

时代教育·国外高校优秀教材精选

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(英文版·原书第3版)

# 电力系统分析与设计

Power System Analysis and Design

(美) J.邓肯·格洛弗 (J. Duncan Glover) 著  
穆卢库特拉 S. 萨尔马 (Mulukutla . S. Sarma)

机械工业出版社  
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J. Duncan Glover, Mulukutla S. Sarma

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随着我国加入 WTO，国际间的竞争越来越激烈，而国际间的竞争实际上也就是人才的竞争、教育的竞争。为了加快培养具有国际竞争力的高水平技术人才，加快我国教育改革的步伐，国家教育部近来出台了一系列倡导高校开展双语教学、引进原版教材的政策。以此为契机，机械工业出版社陆续推出了一系列国外影印版教材，其内容涉及高等学校公共基础课，以及机、电、信息领域的专业基础课和专业课。

引进国外优秀原版教材，在有条件的学校推动开展英语授课或双语教学，自然也引进了先进的教学思想和教学方法，这对提高我国自编教材的水平，加强学生的英语实际应用能力，使我国的高等教育尽快与国际接轨，必将起到积极的推动作用。

为了做好教材的引进工作，机械工业出版社特别成立了由著名专家组成的国外高校优秀教材审定委员会。这些专家对实施双语教学做了深入细致的调查研究，对引进原版教材提出了许多建设性意见，并慎重地对每一本将要引进的原版教材一审再审，精选再精选，确认教材本身的质量水平，以及权威性和先进性，以期所引进的原版教材能适应我国学生的外语水平和学习特点。在引进工作中，审定委员会还结合我国高校教学课程体系的设置和要求，对原版教材的教学思想和方法的先进性、科学性严格把关。同时尽量考虑原版教材的系统性和经济性。

这套教材出版后，我们将根据各高校的双语教学计划，举办原版教材的教师培训，及时地将其推荐给各高校选用。希望高校师生在使用教材后及时反馈意见和建议，使我们更好地为教学改革服务。

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# 序

本书的主要内容是介绍电力系统分析和设计的方法,使学生对有关电力系统工程的宽范围内的课题有清楚的认识,特别是可以借助个人计算机,使大学本科生充分地理解电力系统的基本理论和方法,并得到相应的训练。

本书的主要特点有:

1. 对于电气工程专业的大学生来说,本书内容十分全面,这是美国教材不同于我国教材之处。对于本书的内容,国内通常是分成几本教材来编写出版的,类似的教材如《电力系统分析》、《电力工程》、《电能系统基础》等都没有本书全面。

2. 编写内容新。本书是第3版,内容反映了电力系统领域内的最新问题和研究成果,包括电力市场环境下电力系统的一些问题。

3. 每章开始均有“案例研究”(Case Study)部分,介绍与本章学习内容有关的历史、最新进展等,并提出一些问题。例如,第6章“潮流”的案例研究介绍了可视化电网和潮流研究的简要历史。可视化电网是最新的研究成果,也是今后电力系统潮流计算、研究的方向。其中关于潮流管理、网络控制、电力市场环境下的线路阻塞、三维网络图、市场力等问题都是很新的。第13章“暂态稳定性”的案例研究讲述了美国的大停电,这能使學生更加明确学习本课程的意义,很能激发学生的学习兴趣。

4. 本书附有一张CD光盘,内容是“电力世界仿真器”(Power World Simulator)。Power World Simulator是一个优秀的软件包,能够处理任何规模的电力系统,在大学、公司、政府管理人员、电力市场人员等中被广泛使用。本书的CD在该软件平台上集成了计算例题、问题和课程设计,对学生学习及理解概念和方法很有帮助。

5. 每章都有丰富的习题和问题,有助于学生理解课程内容和基本概念。特别是书中还安排了6个课程设计(Design Project),如“设计电力系统规划”、“潮流/短路研究”等,学生可借助于Power World Simulator来完成这些设计。而在国内教学中,设计这一项基本被取消了。实际上,对于工科大学生来说,这是很重要的。本书中的设计(Design)内容,很值得国内教学借鉴。

本书两位作者都来自美国东北大学,该校在电力方面的教学和科学研究是比较优秀的。作者编写本书时,同时也吸收了其他院校的一些教学成果。

本书适合作为本科电力系统或电气工程专业,以及机电类专业“电气工程”相关课程的双语教学教材,也可作为相关专业研究生或电气工程师的参考书。

清华大学

周双喜

2004年5月

**TO LOUISE**

Love cannot remain by itself—it  
has no meaning.

Love has to be put into action and  
that action is service.

Whatever form we are,  
able or disabled,  
rich or poor,  
it is not how much we do,  
but how much love we put in the  
doing;  
a lifelong sharing of love with  
others.

*Mother Teresa*

## P R E F A C E

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The objective of this book is to present methods of power system analysis and design, particularly with the aid of a personal computer, in sufficient depth to give the student the basic theory at the undergraduate level. The approach is designed to develop students' thinking process, enabling them to reach a sound understanding of a broad range of topics related to power system engineering, while motivating their interest in the electrical power industry. Because we believe that fundamental physical concepts underlie creative engineering and form the most valuable and permanent part of an engineering education, we highlight physical concepts while giving due attention to mathematical techniques. Both theory and modeling are developed from simple beginnings so that they can be readily extended to new and complex situations.

This edition of the text has four new features: case studies for 12 chapters describing present-day, practical applications including ample coverage of the ongoing restructuring of the electric utility industry; the integration of PowerWorld Simulator (PW Simulator), a user-friendly power system analysis and simulation software package, with the text; six design projects including four at the end of Chapter 6, one that begins at the end of Chapter 6 and continues at the end of Chapters 7 and 9, and one at the end of Chapter 9; and updated as well as additional problems at the end of each chapter. Also, in response to a questionnaire sent to a number of power-engineering educators, Symmetrical Components covered in Chapter 3 of the first two editions has been moved to Chapter 8 in this edition, just before Unsymmetrical Faults.

One of the most challenging aspects of engineering education is giving students an intuitive feel for the systems they are studying. Engineering systems are, for the most part, complex. While paper-and-pencil exercises can be quite useful for highlighting the fundamentals, they often fall short in imparting the desired intuitive insight. To help provide this insight, a CD enclosed with the book contains PW Simulator, which is used to integrate computer-based examples, problems, and design projects throughout the text.

PW Simulator was originally developed at the University of Illinois at Urbana-Champaign to teach the basics of power systems to nontechnical people involved in the electricity industry, with version 1.0 introduced in June 1994. The program's interactive and graphical design made it an immediate hit as an educational tool, but a funny thing happened—its interactive and graphical design also appealed to engineers doing analysis of real power systems. To meet the needs of a growing group of users, PW Simulator was commercialized in 1996 by the formation of PowerWorld Corporation. Thus



while retaining its appeal for education, over the years PW Simulator has evolved into a top-notch analysis package, able to handle power systems of any size. PW Simulator is now used throughout the power industry, with a range of users encompassing universities, utilities of all sizes, government regulators, power marketers, and consulting firms.

In integrating PW Simulator with the text, our design philosophy has been to use the software to extend, rather than replace, the fully worked examples provided in previous editions. Therefore, except when the problem size makes it impractical, each PW Simulator example includes a fully worked hand solution of the problem along with a PW Simulator case. This format allows students to simultaneously see the details of how a problem is solved and a computer implementation of the solution. The added benefit from PW Simulator is its ability to easily extend the example. Through its interactive design, students can quickly vary example parameters and immediately see the impact such changes have on the solution. By reworking the examples with the new parameters, students get immediate feedback on whether they understand the solution process. The interactive and visual design of PW Simulator also makes it an excellent tool for instructors to use for in-class demonstrations. With the many examples and problem cases contained on the CD, instructors can easily demonstrate many of the text topics. Additional PW Simulator functionality is introduced in the text examples, problems, and design projects.

The text is intended to be fully covered in a two-semester or three-quarter course offered to seniors and first-year graduate students. The organization of chapters and individual sections is flexible enough to give the instructor sufficient latitude in choosing topics to cover, especially in a one-semester course. The text is supported by an ample number of worked examples covering most of the theoretical points raised. The many problems to be worked with a calculator as well as problems to be worked using a personal computer have been expanded in this edition.

As background for this course, it is assumed that students have had courses in electric network theory (including transient analysis) and ordinary differential equations and have been exposed to linear systems, matrix algebra, and computer programming. In addition, it would be helpful, but not necessary, to have had an electric machines course.

After an introduction to the history of electric power systems along with present and future trends, Chapter 2 on fundamentals orients the students to the terminology and serves as a brief review. The chapter reviews phasor concepts, power, and single-phase as well as three-phase circuits.

Chapters 3 through 6 examine power transformers, transmission-line parameters, steady-state operation of transmission lines, and power flows including the Newton–Raphson method. These chapters provide a basic understanding of power systems under balanced three-phase, steady-state, normal operating conditions.

Chapters 7 through 10, which cover symmetrical faults, symmetrical components, unsymmetrical faults, and system protection, come under the

general heading of power system short-circuit protection. Chapter 11 is a self-contained chapter on power system controls, including turbine-generator controls, load-frequency control, economic dispatch, and optimal power flow.

The last two chapters examine transient operation of transmission lines, including surge protection; and transient stability, which includes the swing equation, the equal-area criterion, and multimachine stability. These self-contained chapters come under the general heading of power system transients.

## **ACKNOWLEDGMENTS**

The material in this text was gradually developed to meet the needs of classes taught at universities in the United States and abroad over the past 25 years. The 13 chapters were written by the first author, J. Duncan Glover, who is indebted to many people who helped during the planning and writing of this book. The profound influence of earlier texts written on power systems, particularly by W. D. Stevenson, Jr., and the developments made by various outstanding engineers are gratefully acknowledged. Details of sources can only be made through references at the end of each chapter, as they are otherwise too numerous to mention.

The examples and problems using PW simulator were provided by Thomas Overbye, *University of Illinois at Urbana-Champaign*, one of the creators of PW Simulator and a board member of PowerWorld Corporation. Professor Overbye also provided three of the design projects in the text. Mulukutla Sarma, *Northeastern University*, contributed to end-of-chapter problems.

We commend William Stenquist and Heather Shelstad of Brooks/Cole for their broad knowledge, skills, and ingenuity in publishing this edition. The reviewers of the third edition are as follows: Sohrab Asgarpour, *University of Nebraska-Lincoln*; Mariesa L. Crow, *University of Missouri-Rolla*; Ilya Y. Grinberg, *State University of New York, College at Buffalo*; Iqbal Husain, *The University of Akron*; W. H. Kersting, *New Mexico State University*; John A. Palmer, *Colorado School of Mines*; Satish J. Ranada, *New Mexico State University*; and Shyama C. Tandon, *California Polytechnic State University*.

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In conclusion, the objective in writing this text and the accompanying software package will have been fulfilled if the book is considered to be student-oriented, comprehensive, and up to date, with consistent notation and necessary detailed explanation at the level for which it is intended.

## LIST OF SYMBOLS, UNITS, AND NOTATION

---

Symbol	Description	Symbol	Description
$a$	operator $1/\angle 120^\circ$	$P$	real power
$a_t$	transformer turns ratio	$q$	charge
$A$	area	$Q$	reactive power
$A$	transmission line parameter	$r$	radius
$A$	symmetrical components transformation matrix	$R$	resistance
$B$	loss coefficient	$R$	turbine-governor regulation constant
$B$	frequency bias constant	$\mathbf{R}$	resistance matrix
$B$	phasor magnetic flux density	$s$	Laplace operator
$B$	transmission line parameter	$S$	apparent power
$C$	capacitance	$S$	complex power
$C$	transmission line parameter	$t$	time
$D$	distance	$T$	period
$D$	transmission line parameter	$T$	temperature
$E$	phasor source voltage	$T$	torque
$E$	phasor electric field strength	$v(t)$	instantaneous voltage
$f$	frequency	$V$	voltage magnitude (rms unless otherwise indicated)
$G$	conductance	$V$	phasor voltage
$G$	conductance matrix	$\mathbf{V}$	vector of phasor voltages
$H$	normalized inertia constant	$X$	reactance
$H$	phasor magnetic field intensity	$\mathbf{X}$	reactance matrix
$i(t)$	instantaneous current	$Y$	phasor admittance
$I$	current magnitude (rms unless otherwise indicated)	$\mathbf{Y}$	admittance matrix
$I$	phasor current	$Z$	phasor impedance
$\mathbf{I}$	vector of phasor currents	$\mathbf{Z}$	impedance matrix
$j$	operator $1/\angle 90^\circ$	$\alpha$	angular acceleration
$J$	moment of inertia	$\alpha$	transformer phase shift angle
$l$	length	$\beta$	current angle
$l$	length	$\beta$	area frequency response characteristic
$L$	inductance	$\delta$	voltage angle
$\mathbf{L}$	inductance matrix	$\delta$	torque angle
$N$	number (of buses, lines, turns, etc.)	$\epsilon$	permittivity
p.f.	power factor	$\Gamma$	reflection or refraction coefficient
$p(t)$	instantaneous power		

Symbol	Description	Symbol	Description
$\lambda$	magnetic flux linkage	$\theta$	impedance angle
$\lambda$	penalty factor	$\theta$	angular position
$\Phi$	magnetic flux	$\mu$	permeability
$\rho$	resistivity	$v$	velocity of propagation
$\tau$	time in cycles	$\omega$	radian frequency
$\tau$	transmission line transit time		

#### SI Units

A	ampere
C	coulomb
F	farad
H	henry
Hz	hertz
J	joule
kg	kilogram
m	meter
N	newton
rad	radian
s	second
S	siemen
VA	voltampere
var	voltampere reactive
W	watt
Wb	weber
$\Omega$	ohm

#### English Units

BTU	British thermal unit
cmil	circular mil
ft	foot
hp	horsepower
in	inch
mi	mile

#### Notation

Lowercase letters such as  $v(t)$  and  $i(t)$  indicate instantaneous values.

Uppercase letters such as  $V$  and  $I$  indicate rms values.

Uppercase letters in italic such as  $V$  and  $I$  indicate rms phasors.

Matrices and vectors with real components such as  $\mathbf{R}$  and  $\mathbf{I}$  are indicated by boldface type.

Matrices and vectors with complex components such as  $\mathbf{Z}$  and  $\mathbf{I}$  are indicated by boldface italic type.

Superscript T denotes vector or matrix transpose.

Asterisk (\*) denotes complex conjugate.

■ indicates the end of an example and continuation of text.

**PW** highlights problems that utilize PowerWorld Simulator.

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