

SOME STUDIES ON
ADVANCED LOAD-FREQUENCY CONTROL STRATEGIES

K.VENKATESWARLU, B.E., M.Sc. (Engg)

THESIS SUBMITTED
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN
ELECTRICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY , DELHI
NEW DELHI-110029

1975

My Parents

PREFACE

The thesis contains the results of investigation carried out by the author in the department of Electrical Engineering, Indian Institute of Technology, Delhi, over the period September 1972 to August 1975. The basic motivation for this study has been a desire to obtain some new results on Load-frequency control problem through application of modern control theory. More emphasis has been placed on the ease of implementation through output dependent control strategies. The question of achieving control by feeding back the outputs either to a central controller or to (decentralized) area controllers has been studied in some detail.

The author would like to take this opportunity to record his appreciation of the guidance and encouragement provided by Professor A.K.Mahalanabis, during the course of investigation. He would like to express his indebtedness to the authorities of Regional Engineering College, Warangal and of Indian Institute of Technology, Delhi; for providing him with an opportunity to carry out the investigations. He is also thankful to the National Science Foundation, Washington, U.S.A., for making it possible to undertake simulation studies on an IBM 360/44 system with the Indian Meteorological Department, Delhi. The author would like to thank his colleagues, Dr. J. Panda, Dr. B.S. Rao and Dr. K.K. Biswas for helpful discussions at various stages of this work and to Mr. J.N. Saini for his excellent typing work. Finally, he would like to record his appreciation of the excellent understanding and cooperation extended by his wife and children.

August 25, 1975
New Delhi

K. Venkateswarlu

C O N T E N T S

<u>CHAPTER 1</u>	POWER SYSTEM OPERATION AND THE ROLE OF LOAD FREQUENCY CONTROL	...	1
1.1	Introduction	...	1
1.2	Power System Operation and the LFC Problem	...	2
1.3	Review of Earlier Work	...	4
1.4	Outline of the Chapters.	...	9
<u>CHAPTER 2</u>	DETERMINISTIC VERSION OF THE LFC PROBLEM	...	13
2.1	Introduction	...	13
2.2	Application of IQ Regulator Theory.	...	14
2.2.1	Problem Formulation	...	14
2.2.2	Solution of Optimal LFC Strategy	...	17
2.2.3	Computational considerations.	...	18
2.3	LFC Strategies Based on Modal Control Theory	...	21
2.3.1	Problem Formulation.	...	21
2.3.2	Derivation of the Control Law.	...	22
2.4	LFC Problem with Constraints on the Rate of Change of Generation	...	26
2.4.1	Problem Formulation	...	26
2.4.2	A Dual Mode LFC Strategy	...	27
2.5	Simulation Studies of a 2-Area LFC System	...	29
2.5.1	System Model	...	29
2.5.2	Results of Simulation	...	32

<u>CHAPTER 3</u>	STOCHASTIC VERSION OF THE LFC PROBLEM	...	39
3.1	Introduction	...	39
3.2	Design of Proportional Plus Integral Type LFC Regulators.	...	40
3.2.1	Problem Formulation	...	40
3.2.2	Method of Solution	...	41
3.2.3	Implementation of 'P+I' LFC Strategy	...	44
3.2.4	Bias Estimation Technique for Load Demand Variation.	...	47
3.3	Feedforward Control Strategy.	...	49
3.3.1	Problem Formulation	...	49
3.3.2	Derivation of 'P+F' Control Strategy	...	51
3.3.3	Implementation of 'P+F' Strategy	...	55
3.4	Simulation Studies of a 2-Area LFC System	...	56
3.4.1	Application of 'P+I' Strategy	...	56
3.4.2	Application of 'P+F' Control Strategy.	...	57
<u>CHAPTER 4</u>	LFC REGULATOR DESIGN USING OUTPUT FEEDBACK	...	60
4.1	Introduction	...	60
4.2	Output Feedback LFC Strategies	...	61
4.2.1	Problem Formulation	...	61
4.2.2	Solution of Problem 1	...	63
4.2.3	Solution of Problem 2	...	68
4.3	Two Approximations to Constrained output controller Design.	...	72
4.3.1	Minimum Error Excitation Solution	...	72
4.3.2	Minimum Norm Solution	...	76
4.4	Application of Minimum Norm Solution to A 2-Area LFC System.	...	78

<u>CHAPTER-5</u>	DESIGN OF OUTPUT FEEDBACK REGULATORS FOR THE STOCHASTIC LFC PROBLEM	...	83
5.1	Introduction	...	83
5.2	Centralized Output Feedback Control	...	84
5.2.1	Problem Formulation	...	84
5.2.2	Derivation of the Control Strategy	...	85
5.3	Decentralized Output Feedback LFC Strategies	...	89
5.3.1	Problem Formulation	...	89
5.3.2	Method of Solution	...	91
5.4	Minimum Norm Solution And Numerical Results.	...	94
<u>CHAPTER-6</u>	DECENTRALIZED LFC STRATEGIES VIA MODELLING ERROR CORRECTION TECHNIQUE	...	97
6.1	Introduction	...	97
6.2	Problem Formulation	...	98
6.3	Proposed Decentralized Control Scheme	...	101
6.4	Application to a 2-Area LFC System	...	108
6.4.1	System Model	...	108
6.4.2	Numerical Results	...	110
<u>CHAPTER-7</u>	SUMMARY OF RESULTS AND SUGGESTIONS FOR FURTHER WORK.	...	113
7.1	Introduction.	...	113
7.2	Summary of Results	...	113
7.3	Suggestions for Further Work.	...	118
	REFERENCES	...	120