Course Syllabus

ISEN 431 Storage and Microgrids (0.5 credit)
Northwestern University

Instructor:
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Guest Lecturers:
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Office Hours: By appointment
Teaching Assistant: Shannon Kollasch <shannonkollasch2019@u.northwestern.edu>
Class Room: Frances Searle 2-107
Class Timing: Fall Quarter, Wednesday 1:50 pm to 4:30 pm

Course Synopsis: This course will cover the primary aspects of energy storage systems and microgrids. It will provide students with a high-level understanding of electrical storage technologies and microgrids and their key market applications.

Course Goals:

- Understand the core (hardware) technologies for storage and their characteristics
  - Develop an understanding of the operating principles of energy storage technologies—batteries, fuel cells, super capacitors
  - Components of batteries—cathode, anode, electrolyte materials.
  - Compare systems in terms of performance, life-cycle, efficiency, and capacity tradeoffs.
  - Explore other storage media such as Hydro, Thermal, Compressed-Air Energy Storage (CAES), Flywheels, etc.

- Establish an understanding of microgrids and their function
  - Build knowledge in the purpose of microgrids and the technology required to deliver new energy outcomes
  - Ensure basic understanding of energy and power management, electrical conversion and distribution, centralized and distributed protection and control, and the orchestration of distributed energy resources including primary, secondary, and tertiary control methodologies.
  - Introduce grid integration: methods, benefits, drawbacks.

- Develop the capability to assess opportunities to deploy storage and microgrids from an economic, technology and regulatory point of view
  - Analyze and discuss economic implications and key market applications for storage media and microgrids
Understand the core technology requirements to deploy storage and/or build a microgrid

Build a high-level understanding of policies and regulation that govern microgrids

**Grading/Assessment:**
Grading will be based on the following rubric:

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<thead>
<tr>
<th>Component</th>
<th>Weight</th>
<th>Details</th>
<th>Due</th>
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<tbody>
<tr>
<td>Effort and Attendance</td>
<td>20%</td>
<td>Based on attendance and instructor assessment of preparations and participation in class; Instructor will use “warm call” method by listing names of those that he will call on at the beginning of class</td>
<td>Ongoing</td>
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<tr>
<td>Response Papers</td>
<td>40%</td>
<td>Papers that comment on that week’s lecture topic(s). Papers will be 2-3 pages in length and will address question posed by the instructor (weekly basis x4)</td>
<td>Weeks 1-4</td>
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<tr>
<td>Final Project</td>
<td>40%</td>
<td>Proposed a suitable location / design / market for a new microgrid. In an 8-10 page paper, explain:</td>
<td>Week 5</td>
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<td>• Rationale for choosing this market or application</td>
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<td>• Explanation of expected value drivers / economic case</td>
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<td>• Overview of the regulatory environment and any key challenges or opportunities</td>
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<td>• (bulk of paper) Explanation of key technologies to deployed in your proposed microgrid and a deeper assessment of one key technology you would propose to include (e.g.)</td>
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**Grading Policy:**
Grades will be assigned based on all the work you have completed during the semester following the traditional practice of A=90-100, B=80-89, C=70-79, D=60-69, F<60.

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<thead>
<tr>
<th>Letter Grade</th>
<th>Percentages</th>
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<tr>
<td>A</td>
<td>93 - 100 %</td>
<td>C+</td>
<td>77 - 79.9 %</td>
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<tr>
<td>A-</td>
<td>90 - 92.9 %</td>
<td>C</td>
<td>70 - 76.9 %</td>
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<tr>
<td>B+</td>
<td>87 - 89.9 %</td>
<td>D</td>
<td>60 - 69.9 %</td>
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<td>B</td>
<td>83 - 86.9 %</td>
<td>F</td>
<td>&lt; 60 %</td>
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<td>B-</td>
<td>80 - 82.9%</td>
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Required Course Materials:
- S Al-Hallaj, G Wilk, G Crabtree, M Eberhard, “Overview of distributed energy storage for demand charge reduction”, MRS Energy & Sustainability, 2018
- Selected Lazard materials such as “Energy Storage Systems: Disrupting the Power Sector, Again”
- Selected readings from Navigant Research (specific reports to be assigned by instructor)
  - https://www.navigantresearch.com/research-solutions/distributed-energy-storage
  - https://www.navigantresearch.com/research-solutions/microgrids

1 https://microgridnews.com/energy-storage-disrupting-power-sector/
Additional Course Materials:


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<tr>
<th>Weekly Topic</th>
<th>Description</th>
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| **1: Introduction to course & Energy Storage Technology Basics** | • Overview of storage technologies: electrochemical, thermal, hydrogen, CAES etc.  
• How do energy storage technologies operate?  
• Batteries  
• Fuel cells/Supercapacitors  
**Response Paper #1:** Discuss a material challenge or new opportunity with battery technology |
| **2: Assessing Storage Technologies + Key Market Applications** | • What are the benefits/drawbacks of energy storage technologies? What are the insights from a supply chain, performance/resilience, operating environment/flexibility & cost perspective?  
• How do each play a role in the US and global economy?  
• What is the Hydrogen Economy and what are the key challenges?  
**Response Paper #2:** Outline an ideal market or customer for deployment of battery technology |
| **3: Microgrids** | • What are microgrids and how do they work?  
• Microgrid power electronic interfaces  
**Response Paper #3:** Provide an assessment of the strengths and weaknesses of your “favorite” microgrid |
| **4: Microgrid Control and Integration** | • Microgrid architecture and control  
• Grid integration  
**Response Paper #4:** Discuss an emerging solution in microgrid software / control architecture |
| **5: Market Applications of Microgrids + Final Project Presentations** | • Where do microgrids fit into the US and global economy today? In the future?  
**Final Project:** Propose a microgrid including high level commentary on the economics & technology and a deeper assessment of a key technology you would propose to include (given the economics and policy environment) |