POWER QUALITY ENHANCEMENT USING CUSTOM POWER DEVICES

Arindam Ghosh
Gerard Ledwich

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by

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Dedicated to my father Bholanath and the memory of my loving mother Arati.

Arindam Ghosh

I dedicate this book in memory of my father Harry and give thanks to God for His continued blessings.

Gerard Ledwich

Preface

Reliability and quality are the two most important facets of any power delivery system. A power distribution system is reliable if all its customers get interruption-free power for 24 hours a day and 365 days a year. The term power quality is often referred to as maintaining near sinusoidal voltage at the stipulated frequency of 50 or 60 Hz at the customer inlet points. It could be argued that maintaining voltage levels and frequency are the responsibility of generation. However, it will be shown in this book that there is no guarantee that the customers get quality power, even if the generation quality levels are met.

The aim of the book is two-fold – to introduce the power quality problems and to discuss the solutions of some of these problems using power electronic controllers. To achieve these aims, we discuss the power quality problems and their impacts on the end users at the beginning of the book. In the remainder of the book we present the custom power solutions to some of the power quality problems. We define those devices that provide power electronic solutions to the power quality problems as custom power devices.

The power quality problems in power distributions systems are not new, but customer awareness of these problems has increased. Similarly there are sets of conventional solutions to the power quality problems which have existed for a long time. However these conventional solutions use passive elements and do not always respond correctly as the nature of the power system conditions change. Custom power offers flexible solutions to many power quality problems.

In recent times, the issues involved with power quality issues and custom power solutions have generated a tremendous amount of interest amongst power system engineers. This is reflected by a large number of publications

in IEEE Transactions on Power Delivery and Industry Applications and other journals like Proceedings of IEE, Electric Power System Research etc. Also power quality and customer power are regularly discussed in IEEE and CIGRE conferences. From this point of view, we hope that this book will be able to provide an insight into these two very important aspects. It is however to be remembered that every book represents the viewpoint of the authors and cannot be treated as the final word on the subject. We shall therefore be delighted if this book generates increased research and development in custom power devices and their application.

A large number of numerical examples are presented in the book. Many softwares are commercially available for simulating power electronic circuits. We have found that Manitoba HVDC Research Center's EMTDC/PSCAD is a very useful tool for simulating power systems and related power electronic circuits. Also for system level simulations using mathematical models, MATLAB, a product of Math Works Inc., is most suitable. The advantage of using MATLAB is that complex control algorithms can easily be incorporated in the models. All the simulation results that are presented in this book have been prepared using either of these two packages.

The book is organized in twelve chapters. In Chapter 1 we introduce the concepts of power quality and custom power solutions. Some of the flexible ac transmission systems (FACTS) devices are also discussed in this chapter as they can be considered as precursors to the custom power devices. We also introduce the concepts of distributed generation and grid interconnection.

In Chapter 2 we discuss power quality terms and their definitions. We also discuss the impacts of poor power quality on the end users.

Chapter 3 presents the analysis and indices of the power quality problems. In this chapter we present some of the important concepts that are used extensively in the later chapters. Also the conventional mitigation methods of some of the power quality problems are presented in this chapter.

We introduce the custom power devices in Chapter 4. These devices are categorized into two broad classes – network reconfiguring devices and compensating devices. The network reconfiguring devices include SSCL, SSB and SSTS, while the load compensating devices include DSTATCOM, DVR and UPQC. We also discuss the concept of custom power park in this chapter.

Chapter 5 deals with the structure of power electronic converters and their controls. Since most of the custom power compensating devices are realized by power electronic converters, this chapter elucidates their topology, operating principles and control to make the book self-contained.

Chapter 6 discusses the topology and operating principles of the network reconfiguring devices and illustrates how these devices can be used to protect distribution systems from abnormal operations.

Chapter 7 discusses the theory of shunt compensation. It illustrates how an ideal shunt compensator can be used for load balancing, power factor correction and active filtering. Most emphasis is given to discussing the theory behind instantaneous correction of disturbances, as these developments facilitate the generation of compensator reference currents based on the measurements on instantaneous currents and voltages.

Chapter 8 deals with practical shunt compensator structures and their applications. It illustrates how a DSTACOM can be used in a distribution system for load compensation when the supply voltage is stiff or non-stiff. It also discusses how a DSTATCOM can be controlled to regulate the voltage of a power distribution bus.

In Chapter 9 we discuss the principles of series compensation. Here we illustrate how a series device can regulate the voltage at a load terminal against sag/swell or distortion in the supply side. We also illustrate how a series device, in conjunction with shunt passive devices, can be used as active filter.

In Chapter 10 we discuss the unified power quality conditioner. Two different structures of this device are discussed in this chapter along with their merits or demerits.

Chapter 11 discusses the distributed generation and grid interconnection issues. It presents a range of issues from standards to grid friendly inverters to islanding.

The book concludes in Chapter 12 where some future directions and opportunities in power quality enhancements are provided.

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Gerard Ledwich

July 2002

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AG

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GL

Contents