

Preface

This book aims to provide wider knowledge to researchers, engineers, postgraduates and policymakers in research and development in the area of smart grids and integration of renewable energy systems. The operating paradigms of traditional power grids are advancing towards smarter operations to face the current and future challenges and to supply electricity to consumers in a smart grid environment. Power systems are stressed to accommodate increased volumes of renewable power generation with limited resource corridors. With the developments of smart grids, information on the frequency, magnitude and duration of the occurrence of the future power system load demand is expected to be widely available with advances in the forecasting, smart metering and control techniques. The increased accommodation of smart appliances and the autonomous operation of power plants may increase efficiency; however, the security of supply at major power and cyber network incidents may not necessarily be limited due to interaction of highly intelligent systems within a power system environment, owing to the increased risk of restoration process of power supply following large system disturbances and cyber security threats. Thus, it is vital to understand the past, present and anticipated future of power system developments, challenges and needs in order to effectively address planning and operational needs of a smart grid environment. This book attempts to give a solid framework surrounding these problems, research challenges, current and anticipated developments, and the regulatory frameworks through in-depth explorations and case studies. The book covers these aspects through ten chapters.

Chapter “[Fundamentals of Power Systems](#)” presents the history, evolution and fundamental analysis frameworks of a power system. Power systems started modestly as small-scale DC systems. As the dependence on electricity increased, the complexity and demands placed on electricity have also increased. The chapter starts with a description of the history of power systems and then describes the major events that have shaped the modern power industry. A description of basic power system components are presented along with analysis techniques such as

load flow, optimal dispatch and transient stability. The chapter fundamentals will aid in better understanding of the remaining chapters.

Chapter “[Modelling and Simulation of Power Systems](#)” presents major modelling and simulation techniques used in power systems research. As smart grids will be a journey through the modern power system environment, it is vital to know how these models and techniques are applied in a traditional power grid environment and how they can make advances to realize smart grid objectives. The chapter particularly addresses optimization techniques applied in power systems research, is extended to incorporate stochastic elements, and ends with a brief exploration into the Monte Carlo simulation-based research.

Chapter “[Micro Grid Planning and Operation](#)” investigates specific challenges in a micro grid, planning and operation, control strategies and case studies of micro grids. A micro grid is a smaller entity that can intelligently control and coordinate distributed energy resources with the support of intelligent controllers and other necessary architectures. However, achieving such objectives that lead to smart operation require significant advances to planning and operation of the micro grids as their collective operation can potentially provide business cases. Roles of micro grids include improving reliability, resilience and security at normal and emergency operating conditions of the utility power grid. Each mode of operation presents challenges such as frequency control in an islanded mode and voltage control in a utility grid connected mode.

Chapter “[A Preliminary Study on Conversion Efficiency Improvement of a Multi-junction PV Cell with MPPT](#)” presents a preliminary study conducted to improve photovoltaic cell conversion efficiency using MATLAB/Simulink platform. The study uses multijunction solar cell and investigates the maximum performance compared with the conventional silicon PV cell. Maximum Power Point Tracker is applied to assess the conversion efficiency of the PV system. The study integrates thermoelectric generator with PV cells, as these work by converting high frequency irradiation, whereas a thermoelectric generator has the ability to convert wasted low frequency heat into electricity. The combination drives to enhance energy efficiency.

Chapter “[Grid Integration of Renewable Energy Systems](#)” explores the technical and regulatory framework, planning and operation challenges, and the roles of balancing technologies in the context of grid integration of renewable energy systems. There are short-term operational challenges as well as long-term planning challenges due to the presence of intermittent power generation. The chapter also investigates the optimal technical and regulatory framework that can effectively manage the short- and long-term challenges with large-scale renewable power penetration. Operational challenges addressed in the chapter include the maintenance of frequency and voltage stability due to intermittency of power generation and network congestion. Planning challenges included long-term capacity credit allocation of wind and solar power generation.

Chapter “[Technical Challenges, Security and Risk in Grid Integration of Renewable Energy](#)” focuses on technical challenges associated with the grid integration of renewable energy systems. PV power generation is typically integrated at

the power distribution system level, while wind power can also be integrated in the power transmission system level depending on the level of power generation. Utilities around the world are discussing and conducting feasibility studies of 100 % renewable energy-based power systems. Although a very high penetration level of renewable energy looks plausible, the technical challenges associated with them could be a hindrance to seamless integration. This chapter also highlights security concerns and associated risks, which are categorized in this chapter as technical and non-technical issues. At the end of the chapter, the way forward for renewable energy integration in a power system is also summarized.

Chapter “[Dynamic Modelling, Simulation and Control of a Commercial Building Microgrid](#)” presents the dynamic modelling of a commercial building micro grid system and conducts stability analysis of the micro grid under various operating conditions. Commercial building micro grids depict unique characteristics due to generation mix and various types of loads connected at the commercial building installations. Therefore, these micro grids require distinct consideration during the operation and control stages. Thus, the chapter addresses these aspects in detail and uniquely distributes the dynamic models of a micro grid for researchers in this area to investigate the operational performance and control techniques before the control schemes are implemented in the micro grid system.

Chapter “[Probabilistic Methods Applied in Power and Smart Grids](#)” presents an investigation into the probabilistic methods applied in power and smart grids. The chapter explores the existing probabilistic methods in traditional power grids and then looks at the extended framework for the smart grid environment. In a stochastic-natured and increasingly uncertain smart grid environment, probabilistic methods have been applied in a growing number of research areas, and have shown their increasing importance for handling the uncertainties involved in system stability, reliability, forecasting, and optimization. The chapter also extends to cover the need for tools and techniques to manage novel risks and uncertainties in smart grids.

Chapter “[Planning and Operational Challenges in a Smart Grid](#)” presents smart grid challenges in particular in the context of planning and operation. Smart grid is a pathway to achieve smarter objectives, thus one can expect a significant number of challenges that should be addressed throughout the journey. The chapter at first gives the reader an introduction to planning and operation in a traditional power grid environment and then explores the added needs for smart grids to achieve their objectives. It comprehensively covers generation, transmission, and distribution system planning and operation prior to embarking into each stream of smart grid planning and operation. As the key success of a smart grid will be the cyber network operation, its challenges in terms of integration with the physical power system and interoperability are discussed. The chapter explores load forecasting in a smart grid context in detail as the detailed knowledge of load at the smart grid customers is vital in planning and operation of the smart grid. The chapter ends with a discussion of the potential interaction of a smart power grid with other smarter networks and the need for cross-disciplinary research.

Chapter “[Applied Research in Energy Storage](#)” presents applied research in the area of energy storage. The development and incorporation of energy storage into large electricity networks, micro-grids and partially or fully islanded energy supplies have numerous applications as the sustainable energy generation uptake increases. The notions of sustainable energy supplies are driving energy storage in two distinct directions. First, there will be large-scale energy storage such as pumped land or sea-based hydro-energy that can absorb excess renewable energy for later discharge when there is a deficit in dispatchable energy available. As an alternative to such large industrial scale units, there is also potential to develop smaller but numerous distributed smaller energy storage systems that are based on inertial or electrochemical battery storage. These developments present huge opportunities to change the way the sustainable energy uptake continues. The chapter also briefly looks into the interdisciplinary research on energy storage in other potential areas.

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