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

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Under the Supervision of

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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
ΔI_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
ΔV_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_{phase}	RMS value of the phase voltage

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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 threats 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.