STUDIES ON SOLAR GRID-INTERCONNECTED QUASI Z-SOURCE INVERTER

By

Ahmed Salah Nabih Ahmed

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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Dedication

I’d like to dedicate this work to my supportive friends; Mohamad Fawzy, Islam El-sharawy, Taha, El-Batch and Gamal. Without my friends I wouldn’t, truly, be where I’m today. I pray for Allah to grant them peace and success through their life.

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ΔI_L	Peak to peak inductor current ripple
ΔV_C	Peak to peak capacitor voltage ripple
B	Boost factor of the inverter
BC-VSI	Boost converter cascaded with voltage source inverter
C	Capacitance of the impedance network
D	Steady state Shoot Through - ST duty ratio
d	Controlled (transient) ST duty ratio
f_0	Power frequency
f_c	Corner frequency of the Filter
f_s	Switching frequency of the PWM carrier
G	Theoretical voltage gain of the QZSI
i_D	Instantaneous diode current
i_{dq}	Vector of grid current in dq axes
I_g	Line RMS current
I_i	Instantaneous inverter bridge current
I_L	Average inductor current
I_{PV}	Operating current of PV string
L	Inductance of the impedance network
M	Modulation index
MBC	Maximum Boost Control
MCBC	Maximum Constant Boost Control
NST	Non-shoot through
P_s	Injected active power to grid
PV	Photovoltaic
Q_s	Injected reactive power to grid
QZSI	Quasi Z-source inverter
SBC	Simple Boost Control
ST	Shoot through
SVM	Space-vector modulation
T_0	Shoot through time

T_1	Non-shoot through time
THD	Total Harmonic Distortion
T_s	PWM switching time
V_c	Average capacitor voltage
V_{C1}	Average voltage across the capacitor C_1
V_{C2}	Average voltage across the capacitor C_2
V_{DC}	Peak value of the DC-link voltage
V_{in}	Input voltage
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_{PV}	Operating voltage on PV string terminals
V_s	Phase voltage at PCC
VSI	Voltage source inverter
V_t	AC phase voltage at converter terminals
WTHDn	Weighted Total Harmonic Distortion of the n^{th} order
ZSI	Z-source inverter
ZSVM2	Modified SVM (with two modified reference signals)
ZSVM4	Modified SVM (with four modified reference signals)
ZSVM6	Modified SVM (with six modified reference signals)

Abstract

Renewable energy sources present a trendy solution for energy shortage problem. However, these sources features variable and inconsistent power delivery over the course of the day. Power converters is, therefore, installed to stabilize the power delivery and regulate the output voltage to the utility level. Quasi Z-Source Inverter (QZSI) represents a single-stage buck-boost DC-AC converter, alternative to the traditional DC-DC converter cascaded with voltage-sourced inverter VSI topology, and is suitable for renewable energy integration systems.

In this thesis, a detailed analysis and design of QZSI is presented for grid-interconnected applications. The design procedure of the output low-pass filter is addressed; taking into account the variation in harmonic performance between the traditional PWM techniques for voltage source inverters and the modified PWM techniques for ZSIs. Moreover, an analytical study of harmonic performance of six different modulation techniques for ZSIs is presented. The harmonic spectrum of each modulation technique is estimated using double Fourier series approach. The analytical approach is adopted to exclude the common errors caused by practical conditions from simulation or experimental setups, and to present a fair comparison between the different modulation techniques. A collective evaluation of the modulation techniques using weighted total harmonic distortion is presented; taking into account the impact of the applied voltage gain on the harmonic performance.

This thesis, furthermore, proposes a control system design for QZSI in PV grid-tied applications. The control system is designed based on the dynamic characteristics of the converter and comprises three cascaded controllers. The first is output current controller designed in the synchronous rotating frame. The second is DC-link voltage controller. Sampling and measurement of the DC-link voltage signal is discussed using modified space-vector modulation. The last is maximum power point tracking (MPPT) in which a new strategy is proposed to provide wide operating range of DC-link voltage and shoot-through duty ratio, minimize the voltage stress on the inverter bridge, and prevent overlap between shoot-through duty ratio and modulation index. Simulation results are presented to validate the controllers design.