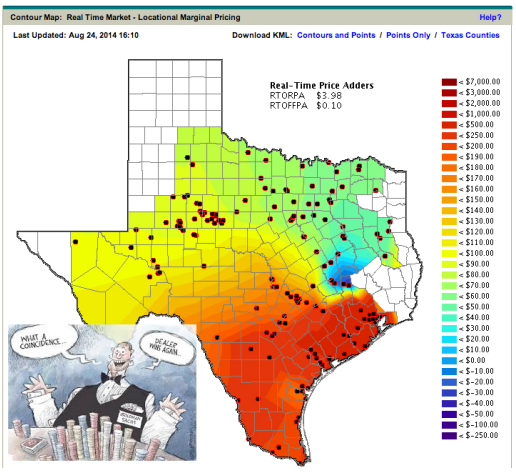
EEL 4930/5934 ***Smart Grid for Sustainable Energy*** Fall 2022

meyn.ece.ufl.edu/smart-grid-for-sustainable-energy

Control, modeling, and markets for the grid of the future

Prof. Sean Meyn, `meyn@ece.ufl.edu` MAEA 0327, Tues 3:00-4:55, Thur 4:05-4:55

**Course topics**




- Overview of electricity demand and supply, industry structure, and renewable energy today. Fundamentals of energy and electric power; a survey of traditional and new energy resources
- Power markets today and tomorrow
- The Grid: What are the characteristics of transmission? How will grid operators of the future make use of newly available online measurements, and new resources such as a vast arsenal of relays and high voltage DC technologies?
- Control on many time-scales: Economic dispatch/unit commitment (scheduling), reserve management, and second by second regulation.

The course is intended for undergraduate *and* graduate students who have some background in control. Experience with *Matlab* is essential.

**Office hours:** Sean Meyn: Tuesdays after lecture, 2:00-3:00 p.m. in 455 NEB
I can be reached for questions by electronic mail at meyn@ece.ufl.edu **(not via e-learning)**
Neil Cammardella: Wednesdays, 1:00-2:30 p.m. in 484 NEB (ncammardella@ufl.edu)

**Exams, homework, etc.** Homework problems will be assigned on a ∼bi-weekly basis, to be handed in at the beginning of class on the date due. They will be graded and returned the following week. *Late homework cannot be accepted.*

There is no final exam! However, *mark your calendars*: there are two evening midterm exams, Oct 12 and Dec 7; 90 minutes each, starting at 7:20pm. You will be allowed *one* sheet of notes ($8\frac{1}{2} \times 11$; both sides) in the first exam, and *two* in the second. Calculators are allowed. Otherwise, the exams are closed-book and closed-notes.

Graduate students will present material from a research paper of their choosing, and will also submit a report.

**Evaluation** Undergraduates: Mid-term exams 75%, homework 25%
Graduate students: Mid-term exams 70%, homework 15%, oral/written project 15%

I encourage collaboration on homework!

## References – Textbooks

- ⊙ Wood, Wollenberg, and Sheblé, *Power Generation, Operation and Control*. 3rd ed., 2013.
  *This is the main text for the course. It contains good introductory material on power systems, control, and markets.*

- ⊙ David MacKay, *Sustainable Energy — without the hot air*. In print 2009, and online at `www.withouthotair.com`
  *Broad issues surrounding energy sustainability.*

- ⊙ Gilbert M. Masters, *Renewable and Efficient Electric Power Systems*. 3rd ed., 2004
  *Encyclopedia of renewable energy facts.*

There is no perfect text for this course. Course notes and other supplementary material will be available at the course website, `http://www.meyn.ece.ufl.edu/courses/sgcourse-2016`

## Other References

- ⊙ Brendan Kirby *The Value of Flexible Generation*, `www.consultkirby.com`
  *Wonderful survey of ancillary service and today's ISO/RTO markets.* Kirby has several other valuable surveys.

- ⊙ G. Wang, M. Negrete-Pincetic, A. Kowli, E. Shafieepoorfard, S. Meyn, and U. V. Shanbhag. *Dynamic competitive equilibria in electricity markets.* In A. Chakrabortty and M. Illic, eds., *Control and Optimization Methods for Electric Smart Grids*, pages 35–62. Springer, 2012. `http://tinyurl.com/ChoMeyn`
  *Class material on competitive markets is based on this book chapter.*

- ⊙ An essay on markets for a general audience may be found here:
  *Addressing misconceptions on the performance of the energy market in Texas*, Utility Dive, April 15, 2021, `https://tinyurl.com/y58ecgg7`

## Course topics — a bit more detail

- ◦ Generation: Dynamics and costs of traditional generators; characteristics of renewables.

- ◦ "Lagrangian relaxations". Basic optimization theory will be developed in lecture. *This is a foundation of much of the remainder of the course.*

- ◦ Resource allocation problems and convex optimization.

- ◦ Economics of Power. "Micro- and Macro-regulation" (WWS Ch. 2); why are power markets so volatile and hostile?

  Competitive Equilibrium Theory of economics and Lagrangian relaxations: static and dynamic settings.

- ◦ Power reserves. Some basic probability is needed. This will be developed in lecture.

- ◦ Ancillary Services — Why they are needed, and how to use them.

  Classification based on bandwidth. New FERC orders to incentivize them.

- ◦ The Grid: Transmission, Distribution, Grid dynamics

  Real and Reactive Power

  DC and AC Power Flow (*for details, take a power systems course*)

- ◦ Demand response: Prices to devices? Buildings as batteries and automated DR.