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DESIGN OF Z-SOURCE INVERTER FOR SOLAR FED THREE PHASE INDUCTION MOTOR

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Abstract- **Z-Source Inverter have recently been observed and investigated as alternative for the traditional inverters. The Z-Source Inverter uses LC impedance network to couple the main inverter circuit to the power source, which provides the boosting or bucking of input voltage that is not possible in traditional voltage-source (voltage-fed) inverter (VSI) and current-source (current fed) inverter (CSI). By controlling the shoot-through duty cycle, the Z-source can produce any desired output ac voltage, even greater than the line voltage.By controlling shoot-through duty cycle, which is forbidden in traditional voltage source inverter, the DC input can be boosted or decreased and the desired AC output can be obtained.**

In this project, Z-Source Inverter has been designed for a three phase load to be driven by a solar PV source with 100V. The simulation model of Z-Source Inverter is developed using MATLAB software with designed inductance and capacitance values and the output is verified. The Z-source inverter proposed in this project can be applied to the converter control of any industrial drives.

Keywords: Z- Source Inverter, Solar PV, MATLAB/ Simulink, Induction motor

I. INTRODUCTION

As the enervation of fossil fuel and its impression in the surroundings are getting serious day by day, the use of renewable-energy producing system is drawing more and more consideration [1]. As a renewable-energy source, photovoltaic (PV) energy has accomplished rapid growth and grid-connected PV system has become one of the major uses of solar energy. It is commonly identified that the output voltage of PV array differs broadly under dissimilar irradiance and also in environment temperature; the typical ratio of the maximum output voltage and the minimum is 2:1, and even bigger [2].

As cultures develop, the energy requirement increased hastily. The carbon dioxide emission caused by burning fossil fuel leads to global warming issue by escalating the greenhouse effect. It also caused severe climate changes worldwide [2] [3].therefore, reducing fossil energy has become crucial in reducing greenhouse gas emission and hence, searching for an alternative energy source has become imperative [3].It is important to consider green and safety characteristics in the expansion of alternative energy sources. Thus, nearly every country has planned natural and clean renewable energy such as wind energy, solar energy and marine energy. Among the renewable energy, solar energy has gained the most attention [4].

The Voltage Source Inverter (VSI) is the buck inverter, where output voltage will be always less than the input voltage. On the other hand, the output voltage of Current Source Inverter (CSI) will always be greater than the input [5]. Z-Source Inverter (ZSI) as a single converter can achieve the buck-boost operation, eliminating the need for both VSI and CSI to be implemented for the same. The impedance source consists of a split inductor and a split capacitor connected in Z-shape [6].

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This paper demonstrates the concept of ZSI in various Sections. Section II describes about ZSI applicable to three phase load and the design procedure of ZSI has been presented in section III. MATLAB/Simulink model of ZSI has been presented in Section IV along with the simulation results.

II. DESCRIPTION OF Z - SOURCE INVERTER

In Z-Source Inverter, the buck-boost in the output voltage is achieved by introducing a non-active state called Shoot-Through (ST) zero state. Without ST zero state the Z-Source inverter will act as a normal VSI [7]. The ST zero state can be achieved by triggering the switches present in the same leg. During this ST zero state periods, the impedance source will store the energy and during normal active state the deposited energy will be out, so the output voltage across the load will be amplified. The reverse power flow from Z-Source to DC source will be avoided by placing a diode between the input DC voltage and the Z-Source. Depending on the number of stages between input and output, inverters could be classified as single stage or two stage inverters [10]. The Inverters can be a buck inverter, boost inverter or buck-boost inverter. The Inverter stages so far extracting maximum power from PV module,Boost low DC output voltage to a high voltage level and Injecting a sinusoidal with a low THD in case of grid connection. .[9] discussed about E-plane and H-plane patterns which forms the basis of Microwave Engineering principles.The block diagram of ZSI proposed for solar fed three phase induction motor shown in Fig 1. It consists of two stages, where in the first stage includes DC/DC converter to boost the voltage and the second stage contains DC/AC converter to convert DC voltage into AC voltage suitable for three phase load.

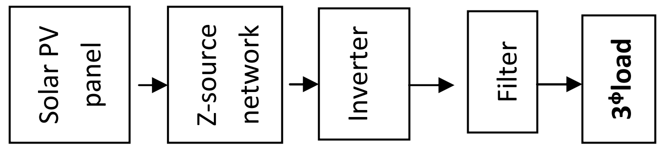

Fig1. Block Diagram of Z-Source Inverter

III. DESIGN OF ZSI FOR THE PROPOSED SYSTEM

Z-Source Inverter has been designed for solar fed three phase induction motor based on the design procedure given in the Sections. The exceptional feature of the ZSI is that the AC output voltage can be any value between zero and other value. The traditional Voltage or Current Source Inverters cannot provide such feature. The components of Z-Source network are designed as given below.

$$V_d = 2V_c,\ V_L = V_c \text{ and } V_i = 0$$

$$-V_C - V_L = -V_0 \quad (1)$$

$$V_C / V_0 = T_1/(T_1 - T_0) \quad (2)$$

The input voltage is given in Equation (3):

$$V_i = BV_0 \quad (3)$$

The output peak phase voltage from the inverter is given in Equation (4):

$$V_{ac} = mV_i / 2 \quad (4)$$

The capacitor voltage during that condition is given in equation (5)

$$V_C = mBV_0 / 2 \quad (5)$$

The inductance and capacitance of Z-Source network is given in Equation (6) and (7)

$$L = (T_0 V_C) / I_L \quad (6)$$

$$C = (I_L T_0) / V_{C*}0.03 \quad (7)$$

Where D_0 is the shoot-through duty cycle is given in Equation (8):

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$$D_0 = T_0 / T \quad (8)$$

The boost factor of the input voltage is given in Equation (9):

$$B = 1 / (1-2D_0) \quad (9)$$

The modulation index is given in Equation (10):

$$m = (B+1) / (\sqrt{3}B) \quad (10)$$

The three-phase ZSI Bridge has nine permissible switching states unlike the traditional three-phase V-source inverter that has eight as given in Table 1. The traditional three-phase VSI has six active vectors when the DC voltage is impressed across the load and two zero vectors when the load terminals are shorted through either the lower or upper three devices respectively. Equivalent circuit of the Z-source inverter viewed from the DC link, when the inverter bridge is in the shoot-through zero state. When the inverter bridge is in one of the eight non shoot-through switching states when the load terminals are shorted through the upper and lower devices of any one phase leg, any two phase legs or all three phase legs [11]. This shoot-through zero state is forbidden in the VSI, because it would cause a shoot-through. The ZSI makes the shoot-through zero state possible [12], [13]. Based on the designed parameters, the MATLAB Simulink model of the proposed system is developed as shown in Fig.2.

Switching state	Status of Switches					
	S1	S2	S3	S4	S5	S6
Zero	ON	X	ON	X	ON	X
	X	ON	X	ON	X	ON
states (Shoot through state)	ON	X	X	ON	X	X
	X	X	ON	X	X	ON
	X	ON	X	X	ON	X
	ON	ON	ON	ON	X	X
	X	X	ON	ON	ON	ON
	ON	ON	X	X	ON	ON
	ON	ON	ON	ON	ON	ON
Non Shoot through state	ON	X	X	X	X	ON
	ON	ON	X	X	X	X
	X	ON	ON	X	X	X
	X	X	ON	ON	X	X
	X	X	X	ON	ON	X
	X	X	X	X	ON	ON

Table 1. Switching sequences for Z-Source Inverter

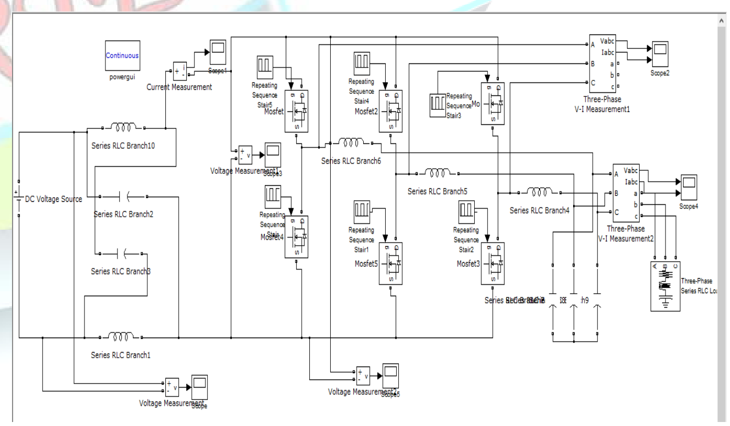

Fig2. MATLAB/Simulink model for ZSI

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IV. SIMULATION RESULTS AND DISCUSSION

The inductance (L) and capacitance (C) values of the Z-Source networkare obtained as 160µH and 1000µF respectively for achieving to obtain 200-400V, 50Hz AC output for an input voltage range of 100 to 150V. The carrier frequency of the inverter is 10 kHz and the output filter cut-off frequency is 1 kHz. The modulation index is fixed as this value 0.642. The Boost factor is 3.52.The output rms voltage is 208V. The load used considered for the simulation is 3 phase induction motor with the rating of 200V, fhp motor. The input voltage of 100V is obtained from the solar PV panel by cascading three panels each rated 39V.

The input voltage, third harmonic rejection for Pulse Width Modulation (PWM) and respective output voltages as shown in Fig 3, 4, 5 and 6 respectively. The PWM output after third harmonic reduction is shown in Fig 5.

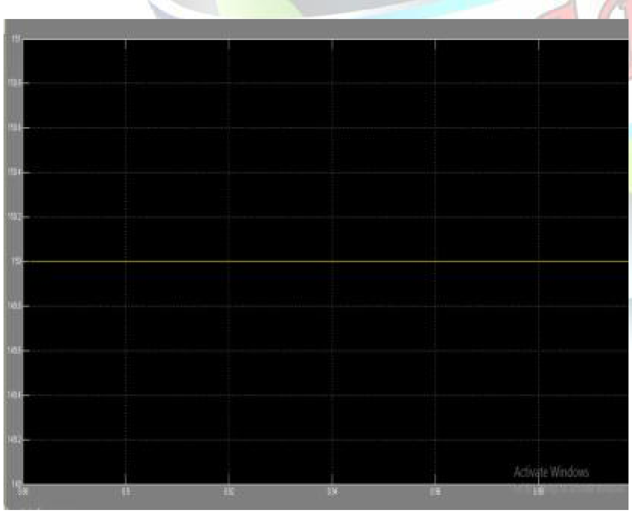

Fig 3. Input Voltage for ZSI

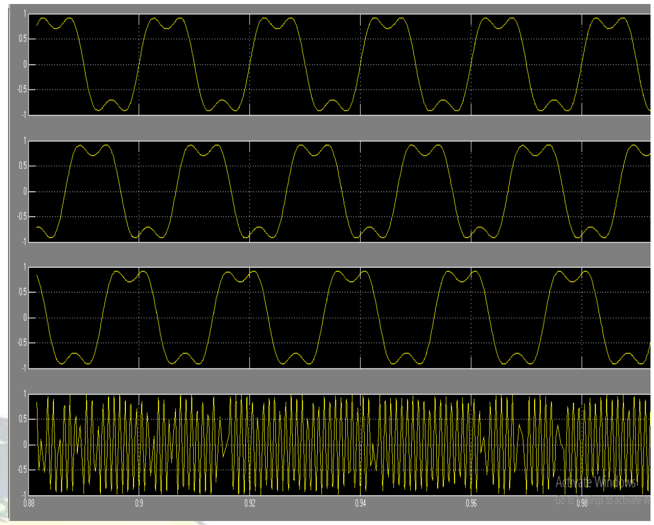

Fig4. Third harmonic rejection

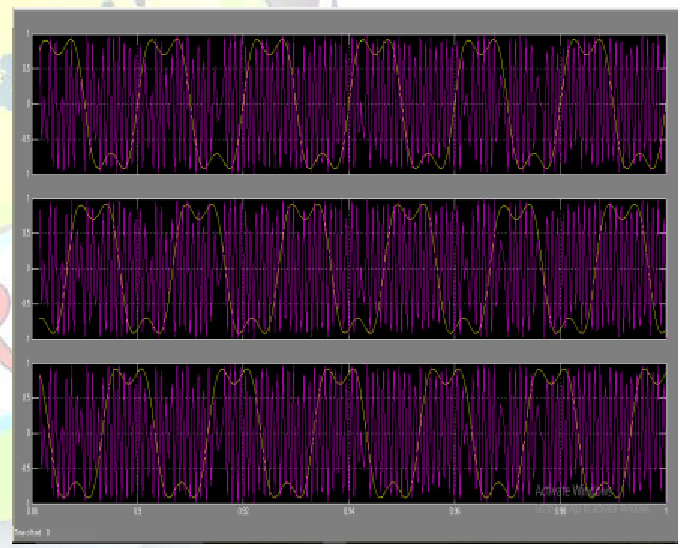

Fig5. Pulse Width Modulation waveform

Based on the switching pulses generated during the shoot through state and non-shoot through state is given in Section III, the output voltage of ZSI and the load current are shown in Fig 6.

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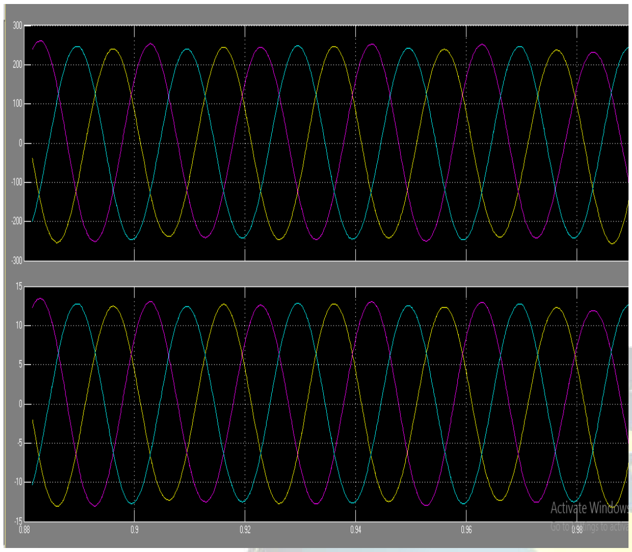

Fig 6. Output waveform for 3 phase ZSI

It is observed from the simulation results that the input voltage of 100V DC obtained from solar PV system has been boosted to 208V AC. The variable input voltage is given and their respective output voltages are tested. It shows that the Z-Source Inverter designed in this paper is capable of driving a three phase induction motor load.

V.CONCLUSION AND FUTURE WORK

This paper presents the design and application of hardware of a basic Z-source inverterwhich reveals the boosting capability. In this circuit a three- phase induction motor of fractional hp is coupled as a load and with the help of a switch the boosting up of voltage is practical. Thus the calculated circuits are working satisfactorily and are delivering the required performance. TheZ-source converter uses an impedance source network to replace the boundaries of traditional voltage source and current source inverters while working with the light load. Z source inverter is used for buck and boost operation so that it increases the efficiency with low cost andless power loss. Recently Z Source inverter is in demand because of its smartpower conversion.

Improvement of grid connected model of the proposed Z source inverters can be demonstrated with new control strategies employing MPPT techniques for solar photovoltaic systems.The suggested Z source multilevel inverters can be coupled to Z Source inverter builtDC/DC converters and its integration with Suitable rectifier circuits and necessary modulation schemes is left for future surveys.

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Appendix

Parameter	Description
V_d	Diode voltage
V_i	Input voltage
V_0	Output voltage
V_{ac}	Peak phase voltage
V_l	Inductance voltage
V_c	Capacitance voltage
m	Modulation index
B	Boost factor
T_o	On time
T	Total time
L	Inductance
C	Capacitance