ECE WXYZ:
Computational Power System Analysis

Lorem Ipsum University

Fall 2026

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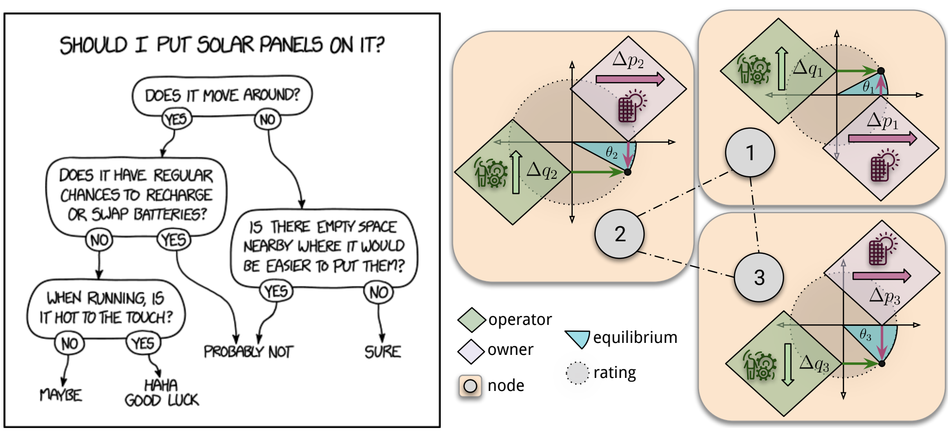
Class Room: Lorem Ipsum XYZ
Class Hours: T/Th 5-6:15pm
Instructor Office: Lorem Ipsum XYZ
Office Hours: Th/F 11:30am-1pm



Simplified and detailed illustrations of what we will learn in the class (leftmost courtesy of xkcd).

Course Description

In this course, we will embark on a journey to unravel the *power flow equations*—the fundamental laws that govern our electric power grid. Despite more than a century of study, many properties of these non-linear equations present captivating engineering challenges. To this day, just counting the total number of solutions is still an unsolved mystery. Together, we will dive deep into the mathematical structure of these equations, explore their various representations, and learn how to harness scientific computing techniques to find practical solutions that power our world.

Learning Objectives

By the end of this class, you will be well-prepared to **computationally model power flow** in electrical networks and integrate these models into engineering decision-making processes. We will have a special emphasis on modern appplications of interest, like optimization, control, and statistical analysis. These skills are crucial for addressing present and future real-world challenges such as integrating renewable energy sources, optimizing the efficiency of the power grid, and bolstering the grid's resilience to unexpected extremes.

Moreover, we will explore surprising and exciting connections between power systems and broader mathematical fields like graph theory, high dimensional statistics, and optimization. At the end of this course, you will be well-prepared for advanced studies in smart grid technologies, sustainable energy systems, and interdisciplinary research beyond the classroom.

Upon successful completion of this course, students should be able to:

- Construct matrix-based network models for electric power systems.
- Recognize the appropriateness of using different representations of the power flow equations to perform a power flow analysis.
- Develop optimization and control programs whose solutions are ensured to satisfy the power flow equations.
- Predict future grid operating conditions by constructing and testing statistical grid models.
- Summarize the ethical considerations of different optimization and statistical models for power flow.
- Manage large data sets of measurements collected from electric power systems.
- Design a computational tool that solves optimal power flow problems.

Resources

- **Our course notes:** Will be made periodically available on Canvas.
- **Main textbooks (available for free online):**
  - Steven H. Low, "Power System Analysis: Analytical tools and structural properties", Caltech, 2024. Link.
  - Daniel K. Molzahn, "A Survey of Relaxations and Approximations of the Power Flow Equations", Foundations and Trends in Electric Energy Systems, 2018. Link.
- **Additional resources:** This is a collection of free textbook resources that I have found useful over the years. Our studies together will only use a subset of this material, and these books are *not* required for this course. We will go over anything we need from these books together, but these are great places to start your research career.
  - Roman Vershynin, "High Dimensional Probability: An Introduction with Applications in Data Science", Cambridge University Press, 2019. Link.
  - Stephen Boyd and Lieven Vandenberghe, "Convex Optimization", Cambridge University Press, 2004. Link.

Prerequisites/Corequisites

Familiarity with the core elements of these courses will be assumed and central to this class:

- Undergraduate circuit analysis, sometimes known as 'Circuits 1 and 2".
- Undergraduate matrix theory and linear algebra.

The following skills are helpful for ensuring success in this course, but are *not* prerequisites:

- Probability theory and statistical inference.
- Linear and convex optimization.
- Linear systems and controls.

Course Structure

Problem sets

There will be a problem set assigned approximately every 1-2 weeks. Problem sets are intended to assess both basic knowledge of the course material and to encourage a deeper understanding, so it is likely that some additional research will be required beyond coming to class. Each problem in a problem set will be graded from 0-2 for understanding and completion. Credit will be assigned as follows:

- Solution was complete and correct: 2/2
- Solution was almost completely correct with a minor technical error 1.5/2
- Solution showed solid grasp of the problem, and was partially correct: 1/2
- Solution was partially attempted but was incomplete: 0.5/2
- Solution could not be understood or was not attempted: 0/2

The minimum of your problem set scores will not be considered in your final grade.

Participation puzzles

Beginning the second week of class, *participation puzzles* may occasionally appear in class. During a puzzle, a challenging, counter-intuitive problem will be presented in a fun or "game-ified" manner. The puzzle will be followed by a period of group discussion and peer feedback, and then reviewing the solution together. Puzzles will be graded on a binary scale, where full credit is earned for any submission. Per the name, you will always receive full credit for participating. The goal of the puzzles is to promote outside-the-box thinking, promote a community atmosphere, and encourage in-person attendance. I expect all students to receive full points in this section.

Midterm exam

There will be one take-home midterm exam given halfway through the course. It will be available for 48 hours. *The midterm exam may be revised*; this opportunity is intended to encourage a growth mindset and to serve as a redemption opportunity for those who wish to improve their final grade. If you choose to revise your midterm exam, you must submit a 1 page reflection statement.

Assignments

Credit will be awarded for the work you do according to the following distribution:

- **0%**: Self-assessment
- **2%**: Participation puzzles
- **48%**: Take-home problem sets (x5-6, percentages evenly distributed)
  - HW1: Matrix methods for power flow analysis
  - HW2: Power flow equations and approximations
  - HW3: Statistical analysis of power flow and state estimation
  - HW4: Optimization and control with embedded power flow equations
  - HW5: Data-driven and randomized control of power flow
  - HW6: Computational techniques and dataset handling
- **30%**: Final class project
  - **0%**: Project proposal/interest statement
  - **5%**: Progress report
  - **20%**: Final report
  - **5%**: In-person project presentation
- **20%**: Midterm exam + revisions

Credit will be recorded on Canvas. Please contact me if anything on Canvas is incorrect. Your grade will be calculated based on the following credit thresholds:

$$A \geq 90.0\%, \quad B \geq 80.0\%, \quad C \geq 70.0\%, \quad D \geq 60.0\%, \quad F < 60\%.$$

Required materials

This is a computational and theoretical course, so the only required materials are a pen, a notebook, and a computer. However, we will be performing simulations using the Julia programming language in this course, which is a compiled programming language. Compiled programming languages can sometimes be a bit more resource-intensive than scripting languages like Python. The ECE Laptop Loaner program can provide you with a computer for the semester if your computer is not powerful enough; please reach out to me if I can help you on this front.

Course Expectations and Guidelines

Support for student health and well-being

I would like to ask that you please be kind to yourself. Your physical and mental health matter. I affirm my support for your well-being and I am thrilled that you have joined us to learn something new together this semester.

Communication

There will be a Piazza section set up and linked to Canvas. That is the preferred place to ask technical questions so that everyone in the class can see the answer (or answer themselves) and ask follow-up questions in the same place. Find our class signup link at: `https://piazza.com/asdf`

Attendance and participation

Lecture attendance is expected unless you have a compelling reason not to do so, but you are fully trusted and your time is respected. If you miss a lecture with a valid excuse, feel free to email me to check what you missed that day. In particular, excused absences include, but are *not limited to* religious or cultural observations, physical or mental health matters, job search obligations, or housing instability.

Late Work Guidelines

- **Homework:** Extensions will be made on a case-by-case basis. Without prior arrangements, it cannot be submitted late. After solutions are released, late submissions will not be accepted. Please email me with excused delays so that we can work out submission details.
- **Midterm:** The midterm exam is take home, but if you are sick or unable to take the exam during the time period, you will be able to take a make-up midterm. The make-up exam may be different than the original.
- **Project:** The final project is due by the final day of the term, as such, this is a hard deadline.

Collaboration and group work

Students are *strongly* encouraged to discuss and collaborate on homework problems with one another. However, each student must individually produce and turn in their own solutions written in their own words. Cases where solutions appear to be identical or nearly identical will be immediately referred to the Office of Student Integrity.

Use of Artificial Intelligence

Use of Artificial Intelligence as a collaborator in your study is acceptable, but cautioned. Additionally, please note that your AI collaborator is not you. The above Collaboration and Group Work policy applies to AI in the same way as a human—you must type up all solutions in your own words. Cases of clear plagiarism, such as hallucinated or unrelated content, will not receive credit.

Academic Integrity and Honesty

At Georgia Tech, we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See `http://www.catalog.gatech.edu/rules/22/` for an articulation of some basic expectations that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at `(404) 894-2563` or `http://disabilityservices.gatech.edu/` as soon as possible to make an appointment to discuss your special needs and to obtain an accommodations letter. In addition, if you are a student with **visible or invisible** challenges, please know that you can reach out to me to discuss your learning needs, so that I can best serve you.