Robust Power System Frequency Control

Bevrani. H

Published (to be published) in: ***Springer***

publication date: **2009**

POWER ELECTRONICS AND POWER SYSTEMS

Hassan Bevrani

Robust Power System Frequency Control

Springer

Robust Power System Frequency Control

Power Electronics and Power Systems

Series Editors: M.A. Pai
University of Illinois at Urbana-Champaign
Urbana, Illinois

Alex Stankovic
Northeastern University
Boston, Massachusetts

Robust Power System Frequency Control
Hassan Bevrani
ISBN 978-0-387-84877-8

Synchronized Phasor Measurements and Their Applications
A.G. Phadke and J.S. Thorp
ISBN 978-0-387-76535-8

Digital Control of Electical Drives
Slobodan N. Vukosavić
ISBN 978-0-387-48598-0

Three-Phase Diode Rectifiers with Low Harmonics
Predrag Pejović
ISBN 978-0-387-29310-3

Computational Techniques for Voltage Stability Assessment and Control
Venkataramana Ajjarapu
ISBN 978-0-387-26080-8

Real-Time Stability in Power Systems: Techniques for Early Detection of the Risk of Blackout
Savu C. Savulesco, ed.
ISBN 978-0-387-25626-9

Robust Control in Power Systems
Bikash Pal and Balarko Chaudhuri
ISBN 978-0-387-25949-9

Applied Mathematics for Restructured Electric Power Systems: Optimization, Control, and Computational Intelligence
Joe H. Chow, Felix F. Wu, and James A. Momoh, eds.
ISBN 978-0-387-23470-0

HVDC and FACTS Controllers: Applications of Static Converters in Power Systems
Vijay K. Sood
ISBN 978-1-4020-7890-3

Power Quality Enhancement Using Custom Power Devices
Arindam Ghosh and Gerard Ledwich
ISBN 978-1-4020-7180-5

Computational Methods for Large Sparse Power Systems Analysis: An Object Oriented Approach
S.A. Soman, S.A. Khaparde, and Shubha Pandit
ISBN 978-0-7923-7591-3

Operation of Restructured Power Systems
Kankar Bhattacharya, Math H.J. Bollen, Jaap E. Daalder
ISBN 978-0-7923-7397-1

Transient Stability of Power Systems: A Unified Approach to Assessment and Control
Mania Pavella, Damien Ernst, and Daniel Ruiz-Vega
ISBN 978-0-7923-7963-8

Continued after index

Hassan Bevrani

Robust Power System Frequency Control

Springer

Hassan Bevrani
University of Kurdistan
Sanandaj, Kurdistan
Iran
bevrani@uok.ac.ir

Queensland University of Technology
Brisbane, QLD
Australia
bevrani@qut.edu.au

ISBN: 978-0-387-84877-8 e-ISBN: 978-0-387-84878-5
DOI: 10.1007/978-0-387-84878-5

Library of Congress Control Number: 2008934165

Printed on acid-free paper

springer.com

Dedicated to my parents

Preface

Frequency control as a major function of automatic generation control is one of the important control problems in electric power system design and operation, and is becoming more significant today because of the increasing size, changing structure, emerging new uncertainties, environmental constraints and the complexity of power systems.

In the last two decades, many studies have focused on damping control and voltage stability and the related issues, but there has been much less work on the power system frequency control analysis and synthesis. While some aspects of frequency control have been illustrated along with individual chapters, many conferences and technical papers, a comprehensive and sensible practical explanation of robust frequency control in a book form is necessary.

This book provides a thorough understanding of the basic principles of power system frequency behaviour in wide range of operating conditions. It uses simple frequency response models, control structures and mathematical algorithms to adapt modern robust control theorems with frequency control issue and conceptual explanations. Most developed control strategies are examined by real-time simulations. Practical methods for computer analysis and design are emphasized.

This book emphasizes the physical and engineering aspects of the power system frequency control design problem, providing a conceptual understanding of frequency regulation, and application of robust control techniques. The main aim is to develop an appropriate intuition relative to the robust load frequency regulation problem in real-world power systems, rather than to describe sophisticated mathematical analytical methods.

This book could be useful for engineers and operators in power system planning and operation, as well as for academic researchers. It could be useful as a supplementary text for university students in electrical engineering at both undergraduate and postgraduate levels in standard courses of power system dynamics, power system analysis and power system stability and control.

Outlines

The book is divided into ten chapters and two appendices. Chapter 1 provides an introduction on the general aspects of power system controls. Fundamental concepts and definitions of stability and existing controls are emphasized. The timescales and characteristics of various power system controls are described and the importance of frequency stability and control is explained.

Chapter 2 introduces the subject of real power frequency control, providing definitions and basic concepts. The load–frequency control (LFC) mechanism of a single control area is first described and then extended to a multi-area control system. Frequency operating standards, tie-line bias and its application to a multi-area frequency control system are presented. Past achievements in the frequency control literature are briefly reviewed.

Chapter 3 describes LFC characteristics and dynamic performances. Static and dynamic performances are explained, and the effects of physical constraints (generation rate, dead band, time delays and uncertainties) on power system frequency control performance are emphasized. The impacts of power system restructuring on frequency regulation are discussed, and a dynamical model to adapt a well-tested classical LFC model to the changing environment of power system operation is simulated.

Chapter 4 describes a systematic H_∞ control technique using a fundamental control theorem and an iterative linear matrix inequalities (ILMI) algorithm for proportional–integral (PI)-based LFC design. In the proposed synthesis approach, the frequency control synthesis is reduced to static output feedback control problem. The closed loop performance is compared with conventional control design.

Chapter 5 provides an H_∞ control method to the design of robust PI-based LFC system in the pretense of communication delays. A laboratory environment for doing real-time simulations to evaluate the developed power system frequency control framework is described. A simplified model of a real power system is used to perform a comparison study on the proposed control strategy.

Chapter 6 is organized into two main parts. First, the mixed H_2/H_∞ control technique is used to synthesize simple robust PI controllers in a multi-area power system. Then, the LFC problem, considering multiple delays/uncertainties, is formulated as a multi-objective control problem. The advantages of the proposed method are examined by an experimental study and real-time non-linear simulations.

Chapter 7 presents an agent-based control strategy for the designing of the decentralized LFC system. A two-agent control system measures/receives the required signals/data and estimates the total power imbalance, generator participation factors and produces control action signal through an H_∞-based PI controller. The results are examined using an analog power simulator.

Chapter 8 presents the application of structured singular value theory (μ) for robust decentralized LFC design. System uncertainties and practical constraints are properly considered during a synthesis procedure. The robust performance is formulated in terms of the structured singular value for the measuring of control performance within a systematic approach.

Chapter 9 describes the power system frequency behaviour in emergency conditions. The conventional frequency response model is generalized by considering the dynamics of emergency control/protection schemes such as under-frequency load shedding (UFLS) and under-frequency/over-frequency generation trips. A method for UFLS by using the regional frequency decline rate is proposed.

Chapter 10 presents an overview of the key issues and the new challenges on frequency regulation, concerning the integration of renewable energy units into the power systems. The impact of power fluctuation produced by variable wind and solar renewable sources on system frequency performance via a simulation study is analysed. An updated LFC model is introduced, and the need for the revising of frequency performance standards is emphasized. Finally, a brief survey on the recent studies on the frequency regulation in the presence of renewable energy resources (RESs) and associated issues is presented. Appendices include mathematical descriptions and simulation data.

Acknowledgements

Much of the information, outcomes and insight presented in this book were achieved through a long-term research conducted by the author on robust control and power system frequency regulation over the last 15 years in Iran (1993–2002: K.N. Toosi University of Technology, West Regional Electric Company, and University of Kurdistan), Japan (2002–2006: Osaka University, Kumamoto University and Research laboratory of Kyushu Electric Power Company) and Australia (2007–2008: Queensland University of Technology).

It is pleasure to acknowledge the scholarships, awards and support the author received from various sources: The Ministry of Education, Culture, Sports, Science and Technology, Government of Japan (Monbukagakusho); Japan Society for the Promotion of Science (JSPS); West Regional Electric Company (WREC); Research Office at University of Kurdistan (UOK) and the Australian Research Council (ARC).

The author thanks Prof. T. Hiyama (Kumamoto University), Prof. Y. Mitani (Kyushu Institute of Technology), Prof. K. Tsuji (Osaka University), Prof. G. Ledwich and Prof. Arindam Ghosh (Queensland University of Technology) for their continuous support and valuable comments. The assistance provided by Dr. J.J. Ford, Dr. J. Banks and Ms J. Stanbrook (Queensland University of Technology) is appreciated. Special thanks go to Prof. M.A. Pai (University of Illinois) for his support to provide this book. Finally, the author offers his deepest personal gratitude to his family for their support and patience during his work on this book.

Contents