International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 7, No. 3, September 2016, pp. 908~914
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v7.i3.pp908-914

Simulation and Implementation of Quasi-Z-Source Based Single-stage Buck/boost Inverter Fed Induction Motor

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Article Info

Article history:

Received Nov 12, 2015
Revised Apr 3, 2016
Accepted May 4, 2016

Keyword:

Buck/boost inverter
Induction motor
Photovoltaic
Z-source inverter

ABSTRACT

Renewable power systems as distributed generation units often experience big changes in the inverter input voltage due to fluctuations of energy resources. Z-source inverter (ZSI) is known as a single-stage buck/boost inverter. The ZSI achieves voltage buck/boost in single stage, without additional switches. Triggering on state enables energy to be stored in inductors, which is released when at non-shoot-through state, followed by the voltage boost feature. The voltage-fed Z-source inverter/quasi-Z-source inverter (QZSI) has been presented suitable for photovoltaic (PV) applications mainly because of its single-stage buck and boost capability and the improved reliability.

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1. INTRODUCTION

More efforts are now being put into distributed power generation of renewable energy sources (RESs), such as photovoltaic, fuel cells and wind power which are sustainable and environmental friendly [1]. Practically, several distributed generations (DGs) consist of distributed power grid and further construct micro grid with local loads and managements. To ensure proper performance of the micro grid, DG is usually required to work in two modes: stand-alone or grid connected because of the interface between RES and distributed power grid, the performance of power electronic converters becomes critical. Z-source inverter (ZSI) is known as a single-stage buck/boost inverter. With an impedance network coupling the inverter main circuit to the DC supply, the impedance network attains voltage buck/boost in single stage, without more switching devices. Shoot-through state provides energy to be stored in inductors, which is released when at non-shoot-through period, which also follows the voltage boost feature.

For the voltage-fed type ZSI (abbreviated as ZSI), voltage boost methods based on pulse width modulation (PWM) have been first investigated as simple boost control, maximum boost control, and maximum constant boost control [2]. Because of its single-stage voltage buck/boost properties, the impedance inverter can ensure with the input voltage fluctuation in a wide range, which is achieved by a two-stage DC-DC converter cascaded by DC-AC structure conventionally. The voltage source inverter and current source inverter are two types of traditional power in inverter topology. For the voltage souce inverter fed from voltage source, the ac output voltage is lower than the available dc bus voltage thus it can only perform the buck. Dc-ac power conversion [3]. With the economical advantages and improved reliability due to the allowance of shoot-through state, impedance inverter I gained increasing attention and was presented for use in several applications, such as Diesel generator, uninterruptible power system, fuel cell vehicles, PV or wind power conversion, and electronic loads Design guidelines of the impedance network are analyzed in terms of both steady-state and dynamic performances. By applying state-space averaging, the dynamic modeling and transient analysis of the Z-source network are investigated. Closed-loop controller is developed for ZSI control.

The dependence of control variables D_0 (shoot-through duty ratio) and M (modulation index) of the ZSI are taken into consideration. Moreover, the discontinuous conduction mode of the ZSI with small inductance or low load power factor and its associated circuit characteristics are analyzed [4]. The performances of the control methods of ZSI to achieve the maximum voltage output with in the prescribed limit of harmonics and THD percentages and it can also achieve the minimum passive component requirement and hence the low voltage stresss at the same time [5]. The Shoot-through zero states of the Z-Source inverter boost the low level input into higher level ac, which is not possible with the help of conventional inverter [6]. The Modular emulator where the characteristics of the converters and of the low level controller are summed up and included in a Hybrid state phase representation and it is ready to use with the supervisory control design according to the discrete variables [7]. In order to provide researchers with a global picture of the impedancesource networks proposed in the literature, major *Z*-source network topologies have been surveyed and categorized based on conversion functionality and switching configurations. The above literature does not deal with the comparison of simulation and hardware results for QZSI systems. This work compares the hardware results with the simulation results.

2. IMPEDANCE SOURCE INVERTER

This Impedance Source Inverter is used to overcome the problems in the traditional source inverters. This impedance source inverter 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

Three phase A.C. supply is fed to the rectifier, which would convert three phase A.C. supply to D.C. The rectified D.C. supply is now given to an inverter through an impedance network. The impedance inverter output is now fed to the induction motor as input. The process is explained using the flow diagram shown in Figure 1.

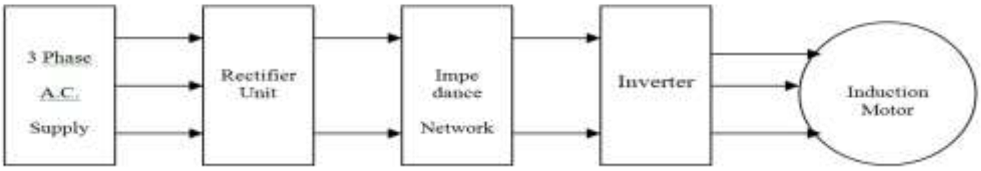

Figure 1. Block Diagram

3. MATHEMATICAL ANALYSIS OF IMPEDANCE NETWORK

Assume the inductors (L_1 and L_2) and capacitors (C_1 and C_2) have the same inductance and capacitance values respectively, as Figure 2.

L_1 and L_2-series arm inductors;

C_1 and C_2-parallel arm Capacitors;

V_1 is input voltage; V_2 is output voltage

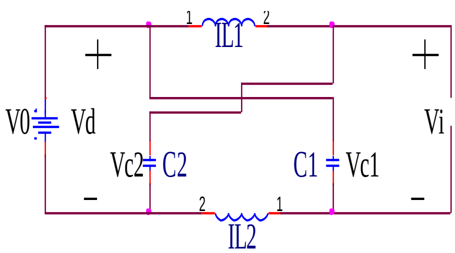

Figure 2. Z Network

V_{DC}= [1/ [1-2D]]* Vin

L= [D_0 [1-D_0] T*V_0] / [[1-2D]*[ΔI_L]]

C = I_0 D T_S / ΔV_C

Block Diagram of QZSI system is shown in Figure 3.

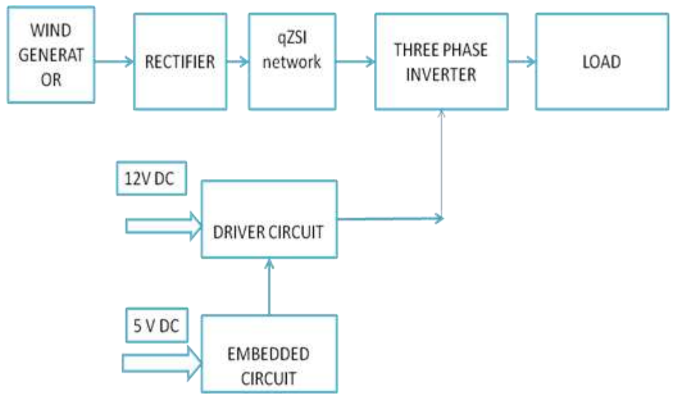

Figure 3. Block Diagram of QZSI system

4. QUASI Z-SOURCE INVERTER SYSTEM

The simulink model of QZSI system is shown in Figure 4. Conventional Z network is replaced by Quasi Z network .The output of the rectifier is shown in Figure 5. The phase voltage waveforms are shown in Figure 6. The phase currents are shown in Figure 7. The FFT analysis is done and the frequency spectrum is obtained, as Figure 8 that the THD is 7.08%.

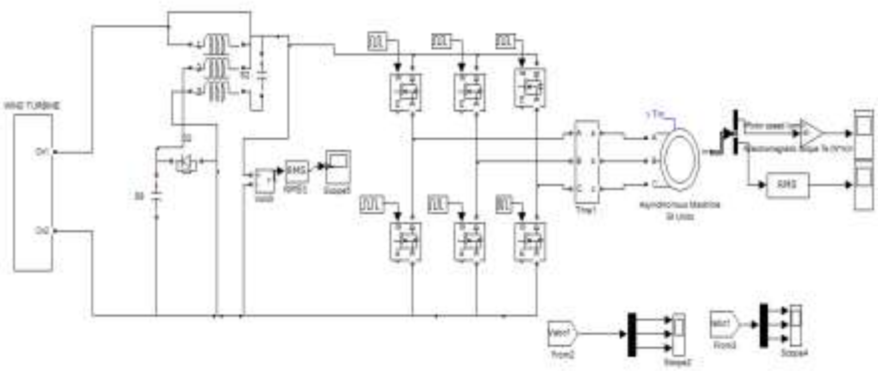

Figure 4. Simulink Model of QZSI System

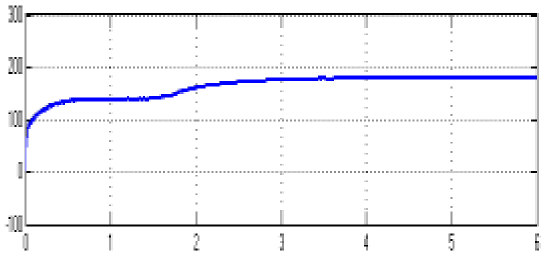

Figure 5. Output Voltage of Rectifier

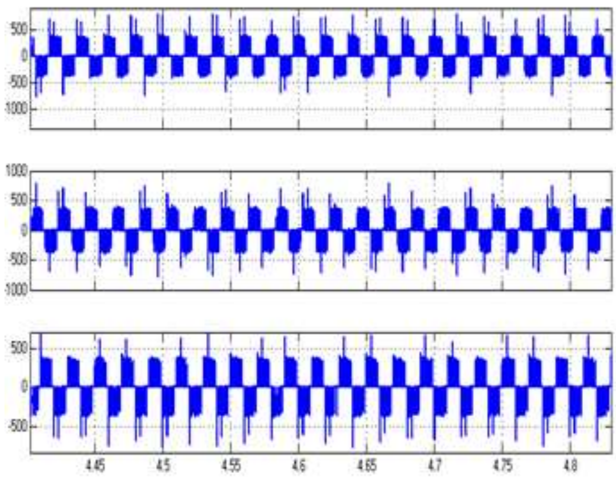

Figure 6. Inverter Phase Voltages

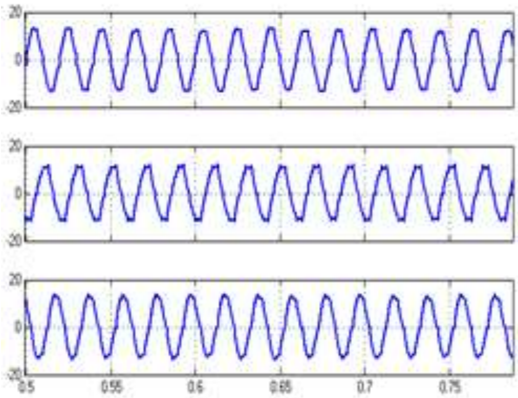

Figure 7. Inverter Phase Currents

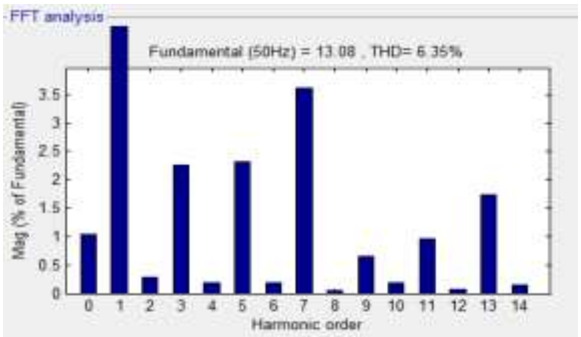

Figure 8. Frequency Spectrum

5. EXPERIMENTAL RESULTS

The Hardware of QZSI fed induction motor is fabricated and tested in the laboratory. The top view of the hardware is shown in Figure 9. A.C input voltage applied to the rectifier is shown in Figure 10. The output voltage of QZ network is shown in Figure 11. The switching pulses for M1, M3 and M5 are shown in Figures 12, 13 and 14 respectively. Amplified pulses for M1, M3 and M5 are shown in Figures 15, 16 and 17 respectively. Voltage across the load per phase is shown in the Figure 18. Line to line voltage is shown in the Figure 19. The phase voltage is a three level waveform and the line to line voltage is a five level waveforms. It can be seen from Figures 4 and 5 that the experimental results match with the simulation results.

Figure 9. Experimental set up

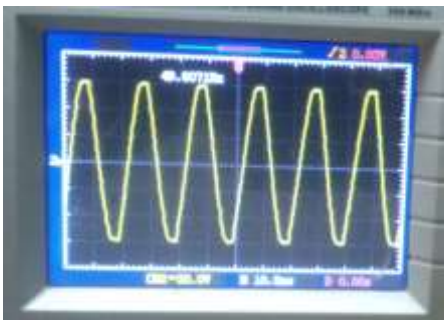

Figure 10. Input Voltage

Figure 11. Quasi Z -Source Output Voltage

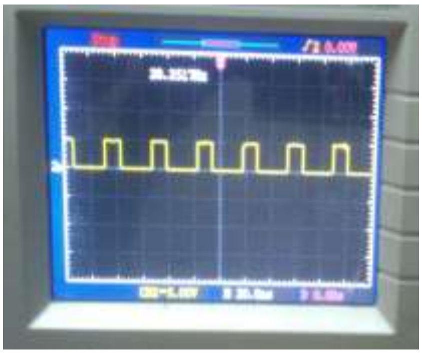

Figure 12. Switching Pulse for M1

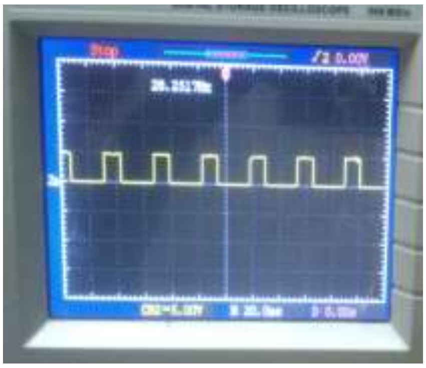

Figure 13. Switching Pulse for M3

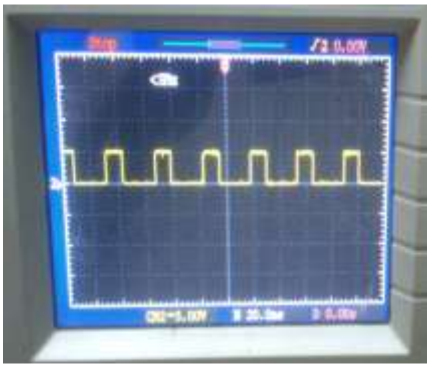

Figure 14. Switching Pulse for M5

Figure 15. Driver Output Pulse for M1

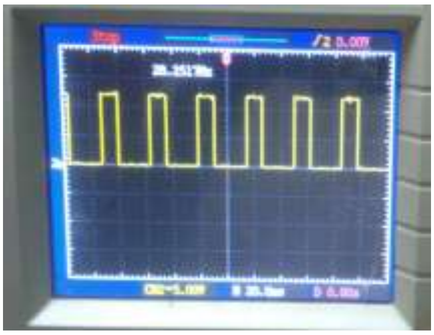

Figure 16. Driver Output Pulse for M3

Figure 17. Driver Output Pulse for M5

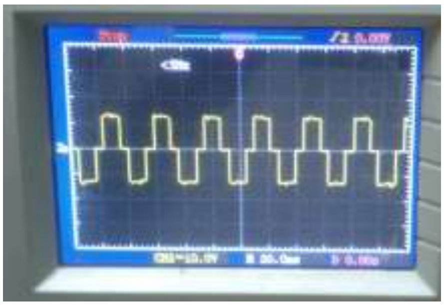

Figure 18. Line to Neutral Voltage

Figure 19. Line to Line Voltage

6. CONCLUSION

QZSI system is successfully designed; modeled and simulated using MATLAB and the results are presented. The Prototype hardware of current fed Quasi Z source Inverter based Induction Motor drive is fabricated and tested. The speed of the Induction Motor is successfully controlled using PIC 16F84. The experimental results closely matched with the simulation results. This drive system has advantages like reduced number of switches, voltage boosting ability and low cost controller. The disadvantage of the system is that, it requires two inductors and two capacitors. The scope of the present work is to investigate the performance of Quasi ZSI based Induction Motor with gamma Z source based Induction Motor drive systems.

ACKNOWLEDGEMENT

The authors would like to acknowledge the HOD, Dean and Vice-chancellor of Sathyabama University for providing the facilities in power Electronics lab.

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