EEEL E4220: Energy System Economics and Optimization – Fall 2024

Learning Outcomes:
Upon completing this course, the student should be able to:

- Define and discuss the major problems in power system economics
- Formulate these problems as optimization problems
- Solve simple power system optimization problems by hand
- Use optimization packages to solve more complex problems
- Describe the various types of electricity markets and discuss their purposes
- Discuss bidding strategies in electricity markets with perfect and imperfect competition
- Explain and calculate locational marginal prices
- Explain and the economic pros and cons of different energy resources
- Discuss the factors that affect energy system investments

Pre-requisites:

- Senior standing
- Basic linear algebra and calculus
- Programming experiences using Python or a similar language

Time: Mon, Wed 10:00 am – 11:30 pm; **Classroom:** Uris 326

Instructor: Bolun Xu
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Email: bx2177@columbia.edu
Office hours: Tue 3:00 pm – 4:00 pm

Teaching Assistant: Liudong Chen
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Office hours: Fri 1:00 pm – 2:00 pm @ Mudd 918 Project Room

Grader: Arihant Jain
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Grading:		
	Homework:	40%
	Midterm:	30%
	Final project:	20%
	Participation (market experiments):	10%

All group communications will take place through **Courseworks**, use it to

- Check for announcements
- Get lecture slides and other material
- Get homework and project assignments
- Submit your homework and check grades

Textbooks [All Available Online via Columbia Library]:

Required**:** **K&S:** Kirschen & Strbac: Fundamentals of Power System Economics, Second Edition, Wiley, 2018

Supplemental: **M:** Masters: Renewable and Efficient Electric Power Systems, Wiley 2004
C&B: Conejo & Baringo: Power System Operations, Springer 2018

Tentative timetable of topics:

Week 1	9/2	Labor day	
	9/4	Introduction	M Ch3.1-3.2, D&S Ch1
Week 2	9/9	Basic concepts from economics	D&S Ch2.1-2.3
	9/11	Basic concepts from economics	D&S Ch2.4-2.6
Week 3	9/16	Organization of electricity markets	D&S Ch3
	9/18	Risks, markets, and contracts	
Week 4	9/23	Contracts	
	9/25	Class cancelled	
Week 5	9/30	Electricity markets	
	10/2	Linear programming and economic dispatch	C&B Ch7
Week 6	10/7	Inequality constraints	
	10/9	Solution algorithms for economic dispatch	
Week 7	10/14	Unit commitment	
	10/16	Mixed-integer linear programming	D&S Ch5.1-Ch5.3.4
Week 8	10/21	Class cancelled	
	10/23	**Midterm**	
Week 7	10/21	Introduction to power flow	D&S Ch5.3.5
	10/28	Transmission in electricity markets	D&S Ch4
Week 8	10/30	Security constrained economic dispatch	
	11/6	Nodal prices	D&S Ch6
Week 9	11/11	Nodal pricing and FTR	M6.1-6.5,6.11,8.5,9.4-9.6
	11/13	Participating electricity markets	
Week 10	11/18	Equilibrium models	
	11/20	No class	
Week 11	11/25	Power system operations	D&S Ch8
	11/27	Ancillary service markets	
Week 12	12/2	Renewables and storage	
	12/4	Project presentation	
Week 13	12/9	Project presentation	

Homework

Due Fridays at 11:59 PM ET. Submission by file upload via Courseworks Assignment, Jupyter Notebook is **required** to complete the homework. Please submit both the .**ipynb** file and the .**html** file output (or .pdf file if your solution includes external files) to Coursework. Failure to submit .html or .pdf file will reduce 10% of your homework grade assuming the TA or grader can grade your homework successfully using the submitted. ipynb file. Failure to submit. ipynb file will be treated as incomplete submission and receive zero grade for the homework.

Each homework counts toward 5% of the final grade. Homework submitted after the due date will be charged 10% late penalty (0.5% final grade); no homework accepted after Saturday.

Homework	Topics	Due date
HW0	Python backgrounds and optimization set-up	9/13
HW1	Supply and demand	9/20
HW2	Markets and settlements	9/27
HW3	Contracts	10/4
HW4	Basic optimization	10/11
HW5	Economic dispatch	10/18
HW6	Transmission and congestions	11/1
HW7	Market participation and equilibriums	11/8

Midterm

Midterm exam will be a 90-minute in-class exam. Students can bring **a calculator and a A-4 page cheat sheet**, no other reference material will be allowed. A sample exam from the previous year is available on Coursework. The cheat sheet should be single-sided and handwritten only.

Optimization Software

We will be using Python to solve optimization problems, the set-up in this course is Jupyter Notebook + Python + CVXPY. Please check on Courseworks -> Files -> Optimization_Setup for set-up instructions. Optimization will be required for HW4 to HW7, and the final project.

Market experiments

Participation of market experiments counts towards 10% of the total course credit as participation. Market experiment results will be recorded and the top 3 will receive 3% extra total course credits.

Project

Students are expected to work in **a group of three** over a project topic either provided by the course or self-defined. Please check coursework for course provided project topics. Self-defined project topics are high encouraged but should meet the following requirements:

- Related to energy system

- Involve the use of economics metrics relevant to this course
- Involve the use of optimization techniques relevant to this course

Groups interested in working on self-defined topics should draft a one-page proposal specifying project motivation, data source, and expected outcomes.

Contribution Evaluation. All students will separately complete a questionnaire asking to rate teammates and highlight issues such as a particular teammate is not contributing to the project. While students from the same project group will share the project grade by default, modifications will be made if the instructor deems there is a significant disparity in the contribution to the project.

Deadlines: Teaming and project topic proposal is due on November 1rd, one week after the midterm exam. The final project report is due on **Friday, December 13th**. No later submission will be accepted.

Honor Code:

Please revise the Columbia SEAS Honor Code: https://www.wikicu.com/SEAS_Honor_Code

Homework: Students are encouraged to work together, but homework write-ups must be done individually and must be entirely the author's own work.

Project: Groups can communicate their approach conceptually, but each group must finish the calculation, coding, and the report by their group members only.

Exam: No form of collaboration or communication is allowed for the exam.

Please contact TA or the course instructor if you have any questions.

Grading:

Presentation 30%
Formulation 20%
Code format 10%
Result analysis 40%

Grade distributions (curve up is possible depends on the grade distribution):

A+	97%
A	94%
A-	90%
B+	87%
B	84%
B-	80%
C+	77%
C	74%
C-	70%
D	< 70%