**EEL 4287- Smart Grid for Sustainable Energy**
**Prerequisite: EEL 4657C**

**EEL 5285- Smart Grid for Sustainable Energy**
**Prerequisite: Linear Controls and Experience with MATLAB.**
**Students may not take this course if they have already taken EEL4287.**

***Class Periods:*** 3 class periods each week consisting of 50 minutes each.
***Location:*** Tuesday Period 7 (1:55 PM - 2:45 PM)
Thursday Period 7-8 (1:55 PM - 3:50 PM)
LAR 0239

***Academic Term:*** Fall 2023

***Instructor:*** Sean Meyn meyn@ece.ufl.edu.
***Teaching Assistant:*** Mario Daniel Baquedano Aguilar m.baquedanoaguil@ufl.edu
Office hours: TBA

***Course Description***
(3 credits) Survey of power grid operations and markets for students with interest in power systems and/or sustainable energy. Characteristics of traditional and new energy resources; how resources impact the grid; control on many time-scales; how the power grid and power markets of tomorrow will differ from those of today.

***Course Objectives***
The student will be able to explain the supply and demand of a power system; to design and analyze innovative policy, regulation, and business models to implement the next-generation grid architectures.

***Materials and Supply Fees***
None

***Required Textbooks and Software***
None

***Recommended Reading***

- Title: Renewable and Efficient Electric Power Systems
  Author: Gilbert M. Masters
  Publication date and edition: 2004, Wiley
  ISBN number: 978-1-118-14062-8

- Title: Sustainable Energy-without the hot air
  Author: David MacKay
  Publication date and edition: available free online: http://www.withouthotair.com/
  ISBN number: 9780954452933

- Title: Power Generation, Operation and Control
  Author: Allen J. Wood, Bruce F. Wollenberg, Gerald B. Sheblé
  Publication date and edition: 3rd edition, 2013, Wiley
  ISBN number: 978-0471790556

| Week | Topics | Reading | Homework |
|---|---|---|---|
| 1 | Course overview. Role of generation beyond electric power. Dynamics and costs of traditional generators; characteristics of renewables. Grid architecture today: ISOs, RTOs, FTRs & CCAs. Why are power markets so volatile and hostile? | MacKay, WWS Ch. 1 & 2 | |
| 2 | Introduction to Economic Dispatch and Optimization.<br><br>Convex optimization for resource allocation: Basic optimization theory will be developed throughout the course. | WWS Ch. 3 Appendix and handouts | #1: Optimization and power flow |
| 3 | Economic dispatch and Lagrangian relaxations. Basics of Unit Commitment. | WWS Ch. 3 | |
| 4 | Dispatch, Markets, Competitive Equilibrium Theory | WWS Ch. 3 / Lecture notes | #2 Lagrangian decomposition |
| 5 | Locational Marginal Prices and the role of dynamics in markets | Lecture notes | #3 Economics and probability review |
| 6 | Introduction to Risk. Some basic probability is needed - to be reviewed in lecture. | WWS Section 4.1 | #4 Optimal reserves and control review |
| 7 | Reserves, value of lost load, probability of blackout: science and critique.<br><br>*Exam 1* | Handouts | |
| 8 | Introduction to grid dynamics with review of Laplace transforms. Introduction to today's distributed grid control architecture | WWS Section 10.2 and 10.5 | #5 Grid level control design |
| 9 | Review of classical control. Primary control (droop) and grid modeling. Introduction to Automatic Generation Control (AGC) | Lecture notes | |
| 10 | AGC and secondary control | WWS Section 10.5-10.7 | #6 Grid level control design |
| 11 | Demand Response today and the role of federal policy. Storage and Virtual Energy Storage (Flexiwatts – latest term since 2019!) | | |
| 12 | How to create grid services from flexible loads. | Lecture notes | #7 Storage and demand response |
| 13 | Energy Storage, Demand Dispatch: Buildings as batteries and automated demand response. The role of policy. | Lecture notes | |

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|---|---|---|---|
| 14 | Grid architectures of the future - how should resources and control architecture change? *Exam 2* | | #8 Demand dispatch |
| 15 | Conclusions and student presentations | | |
| 16 | Conclusions and student presentations | | |

***Attendance Policy, Class Expectations, and Make-Up Policy***

Cell phones and other electronic devices are to be silenced. No text messaging during class or exams.

All exams are closed-book. Calculators are allowed.

The course project is required for graduate students and optional for undergraduates. It is based on a reading of a paper from the literature of your choice, subject to approval of the instructor. The following guidelines must be met:

(a) The report will be about four pages long, *not including any references, illustrations, or computer plots you might want to include*. It should be typed, and double spaced, and 11pt font.
(b) The report will consist of three parts: A summary of the paper considered, a critique, and discussion of possible extensions of the results described in the paper.
(c) The *summary* must be concise — consisting of approximately one page. It should be clear enough to allow a fellow student to understand the main ideas of the paper.
(d) The *critique* should compare the results of the paper to what has been discussed in class, and should indicate the merits/shortcomings of the paper.
(e) *Numerical experiments* are not required, but might be valuable in your critique or the ex- tensions

Make-Up Exam Policy - If you have a University-approved excuse and arrange for it in advance, or in case of documented emergency, a make-up exam will be allowed and arrangements can be made for making up missed work. Otherwise, make-up exams will be considered only in extraordinary cases, and must be taken before the scheduled exam. The student must submit a written petition to the instructor two weeks prior to the scheduled exam and the instructor must approve the petition.

Requirements for class attendance and make-up exams, assignments, and other work in this course are consistent with university policies. Excused absences are consistent with university policies in the undergraduate catalog (https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx) and require appropriate documentation.

***Evaluation of Grades***

| Assignment | % of Final Grade Grads | % of Final Grade Undergrads |
|---|---|---|
| Homework | 15% | 30% |
| Exam 1 | 35% | 35% |
| Exam 2 | 35% | 35% |
| Oral Presentation & Written Project Report | 15% | 0% |
| TOTAL | 100% | 100% |

Note: This course is co-listed with the undergraduate class.

The homework portion of the graduate section will involve additional work and more advanced concepts with respect to the undergraduate section, in the form of one additional problem in some assignments. The exams will involve more advanced concepts with respect to the undergraduate section, in the form of one additional question in each exam. Graduate students will prepare a project report and presentation. Attendance at graduate student presentation is required by all students.

***Grading Policy***

| Percent | Grade | Grade Points |
|---|---|---|
| 93 - 100 | A | 4.00 |
| 90 - 92 | A- | 3.67 |
| 87 – 89 | B+ | 3.33 |
| 83 - 86 | B | 3.00 |
| 80 - 82 | B- | 2.67 |
| 77 - 79 | C+ | 2.33 |
| 73 - 76 | C | 2.00 |
| 70 - 72 | C- | 1.67 |
| 67 - 69 | D+ | 1.33 |
| 63 - 66 | D | 1.00 |
| 60 - 62 | D- | 0.67 |
| 0 - 59 | E | 0.00 |

More information on UF grading policy may be found at:
https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx

***Students Requiring Accommodations***
Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, https://www.dso.ufl.edu/drc) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

***Course Evaluation***
Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at https://evaluations.ufl.edu/evals. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results/.

***University Honesty Policy***
UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (https://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

***Campus Resources:***

*Health and Wellness*

**U Matter, We Care:**

If you or a friend is in distress, please contact umatter@ufl.edu or 352-392-1575 so that a team member can reach out to the student.

**Counseling and Wellness Center:** http://www.counseling.ufl.edu/cwc, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

**Sexual Assault Recovery Services (SARS)**
Student Health Care Center, 392-1161.

**University Police Department** at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.

*Academic Resources*

**E-learning technical suppor***t*, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

**Career Resource Center**, Reitz Union, 392-1601. Career assistance and counseling. https://www.crc.ufl.edu/.

**Library Support**, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

**Teaching Center**, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/.

**Writing Studio, 302 Tigert Hall***,* 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

**Student Complaints Campus***:* https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf.

**On-Line Students Complaints***:* http://www.distance.ufl.edu/student-complaint-process.