Economics of Modern Power Systems

ENVIRON/ENERGY 590.05

Fall 2021

Class Hours: MW 10:15 to 11:30 am (LSRC A158) (in person)

Office hours: Wed 12:00 - 1:00 pm or by appointment

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

Teaching Assistant - Grader only

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 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 & final project (70%);
- journal entries (30%);

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. There will be 5 assignments. The assignments involve reading and applying concepts and tools learned in class to an specific data set or problem. For the assignment you can choose your own group. But for the journal you will be rotating pairs. Two students should not work together for more than one week. 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 Acknowledgment

"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 it 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

The class topics are divided into nine 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 — Solar Industry Outlook — Rooftop PV Study Case
5. Distributed generation integration challenges
6. Distributed Energy Resources — Energy Storage — Intro to LP in R — Energy Storage Management — Rooftop PV + battery study case
7. Economic dispatch under uncertainty
8. Rate Structure: Introduction to Network Pricing & Operational Expenditure
9. Rate Structure: 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. 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**	**Assignment**
1	1	Aug 23 - 25	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	J1
2	2	Aug 30 - Sep 1	Smart Grid from Global Perspective: How energy distribution will change, ICT Perspectives, Smart-meter deployment, End user view, DSO view, AMI deployment experience Vermont and Sweden	J2
3	3	Aug 31 - Sep 4	Smart Grid from Global Perspective: How generation will change, paradigm shift, renewable energy sources, challenges of renewable resource integration, Distributed Generation: definition, history, planning and operation	J3
4	4	Sep 6-8	Rooftop PV study case — Solar Penetration Outlook — The Duck Curve and Possible Solutions	A1

Week	Module	Date	Topic	Assignment
5	5	Sep 13-15	Distributed Generation: challenges of DG integration, location, power quality and stability	J4
6	6	Sep 20-22	DER: Energy Storage Applications to Power Systems — Intro to LP in R using "lpsolveAPI" package	A2
7	6	Sep 27 - 29	Energy Storage Management, Residential PV+battery — Residential PV+battery study case: problem formulation	A3
8	-	Oct 4-6	Fall break, we will use the class on Wed to work on assignment and/or project	J5
9	7	Oct 11-1	Impact of DER on grid operation/scheduling and planning — ED problem with Renewables — Case study - Hydro-thermal scheduling Brazil	J6
10	8	Oct 18-20	Intro to Network Pricing — Economics of Transmission and Distribution Network Pricing — Revenue Requirement (CAPEX + OPEX)	J7
11	9	Oct 25-27	OPEX - Utility benchmark analysis — Data Envelopment Analysis	A4
12	9	Nov 1-3	Distribution Use of System Charges: Cost Allocation Part I - Principles and Assumptions & Cost Allocation Part II - Fixed cost methods — DC Power Flow	J8
13	-	Nov 8-11	Energy Week - no classes - use that time to attend events and work on project	
14	10	Nov 15-17	Distribution Use of System Charges Cost Allocation Part III - Case Study - Part IV - Incremental/Marginal cost methods	A5
15	-	Nov 22	LDOC - Final Project Presentations	-