ESE 562: AI Driven Smart Grids

Fall 2025

1. Course Staff

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Light Engineering 215

Office Hours: Wednesday 1 pm-5 pm (in-person or online)

2. Course Description

The course focuses on Artificial Intelligence (AI) applications to power system modeling, analysis, and operation. Topics include basics of AI and smart grid, AI-driven modeling such as load/renewable energy prediction and dynamic model discovery, AI-driven power system analysis such as dynamic simulation, and stability and security assessment, and AI-based operation such as optimal dispatch and emergency control. Emerging topics, including generative AI, quantum machine learning, and trustworthy AI, will also be discussed. This course is part of the Engineering Artificial Intelligence program. The emphasis of the course is the practical AI algorithms in power system applications and hands-on experiments for developing AI-enabled power system programs.

Prerequisites: Any one of ESE350, ESE435, ESE576, ESE586, or an equivalent course (such as electrical power systems, power and energy systems, power system analysis, power system operation and control)

Credits: 3

3. Reference

- Lecture notes
- Stevenson. William D, "Elements of power system analysis". McGraw-Hill.
- J. Han, M. Kamber, J. Pei, "Data Mining. Concepts and Techniques", Third edition, Morgan Kaufman, 2012.

4. Course Learning Objectives

The goal of the course is to help students build a solid foundation for AI applications to smart grids. Basic principles of data sciences and practical AI algorithms are studied for data-driven power grid analysis and operations. Homework assignments and term projects are designed to improve students' ability to develop data-driven programs for pivotal power system problems.
Upon completion of this course, students will understand fundamental AI algorithms which are particularly useful for power industry applications and will gain hands-on experiences for implementing typical AI algorithms in solving power system problems. This course will also enhance students' knowledge in Engineering Artificial Intelligence.

5. Student Learning Outcomes

In this course, students will acquire knowledge and skills in data-driven power system modeling and analysis, which include:

- Fundamental knowledge of smart grid operation and control.
- Fundamental knowledge of machine learning and AI technologies.
- Understanding of AI-driven smart grid, its promise, challenges, and future directions.
- Understanding of data-driven power system modeling, analysis and operation approaches.
- Understanding of various machine learning algorithms, such as regression, classification, clustering, reinforcement learning, physics-informed learning, transfer learning, and their engineering applications.
- Being able to develop typical data-driven power system tools and apply them to real-scale power grids.

6. Grading

Quiz: 9% (3 quizzes in total)
Homework Assignments: 20% (4 assignments in total)
Presentation 1: 20%
Presentation 2: 20%
Presentation 3: 25%
Class participation: 6%

7. Schedule of Lectures, Quiz, Hands-on Experiment (HE), and Homework (HW)

<table>
<tr><th>Week</th><th>Topic</th><th>Quiz</th><th>HE</th><th>HW</th></tr>
<tr><td>Week 1
(8/27)</td><td>Preliminaries: Introduction of smart grids and AI:
– What is a smart grid?
– What is AI?
– Why AI for smart grids?</td><td></td><td></td><td></td></tr>
<tr><td>Week 2
(9/3)</td><td>Modeling (1): Learning-based prediction in power systems:
– Static load model in power systems and data-driven load prediction
– Renewable energy models in power systems and data-driven renewable energy prediction</td><td></td><td>HE1</td><td>HW1</td></tr>
<tr><td>Week 3
(9/10)</td><td rowspan="2">Modeling (2): Learning-based power system dynamic modeling
– Basis of power system dynamic models: generators, dynamic loads and control
– Data-driven dynamic modeling via deep neural networks</td><td></td><td>HE2</td><td></td></tr>
<tr><td>Week 4
(9/17)</td><td></td><td>HE3</td><td></td></tr>
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	– Physics-informed dynamic model discovery			
Week 5 (9/24)	**Presentation 1** (online)			
Week 6 (10/1)	**Analytics (1): Learning-based steady-state analysis** – Basis of power system steady-state analysis (power flow analysis) and conventional power flow solvers – AI-driven power flow solvers – Topology changes in AI-driven power flow analysis		**HE4**	**HW2**
Week 7 (10/8)	**Invited Talk (TBD)**			
Week 8 (10/15)	**Analytics (2): Learning-based dynamic analysis** – Basis of time-domain simulation and its role in power system analysis – ML-based dynamic simulation – Basis of power system stability assessment – ML-based power system stability assessment	**Q1**		
Week 9 (10/22)		**Q2**	**HE5**	**HW3**
Week 10 (10/29)	**Presentation 2** (online)			
Week 11 (11/5)	**Operation (1): AI techniques in power system optimal dispatch** – Power system economic dispatch and unit commitment – AI-driven optimization approaches – Learning-based optimal dispatch and unit commitment		**HE6**	**HW4**
Week 12 (11/12)	**Operation (2): Learning-based power system control** – Learning-based offline controller design for power systems – Basis of reinforcement learning (RL) techniques – RL-based power system online operation	**Q3**		
Week 13 (11/19)			**HE7**	
Week 14 (11/26)	**Thanksgiving Break (no classes in session)**			
Week 15 (12/3)	**Presentation 3** (in-person)			

8. Quiz

The quiz mainly consists of some short-answer questions related to the previous lecture.

9. Hands-on Experiments

For most lectures, Python code will be provided to give students hands-on experience with the topics discussed. These codes typically serve as a foundational version to help students understand the lecture material and act as a starting point for related homework assignments.

We will work through the program together at the end of the lecture.

10. Homework

Graduate homework mainly consists of short-answer questions, mathematical problems, and simple programming problems for applying fundamental machine learning methods to power system problems.
Homework assignments are posted every Wednesday and are typically due by midnight the following Wednesday.

11. Course Project (for Graduate Students)

- **Presentation 1: Survey of trustworthy AI technologies.** Students are required to choose **a topic related to trustworthy AI**, read at least 3 relevant papers, and make a 25-minute presentation on 9/24/2025.
  Please submit your presentation by 9/24/2025 through Brightspace.

- **Presentation 2**: **Survey of AI security.** Students are required to choose **a topic related to AI security**, read at least 3 relevant papers, and make a 25-minute presentation on 10/29/2025.
  Please submit your presentation by 10/29/2025 through Brightspace.

- **Presentation 3: Programming for AI-enabled smart grids**. Students are required to **choose one topic from the given list**, finish a 5-page technical report, and make a 25-minute presentation on 12/3/2025. Please submit your teaming information and selected topic by 11/5 via email. Please submit your **final report and related codes and data** by 12/10/2025 through Brightspace.

- Presentation 3 can be done individually or in teams of two (projects done individually will receive a 5% bonus).

Student Accessibility Support Center Statement
If you have a physical, psychological, medical, or learning disability that may impact your course work, please contact the Student Accessibility Support Center, Stony Brook Union Suite 107, (631) 632-6748, or at sasc@stonybrook.edu. They will determine with you what accommodation is necessary and appropriate. All information and documentation are confidential.

Academic Integrity Statement
Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty is required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology and Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty

please refer to the academic judiciary website at http://www.stonybrook.edu/commcms/academic_integrity/index.html.

Critical Incident Management

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of University Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures. Further information about most academic matters can be found in the Undergraduate Bulletin, the Undergraduate Class Schedule, and the Faculty-Employee Handbook.