

FREQUENCY CONTROL OF A SMART MICROGRID

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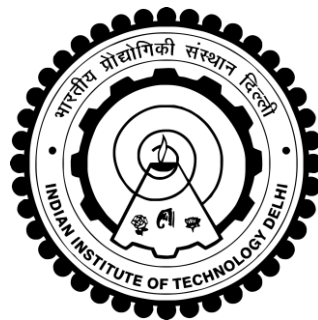
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Doctor of Philosophy

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CERTIFICATE

This is to certify that the thesis entitled “**Frequency Control of a Smart Microgrid**” being submitted by **Mr. Gaddam Mallesham** 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.

Mr. Gaddam Mallesham has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to our knowledge has reached the requisite standard. The results obtained here, have not been submitted to any other University or Institute for the award of any degree.

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ABSTRACT

Today's world is very much concerned to reduce greenhouse gas emissions from the conventional thermal power plants as cutting down emissions from transport and heating sector may not be realistic in the near future. To reduce pollution from electrical power sources, the world is now marching towards the usage of renewable energy sources. These sources being small in capacity are mostly connected at the distribution voltage level. This indirectly reduces transmission and distribution losses since the sources are near the load. This distribution system having small scale energy sources is called as a *microgrid* or *active distribution network*.

Microgrid operates generally in a grid connected mode. However, circumstances such as fault, voltage sag and large frequency oscillations in the main grid may force the active distribution network to be disconnected from the main grid and operate as an isolated microgrid. During this isolation period, there will be changes in output power from the controllable micro sources which are to be regulated properly to have a stable operation in regard to power balance and frequency of operation within the isolated microgrid. To bridge the gap between the load consumption and power produced by the renewable energy sources, the controllable sources: diesel generator, combine cycle gas turbine based system, fuel cell, aqua electrolyzer, battery and wind etc. are used as possible alternate solutions, if available in the microgrid.

The regulation is not linear due to the inherent time delay and ramp rate limit/generation rate constraint (GRC), therefore this leads to oscillations in the frequency. These oscillations should be damped out using proper controllers. In microgrid when all sources are in parallel to obtain a stable feedback loop, there is a

requirement of proper load sharing among the sources, hence we introduce the power-frequency (P-f) droop characteristics (R) for the power generating sources which are participating in frequency control. Similarly, each controllable source should have a proper control signal, to regulate output power proportional to the frequency deviation called frequency bias (B). The control signal for each controllable source is to be properly selected.

In modern power system the secondary control for frequency regulation is carried out with the help of supervisory control and data acquisitions (SCADAs) and remote terminal units (RTUs), being employed at the load dispatch centre and substations respectively. The scanning rate of SCADA to fetch the data from the RTUs is quite slow. Since SCADA houses the secondary controller, its influence over the dynamics of load frequency control is slow. Moreover, the data obtained at the SCADA level may not be of much use for improving the dynamic performance of the system as it does not bear any time stamping. Therefore, to overcome this, phasor measurement units (PMUs) are placed in strategic locations. This enables to use a dedicated link/internet between different entities in a microgrid for the data exchange. The microgrid central controller (MGCC) analogous to SCADA can handle both primary as well as secondary controllers. However, the decision depends on the reliability and bandwidth of the communication channels. Hence, a smart microgrid is developed for efficient resource utilization, monitoring and control of power sources based on Multi Agent System (MAS) concept with agents being connected over internet.

The tuning of proportional and integral of controller parameters (PI) for frequency regulation is addressed by gradient descent method (GD), and some evolutionary

algorithms (EA): genetic algorithms (GA), bacterial foraging algorithm (BFO) and biogeography based optimization (BBO) are used. The PI controller tuned with BBO best among the above methods with minimum cost function, so BBO based tuning is used in subsequent chapters. However the PI controller tuned with the above methods may fall in local minimum which give suboptimal performance as some of the information of the microgrid is not be available.

To overcome this, Kalman state observer with linear quadratic regulators (LQR) is proposed. But the challenging issue here is tuning of weightage matrices ‘Q’ and ‘R’ simultaneously in a non linear microgrid.

The limitation of LQR method is the requirement of mathematical model of a microgrid. This is addressed by using non linearly variable gain controller reinforced learned multi layer perceptron (MLP) neural networks which resulted improved transient response of a smart microgrid.

TABLE OF CONTENTS

	Page No.
Certificate	i
Acknowledgements	iii
Abstract	v
Table of Contents	ix
List of Figures	xv
List of Tables	xix
List of Symbols	xxi
List of Abbreviations	xxvii
CHAPTER 1 INTRODUCTION	1
1.1 General	1
1.2 Distributed Generation	2
1.3 The Microgrid	5
1.4 The Smart Microgrid	6
1.5 Literature Review	9
1.6 Evolutionary Algorithms for Determination of Controller Gains	15
1.7 Objective of Proposed Work	15
1.8 Outline of the Thesis	17

CHAPTER 2	MODELING OF A SMART MICROGRID	21
2.1	Introduction	21
2.2	Rotating Machine Based Controllable Source (Diesel Generator)	23
	2.2.1 The Governor of the Diesel generation	23
	2.2.2 The Diesel Engine or Turbine	24
2.3	Voltage Source Converter (VSC) Based Controllable Source	24
2.4	Aqua Electrolyzer	25
2.5	Fuel Cell	27
2.6	Hydrogen Storage	27
2.7	Battery	29
2.8	Renewable Energy Sources	30
	2.8.1 Wind Energy Conversion System (WECS)	30
	2.8.2 Photovoltaic Based Uncontrollable Source	33
	2.8.2.1 Solar panel Modeling under MPPT operation	33
	2.8.2.2. Design of PV cell transfer function gain parameter	34
2.9	Power and Frequency Deviation	36
2.10	Frequency Bias in Smart Microgrid	38
2.11	Designing of P-f Droop for Different Controllable Sources in the Smart Microgrid	38
2.12	Generation Rate Constraint (GRC) in Smart Microgrid	42
2.13	The Smart Microgrid	44
	2.13.1 The Microgrid Central Controller (MGCC)	46
	2.13.2 Smart Microgrid with Communication Channel	48
2.14	Summary	50

CHAPTER 3	TUNING OF PI CONTROLLERS IN SMART	51
	MICROGRID	
3.1	Introduction	51
3.2	Problem Statement	51
3.3	Gradient Descent Optimization Method for Smart Microgrid	53
	3.3.1 Application of GD to tune the controller parameters in Smart Microgrid	53
3.4	Evolutionary Algorithms for Tuning of PI Controllers in Smart Microgrid	54
	3.4.1 Genetic algorithms (GA) for tuning of controllers in Smart Microgrid	55
	3.4.2 Bacterial foraging optimization technique (BFO) for tuning of controllers in Smart Microgrid	59
	3.4.2.1 BFO algorithm for tuning of controllers parameters in Smart Microgrid	62
	3.4.3 Biogeography based optimization (BBO)	67
	3.4.3.1 BBO algorithm used for Tuning of Controllers Parameters in Smart Microgrid	71
	3.4.3.2 Application of BBO for Tuning of the Parameters in Smart Microgrid	72
3.5	Simulation Results and Analysis	74
	3.5.1 Case 1: Study of Smart Microgrid with GRC, Battery and Secondary Control	76
	3.5.2 Case 2: Sudden increase in solar power	79

3.5.3	Case 3: Effect of Sampling Time over the Controller, uncertainty in data transmission using UDP/IP in Smart Microgrid.	81
3.6	Summary	84
CHAPTER 4	DESIGN OF STATE ESTIMATED LQR CONTROLLER FOR SMART MICROGRID	85
4.1	Introduction	85
4.2	The Problem Statement	86
4.3	Optimal Control Theory for Smart Microgrid modeling	86
4.3.1	Dynamic Model of Smart Microgrid in State Variable Form	87
4.4	State Feedback LQR Control in Smart Microgrid	89
4.5	Output Feedback LQR Control Smart Microgrid	90
4.5.1	Kalman State observer for Smart Microgrid	83
4.6	Tuning of Weightage Matrices ‘Q’ and ‘R’	95
4.6.1	Bryson Method	95
4.6.2	Conventional Iterative Based Approach	96
4.6.3	Evolutionary Algorithms based Iterative Approach	97
4.7	Simulation Results and Analysis	100
4.7.1	Case 1: Sudden load increase by 5% when WECS is either in MPPT or participating in frequency control	100
4.7.2	Case2: Dynamic response of the Smart Microgrid for sudden increase in solar insolation by 3%	103

4.8	Summary	104
CHAPTER 5	DESIGN OF REINFORCED LEARNED MULTI LAYER PERCEPTRON NEURRAL NETWORKS FOR THE SMART MICROGRID	105
5.1	Introduction	105
5.2	Multilayer Perceptron (MLP)	106
5.3	Design of Reinforced Learned MLP Based Controller for the Smart Microgrid	107
	5.3.1 The Architecture of the MLP Controller	109
	5.3.2 The Weights Updation in the MLP	110
5.4	Simulation Results and Analysis	114
	5.4.1 Case I: Increase in load by 5% at 10 s.	114
	5.4.2 Solar power is increased by 3% at 10 s.	116
5.4	Summary	117
CHAPTER 6	SUMMARY AND CONCLUSIONS	119
6.1	Summary of the Present Work	119
6.2	Conclusions of the Present Work	121
6.3	Suggestions for the Future Research	121
	REFERENCES	123
	APPENDIX	141
	LIST OF PUBLICATIONS	145
	BIO-DATA	147