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Simulation of Z-source Inverter Fed Induction Motor Drive

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ABSTRACT: The Z-source inverter is a recent topological invention in the field of power conversion. It has both buck and boost capabilities as they allow the operation of the inverter in the shoot though state. This feature of shoot through state is not permitted in traditional voltage and current source inverters as it would destroy the device. Z-source inverter employs a unique LC network in between the DC source and the inverter. By controlling this shoot through state, it is possible to produce any desired output ac voltage. This paper presents a Z-source network for induction motor drive. The proposed system is developed with the help of PIC microcontroller which generates the PWM pulses to drive the gate. Simple Boost Control PWM technique has been employed in this inverter to supply the motor with ac voltage. The proposed drive system is simulated using Matlab/Simulink.

KEYWORDS: Voltage Source Inverter (VSI), Current Source Inverter (CSI), Z Source Inverter (ZSI)

I. INTRODUCTION

An inverter is the circuit used to convert the dc input signal into alternating current output. Depending on the nature of the input source, inverters are classified as voltage source inverters and current source inverters .In case of voltage source inverters, input is provided by a dc voltage source, whereas in current source inverters, voltage source is first converted into current source and then it is used as an input to inverter i.e. in VSI a capacitor is used to obtain a constant voltage source whereas in CSI a large inductor is used to obtain a constant current source. The drawback of traditional voltage and current source inverters is that two switches of the same phase leg cannot be turned on/off simultaneously as it would destroy the device, hence dead time is required for safe operation. Also the obtainable output voltage range is limited, and the main bridge circuits of voltage and current source inverter are not interchangeable. Thus to overcome the drawback of traditional inverters, the concept of Z-source inverter is proposed. A Z-source based inverter system can

1) Can produce any desired output ac voltage ,even greater than the line voltage;
2) Provides ride through during voltage sags without any additional circuits;
3) Reduces inrush and harmonic current.

Z-source inverter employs a unique LC network in between the DC source and the inverter. With the LC network added, any two switches of the same phase leg can be switched on simultaneously resulting in a state called as shoot through state. This shoot through state is forbidden in traditional voltage and current source inverters. There are 7 different ways in which the shoot through can be achieved: shoot through via any one phase leg, shoot through via combination of two phase legs, shoot through via all three phase legs. This shoot through state provides the buck-boost feature to the Z-source inverter. The shoot through state boosts the capacitor voltage while producing zero voltage across the load.In this paper, modeling and simulation of the Z-source inverter and its control method for implementing dc-ac power conversion is presented. The design of the Z-source modulation and simulation is carried in Matlab/Simulink environment along with pulse width modulation control strategy.

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II. RELATED WORK

The Z-source inverter was proposed in 2002 by F.Z.Peng [1]. The Z-source inverter has an extra switching state, the shoot through state, which occurs when turning on both switches in the same phase leg. Based on the distribution of the shoot-through ,various pulse width modulation strategies[2-4] exist to control the Z-source inverter such as simple boost, maximum boost, maximum constant PWM, modified space vector PWM and sine carrier PWM. The advantage of using the Z-source inverters is that harmonic distortion is reduced as compared with the traditional inverters [5]. There exist diverse power converter topologies networks mainly derived from the Z-source network by modifying the original impedance network, or by rearranging the connections of inductors and capacitors [6].Z-source inverter finds vast applications in the area of solar, fuel applications etc. In [7], a low cost Z-source inverter for photovoltaic application is presented. The proposed inverter can control the inverter output power, track the PV panel's maximum power point, and manage the battery power, simultaneously. Fuzzy logic controlled Z-source inverter is proposed in [8].A standalone power generation system or UPS is implemented using Z-source inverter in [9]. A seven level diode clamped Z-source inverter for PV application provides higher output voltage through its Z-source network [10]. Z-source inverter based DG (distributed generation) system to improve power quality of distribution systems is proposed in [11]. Application of Z-source inverter in photovoltaic grid connected transformer-less inverter is presented in [12].

III.Z-SOURCE INVERTER

The Z-source inverter consists of unique impedance network placed in between the power source and the inverter circuit. This impedance network helps in providing buck-boost feature that cannot be observed with traditional inverters. The impedance network consists of two inductors and two capacitors connected to each other as shown. The inductors are connected in series arm and the capacitors are connected in diagonal arms. The dc voltage source can be a battery, fuel cell, photovoltaic array, diode rectifier.

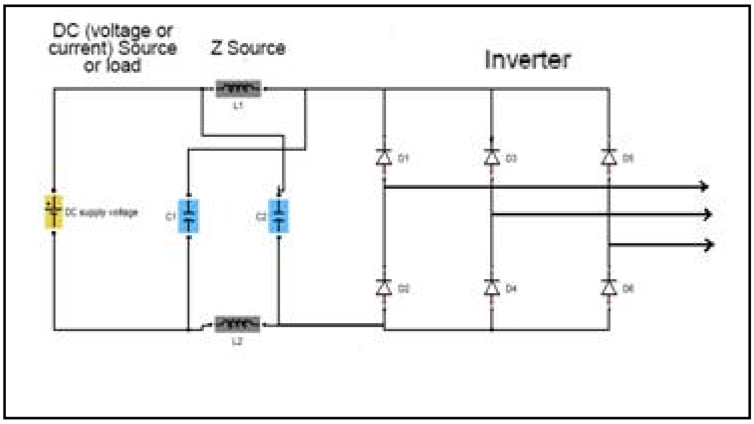

Figure 1: Z-source inverter

To describe the operating principle and control of the Z-source inverter in Fig. 1, let us briefly examine the Z-source inverter structure. The Z-source network operates in two states: shoot through state and the non shoot through state. The non shoot through state is same as in the traditional inverter where the output voltage depends on inverter bridge and the modulation index. In the shoot through state however, the Z- source network boost the voltage across the capacitors thereby raising the voltage at the inverter bridge. In the shoot through state, the Z source network is shorted and in the non shoot state or active state, the Z source network sees the load.

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IV. MATHEMATICAL ANALYSIS

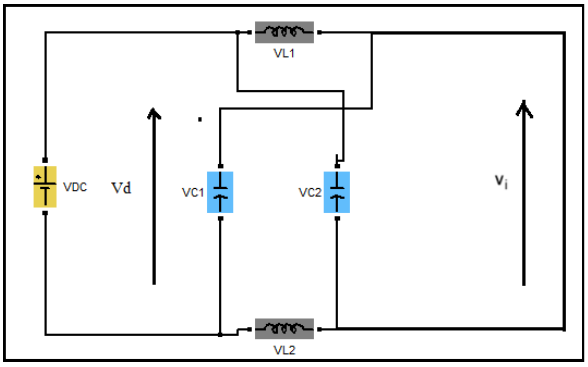

Figure 2:Equivalent circuit when ZSI is in shoot through state

The impact of the shoot through state on the inverter performance can be analysed using the equivalent circuit in figure 2. In shoot through state the inverter side of Z-Source network is shorted during time interval T_0.Therefore $L_1=L_2=L$ and $C_1=C_2=C$

$V_{C1} = V_{C2} = V_C$,$V_{L1}= V_{L2}= V_L$

$V_L = V_C$ $V_d=2V_C$ $v_i=0$

Now consider that the inverter bridge is in nonshoot- through state for an interval of T_1, during the switching cycle T, and from the equivalent circuit,

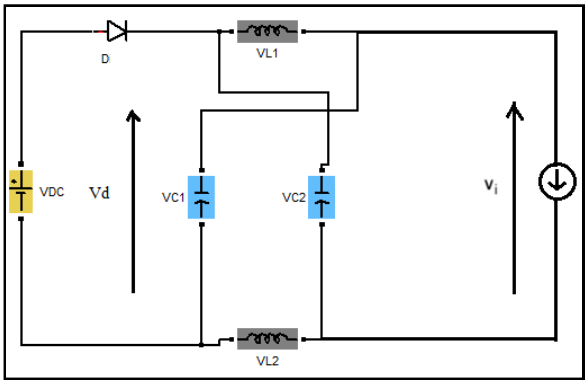

Figure3: Equivalent circuit when ZSI is in non shoot through state

$V_L = V_{DC} - V_C$ $V_d = V_{DC}$ $V_i = V_C - V_L = 2 V_C - V_{DC}$

Averaging the voltage across a Z-source inductor over a switching period (0 to T)

$VC = T1 / (T1 - To) V_{dc}$

The peak DC-link voltage across the inverter bridge is

$Vi= 2V_C - V_{dc} = V_{dc}[(2T_1 / T_1-T_O) - 1]$

Vi = B. Vdc

Where,

B is a boost factor and is given by

$B = [(2T1 / T1-To) - 1]$ i.e. ≥ 1

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The peak ac output phase voltage, For Z- source

$$Vac = M.V_i /2 = B.M\ Vdc /2$$

In the traditional sources

$$Vac = M.\ V_{dc} /2$$

Where,

M is modulation index.

Simple boost PWM strategy is employed to control shoot through of Z-source inverter. This strategy utilizes two straight lines/ envelope .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. This method is less uncomplicated; however, the resulting voltage stress across the device is relatively high because some traditional zero states are not utilized either partially or fully.

V. Simulation Results

Simulations have been performed. Figure 4 shows the circuit configuration of Z- Source fed Induction motor using simple boost PWM technique. The simulation parameters are as follows:

1. DC input voltage: 48V
2. Z-source network:
   $L_1 = L_2 = 1$ mH, $C_1 = C_2 = 1000$ µF
3. Switching frequency: 10 KHz

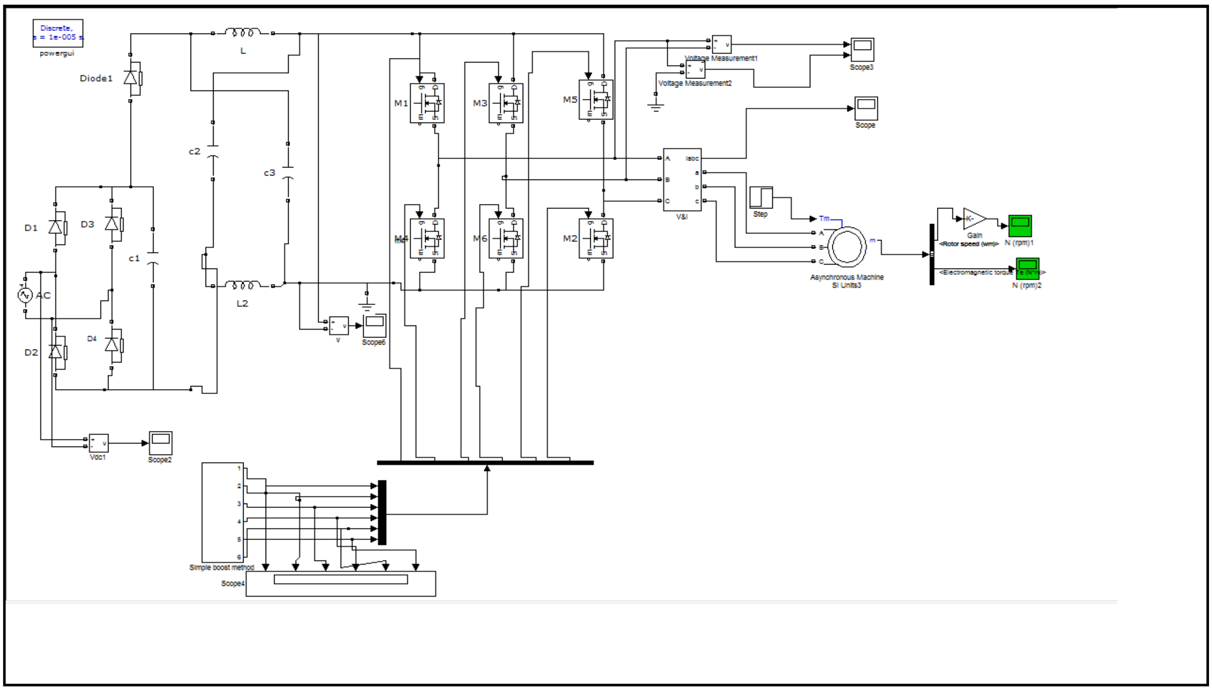

Figure 4: Simulation model of Z- Source Inverter Fed IM

The following figure shows the simulation results of Z- source fed induction motor drive. Figure 5,6,7 shows the simple boost control technique implementation, output voltage of Z-source network and output current waveform.

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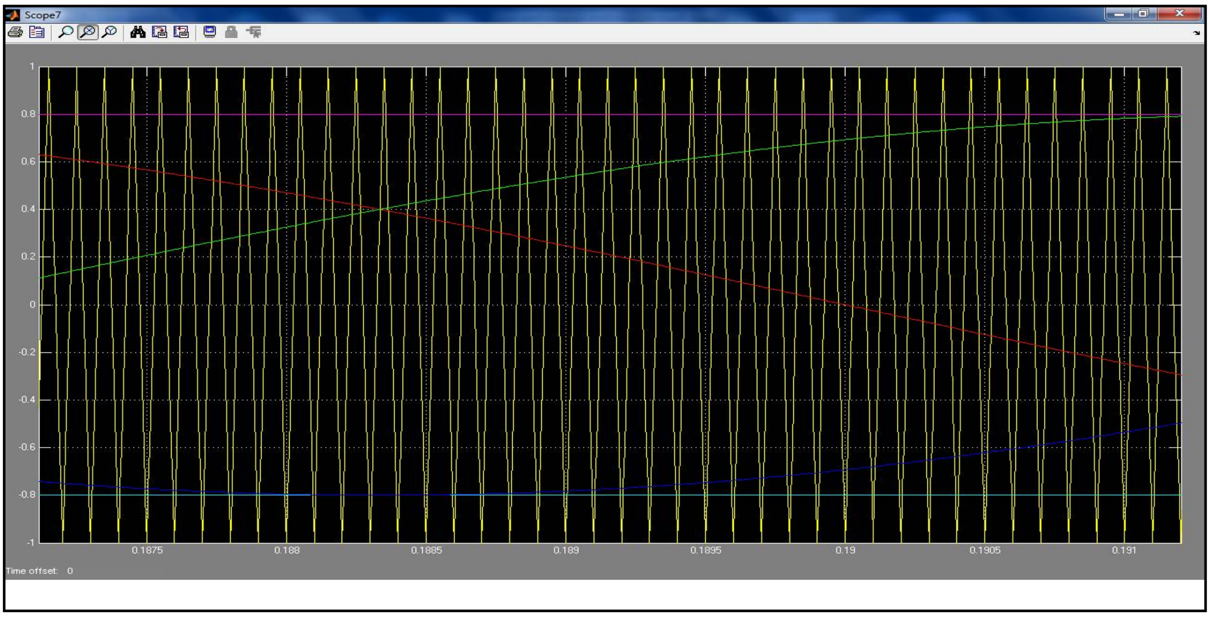

Figure 5: Simple boost control waveform

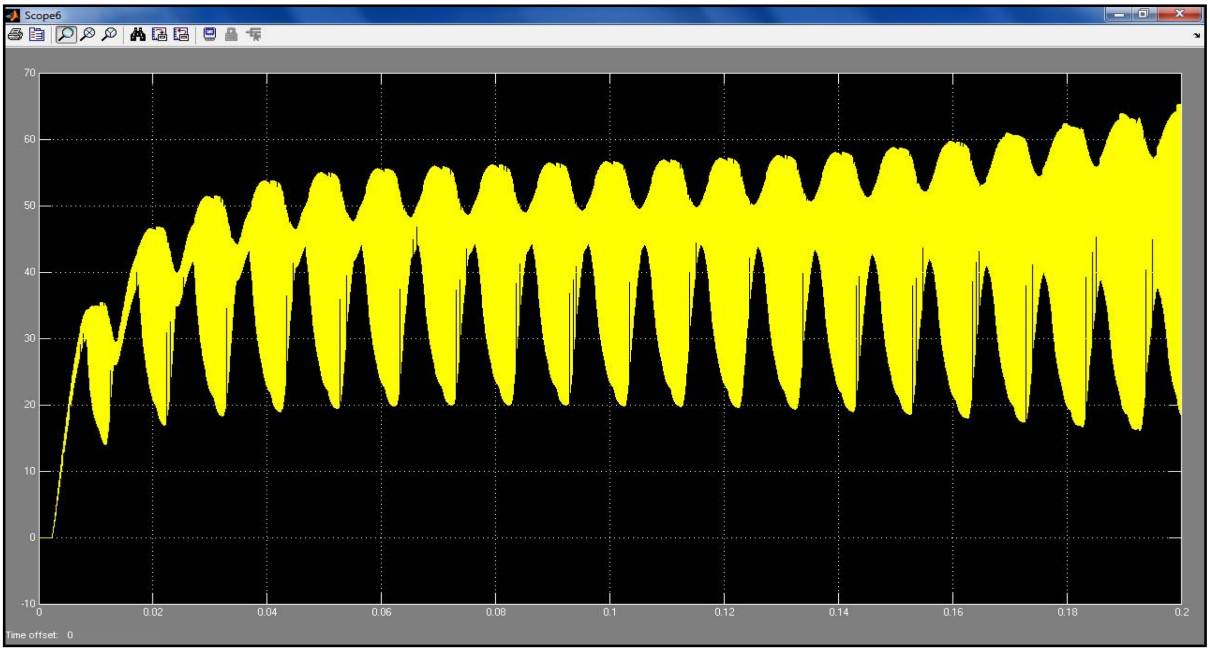

Figure 6: Z source boosted output

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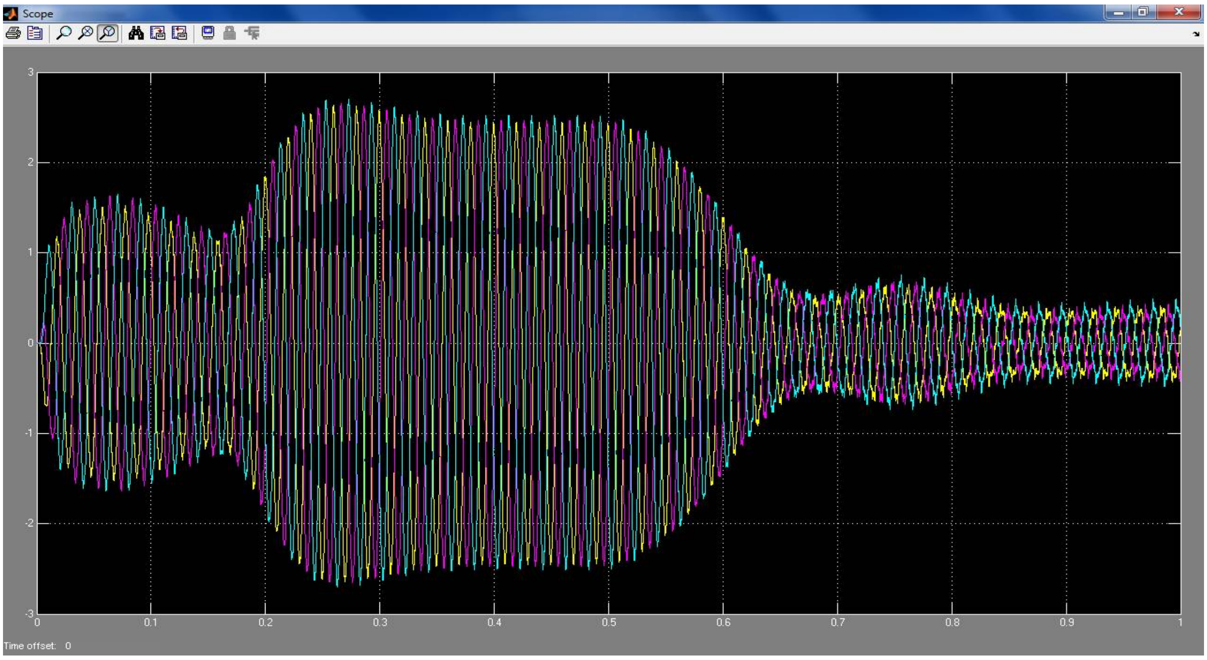

Figure 7: Output current

VI. CONCLUSION AND FUTURE WORK

This paper has presented a new concept of inverters called Z-source inverters in which the impedance network is placed in between power source and inverter circuit. The paper describes the operating principle, circuit characteristics, and demonstrates its concept and superiority over traditional inverters. Z-Source inverter fed IM drive system is simulated using MATLAB/Simulink software. There are several PWM methods used to achieve voltage control within the inverter. Simulation of the Z-source inverter under simple boost control method using two straight lines is demonstrated. The Z-source inverter (ZSI) can be implemented by using maximum boost PWM technique also. A fuel cell system/solar panel can be used as the input source and effectiveness of the proposed control method can be verified.

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