

FREQUENCY REGULATION IN MICROGRIDS

by

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CERTIFICATE

This is to certify that the thesis titled, “**Frequency Regulation in Microgrids**”, being submitted by **Mr. K.V. Vidyanandan** for the award of the degree of **Doctor of Philosophy** is a record of bonafide research work carried out by him in the Department of Electrical Engineering of the Indian Institute of Technology, Delhi, India. Mr. Vidyanandan has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to my knowledge, has reached the requisite standard. The results obtained herein have not been submitted to any other University or Institute for the award of any degree.

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ABSTRACT

Some of the major challenges the world faces today are linked to hydrocarbon based energy systems; the fast depletion of its stock and the pollutions resulting from its conversion. Supplying power to remotely located communities, where extension of central grid power is either difficult to provide due to the geographical constraints or frequently disrupted due to adverse conditions, further aggravates the challenges. For sustainable growth in power sector promoting environmental balance, renewable energy plays an important role. Among various renewable resources, wind energy is the most potential resource currently focused as a means for energy security and sustainability. Many countries are targeting for 20% wind energy in the total generation mix by the year 2020.

Although wind based power generation technology has been in existence for several years, because of the low penetration levels of these systems, focus of the industry was mainly on the turbine and generator protection aspects. However, with the increasing percentage of wind energy in the electric grid, new challenges, both technical and regulatory, with regards to the functioning of the current power system are emerging. Apart from the issues related to intermittency, fluctuations and power quality, the increasing penetration of wind energy in the existing power grid will effectively reduce the percentage share of conventional synchronous generators.

For harnessing optimum energy from the wind resource, modern wind turbine generators (WTGs) incorporate variable speed technology. Except type: B limited variable speed WTG, most of the variable speed WTGs need a power electronics converter-inverter combo either in the rotor circuit (e.g. type: C, DFIG based WTG) or in the stator circuit (e.g. type: D, PMSG based WTG) for the interface between the machine and the network.

In order to maintain network frequency within safe limits after load events, the participation of all generating resources in frequency regulation is a critical requirement.

However, power electronics based generating systems, such as wind turbine generators, currently do not take part in frequency regulation due to various reasons such as missing inertial effects arising out of the decoupling of speed-frequency link, lacking of governor response to frequency changes (or the droop characteristics) and the non-availability of sufficient reserve generation capacity.

The work in this thesis deals with the application of DFIG based variable speed wind turbines in system frequency regulation. To analyze their frequency regulation capability, dynamic models of wind turbine generator appropriate for steady and fluctuating winds have been developed. While the nonlinear model is used for fluctuating wind, the linearized model is used for steady wind conditions.

For the creation of sufficient reserve generation capacity needed for taking part in frequency regulation, wind turbines are deloaded from the optimum power corresponding to the existing wind speed. Using the power margins thus created, the WTGs are controlled to provide relief to the grid during depressed frequency conditions. Frequency support from individual WTGs is regulated based on the available reserve, which depends on the prevailing wind velocities. The impact of variable droop operation on two aspects of WTG operation is investigated – primary frequency contribution and smoothening power fluctuations caused due to changes in wind speed.

The thesis also investigates the impact of adding energy buffers such as flywheel, fuel cells and water electrolyzer in a wind dominated microgrid supplemented by diesel generator.

In totality, the work in this thesis demonstrates that variable speed WTGs can be used effectively for regulating system frequency so that the reliability of standalone microgrids can be enhanced and thus the dependence on costly and polluting fossil fuels reduced.

TABLE OF CONTENTS

Description	Page No.
Certificate	i
Acknowledgements	iii
Abstract	v
Table of Contents	vii
List of Figures	xiii
List of Tables	xix
List of Symbols	xxi
 CHAPTER-1 INTRODUCTION	 1
1.1. General	1
1.2. Frequency Regulation in Electric Power System	3
1.2.1 System Inertia	3
1.2.2 Speed Droop	5
1.2.3 Reserve Generation Capacity	6
1.3. Wind Power in Rural Areas	6
1.4. Literature Review	7
1.5. Objective of the Research Work	14
1.6. Organization of the Thesis	15
 CHAPTER-2 OVERVIEW OF WIND ENERGY CONVERSION SYSTEMS	 19
2.1. Introduction	19
2.2. Wind Power	20
2.3. Aerodynamic Power Control	24
2.4. Wind Energy Conversion Systems	25
2.4.1 Fixed Speed Wind Turbines	26
2.4.2 Variable Speed Wind Turbine	26

2.4.2.1	Limited Variable Speed Wind Turbine	28
2.4.2.2	Doubly Fed Induction Generator Wind Turbine	29
2.4.2.3	Permanent Magnet Synchronous Generator Wind Turbine	31
2.5.	Conclusion	35
CHAPTER-3 ENERGY STORAGE SYSTEMS		37
3.1.	Introduction	37
3.2.	Pumped Hydro Energy Storage	39
3.3.	Compressed Air Energy Storage	40
3.4.	Battery Energy Storage	41
3.4.1	Deep Cycle Lead-Acid Battery Energy Storage	41
3.4.2	Lithium-Ion Battery Energy Storage	41
3.4.3	Sodium-Sulphur Battery Energy Storage	42
3.4.4	Flow Battery Energy Storage	42
3.5.	Super-Capacitor Energy Storage	43
3.6.	Super-Conducting Magnetic Energy Storage	44
3.7.	Flywheel Energy Storage	44
3.8.	Hydrogen Energy Storage and Fuel Cells	48
3.9.	Conclusion	52
CHAPTER-4 SYSTEM MODELING		55
4.1.	Introduction	55
4.2.	Wind Speed	55
4.3.	Wind Turbine Aerodynamics	56
4.4.	Drivetrain	57
4.5.	Pitch Angle Controller	58
4.6.	Doubly Fed Induction Generator	58
4.7.	Maximum Power Point Tracking	61
4.8.	Deloaded Operation of DFIG Based WTGs	63

4.9. Speed Droop	66
4.10. Diesel Engine Generator	67
4.11. Flywheel Energy Storage System	67
4.12. Solid Oxide Fuel Cell	71
4.13. Water Electrolyzer	76
4.14. Hydrogen Gas Compressor	79
4.15. Hydrogen Storage Tank	80
4.16. Conclusion	80
 CHAPTER-5 IMPACTS OF INCREASED WIND PENETRATION	 81
5.1. Introduction	81
5.2. Effect of Variable Speed WTGs on System Inertia and Droop	81
5.3. Impact of Increased Wind Penetration	83
5.4. WTGs Do Not Participate in System Frequency Regulation	83
5.4.1 Increased Wind Penetration and its Effect on System Droop	85
5.4.2 Increased Wind Penetration and its Effect on System Inertia	85
5.4.3 Effect of Increased Wind Penetration on the Combined Droop and Inertia	86
5.5. Emulating Inertia And Droop In Wind Turbine Generators	87
5.6. WTGs Participate in System Frequency Regulation	89
5.7. Conclusion	91
 CHAPTER-6 DYNAMIC MODELS OF WIND TURBINE GENERATORS	 93
6.1. Introduction	93
6.2. Microgrid	93
6.3. Non-Linear Model of DFIG Based Wind Turbine Generator	94
6.4. Linear Model of DFIG Based Wind Turbine Generator	94
6.5. Deloaded WTG During Fluctuating Wind	98
6.5.1 Wind Farm Without Considering Spatial Smoothing	99

6.5.2	Wind Farm Considering Spatial Smoothing	102
6.6.	Conclusion	104
CHAPTER-7	PRIMARY FREQUENCY REGULATION BY DELOADED WIND TURBINES USING VARIABLE DROOP	107
7.1.	Introduction	107
7.2.	Creation of Reserve Generation Margin	107
7.3.	Selection of Appropriate Droop Value	108
7.4.	Variable Droop in WTGs	112
7.5.	Primary Frequency Regulation by Deloaded WTG Using Variable Droop	114
7.5.1	Step Change in Wind Speed	114
7.5.2	Change in Wind Speed as per ARMA Model	119
7.6.	Impact of Deloaded Operation on Annual Energy Served by WTGs	122
7.7.	Challenges in Choosing Variable Droop Operation in WTGs	124
7.8.	Conclusion	125
CHAPTER-8	INTEGRATION OF FLYWHEEL AND FUEL CELL WITH WIND ENERGY SYSTEMS	127
8.1.	Introduction	127
8.2.	Microgrid	127
8.3.	Control Strategy	128
8.4.	Simulation Results	129
8.5.	Conclusion	135
CHAPTER-9	CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH	137
9.1.	Introduction	137
9.2.	Summary and Conclusions	137
9.3.	Suggestions for Further Research	140
	References	141

Appendices	161
Lists of Publications	163
Bio-Data	165