Preface

The modern electric power systems are more expanded worldwide and include more energy resources and critical parts based on the requirements of the twenty-first century. General parts of electric power systems as generation, transmission and consumption are important to be analyzed and well operated for the development of industry and life.

The engineers and scientists need applicable and renewable methods for analyzing and controlling each part of the electric power systems and to overcome complicated actions which occur in the systems due to their operational and interconnection behaviors. The objective of the analysis is minimizing the losses of the networks and increasing the overall efficiency and economic advantages.

The central and distributed generation of electric power networks connect to more loads, transmission lines, transformers and energy sources together including nonlinear equipment such as power semiconductor devices. The engineers and scientists are interested in analyzing the power systems operations to control and develop the AC/DC networks including high voltage transmission lines and equipment.

Flexible and fast power flow control and transmission are expected to raise the network effective operation, power wheeling requirement and transmission capability as well as voltage stability. Computational intelligence methods are applied to electric power analysis to facilitate the effective analysis techniques and solve several power system problems especially in power transmission and voltage stability.

Reactive Power Control in AC Power Systems: Fundamentals and Current Issues is a book aimed to highlight the reactive power control and voltage stability concepts and analysis to provide understanding on how they are affected by different criteria of available generations, transmissions and loads using different research methods.

A large number of specialists joined as authors of the book chapters to provide their potentially innovative solutions and research related to reactive power control and voltage stability, in order to be useful in developing new ways in electric power analysis, design and operational strategies. Several theoretical researches, case analysis, and practical implementation processes are put together in this book that aims to act as research and design guides to help graduates, postgraduates and researchers in electric power engineering and energy systems.

The book, which presents significant results obtained by leading professionals from industries, research and academic fields, can be useful to a variety of groups in specific areas. All works contributed to this book are new, previously unpublished material or extended version of published papers in the proceedings of international conferences and transactions on international journals. The book consists of 16 chapters in three parts.

Part I Fundamentals of Reactive Power in AC Power Systems

The six chapters in the first part of this book present the fundamentals of reactive power in AC power systems considering different operating cases. The topics in this part include the advanced methods and applications in electric power systems and networks related to the fields of fundamentals of reactive power in AC power systems, reactive power role in AC power transmission systems, reactive power compensation in energy transmission systems with sinusoidal and nonsinusoidal currents, reactive power importance in wind power plants, and fundamentals and contemporary issues of reactive power control in AC power systems.

Chapter 1 describes the general overview of electric power systems including power generation, transmission and distribution systems, linear AC circuits in steady state conditions, flow of power between generator and customers is studied by using the active, reactive, apparent and complex power, electric power system quality, measurement and instrumentation methods of power systems parameters, and general standards in energy generation, transmission and marketing. The importance of reactive power in AC power systems and its various interpretations are also discussed in this chapter.

The basic theory of AC circuits, behavior of two-port linear elements and analysis methods of AC circuits are given in Chap. 2. The physical interpretation of electric powers in AC power systems, fundamental problems of reactive power consumption automated management in power systems, equipment for power factor correction, designing simple systems for compensating of reactive power for different levels of installation, the overall harmonic distortion of voltage and current, and qualitative and quantitative aspects related to active and reactive power circulation in AC power systems including several examples and case studies referring to classical linear AC circuits under sinusoidal and nonsinusoidal conditions are also the topics of this chapter.

Chapter 3 presents basic principles of power transmission operation, equipment for reactive power generation, shunt/series compensation, control of reactive power in power transmission system. The chapter describes the capacitive and inductive properties of power transmission lines and also reactive power consumption by transmission lines which increases with the square of current. The chapter states the sources, effects and limitations of the reactive power and flowing in transmission lines and transformers as well as control of reactive power should satisfy the bus voltages, system stability and network losses in the power systems.

The definition of reactive power under nonsinusoidal conditions in nonlinear electric power systems is described in Chap. 4. This chapter discusses and simulates the reactive power compensation for sinusoidal and nonsinusoidal situations, where nonlinear circuit voltages and currents contain harmonics and also the control algorithms of automatic compensators. The main aim of the chapter is based on the dissipative systems and cyclodissipativity theories for calculation of compensation elements for reactive power compensation by minimizing line losses. The chapter is also including the examples and computer simulations to show the mathematical framework for analyzing and designing of compensators for reactive power compensation in general nonlinear loads.

Chapter 5 deals with the rate of reactive power absorption or injected by the wind units and also the key role of reactive power generation and consumption in large-scale wind farms. The chapter describes requirements of reactive power compensation, voltage stability and also power quality improvement in the electric grid of wind turbine to reduce the power losses and control of voltage level. The units of wind turbines of types 1 to 4 are also categorized and discussed in the chapter considering their construction, generation, converters, reactive power and voltage control abilities. The coordination related to reactive power adjustment in the wind turbines is also discussed in this chapter.

The concept of power quality and voltage stability improvement based on the reactive power control is introduced in Chap. 6. The chapter describes the impact of reactive power flow in the power system and defines the power components of electrical equipment that produces or absorbs reactive power. Then the reactive power control and relations between reactive power and voltage stability are presented. The chapter also contains reactive power control methods for voltage stability and presents voltage control management based on case studies.

Part II Compensation and Reactive Power Optimization in AC Power Systems

The second part of this book tries to highlight in six chapters the concepts of reactive power optimization and compensation. The topics in this part include optimal reactive power control for voltage stability improvement, reactive power compensation, optimal placement of reactive power compensators, reactive power optimization in classic methods and also using MATLAB and DIgSILENT, and multi-objective optimal reactive power dispatch.

Chapter 7 is entirely focused on the voltage stability control using three main techniques of reactive power management, active power re-dispatch, and load shedding. The chapter discusses about determining the location of VAR sources and their setting and installation, online and offline reactive power dispatch, and optimal reactive power flow (ORPF). The reactive power flow and voltage magnitudes of generator buses, shunt capacitors/reactors, output of static reactive power compensators, transformer tap-settings are considered as the control parameters and are used for minimizing the active power loss and improving of the voltage profile in ORPF. This chapter also confers the reactive power dispatch as a nonlinear and nonconvex problem with equality and inequality constraints.

The reactive power compensators based on advanced industrial applications are highlighted in Chap. 8. The basic theoretical background of reactive power compensation as well as conventional compensators and improved FACTS are introduced in the chapter. The compensation devices including shunt, series and shunt-series configurations for transmission lines regarding their characteristics and also analytical expressions are presented in the chapter. The power flow control, voltage and current modifications as well as stability issues are also analyzed and compared for similar compensation devices and emerging technologies.

Chapter 9 provides a framework and versatile approach to develop a multi-objective reactive power planning (RPP) strategy for coordinated handling of reactive power from FACTS devices and capacitor banks. This chapter deals with power system operators for determining the optimal placement of FACTS devices and capacitor banks should be injected in the network to improve simultaneously the voltage stability, active power losses and cost of VAR injection. A formulation and solution method for reactive power planning, and voltage stability based on cost functions are also presented in the chapter.

Chapter 10 presents the reactive power optimization using artificial optimization algorithms as well as the formulations and constraints to implement reactive power optimization. The classic method of reactive power optimization and basic principles and problem formulation of reactive power optimization using artificial intelligent algorithms are discussed in the chapter. In addition, this chapter focuses on the particle swarm optimization algorithm and pattern search method application in reactive power optimization including the case studies.

The efficient approach using parallel working of MATLAB and DIgSILENT software with the intention of reactive power optimization is discussed in Chap. 11. This chapter presents the toolboxes, functions and flexibility powers of MATLAB and DIgSILENT in electrical engineering calculation and implementation. Also it provides the advantages of parallel calculations of MATLAB and DIgSILENT and relation of two software to carry out the heuristic algorithms as fast, simple and accurate as possible to optimize reactive power in AC power systems.

In Chap. 12, the reactive power compensation devices are modeled using deterministic multi-objective optimal reactive power dispatch (DMO-ORPD) and two-stage stochastic multi-objective optimal reactive power dispatch (SMO-ORPD) in discrete and continuous studies. They are formulated as mixed integer nonlinear program (MINLP) problems, and solved by general algebraic modeling system (GAMS). A case study for evaluation of the performance of different proposed MO-ORPD models is also shown in the chapter. This chapter presents the MO-ORPD problem taking into account different operational constraints such as bus voltage limits, power flow limits of branches, limits of generators voltages, transformers tap ratios and the amount of available reactive power compensation at the weak buses.

Part III Challenges, Solutions and Applications in AC Power Systems

The final part of this book consists of four chapters and considers some applications and case studies in AC power systems related to the issues of active and reactive power concepts. The topics in this part include self-excited induction generator, communications for electric power systems, SCADA applications for electric power systems and effect of geomagnetic storms on electrical networks.

Chapter 13 discusses about a three-phase self-excited induction generator in an autonomous power generation mode. The chapter presents generator operating points and control strategies to maintain the frequency at quasi-constant values and to use it as power converter such as a simple dimmer to control the reactive power. The frequency analysis in steady state and transient cases is studied in this chapter using a single-phase equivalent circuit as well as theoretical and numerical results are also validated on a laboratory test bench.

Chapter 14 describes communications applied for electric power systems including communication standards and infrastructure requirements for smart grids. The chapter presents three primary functions of smart grids to accomplish in real time requests of both consumers and suppliers based on communications technologies. The most usual communication systems including fiber optic communication, digital subscriber line/loop, power line communications, and wireless technologies for using the power system control for smart grids architecture are highlighted in the chapter. The case studies related to communication systems of electric power system are also carried out in this chapter.

The SCADA systems and applications in electric power networks are studied in Chap. 15. The chapter explains the role and theory of SADA systems, security, real-time control and data exchange between remote units and central units. The SCADA systems are also applied for optimization and realization of reactive power in AC power systems. Some disadvantages of dispatching systems such as graphical information and interface are explained in the chapter and the rules of improving them are also carried out. The flexibility designing of the systems for small and large networks are also explained.

Chapter 16 introduces the effect of geomagnetic fields called as storms on electric power systems. This chapter discusses about the physical nature of earth's magnetic field and its measurements in geomagnetic observatories and shows that the variation of geomagnetic field affect the operation of various distracting electronic devices, such as electrical transmission systems. An algorithm for calculating induced currents in the power transmission lines and also the violation of stability of the system considering the illustrative example are also derived in this chapter.

The editors recommend this book as suitable for an audience professional in electric power systems, as well as researchers and developers in the field of energy and power engineering. It is anticipated that the readers have sufficient knowledge in electric power engineering and also advanced mathematical background.

In total, the book includes theoretical background and case studies in reactive electric power and voltage stability concepts. The editors have made efforts to cover the essential topics of reactive electric power to balance theoretical and applicative aspects in the chapters of this book. The book has been written by a team of researchers from which use the dedicated intensive resources for achieving certain mental attitudes for interested readers. At the same time, the application and case studies are intended for real understanding and operation.

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

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