

ANALYSIS OF DIFFERENT CONFIGURATIONS OF DOUBLY FED INDUCTION GENERATOR UNDER ISOLATED MODE OPERATION

DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE

OF

**MASTER OF TECHNOLOGY
IN
CONTROL AND
INSTRUMENTATION**

Submitted by:

Sidhant Chhabra

(2K13/C&I/18)

Under the supervision of

Dr. Dheeraj Joshi



DEPARTMENT OF ELECTRICAL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi-110042

2015

DEPARTMENT OF ELECTRICAL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CERTIFICATE

I, **Sidhant Chhabra**, Roll No. 2K13/C&I/18 student of **M. Tech. (Control and Instrumentation)**, hereby declare that the dissertation titled “**Analysis of different configurations of doubly fed induction generator under isolated mode operation**” under the supervision of Dr. Dheeraj Joshi, Associate Professor, Department of Electrical Engineering, Delhi Technological University in partial fulfilment of the requirement for the award of the degree of Master of Technology has not been submitted elsewhere for the award of any Degree.

Place: Delhi

Sidhant Chhabra

Date: 20.07.2015

Dr. Dheeraj Joshi
Associate Professor
Department of Electrical Engineering
Delhi Technological University

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to Dr. Dheeraj Joshi for his guidance and assistance in the dissertation. The technical discussions with him were always been very insightful, and I will always be indebted to him for all the knowledge he shared with me. His prompt responses and availability despite his constantly busy schedule were truly appreciated. He always helped me in all the technical and non-technical issues during the production of this dissertation. Without his consistent support, encouragement and valuable inputs, this dissertation would not have become possible.

I would like to express my deep gratitude to Prof. Madhusudan Singh, Head, Department of Electrical Engineering for providing his support during my project.

I would also like to thank my batch-mates and friends who encouraged and helped me in completing the dissertation.

Finally, I express my deep sincere thanks to my Parents, without them it wouldn't have been possible.

Sidhant Chhabra
(2K13/C&I/18)
M.Tech (Control and Instrumentation)

ABSTRACT

This dissertation work deals with the modeling, operation and control of the doubly fed induction generator in isolated mode. The various wind energy generation systems along with their parallel operation have been discussed. Various configurations using DC and AC supply integrated with novel architecture of boost derived hybrid converter and solar PV panel have been made and their operation with varying wind speed and load has been seen. The corresponding MATLAB/Simulink models for the different configurations have been drawn and their closed loop operation for varying load and wind speed variation has been done under isolated mode of operation.

CONTENTS

CIRTFIFICATE	i
ACKNOWLEDGEMENT	ii
ABSTRACT.....	iii
CONTENTS.....	iv
LIST OF FIGURES.....	vii
LIST OF TABLES.....	x
NOMENCLATURE	xi
CHAPTER 1. INTRODUCTION TO WIND ENERGY SYSTEMS	1
1.1 BACKGROUND	1
1.2 VARIABLE SPEED WIND ENERGY SYSTEMS.....	3
1.2.1 Doubly Fed Induction generator.....	4
1.2.2 Full Converter geared solution.....	5
1.2.3 Full Converter direct drive solutions.....	6
1.3 DOUBLY FED INDUCTION GENERATOR	7
1.4 WIND TURBINE CONTROL REQUIREMENTS	8
1.4.1 General control requirements.....	9
1.5 DFIG SYSTEMS SUPPLYING ISOLATED LOADS	10
CHAPTER 2. LITERATURE SURVEY.....	11
2.1 INTRODUCTION	11
2.2 GENERATOR OVERVIEW	11
2.3 COMPARISON AND PARALLEL OF INDUCTION GENERATORS.....	12
2.4 DFIG SYSTEMS SUPPLYING ISOLATED LOADS	13
2.5 DFIG FED WITH DC SUPPLY.....	13

CHAPTER 3. MODELING OF INDUCTION GENERATOR15

CHAPTER 4. COMPARISON OF WIND ENERGY GENERATION17

SYSTEMS AND THEIR PARALLEL OPERATION

4.1 INTRODUCTION17

4.1.1 SCIG BASED ON FIXED SPEED WIND TURBINE..... 18

4.1.2 DFIG BASED ON VARIABLE SPEED WIND CONCEPT.....19

4.2 COMPARISON OF CAPABILITIES OF SCIG AND DFIG20

4.3 PARALLEL OPERATION OF TWO GENERATORS21

4.3.1 Parallel operation of two SCIG's.....21

4.3.2 Parallel operation of a SCIG and a DFIG..... 22

4.3.3 Parallel operation of two DFIG's.....25

4.4 RESULTS AND DISCUSSIONS.....25

CHAPTER 5. DIFFERENT CONFIGURATIONS OF ISOLATED MODE DFIG....27

5.1 INTRODUCTION27

5.2 ISOLATED MODE OPERATION OF DFIG FED WITH THREE PHASE.....27

SUPPLY

5.3 ISOLATED MODE OPERATION OF DFIG FED WITH DC SUPPLY35

5.3.1 DFIG fed with three lead DC supply..... 35

5.3.2 DFIG fed with two lead DC supply..... 38

5.4 NOVEL ARCHITECTURE FEEDING DFIG WITH PV PANEL AND BDHC....41

5.4.1 Boost Derived hybrid converter (BDHC) 43

5.5 DFIG FED WITH SINGLE PHASE AC SUPPLY.....46

CHAPTER 6. CONTROLLED OPERATION OF DFIG	49
6.1 INTRODUCTION	49
6.2 WIND TURBINE AND PITCH CONTROL	49
6.3 CLOSED LOOP OPERATION WITH THREE LEAD DC SUPPLY	50
6.4 CLOSED LOOP OPERATION WITH TWO LEAD DC SUPPLY	51
6.5 RESULTS AND DISCUSSIONS	52
CHAPTER 7. CONCLUSION AND FUTURE SCOPE	56
7.1 CONCLUSION.....	56
7.2 FUTURE SCOPE.....	56
APPENDIX.....	57
REFERENCES	59

LIST OF FIGURES

Figure No.	Name	Page No
Fig 1.1	World Total Installed Capacity of Wind Energy	1
Fig 1.2	State wise Installed Capacity in India	2
Fig 1.3	Doubly Fed Induction Machine based wind turbine system	4
Fig 1.4	Induction Machine (SCIG) based wind turbine	5
Fig 1.5	Synchronous Machine (PMSG) based wind turbine	6
Fig 1.6	Synchronous Machine Direct Drive based wind turbine	7
Fig 1.7	DFIG operation under sub-synchronous condition	8
Fig 1.8	DFIG operation under super-synchronous condition	8
Fig 3.1	Equivalent circuit in Q - axis	15
Fig. 3.2	Equivalent circuit in D - axis	15
Fig 4.1	SCIG system connected to the grid	18
Fig 4.2	DFIG system connected to the grid	19
Fig 4.3	Variation of stator voltage with load for SCIG and DFIG	20
Fig 4.4	Variation of stator frequency with load for SCIG and DFIG	21
Fig 4.5	Variation of voltage and frequency for two SCIG's operated in parallel	22
Fig 4.6	Parallel operation of SCIG and DFIG	23
Fig 4.7	Variation of active power supplied by SCIG and DFIG with load	24
Fig 4.8	Variation of voltage and frequency with load for parallel	24

operation of SCIG and DFIG

Fig 4.9	Variation of voltage and frequency with load for two DFIG's operated in parallel	25
Fig 5.1	MATLAB model showing DFIG fed with 3 phase supply	28
Fig 5.2	Variation of rotor voltage for variable wind speed at rated output for fixed load	29
Fig. 5.3	Variation of rotor frequency for variable wind speed at rated output for fixed load	29
Fig. 5.4	Variation of rotor voltage and frequency for variable wind speed for inductive load of 0.9 power factor	30
Fig. 5.5	Variation of rotor voltage and frequency for variable load at constant speed	31
Fig. 5.6	Variation of rotor voltage and frequency for variable wind speed at rated load	32
Fig. 5.7	Variation of stator voltage and frequency with varying load for a given wind speed and rotor excitation	33
Fig. 5.8	MATLAB model showing showing DFIG fed from DC supply with three lead connection	35
Fig. 5.9	Variation of load voltage with shunt capacitance for different values of applied DC voltages	36
Fig. 5.10	MATLAB model showing DFIG fed from DC supply with two lead connection	39
Fig. 5.11	Practical model of PV cell	42
Fig. 5.12	MATLAB model showing DFIG fed from integrated PV	42

panel and BDHC

Fig. 5.13	Boost Derived Hybrid Converter with single phase inverter bridge network	43
Fig. 5.14	Simulink Model showing the boost derived hybrid converter	44
Fig. 5.15	Circuit to generate unipolar sine PWM	45
Fig. 5.16	Switching pulses for Q1-Q4	45
Fig. 5.17	DFIG fed with single phase AC supply and series compensation	46
Fig. 5.18	Variation of voltage unbalance with series capacitance	47
Fig. 5.19	Variation of voltage unbalance with load	48
Fig. 6.1	Closed Loop Operation of DFIG fed with three lead connection	50
Fig. 6.2	Closed Loop Operation of DFIG fed with two lead connection	51
Fig. 6.3	Load voltage for open loop operation with varying load	52
Fig. 6.4	Load voltage for closed loop variation with varying load	52
Fig. 6.5	Variation of load with time	53
Fig. 6.6	Control of voltage with varying load	54
Fig. 6.7	Variation of wind speed with time	55
Fig. 6.8	Control of frequency of with varying speed	55

LIST OF TABLES

Table No.	Name	Page No
Table 5.1	Comparative study of experimental and simulated results	34
Table 5.2	Variation of input DC voltage with load, wind speed and capacitance for three lead connection	37
Table 5.3	Variation of input DC voltage with load, wind speed and capacitance for two lead connection	39

NOMENCLATURE

DFIG	Doubly Fed Induction Generator
PMSG	Permanent Magnet Synchronous Generator
SCIG	Squirrel Cage Induction Generator
PWM	Pulse Width Modulation
MPMG	Multipole Permanent magnet Generator
WRSG	Wound Rotor Synchronous Generator
P_m	Mechanical power
P_s	Stator active power
P_r	Rotor active power
WECS	Wind Energy Conversion Systems
f_s	Stator frequency
R_l	Load resistance
X_l	Load inductive reactance
V_r	Rotor voltage
V_s	Stator voltage
f_r	Rotor frequency
pu	Per unit

