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Matrix converter technology in doubly-fed induction generators for wind generators

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Matrix Converter Technology in Doubly-Fed Induction Generators for Wind Generators

A thesis submitted in fulfilment of the

requirements for the award of the degree

Master of Engineering (Research)

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by

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School of Electrical, Computer and Telecommunications Engineering

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To the special people in my life. Thank you for your support.

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Certification

I, Benjamin James Harris declare that this thesis, submitted in fulfilment of the requirements for the award of Master of Engineering (Research), in the School of Electrical, Computer and Telecommunications Engineering, University of Wollongong, is entirely my own work unless otherwise referenced or acknowledged. This manuscript has not been submitted for qualifications at any other academic institute.

Benjamin James Harris

Abstract

Wind generator technologies have been widely researched and documented. Modern wind generator systems are now being implemented with an output power of up to 5 MVA. They adopt power electronic control systems which allow the system to operate with a wide range of turbine shaft speeds, as well as with Maximum Power Point Tracking (MPPT) algorithms to maximise the energy delivery to the power system.

Despite the extensive development, maximum power transfer from the total available power in the wind gusts to the grid is limited by the mechanical and electrical losses in the generation process. A Doubly-Fed Induction Generator (DFIG) uses a two stage power converter process in the rotor circuit which contributes to the electrical losses in the system. By adopting a Matrix Converter (MC), the electrical losses may be reduced as the power conversation is conducted as a single stage process. This thesis presents existing variable speed generator technologies with a focus on DFIG systems. Based on this research, an alternative design for a DFIG control system using an MC is developed and analysed.

The work begins with the presentation of existing DFIG systems using back-to-back PWM converters connected between the rotor circuit and the grid. The study examines MC technology and the application of current commutation techniques to MC systems. A non-ideal MC model and commutation controller is developed in the PSCAD® / EMTDC^{TM} environment. Simulation and analysis are conducted on the MC system connected to a passive load to determine its suitability for application in DFIG systems.

The MC is connected to the rotor circuit of the DFIG system in the simulation and analysis is carried out to investigate the viability of the system. From this the MC excited DFIG is extended with the development of a hybrid Maximum Power Point Tracking (MPPT) algorithm. The wind generator system is tested using pseudo-random wind speeds with varying wind gusts. The results of the simulation are presented and compared with existing MPPT technologies to assess the overall performance of the system in relation to existing technologies.

Finally, the MC excited DFIG control system is adapted to provide reactive power compensation to the power system for the regulation of voltage in distribution networks. Testing of the system using a variable load connected to a common bus bar and single transmission line is conducted. Observations from the simulation show that VAr compensation from the DFIG system does reduce voltage fluctuations in power systems.

List of Principal Symbols

P, Q	Active, Reactive Power
v_d, v_q	Direct, Quadrature Voltage
i_d, i_q	Direct, Quadrature Current
λ	Flux linkage or Tip-speed ratio
i_{ms}	Stator magnetizing current
L_s, L_r	WRIM stator, rotor self-inductance
L_{ls}, L_{lr}	WRIM stator, rotor leakage inductance
L_m	WRIM magnetizing inductance
X_s, X_r	WRIM stator, rotor self-reactance
X_{ls}, X_{lr}	WRIM stator, rotor leakage reactance
X_m	WRIM magnetizing reactance
r_s, r_r	Stator, Rotor resistance
$\omega_e, \omega_r, \omega_{slip}$	Electrical, Rotor, Slip angular velocity
P_t	Mechanical Power output of a wind turbine
T_t	Mechanical Torque of a wind turbine
C_p	Coefficient of power of a wind turbine
ρ	Air density
R	Radius of a wind turbine
V_w	Wind velocity
β	Pitch angle
f_s, t_s	Switching frequency / time
d_x	Duty Cycle of SSV_x
P	Poles
p	Pole Pairs

Subscripts, Superscripts

d, q	Direct, Quadrature axis values
A, B, C	Utility grid phase values
a, b, c	Output phase values
s, r	stator, rotor
$'$	Stator referred value
$*$	Reference value
e	Synchronous value

Acronyms

2QSW	Two Quadrant Switch
4QSW	Four Quadrant Switch
AC	Alternating Current
ASG	Adjustable Speed Generator
DC	Direct Current
DFIG	Doubly-Fed Induction Generator
EMTDC	Electromagnetic Transient Program for Direct Current
FFT	Fast Fourier Transform
FIR	Finite Impulse Response (filter)
FSG	Fixed Speed Generator
HF	High Frequency
MC	Matrix Converter
MPPT	Maximum Power Point Tracking
PCC	Point of Common Coupling
PSCAD® / EMTDC^{TM}	Power Systems Computer Aided Design
PWM	Pulse Width Modulation

RMS	Root Mean Square
SSCC	Semi-Soft Commutation Controller
SSV	Stationary Switch Vector
STATCOM	Static Synchronous Compensator
SVC	Static VAr Compensator
SVM	Space Vector Modulation
SVMC	Space Vector Modulation Controller
THD	Total Harmonic Distortion
VSG	Variable Speed Generator
VSI	Voltage Source Inverter
VSR	Voltage Source Rectifier
VVVF	Variable Voltage / Variable Frequency
WRIM	Wound Rotor Induction Machine

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