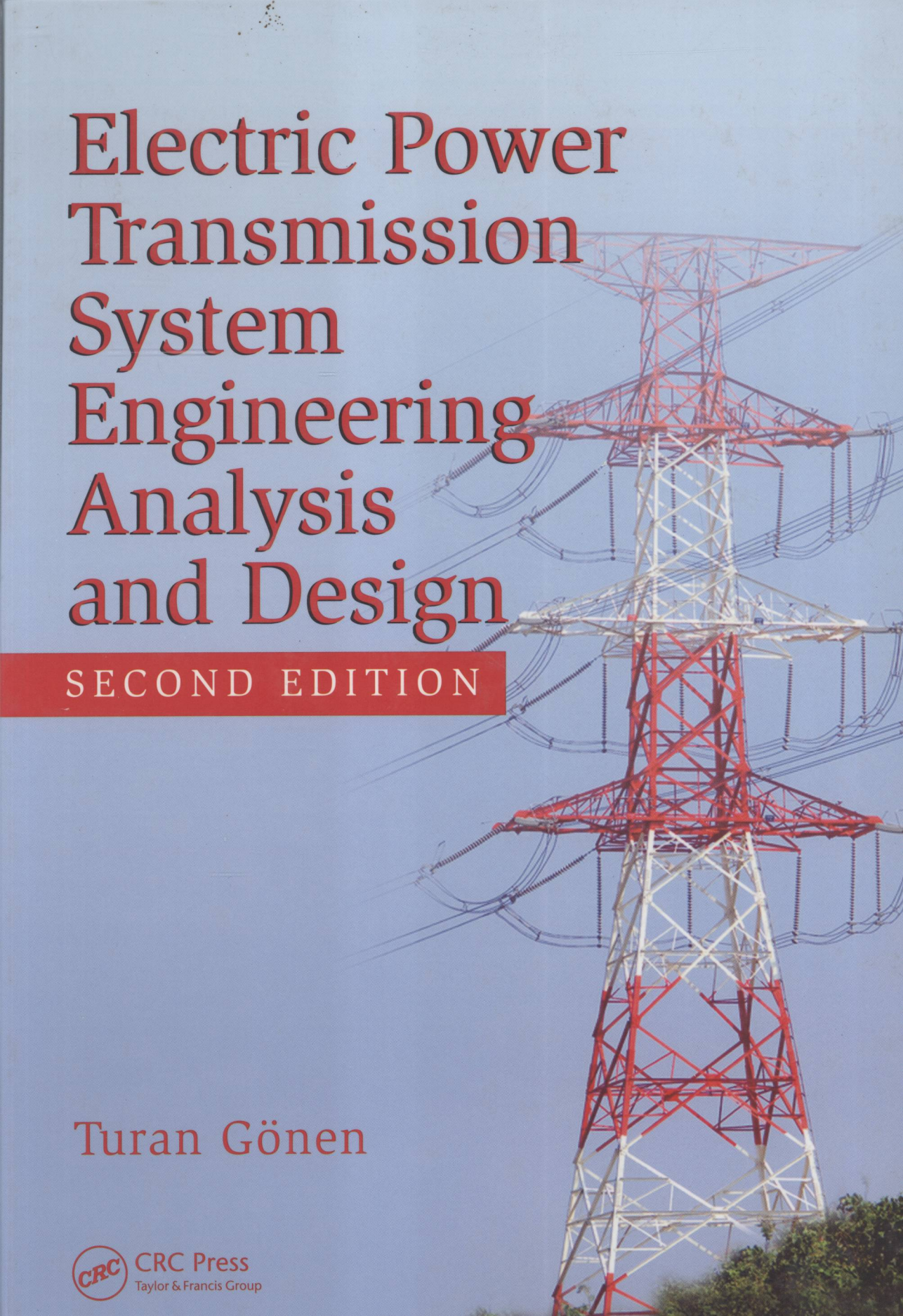
Electric Power Transmission System Engineering Analysis and Design

SECOND EDITION



Turan Gönen

CRC Press
Taylor & Francis Group

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CRC Press
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Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **Informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number-13: 978-1-4398-0254-0 (Hardcover)

Library of Congress Cataloging-in-Publication Data

Gönen, Turan.
Electrical power transmission system engineering : analysis and design / Turan Gönen. -- 2nd ed.
p. cm.
"A CRC title."
Includes bibliographical references and index.
ISBN 978-1-4398-0254-0 (hard back : alk. paper)
1. Electric power transmission. I. Title.

TK3001.G583 2009
621.319--dc22 2009010935

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We are all ignorant, just
about different things.
—Mark Twain

There is so much good in the worst of us,
And so much bad in the best of us,
That it little behooves any of us,
To talk about the rest of us.
—Edward Wallis Hoch

For everything you have missed,
You have gained something else;
And for everything you gain,
You lose something else.
—R. W. Emerson

Dedicated to my brother, Zaim Suat Gönen for motivating me.

Preface

The structure of an electric power system is very large and complex. Nevertheless, its main components (or subsystems) can be identified as the generation system, transmission system, and distribution system. These three systems are the basis of the electric power industry. Today, there are various textbooks dealing with a broad range of topics in the power system area of electrical engineering. Some of them are considered to be classics. However, they do not particularly concentrate on topics dealing specifically with electric power transmission. Therefore, this text is unique in that it is specifically written for in-depth study of modern power transmission engineering.

This book has evolved from the content of courses given by the author at the California State University, Sacramento; the University of Missouri at Columbia; the University of Oklahoma; and Florida International University. It has been written for senior-level undergraduate and beginning-level graduate students, as well as practicing engineers in the electric power utility industry. It can serve as a text for a two-semester course or, by judicious selection, the material in the text can also be condensed to suit a one-semester course.

This book has been written especially for students or practicing engineers who want to teach themselves. Basic material has been explained carefully, clearly, and in detail with numerous examples. Each new term is clearly defined when it is introduced. Special features of the book include ample numerical examples and problems designed to apply the information presented in each chapter. A special effort has been made to familiarize the reader with the vocabulary and symbols used by the industry. The addition of the numerous impedance tables for overhead lines, transformers, and underground cables makes the text self-contained.

The text is divided into two parts: electrical design and analysis and mechanical design and analysis. The electrical design and analysis portion of the book includes topics such as transmission system planning; basic concepts; transmission line parameters and the steady-state performance of transmission lines; disturbance of the normal operating conditions and other problems: symmetrical components and sequence impedances; in-depth analysis of balanced and unbalanced faults; extensive review of transmission system protection; detailed study of transient overvoltages and insulation coordination; underground cables; and limiting factors for extra-high and ultrahigh-voltage transmission in terms of corona, radio noise, and audible noise. The mechanical design and analysis portion of the book includes topics such as construction of overhead lines, the factors affecting transmission line route selection, right-of-way; insulator types, conductor vibration, sag and tension analysis, profile and plan of right-of-way, and templates for locating structures. Also included is a review of the methods for allocating transmission line fixed charges among joint users.

Turan Gönen

Acknowledgments

The author wishes to express his sincere appreciation to Dr. Dave D. Robb of D. D. Robb and Associates for his encouragement and invaluable suggestions and friendship over the years.

The author is also indebted to numerous students who studied portions of the book, at California State University, Sacramento; the University of Missouri at Columbia; and the University of Oklahoma, and made countless contributions and valuable suggestions for improvements. The author is also indebted to his past students Joel Irvine of Pacific Gas & Electric Inc., and Tom Lyons of The Sacramento Municipal Utility District for their kind help.

Author

Turan Gönen is professor of electrical engineering at California State University, Sacramento. He holds a BS and MS in electrical engineering from Istanbul Technical College (1964 and 1966, respectively), and a PhD in electrical engineering from Iowa State University (1975). Dr. Gönen also received an MS in industrial engineering (1973), a PhD co-major in industrial engineering (1978) from Iowa State University, and a Master of Business Administration (MBA) degree from the University of Oklahoma (1980).

Professor Gönen is the director of the Electrical Power Educational Institute at California State University, Sacramento. Previously, Dr. Gönen was professor of electrical engineering and director of the Energy Systems and Resources Program at the University of Missouri-Columbia. Professor Gönen also held teaching positions at the University of Missouri-Rolla, the University of Oklahoma, Iowa State University, Florida International University and Ankara Technical College. He has taught electrical electric power engineering for over 31 years.

Dr. Gönen has a strong background in the power industry; for eight years he worked as a design engineer in numerous companies both in the United States and abroad. He has served as a consultant for the United Nations Industrial Development Organization (UNIDO), Aramco, Black & Veatch Consultant Engineers, and the public utility industry. Professor Gönen has written over 100 technical papers as well as four other books: *Modern Power System Analysis*, *Electric Power Distribution System Engineering*, *Electrical Machines*, and *Engineering Economy for Engineering Managers*.

Turan Gönen is a fellow of the Institute of Electrical and Electronics Engineers and a senior member of the Institute of Industrial Engineers. He served on several committees and working groups of the IEEE Power Engineering Society, and is a member of numerous honor societies including Sigma Xi, Phi Kappa Phi, Eta Kappa Nu, and Tau Alpha Pi. Professor Gönen received the Outstanding Teacher Award at CSUS in 1997.

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