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Analysis and Simulation of Z-Source Inverter Fed to Single Phase Induction Motor Drive

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Abstract-The Z-source inverter utilizing a unique LC network and shoot-through states provides unique features, such as the ability to buck & boost voltage with a single stage structure .The output of inverter is used to control the speed of an induction motor. A model of z-source inverter fed to single phase induction motor drive is built in MATLAB/SIMULINK and its performance is analyzed with simple boost PWM control technique.

Keywords- Z-source inverter (ZSI), Simple boost PWM (SBPWM), boost factor, modulation index.

I. Introduction

Z-source inverter can boost dc input voltage with no requirement of dc-dc boost converter or step up transformer, hence overcoming output voltage limitations of traditional voltage source inverter as well as lower its cost. A comparison among conventional PWM inverter, dc-dc boosted PWM inverter and Z-source inverter shows that z-source inverter needs lowest semiconductors and control circuit cost , which are the main cost of a power electronics system [1] this result increasing attention on z-source inverter .

II.Z-Sources Inverter

The new impedance-source power inverter has been recently invented, eliminates all problems of the traditional V-source and I-source inverters. It is being used in ac/dc power conversion applications. Fig.1 shows the general Z-source converter structure. The power source can be either voltage source or current source. The Z-source inverter consists of a unique impedance network which couple the converter main circuit to the power source, load, or other converter [1], for providing unique features that cannot be observed in the traditional VSI and CSI inverters. The impedance network consists of two inductors and two capacitors connected to each other as shown in the figure forms the second order filter network. The values of both inductor and both capacitor are equal. The two inductors can be two separate inductors or two inductors inductively coupled to each other on a single core. For size and cost reduction film capacitors of desired value and voltage rating can be selected.

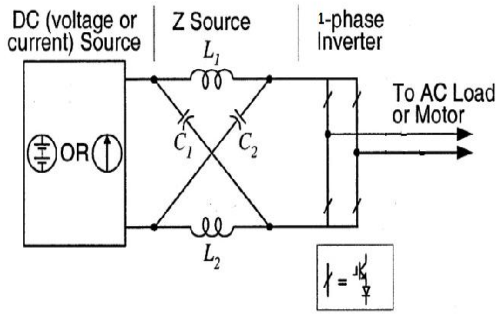


Fig.1 Z-Source inverter structure

III. PWM Control of ZSI

The conventional PWM inverter topology imposes high voltage stresses to the switching devices and motor and limits the motor's constant power speed ratio [7]. The dc/dc boosted PWM inverter topology can alleviate the stresses and limitations, however, suffers from problems such as high cost and complexity associated with the two-stage power conversion. Traditional PWM consists of six active states and two zero states. In traditional zero state either upper two or lower two switching devices of inverter are on and does not provide current to the load so the load voltage is essentially zero in the zero state. In case of Z-source inverter in addition to six traditional active states and two zero state it consists of one more state called as shoot-through state. In a shoot-through state both upper and lower switching devices in a single arm or all the two arms conducts simultaneously, hence producing short circuit across load. Therefore output voltage across the load remains zero in the shoot-through state. Thus the effect of shoot-through state is same as traditional zero state. In Z-source inverter the part of zero state or entire zero state is converted in to shoot-through state, where both upper and lower switching device of one or all the two arm of inverter conducts simultaneously. The shoot-through zero state is forbidden in the traditional voltage source inverter, because it would cause a shoot-through. The Z source network makes the shoot-through zero state possible. This shoot-through zero state provides the buck-boost feature to the inverter. Therefore, to maintain sinusoidal output voltage, the active-state duty ratio is maintained same and some or all of the zero states turned into shoot-through state. The traditional PWM control methods that can be used to control Z-source inverter are:

1. Simple boost control
2. Maximum boost control
3. Maximum constant boost control

The comparison of all of these PWM methods is presented in [6] and [7].

Shoot-through pulses are generated as shown in fig.2. These shoot-through pulses can be generated by using triangular waveform generator and comparator. Shoot-through time is decided by the two reference levels called shoot-through level. When triangular carrier wave exceeds above upper shoot-through level or below lower shoot-through level a shoot-through pulse is generated. Shoot-through time remains almost constant from switching cycle to switching cycle. These shoot-through pulses are evenly spread in traditional PWM waveform to obtain PWM waveform with shoot-through.

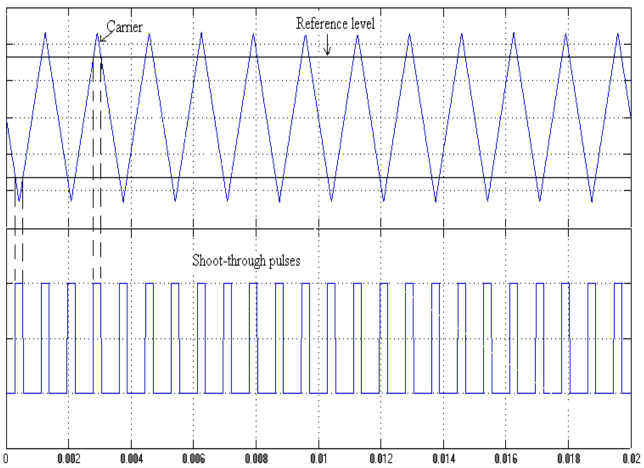


Fig. 2 Shoot-through pulses

VI. Z-source inverter analysis

The equivalent circuit of Z-Source inverter in the active state is shown in Fig. 3. In the active state the inverter circuit acts as a current source as shown in the figure 3. The input power source is a dc voltage source V_{dc} that is applied to the Z-Source inverter through reverse blocking diode D. All traditional PWM techniques are applicable for Z-Source inverter. During the shoot-through time (T0) the DC link voltage V_{dcl} is boosted to a value greater than input voltage, hence input diode will be reverse biased blocking reverse flow of current. The detailed analysis of Z-source inverter is given in [1]. The average dc-link voltage across the inverter is given by:

$$V_{dcl} = V_c = ((1 – T0/T) / (1 – 2T0/T))\ V_{dc} \quad (1)$$

Where,

V_{dcl} is the average dc link voltage equal to capacitor voltage V_c, T is a switching period and T0 is shoot-through time over a switching period. The peak dc-link voltage across the inverter is expressed as

$$V_{dclp} = (T / (T1 – T2))\ V_{dc} = B\ V_{dc} \quad (2)$$

Where,

$$B = T / (T1 – T0) = 1 / (1 – 2T0/T) \geq 1 \quad (3)$$

is the boost factor resulting from the shoot-through zero state.

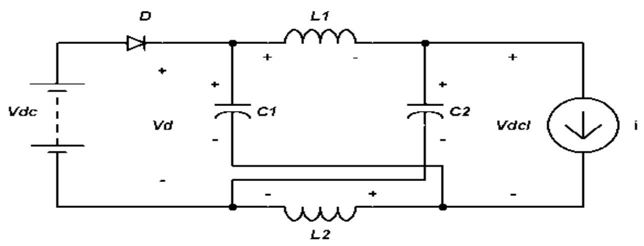


Fig. 3 Equivalent circuit of Z-Source inverter with inverter in active state.

The peak dc-link voltage is the equivalent dc-link voltage of the inverter. On the other side, the output peak phase voltage from the inverter can be expressed as;

$$V_{acp} = M\ V_{ip} / 2 \quad (4)$$

In above equation *M* is the modulation index of PWM waveform, V_{acp} is output peak phase voltage and V_{ip} is peak dc link voltage across inverter. Using (2) and (4) peak phase voltage can be expressed as

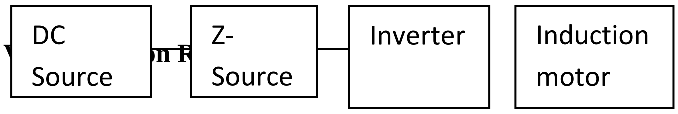
$$V_{acp} = M\ B\ V_{dc} / 2 \quad (5)$$

For the traditional V-source PWM inverter, the output peak phase voltage is given by

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

Where Modulation index M is always less than unity hence in traditional inverter the output voltage is always less than input dc voltage. Equation (5) shows that in Z-Source inverter the output voltage can be stepped up and down by choosing an appropriate buck–boost factor *BB.* The buck–boost factor is determined by the modulation index M and boost factor B. For Z-source inverter the boost factor is always greater than or equal to unity. When boost factor is equal to unity the Z-source inverter acts like traditional inverter. The boost factor *B* as expressed in (3) can be controlled by varying shoot-through duty cycle T0/T of the inverter PWM input.

V. Complete Block Diagram



Simulation is performed using MATLAB/SIMULINK software. Simulink library files include inbuilt models of many electrical and electronics components and devices such as diodes, MOSFETS, capacitors, inductors, motors, power supplies and so on. The circuit components are connected as per design without error, parameters of all components are configured as per requirement and simulation is performed. Simple boost control method is used for PWM generation and simulation. The component values of Z-source inverter depends on switching frequency only. The complete simulation diagram is shown in the fig.4

The parameters used for simulation are:

PWM generation

Parameter	Value
AC voltage	110Vrms
Z-source inductance	160 mH
Z-Source capacitance (C1 & C2)	1000µF
Fundamental Frequency	50Hz

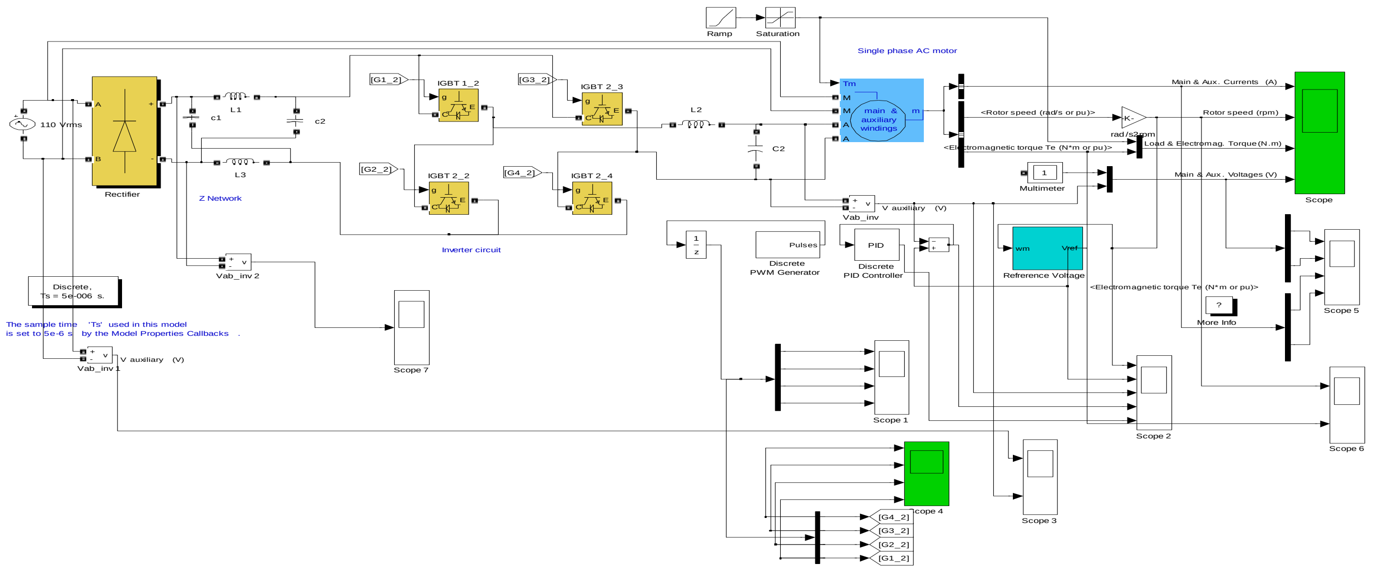


Fig. 4 Single phase induction motor drive system using z-source inverter .

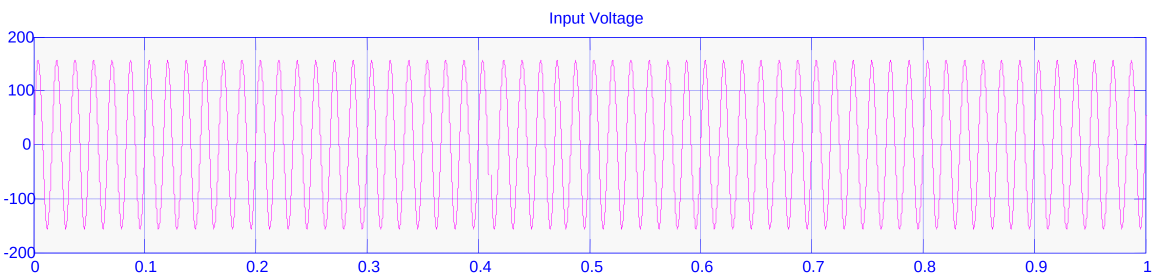


Fig.5 Input voltage waveform.

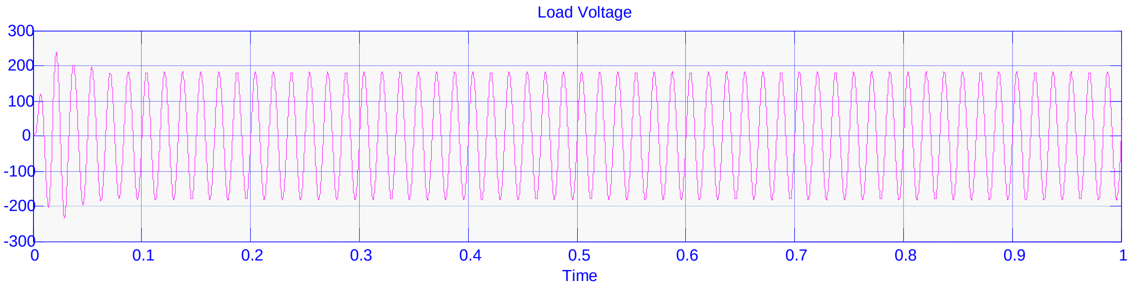


Fig.6 Load voltage waveform

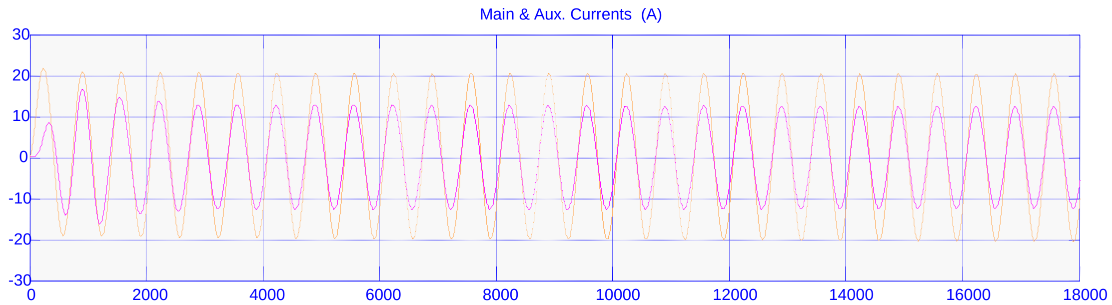


Fig.7 Main & Auxilary Current waveform

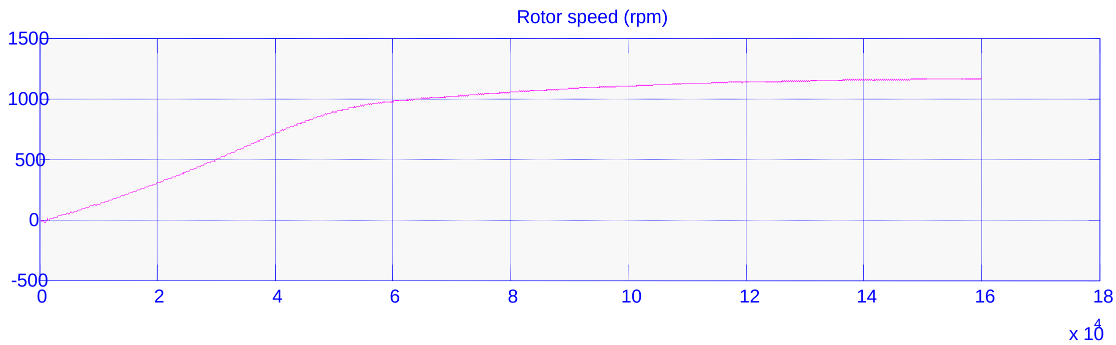


Fig.8 Rotor Speed waveform

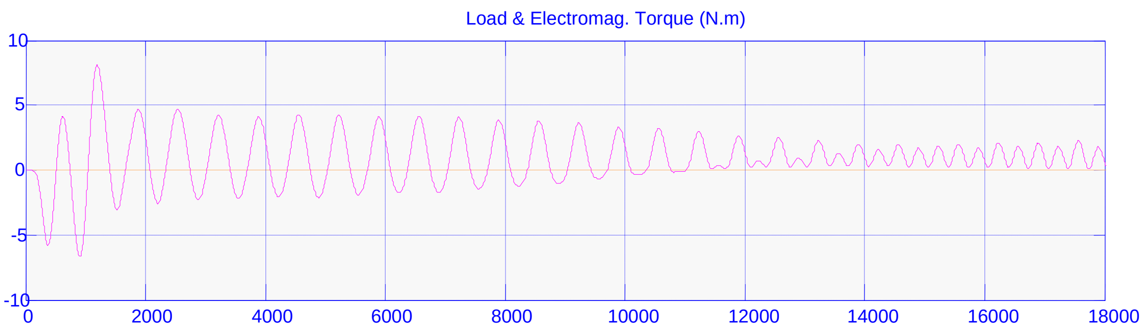


Fig.9 Load & Electromagnatic torque

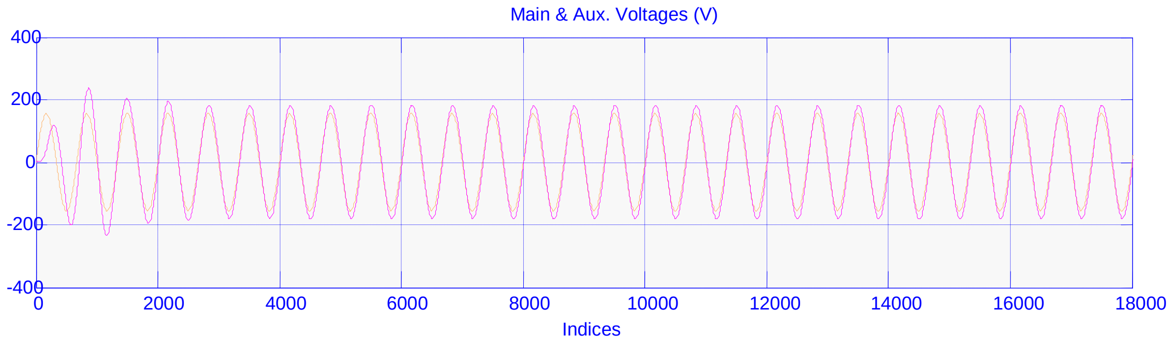


Fig.10 Main & Auxillary voltage waveform

VII. Conclusion

A PWM control method was carried out in this paper for Z-source Inverter fed induction motor drive. The output voltage obtained from ZSI is not limited and can be boosted beyond the limit imposed by conventional VSI.

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