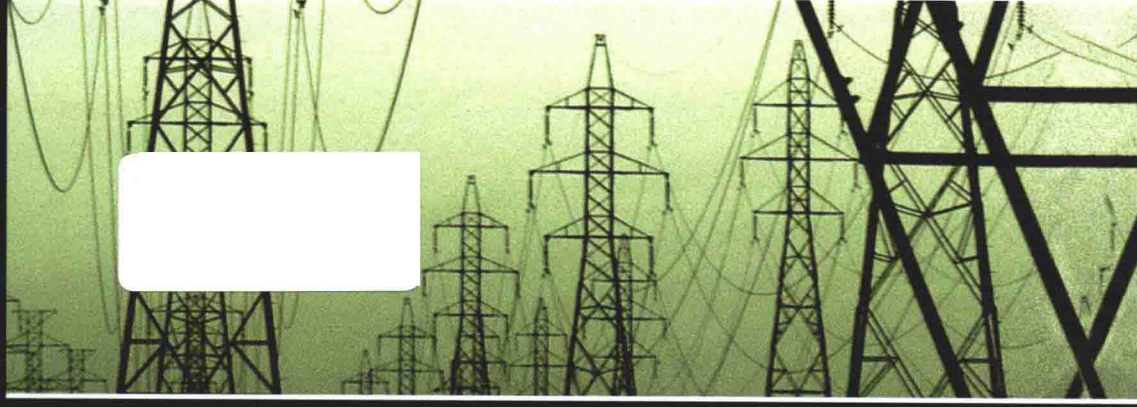
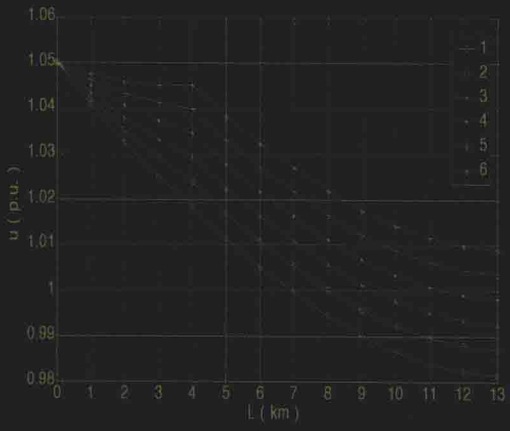


Optimization of Power System Operation

Second Edition



Jizhong Zhu

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JIZHONG ZHU

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To My Wife and Son

PREFACE

It has been five years since the first edition was published. Some developments have taken place in the power industry. The renewable energy and smart grid include many fresh and vital technologies that are needed to make enormous progress in power grid development. With the development of information technology and computer-based remote control and automation, the systems and technologies for the smart grid are made possible by two-way communication technology and computer processing. This modernized electricity network, which sends electricity from power suppliers to consumers using digital technology to save energy, reduce cost, and increase reliability and transparency, is being promoted by many governments as a way of addressing energy independence, global warming, environment protection, and emergency resilience issues.

In this new edition, *Optimization of Power System Operation*, continues to provide engineers and academics with a complete picture of the optimization techniques used in modern power system operation. It offers a practical, hands-on guide to theoretical developments and to the application of advanced optimization methods to realistic electric power engineering problems. Although the topic areas and depth of coverage remain about the same, the book has been updated to reflect the changes that have taken place in the electric power industry since the First Edition was published five years ago. The research and application of renewable energy and smart grid have being widely addressed in recent years, which have brought a host of new opportunities and challenges to modern power system operation. Thus, in this edition two new Chapters have been added—Chapter 10 on "Application of renewable energy" and Chapter 14 on "Operation of smart grid." The original Chapter 10 on "Reactive power optimization" in the first edition is removed because of limitation of the space. But some contents related to reactive power optimization can still be found in Chapter 8 on "Optimal power flow" and Chapter 13 on "Uncertainty analysis in power systems". In the new Chapter 10, in addition to the introduction of renewable energy resources and the corresponding mathematical models, the optimization operation of renewable energy in power systems, such as maximum power point tracking, voltage calculation for the grid-connected PV system, and voltage analysis in power system with wind energy, is focused. In the new Chapter 14, applications of optimization techniques to smart grid are addressed and the following topics are included: smart grid economic dispatch, two-stage-approach for optimal operation of a smart grid, optimal operation of virtual power plant, smart distribution operation, microgrid operation with wind and PV resources, optimal power flow for smart microgrid, renewable energy and distributed generation technologies, and a new phase angle measurement algorithm.

The author appreciated the suggestions and feedback offered by professors and engineers who have used the first edition. Some professors commented that this book comprehensively applies all kinds of optimization methods to solve power system operation problems, but it needs to provide some problems or exercises at the end of each chapter so that it can be used as a textbook. Some students remarked that they like the examples in the book, and they even have tried to use different methods or written some programs to resolve them. Some readers did an excellent job to find some errors and typos. I have gone through the book and made necessary corrections. Over ten exercises and problems at the end of each chapter have been included in the second edition.

I wish to express my gratitude to IEEE book series editor, Wiley Acquisitions Editor, Project Editor, and the reviewers of the book for their valuable comments and suggestions.

Jizhong Zhu

PREFACE TO THE FIRST EDITION

I have been undertaking the research and practical applications of power system optimization since the early 1980s. In the early stage of my career, I worked in universities such as Chongqing University (China), Brunel University (UK), National University of Singapore, and Howard University (USA). Since 2000 I have been working for ALSTOM Grid Inc. (USA). When I was a full-time professor at Chongqing University, I wrote a tutorial on power system optimal operation, which I used to teach my senior undergraduate students and postgraduate students in power engineering until 1996. The topics of the tutorial included advanced mathematical and operations research methods and their practical applications in power engineering problems. Some of these were refined to become part of this book.

This book comprehensively applies all kinds of optimization methods to solve power system operation problems. Some contents are analyzed and discussed for the first time in detail in one book, although they have appeared in international journals and conferences. These can be found in Chapter 9 "Steady-State Security Regions", Chapter 11 "Optimal Load Shedding", Chapter 12 "Optimal Reconfiguration of Electric Distribution Network", and Chapter 13 "Uncertainty Analysis in Power Systems."

This book covers not only traditional methods and implementation in power system operation such as Lagrange multipliers, equal incremental principle, linear programming, network flow programming, quadratic programming, nonlinear programming, and dynamic programming to solve the economic dispatch, unit commitment, reactive power optimization, load shedding, steady-state security region, and optimal power flow problems, but also new technologies and their implementation in power system operation in the last decade. The new technologies include improved interior point method, analytic hierarchical process, neural network, fuzzy set theory, genetic algorithm, evolutionary programming, and particle swarm optimization. Some new topics (wheeling model, multiarea wheeling, the total transfer capability computation in multiareas, reactive power pricing calculation, congestion management) addressed in recent years in power system operation are also dealt with and put in appropriate chapters.

In addition to the rich analysis and implementation of all kinds of approaches, this book contains considerable hands-on experience for solving power system operation problems. I personally wrote my own code and tested the presented algorithms and power system applications. Many materials presented in the book are derived from my research accomplishments and publications when I worked at Chongqing

University, Brunel University, National University of Singapore, and Howard University, as well as currently with ALSTOM Grid Inc. I appreciate these organizations for providing me such good working environments. Some IEEE papers have been used as primary sources and are cited wherever appropriate. The related publications for each topic are also listed as references, so that those interested may easily obtain overall information.

I wish to express my gratitude to IEEE book series editor Professor Mohammed El-Hawary of Dalhousie University, Canada, Acquisitions Editor Steve Welch, Project Editor Jeanne Audino, and the reviewers of the book for their keen interest in the development of this book, especially Professor Kit Po Wong of the Hong Kong Polytechnic University, Professor Loi Lei Lai of City University, United Kingdom, Professor Ruben Romero of Universidad Estadual Paulista, Brazil, and Dr. Ali Chowdhury of California Independent System Operator, who offered valuable comments and suggestions for the book during the preparation stage.

Finally, I wish to thank Professor Guoyu Xu, who was my PhD advisor twenty years ago at Chongqing University, for his high standards and strict requirements for me ever since I was his graduate student. Thanks to everyone, including my family, who has shown support during the time–consuming process of writing this book.

Jizhong Zhu

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I would like to express my appreciation to the IEEE Press Power Engineering book series editor, Professor Mohamed El-Hawary of Dalhousie University, Canada, Wiley-IEEE Press Acquisitions Editor Mary Hatcher, and the technical reviewers of the book for their keen interest and valuable comments in the development of this new edition. I would also like to thank all editors and technical reviewers of the first edition of the book for their constructive suggestions and encouragement during the preparation stage of the book.

I would also like to extend my thanks to Professor Guoyu Xu of Chongqing University, who was my PhD advisor 25 years ago, for his patient guidance, enthusiastic encouragement, and useful critiques of my research work related to the book.

Finally, I wish to thank my family for their support and encouragement throughout the process of writing this book.

AUTHOR BIOGRAPHY

Jizhong Zhu is currently working at ALSTOM Grid Inc. as a senior principal power systems engineer, as well as a Fellow of the ALSTOM Expert Committee. He received his Ph.D. degree from Chongqing University, P.R. China, in February 1990. Dr. Zhu was a full professor in Chongqing University. He won the "Science and Technology Progress Award of State Education Committee of China" in 1992 and 1995, respectively, "Sichuan Provincial Science and Technology Advancement Award" in 1992, 1993, and 1994, respectively, as well as the "Science and Technology Invention Prize of Sichuan Province Science and Technology Association" in 1992. In recognition of Dr. Zhu's work, the Chongqing City Government conferred on him the award of Excellent Young Teacher by in 1992. He was selected as an Outstanding Science and Technology Researcher and won the annual Science and Technology Medal of Sichuan Province in 1993. He was also selected as one of four outstanding young scientists working in China by The Royal Society of UK and China Science and Technology Association and awarded the Royal Society Fellowship in 1994 and the national research prize "Fok Ying-Tong Young Teacher Research Medal" in 1996. He has worked in a number of different institutions all over the world, including Chongqing University in China, Brunel University in the United Kingdom, the National University of Singapore, and the Howard University in the United States, and has been with ALSTOM Grid Inc. (since 2000). He is also an advisory professor at Chongqing University. His research interest is in the analysis, operation, planning, and control of power systems as well as application of renewable energy. He has published six books as an author and co-author, and has published over 200 papers in international journals and conferences.

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