Preface

Hybrid power systems use both conventional generation systems such as thermal and nuclear power systems and also renewable resources such as wind turbine, photovoltaic cell, fuel cell, etc., to supply demand. Conventional systems have serious environmental problems such as emissions and greenhouse gas effects, high cost of fuel and low efficiency, and reliability that can be improved by combination with the renewable energy resources. Usually, hybrid power systems combine two or more energy sources accompanied with energy storage devices to deliver power continually to the DC load or to the AC load via the inverter system.

However, designing and operation of hybrid power systems are complicated as the control systems comprise several subsystems from the stability issue. Hybrid power systems also include problems of loop control and feedback configurations that are solved by conventional and modern control methods.

Hybrid power systems as nonlinear electrical networks should be modeled and analyzed in various operational situations considering the related topological structures. The models use mathematical formulas and physical principles to describe the appropriate system behavior. The optional modeling approaches also denote the parametric and non-parametric identification procedures. In this case the physical structure of the hybrid power system would be known to have adequate results from the physical correctness point of view and concern the observability, controllability, and state minimality of the system representations.

As power demand grows rapidly and transmission and generation fields expanded, the availability of hybrid power systems and related resources are affected by constraints of more loading and stability limitations. Therefore, the stability and dynamic performance of the power system should be improved by Power System Stabilizers (PSSs). The adverse effect of PSSs in voltage profile and server disturbances is damped by using Flexible AC Transmission System (FACTS) controllers, such as Static VAR Compensators (SVCs), Thyristor Control Series Compensators (TCSCs), Static Synchronous Compensators (STATCOMs), and Unified Power Flow Controller (UPFC) as the supplementary signal for main control loops. Voltage Source Converter (VSC)-based High Voltage DC (HVDC) transmission systems are also used in hybrid power systems and provide various forms of modulation for damping power system oscillation and improving dynamic performance.

The UPFC acts as a shunt compensating and a phase shifting device simultaneously, which has the ability to control the hybrid power flow transmission, improve the transient stability, mitigate system oscillation, and provide voltage support. The global optimization techniques and heuristic population-based search procedures like Genetic Algorithms (GA) have been applied to the UPFC-based damping controller parameter optimization. To overcome the highly correlated and large number of optimized parameters, the classic and quantum behaved particle swarm optimization (PSO) techniques are used for optimal tuning of controller parameter to improve optimization synthesis and the speed of algorithm convergence.

Hybrid power systems should be evaluated carefully to reduce the investment cost of transmission system expansion and solve the far location between the generating plants and the load centers. Transmission Network Expansion Planning (TNEP) is an important part of power system planning to minimize the network construction and operational cost while satisfying the requirement of delivering electric power safely and reliably to load centers. The TNEP could be classified as static to determine the information about new required transmission lines, and a dynamic one to verify the optimal expansion design over the whole time restrictions planning period. For solution of TNEP problem, the classic method based on mathematical principles with linearization, and non-classic methods based on random search algorithms are applied.

Hybrid power systems include more energy sources and the hybrid Energy Storage Devices (ESD) as well as Power Dynamic Compensators (PDC) as the embedded power unit to deliver or store energy and enhance the performance of the entire system. Some hybrid power systems use Fuel Cells (FC) topologies with ultracapacitor, battery, and hybrid types in some dynamic load applications. Therefore, the fuel cells-based hybrid power systems are important with regard to designating, modeling, analyzing, and operating including active controlled topologies to obtain both performances in energy conversion and in ripple mitigation.

Advanced Techniques and Applications on Stability, Control, and Optimal Operation of Hybrid Power Systems is a book aimed to highlight the above concepts and challenges by a systematic approach and, therefore, to provide understanding on the hybrid power system structures and topologies, in flow of generation and transmission, designing, modeling, analyzing, operation, and the ways of controlling different systems by using different research methods.

Some of the specialists are joined as authors of the book chapters to provide their potentially innovative solutions and research related to the field of hybrid power systems, in order to be useful in developing new ways in their technologies, design, and operational strategies. Efficient theoretical researches, case analysis, and practical implementation processes are put together in this book that aims to act research and design guides to help the postgraduates and researchers in electrical power engineering and energy systems. In particular, the specific purposes of the subjects also include the knowledge base and applications used by undergraduates with regard to indicating research fields and innovative solutions as the challenges and opportunities for solving problems.

The book presents significant results obtained by leading professionals from the industry, research, and academic fields, and can be useful to various groups in the specific areas analyzed in this book. All works contributed to this book are new, previously unpublished material, or extended versions of published papers in the proceedings of international conferences and transactions on international journals.

"Overview of Hybrid Power System" introduces an overview of hybrid power systems combining renewable energy resources and conventional generators. The chapter describes the components of conventional generators and renewable energy resources, power electronic converter, and elements of control systems. The chapter includes some important objects related to main power plants, generators, renewable energy resources, supervisory control of hybrid power systems and their modeling, control and management as well as their relevant operation strategies. Besides, the chapter introduces storage devices as a part of hybrid power systems and any possible combination of conventional and renewable resources.

The general condition of problems of loops control is given in "Revisiting and Generalizing Barkhausen's Equality". It shows that the fixed point equations over a space of functions are essential for loops control. The chapter discusses that the particular conditions as Barkhausen for the loops especially with at least two subsystems are derived as solutions in the functions space. The entire power of the loop concept and fixed point conditions is described by the differential loops equations and deal with the inverse function and fixed point condition.

"State Energy-Based Approach as a Tool for Design and Simulation of Linear and Nonlinear Systems" presents the detection of the physical interaction correctness in the strictly causal system representations as energy exchanging. The chapter also investigates the proposed solution approach related to the generalization of Tellegen's theorem. The analyzing and synthesizing of linear and nonlinear causal systems is mainly contributed in the chapter. The state observability and controllability properties are proven as the complete analysis of the system behavior. The chapter presents the state space energy and port-Hamiltonian approaches for modeling the physical systems using their energetic behavior and their internal interconnection structure.

The linearized Phillips-Heffron model of a parallel AC/DC power system for studying power system stability is described in "Power Systems Stability Analysis Based on Classical Techniques in Work". The chapter also presents the modeling of a Back-to-Back Voltage Source Converter (BtB VSC) HVDC to damp low frequency oscillations in a weakly connected system using Relative Gain Array (RGA), Singular Value Decomposition (SVD), and Damping Function (DF) as the supplementary controllers. The chapter shows that the SVD analysis evaluates the electromechanical controllability to enhance the dynamic stability of HVDC system via SVC supplementary controller. A UPFC-based linearized power system is also analyzed for increasing the dynamic stability and damping the load angle oscillations by adding an extra signal to its control loops. On-line adaptive controllers are also simulated to decrease rotor speed oscillations and identify power system parameters.

In "Optimal Design of UPFC Based Damping Controller Using PSO and QPSO", damping controller formulation is discussed based on the UPFC and using Classic and Quantum behaved Particle Swarm Optimization technique (CPSO, QPSO). The UPFC is advantageous as a FACTS device related to transient stability improvement, oscillation system mitigation and voltage support providing is also presented in the chapter considering the different objective functions in damping controller designing. The objective functions are related to the damping factor eigenvalues and time domain basis. The chapter shows the performance of controllers using eigenvalue analysis and nonlinear time domain simulation applied to the single machine infinite bus and multimachine power systems.

A review of the researches in the field of TNEP is described in "Application of PSO and GA for Transmission Network Expansion Planning" considering the effects of GA and PSO algorithms. The chapter introduces the TNEP as a large-scale and nonlinear combinatorial optimization problem to determine the number and location of new additional lines to transmission network. As the chapter description, mathematical principles based classic method like linear programming and Bender decomposition, and non-classic or heuristic methods like GAs can be applied for solution of complex problems. The ability to deal with non-convex, nonlinear, integer-mixed optimization problems like the STNEP problem has been demonstrated by global optimization techniques like GA as a random search method.

The control of Hybrid Power Sources (HPS) with some applications is analyzed in "Applications in Control of the Hybrid Power Systems". The chapter proposes an efficient fuel cell/battery HPS topology for high power applications which uses an inverter system directly powered from the appropriate Polymer Electrolyte Membrane Fuel Cell (PEMFC) stack. The chapter discusses about the FC HPS supply inverter systems and PEMFC current ripple in operation of the inverter system and the Low Frequency (LF) ripple mitigation based on the active nonlinear control in the fuel cell current ripple. The anti-ripple current generation and control in buck Controlled Current Source related to the output of the HPS is also reviewed. The chapter shows that good ripple performances related to the LF harmonics mitigation are also obtained with the hysteretic current-mode control as the better performances for nonlinear control. The control performances are also shown by simulations and the designed control law is validated using a Fuzzy Logic Controller (FLC). At the end of the chapter a nonlinear control for FC HPS based on bi-buck topology is proposed and analyzed in comparison with the FLC approach. The nonlinear voltage control to stabilize the HPS output voltage with a low voltage ripple is also analyzed, designed, and simulated.

The editors recommend this book as suitable for dedicated and general audiences that include the power system professionals, as well as researchers and developers of energy sectors and the electrical power engineering community. It is expected that readers will be graduates of energy and power engineering degree programs having a basic mathematical background.

As a whole, the book covers both theoretical background and application examples in hybrid power systems, and special and professional fields of electrical energy systems altogether. Because the subject approached in this book is vast in itself, it has been slightly difficult to balance the theoretical and applicative aspects in each of the chapters, so efforts of editors have been made to well cover the essential topics of the book. Specific in-depth further studies are pointed to the dedicated intensive resources of the book subjects for interested readers. Meanwhile, the application and study cases are possibly selected with as much real implications.

Finally, the editors hope that this book will be helpful to undergraduate and graduate students, researchers, and engineers, trying to solve energy and power engineering problems using modern technical and intelligent systems based on theoretical aspects and application case studies.

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