
PREFACE

In writing this new textbook, my sincere **hope** is to get the following type of reaction from undergraduates in courses where it is adopted – “Wow, in just one semester, I gained a thorough overview of the entire power systems from generation-to-load and learned the underlying fundamental principles that will be crucial to me as a practicing engineer and a lifelong learner, or if I choose to go into a graduate-level research-oriented career.”

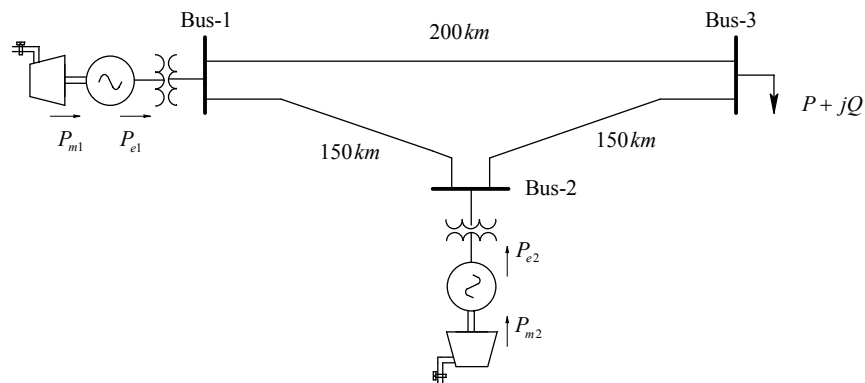
So why write another Power Systems textbook? Power Systems in many respects is a mature subject and many good textbooks abound. However, all textbooks this author is familiar with are written for use in two semesters and/or fail to cover the recent and potential changes in power systems. It is based on the author asking himself the following question: if students were to take **just one course** on Power Systems in their undergraduate curriculum, what knowledge should they graduate with that will be most helpful to them? This textbook is in response to this question and takes a balanced approach to cover many more topics in a way that also provides a deeper understanding of the subject matter in just a **one-semester** course.

A selected list of covered topics, some of them new, which are becoming increasingly important in present and future power systems, is as follows:

1. Changing Power Systems Landscape. Distributed generation (DG) (Chapter 1)
2. Energy sources including Renewable; Environmental Consequences (Chapter 2)
3. Loadability of transmission lines (Chapter 4)
4. High Voltage DC (HVDC) Transmission lines (Chapter 7)
5. Power Electronics based FACTS devices and their applications (Chapter 7)
6. Utility Loads: Voltage dependence and Power Factor; Power Quality (Chapter 8)
7. Synchronous generators and how they supply reactive power (Chapter 9)
8. Voltage Regulation and Stability; means to prevent voltage collapse (Chapter 10)
9. Qualitative discussion of Dynamic Stability (Chapter 11)
10. Automatic Generation Control (AGC); simulation using *Simulink* (Chapter 12)
11. Switching Transients and their calculations using *EMTDC* (Chapter 14)

A Simple Example Power System: The author was recently asked by a student the following question: “I am about to graduate and return to my native country where my

family expects me to help design a much needed power infrastructure. I have taken courses in the energy related area here. Would I able to design such a system?" My answer was that it takes a great deal of combined experience of many experts to design a power system; taking a few courses by itself is not sufficient. However, it made me think that this question, although unique to this student, is pertinent to students all over the world, be it from developing countries or from countries where there is a huge basic infrastructure that is evolving, such as in the United States. Therefore, what if we teach students to design a simple 3-Bus power system as shown below which can be designed with paper-and-pencil and some simple computer programs specifically written for this objective, but that can be generalized to a very large interconnected system with buses that number in thousands?



A 345-kV Example System.

Most of the topics in this textbook are covered with this example system in mind and they have been generalized to an n-Bus system.

What to cover? The intent of the course for which this textbook is designed is to teach students the basic fundamental concepts in Power Systems. But there are dilemmas. Take the case of Power Flow using Newton-Raphson method. Should we cover this method at all, rationalizing our decision on the basis that several professional tools are already available and most students are going to use such software rather than designing it? Although the answer to the preceding question is clear, this author would argue that we are not teaching in a trade school (needless to say there is nothing wrong with that, if that's the mission) and we shouldn't leave this subject completely as a "black box". However, we should teach it in a balanced manner perhaps covering it in 3 lectures rather than in 3 weeks. The same argument applies in covering many other topics.

Role of Software: Extending the earlier discussion further, if we agree to teach Newton-Raphson method for calculating power flow, it will be a total waste to do so without a simple numerical example. This is where *MATLAB* and *Simulink* (or similar software)

can play an important role. *MATLAB* and *Simulink* are widely used in universities and students are often familiar with them prior to taking this course.

State-of-the-Art Software:

A win-win situation is if a simulation example of power flow in *MATLAB*, for example, is verified by a commercial software *PowerWorld*, whose evaluation version is free for educational purposes. Having done so, what-if type of studies can be done using this highly graphical software. This is the approach followed in this textbook, where the use of *PowerWorld* is made for power flow and fault-current calculations. *Simulink* is used for inter-area dynamic oscillations. Unfortunately, no easily accessible and free software for educational purposes is available for transient stability studies. Therefore, *MATLAB* is utilized on the 3-Bus example test power system. For switching transient calculations, writing a software code is impractical in a first course on Power Systems, and thus a software called *PSCAD/EMTDC* that is widely accepted in industry is used, whose evaluation version is free for educational purposes.

SOFTWARE LABORATORY

The course for which this book is written is intended to be accompanied by a laboratory component. In the past, such laboratories consisted of hardware experiments. However, unlike for the courses in Power Electronics and Electric Drives, it is difficult to design a hardware laboratory for Power Systems that is a tight accompaniment to the lecture course. Rather, a software laboratory is much better suited to illustrate and validate the concepts learned in lectures. Based on this rationale, a software laboratory is developed, and the Manual that contains the Lab Exercises based on the Software Examples are supplied on the accompanying CD to this book. The connection between the book chapters and the laboratory exercises is shown in the Table below over a typical 13-week period.

<u>Week</u>	<u>Book Chapters</u>	<u>Laboratory</u>
1	Chapter 1: Overview Chapter 2: Energy Sources	Lab 1: Visit to a local substation; otherwise a virtual substation
2	Chapter 3: Fundamentals	Lab 2: Introduction to <i>PSCAD/EMTDC</i> ; 3-phase circuits, vars, power-factor correction
3	Chapter 4: Transmission Lines	Lab 3: Transmission Lines using <i>PSCAD-EMTDC</i>
4	Chapter 5: Power Flow	Lab 4: Power Flow using <i>MATLAB</i> and <i>PowerWorld</i>
5	Chapter 6: Transformers	Lab 5: Including Transformers in Power Flow using <i>PowerWorld</i> and <i>MATLAB</i>

6	Chapter 7: HVDC, FACTS	Lab 6: Power Converters and HVDC using <i>PSCAD-EMTDC</i> , HVDC in <i>PowerWorld</i>
7	Chapter 8: Distribution Systems	Lab 7: Power Quality using <i>PSCAD-EMTDC</i>
8	Chapter 9: Synchronous Generators	Lab 8: Synchronous Generators and AVR using <i>PSCAD-EMTDC</i> .
9	Chapter 10: Voltage Stability	Lab 9: Voltage Regulation using <i>PowerWorld</i>
10	Chapter 11: Transient Stability	Lab 10: Transient Stability using <i>MATLAB</i>
11	Chapter 12: Interconnected Systems, Economic Dispatch	Lab 11: AGC using <i>Simulink</i> , and Economic Dispatch using <i>PowerWorld</i>
12	Chapter 13: Short-Circuit Faults, Relays, Circuit Breakers	Lab 12: Transmission Line Faults using <i>PowerWorld</i> and <i>MATLAB</i>
13	Chapter 14: Transient Over-Voltages, Surge Arrestors, Insulation Coordination	Lab 13: Over-voltages and Surge Arrestors using <i>PSCAD-EMTDC</i>

CD-ROM

The accompanying CD-ROM includes the following:

- Extremely useful for Instructors: PowerPoint-based slides in PDF format are included for every chapter to quickly prepare lectures and to review the material in class. All the slides on this accompanying CD can be printed.
- Student (Evaluation) versions of *PowerWorld* and *PSCAD/EMTDC* that are sufficient for educational purposes and are ready-to-use; nothing to download or purchase.
- Ready-to-execute examples using *PowerWorld* and *PSCAD/EMTDC*.
- Simulations and design examples using *MATLAB* and *Simulink*.
- Laboratory Manual containing all the Laboratory Exercises.

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During the course of writing this textbook over several years, the author has benefited from the knowledge and advice of several individuals – many of them I consider my mentors. In the recent months leading to the publication of this book, I sincerely appreciate the help of two individuals from industry and academia: Jack Christofersen (retired after over 40 years of experience in the utility industry and now an independent consultant) who believed in this project from its inception and took a deep interest in its success, and Professor Ani Golé of the University of Manitoba for once again introducing me to *PSCAD/EMTDC*. I would also like to take this opportunity to thank my graduate students and post-docs with whom I often interacted and who have provided me their unique perspectives which I believe have been very influential in molding this book.

SUGGESTED REFERENCE BOOKS:

Over the years, this author has immensely benefited from the following books (in no particular order) and their authors are my teachers. These are excellent books that are highly recommended as references in this course:

1. [Electric Utility Systems and Practices, 4th Edition](#) by Homer M. Rustebakke (Editor), John Wiley & Sons, August 1983.
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