Intelligent Automatic Generation Control

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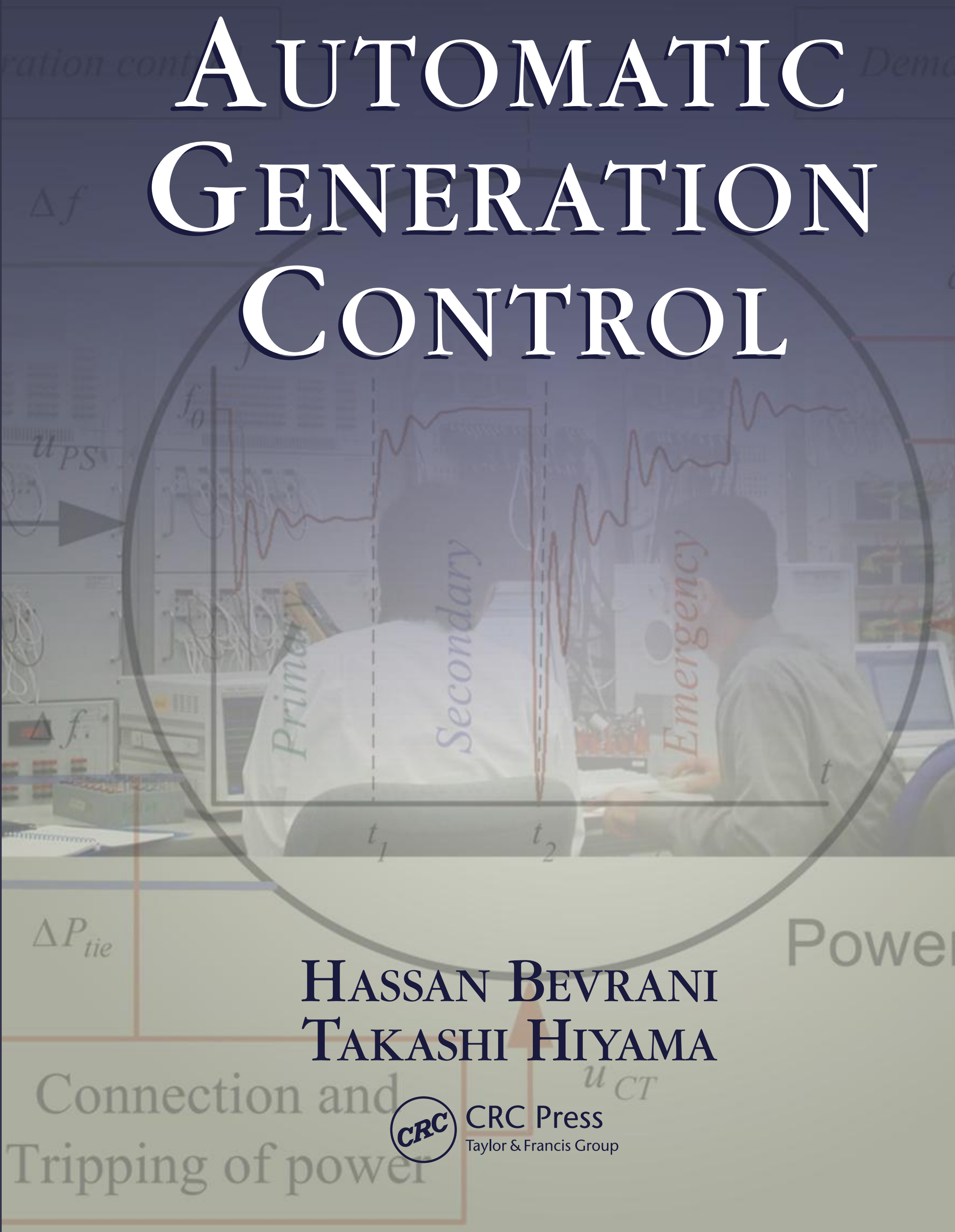

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To Sabah, Bina, and Zana

and

To Junko, Satoko, Masaki, Atsushi, and Fuyuko

Contents

Preface

Automatic generation control (AGC) is one of the important control problems in interconnected power system design and operation, and is becoming more significant today due to the increasing size, changing structure, emerging renewable energy sources and new uncertainties, environmental constraints, and complexity of power systems. Automatic generation control markets require increased intelligence and flexibility to ensure that they are capable of maintaining a generation-load balance, following serious disturbances.

The AGC systems of tomorrow, which should handle complex, multiobjective regulation optimization problems characterized by a high degree of diversification in policies, control strategies, and wide distribution in demand and supply sources, surely must be intelligent. The core of such intelligent systems should be based on flexible intelligent algorithms, advanced information technology, and fast communication devices. The intelligent automatic generation control interacting with other ancillary services and energy markets will be able to contribute to upcoming challenges of future power systems control and operation. This issue will be performed by intelligent meters and data analyzers using advanced computational methods and hardware technologies in both load and generation sides.

Intelligent automatic generation control provides a thorough understanding of the fundamentals of power system AGC, and addresses several new schemes using intelligent control methodologies for simultaneous minimization of system frequency deviation and tie-line power changes to match total generation and load demand, which is required for successful operation of interconnected power systems. The physical and engineering aspects have been fully considered, and most proposed control strategies are examined by real-time simulations.

The present book could be useful for engineers and operators in power system planning and operation, as well as academic researchers and university students in electrical engineering. This book is organized into twelve chapters.

Chapter 1 provides a review on intelligent power system operation and control, and is mainly focused on the application examples of intelligent technologies in Japanese power system utilities. The chapter presents the state of the art of intelligent techniques in Japanese utilities based on the investigation by the Subcommittee of the Intelligent Systems Implementations in Power Systems of Japan. The current situation of intelligent methods application in Japanese power systems in general is described. Artificial intelligent applications in power system planning and control/restoration are addressed, and next steps and future implementations are explained.

Chapter 2 presents the fundamentals of AGC, providing structure, definitions, and basic concepts. The AGC mechanism in an interconnected power system, and the major functions, constraints, and characteristics are described. The role of AGC systems in connection with the power system monitoring/control master stations, and remote site control centers to manage the electric energy, is emphasized. Power system operations and frequency control in different ranges of frequency deviation are briefly explained. A frequency response model is described, and its usefulness for the sake of AGC dynamic analysis and simulation is examined.

Chapter 3 emphasizes the application of intelligent techniques on the AGC synthesis and addresses the basic control configurations with recent achievements. New challenges and key issues concerning system restructuring and integration of distributed generators and renewable energy sources (RESs) are also discussed. The applications of fuzzy logic, neural networks, genetic algorithms, multiagent systems, combined intelligent techniques, and evolutionary optimization approaches on the AGC synthesis problem are briefly reviewed. An introduction to AGC design in deregulated environments is given, and AGC analysis and synthesis in the presence of RESs and microgrids, including literature review, present worldwide status, impacts, and technical challenges, are presented. Finally, a discussion on the future works and research needs is given.

Chapter 4 reviews the main structures, configurations, and characteristics of AGC systems in a deregulated environment and addresses the control area concept in restructured power systems. Modern AGC structures and topologies are described, and a brief description on AGC markets is given. Concepts such as AGC market and market operator, and the need for intelligent AGC markets in the future are also explained. The chapter emphasizes that the new challenges will require some adaptations of the current AGC strategies to satisfy the general needs of different market organizations and the specific characteristics of each power system. The existing market-based AGC configurations are discussed, and an updated frequency response model for decentralized AGC markets is introduced.

Chapter 5 describes a methodology for AGC design using neural networks in a restructured power system. Design strategy includes enough flexibility to set a desired level of performance. The proposed control method is applied to single- and three-control area examples under a bilateral AGC scheme. It is recognized that the learning of both connection weights and neuron function parameters increases the power of learning algorithms, keeping high capability in the training process. It is shown that the flexible neural-network-based supplementary frequency controllers give better area control error minimization and a proper convergence to the desired trajectory than do the traditional neural networks.

Chapter 6 covers the AGC system and related issues concerning the integration of new RESs in the power systems. The impact of power fluctuation produced by variable renewable sources (such as wind and solar units) on the system frequency performance is presented. An updated power system frequency response model for AGC analysis considering RESs and associated issues is introduced. Some nonlinear time-domain simulations on standard power system examples are presented to show that the simulated results agree with those predicted analytically. Emergency frequency control concerning the RESs is discussed. Finally, the need for revising frequency performance standards, further research, and new AGC perspectives is emphasized.

Chapter 7 addresses the application of multiagent systems in AGC design for multiarea power systems. General frameworks for agent-based control systems based upon the foundations of agent theory are discussed. A new multiagent AGC scheme has been introduced. The capability of reinforcement learning in the proposed AGC strategy is examined, and the application of genetic algorithms (GAs) to determine actions and states during the learning process is discussed. The possibility for building more agents, such as estimator agents to cope with real-world AGC systems, is explained. Finally, the proposed methodology is examined on some power system examples. The application results show that the proposed multiagent control schemes provide a desirable performance, even in comparison to recently developed robust control design.

Chapter 8 proposes a Bayesian-network-based multiagent AGC framework, including two agents in each control area for estimating the amount of power imbalance and providing an appropriate control action signal according to load disturbances and tie-line power changes. The Bayesian network's construction, concepts, and parameter learning are explained. Some nonlinear simulations on a standard test system concerning the integration of wind power units, and also a real-time laboratory experience, are performed. The results show the proposed AGC scheme guarantees optimal performance for a wide range of operating conditions.

Chapter 9 gives an overview on fuzzy-logic-based AGC systems with different configurations. Two fuzzy-logic-based AGC design methodologies based on polar information and particle swarm optimization are presented for the frequency and tie-line power regulation in multiarea power systems. By using the proposed polar-information-based fuzzy logic AGC scheme, the megawatt hour (MWh) constraint is satisfied to avoid the MWh contract violation. The particle-swarm-optimization-based fuzzy logic AGC design is used for frequency and tie-line power regulation in the presence of wind turbines. The efficiency of the proposed control schemes is demonstrated through nonlinear simulations.

Chapter 10 presents a coordinated frequency regulation for the small-sized, high-power energy capacitor system and the conventional AGC participating units to improve the frequency regulation performance. To prevent unnecessary excessive control action, two types of restrictions are proposed for the upper and lower limits of the control signal, as well as for the area control error. By the proposed coordination, the frequency regulation performance is highly improved.

Chapter 11 starts by introducing GAs and their applications in control systems. Then, several methodologies are presented for a GA-based AGC design problem: optimal tuning of conventional AGC systems, AGC formulation through a multiobjective GA optimization problem, GA-based AGC synthesis to track the well-known standard robust performance indices, and using GA to improve the learning performance in the AGC systems. The proposed design methodologies are illustrated by suitable examples. In most cases, the results are compared with recently developed robust control designs.

Chapter 12 presents an intelligent multiagent-based AGC scheme for a power system with dispersed power sources such as photovoltaic, wind generation, diesel generation, and energy capacitor system. In the proposed AGC scheme, the energy capacitor system provides the main function of AGC, while the available diesel units provide a supplementary function of the AGC system. A coordination system between the energy capacitor system and the diesel units is proposed. The developed multiagent system consists of three types of agents: monitoring agents for the distribution of required information through a secure computer network; control agents for the charging/discharging operation on the energy storage device, as well as control of regulation power produced by diesel units; and finally, a supervisor agent for the coordination purpose. Experimental studies in a power system laboratory are performed to demonstrate the efficiency of the proposed AGC scheme.

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