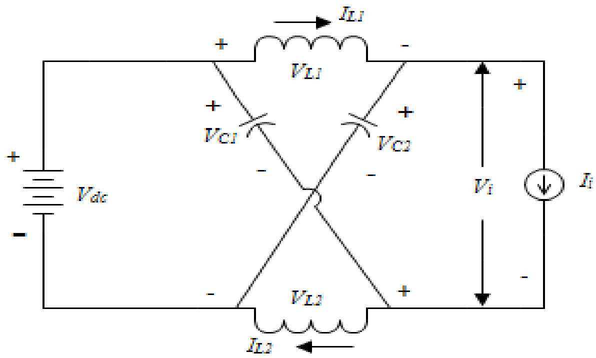


Fig 2.1. Z-Source inverter

A two-port system that comprises of a split-inductors and capacitors that are associated fit as a X shaped network is utilized to give a Z-source coupling the inverter to the dc source or another converter. We can deliberately include a shoot-through with the remarkable LC system to help the yield voltage. By using the changing states to help the yield voltage we get the yield voltage higher or beneath the dc interface voltage. In this manner the inverter is a buck-support sort converter and can yield whatever voltage desired, and to defeat the demerits of conventional inverters. The ST causes be EMI cans no longer failure of the inverter, which increases the reliability of the inverter greatly. Because of dead time is not required, perfect sinusoidal output waveform is obtainable. The equivalent network represented in figure 2.2.



(a)



(b)

Fig 2.2 Z-Source Inverter Equivalent Circuits when in (a) shoot-through (ST) (b) non-shoot-through (NST).

Let us consider inductors $L_{1,}$ L_2 and capacitors $C_{1,}C_2$ have the equal inductance,capacitance respectively, a z-source circuit gets identical.

$$V_{C1} = V_{C2} = V_C \qquad (1)$$

$$V_{L1} = V_{L2} = V_L \qquad (2)$$

The inverter in ST zero state for a time T_0.During a switching cycle, T and from the equivalent circuit, figures 2.2 (a)

$$V_L = V_C$$

$$V_d = 2V_C$$

$$V_i = 0$$

Now consider the NST switching states for a of time T_1, during the switching cycle, T and from the equivalent circuit, figure 2.2 (b).

$$V_L = V_{dc} - V_C$$

$$V_d = V_{dc} \qquad (3)$$

$$V_i = V_C - V_L = V_C - (V_{dc} - V_C)$$

$$V_i = 2V_C - V_{dc} \qquad (4)$$

Where V_{dc} is the input DC source voltage.

$$T = T_0 + T_1 \qquad (5)$$

The inductor average voltage by single switching period is zero in stable state, thus we have

$$V_L = \frac{T_0 V_C + T_1 (V_{dc} - V_C)}{T} = 0$$

$$V_L = \frac{(T_0 V_C + T_1 V_{dc} - T_1 V_C)}{T} = 0$$

$$V_L = (T_0 - T_1) V_C / T + (T_1 V_{dc}) / T$$

$$\frac{V_C}{V_{dc}} = \frac{T_1}{T_1 - T} \qquad (6)$$

Thus the dc link average the inverter voltage will be

From equation (4)

$$V_i = (T_0 * 0 + T_1 (2V_C - V_{dc}))/T \qquad V_i = (2V_C * T_1/T) - (T_1 * V_{dc}/T)$$

$$2V_C = V_0 \qquad (7)$$

From equation (6)

$$T_1 * V_{dc}/(T_1 - T_0) = 2V_C * T_1/(T_1 - T_0) \qquad V_C = V_{dc} * T_1/(T_1 - T_0)$$

The maximum dc-link voltage of the inverter is

$$V_i = V_C - V_L = 2V_C - V_0 \qquad V_i = T/(T_1 - T_0).V_{dc} = B * V_{dc} (8)$$

Where

$$B = T/(T_1 - T_0) \geq 1$$

B is a boosting factor

The inverter output maximum phase voltage is

$$V_{out} = M.V_{dc} / 2 \qquad (9)$$

Where M = modulation index

The source

$$V_{out} = M.B.V_{dc} / 2 \qquad (10)$$

The output voltage is increase and decrease by choosing a proper buck-boost factor B*.

B*=B. M (It changes from 0 to α) (11)

The capacitor voltage will be illustrated as

$$V_{C1} = V_{C2} = V_C = (1 - T_0 / T_1).V_0 / (1 - 2T_0 / T)$$

The boosting parameter B is sustained by modulation index (MI). The boosting parameter B is controlled by duty ratio of ST zero switching state over the non-shoot-through exchanging conditions of the inverter. The accessible shoot-through period is constrained by the modulating index and it proportionally creates a similar zero voltage to the load terminals.

Merits of ZSI

- The ZSI allows the buck-boost function by one stage conversion.
- ZSI is less damaged by EMI noise.
- ZSI gives a ride-through at the time of voltage sags beyond any other extra circuits.
- As capacitor and inductor is used in the dc link, it makes a stable high impedance voltage source.
- Provides a less cost, reliable, and highly efficient.

3. PROPOSED CONTROLLING TECHNIQUES:

Various SPWM (sinusoidal pulse width modulation) controlling methods are utilized to control z-source inverter are as follows:

A. Simple boost control (SBC)
B. Maximum boost control (MBC)
C. Constant boost control (CBC)

The modulation index (M) which is the principle control component and it is characterized as the ratio of amplitude of reference wave to amplitude of the carrier wave.

$$M = \frac{V_{ref}}{V_{car}} \qquad (12)$$

The relation of modulation index and output voltage is produced by under modulation index (M<1).

A. Simple Boost control:

In this system, gating pulses are generated by correlating the three sine reference signals and two constant voltage envelope with the carrier triangular wave. The reference signals are phase difference by 120 degrees and amplitude of two envelopes is same as to peak amplitude of reference signals. When the magnitude of the triangular wave is more than or equal to the top envelope (or) lesser than the negative envelope, shoot through pulses are created and then the inverter is operate in shoot-through or else it acts as conventional PWM inverter.

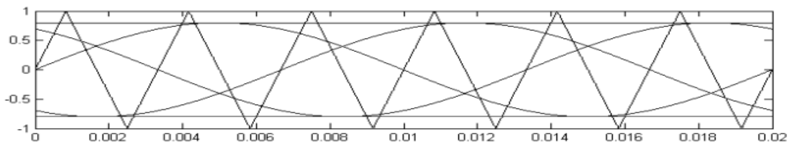


Figure 3.1 Illustration of SBC

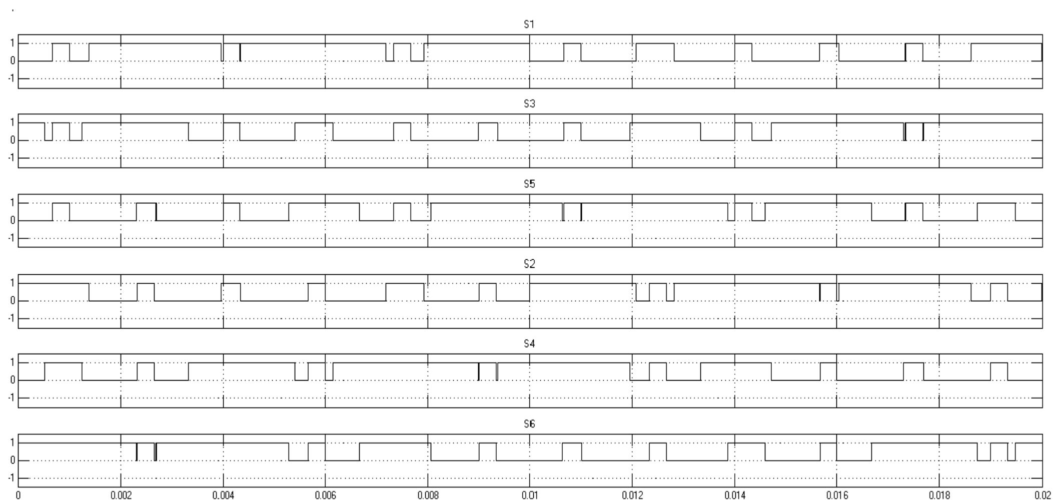


Figure 3.2 Pulses generated using SBC

The sinusoidal voltage signals along with the triangular signal and two constant DC voltages. Figure 3.1 & 3.2 shows the modulation. The pulses produced utilizing this method for a total switching time period T_s, T_0 is the zero/null state time periods and D_0 is the ST duty ratio.

$$D_0 = \frac{T_0}{T_S} \tag{13}$$

The ST duty ratio (D_0), boosting factor (B) and voltage gain (G) with triangular wave are given by,

$$D_0 = 1 - M \tag{14}$$

$$B = \frac{1}{2M - 1} \tag{15}$$

$$G = \frac{M}{2M - 1} \tag{16}$$

B. Maximum Boost Control:

In this strategy, all the zero states are transformed into ST state and consequently the voltage gain is improved. The circuit in ST state when a triangular signal is either more than the most extreme bend of references (Va, Vb, Vc) or lesser than the base of the references. By this control technique the ST duty cycle changes each cycle. The inverter increases most extreme ST time which thus gives the inverter higher boost factor. In this manner, with a similar modulation index (M) as in the basic boost control strategy, we get the higher voltage gain.

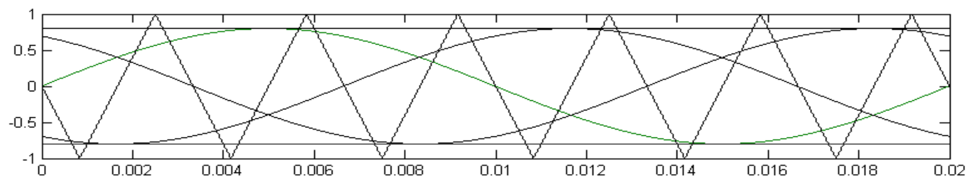


Figure 3.3 Illustration of MBC

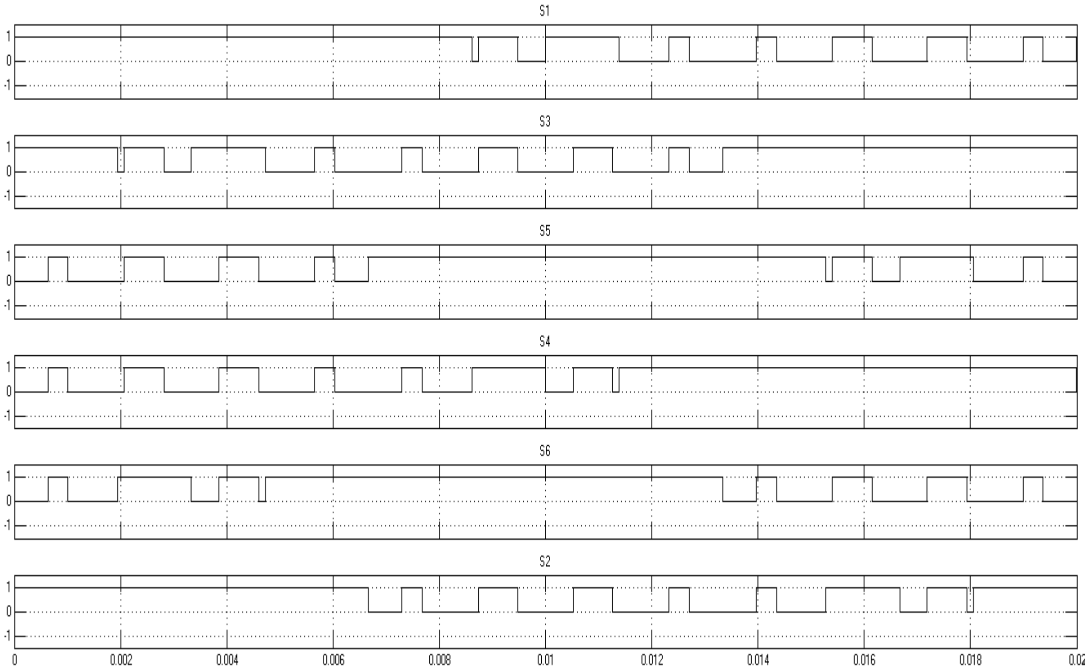


Figure 3.4 Pulses generated using MBC

To create switching signals, three stage reference waveforms having to an incentive with modulation index (M) are contrasted and a similar high recurrence triangular wave. Comparator thinks about these two signals and creates the pulses. These are received by the gates of power IGBT's through disconnection and gate drive circuit are appeared in figure-3.3 and 3.4.

$$D_0 = \frac{2\pi - 3\sqrt{3}M}{2\pi} \qquad (17)$$

$$B = \frac{\pi}{3\sqrt{3}M - \pi} \qquad (18)$$

$$G = \frac{\pi M}{3\sqrt{3}M - 1} \qquad (19)$$

C. Constant / Stable Boost Control:

To minimize the size and cost, it is important always to keep the shoot-through duty cycle is constant. At the same time, a generate voltage boosting for a given any modulation index can be described to minimize the voltage stress across the switches. The generation of pulses by CBC method, which gets the voltage gain is maximum while keeping the shoot-through duty ratio constant.

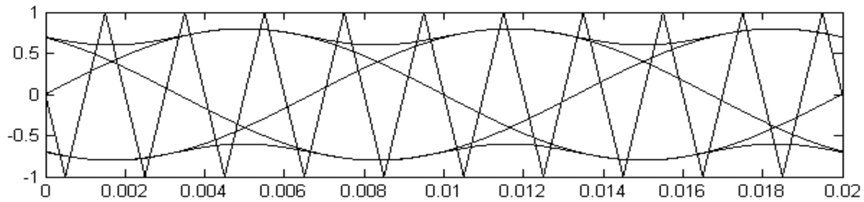


Figure 3.5 Illustration of CBC

Here the V_a, V_b and V_c are the reference signals and ST envelope signals are V_p and V_n.

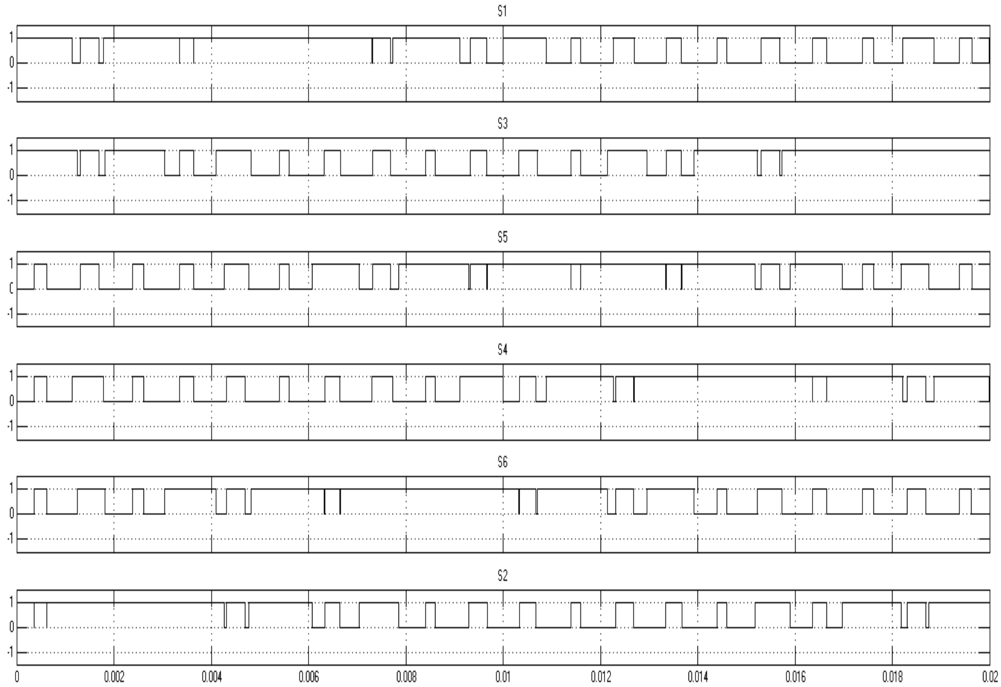


Figure 3.6 Pulses generated using CBC

The triangular wave is more than the top shoot through envelope V_p, or lowers than the shoot through envelope V_n the inverter has turned to a ST zero state. The distance between upper and lower envelopes is constant and its value is √3M the gating pulses are shown in figure 3.5, 3.6.

$$D_0 = 1 - \frac{\sqrt{3}M}{2} \tag{20}$$

$$B = \frac{1}{\sqrt{3}M - 1} \tag{21}$$

$$G = \frac{M}{\sqrt{3}M - 1} \tag{22}$$

4. SIMULATION RESULTS:

Simulations are taken to verify all PWM control methods. The simulation specifications are taken as: Input voltage is 100 volts, inductance L1 and L2 is 0.16mH, capacitance C1 and C2 is 1F and three phase resistance load is R1, R2 and R3 are 10Ω.

For the three controlling techniques are SBC, CBC and MBC techniques the results are analyzed that is output voltage and current, capacitor voltage for the different modulation indices.

I. Results for Output Voltage:

A.Simple B**oost Control:**

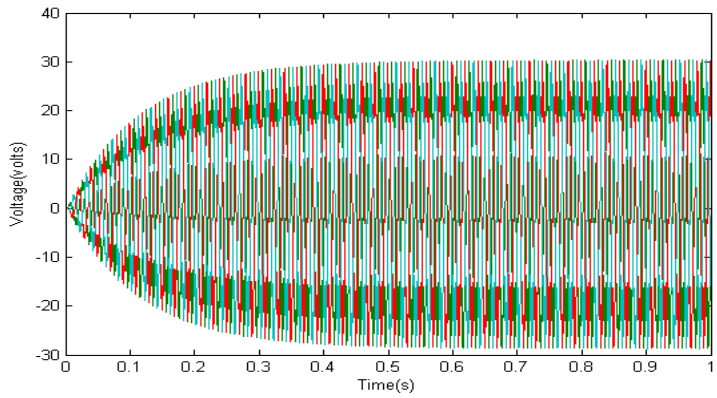


Figure 4.1: M =0.4

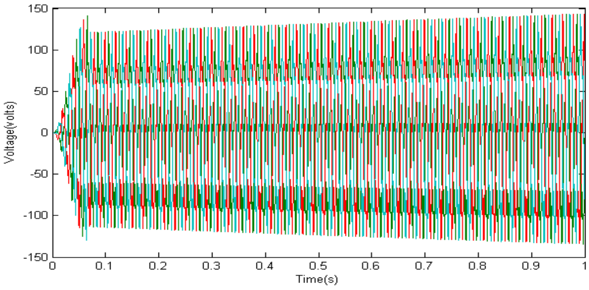


Figure 4.2: M =0.8

B. Maximum Boost Control:

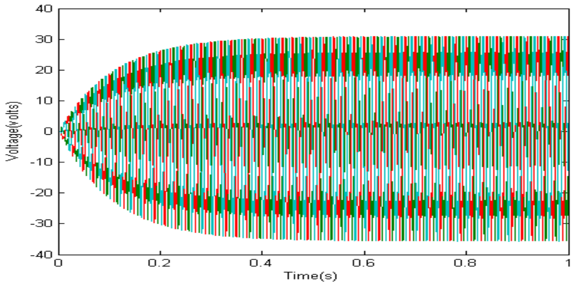


Figure 4.3: M =0.4

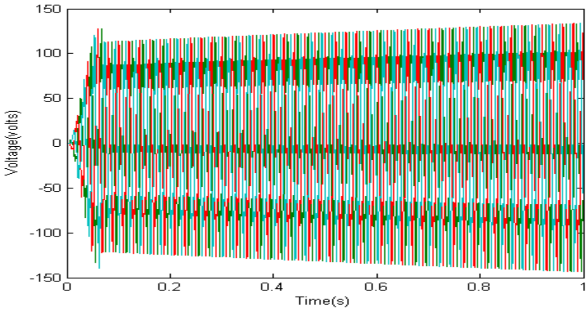


Figure 4.4: M =0.8

C. Constant Boost Control:

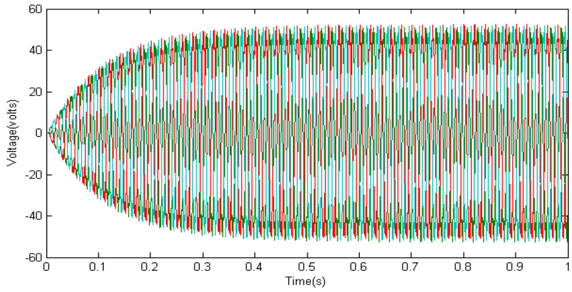


Figure 4.5: M=0.4

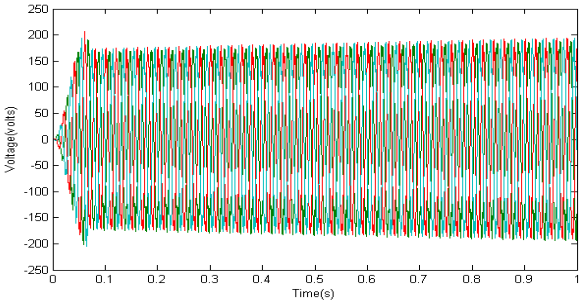


Figure 4.6: M =0.8

II. Results for Output Current:

A.Simple Boost Control:

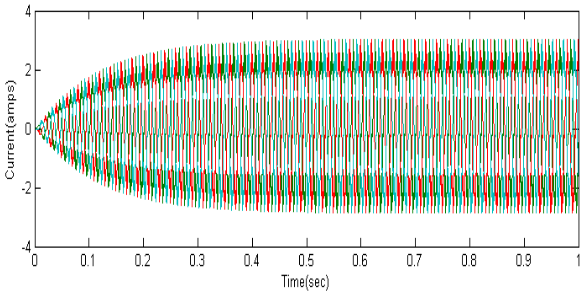


Figure 4.7 M =0.4

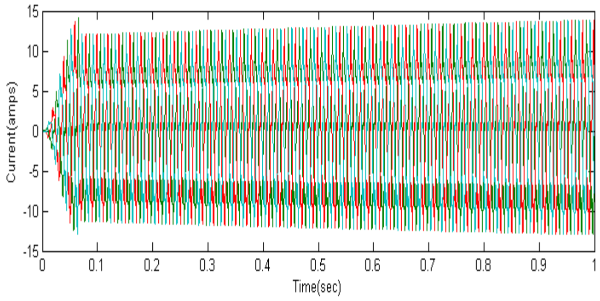


Figure 4.8 M =0.8

B. **Maximum Boost Control:**

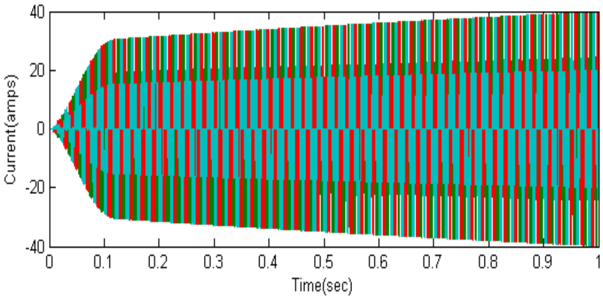


Figure 4.9 Modulation indices from 0.1-1.0

C. Constant Boost Control:

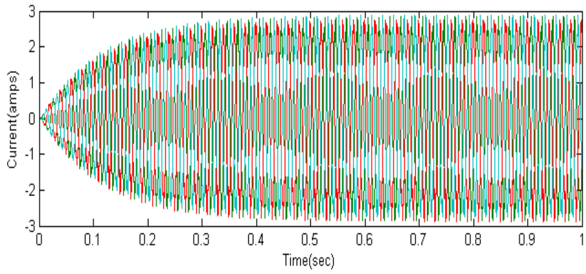


Figure 4.10 M =0.4

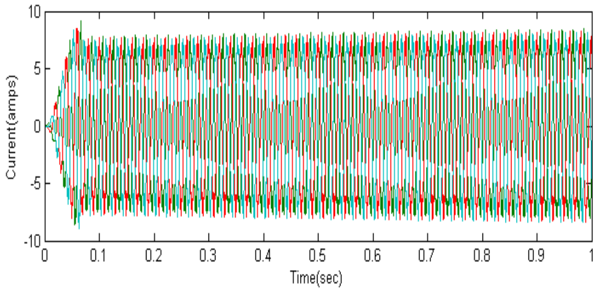


Figure 4.11 M =0.8

III. Results for Capacitor Voltage:

A. Simple Boost Control:

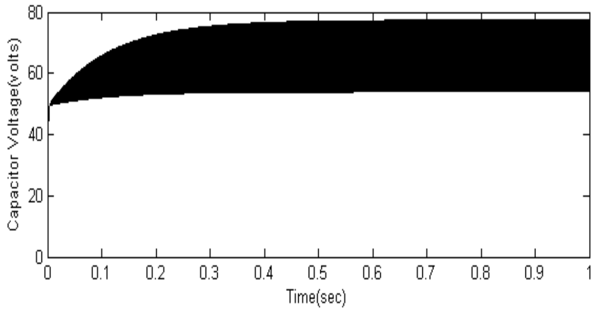


Figure 4.12 M =0.4

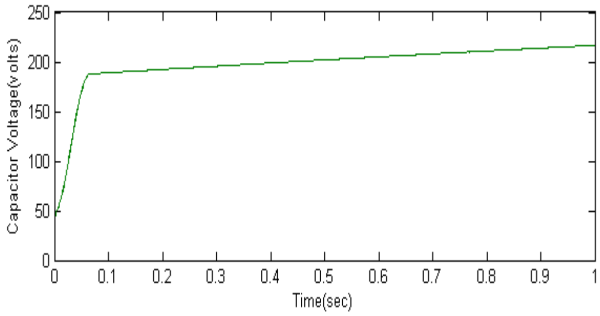


Figure 4.13 M =0.8

B. Maximum Boost Control:

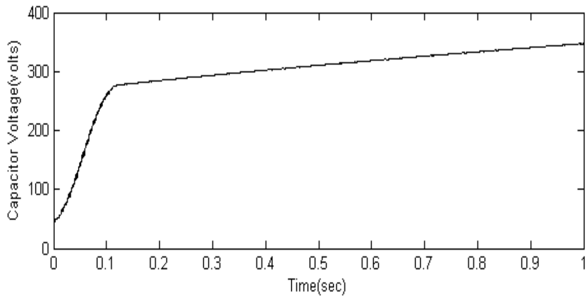


Fig 4.14 modulation indices from 0.1-0.9

C. Constant Boost Control:

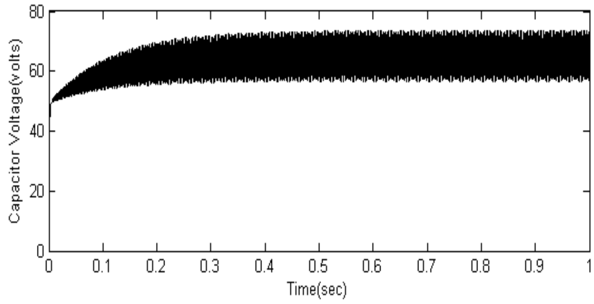


Figure 4.15 M =0.4

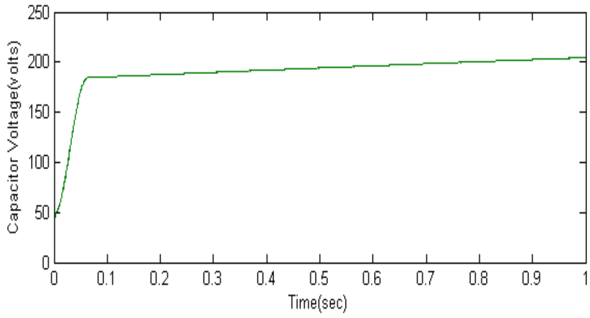


Figure 4.16 M =0.8

5. CONCLUSION

Simulation of three PWM controlling strategies of ZSI is carried out with the similar input voltage and load conditions. The correlation between the modulation index and voltage gain, output current and the capacitor voltages are analysed for different control methods are shown in Tables 5.1, 5.2 and 5.3 from 0.1 to 0.5 modulation indexes, the ZSI acts as a buck converter and from 0.6 to 0.8 it acts as a boost converter in one stage structure. In this three controlling methods the CBC technique is obtained maximum voltage gain. In CBC output currents are less as compared to SBC and MBC, and the output current is constant for all modulation indices from 0.1 to 0.9.The capacitor voltage is maximum in the MBC. In CBC methods the capacitor draws the less voltage than the SBC and MBC. This high output currents and high capacitor voltages are effect on system efficiency and reliability.

Table 5.1: Relationship of M and voltage gain of SBC, MBC, and CBC

Modulation index(M)	Voltage gain of SBC	Voltage gain of MBC	Voltage gain of CBC
0.4	29	32	50
0.8	130	140	190

Table 5.2: Relationship of M and Output Currents of SBC, MBC, and CBC

Modulation index(M)	Output current of SBC	Output current of MBC	Output current of CBC
0.4	3.0	23	2.7
0.8	14	23	6

Table 5.3: Relationship of M and Voltage across capacitor of SBC, MBC, and CBC

Modulation index(M)	Voltage across the capacitor In SBC	Voltage across the capacitor in MBC	Voltage across the capacitor in CBC
0.4	78	350	70
0.8	220	350	210

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