

# SIMULATION OF Z-SOURCE INVERTER FOR INDUCTION MOTOR DRIVE

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**Abstract** - The Z-source inverter system is control for general-purpose motors and motor drives. The Z-source inverter system employs a unique LC network in the dc link. By controlling the shoot-through duty cycle, source can produce any desired output ac voltage, even greater than the line voltage [1]. As a result, the new source inverter system provides ride-through capability under voltage sags, reduces line harmonics, improves power factor and reliability, and extends output voltage range.

The Z-source inverter is an alternative power conversion topology that can both buck and boost the input voltage using passive components. With its unique structure, Z-source inverter can utilize the shoot through states to boost the output voltage, which improves the inverter reliability greatly, and provides an attractive single stage dc to ac conversion that is able to buck and boost the voltage. This paper focuses on study of simulation of Z-source inverter fed Induction motor drive using simple boost control performance under normal and in voltage sag condition.

**Index term:** Shoot through states, Simple boost control, Z Source Inverter (ZSI)

## 1.INTRODUCTION

Inverters are the dc to ac converters. The input dc supply is either in the form of voltage or current is converted in to variable output ac voltage. The output ac voltage can be controlled by varying input dc supply or by varying the gain of the inverter.

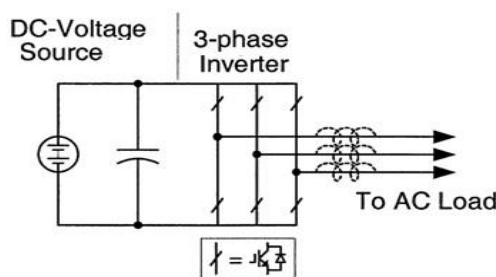


Fig.1.Traditional voltage source inverter

There are two types of traditional inverters based on input source used in industries for variable speed drive and

many other applications; those are a) Voltage-source inverter and b) Current-source inverter.

Figure.1 shows the traditional three-phase voltage-source inverter. The dc voltage source connected at the input side across a large capacitor. DC link voltage produced across this capacitor feeds the main three-phase bridge. The input dc supply can be a battery or fuel cell stack or diode rectifier, and/or capacitor. Three phase bridge inverter circuit consists of six switches; each is composed of a power transistor and an anti-parallel diode to provide bidirectional current flow and reverse voltage blocking capability.

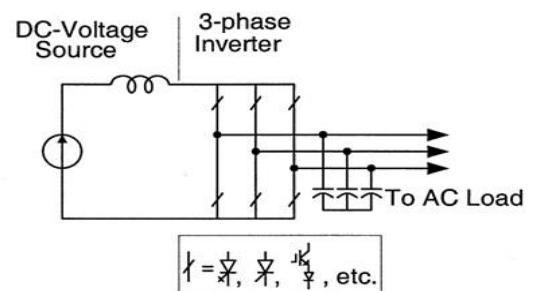


Fig.2.Traditional current source inverter

Figure 2 shows the traditional current-source inverter (CSI). The DC current source is formed by a large dc Inductor fed by a voltage source such as a battery or fuel-cell stack or diode rectifier or converter etc. Like VSI three phase bridge inverter circuit consists of six switches; each is composed of a switching device with reverse block capability such as a gate-turn-off thyristor and SCR or a power transistor with a series diode to provide unidirectional current flow and bidirectional voltage blocking. For voltage source inverter and current source inverter the on/off time the switching devices is controlled by applying control voltage (PWM) to the control terminal i.e. gate of the device.

Traditionally in most of industries these voltage-source inverter and current-source inverter are used in adjustable speed drives. But these traditional inverters have many limitations as summarized below:

1) They are either a buck or a boost converter [2] and cannot be a buck-boost converter. That is, the output voltage is either greater or smaller than the input voltage. The output voltage of voltage source inverter is always

less than input voltage so it is called a buck inverter; hence additional voltage booster circuit needs to be added. While for current source inverter the output voltage is always greater than input voltage so it is called a boost inverter, hence additional voltage regulator circuit needs to be added. This increases additional component cost.

2) For VSI and CSI main bridge inverter circuits cannot be interchangeable. In other words the voltage-source inverter main circuit cannot be used for the current-source inverter or vice versa.

3) The shoot-through problem for Voltage source inverter and open circuit problem for current source inverter by electromagnetic interference (EMI) noises reduce the inverter's reliability. In case of voltage source inverter both upper and lower transistors should not be switched on simultaneously, otherwise it would cause shoot-through, which may damage inverter circuit due to large current. Hence dead time to block both upper and lower devices needs to be provided in the V-source inverter, which causes waveform distortion.

4) In case of current source inverter both upper and lower transistors should not be switched off simultaneously, otherwise it would cause open circuit along the bridge arm, which may damage inverter circuit due large voltage drop across open circuit. Hence overlap time where both upper and lower devices conduct simultaneously needs to be provided for safe operation, which causes waveform distortion.

## 2. ZSI FED INDUCTION MOTOR DRIVE

To overcome the problems associated with the traditional voltage source and current source inverters, this paper presents an impedance-source inverter (abbreviated as Z-source inverter) and its control method for implementing dc-to-ac, ac-to-dc, ac-to-ac, and dc-to-dc power conversion. Figure. 3 shows the general structure of Z-source inverter [3].

Figure 3.1 shows the Basic Z-source inverter topology, which consists of inductors ( $L_1$  and  $L_2$ ) and capacitors ( $C_1$  and  $C_2$ ) connected in X shape to couple the inverter to the dc voltage source. The Z-source inverter can produce a desired ac voltage regardless of dc source voltage. Because of this special structure, the Z-source inverter has an additional switching state, when the load terminals are shorted through both the upper and lower switching devices of any phase leg, which called the shoot-through (ST) state besides the eight traditional non shoot through (NST) states[1]. The Z-source inverter has two operating modes: non-shoot-through mode and shoot-through mode, as shown in Figure 4 and Figure 5

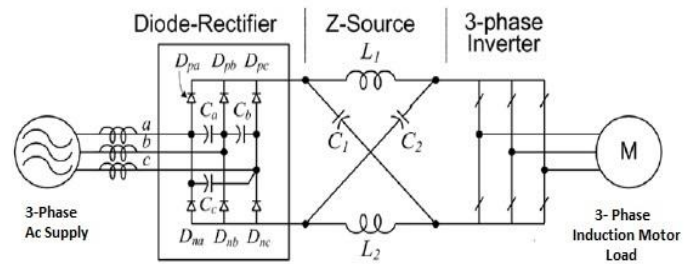


Fig 3: Z-source inverter fed induction motor

Figure 3 shows the power circuit configuration of the Z-source inverter fed induction motor drive system. Similar to that of a traditional inverter fed induction motor system. The Z-source inverter fed induction motor drive system's power circuit consists of four major parts: a front end diode rectifier, Z-network, an inverter bridge and a three phase induction motor load.

The differences are that a DC link circuit is implemented by the Z-source network ( $C_1$ ,  $C_2$ ,  $L_1$  and  $L_2$ ). Small range of input capacitors ( $C_a$ ,  $C_b$  and  $C_c$ ) is connected to the front end diode rectifier[2]. These input capacitors also serves as a DC source feeding the Z-source network and are used to suppress voltage surge that may occur due to the line inductance during diode commutation and shoot-through mode of the inverter, thus requiring a small value of capacitance.

These changes can easily be realized and implemented from the traditional inverter fed induction motor drive systems. Since the Z-source inverter bridge could boost the DC link capacitor ( $C_1$  and  $C_2$ ) voltage to any desired value that is above the average DC value of the rectifier, a desired output voltage is always obtainable regardless of the line voltage. For a 230V adjustable speed drive system, the Z-source capacitor voltage could be boosted to 350V or greater in order to produce 230V rms AC output regardless of the line voltage. Theoretically, the Z-source capacitor voltage can be boosted to any value above the inherent average DC voltage (310–325V for a 230V line) of the rectifier rating in practical use [3].

From the symmetry of the Z-source and equivalent circuit one has,

$$V_{c1} = V_{c2} = V_c; \quad V_{L1} = V_{L2} = V_L \quad (1)$$

Based on the switching states, the operation of the Z-source inverter could be classified in to three operating modes, namely traditional active (non-shoot-through) mode, shoot-through mode and traditional zero mode.

**2.1 MODES OF OPERATION:**

**i) Traditional Active State:**

Figure shows an equivalent circuit of the active mode, during one of the six traditional active states, the inverter bridge acts as a traditional voltage source inverter, thus acting as a current source viewed from the Z-source circuit. The positive group diodes ( $D_{pa}$ ) and the negative group diodes ( $D_{nb}$ ) conduct and carry currents. In traditional inverter based inductor motor drive system, the diode bridge may conduct depending on the DC link capacitor voltage level.

However the diode circuit always forces the Z Source to conduct and carry a difference between inductor current  $I_L$  and current through the inverter  $I_{out}$

Because of the symmetrical configuration of the circuit, both the equal inductors would have identical current value. The diode in the equivalent circuit would be forward biased in this case. From the symmetry of Z-source network and equivalent circuit one could have,

$$\begin{aligned} V_L &= V_{dc} - V_C; V_d = V_{dc} \\ V_o &= V_C - V_L = 2V_C - V_{dc} \end{aligned} \quad (2)$$

where,  $V_o$  peak DC link output voltage,  
 $V_{dc}$  is DC supply voltage  
 $V_d$  is the voltage before dc link.

**ii) SHOOT-THROUGH STATE :**

Figure 4 shows the equivalent circuit representation of shoot-through mode of operation. In this mode, the inverter bridge is under one of the shoot-through states for an interval ( $T_0$ ), over a sampling period ( $T_s$ ). The diode in the equivalent circuit would be reverse biased in this case. During the shoot-through state, both diodes are off, separating the DC link from the AC line and line current flows to the capacitor ( $C_a$ ). This shoot-through period ( $T_0$ ) is applied in every switching cycle ( $T_s$ ) and acquired from the traditional zero time ( $T_Z$ ) period generated by the PWM control.

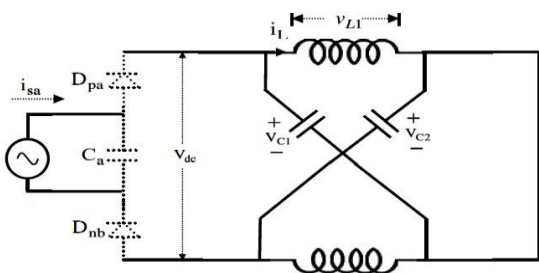


Fig 5 Equivalent circuit under shoot-through state

Depending on a voltage boost needed, the shoot-through time interval or its duty cycle is determined. It could be seen that the shoot-through interval is only a fraction of the switching cycle; therefore it requires a relatively small capacitor to suppress the voltage. The voltage across the impedance elements could be,

$$V_L = V_C; V_d = 2V_C; V_o = 0 \quad (3)$$

where,  $V_o$  = Peak DC link output voltage

**iii) TRADITIONAL ZERO STATE :**

During one of the two traditional zero states ( $T_Z$ ), (i.e. shorting through either the upper or lower three switches) the inverter bridge is acting as an open circuit viewed from the Z-source circuit and the diodes conduct. The equivalent circuit of Z-source inverter fed drive system during traditional zero state is shown in Figure6. Since the inverter bridge is in any one of the traditional zero states (000 or 111), the instantaneous output voltage of the inverter is zero.

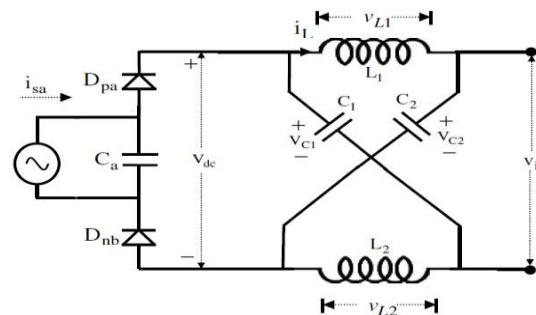


Fig 6: Equivalent circuit under traditional zero state

The peak DC link voltage across the inverter bridge is expressed in equation and it could be written as,

$$\begin{aligned} V_o &= V_C - V_L = 2V_C - V_{dc} \\ &= \frac{1}{1 - 2D_o} V_{dc} = BV_{dc} \end{aligned} \quad (4)$$

where B is boost factor and  $D_o$  shoot-through duty ratio  $D_o = \frac{T_0}{T_s}$

The voltage stress across the switch is equal to the peak DC link voltage  $\hat{v}_i = BV_{dc}$ , therefore, to minimize the voltage stress for any given voltage gain ( $G=Bm_a$ ), one need to minimize B and maximize  $M_a$ , with the restriction of that their product is the desired value. On the other hand, one should maximize B for any given modulation index  $m_a$ , to achieve the maximum voltage gain. The voltage across the Z-source capacitors could be written as

$$V_{C1} = V_{C2} = V_C = \frac{1 - \frac{T_0}{T_s}}{1 - \frac{2T_0}{T_s}} V_{dc} = \left[ \frac{1 - D_o}{1 - 2D_o} \right] V_{dc}$$

$$= \left[ \frac{B + 1}{2} \right] V_{dc} \quad (5)$$

Where,  $B = \frac{1}{1-2D_o}$

Peak value of the AC output voltage could be expressed as  $V_{ac} = m_a B \frac{V_{dc}}{2}$

### 3. GENERATION OF GATE PULSES USING SIMPLE BOOST CONTROL :

Figure shows subsystem for gate pulse generation for Z-Source Inverter. In this system three phase reference voltage is compared with carrier triangular wave, this will generate normal PWM pulses for Inverter operation. In addition to this six normal pulses another two constant levels are included in simple boost control, in which when triangular wave is cut by positive or negative dc level it will generate additional pulses for shoot through.

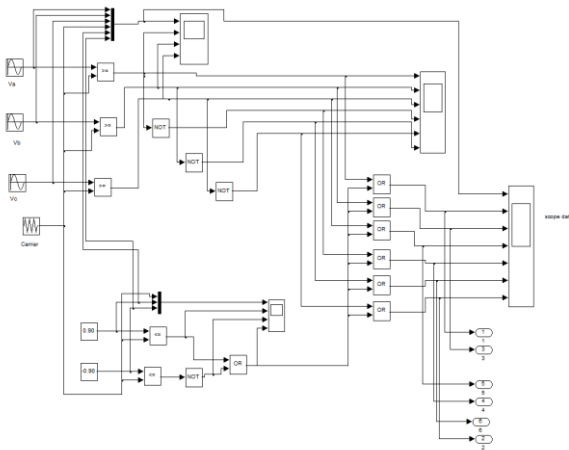


Fig:7 PWM Pulses for Simple Boost Control Method

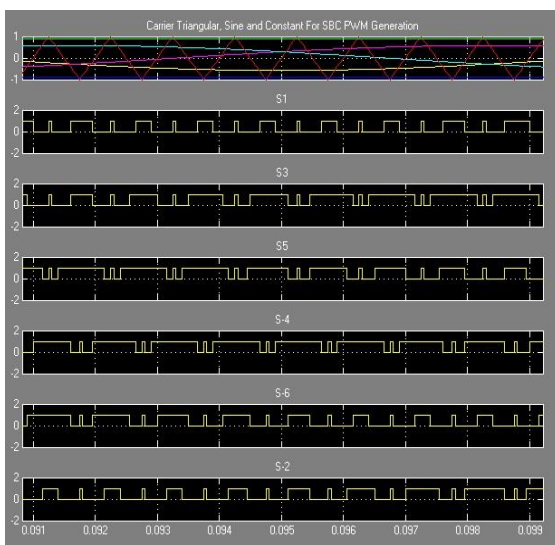


Fig.8 PWM Pulses - Simple Boost Control

### 3 SIMULATION OF Z- SOURCE INVERTER FED INDUCTION MOTOR DRIVE:

Input AC voltage	440V 50Hz AC
Rectifier Output Vdc	325 Volts
L <sub>1</sub> and L <sub>2</sub>	250 mH
C <sub>1</sub> and C <sub>2</sub>	4.57 μF
Load	5KW,3-Phase Induction Motor
PWM Technique	Simple Boost Control
Switching Frequency	1 kHz

Table: 1 Parameters for Simulation of Z Source Inverter and Motor Load

### 4. RESULTS:

#### 1) Simulation of ZSI Fed IM Drive

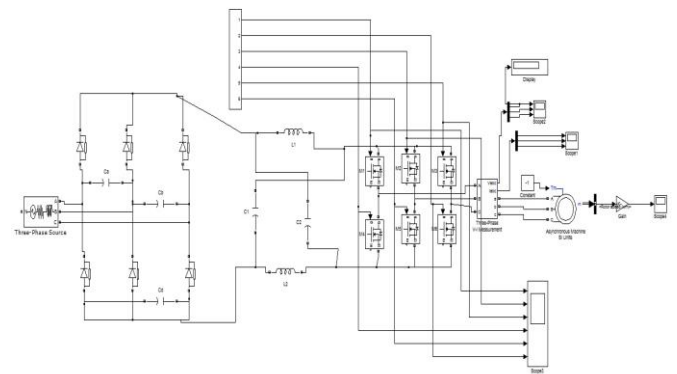


Fig: 9 Actual Simulation of ZSI Fed IM Drive Using Simple Boost Control

#### 2) Input AC Supply Sinewave with normal 230V AC (Phase) without Any voltage sag:

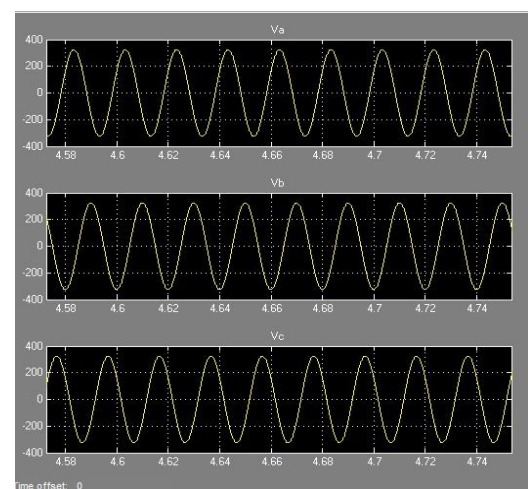


Fig.10 Input AC Supply Sinewave with normal 230V AC (Phase) without Any voltage sag

**3) 230V(Phase) 50Hz Input AC supply with 50% Voltage Sag i.e.115V AC Between 4.6 to 4.8 Sec**

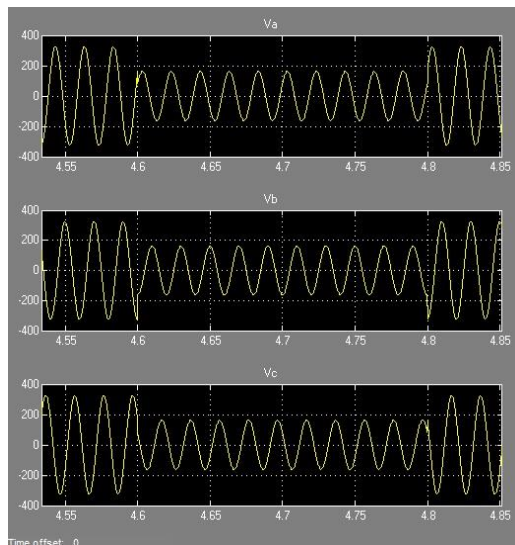


Fig.11 230V50Hz Input AC supply with 50% Voltage Sag i.e.115V AC Between 4.6 to 4.8 Sec

**4) Rectifier Output Voltage Vdc For Normal Input and for Voltage Vdc For 50% Sag**

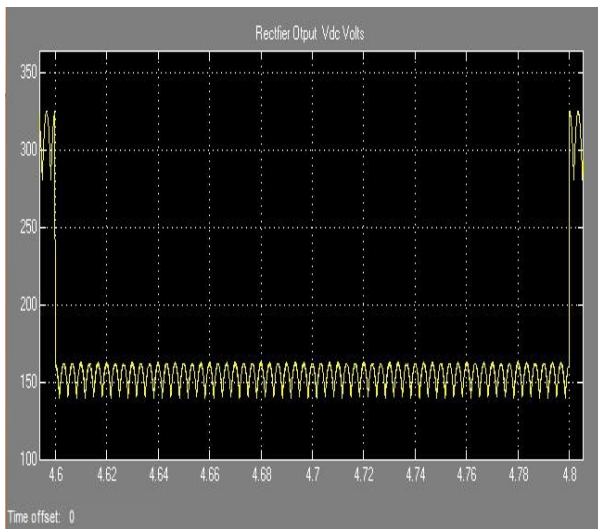


Fig 12: Output of Rectifier 50% Sag (115V)

**5) Inverter Output Voltage for Normal 230V:**

Input voltage is for fig 14, 400V AC that is 230V AC phase to phase rms, inverter dc link voltage is 300 Volt. The purpose of the system is to produce 230V AC i.e. 400V line to line output voltage depending upon the load current. In this case Modulation Index  $M=0.3$  and shoot through duty cycle is set to  $T_o/T = 0.4$  and switching frequency is 1 kHz.

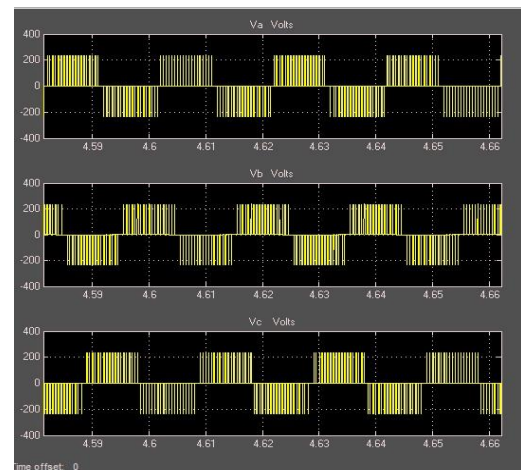


Fig 13: Output of Inverter For Normal Input

**6) Output Voltage waveform with 50% Sag in Input voltage :**

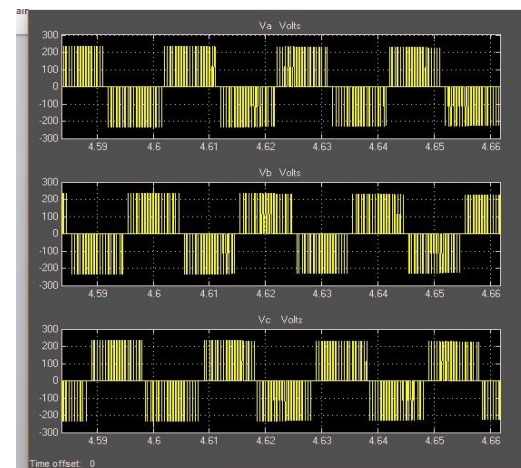


Fig 14: Output of Inverter For 50% 115V AC Input

When the input voltage is for fig 15, 50% i.e. 115V AC phase to phase rms, inverter dc link voltage is 300 Volt. The system produces near to 230V output voltage depending upon the load current. In this case the boost is provided by the shoot through state present in this inverter PWM Control provided Modulation index  $M= 0.3$  which is same as in normal input supply case and shoot through duty ration is also same, The Inverter output is obtained without any close loop and any sensing device. The output is only due to shoot through pulses in the PWM

**CONCLUSION:**

The Z-source converter employs a unique impedance network (or circuit) to couple the converter main circuit to the power source, The Z-source converter overcomes the conceptual and theoretical barriers and limitations of the traditional VSI and CSI provides a novel power

conversion concept. The Z-source inverter has a unique single stage buck boost feature that it can generate any AC output voltage regardless DC input voltage by regulating of shoot-through time. The Z-source inverter based Induction Motor Drive system is proposed. The proposed system worked effectively with the input DC voltage lower than the input voltage. The proposed Z-source inverter was higher efficient, higher performance, cost effective, and uses fewer active components.

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