Preface

The book arises from the conviction that it is necessary to re-think the basic philosophy governing the electricity distribution systems. In the authors' opinion there is a need to exploit fully the potential advantages of renewable energy sources, distributed generation, energy storage and other factors which should not only be connected but also fully integrated into the system to increase the efficiency, flexibility, safety, reliability and quality of the electricity and networks. Transformation of the current electricity grids into a smart (resilient, interactive *etc.*) network necessitates the development, propagation and demonstration of key cost effective technologies enabling (*e.g.*, innovative interconnection solutions, storage technologies for renewable energy sources, power electronics, communications *etc.*). On the basis of the above, the major aim of this book is to present the features, solutions and applications of the power electronics arrangements likely to be useful in future smart electrical energy networks.

The first part of this book introduces the structure and fundamental problems of the current electricity grids together with the concept of smart electrical energy networks.

Next there is a critical overview of power theories, mainly under non-sinusoidal conditions in single-phase and three-phase systems, in both time and frequency domains. The basic criterion for the choice of the discussed theories is historical development of knowledge in this field and the usefulness of power theory in solving practical problems: reactive power compensation, balancing the supply network load and mitigation of voltage and current distortion. Particular attention is given to the theories defining the current components in the time domain as the basis for present-day interconnection, active compensation and filtering systems. The content of this part is essential for understanding both the principle of operation and the control algorithms of the majority of the currently used power quality improvement and interconnecting systems.

Additionally, in this part an overview of control methods in power systems with the focus on damping of electromechanical oscillations and mitigation of power quality problems is presented. The focus is on power systems with increased levels of uncertainty resulting from deregulation of theelectrical power industry and the presence of non-conventional types of generation (renewable energy sources and distributed generation). The issue of finding the best techno-economical solution for the problems is also briefly mentioned. The focus in thepower quality section is on probabilistic modelling of disturbances and their consequences.

In the next part of the book the main emphasis is on low, medium, and high power conversion issues and the power electronic converters that process power for a variety of applications in smart grids. Following recent trends in power electronics technology, greater stress is placed on modern power electronic converters, such as resonant and multi-level inverters or matrix converters, and these are thoroughly covered. Special features include in-depth discussions of all power conversion types: AC/DC, AC/AC, DC/DC, and DC/AC.

After that, both the relationships and the differences between electrical power quality and electromagnetic compatibility are explained and definitions of these notions are provided. The principles of standardization in both fields are also be discussed. The power quality survey is a useful procedure for identifying and resolving power-related equipment or facility problems. It is an organized, systematic approach to problem solving. If all the steps for a power quality survey are completed, information is obtained that either identifies a solution to a power-related problem or reveals that the problem is not related to the electrical power system.

After that, EMC related problems in smart electrical power systems as well as some EMC regulations are overviewed. Special attention is paid to the origin and the spreading of the conducted EMI over power systems containing power converters. This is true because the diversity of power converters makes difficult the general analysis of the EMI spectra. However, there are some common features which can be derived from typical applications and layouts of the systems with power converters. Specific key aspects of electromagnetic compatibility in power electronics are presented, such as a typical role of power converters and their place in the smart power system, a typical frequency range of generated EMI noises, specific features of the common mode source in three-phase power converter systems and traveling wave phenomena. This part gives a detailed analysis based on the authors' own experimental results in the systems with converters that are common in smart power systems.

The next part of the book introduces high frequency AC power distribution systems as relatively new and promising developments in the field of electric power. Compared with low frequency or DC link power systems, the high frequency system offers many key advantages including system compactness due to small filtering and transforming components, better power quality, freedom from acoustic noise and mechanical resonance. In addition, it is particularly conducive to the distributed and amalgamated structures of future power systems, which are likely to converge with the information superhighways. Also described are the motivations and performances of the earliest high frequency systems used in telecommunications and NASA's Space Station, and to those more recently introduced in the fields of electric vehicles, micro-grids and renewable energies. Additionally there is discussion of the many potential benefits these systems can offer in shaping the future electric power infrastructure, and also the challenges that need to be overcome.

Next addresed are the technical considerations for interconnecting distributed generation equipment with conventional electric utility systems. This discussion arises from the fact that most electric distribution systems are designed, protected, and operated on the premise of being a single source of electric potential on each distribution feeder at any given time. Distributed generation violates this fundamental assumption, and therefore special requirements for connecting to the utility distribution grid are critical to ensure safe and reliable operation. Manufacturers, vendors, and end-users often see distributeed generation interconnection requirements as a huge market barrier, whereas utility engineers consider them to be absolutely necessary. Thus tools to help assess practical interconnection for specific projects and equipment are provided; we also create a clearinghouse for the many ongoing domestic and international efforts to develop uniform standards for interconnection.

After that, the next part of this book is targeted at known electric energy storage systems as well as development of methodologies and tools for assessing the economic value and the strategic aspects of storage systems integrated into electricity grids. Such tools should be ble to evaluate and analyse energy storage solutions in a variety of applications, such as integration of distributed/renewable energy resources, reduction of peak loading, improvement of transmission grid stability and reliability. Additionally, electricity storage is presented as a strategic enabling technology which not only reduces costs and increases the efficient use of grid assets, but is key for accelerating the integration of distributed generation and renewable sources of energy.

The next part of our book deals with grid integration of wind energy systems. The focus of this topic is on the electrical side of wind conversion systems. After a short description of the basics, such as energy conversion, power limitation and speed control ranges, the existing generator types in wind energy conversion system are described. Because of the practical problems arising with wind turbine installations, their grid integration is an interesting field, whereas the characteristics of wind energy conversion itself, the common types of grid coupling and resulting wind park designs are discussed. On the point of common coupling, wind energy generation may produce distortions of the grid, *e.g.*, flicker effects and harmonics. The causes of their generation, superposition and mitigation are described in detail. Existing standards and the requirements of the transmission system operators are also discussed from the point of view of the conversion system.

Because of limited onshore areas for wind energy systems in Europe, powerful wind parks can be installed only at selected places. A solution of this problem is offshore technology which, due to better wind conditions, brings higher energy yields, but also a lot of additional requirements for the installation and operation of the wind turbines. This includes a special generator design necessitated by the salty environment and different possibilities for the wind park structure, which has internal fixed or free adjustable parameters such as frequency, voltage range and transmission type. The external energy transmission to the onshore substation can be realized with different system configurations. Their advantages and disadvantages are explained.

The next part of the book describes grid integration of photovoltaic systems and fuel cell systems. First the cell types and their efficiency and place requirement are explained. The focus lies on grid-connected photovoltaics, mainly their plant design and grid interfacing of systems depending on isolation conditions, and the possible use of different components is a topic of current interest. Power quality becomes an important issue if higher unit powers are installed. Special problems arising from common connection at the low voltage level are discussed. Derived from the existing devices and their assigned problems in the grid, possibilities for future development are presented.

Fuel cells, photovoltaic systems, generate DC voltage and need a power electronic conversion unit for their grid connection. The different types of fuel cells and their typical applications are described. But the focus lies on plant design, grid interfacing and future development. At the moment only a few fuel cell applications exist. The big potential of this technology may lead to large installation numbers within the next five years. Existing standards of this technology are listed to assist the understanding of this technology.

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January 2008

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http://www.springer.com/978-1-84800-317-0

Power Electronics in Smart Electrical Energy Networks
Strzelecki, R.M. (Ed.)
2008, XVIII, 414 p., Hardcover
ISBN: 978-1-84800-317-0