

IE 590 Power Systems and Smart Grid

Instructor: Dr. Andrew L. Liu

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Office Hours: MWF, 2:00 – 3:00 PM, GRIS326

Course Information

Term: Spring, 2012

Time: MWF 12:30 – 1:20 PM

Location: Potter 268

Course Webpage: Blackboard

TA #1 – Jingjie Xiao

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Location: GRIS 244

TA #2 – James Okullo

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Course Description

This course serves as a graduate entry-level introduction to the broad subject of power systems. It will focus on the economic fundamentals of power systems and electricity markets, instead of on the electric engineering aspects. The course will cover the basics of electricity, electricity generation, economics of supply and demand, and the various aspects of electricity market operations in both regulated and deregulated environment. The other part of the course will concentrate on introducing the concepts of various components of Smart Grid, and their impacts on the energy industry, including renewables integration, PHEV penetration, demand side management, and greenhouse gas (GHG) emissions reductions. Energy policy modeling and analysis, such as policies on GHG emissions reductions and incentives to green energy investments, will be integrated into the course as well.

Prerequisites

This course will be self-contained, with minimal requirements on graduate-level training. However, undergrad-level training in calculus and linear algebra is required. Advanced training in Operations Research (especially Optimization), Economics, or Electrical Engineering, though not required, will certainly be an asset. Sufficiency in Excel (or the equivalent) and in at least one mathematical package (Matlab, Maple, etc) or modeling language (AMPL, GAMS, etc) is expected.

Course Goals

This course has three main objectives. The first is to provide the students a systems perspective of modern electricity markets and a systems approach to address various issues faced by the electricity sector. The second is to provide the students an in-depth knowledge of how electricity markets operate from short-term system dispatch to long-term asset investments. The third is to present the student a vision of how Smart Grid will transform the current electricity grid to a reliable and sustainable modern energy system.

Learning Objectives

At the conclusion of this course, the students should be able to:

- Understand the structure of an electricity market in either regulated or deregulated market conditions.
- Understand how (wholesale) electricity is priced in a transmission network.
- Evaluate the trade-off between economics and reliability of an electric power system.
- Understand the impacts of renewable resources to the grid and the various issues associated with integrating such resources to the grid.
- Evaluate various investment options (e.g. generation capacities, transmission, renewables, demand-side resources, etc) in electricity markets.
- Understand the concepts and principles of Smart Grid, technology enabling, and demand participation.

Textbooks

(Note: All of the books listed below are available online through Purdue's library)

- Power Systems Economics
 - **Fundamentals of Power System Economics, by D. S. Kirschen and G. Strbac. Reprinted edition. John Wiley & Sons Ltd. 2009. (Highly recommended)**
 - Power System Economics: Designing Markets for Electricity, by S. Stoft, Wiley-Interscience, 2002. (Reference)
 - Electric Power Planning for Regulated and Deregulated Markets, by A. Mazer. John Wiley & Sons, Inc, 2007. (Reference)
 - Understanding Electric Utilities and De-Regulation, by Philipson and Willis. 2nd Edition, Taylor & Francis Group, 2006. (Reference)
- Power Systems (Engineering Aspects)
 - **Renewable and Efficient Electric Power Systems, by G. M. Masters. John Wiley & Sons, Inc. 2004. (Highly recommended)**
 - Electric Power System Basics for the Nonelectrical Professional, by S. W. Blume, Wiley-Interscience, 2007. (Recommended for students without formal training in electrical engineering)
 - Electric Power Systems: A Conceptual Introduction, by A. von Meier. Wiley-IEEE Press; 1st edition, 2006). (Reference)
 - Power Generation, Operation, and Control, by A. J. Wood and B. F. Wollenberg. 2nd edition, John Wiley & Sons, Inc, 1996. (Reference)
- Optimization (The following books are highly recommended for students without formal training in optimization)
 - Optimization Principles: Practical Applications to the Operation and Markets of the Electric Power Industry, by N. S. Rau. Wiley-IEEE Press, 2003.
 - Introduction to Applied Optimization, by U. Diwekar. Springer, 2008.

There will be more reading materials (academic papers, reports, etc) to be posted on Blackboard.

Policies

Homework, Exam and Project

- Homework: Problem sets will be given approximately once every two weeks, and will be due in two weeks, unless stated otherwise.
- Midterm Exam: There will be 1 take-home mid-term exam. The students will be given 2 weeks to complete the exam.
- Final Project: There will be one final project to deliver in the final week of the semester. The project should be delivered in the form of a written report, and is due by May 4th, 2012. The students can choose one topic to work on from a list of topics, to be provided by the instructor. The students are strongly encouraged to plan their final project at the BEGINNING of this course.

Note for distance students:

- All assignments are expected to be sent to the instructor in PDF format through email attachments. Please contact the instructor as soon as possible if such an option is not feasible to you.
- When sending files electronically, please use the following naming convention.
 - o For homeworks, name your file as "ie590_PSSG_hw#_YourLastName.pdf". where "#" is to be replaced by the number of the homework assignment. For example, suppose your last name is Johnson. For homework assignment number 2, you should name your file as "ie590_PSSG_hw2_Johnson.pdf".
 - o For the midterm, name your file as "ie590_PSSG_exam_YourLastName.pdf".
 - o For the final project, name your file as "ie590_PSSG_project_YourLastName.pdf".

Grading

- Homework: 35%
- Mid-term: 30%
- Final project: 35%

Late Work

Late homeworks, exam or project in general will not be accepted, unless there are legitimate reasons. Should a student anticipate that he or she cannot turn in the assignment on time, they must inform the instructor BEFORE the assignment's due date.

Communication for Off-Campus Students

- Distance students can contact the instructor through emails 7 days a week, and you should in general receive a reply within 24 hours.

- When sending the instructor emails, please make sure to cc BOTH TAs as well, unless the content is meant to be read by the instructor only.

Academic Dishonesty

Purdue prohibits "dishonesty in connection with any University activity. Cheating, plagiarism, or knowingly furnishing false information to the University are examples of dishonesty." [Part 5, Section III-B-2-a, University Regulations] Furthermore, the University Senate has stipulated that "the commitment of acts of cheating, lying, and deceit in any of their diverse forms (such as the use of substitutes for taking examinations, the use of illegal cribs, plagiarism, and copying during examinations) is dishonest and must not be tolerated. Moreover, knowingly to aid and abet, directly or indirectly, other parties in committing dishonest acts is in itself dishonest." [University Senate Document 72-18, December 15, 1972]

Further information on Purdue's student guide for academic integrity can be found at <http://www.purdue.edu/odos/aboutodos/academicintegrity.php>.

Attendance

On-campus students are expected to be present for every meeting of the classes. When absences of legitimate reasons can be anticipated, the student should inform the instructor of the situation as far in advance as possible.

Grief Absence Policy for Students

Purdue University recognizes that a time of bereavement is very difficult for a student. The University therefore provides the following rights to students facing the loss of a family member through the Grief Absence Policy for Students (GAPS). GAPS Policy: Students will be excused for funeral leave and given the opportunity to earn equivalent credit and to demonstrate evidence of meeting the learning outcomes for misses assignments or assessments in the event of the death of a member of the student's family.

Emergencies

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.

Tentative Class Schedule

Major Topics	Sub-Topics
The basics and the supply side of electricity (Week 1)	- Basics of electricity - Fossil fuel and hydro power plants - Renewable and alternative energy - Supply curve
The demand side of electricity (Week 2)	- Load characteristics - Load curve and load duration curve - Demand side management - Plug-in hybrid vehicles and smart appliances
The economics of supply and demand in energy markets (Week 3 – 5)	- Review of optimization (linear and nonlinear programming) - Modeling the consumers and producers - Market equilibrium - Long-run vs. short-run costs - Energy market deregulation
Transmission and distribution networks (Week 6 – 8)	- Physical laws of electricity; AC vs. DC Power flow - Optimal power flow and unit commitment models - Locational marginal prices - Distribution network basics - Guest lecture
System reliability (Week 9 – 12)	- Ancillary services - Investments in generation and transmission - Long-term planning
Renewable integration and investment valuation (Week 12 – 14)	- Renewable integration: dealing with short-term variation - Renewable integration: impacts on long-term reliability - Price forecasts and investment valuation - Guest lecture
Smart Grid (Week 15 – 16)	- Key characteristics of Smart Grid - Demand-side participation and dynamic pricing - Impacts of Smart Grid on reliability - Impacts of Smart Grid on air pollutant emissions reduction - Guest lecture

Note: This syllabus is subject to change by the instructor. Any changes will be notified to the students promptly.