Economics of Modern Power Systems

ENV 790.05

Nicholas School of the Environment - Duke University
Fall 2020

Class Hours: On-line assynchronus (pre-recorded classes will be posted on Mondays)

Office hours: TBD (meeting time will be used for Q&A and/or class discussions)

Instructor
Luana Medeiros Marangon Lima
Visiting Assistant Professor of Energy and Environmental Sciences and Policy
Office: Gross Hall 101K
e-mail: luana.marangon.lima@duke.edu

Teaching Assistant - Grader only
TBD
e-mail: -
Office hours: None

Course Description and Objectives

The electric power grid is undergoing a major transformation. On the generation side we see an increase in renewable energy penetration driven by the need to reduce CO_2 emissions. On the demand side we face new consumption profiles such as plug-in vehicles, smart homes and smart buildings. The course will focus on the economics of modern power grids to facilitate the integration of these new agents.

Students will learn about the additional strains placed on the existing grids to balance electricity supply and demand. We will discuss energy storage that gained a lot of attention due to the intermittent and fluctuating energy availability from renewable energy sources.

Since most of the transformation is happening at the distribution level we will also talk about distribution network pricing. The pricing mechanism is the key to ensure the success of the

new Smart Grid environment and has an important role in sending economic signals to network users. Yet there is no established practice or common pricing principle that can best serve the industry in the coming period of great change.

Upon completion of this course students will understand how information and communication technology will be incorporated into every aspect of electricity generation, delivery and consumption to minimize environmental impact and improve reliability and efficiency.

Course Prerequisites
Energy Technology (ENVIRON/ENERGY 631) is a prerequisite.

Course Format and Grading
The course consists of pre-recorded lectures and discussion based on the readings. There will be a set of assignments and a journal. Grades will be based on:

- homework assignments (70%);
- journal entries (30%);

Note that there will be no final project this year. Instead I will increase the number of assignments so homework load is evenly distributed throughout the semester. You will work on assignments and journal in groups of two to ensure you are getting to know each other and also getting experience working as a team. Two students cannot work together for more than one week. You should be rotating pairs! More information to come later once I have the final number of enrolled students.

Class Etiquette
You should take responsibility for your education. I expect students to attend every class and get to class on time. If you must enter the class late, please do so quietly. Retain from using phones and tablets for social media during class. Some classes will involve coding on your laptop. I expect you to focus on the assignment and refrain from any web browsing that may disrupt the progress of your work.
Your classmates deserve your respect and support. We will likely have students from many different backgrounds and countries in this class and you should all feel comfortable and make each other comfortable while participating.

Nicholas School Honor Code

All activities of Nicholas School students, including those in this course, are governed by the Duke Community Standard, which states:

"Duke University is a community dedicated to scholarship, leadership, and service and to the principles of honesty, fairness, respect, and accountability. Citizens of this community commit to reflect upon and uphold these principles in all academic and nonacademic endeavors, and to protect and promote a culture of integrity. To uphold the Duke Community Standard:

- *I will not lie, cheat, or steal in my academic endeavors;*
- *I will conduct myself honorably in all my endeavors; and*
- *I will act if the Standard is compromised."*

Please add the following affirmation to the end of all assignments, and sign your name beside it: "I have adhered to the Duke Community Standard in completing this assignment."

Land Acknowledgement

"What is now Durham was originally the territory of several Native nations, including Tutelo (TOO-tee-lo) and Saponi (suh-POE-nee) - speaking peoples. Many of their communities were displaced or killed through war, disease, and colonial expansion. Today, the Triangle is surrounded by contemporary Native nations, the descendants of Tutelo, Saponi, and other Indigenous peoples who survived early colonization. These nations include the Haliwa-Saponi (HALL-i-wa suh-POE-nee), Sappony (suh-POE-nee), and Occaneechi (oh-kuh-NEE-chee) Band of Saponi. North Carolina's Research Triangle is also home to a thriving urban Native American community who represent Native nations from across the United States. Together, these Indigenous nations and communities contribute to North Carolina's ranking as the state with the largest Native American population east of Oklahoma."

Class Communication Format

The communication platform we will use is Slack. It will facilitate communication among instructor and students. We can exchange files, post announcements, students can use to ask questions. It is very user friendly and can be easily accessed from any device. Once I have the class roster I will create a workspace and send an invitation to all the students. My goal here is to be one text message away from you. :)

Class Topics and Proposed Schedule

Tha class topics are divided into ten modules as follows.

1. Introduction to Smart Grid (SG)
2. SG: How electricity distribution will change?
3. SG: How electricity generation will change?
4. Distributed generation & Distributed Energy Resources
5. Rooftop PV + battery study case
6. Solar Industry Outlook
7. Energy Storage Management
8. Economic dispatch under uncertainty
9. Introduction to Network Princing & Operational Expenditure
10. Cost Allocation Methods

Each module will have an assignment associated that could be a simple quiz, a reflection piece or solving a LP model in R, Python or Excel. The readings associated with each module will be posted on Sakai. The proposed schedule below is subject to change. This will be the first time this class is taught online. My initial plan is to cover all the material listed here but I might modify it if extra time is needed for some particular topics. I will provide updates via Sakai or Slack.

Week	Module	Date	Topic
1	1	Aug 17-21	Review of Electric Power Systems: Generator, Transmission, Distribution, Load — "Old" Grids and Its Problems — The Solution: Smart Grid — Introduction to Smart Grids or Modern Power Grids: Definition, Benefits, Opportunities and Challenges
2	2	Aug 24-28	SG from Global Perspective: How energy distribution will change, ICT Perspectives, Smart-meter deployment, End user view, DSO view, AMI deployment experience Vermont and Sweden
3	3	Aug 31 - Sep 4	SG from Global Perspective: How generation will change, paradigm shift, renewable energy sources, challenges of renewable resource integration, Distributed Generation: definition, history, planning and operation

Week	Module	Date	Topic
4	4	Sep 7-11	Distributed Generation: challenges of DG integration, location, power quality and stability — Distributed Energy Resources ,
5	5	Sep 14-18	Rooftop PV study case — Guest Lecture - Hadi Eshraghi (PhD from NCSU) - Model-based Analysis of the US Energy System
6	6	Sep 21-25	Solar Penetration Outlook, The Duck Curve and Possible Solutions
7	7	Sep 28 - Oct 2	Energy Storage Management, Residential PV+battery — Residential PV+battery study case: problem formulation and intro to LP in R using "lpsolveAPI" package
8	7	Oct 5-9	Guest Lecture - Faeza Hafiz (PhD from NCSU) - Storage Management & Impact of DER on grid operation and planning
9	8	Oct 12-16	ED problem with Renewables — Case study - Brazil)
10	9	Oct 19-23	Intro to Network Pricing - Economics of Transmission and Distribuiton Network Pricing - Revenue Requirement (CAPEX + OPEX)
11	9	Oct 26-30	OPEX - Utility benchmark analysis — Data Envelepment Analysis
12	10	Nov 2-6	Energy Week — Distribution Use of System Charges: Cost Allocation Part I - Principles and Assumptions & Cost Allocation Part II - Fixed cost methods — DC Power FLow
13	10	Nov 9-12	Distribution Use of System Charges Cost Allocation Part III - Case Study - Part IV - Incremental/Marginal cost methods