



Cairo University

# **DESIGN AND IMPLEMENTATION OF A QZSI FED FROM WIND ENERGY CONVERSION SYSTEM**

**By**

**Abd Allah Hussien Rashad Mohamed**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
in Partial Fulfillment of the  
Requirements for the Degree of  
**MASTER OF SCIENCE**

In  
**ELECTRICAL POWER AND MACHINES ENGINEERING**

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
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Under the Supervision of

**Prof. Osama A. Mahgoub**

**Faculty of Engineering**

**Cairo University, Egypt**

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Approved by the Examining Committee

**Prof. Osama Ahmed Mahgoub (Supervisor)**

Faculty of Engineering - Cairo University

.....

**Prof. Abdelatif Elshafei (Internal Examiner)**

Faculty of Engineering - Cairo University

.....

**Prof. Aziza Mahmoud (External Examiner)**

Institute of Electronics Research

.....

FACULTY OF ENGINEERING, CAIRO UNIVERSITY  
GIZA, EGYPT  
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## Table of contents

<b>Table of contents</b> .....	<b>iv</b>
<b>List of Symbols</b> .....	<b>vii</b>
<b>List of Figures</b> .....	<b>ix</b>
<b>List of Tables</b> .....	<b>xi</b>
<b>Acknowledgment</b> .....	<b>xii</b>
<b>Abstract</b> .....	<b>xiii</b>
<b>Chapter 1 - Introduction</b> .....	<b>1</b>
1.1 General.....	1
1.2 Stand-Alone Systems .....	2
1.3 Grid Connected Systems.....	2
1.4 Boost converter based wind energy conversion system .....	3
1.5 PWM rectifier based system .....	4
1.6 QZSI based system .....	4
1.7 QZSI steady-state analysis.....	5
1.7.1 Non-Shoot-through State .....	6
1.7.2 Shoot-through State .....	7
1.8 Voltage Gain Calculation.....	8
1.9 Brief Literature Survey .....	9
1.10 Thesis Objectives .....	11
1.11 Outline of the thesis .....	11
<b>Chapter 2 - Proposed system design</b> .....	<b>13</b>
2.1 General.....	13
2.2 The rectifier design .....	14
2.2.1 The peak inverse voltage (PIV) .....	14
2.2.2 The diode rated RMS current.....	15
2.3 The impedance network design .....	16
2.3.1 The capacitor design .....	16

2.3.2 The inductor design .....	17
2.4 The voltage source inverter design .....	18
2.5 The LC filter design .....	18
2.5.1 The filter inductor design.....	19
2.5.2 The filter capacitor design .....	19
2.6 The MSVPWM.....	20
2.7 The DC link controller design .....	21
2.8 Conclusion .....	23
<b>Chapter 3 - Simulation of the Proposed System .....</b>	<b>24</b>
3.1 General.....	24
3. 2 Generation Side Waveforms.....	25
3. 3 DC Link Voltage Controller Waveforms.....	28
3. 4 Inversion Side Waveforms.....	30
3. 5 Load Side Waveforms .....	32
3. 6 Conclusion .....	33
<b>Chapter 4 - Wind Turbine Emulation System .....</b>	<b>34</b>
4.1 General.....	34
4.2 Wind Turbine Model .....	34
4.3 Emulation system structure.....	36
4.3.1 Separately excited DC motor.....	37
4.3.2 Three phase Semi-controlled rectifier bridge .....	38
4.3.3 Measurement, signal conditioning and firing circuit.....	40
4.3.3.1 Current sensing .....	40
4.3.3.2 Speed sensing.....	41
4.3.3.3 Firing Circuit.....	41
4.3.4 DSP for model and PID implementation .....	41
4.3.5 DC Motor Load.....	42
4.4 Experimental Results .....	43
4.5 Conclusion .....	46
<b>Chapter 5 - Experimental Results .....</b>	<b>47</b>

5.1 General.....	47
5.2 Software tasks .....	48
5.3 Generation side waveforms .....	48
5.4 DC link Controller results.....	49
5.5 Inversion Side results.....	51
5.6 Load side results .....	53
5.6 Conclusion .....	54
<b>Chapter 6 - Conclusion and future work.....</b>	<b>55</b>
6.1 Conclusion .....	55
6.2 Future Work.....	56
<b>References .....</b>	<b>57</b>

## List of Symbols

$B$	Boost factor of the inverter
$C$	Capacitance of the impedance network
$D$	Shoot Through - ST duty ratio
$f_c$	Corner frequency of the Filter
$f_{sw}$	Switching frequency of the PWM carrier
$f_{power}$	Power frequency
$G$	Theoretical voltage gain of the QZSI
$i_D$	Instantaneous diode current
$I_L$	Average inductor current
$\Delta I_L$	Peak to peak inductor current ripple
$i_{Line}$	Line RMS current
$i_{PN}$	Instantaneous inverter bridge current
$L$	Inductance of the impedance network
$M_a$	Modulation index
$P_{rated}$	Rated active power of the inverter
$T$	PWM switching time
$T_1$	Non-shoot through time
$T_o$	Shoot through time
$V_c$	Average capacitor voltage
$V_{C1}$	Average voltage across the capacitor $C_1$
$V_{C2}$	Average voltage across the capacitor $C_2$
$\Delta V_C$	Peak to peak capacitor voltage ripple
$V_{DcLink}$	Peak value of the DC Link voltage
$V_{in}$	Input voltage
$V_{inverter}$	Voltage stress across the inverter bridge
$V_L$	Instantaneous voltage across the inductor

$V_{\max}$	Peak value of the fundamental component of the phase voltage
$V_n$	Lower shoot through reference
$V_p$	Upper shoot through reference
$V_{\text{phase}}$	RMS value of the phase voltage



## List of Figures

Figure 1-1 Hybrid source stand-alone system. ....	2
Figure 1-2 Hybrid source grid connected system .....	3
Figure 1-3 Boost converter based wind energy generation system .....	4
Figure 1-4 PWM rectifier based system .....	4
Figure 1-5 QZSI based system.....	5
Figure 1-6 Voltage fed - quasi impedance source inverter .....	5
Figure 1-7 QZSI model during the non-shoot-through state .....	6
Figure 1-8 QZSI model during the shoot-through state.....	7
Figure 1-9 Voltage fed - QZSI with continuous input current.....	10
Figure 2-1 Block diagram of the proposed system. ....	13
Figure 2-2 Power/Speed characteristics of the wind turbine. ....	15
Figure 2-3 Switching pulses of the inverter switches. ....	20
Figure 2-4 Bode plot of the system after adding a PID controller.....	23
Figure 3-1 SIMULINK Blocks of the system.....	24
Figure 3-2 (a) Wind Speed (m/s), (b) Wind Power (W), (c) Generator Speed (r/s), (d) Rectifier Voltage (V) .....	26
Figure 3-3 Load power.....	27
Figure 3-4 stator phase current .....	28
Figure 3-5 Controller Performance Results .....	29
Figure 3-6 DC Link Voltage at 14, 12 and 10 m/s wind speed. ....	30
Figure 3-7 Impedance network inductor current and capacitor voltage waveforms .....	31
Figure 3-8 output Voltage and current waveforms .....	33
Figure 4-1 Torque-speed curve of the wind turbine .....	35
Figure 4-2 Emulation system block diagram. ....	36
Figure 4-3 Wind turbine Implemented emulation system. ....	36
Figure 4-4 DC Motor torque-speed curve.....	38
Figure 4-5 Three phase semi-controlled bridge. ....	39
Figure 4-6 simulated armature voltage. ....	39
Figure 4-7 DSP emulator program blocks. ....	41

Figure 4-8 Torque and speed of the DC motor. ....	43
Figure 4-9 Reference/Feedback armature current.....	44
Figure 4-10 Torque controller control signal ( $E_c$ ).....	45
Figure 4-11 Armature voltage at 14m/s. ....	45
Figure 5-1 Experimental setup block diagram.....	47
Figure 5-2 Experimental Laboratory Setup .....	48
Figure 5-3 Experimental generation side results. ....	49
Figure 5-4 DC link voltage controller block diagram.....	50
Figure 5-5 (a) Peak dc link voltage (b) shoot-through duty ratio .....	50
Figure 5-6 Capacitors voltage. ....	51
Figure 5-7 DC link voltage at different wind speeds.....	53
Figure 5-8 Three phase output voltages.....	54

## List of Tables

Table 2.1 Case study parameters .....	14
Table 2.2 operating rotational speed and generator voltage .....	14
Table 2.3 The Rectifier ratings .....	16
Table 2.4 Capacitor design calculations .....	17
Table 2.5 inductor design calculations.....	17
Table 2.6 VSI design calculations .....	18
Table 2.7 Filter design calculations .....	19
Table 2.8 The controller design calculations .....	22
Table 2.9 The controller parameters .....	22
Table 3.1 Generation side results.....	25
Table 3.2 Controller results.....	28
Table 3.3 Impedance network results .....	30
Table 3.4 output voltage and current results.....	32
Table 4.1 Motor parameters .....	37
Table 4.2 Motor specifications .....	37
Table 4.3 simulation parameters .....	40
Table 5.1 Experimental generation side results .....	48
Table 5.2 Experimental DC link controller results .....	50
Table 5.3 Inversion side results .....	51

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## Abstract

In this thesis a Quasi Impedance Source Inverter - QZSI fed from wind energy conversion system for isolated loads is designed. The impedance network coupling the source to the inverter bridge allows boosting the input voltage through utilizing shoot-through states. The desired line voltage at the inverter's output is achieved through a single conversion stage, instead of the mandatory additional conversion stages associated with the conventional inverters. The Space vector Pulse Width Modulation - SVPWM switching method is modified for intentional shoot through generation.

The introduced system consists of a wind turbine, a permanent magnet synchronous generator (PMSG); a three phase uncontrolled rectifier, the QZSI and LC passive filter. A detailed design procedure for the rectifier, impedance network, the voltage source inverter and the passive LC filter is carried out.

The rotational speed of the PMSG changes as the wind speed changes which results in changes in the generator and the rectifier output voltage. So, a PID controller was designed to regulate the DC link voltage. The amplitude and frequency of the output voltage are controlled by the modified space vector pulse width modulation technique (MSVPWM).

A wind turbine emulator based on a torque controlled separately excited DC motor is implemented to emulate the torque/speed characteristics of the wind turbine providing the PMSG with the mechanical power extracted from the wind kinetic energy.

The verification of the design is achieved through a simulation model using MATLAB/SIMULINK. The simulation results from the generation and inversion sides verify the design and the theoretical analysis of the presented system.

An experimental prototype, utilizing a controller based on TMS320F28335 digital signal processor, is implemented. The experimental results validated the theoretical analysis of the presented system and provided a satisfactory performance for the QZSI.

The thesis is organized as follows;

- Chapter 1** - Describes the different wind energy conversion systems, presents the system under study and explains the QZSI operation.
- Chapter 2** - Presents the design of the rectifier, the QZSI and the LC filter.
- Chapter 3** - Introduces the simulation results.

- Chapter 4 -** Explains the implemented wind turbine emulation system and presents the experimental results of the emulation system.
- Chapter 5 -** Provides the experimental results of the overall presented system.
- Chapter 6 -** Concludes the thesis and identifies some areas for future researches.

# Chapter 1 - Introduction

## 1.1 General

The utilization of the renewable energy sources is very important nowadays for many reasons. First the environmental impacts caused by gases emitted from burning fossil fuels used in conventional power stations can be avoided. Second, the non-renewable nature of the fuel used threatens the ability to continue producing electricity using it because it can deplete in any time. In contrast, renewable energy sources are always available for utilization in electrical energy generation and storage, the main drawbacks of renewable energy generation are the complexity, increased cost, reduced efficiency and reduced reliability of the renewable energy conversion system. So, researchers are working on reducing such drawbacks by developing new converters and machines with high efficiency and reliability.

Usually in conventional wind energy conversion systems, different types of power electronic converters are used for different purposes; rectifier to rectify the generator output, boost converter to boost the output of the rectifier before feeding the inverter as the output of the inverter is always less than the input voltage, and finally the inverter to convert the DC into AC providing power to the AC load. In this conventional system many converters are used which result in reduced system efficiency and reliability. Also a dead-time should exist between switches of each leg which causes distortion in the output waveform.

The Quasi Z source Inverter (QZSI) based system can be used to enhance the overall performance. The QZSI can perform both the boosting and inversion action in a single stage. Accordingly, the boost converter can be eliminated. As a result, the system cost decreases, and weight also decreases. The QZSI operation involves the shoot-through state in which two switches in one limb could be biased together eliminating the need to the dead time and interlock between the switches of the same leg necessary in the conventional Voltage Source Inverter (VSI). This would increase the system reliability.

All conventional pulse width modulation techniques like Sinusoidal pulse width modulation (SPWM), third harmonic injection and space vector pulse width modulation (SVPWM) can be modified to include the shoot-through states and used in the control of the QZSI[4].

Several electric machines could be used for converting the mechanical power provided by the wind turbine into electrical power valid for power conditioning by the power electronic converters. One of the attractive machines is the permanent magnet synchronous generator (PMSG) due to its high power density and efficiency.