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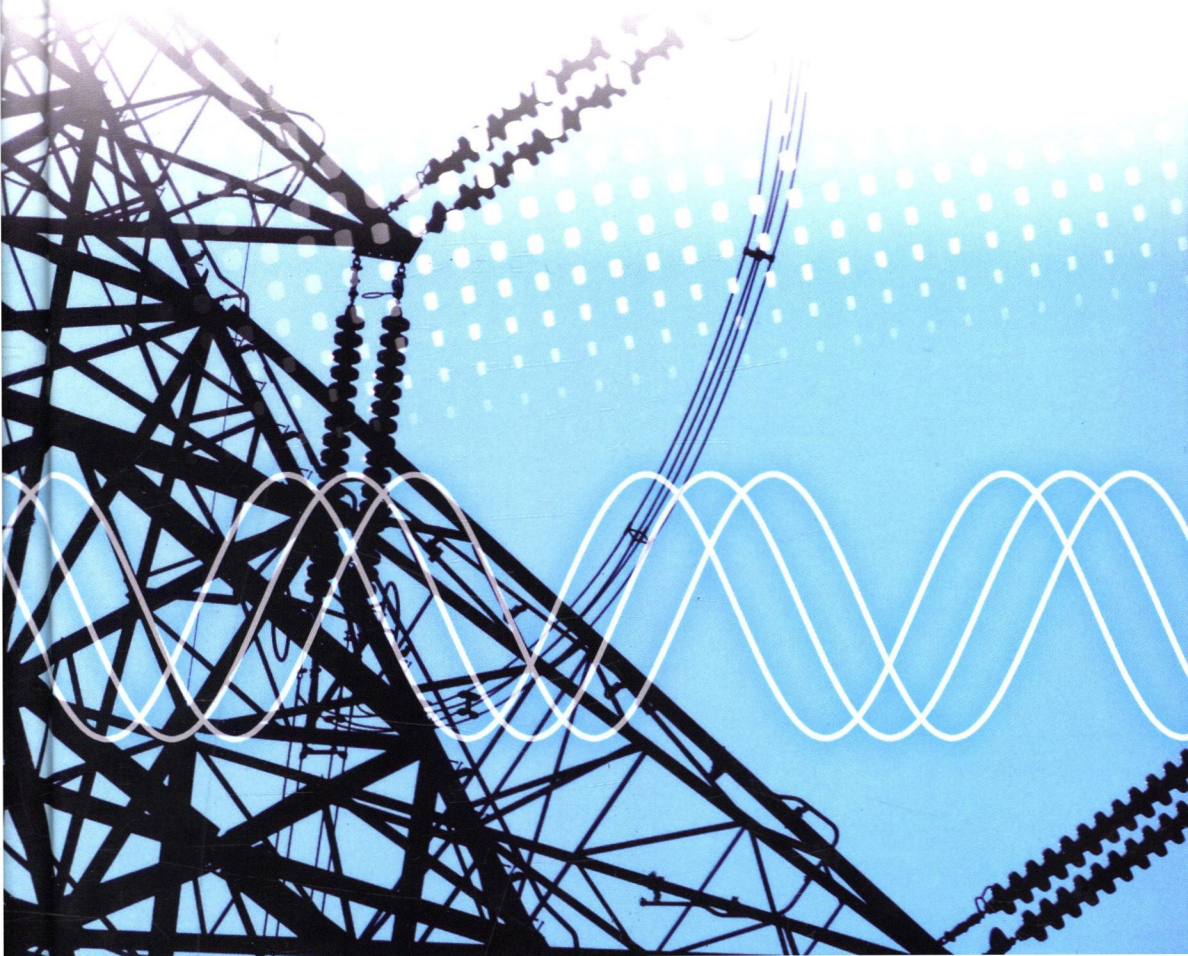
Power Quality in Future Electrical Power Systems

Edited by
Ahmed F. Zobaa and Shady H. E. Abdel Aleem



Power Quality in Future Electrical Power Systems

Power quality is necessary for electrical systems to operate in their intended manner without any deterioration of performance. This book highlights the new emerging challenges of power quality due to the penetration of large-scale renewable energy generation technologies, the advances in nonlinear loads, the increased electricity demands in the deregulated market, and the recent requirements of smart grids that need better hierarchical design with enhanced quality, improved controllability, higher reliability, and security. Novel research that links the past, present and future of electrical power grids from a power quality perspective is also introduced. Topics include power quality definitions; frequency-domain power theory and metering of harmonic pollution responsibility; active and passive harmonic filters; shunt flexible AC transmission; power quality improvement using series FACTS; distributed generation systems; islanding scenario generation algorithm; decentralised voltage control in smart grids; techno-economic issues of power quality; economic robust programming for energy management systems; and future trends in power quality.

Power Quality in Future Electrical Power Systems is a tool for planners, designers, operators and practicing engineers of electrical power systems who are concerned with power network quality, reliability, and security. It is essential reading for postgraduate students, engineers, academics, and researchers who have some background in electrical power systems.

About the Editors

Ahmed F. Zobaa is a Senior Lecturer, and a Full Member of the Institute of Energy Futures at Brunel University London, U.K. His major areas of expertise are power quality, renewable energy and smart grids. Dr Zobaa is a Senior Fellow of the Higher Education Academy of U.K. He is a Fellow of the IET, the Energy Institute, the Chartered Institution of Building Services Engineers, the Institution of Mechanical Engineers, and the African Academy of Science.

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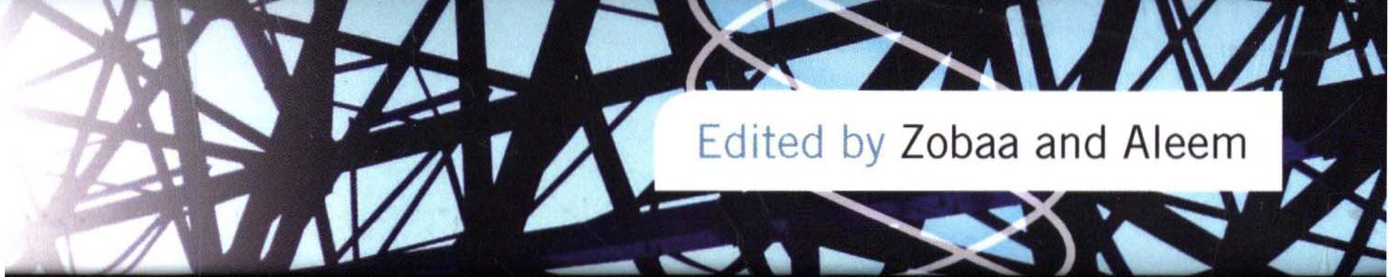

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Preface

Power quality is an important subject of electric power systems for the customers, equipment manufacturers and service suppliers. In general, power quality is an arrangement of requirements or constraints that allow electrical systems to operate with reliable, secure and continuous good quality of power without any additional loss, deterioration of performance, or ageing of any particular equipment due to abnormalities, that is, variations from the standard case.

Because of the on-going complication of the electrical power systems structure and the developments in the smart grid domain around the world, new challenges and opportunities in the power quality area have emerged. Consequently, much attention on power system quality should be paid to meet the future electrical power quality requirements. Besides, extensive analysis of the common and recent power quality problems, improved indices, enhanced standards, better passive/active conditioners and more powerful capabilities for monitoring equipment are required for better readiness of the future electrical power systems.

This book highlights the recent developments in the power systems that have led to the new challenges in the quality of power domain such as the large-scale renewable energy-based generation technologies, and the optimal utilisation of the existing power grid with the growing penetration of renewable-based generation technologies as a necessity for service operators and customers alike. In addition, the increased electricity demands and economic operation of power systems in a deregulated environment causes interconnected power grids to operate closer to their stability margins. Another challenge is the advance of nonlinear loads which may cause some problems such as power system harmonics distortion that may reduce the voltage quality and increase the transmission and distribution losses if they exceed their permissible levels. The book highlights this issue, causes and effects in detail whereas presenting the modern facilities of power conditioners that can solve the problem efficiently.

In addition, some bright opportunities of the future electricity grids with the increased potential of power quality monitoring devices and the enhanced capabilities of the next-generation power grid, namely smart grid, with their improved communication infrastructures are presented and discussed. As these smart networks need to be built in a better hierarchical design approach with enhanced quality, improved controllability and higher reliability and security.

Briefly, this book aimed at introducing novel research outcomes, programmes and ideas that join the past, present and future of the electrical power grids from a quality of power perspective. It is a tool for the planners, designers, operators and

practising engineers of electrical power systems that are concerned with the power networks quality, reliability and security. Likewise, it is a key resource for advanced students, postgraduates, academics and researchers who had some background in electrical power systems. The book is principally focused on applications, but each of the book's chapters begins with the fundamental structure of the problem required for a rudimentary understanding of the methods described. The book is sorted out and organised in 12 chapters.

Chapter 1 reviews power-quality definitions, issues and impacts of poor power quality on customers, equipment manufacturers and service suppliers. The primary power quality disturbances are interpreted in this chapter. In addition, power quality indices and an overview of the international standards cover the various power quality perspectives are presented. The cost of poor power quality, investment analysis to mitigate these power quality costs and economic mechanisms for improving power quality aspects and their discussion are described in the last section of this chapter.

Chapter 2 first presents the widely known apparent power definitions and their resolutions for nonsinusoidal and unbalanced systems. They are summarised and qualitatively analysed, and the measurement results are presented to interpret main properties of the apparent powers and their resolutions included in IEEE and DIN standards. Second, the methods and indices, which are proposed for detection of the harmonic producing loads and quantifying the harmonic pollution responsibility of the loads in the literature, are summarised and qualitatively analysed, and the statistical analysis of the measurement results are presented to illustrate their response for different load cases under several supply voltage cases.

Chapter 3 presents the passive harmonic filters commonly used in industry, their classifications, configurations, advantages and disadvantages, theoretical as well as practical design considerations and the data required for their installation. The goal of this chapter is to present the frequency characteristics variation and consequently the filtration properties of different passive filters.

Chapter 4 addresses the industrial load models and characteristics, active power filter topologies and design considerations, configurations and control strategies. In addition, two case studies for the development and optimisation of an industrial active power filter and hybrid active power filters for AC–DC system are developed.

Chapter 5 discusses the methodology to perform harmonic performance studies for commercial shunt FACTS and all devices regulated with the aid of power electronics switches, such as wind energy plants to assess that the harmonic impact of the devices on the transmission system is below the acceptable limits and to specify equipment ratings for the manufacturers.

Chapter 6 develops simple modelling for the series FACTS into load flow method that can be used to analysis and improve the power quality. In these developed series controllers, the real and/or reactive power flow in single or multi-line transmission system can be controlled, and the problem that arises when the series FACTS device is the only link between two areas has been solved.

Consequentially, the complexity of load flow algorithm with series FACTS has been reduced.

Chapter 7 discusses the power quality issues with the application of distributed generation (DG) technologies. Different modes of DG operation are considered such as the islanded mode, standby mode and grid-connected mode of operation. Control techniques and power quality in DG systems are addressed and discussed in detail. In addition, harmonics issues in DG, power filter configurations with their design principles are proposed and simulated.

Chapter 8 presents a novel stochastic strategy to split an entire power network into several stable subsystems. The proposed stochastic scenario generation algorithm can evaluate the steady-state stability of the created islands in each generated solution. The impact of distributed generators on the splitting problem has comprehensively been studied. It is proved that the proposed optimisation procedure can efficiently reduce the total active power losses and improve voltage profiles in the presence of DGs, which guarantee the power quality of the created islands.

Chapter 9 presents a methodology to use the voltage profile as power quality index in smart microgrids. It addresses the decentralised voltage control in smart grids, the decentralised and distributed control systems and the centralised hierarchical control of the distributed energy resources (DERs). In addition, the reactive power dispatch, the DER integration concealment and the distributed voltage control schemes are presented in detail.

Chapter 10 focuses on the tariff-related issues that are correlated with the quality of power, the different approaches for finding out power quality impact on the tariff, the design of modules to associate disturbance and economic loss, and the cost–benefit investigation indices. It addresses the need of revenues for improving the current behaviour towards power quality through updating or changing the current policies to include more incentives to enhance the quality of power. Two case studies on power quality investment in developing countries are presented.

Chapter 11 introduces the field of energy management systems in the operation of microgrid applications. It proposes a novel formulation for robust optimisation-based EMS for microgrid applications. The novelty recast in the introduction of transmission constraints, and in the avoidance of the use of prediction models for the uncertain variables.

Finally, *Chapter 12* addresses the contracts of PQ in a reconfigured electric power industry, power quality monitoring, measurement, performance indices, equipment requirements, emerging issues and power quality impacts as well as power quality trends, future interface problems with the smart grids. A case study exhibiting three different low-cost FACTS-based modulated/switched filter-compensation devices and smart dynamic control strategies using dynamic fast controlled PWM switching strategies are proposed. In addition, future problems and challenges in measurements, monitoring and analysis tools are presented.

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