Smart Grid

Applications, Communications, and Security

Edited by

Lars T. Berger and Krzysztof Iniewski

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PREFACE

Today's power grid is a system that supports electricity generation, transmission, and distribution operations. It is composed of a few central generation stations and electromechanical power delivery systems operated from control centers. Power flows mainly from the central stations toward the medium and low voltage customers. One prerequisite for grid stability is the balance between energy consumption and generation. Presently, energy generation follows the time variant consumption. With the increasing integration of renewable energy generation facilities, for example, utilizing solar and wind power, the energy flow is in some cases reversed. Energy may flow from the customer into the grid, leading to a more complex grid structure. Besides, many renewable resources reveal an intermittent and unpredictable nature of energy supply. This makes their integration a challenging task and requires an upgrade to the aging electricity infrastructure.

Fostered by growing governmental support, it is expected that the world's energy infrastructure will undergo a major transformation in the coming decade. This transformation is commonly referred to as *Smart Grid*. The evolving Smart Grid combines the electrical power infrastructure with modern distributed computing facilities and communication networks. It is a collection of complex, interdependent systems whose key functions include *reliable and efficient power delivery* facilitated through wide-area situational awareness, *peak energy curtailment* through demand response schemes, *widespread integration of intermittent renewable energy resources* through real-time control and energy storage, and the shift from a largely fossil fuel driven transport system to *electric transportation*.

One important concept within the Smart Grid is *demand response* (DR). It allows managing electricity consumption in response to supply conditions and electricity demand. To enable DR a remote *advanced metering infrastructure* (AMI) is currently being implemented in various locations worldwide. At the heart of AMI are smart meters, which are among others capable of measuring and recording usage data in real time. The smart meters have bidirectional communication links to the utility's central server. This allows transmission of the recorded metering data, and the reception of configuration as well as energy pricing information from the utility. Communication can be established using an IP access network, over digital subscriber line, power line, or wireless network infrastructure. A common flavor of DR schemes counts on household appliances, such as refrigerators or air conditioning units that are informed in real time about the energy price. Dependent on the user's choice, these household appliances could respond to a price increase through a reduction of power usage. Recent studies on DR and the tightly related concept of time-of-use pricing reveal that energy cost awareness alone can lead to changing habits and therewith to a reduction of energy usage on the order of 14%. Dynamic pricing may also be used to prevent transmission and distribution network bottlenecks. This postpones upgrading costs and decreases the risk of grid instabilities.

Furthermore, it is largely believed that *plug-in electric vehicles* (PEVs) will form an important part of the Smart Grid. On the one hand, charging periods can, to a certain degree, be scheduled to times of abundant electricity availability. On the other hand, on-board batteries can be used to administer electricity to the grid in periods of high demand or low production.

This book gives a profound introduction to the various aspects of Smart Grids that have already started to influence many areas of our lives. It contains four major parts: *Applications*, *Communications*, *Security*, and *Cases Studies and Field Trials*.

In Part I, it starts out with a detailed introduction to Smart Grid applications, spanning the transmission, distribution, and customer side of the electricity grid. Issues like fault detection, isolation and restoration, wide area monitoring protection and control, as well as demand response/demand side energy management, and the integration of plug-in electric vehicles are discussed, to name a few.

In general, grids become smart as electrical devices are empowered to collect and exchange information. Advances in communication technology are key. Wireless, wireline, and optical communication solutions are discussed in Part II from the physical layers up to sensing, automation, and control protocols running on the application layers.

Due to the immense importance of the electricity supply in our everyday lives, it is crucial that Smart Grids are at least as reliable as the energy grids we know today. Smart Grid security has therefore to penetrate every aspect of Smart Grid deployments preventing nonintentional faults, like instabilities and natural disasters, as well as intentional faults (e.g, due to cyber attacks). Part III deals with cyber security, raising awareness of security threats, reviewing ongoing cyber security standardization, and presenting methods for authentication and encryption key management.

The book is rounded-off with Part IV, presenting self-contained chapters on Smart Grid case studies and field trials. These chapters allow the reader to benefit from lessons learned in situations where the Smart Grid of tomorrow has already become a reality.

Not only the Case Study and Field Trial chapters, but all chapters are written as far as possible in a self-contained manor. Additionally, chapters are cross-referenced, allowing each reader to encounter a personal reading path. We hope you enjoy the diverse and rich contents contributed by experts from industry and academia, making this book one of the first of its kind in the world of the Smart Grid.

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