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# 电力系统分析与设计

## Power System Analysis and Design

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华北电力大学 艾欣 改编



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# POWER SYSTEM ANALYSIS & DESIGN

## 电力系统分析与设计

(英文改编版·原书第6版)

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本书讲解了当前电力系统分析与设计的基本方法,展现了最新的实用应用技术。书中还列举了许多详细的实例、插图,涉及大多数已提出的理论点。

为了使学生能够了解理论在现实生活中的应用情况,本书在每章开头新增了案例学习,将当今世界实际的工程应用案例作为每一章的讨论材料。

本书改编后共11章,内容包括电力变压器,输电线路参数,输电线路的稳态运行,潮流计算,常规电力系统短路保护下的对称故障、对称分量、不对称故障,暂态稳定和电力系统控制等。

本书适合作为本科生及研究生电力系统分析课程的教材或教学参考书。

## Power System Analysis and Design

J. Duncan Glover Thomas J. Overbye Mulukutla S. Sarma

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# Preface

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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 processes, 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.

## **NEW TO THIS EDITION**

New chapter-opening case studies bring principles to life for students by providing practical, real-world engineering applications for the material discussed in each chapter.

Comprehensively revised problem sets ensure students have the practice they need to master critical skills.

## **Updated Instructor Resources**

These resources include

- Instructor's Solutions Manual with solutions to all problems
- Comprehensive Test Bank offering additional problems
- Annotated Lecture Note PowerPoint Slides
- Lesson Plans that detail how to most effectively use this edition
- Updated PowerWorld Simulator Software
- Student PowerPoint Notes

New design projects in this edition meet Accreditation Board for Engineering and Technology (ABET) requirements to provide valuable hands-on experience and to help ensure students are receiving an education that meets globally recognized accreditation standards.

The latest version of the valuable PowerWorld Simulator (version 19) is included and integrated throughout the text.

## KEY FEATURES

The text presents present-day, practical applications and new technologies along with ample coverage of the ongoing restructuring of the electric utility industry. It is supported by an ample number of worked examples, including illustrations, covering most of the theoretical points raised. It also includes PowerWorld Simulator version 19 to extend fully worked examples into computer implementations of the solutions. Version 19 includes power flow, optimal power flow, contingency analysis, short circuit, and transient stability.

The text includes a chapter on Power Distribution with content on Smart Grids.

It also includes discussions on modeling of wind turbines in power flow and transient stability.

Four design projects are included, all of which meet ABET requirements.

## POWERWORLD SIMULATOR

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, the book uses PowerWorld Simulator version 19 to integrate computer-based examples, problems, and design projects throughout the text.

PowerWorld 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, PowerWorld Simulator was commercialized in 1996 by the formation of PowerWorld Corporation. Thus while retaining its appeal for education, over the years PowerWorld Simulator has evolved into a top-notch analysis package, able to handle power systems of any size. PowerWorld 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 PowerWorld 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 PowerWorld Simulator example includes a fully worked hand solution of the problem along with a PowerWorld 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 PowerWorld 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 PowerWorld Simulator also makes it an ex-

cellent tool for instructors to use for in-class demonstrations. With numerous examples utilizing PowerWorld Simulator instructors can easily demonstrate many of the text topics. Additional PowerWorld Simulator functionality is introduced in the text problems and design projects.

## PREREQUISITES

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.

## ORGANIZATION

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 revised in this edition.

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

*Chapters 3 through 5* examine power transformers including the per-unit system, transmission-line parameters, and steady-state operation of transmission lines. *Chapter 6* examines power flows including the Newton-Raphson method, power-flow modeling of wind generation, economic dispatch, and optimal power flow. These chapters provide a basic understanding of power systems under balanced three-phase, steady-state, normal operating conditions.

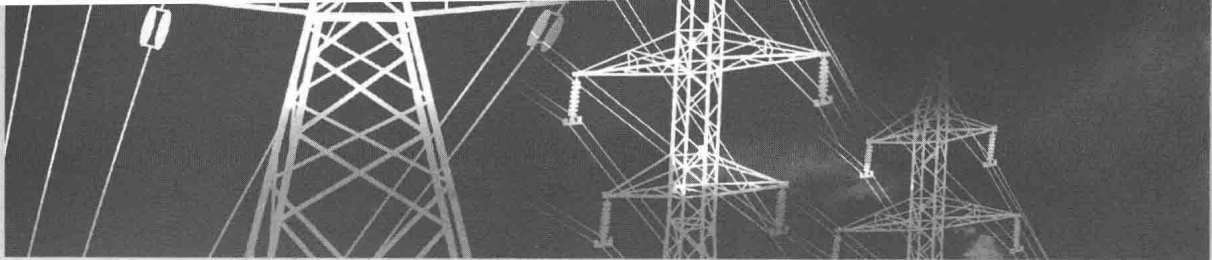
*Chapters 7 through 9*, which cover symmetrical faults, symmetrical components, unsymmetrical faults, and system protection, come under the general heading of power system short-circuit protection. *Chapter 10* examines transient stability, which includes the swing equation, the equal-area criterion, and multi-machine stability with modeling of wind-energy systems. *Chapter 11* covers power system controls, including generator-voltage control, turbine-governor control, and load-frequency control.

*J. Duncan Glover*

*Thomas J. Overbye*

*Mulukutla S. Sarma*





# 前言

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本书讲解了当前电力系统分析与设计的方法，使学生在借助个人电脑的情况下，于本科阶段能够深入了解电力系统的基本理论。这些方法可以培养学生的思维过程，使他们能够深刻地理解与电力系统相关的一系列课题，同时激发他们对电力工业的兴趣。我们坚信基础物理概念是创新工程的基石，也是工程教育中最有价值和最持久的一部分。我们强调物理概念的同时要适当关注数学技术，介绍理论和搭建模型从简单开始，这样学生就可以很容易地将知识扩展到新的和复杂的情况。

## 本版新增内容

为了使学生能够了解理论在现实生活中的应用，章节开头新增案例学习，提供了当今世界实际的工程应用简介作为每一章的讨论材料。

## 最新的指导教师资源

这些资源包括：

- 所有问题解决方案的老师指导手册
- 综合试题库中提供各种附加的问题
- PPT上的演讲注释
- 说明如何能够最有效利用这一版教材的教学计划
- 最新的PowerWorld仿真软件
- 学生的PPT笔记

这个版本中新的设计项目达到了工程与技术认证委员会（ABET）的标准，提供了有价值的实践经验，可以保证学生受到符合全球公认的可信赖标准的教育。

最新版最有价值的PowerWorld仿真软件（19版）也包含并融入其中。

## 主要特点

本书展现了当前的实际应用和新技术，涵盖了很多正在重建的电力行业。书中还列举了许多详细的实例、插图，涵盖了大多数已提出的理论点，介绍了PowerWorld仿真软件的第19版。第19版包含了潮流、最优潮流、偶然性事件分析、短路、暂态稳定，可以将完全处理过的算例用计算机求解实现。

本书包含了一章与智能电网相关的配电内容，还包含了风力发电机在系统潮流及暂态稳定性方面建立模型的若干讨论。另外，本书中有四种满足ABET要求的项目设计。

## PowerWorld 仿真

工程教育中的一大难题是如何令学生对所学系统有一个直观的感受。工程系统绝大部分情况下都是比较复杂的。尽管依靠纸和笔的练习对掌握基础知识很有用，但往往在直观洞察力上有所欠缺。为了给学生提供这种直观的洞察力，本书使用PowerWorld仿真软件第19版来整合基于计算机的算例、问题以及项目设计。

PowerWorld仿真软件最初开发于伊利诺伊大学厄本那香槟分校（UIUC），为从事电力行业的非技术人员提供基本的电力系统知识，软件1.0版于1994年6月开始使用。程序的交互性和图形设计使得该软件作为一种教育工具立即大热，但是一件有趣的事情发生了，它的交互性和图形设计也吸引着工程师用来分析实际的电力系统。为了满足越来越多的用户需求，PowerWorld仿真软件随着PowerWorld公司的成立在1996年正式商业化，同时保留其在教育方面的吸引力。多年来PowerWorld仿真软件已演变成一流的分析软件包，能够处理任意大小的电力系统。PowerWorld仿真软件现在被应用于整个电力行业，用户范围广泛，包括大学、大大小小的公共设施、政府监管机构、电力营销和咨询公司。

在PowerWorld仿真软件与文本的一体化过程中，我们的设计理念已经是使用该软件来扩展的，而不是取代以前版本中提供的完全处理好的例子。因此，除非问题严重到使其无法使用，每一个PowerWorld仿真软件样本都会包含一个全手动解决方案，和相关PowerWorld仿真软件案例。这个模式让学生能看到一个问题是如何解决的，同时看清电脑是如何解决问题的。除此之



外PowerWorld仿真软件还能轻松扩展实例。通过它的互动设计，学生可以快速改变例子中的参数，并即时获取参数对运算方式的影响。通过改变实例中的变量，学生能实时接收到系统反馈，并帮助学生最终理解运算解决过程。PowerWorld仿真软件的交互和视觉设计同样对教师在班级里操作演示是个好工具。教师可通过使用PowerWorld仿真软件里的众多实例轻松演示众多文本话题。更多PowerWorld仿真软件功能在文本问题和设计项目中有介绍。

## 说明

使用本书，应假设学生在开始这门课程之前已经有了电网络理论基础，包括暂态分析和线性系统的常微分方程、矩阵论和计算机编程的背景。此外，学过电机学将对这门课程有所帮助，但不一定是必需的。

## 安排

本书适用于所有的大三及研一学生两学期的教学。书的章节编排和个别内容安排非常灵活，便于导师去选择想要教学的主题，特别是在第一学期中。本书中不仅涵盖了大部分理论知识的实例便于学生去理解，而且这个版本对之前计算难题和计算机难题进行了重新修订。

在电力系统的历史回顾和未来趋势的展望的引言后，第2章帮助学生对基本概念进行了一个简要的回顾。本章回顾了相位的概念、功率以及单相和三相电路。第3~5章研究了电力变压器，包括独立系统、传输线参数以及传输线的稳态运行。第6章研究了潮流计算，包括牛顿-拉夫逊法、风力发电的潮流建模、经济调度以及优化潮流。这几章提供了对电力系统在三相平衡、稳态和正常运行下的基本理解。第7~9章则介绍了在常规电力系统短路保护下的对称故障、对称参数、不对称故障。第10章研究了暂态稳定性，包括摇摆方程式、等面积法则以及考虑风力发电系统的多机稳定性。第11章介绍了电力系统控制，包括发电机电压控制、涡轮调速机控制以及载荷频率控制。



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