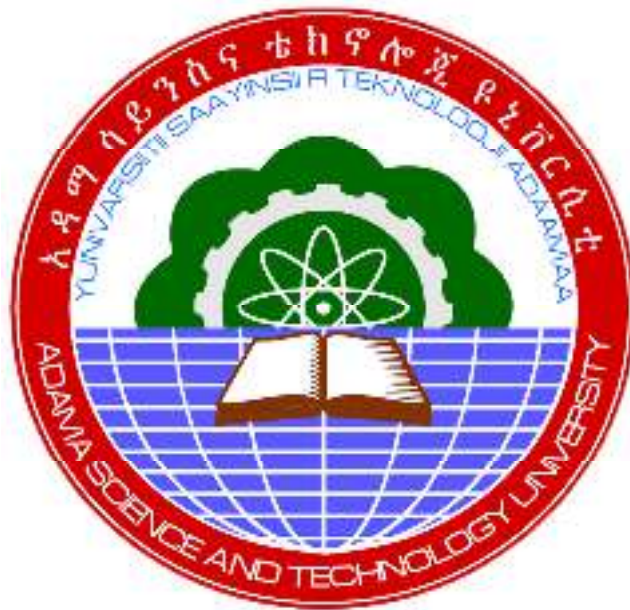


Investigation and Development of Converter-Inverter set for Wind Power Generation

By

Molla Biweta Yimer



A Dissertation Submitted to the Department of Electrical and Computer Engineering
School of Electrical Engineering and Computing

Presented in Fulfillment of the Requirement for the Degree of
Doctor of Philosophy in Electrical Power Engineering

Office of Graduate Studies
Adama Science and Technology University

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DEDICATION

This dissertation work is fully dedicated to my beloved wife Birknesh Tadesse and daughter Rediet Molla for their endless encouragement and motivation during my doctoral study!

APPROVAL OF BOARD OF EXAMINERS

We, the undersigned, members of the Board of Examiners of the final open defense by Molla Biweta Yimer have read and evaluated his dissertation entitled “Investigation and Development of Converter-Inverter set for Wind Power Generation” and examined the candidate. This is, therefore, to certify that the dissertation has been accepted in fulfillment of the requirement for the degree of Doctor of Philosophy in Electrical Power Engineering.

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DECLARATION

I hereby declare that this PhD dissertation is my original work and has not been presented for a degree in any other university and all sources of material used for this dissertation have been duly acknowledged.

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This PhD dissertation entitled “Investigation and Development of Converter-Inverter set for Wind Power Generation” has been submitted for examination with my approval as dissertation Supervisor.

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Molla Biweta Yimer

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TABLE OF CONTENTS

ACKNOWLEDGMENT	v
LIST OF TABLES.....	viii
LIST OF FIGURES	ix
LIST OF ACRONYMS	xi
LIST OF ABBREVIATIONS	xii
ABSTRACT	xiii
CHAPTER 1 INTRODUCTION	
1.1 Background	1
1.2 Motivation	4
1.3 Significance of the research	5
1.4 Scope of the research	6
1.5 Objectives of the research	7
1.6 Research Methodology	8
1.7 Structure of dissertation manuscript	9
CHAPTER 2 LITERATURE REVIEW	
(State-of-the-Art in Wind Energy conversion systems)	
2.1 Overview of Wind Energy Conversion System	10
2.1.1 Power control strategy	11
2.1.2 Speed control strategy	12
2.1.3 Modeling	13
2.2 Power Electronics Background	14
2.3 Power Converters	15
2.3.1 Power Converter Topologies	17
2.3.2 Pulse width modulated (PWM) converters	18
2.3.3 Application-specific and Advanced Converter Topologies	19
2.3.4 Power converter topologies for wind turbines	21
2.4 Control strategy	23

CHAPTER 3 PITCH-CONTROLLED WIND TURBINE GENERATION MODEL BASED ON PERMANENT MAGNET SYNCHRONOUS GENERATOR

3.1 Introduction	26 vii
3.2 Wind Energy Conversion System Block Model Description	27
3.2.1 Wind Model	28
3.2.2 Wind Turbine Model.....	29
3.2.3 Gearbox Model	31
3.2.4 Permanent Magnet Synchronous Generator Model	33
3.2.5 Pitch control model	34
3.3 System Simulation and Results	35
3.4 Conclusion	40

CHAPTER 4 ALTERNATIVE CONTROL STRATEGY OF GENERATOR SIDE TWO-LEVEL VOLTAGE SOURCE CONVERTER USING PLECS TOOLBOX ON MATLAB/SIMULINK

4.1 Introduction	41
4.2 System configuration and topology.	42
4.3 Control structure and strategy of the generator-side PWM converter	43
4.4 Modeling and Simulation	45
4.5 Conclusion	50

CHAPTER 5 CLOSED LOOP CONTROL STRATEGY OF BACK TO BACK PWM CONVERTER FED BY PMSG FOR WIND TURBINE APPLICATION

5.1 Introduction	51
5.2 System Configuration and Topology	52
5.3 Control structure and strategy of back to back PWM converter	53
5.4 Modeling and Simulation	55
5.5 Conclusion	61

CHAPTER 6 CONCLUSION AND RECOMMENDATION

6.1 Conclusion	62
6.2. Recommendation	63
REFERENCES	64
APPENDIX A.....	68
APPENDIX B	69
APPENDIX C	71
APPENDIX D.....	72 viii

LIST OF TABLES

TABLE	PAGE
Table 3.1 Parameters of Wind model	28
Table 3.2 Parameters of wind turbine model	31
Table 3.3 Parameters of gearbox model	32
Table 3.4 Parameters of Synchronous Generator	34
Table 4.1 System Parameters Table 4.2 Controller Parameters	47
Table 5.1 System Parameters Table 5.2 Controller Parameters	57 ix

LIST OF FIGURES

Fig.1.1 Arrangement of main components in wind energy conversion system	6
Fig.2.1 General structures of the two main categories of wind turbines	13
Fig.2.2 Performance limits of gate controlled devices	16
Fig.2.3 Schematic of two-level three phase converter	19
Fig.2.4 Three-level three phase converter with star connected load.....	20
Fig.2.5 Generalized multi-level converter.....	21
Fig.2.6 Unidirectional VSC with a diode rectifier	22
Fig.2.7 Back to Back PWM - VSC with an active IGBT rectifier/inverter	22
Fig.3.1 General block diagram of WECS.....	28
Fig.3.2 Simulink model of the wind turbine rotor	30
Fig.3.3 A three-mass arrangement of wind turbine drive train	31
Fig.3.4 One-mass Simulink model for the turbine drive train.....	32
Fig.3.5 Schematic for the transformed model of PMSM in the dq0 rotor reference frame.....	33
Fig.3.6 Anti-wind up Pitch control model	34
Fig.3.7 Block diagram of a 5 kW WECS Simulink model	35
Fig.3.8 Random wind speed	36
Fig.3.9 Pitch angle controller output	36
Fig.3.10 Turbine shaft rotational speed	37
Fig.3.11 Torque on the Turbine shaft	37
Fig.3.12 Mechanical power on the turbine shaft	38
Fig.3.13 Mechanical power on the shaft of SG	38
Fig.3.14 Generator shaft rotational speed	39
Fig.3.15 Three-phase electrical power	39
Fig.3.16 Stator three-phase voltage (a) and current (b)	40
Fig.4.1 System configuration with generator side converter	42
Fig.4.2 Topology of two-level VSC	43
Fig.4.3 Schematic diagram of the control structure	44
Fig.4.4 Sub system to transform complex to magnitude and angle	45
Fig.4.5 Simulink model for closed loop control system	47
Fig.4.6 Generator 3-phase voltage in full (a) and limited (b) simulation time	48
Fig.4.7 Load current	48
Fig.4.8 DC link voltage regulation	49
Fig.4.9 Generator side 3-phase current response	49
Fig.4.10 Power delivered to the load	50
Fig.5.1 Stand-alone wind power generation system	52

Fig.5.2 System configuration with a back to back voltage source converter	53
Fig.5.3 Schematic diagram of the closed loop control structure	54
Fig.5.4 Load side PWM inverter with LC filter	56
Fig.5.5 Simulink model for closed loop control system	57
Fig.5.6 Generator terminals 3-phase voltage	58
Fig.5.7 DC link voltage regulation	58
Fig.5.8 PWM signals for (a) Generator side and (b) load side converters	59
Fig.5.9 Load side (a) and (b) generator side 3-phase current response	59 x
Fig.5.10 Rotor position angle (α)	60
Fig.5.11 Measured rotational speed of Induction Machine (load) in rad/sec.	60
Figure A-1: Levelized energy cost of wind (a) and solar PV (b)	68
Figure B-1: Mask interface for function block parameters of wind model	69
Figure B-2: Mask interface for function block parameters of wind turbine model	69
Figure B-3: Mask interface for function block parameters of one mass gear box model	70
Figure B-4: Mask interface for function block parameters of PMSM model	70
Figure C-1: Block parameters of AC voltage source	71
Figure C-2: Block parameters of induction machine (connected load)	71
Figure D-1: Published paper on IJAREEIE	72
Figure D-2: Published paper on IJSER	73
Figure D-3: Conference proceeding on SIEFCON 2016	74
Figure D-4: Conference proceeding on IEEE Africon-2017	75 xi

LIST OF ACRONYMS

C	Capacitance
C_p	Power coefficient
C_Q	Torque coefficient
f	Electric frequency
I	Steady-state value of variable current
I_{dc}	DC-link current
i_{ds}	Direct-axis current in the rotor reference frame
I_i	Integral term of current controller
i_{qs}	Quadrature-axis current in the rotor reference frame
I_u	Integral term of voltage controller
$i_{as},$	i_{bs}, i_{cs} Instantaneous stator current of phase-A, B, C
J	Moment of inertia
K_{pi}	Proportional gain of current controller
K_{pu}	Proportional gain of voltage controller
L_d	Direct-axis stator inductance
L_q	Quadrature-axis stator inductance
L_s	Stator inductance
n	Rotational speed
P	Number of pole pairs
P	Active power
P_T	Turbine power
Q	Reactive power
R	Rotor radius
R_s	Stator resistance
T_e	Electromagnetic torque
T_{wt}	Turbine torque
U_{sd}	Direct-axis stator voltage
U_{sq}	Quadrature-axis stator voltage
U	Steady-state value of variable voltage
V	Wind speed
V_{dc}	DC-link voltage
X	Reactance
θ_r	Rotor position angle
λ	Tip-speed ratio
Ψ	Flux linkage
ω_e	Angular electrical speed

ω	Rotor angular velocity
ρ	Air density xii

LIST OF ABBREVIATIONS

AC	Alternating Current
CSC	Current Source Converter
DC	Direct Current
DD	Direct Drive
DFIG	Doubly-Fed Induction Generator
DTC	Direct Torque Control
EMF	Electromotive Force
EMI	Electro-Magnetic Interference
FF	Feed Forward
FOC	Field-Oriented Control
FSWT	Fixed Speed Wind Turbine
FVFF	Fixed Voltage Fixed Frequency
GSC	Generator Side Converter
HAWT	Horizontal Axis Wind Turbines
HF	High Frequency
HVDC	High Voltage DC
IM	Induction Machine
LSC	Load Side Converter
NPC	Neutral-Point Clamped
PI	Proportional-Integral
PM	Permanent Magnet
PMSG	Permanent Magnet Synchronous Generator
PWM	Pulse Width Modulation
RPM	Revolution per Minute
SCIG	Squirrel Cage Induction Generator
SVM	Space Vector Modulation
SVPWM	Space-Vector Pulse Width Modulation
VAWT	Vertical Axis Wind Turbines
VC	Vector Control
VFD	Variable-Frequency Drive
VOC	Voltage Oriented Control
VSC	Voltage Source Converter
VSFP	Variable-Speed Fixed Pitch
VVFF	Variable Voltage Fixed Frequency
VVVF	Variable Voltage Variable Frequency
WECS	Wind Energy Conversion System
WRIG	Wound Rotor Induction Generator
WT	Wind Turbine

ABSTRACT

Wind energy conversion system (WECS) model development for steady and dynamic state analysis and design has been research issue in recent years. This investigative research work presents a new block-based approach for WECS dynamic modelling. The blocks (modules) developed by Aalborg University - Denmark, RISO national laboratory based on Kaimal Spectra have been customized, updated and integrated into Matlab/Simulink platform and then utilized to simulate performance of 5kW WECS based on Permanent Magnet Synchronous Generator (PMSG). In addition to the developed block sets, in this research work, a proportional-integral controller is designed to control the turbine pitch and integrated with the simulation models. The simulation results demonstrate that the model outputs are in agreement with what is expected.

Moreover, in this research work, alternative closed-loop control strategy of generator and load side converters are presented for which an investigation and simulation of two-level, back-to-back voltage source converter has been carried out using PLECS software on Matlab/Simulink. Both rotor speed of the PMSG side and the DC-link voltage of load side are controlled by a PI controller. This control strategy has been achieved by using field oriented control (FOC) often referred as vector control method. Using PLECS software packages for modeling and simulation of circuit-oriented electric and electronic dynamic systems, is considered as special feature for high-speed simulations in graphic modeling (block diagram) method that is commonly used in control engineering. The validity and performance of the applied control scheme has been verified by simulation results and the simulation results demonstrate that the controller is capable of maintaining constant DC-link voltage under varying supply voltage (250V - 400 V) and frequency (25Hz -50Hz) from the source and different electrical load conditions (DC and AC).

KEYWORDS: Wind Energy Conversion system (WECS), Permanent Magnet Synchronous Generator (PMSG), Field Oriented Control (FOC), Modeling and Simulation, Plecs, Matlab/Simulink.