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Z-Source Inverter based Split Phase Induction Motor Drive

N Venkata Ramana
Department of EEE, Shri Vishnu Engineering College for Women (Autonomous), Bhimavaram,AP
ramana.navana @gmail.com

ABSTRACT

A Split phase induction motor drive using Z– source inverter is proposed and analyzed in this paper. It is well known that the output voltage of fuel cell decreases with the increase of the output current. To overcome this problem proposed concept uses Z-source inverter due to its higher efficiency and lower cost, which is very promising for FC systems due to its novel voltage buck/boost ability. The operation principle, system configuration and control method are presented. Finally, MATLAB/Simulink based model is developed and simulation results prove the desired features and feasibility of the proposed drive system.

Keywords: *Split phase induction motor, electric drive system, Z–source inverter, full bridge inverter*

1. INTRODUCTION

For environmental protection and energy saving, fuel cell, photovoltaic cell and super-capacitor can be employed to supply electric energy in the drive applications, due to their environmental friendly features. Especially, fuel cell is regarded as the future clean energy source. It is well known that the output voltage of fuel cell decreases with the increase of the output current. To overcome this problem, there are two main solutions are present, the conventional dc/dc–boosted PWM inverter and the original Z–source inverter proposed [1]. Compared with the former topology, the Z-source inverter has more advantages such as higher efficiency and lower cost, which is very promising for FC systems due to its novel voltage buck/boost ability [2]. The interrelated literatures [1-6] demonstrated the unique features of the Z-source inverter and its feasibility for the Adjustable Speed Drive (ASD) systems with induction machines. This paper investigates the Split phase induction motor drive system fed by a Z-source inverter. Firstly, the configuration, operation principle and control method of proposed electric drive system are described. Finally, simulation results are carried out to verify the desired performance of the proposed drive systems.

2. Z–SOURCE INVERTER

The Z-Source Inverter is used to overcome the problems in the traditional voltage source inverters. This Z-source inverter shown in Figure 1 employs a unique impedance network coupled with the inverter main circuit to the power source. This inverter has unique features compared with the traditional sources.

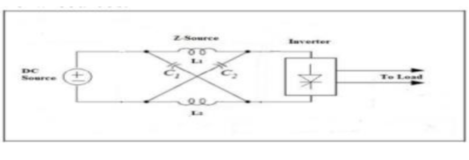


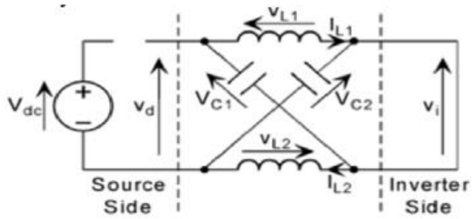
Fig.1.

Z-Source Inverter

It consists of voltage from the fuel cell which represented by DC source in the fig.1,Impedance network, and SPWM based single phase full bridge inverter with single phase A.C. motor load which is split phase induction motor used in this paper. The fuel cell output voltage is fed to the Impedance network. Which consist of two equal inductors (L_1,L_2) and two equal capacitors (C_1,C_2).The network inductors are connected in series arms and capacitors are connected in diagonal arms [7].The impedance network used to buck or boost the input voltage depends upon the boosting factor .This network also act as a second order filter to reduce harmonics present in the output voltage . This impedance network should require less inductance and capacitance and smaller in size. The output voltage from impedance network is fed to the single-phase inverter circuit. The inverter circuit consists of four switches which is operated by Sinusoidal Pulse Width Modulated gating signals. Depends upon the Gating signal inverter operates and the output of inverter is fed to the split phase induction motor.

3. MATHEMATICAL ANALYSIS OF Z-SOURCE NETWORK

The impact of the phase leg shoot through on the inverter performance can be analyzed using the equivalent circuit shown in Fig.2 and Fig.3. Assume the inductors (L_1 and L_2) and capacitors (C_1 and C_2) have the same inductance and



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capacitance values respectively; the Z-source network becomes symmetrical.

Fig.2. Equivalent circuit when ZSI in shoot through state

In shoot through state the inverter side of Z-Source network is shorted during time interval T_0 as in Fig.2.

Therefore,

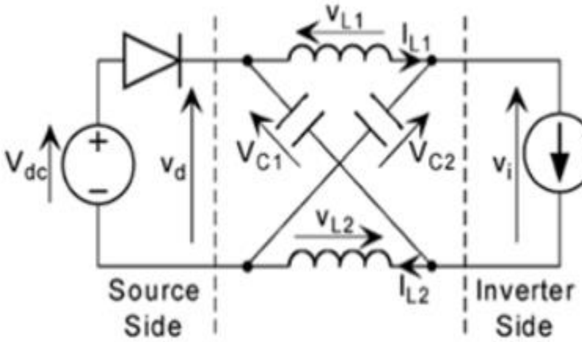
$$L_1 = L_2 = L \text{ and } C_1 = C_2 = C.$$

$$Vc_1 = Vc_2 = Vc = V_{L1} = V_{L2} = V_L$$

$$V_d = V_L + V_c = Vc + Vc = 2\,Vc \;..........(1)$$

$$V_i = 0$$

Alternatively, when in non-shoot through active or null state current flows from Z-Source network through the inverter topology to connect ac load during time interval T_1 .The inverter side of the Z-source network can now be



represented by an equivalent circuit [8] as shown in Fig.3.

Fig.3.Equivalent circuit when ZSI in non-shoot through state

The following equations can be written:

$V_L = Vdc - V_C$

$V_d = V_{dc}$

$V_i = V_C - V_L$

Putting $V_L = V_{dc} - V_C$ in above equation

$V_i = V_C - (V_{dc} - V_C) = V_C - V_{dc} + V_C = 2V_C - V_{dc}$ .... (2)

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

$V_C = T_1 / (T_1 - To)\, Vdc$ ......(3)

Using equations (2) and (3)

The peak DC-link voltage across the inverter bridge is

$Vi = 2V_C - Vdc$

$= 2[T_1 / (T_1 - To)\, V_{dc}] - Vdc$

$= (2T_1 - T_1 + T_0) / (T_1 - T_0)\, Vdc$

$= (T_1 + T_0) / (T_1 - T_0)\, Vdc = (T_1 + T_0) / (T_1 + T_0 - 2T_0)\, Vdc$

$= (T) / (T - 2T_0)\, V_{dc}$

$= 1 / (1 - 2To/T)\, Vdc$ ..... (4)

$V_i = B.\, Vdc$ ......(5)

Where, $B = T / (T_1 - To)$ i.e. ≥ 1 and B is a boost factor, T-Switching period.

The peak ac output phase voltage, For Z- source

$Vac = M.Vi / 2 = B.M\, Vdc / 2$

In the traditional sources, $V_{ac} = M.\, Vdc/2$, where M is modulation index. The output voltage can be stepped up and down by choosing an appropriate buck – Boost factor BB =B.M (it varies from 0 to α), where α=firing angle.

The Buck - Boost factor BB is determined by the modulation index M and the Boost factor B. The boost factor B can be controlled by duty cycle of the shoot through zero state over the non-shoot through states [9] of the PWM inverter. The shoot through zero state does not affect PWM control of the inverter, because it equivalently produce the same zero voltage to the load terminal. The available shoot through period is limited by the zero state periods that are determined by the modulation index.

4. SIMULATION RESULTS AND DISCUSSION

The MATLAB/Simulink based model of proposed concept is shown in figure.4.The output of the fuel cell is fed to Z-source inverter,SPWM based full bridge inveter and output of inverter is fed to the split phase induction motor drive.

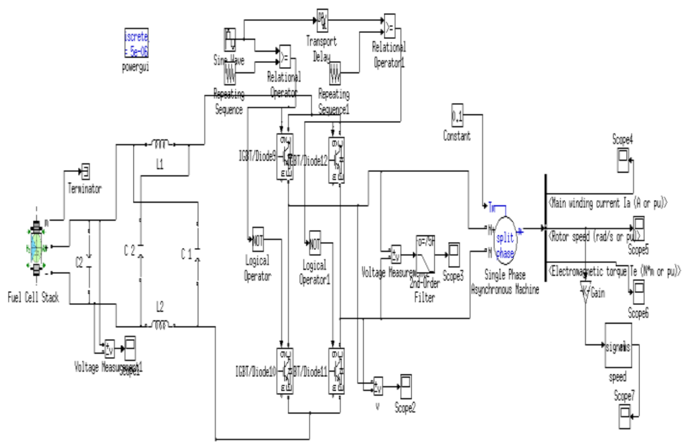


Fig.4.MATLAB/Simulink model of the prposed system

The parameters of the Z-source inverter are as follows:

Inductors of Z – source inverter: $L_1 = L_2 = 500\mu H$

Capacitors of the Z – source inverter: $C_1 = C_2 = 500\mu F$

The specifications used for the motor are as follows:

Nominal Power = 0.25 Hp Voltage = 250 V, Frequency = 50 Hz.

Resistance of Main winding Stator R_s = 2.02 ohm, Leakage Inductance Lls = 7.4mH.

Resistance of Main winding Rotor $R_{r'}$ = 4.12 ohm, Leakage Inductance $L_{lr'}$ = 5.6mH.

Mutual inductance of main winding L_{ms} =0.1772H

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Resistance of Auxiliary winding stator R_s = 7.14ohm, Leakage Inductance L_{ls} =8.5mH.

Figure 5 &6 shows the output of the fuel cell and output voltage of the full bridge inverter respectively.

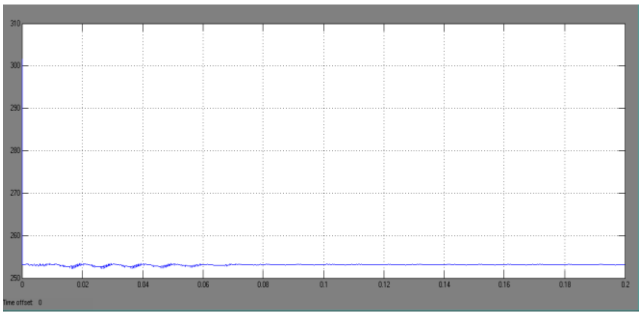

Fig. 5.Fuel cell output

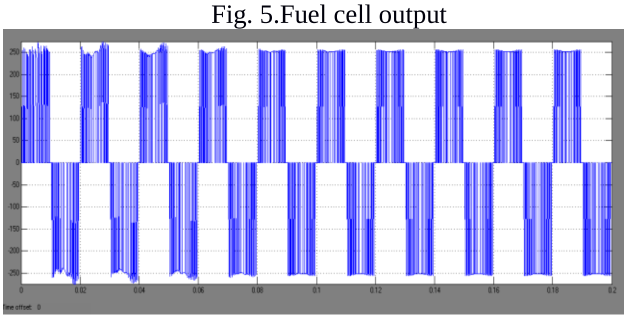

Fig. 6.Output of full-bridge inverter

Figure 7 shows output voltage of the inverter with filter.

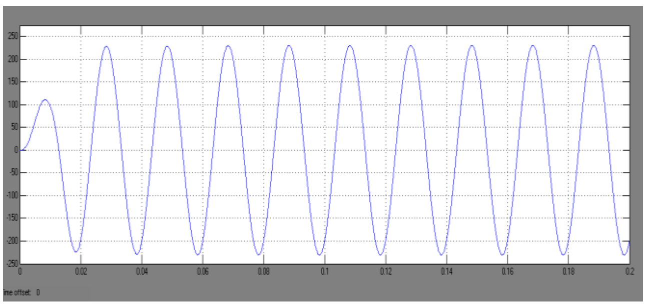

Fig.7.Output of full-bridge inverter with filter

From figures 8-11 shows main winding current, rotor speed, electromagnetic torque and Speed-Torque curve of the split phase induction motor.

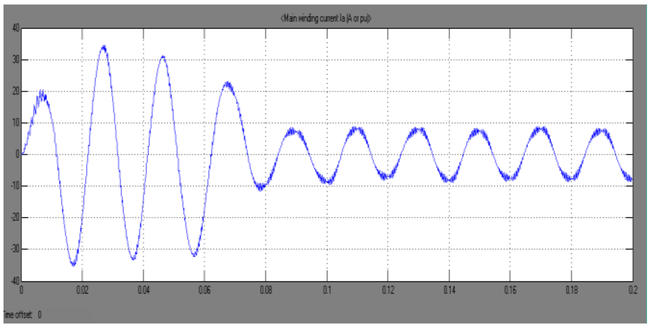

Fig. 8.Main winding current

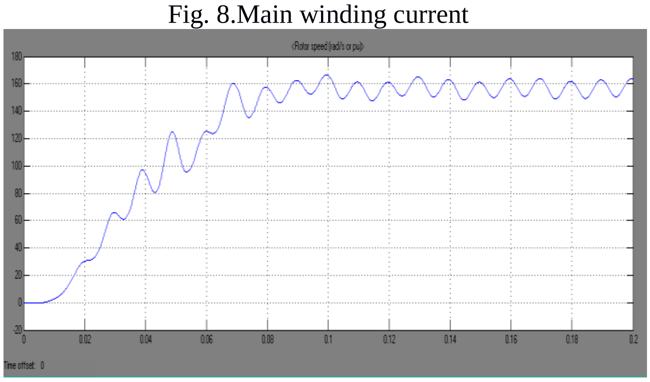

Fig.9. Rotor speed

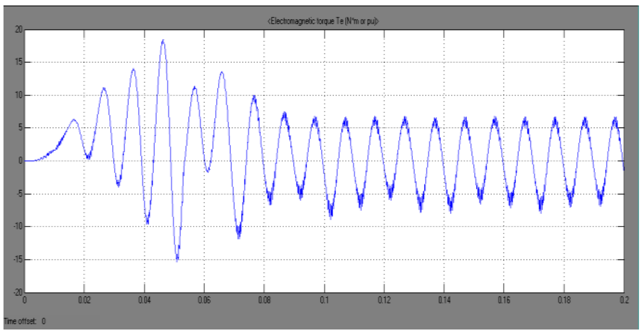

Fig.10.Electromagnetic torque

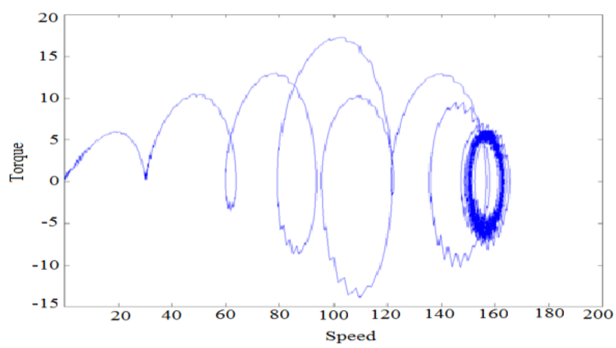

Fig.11.Speed-Torque curve

5. CONCLUSION

This paper has proposed a Z–source inverter based Split Induction motor drive. The proposed concept provides advantage of Z-source inverter such as higher efficiency and lower cost, which is very promising for FC systems due to its novel voltage buck/boost ability. The system configuration, operation principle and mathematical modelling of Z-source inverter have been analyzed in both shoot through state and non shoot through state. Simulation results have validated the preferred features as well as the possibility of the proposed drive system. The proposed configuration well suited for fuel cell based applications.

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