Advances in Renewable Energies and Power Quality

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Edited by

Manuel Pérez-Donsión
and Gianpaolo Vitale

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To all those people who are working for getting a better World and to all those who might benefit from it

To my wife Alicia for her love, patience and continuous collaboration and also to our son Juan José and his wife Bea

- ***Manuel Pérez Dónsion***

To my beloved parents and to my family, for their love, endless support, encouragement and abnegation

- ***Gianpaolo Vitale***

"There are only two ways to live your life. One is as though nothing is a miracle. The other is as though everything is a miracle."

- ***A. Einstein***

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FOREWORD

Renewable sources are expected to make a crucial contribution in meeting the energy demands of our planet and help avoid the detrimental effects we experience from the use of fossil fuels. In addition, it will increase economic growth, with an increase in jobs playing a direct role in the exploitation of renewables.

With this common objective, scientists from 20 different countries meet each year to discuss the exploitation of renewable energy and its implications—some of these scientists are leading authorities in their areas of expertise.

The International Conference on Renewable Energy and Power Quality (ICREPQ) gives us an occasion to address the various challenges of renewable energy. Particular attention is given to photovoltaic cells; wind generation; distributed generation; smart grids; power electronics; FACTS and HVDC; harmonics; filters with other correction devices; voltage sags and dips; and power quality. This book is arranged with a section devoted to each of these topics. The contents have been enriched with original contributions on state-of-the-art technology, approaches, and perspectives for the corresponding part of the book. These chapters are labelled *.

The purpose of this new book is to assess and update the knowledge about and potential advantages of renewable energy sources, distributed generation, energy storage, and other factors relevant to smart systems. It is intended to be a reference work for researchers, technicians, and engineers looking for both theoretical and practical applications.

Preceding this book, two volumes containing a selection of the best papers presented at the ICREPQ conferences between 2003 and 2012 were published in 2013 by the same editor with the titles “Renewable Energy”

and “Power quality.” This new book titled: “Advances in renewable energy and power quality” includes a selection of the best papers presented at the ICREPQ conferences from 2013 to 2017. They have been selected with the help of voluntary reviewers. The authors of the selected papers have been required to improve and update their work before its final publication.

The ICREPQ conferences take place in Spain and each year a different city is chosen. Over the last five years, the following cities have hosted the conference: Bilbao (20–23 March 2013); Córdoba (7–10 April 2014); La Coruña (25–27 March 2015); Madrid (4–6 May 2016); and Málaga (4–6 April 2017). During the last conference in Salamanca (21–23 March 2018), the “Salamanca Declaration” was prepared, which sought to assess the contribution of the scientific community to recognizing the challenges and opportunities offered by renewables. This paper is included here.

A high level of participation has always characterized the ICREPQ conferences. They give an opportunity for academics, scientists, engineers, manufacturers, and users from all over the world to come together in a pleasant location to compare their experiences, research, and results.

All the published papers are available on the conference website: http://www.icrepq.com/ and are collected in the Renewable Energy and Power Quality Journal (RE&PQJ)—this is a free electronic journal edited in Spain by the European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ). The ISSN is 2172-038X; the DOI (Digital Object Identifier) is:

https://doi.org/10.24084/repqjvolume.papernumber.

All papers are indexed in Scopus.

TO WHOM THIS BOOK IS ADDRESSED

This book is primarily intended to meet the demands of researchers and professional engineers dealing with the exploitation of renewable energy. It should also prove useful to postgraduate students and scientists dealing with social, economic, and environmental problems related to the growing use of renewable energy systems and new “green jobs” that play a direct role in reducing the environmental impact of traditional energy sources.

This book will also be useful as a reference book for engineers, physicists, and mathematicians who are interested in the operation, project management, design, and analysis of renewable energy equipment. Each chapter contains references that allow the treated topic to be investigate further.

ACKNOWLEDGMENTS

First of all, special thanks are due to Professor Manuel Perez Donsión, of the University of Vigo (Spain), for his tireless and invaluable efforts in organizing the ICREPQ conferences since 2003.

Special thanks go to all voluntary reviewers as well. Each of them reviewed more than one hundred papers to make the publication of this book possible. They are:

- Prof. Habil. Eng. Mircea Ion Buzdugan (PhD). Dean of the Faculty of Building Engineering, Technical University of Cluj-Napoca, Romania.
- Prof. Kouzou Abdellah. Laboratory of Applied Automation and Industrial Diagnosis, Faculty of Science and Technology, Djelfa University, Algeria.
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- Asst. Prof. Dr. Ali Jafer Mahdi, PhD in Electrical Engineering (2011) from the University of Liverpool, UK, Department of Electrical & Electronic Engineering. College of Engineering, University of Karbala, Karbala, Iraq.
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- Prof. Hamid El Qarnia, (PhD). Fluid Mechanics and Energetics Laboratory, Physics Department, Faculty of Sciences, Cadi Ayyad University, Marrakesh, Morocco.
- Prof. Mario Mañana Canteli. Associate Professor, Department of Electrical and Energy Engineering, University of Cantabria, Spain.
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Thanks go to Cambridge Scholars Publishing for helping publish this book, which contains the most relevant papers of the last five years presented at the ICREPQ conferences dealing with renewable energy and power quality issues.

Finally, a special thanks go to all the authors that have contributed their research with the aim of improving life on our planet.

How to Use this Book

This book can be used in different ways. Each part is self-contained and the first chapter is labelled *. The reader can select a chapter of interest by using the table of contents. The references given in each paper are useful for finding out further information on a paper's topic.

BIOGRAPHIES OF THE EDITORS

Manuel Pérez-Donsión received an MSc in Industrial Engineering from the Polytechnic University of Catalonia in 1980, and his PhD from the University of Vigo in 1986. In 1987 he was made full professor at the University of Vigo.

Among other academic positions, he was the Dean of the Escuela Técnica Superior de Ingenieros Industriales y Minas from 1995 to 2001. From 2001 to 2004 he was also the Head of the Department of Electrical Engineering. He is a member of the Scientific Committee of different conferences and journals. He is the President of the European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ), the European Association for the Development of Electrical Engineering (EADEE), and the Spanish Association for the Development of Electrical Engineering (AEDIE). He is also the Vice-President of the Portuguese Association for the Development of Electrical Engineering (APDEE). He was awarded the Gold Insignia of the Green Week Foundation and has received four awards from electrical engineering journals. His main research interests are related to:

- power quality;
- renewable energy, with special emphasis on small hydropower and wind energy;
- modelling, diagnostics, and control of electric machines;
- permanent magnet synchronous motors;
- transient stability of electrical power systems.

He is the author of two research books; seven other books; and over one hundred research papers, some of which have been presented at national and international conferences, while others have been published in relevant journals. He has also been involved in a number of major

research projects. In recent years he has taught undergraduate courses in Electrical Machines, the Quality and Utilization of Electrical Energy, and the Control of Electrical Motors; at postgraduate level, he has taught Special Electrical Motors and Renewable Energies and Power Quality.

Gianpaolo Vitale received an MD in Electronic Engineering from the University of Palermo (Italy) in 1988. He is senior researcher at the Institute for High Performance Computing and Networking (ICAR), an Institute of the National Research Council (CNR) that belongs to the Department of Engineering, ICT and Technologies for Energy and Transport (DIITET). He received the national scientific qualification ("Abilitazione scientifica nazionale") of full professor in electric energy engineering (cod. 09/E2) in 2013 and as full professor in electronic energy engineering (cod. 09/E3) in 2017. He teaches "Industrial Electronics" as part of the MD course in electronic engineering at the University of Palermo. He has supervised research projects on the electromagnetic compatibility of electrical drives and the intelligent management of electrical energy supplied by renewable sources. He has been a senior member of the IEEE (Institute of Electrical and Electronics Engineers) since 2012 and a member of the IEEE Industrial Electronics Society, the IEEE Power Electronics Society, and the IEEE Robotics and Automation Society. He serves as a reviewer for several journals and conferences. He has been a member of the Organizing Committee of the ICREPQ Conference since 2008. He is the co-author of two books, two edited books and over one hundred scientific articles, of which 40 have been published in international ISI journals.

His current research interests are in the fields of robotics, power electronics, and power generation from renewable sources with problems related to electromagnetic compatibility. E-mail:
gianpaolo.vitale@icar.cnr.it

CHAPTER ZERO

SALAMANCA DECLARATION

- Prof. Manuel Pérez Donsión, Chairman of the ICREPQ Steering Committee. University of Vigo, Spain.
- Prof. Mircea Ion Buzdugan, University of Cluj-Napoca, Romania.
- Prof. Péter Kádár, Óbuda University, Hungary.
- Prof. Mohamed El-Sayed, Kuwait University, Kuwait.
- Prof. Ahmad Pourmovahed, Kettering University, USA.
- Prof. Gianpaolo Vitale, National Research Council of Italy.

This declaration was made during the International Conference on Renewable Energy and Power Quality (ICREPQ'18) XVI held at the University of Salamanca, from the 21st to the 23rd of March 2018. It presents an outline of state-of-the-art technology and approaches in the fields of renewable energy and power quality, including the latest results presented at the conference. At the end of the conference, this declaration was proposed and approved by the participants. This document aims to assess the contribution of the scientific community and to recognize the prestige of the University of Salamanca on the occasion of the commemoration of its first eight centuries in existence, a process that reached its culmination in the same year as ICREPQ'18.

The use of renewable energy sources (RES) is growing apace and offers a valid solution to the mitigation of CO2 emissions. Unfortunately, they exhibit slower growth compared to the energy demand that is still satisfied by fossil fuels. The target of satisfying 50% of the market-share (corresponding to the transition from the use of fossil sources to the use of renewable sources) is still far from being achieved. For this reason, RES need to be sustained by current technology.

There are many factors relevant to the increasing use of RES. Among them is the adoption of power conditioning devices for electrical energy conversion. These lead to increased efficiency conversion and a reduction in the need for additional investment.

The new generation of advanced power electronic devices available to the market, together with new conversion topologies, allow fast switching methods that reduce losses and a higher operating temperature. Moreover,

the efficiency of solar and wind generation is improving, contributing to a reduction in the time taken to achieve a return and encouraging further capital investment.

The continuous growth of RES has to be taken into account during the planning of distribution grids, which were conceived for a unidirectional power flow generated by conventional sources. Now, new techniques of analysis need to be developed to take into account bidirectional power flows in distributed generation and the presence of harmonics.

The adoption of RES reduces the inertia of conventional generation systems, leading to possible instabilities, especially for non-robust grids. Therefore, a virtual inertia must be provided, so that in the case of failure a relevant amount of power can be delivered to the grid to maintain voltage and frequency stability and avoid collapse.

The availability of energy generated by RES requires that the maximum energy is extracted to cover the demand required by the customer. This situation is very different from conventional generation by fossil fuel sources where energy can be reduced according to the demand of the customer. For efficient utilization of the available renewable energy, maximum power tracking techniques have to be considered that interface RES with the grid. As a matter of fact, the intermittency of energy produced by RES means that it is usually not enough to satisfy demand. In the case of a renewable energy deficit, fossil fuels are required. If RES generation overproduces the required energy, this excess energy is lost. The solution is to be found in the adoption of a storage system. There are a few solutions currently available on the market, but they need further study to reduce overall costs and enhance system performance. In addition, environmental aspects need to be taken into account. Storage facilities that currently exist include batteries, plug-in-hybrid electric vehicles, flywheels, supercapacitors, superconducting coils and others. All these systems store energy, but further study is needed to optimize their design and operation and fulfil customer requirements.

There are many fields for which the use of RES can be promoted. For example, the process of water desalination requires electricity, which can be produced by RES, avoiding its transmission over long distances and ensuring the production of clean water.

The tri-generation of combined cooling, heating and electrical power is able to produce chilled water for air conditioning or refrigeration using a part of the heat delivered by co-generation plants. This type of plant sees high efficiency in the production of electricity and heat, with reduced fuel and energy costs. Moreover, such plants lower peak demand during hot seasons. The management of hybrid energy generation, including the new

trend of producing electric vehicles, requires the availability of efficient communication facilities in smart grid operations.

Deregulation of the electrical power industry, namely its classification into generation, transmission, and distribution subsystems, has led to increased research interest into the power quality delivered. This is no longer just an issue for technical groups working with power utility's, but also requires the investigation of unusual problems of interaction between the power system and customer facilities, including their basic design, maintenance issues, and the investment required to protect the equipment within these facilities, as well as the implementation of new technologies.

Electrical power quality issues do not just have significant economic consequences for customers, but also serious economic impacts on utility companies, because of the ability of the customer to choose which power sources serve them in new and free competitive markets. In practice, these new, free markets are changing the framework in which power quality is addressed across the world, and power quality objectives are now of great importance to all power system operators.

Power quality is a complex area covering many different topics. However, simplifying the matter, it can be seen as a set of electrical boundaries allowing equipment to function in its intended manner without significant loss of performance or decrease in life expectancy.

The subject of power quality is very broad by nature, covering all aspects of power system engineering, from generation, transmission and distribution to end-user problems. Of the three primary components of the electricity infrastructure, the distribution system is often the most critical part of a unified power system in terms of its effect on reliability, quality of service, cost of electricity, and impact on society.

From this perspective, electric power quality is a major concern of utilities, end users, and manufacturers. Suppliers are interested in the quality of their service; manufacturers have to build equipment that is compliant with power quality standards and regulations; and finally, customers have requirements that need fulfilment so that they feel secure in using electrically powered products.

The term power quality may often seem ambiguous, having different meanings for different people. As such, power quality can, at the same time, be a problem to be solved and a product, depending on a person's perspective. For power quality experts, power quality is obviously a problem that must be solved, while for a power marketer for instance, power quality is an important feature of a product named electrical power.

Problems related to power quality are often difficult to solve, and may have various solutions, so the choice is not always simple. The optimal

solution to a power quality problem usually involves a mix of solutions for each specific situation. The evaluation of solutions is certainly a key element in solving power quality problems, for both technical and economic reasons.

There are several factors driving an increased need to prevent and solve power quality problems:

- The increased use of power quality-sensitive equipment;
- The increased use of equipment that causes power quality problems;
- The increased interconnectedness of power systems;
- The deregulation of the power industry.

The increased use of power electronic components within distribution systems and a reliance on renewable energy sources, which use converters as the interface between the source and the power system, lead to power quality problems.

The problem of voltage quality is gaining increasing importance due to the widespread use of power electronics (increasing emitted interference) on the one hand, and the reduction in the signal levels of electronic equipment (increased interference susceptibility) on the other.

Electromagnetic interference causes degradation in the performance of equipment, the transmission channel, or the system through electromagnetic disturbance—any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter.

The concept of electromagnetic interference is an important part of electromagnetic compatibility, defined as the ability of equipment or a system to satisfy three criteria:

- To cause no interference with other systems;
- To not be susceptible to emissions from other systems.
- To cause no interference with itself.

The lack of electromagnetic compatibility or a precarious solution of its issues may have several consequences, such as the unforeseeable and unreliable operation of equipment, and bring high risks for the ecosystem and/or human life.

In most electromagnetic compatibility issues, there is the “aggressor” of the electromagnetic environment and one or more “victims.” The aggressor conducts or radiates a sufficient amount of electromagnetic

energy, that it is able to interfere with equipment, representing a victim. On the other hand, the victim misoperates due to interference with the aggressor or due to the electromagnetic fields present in its environment.

Unfortunately, “victims” are not always completely innocent and that is why poor design of electromagnetic compatibility in equipment can make them sensitive to environmental electromagnetic fields and highly susceptible to electromagnetic noise.

In recent years, there has been a considerable increase in nonlinear loads. These draw harmonic currents, which have detrimental effects including communication interference; loss of reliability; increased operating costs; overheating of equipment; machine, transformer and capacitor failures; and inaccurate power metering.

A deficient quality of electrical power supplied to equipment results in the degradation of its performance; loss of productivity; damage to equipment, injury to personnel; and in some cases, loss of life. All that is needed to prevent such consequences is a clear understanding of electrical power quality and its effects on power system performance.

Based on the above, the participants of the conference suggest that the scientific community comprehensively cooperate to achieve the future goals of energy sustainability, the protection of our planet, and the assurance of a better quality of life for future generations.

PART I:

PHOTOVOLTAIC GENERATION

CHAPTER ONE

PV SYSTEM WAY OF THE FUTURE

ISAIAS GOMES[1,2,3] RUI MELICIO[1,2,3]
VICTOR MENDES[2,4,5]

Abstract

This chapter synthesizes the research on solar resources, which are an important factor in ensuring a sustainable future through the photovoltaic conversion of solar energy into electric energy. Various aspects are presented including: irradiance and irradiation on the earth; current and emerging technology in photovoltaic systems; the hot-spot effect due to shade in photovoltaic systems; job creation potential; electronic power inverters; and issues concerning the integration of photovoltaic systems into the electric grid.

Keywords: PV technologies, sustainable future, hot-spot, job opportunities, distributed power generation, emerging technology.

1. Introduction

The vision of a sustainable future has been brought to the fore through environmental concern about anthropogenic greenhouse gas emissions and social demand for measures to further mitigate damage to the Earth's

[1] ICT, Universidade de Évora, Portugal.
[2] Departamento de Física, Escola de Ciências e Tecnologia, Universidade de Évora, Évora, Portugal.
[3] IDMEC, Instituto Superior Técnico, Universidade de Lisboa, Portugal.
[4] CISE, Electromechatronic Systems Research Centre, Universidade da Beira Interior, Portugal.
[5] Department of Electrical Engineering and Automation, Instituto Superior de Engenharia de Lisboa, Lisbon, Portugal.