# Electric Power Systems

Edited by Michel Crappe

iSTE

WILEY

# Electric Power Systems

Edited by
Michel Crappe



ISTE

WILEY

First published in France in 2003 by Hermes Science/Lavoisier under the titles "Commande et régulation des réseaux électriques" and "Stabilité et sauvegarde des réseaux électriques"
First published in Great Britain and the United States in 2008 by ISTE Ltd and John Wiley & Sons, Inc.



ISTE Ltd
6 Fitzroy Square
London W1T 5DX
UK

www.iste.co.uk

John Wiley & Sons, Inc.
111 River Street
Hoboken, NJ 07030
USA

www.wiley.com



Library of Congress Cataloging-in-Publication Data

Commande et regulation des reseaux electriques. English.
Electric power systems / edited by Michel Crappe.
p. cm.
Includes bibliographical references and index.
ISBN-13: 978-1-84821-008-0
1. Electric power systems. I. Crappe, Michel. II. Stabilite et sauvegarde des reseaux electriques. English. III. Title.
TK1001.C594 2008
621.319'1--dc22

2007045058

British Library Cataloguing-in-Publication Data
A CIP record for this book is available from the British Library
ISBN: 978-1-84821-008-0

Printed and bound in Great Britain by Antony Rowe Ltd, Chippenham, Wiltshire.

FSC
Mixed Sources
Product group from well-managed forests and other controlled sources
Cert no. SGS-COC-2953
www.fsc.org
© 1996 Forest Stewardship Council

Electric Power Systems

# Table of Contents

# Preface

This book, which deals with electric transmission systems, is the English translation of two books written in French and published in 2003 by Hermes Science Publications (*Commande et Régulation des Réseaux Electriques, Stabilité et Sauvegarde des Réseaux Electriques*) in the electrical engineering series of the Traité EGEM (series in electronics and electric engineering and micro-electronics). It consists of two parts, corresponding to the two books in question. The first deals with the control, regulation and security of large scale electric power networks and the second with the stability and safety of the systems. The two parts include 5 and 4 chapters respectively, written by renowned experts from the industrial world or from universities. Its aim is to present the state of the art in the concerned domains as well as future prospects, especially in the fields of research and development. It is aimed at specialists, scientists and people involved in research in the electricity sector; it presupposes thorough knowledge of the basic concepts of electrical engineering. It has not been possible to cover all the problems related to the subject in an exhaustive manner in a single book. The subjects discussed in this collective work are the result of a choice made by the editor and based on his experience in research and teaching.

If some repetitions have occurred, they show the different approaches and attitudes towards essential phenomena and have been deliberately maintained with a pedagogical aim in mind and to reinforce the perception of sensitive issues. Moreover, it also makes it possible for each chapter to be read independently of the others. Different solutions are sometimes suggested to resolve some problems, which proves that the field is wide open and a lot of research and development remains to be carried out.

Electricity is an energy carrier that is indispensable to human activities in developed countries, and is an essential factor in development for poorer countries. Electric transmission systems are key elements in ensuring a reliable supply of good quality electric power. The introduction of new generation systems or management methods of electric power must, as a result, be the subject of in-depth study to ensure compatibility with sure and reliable functioning of transmission networks. The recent changes in electric transmission systems and new constraints in the electric power sector in Europe have particularly complicated matters. The new paradigm in the field of development and management of the electric power sector, due to the recent restructuring of the latter on the application of European Directives to organize the electricity market in Europe, appears if not explicitly then at least in a subtle manner in most of the chapters. At present, the setting up of the European market for electric power, concomitant with environmental constraints, is proving to be much more difficult than expected by its protagonists and is presenting numerous challenges, which can only be removed at the cost of significant efforts in research and development. Moreover, recent major blackouts that have occurred in Europe in a number of countries (Sweden, Denmark, Switzerland, Italy and Greece) and the blackout of 4 November 2006 have reminded us that the stability and the collapse of electric systems are problems that are very real and not purely academic. The blackout of 4 November is particular affected several millions of Europeans for several minutes to an hour, and moreover led 200 million people to be at risk of being deprived of electricity for several hours, even several days. The current situation therefore considerably reinforces the value of books on electric power transmission networks, such as this one.

In the first part, the book focuses on fundamental aspects of electric power systems, the evolution of European transmission networks in the face of new regulations, the impact of decentralized production, generation and transmission planning, quality of the electric power supply and finally advanced control methods.

The second part deals with voltage stability, transient stability, the defense plan, electromechanical aspects of digital simulation and finally power electronics to enhance controllability, stability and power transfer capability of large transmission networks. It naturally completes the first part.

If this book could guide the reader towards research and development in the field of electric power systems, it would amply fulfill its aim.

Sincere gratitude once again to the different authors and all the people who have contributed from near or far to the publication of these two books in French, especially Olivier Deblecker of the Faculté Polytechnique de Mons (Faculty of Engineering, Mons) for his help in the formatting of the different contributions. I especially thank the editor of ISTE/Hermes Science for having decided on the publication of the two books in English and for having ensured its translation.

Michel CRAPPE
Professor Emeritus of the Faculté Polytechnique de Mons
(Faculty of Engineering, Mons)

Chapter 1

# General Aspects of the Control, Regulation and Security of the Energy Network in Alternating Current

## 1.1. Introduction

### 1.1.1. *History*

Though Edison managed to distribute electricity through direct current (at 110 V) for lighting for the first time in 1882 and the first long distance transmission was achieved in 1882 between Miesbach and Munich (57 km, 2,000 V), it soon became clear that long distance transmission needed a higher voltage if the volume of copper was to be kept low (Deprez in 1881) and thus should use alternating current and a transformer, whose principle was patented by Gaulard and Gibbs in 1881. Three phase generators have a simpler design concept and easier current breaking facility than that of direct current machines. In 1891, a power plant on the Neckar in Lauffen was linked to Frankfurt (a distance of 176 km) through a 15 kV alternating current line. Around 1920, with Europe standardizing its frequency at 50 Hz and suspended insulators coming into the picture, the voltage was raised to 132 kV. In the beginning, the distance between the hydroelectric power plants and the cities was the main reason for this long distance transmission. With the development of thermal power plants it became obvious that there existed a complementarity between these different modes of production giving rise to a better use of resources through interconnections within a country as well as between neighboring countries. As a result international connections

---

Chapter written by Noël JANSSENS and Jacques TRECAT.