ECE XX: Computational Power Flow Analysis — Course Assessment Plan

Learning Objective	Low/No Stakes Assessment 1	Low/No Stakes Assessment 2	Low/No Stakes Assessment 3	Major Assessment
At the end of this course, you should be able to know/do…	***Before Instruction***: Students answer a few questions or complete a task assessing their conceptual understanding about the material.	***During Instruction***: Students answer questions/complete a task relevant to the day's topic.	***Following Instruction***: Students complete an assignment practicing the topic of the class.	How will the students demonstrate mastery of the learning objective?
Construct matrix-based network models for electric power systems.	Narrative discussion in class about how to use Ohm's Law to represent flows in a network. Informally introduce nodal admittance (graph Laplacian) matrix for solving linear graph systems.	Homework (graded for correctness solely for feedback, with unlimited revision opportunities). Project-style problem sets in pairs with peer review. Build up to graph-theoretic interpretation of the power flow equations.	In-class quizzes, Q/A, discussion, reflection (e.g. why is this important, where have I seen this before?)	Midterm exam (with exam wrapper), see Problem 1 of sample exam for example.
Recognize the appropriateness of using different representations of the power flow equations to perform a power flow analysis.	Informal history of how the power flow equations were discovered, classical and contemporary history of relaxations. Informally assess understanding of branch flow/bus injection models by motivating discussion with Europe's single-phase balanced distribution grid vs. North America	Homework (graded for correctness solely for feedback, with unlimited revision opportunities). Project-style problem sets in pairs with peer review. Derive LinDistFlow model from scratch using the power flow Jacobian Matrix.	In-class quizzes Q/A discussion. Self reflection opportunity to identify potential pitfalls in understanding the differences between relaxations and approximations.	Midterm exam (with exam wrapper), see Problem 2 of sample exam for example.
Develop optimization and control programs whose solutions are ensured to satisfy the power flow equations.	Class demonstration with real-world case studies, explaining different optimization methods. Assess informal understanding of linear vs. non-linear optimization.	Homework where students implement optimization programs on small-scale power grids. Metacognitive exercise where students are asked to reflect on different ways to implement these constraints (data-driven vs. relaxation vs. approximation).	Group discussions and feedback sessions on optimization techniques. Self-reflection opportunity to assess the weaknesses of approximations in optimization models.	Midterm exam (with exam wrapper), see Problem 4 for example. Could potentially be tangentially explored in course project depending on topical selection of students.
Predict future grid operating conditions by constructing and testing statistical forms of the power flow equations.	Narrative discussion in class introducing statistical methods for forecasting grid behavior. Assess conceptual through in-class questioning. Group understanding discussion on the appropriateness of learning techniques in power systems.	Homework on creating simple statistical models based on historical grid data. Metacognitive exercise where students are asked to reflect on the pitfalls of deep learning methods in this setting, and the benefits of structured physics-informed learning techniques.	Group project: Construct and present a statistical model predicting grid performance. Gamified in-class "slot-machine" discussion of random power generation from solar panels. Connect randomized analysis to solar weather patterns, extreme events, wildfire risk, etc.	Midterm exam, see Problem 3 and Problem 5 of sample exam for example. Anticipated to be the most likely course project topic to be selected by students.
Summarize the ethical considerations of different computational and statistical models for the power flow equations.	Discussion of the Energy Burden metric. Class discussion on ethical issues in power grid modeling, focusing on fairness and transparency. Informal assessment of students understanding of energy cost disparities across communities, renewable energy access disparities, and privacy	Homework assignment exploring case studies on ethical concerns (e.g., data privacy, accessibility). Assignment develops the Locational Marginal Burden matrix for computing the change in energy burden faced by communities incurred by changes in	Energy burden visualization and discussion. Group debate on ethical trade-offs in different models, assessed through peer and instructor feedback.	Course project—required analysis of ethical considerations of the required data inputs for the algorithm: in particular, privacy concerns, socioeconomic disparities in access, etc.

	concerns in the age of data-driven power systems engineering.	energy consumption in other communities.		
Demonstrate how to manage large data sets of measurements collected from real-world electric power systems.	Informal assessment of understanding of accessible visualization techniques; stress importance of color-blindness in network models. Class tutorial on handling real-world datasets. Informally assess through Q&A or quick exercises during the tutorial.	Homework assignment: Manipulate and analyze a small real-world dataset, with feedback focused on data handling techniques. Special focus on asking students to identify privacy concerns.	In-class group activity where an inaccessible visualization figure is made more accessible and color-blind friendly. In-class peer review of each other's datasets and in-progress project visualizations, followed by a group discussion on data accuracy and relevance.	Course project—use real dataset from Greensboro, NC to visualize and demonstrate behavior of grid control algorithm.
Design a computational tool that solves optimal power flow problems.	Narrative demonstration of existing tools (e.g., PowerModels.jl or OpenDSSDirect.py) and their features. Informally assess students' understanding through questions.	Homework: Students design basic computational models using the tools demonstrated in class.	Group presentations where students demonstrate their computational tools, assessed by peers and instructor.	Course project—use real dataset described above in software implementation of algorithm in Julia (PowerModels.jl) or Python (OpenDSSDirect.py)
Recognize the the societal impacts of pricing mechanisms in electricity markets.	Demonstration of computing locational marginal prices (LMPs) using the optimal power flow (OPF) model in PowerModels.jl. Discussion of the energy burden metric and how it can be used to assess pricing fairness.	Homework assignment: Differentiate the energy burden function with respect to demand and design a grid upgrade mechanism that systematically reduces energy burden. Analysis of how average income levels, population level, and education level correlate with energy burden.	In-class group activity where real-world census tracts and income data is mapped to a synthetic grid network—most likely the Texas 2k bus test case. A simulation is demonstrated where an extreme weather event produces systemically unfair pricing conditions.	Midterm exam—LMP calculation is assessed. Course project—Students will be encouraged to explore societal applications of the Locational Marginal Burden (LMB) metric as a course project.

List of assignments and weights:

- (0%) Self-assessment puzzles pre-assessment, contains high-level content from each learning objective
- Homework assignments (5-6) total (40%)
  - HW1—Matrix methods for power flow analysis,
  - HW2—Power flow equations, approximations,
  - HW3—Statistical analysis of power flow equations, state estimation theory, dataset handling
  - HW4—Optimization and control with embedded power flow equations
  - HW5—Data-driven and randomized control of power flow equations
  - HW6—Computational techniques
- Mid-semester feedback survey (+1%):
  - Anonymous survey on instruction quality, content, and recommended changes from students
  - Specifically focuses on **the interest and learning goals of the students** to make changes in course content delivery.
  - Close the loop by providing a "response presentation" from instructor to the feedback.
- Midterm exam (to be given between HW4-HW5), (25%)
  - Take home, 48 hours
  - Introduces the merger between randomized analysis of the power flow equations, control, and optimization
  - Project-style, open-ended questions
  - Collaboration permitted on second revision for partial credit
- Final course project (35%)
  - Proposal (5%):
    - 1 page document declaring the interests of the students and team assignments
    - Proposal is due *before midterm exam*, and the midterm exam will be tailored to the interests of the students to encourage the development of their projects.
  - Progress report (10%):
    - 3-4 page document declaring the project topic, provides **scaffolding for the project.**
    - Report of methodological developments and/or technical plans.
    - Literature review of related work, identification of relevant resources
    - Potential preliminary results
  - Project report (20%):
    - Option A: Literature review of research state of the art in topic of relevance to the course
    - Option B: Computational application of content covered in course
    - Option C: Preliminary theoretical investigation of new research direction related to topic covered in this course
  - Project presentation (5%):
    - Oral presentation by student pairs at the end of the semester detailing findings, limitations, and future work.

Rationale

The selected topics were chosen to encourage research-oriented thinking in early graduate students. The course content is designed to merge several branches of knowledge into a single, cohesive discipline that is oriented around the mathematical analysis of the grids that power our world. The assessment plan intentionally de-emphasizes exams, in an effort to empower students to develop new knowledge while simultaneously learning the state of the art. The midterm exam, in particular, is a take-home exam designed to create new connections between the studied material and the interests of the students, and will be tailored to the project proposals provided by the students prior to the exams. Formative assessments are incorporated throughout the course to help students track their understanding and receive timely feedback without the pressure of high-stakes grading. The emphasis on project-based learning allows students to apply what they have learned to real-world problems and encourages collaboration and creativity. By allowing students to focus on their individual interests in the final project, the course fosters independent thinking and the ability to connect course material with ongoing research. The goal is to prepare students for both the technical and conceptual challenges they'll encounter in their academic and professional careers.