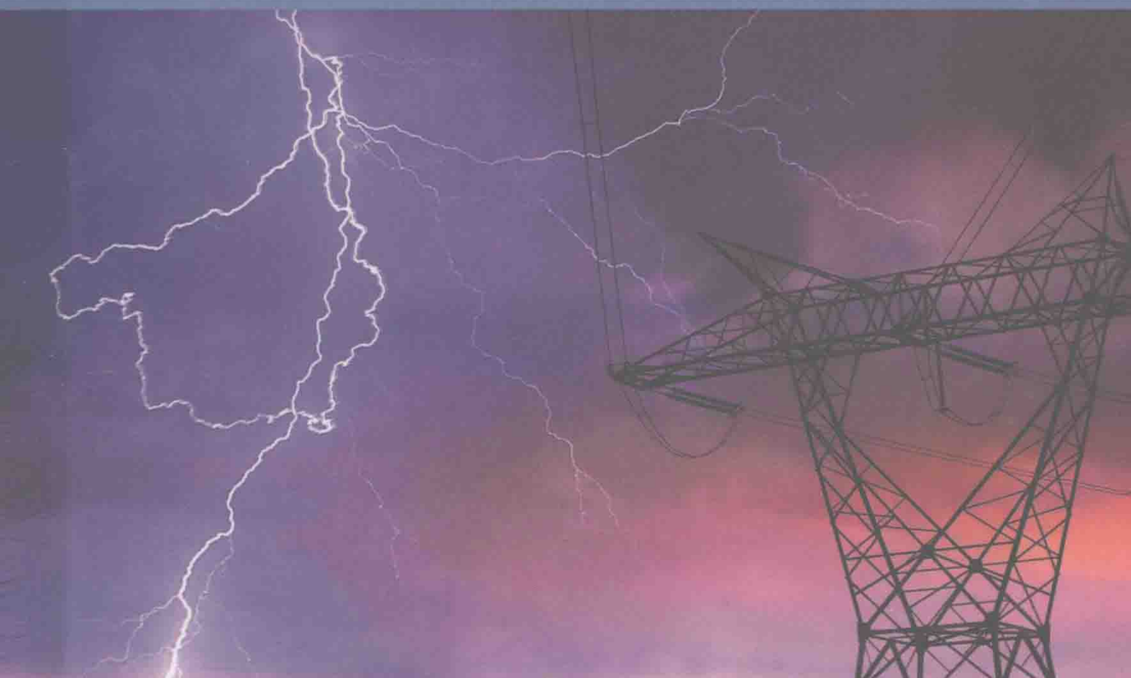
Communication and Networking in Smart Grids



Edited by Yang Xiao

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Preface

Smart grids are an integration of power delivery systems with communication networks and information technology (IT) to provide better services. Communication and networking will provide significant roles in building future smart grids. The purpose of this book is to provide state-of-the-art approaches and novel technologies for communication networks in smart grids, covering a range of topics in the areas, making it an excellent reference book for students, researchers, and engineers in these areas.

This book investigates fundamental aspects and applications of smart grids, its communications, and networks. It presents a collection of recent advances in these areas. Many prominent researchers working on smart grids and related fields around the world have contributed to this work. The book contains 12 chapters, that are divided into two parts: "Smart Grids in General" and "Communications and Networks in Smart Grids." We believe this book will be a solid reference tool for researchers, practitioners, and students who are interested in the research, development, design, and implementation of smart grid communications and networks.

This book was made possible by the great efforts of our contributors and publishers. We are indebted to our contributors, who have sacrificed their valuable time to put together these chapters for our readers. We thank our publisher Taylor & Francis—without their encouragement and quality work, this book would not be possible.

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About the Editor

Dr. Yang Xiao worked in industry as a medium access control (MAC) architect involving IEEE 802.11 standard enhancement work before he joined the Department of Computer Science at the University of Memphis in 2002. He is currently a tenured professor in the Department of Computer Science at the University of Alabama. He was a voting member of IEEE 802.11 working group from 2001 to 2004, and is currently an IEEE senior member. He serves as a panelist for the U.S. National Science Foundation (NSF), Canada Foundation for Innovation's (CFI) Telecommunications expert committee, and the American Institute of Biological Sciences (AIBS), as well as a referee/reviewer for many national and international funding agencies. His areas of research are security, communications/networks, robotics, and telemedicine. He has published more than 180 refereed journal papers and over 200 refereed conference papers and book chapters related to these research areas. Dr. Xiao's research has been supported by the U.S. National Science Foundation (NSF), U.S. Army Research, Global Environment for Network Innovations (GENI), Fleet Industrial Supply Center–San Diego (FISCSD), FIATECH, and the University of Alabama's Research Grants Committee. He currently serves as editor-in-chief for the *International Journal of Security and Networks* (*IJSN*) and the *International Journal of Sensor Networks* (*IJSNet*). He was the founding editor-in-chief for the *International Journal of Telemedicine and Applications* (*IJTA*) (2007–2009).

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SMART GRIDS IN GENERAL

I

Chapter 1

Smart Grids

Autumn Nicole Smith and Yang Xiao

Contents

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Our current grid system is quickly becoming obsolete. This grid system will not be able to meet our future electricity demands. New efficient technology must be introduced to solve this problem. One solution to this problem is smart grid. Smart grids will be able to efficiently handle our increasing energy demands and reduce the environmental impact by incorporating renewable resources. In this chapter, we will discuss why smart grids are vital to our future, the different types of new technology that they are comprised of, the current advancements, and research that is being conducted.

1.1 Introduction

The North American power grid has made few advances in the past century. The current grid is unable to meet the growing demand for energy. Grid congestion and congested transmission lines are becoming more frequent across the country. These issues can be addressed by implementing smart grid technology. Smart grids will be able to monitor and control the flow of electricity in real time. Smart grids will apply our new developments in information management and automation technology to the existing grid. They will also offer more control and be able to process more information, which will provide many benefits to consumers. These smart grids would provide a more efficient, reliable, environmentally friendly, and secure alternative to our current grid system.

1.1.1 Efficiency and Reliability

Our current grid system is unable to efficiently supply the energy needed by our country. Heavily populated areas in the United States are often plagued with blackouts and congested transmission lines, also known as *bottlenecks*. The U.S. Department of Energy reports that these power disturbances and outages cost the country "from $25 to 180 million" every year [1]. With an ever-increasing population and advancements in technology, there is a greater demand for a more resourceful and reliable power grid. The energy consumption rate has risen from 10% in 1940 to 40% in 2003 [1]. These increasing failures of our current grid come at a time when the demand for electricity is the highest. In the past decade, our society has been increasingly digitalized. We are more dependent on electricity than ever before. There is a rapidly growing market of technologies that rely on electricity. Just as communication has evolved with technologies such as the Internet and wireless cell phones, our power grid must also evolve. Our current grid will have to evolve quickly to combat the changes that are taking place in our increasingly digital society. Smart grids will be able to monitor energy usage in real time and predict outages and equipment failures.

A smart grid will be able to restore itself after a blackout or a weather-related outage.

1.1.2 Environmental Benefits

Our aging grid relies heavily on dwindling fossil energy resources. The cost of natural gas, coal, and oil is rising steadily. Oil, specifically, has seen a sharp price increase. Prices for oil have increased 800% from 1998 to 2008 [2]. Using these fossil fuels to supply energy to our country also contributes to our growing climate change problem. A cleaner alternative to fossil fuels is needed, and one can be implemented by using our readily available renewable resources. These resources reduce the amount of pollution being expelled into the atmosphere. Wind and solar energy production sites are being placed in remote locations and even offshore. Transporting electricity over long distances, thus far, has proved to be inefficient. Smart grids will be able to efficiently transport energy over vast distances, and therefore utilize the energy from distant renewable resources.

Recently, President Barack Obama has addressed our current energy and environmental issues [3]. In his energy plan, he calls for $3.4 billion of federal stimulus funds to be invested to modernize our current grid system by specifically using smart grids [3]. This investment will serve as a downpayment on our future grid system. President Obama is also an advocate of smart metering and has made it a point to invest in smart meter technology for American homes.

1.1.3 Benefits to Consumers

Smart grids will also help consumers save money. Consumers will be able to monitor their home usage by using smart meters. This will encourage consumers to use less energy and will reduce the amount of overall energy needed by the grid. Using less energy at times of peak demand saves money for the consumer. This is because energy produced in periods of high demand costs more to produce than energy produced in times of low demand. Consumers will actively help balance supply and demand and increase reliability by changing the way they use and purchase electricity. Allowing consumers to see the real-time price of electricity will make them more conscious of their usage. Reducing the demand for energy needed from the grid also reduces the amount of pollution being created. Many jobs will be created during both the production (i.e., planning and construction) and postproduction (i.e., maintenance, development, etc.) stages.

Smart grids will be compatible with electric vehicles. Smart grids will be able to use electric cars as energy storage by drawing power from the charging cars when demand is peaking. Thousands of electric cars charging in the grid will decrease the amount of backup power needed and help control peak load leveling. Consumers will be able charge their cars during off-peak times and therefore receive the cheapest energy possible.

1.1.4 Security

Our current grid is susceptible to attacks and natural disasters. Smart grids will use a large number of smaller, widely distributed plants instead of a few high-producing plants. This decentralization of the grid will help it become more secure. If such an attack or disaster occurs, the smart grid will be able to restore itself quickly. This is referred to as a self-healing network. Smart grids will able to isolate problems on the line and reroute the power supply. This will be done by using intelligent switches. These intelligent networks will be able to combat the "domino effect" that is a risk for our current grids. They will be able to stop, start, or reroute the energy. This will ensure that the greatest number of customers receive the energy that they require. The smart grid is a fiscally sound proposition because it will be interconnected to Canada and Mexico, and therefore increase and improve the economic relations with these countries.

1.2 Technical Aspects

Smart grids will rely on several different technologies. These new technologies will combine with the existing grid to create a more efficient and intelligent grid system. Most of these technologies are already available and are being used in other areas. Smart grids will use integrated two-way communications, superior control and monitoring techniques, advanced components, energy storage, improved interfaces, and decision support to operate.

1.2.1 Two-Way Communications

Smart grids will rely greatly on two-way communications. These communications include advanced metering infrastructure (AMI). AMI is a vital component to the implementation of the smart grid. AMI is a system that involves two-way communication with smart meters and other smart devices. AMI will benefit both consumers and electric companies. AMI will allow utilities to provide real-time pricing information to consumers. AMI will also allow utilities to react more quickly to potential power issues. Consumers will be able to reduce their usage when prices are high. AMI will allow electric companies to communicate directly with the smart devices. Electric companies will be able to reduce the power being used by these devices during peak periods, depending on the preference of the