

Course Syllabus

ISEN 431 Storage and Microgrids (0.5 credit)

Northwestern University

Instructor:

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Guest Lecturers:

<https://www.linkedin.com/in/markfeasel/>

Office Hours: By appointment

Teaching Assistant: TBD

Class Room: Tech F281

Class Timing: Fall Quarter, Tuesday 3:30 pm to 6:20 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:

Component	Weight	Details	Due
Effort and Attendance	10%	<i>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</i>	Ongoing
Response Papers	40%	<i>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)</i>	Weeks 1-4
Final Project	50%	Proposed a suitable location / design / market for a new microgrid. In an 8-10 page paper, explain: <ul style="list-style-type: none"> • Rationale for choosing this market or application • Explanation of expected value drivers / economic case • Overview of the regulatory environment and any key challenges or opportunities • (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.) 	Week 5

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.

Letter Grade	Percentages	Letter Grade	Percentages
A	93 - 100 %	C+	77 - 79.9 %
A-	90 - 92.9 %	C	70 - 76.9 %
B+	87 - 89.9 %	D	60 - 69.9 %
B	83 - 86.9 %	F	< 60 %
B-	80 - 82.9%		

COVID-19 Classroom Expectations Statement

Students, faculty, and staff must comply with University expectations regarding appropriate classroom behavior, including those outlined below and in the [COVID-19 Code of Conduct](#). With respect to classroom procedures, this includes:

- Policies regarding masking and social distancing evolve as the public health situation changes. Students are responsible for understanding and complying with current masking, testing, Symptom Tracking, and social distancing requirements.
- In some classes, masking and/or social distancing may be required as a result of an Americans with Disabilities Act (ADA) accommodation for the instructor or a student in the class even when not generally required on campus. In such cases, the instructor will notify the class.
- No food is allowed inside classrooms. Drinks are permitted, but please keep your face covering on and use a straw.
- Faculty may assign seats in some classes to help facilitate contact tracing in the event that a student tests positive for COVID-19. Students must sit in their assigned seats.

If a student fails to comply with the [COVID-19 Code of Conduct](#) or other University expectations related to COVID-19, the instructor may ask the student to leave the class. The instructor is asked to report the incident to the Office of Community Standards for additional follow-up.

Class Recording

This class or portions of this class will be recorded by the instructor for educational purpose and available to the class during the quarter. Your instructor will communicate how you can access the recordings. Portions of the course that contain images, questions or commentary/discussion by students will be edited out of any recordings that are saved beyond the current term.

Unauthorized student recording of classroom or other academic activities (including advising sessions or office hours) is prohibited. Unauthorized recording is unethical and may also be a violation of University policy and state law. Students requesting the use of assistive technology as an accommodation should contact [AccessibleNU](#). Unauthorized use of classroom recordings – including distributing or posting them – is also prohibited. Under the University's [Copyright Policy](#), faculty own the copyright to instructional materials – including those resources created specifically for the purposes of instruction, such as syllabi, lectures and lecture notes, and presentations. Students cannot copy, reproduce, display, or distribute these materials. Students who engage in unauthorized recording, unauthorized use of a recording, or unauthorized distribution of instructional materials will be referred to the appropriate University office for follow-up.

Expectations for Class Participation

Being prepared for class is about more than just showing up, it's also about making sure you've completed the readings, homework, etc. so that you are able to make thoughtful contributions during class. Sitting silently and/or being unprepared can damage your participation grade. When in a virtual class, we expect students to keep their camera and mute on as much as possible. When in the classroom, we expect students to keep their phones off and put away.

Academic Integrity

Academic integrity is taken very seriously at Northwestern. Students are responsible for reading and understanding Northwestern's Academic Integrity policies. All suspected violations will be reported to the McCormick College of Engineering's Dean's Office. These include cheating, plagiarism, fabrication, unfair advantage, unauthorized collaboration, and aiding and abetting of academic dishonesty. Students found in violation of academic integrity may receive a zero on the assignment or a failing grade for the course and may be suspended or permanently expelled from the University. See [Academic Integrity: A Basic Guide](#) for more information.

The Writing Place

When working on writing assignments for this class, I encourage you to visit the Writing Place, Northwestern's peer writing center. You will work with juniors and seniors who have been trained to provide you feedback and assistance on any type of writing at any stage in the writing process. They will not edit your work. Rather, they will work with you to brainstorm ideas, organize or outline an essay, clarify your argument, document your sources correctly, or refine grammar and style.

Accessibility Statement

Northwestern University is committed to providing the most accessible learning environment as possible for students with disabilities. Should you anticipate or experience disability-related barriers in the academic setting, please contact AccessibleNU to move forward with the university's established accommodation process (e: accessiblenu@northwestern.edu; p: 847-467-5530). If you already have established accommodations with AccessibleNU, please let me know as soon as possible, preferably within the first two weeks of the term, so we can work together to implement your disability accommodations. Disability information, including academic accommodations, is confidential under the Family Educational Rights and Privacy Act.

Illness and Medical Leave of Absence

Review the University's [policy](#) on missing academic work due to illness. Your instructor cannot waive an assignment missed due to illness unless the illness can be verified (e.g., by University Health Services or other licensed health professionals).

Discrimination and Sexual Harassment

Northwestern's Policies on Discrimination, Harassment, and Sexual Harassment apply to all members of the University community, including students, staff, faculty, and third parties. Any student, staff, faculty member, or third party who believes that they have been discriminated

against or harassed on the basis of their race, color, religion, national origin, sex, sexual orientation, gender identity, gender expression, pregnancy, parental status, marital status, age, disability, citizenship, veteran status, genetic information or any other classification protected by law, should contact the Office of Equity at (847) 467- 6571. Additional information about the University's discrimination and harassment policies, including the campus resources available to assist individuals with discrimination or harassment concerns, is available online on the [Office of Equity Website](#). Students, staff, and faculty who report harassment, discrimination, or sexual misconduct are also protected under the [University's Policy on Non-Retaliation](#).

Sexual Misconduct and Reporting

Northwestern University is committed to fostering an environment where students are safe and free from sexual misconduct. [Confidential resources](#) are available to those who have experienced sexual misconduct. Faculty and instructors are not confidential resources and are required to report incidents of sexual misconduct, whether discussed in your assignments or in person, to the Office of Equity, which can provide information about resources and options. We encourage students who have experienced sexual misconduct to talk with someone to get support. For more information, including how to request interim protective measures and academic accommodations or file a complaint, see the [Get Help page](#).

Other Resources

Students can find useful resources for safety and security, academic support, and mental and physical health and well-being at the [NUhelp website](#).

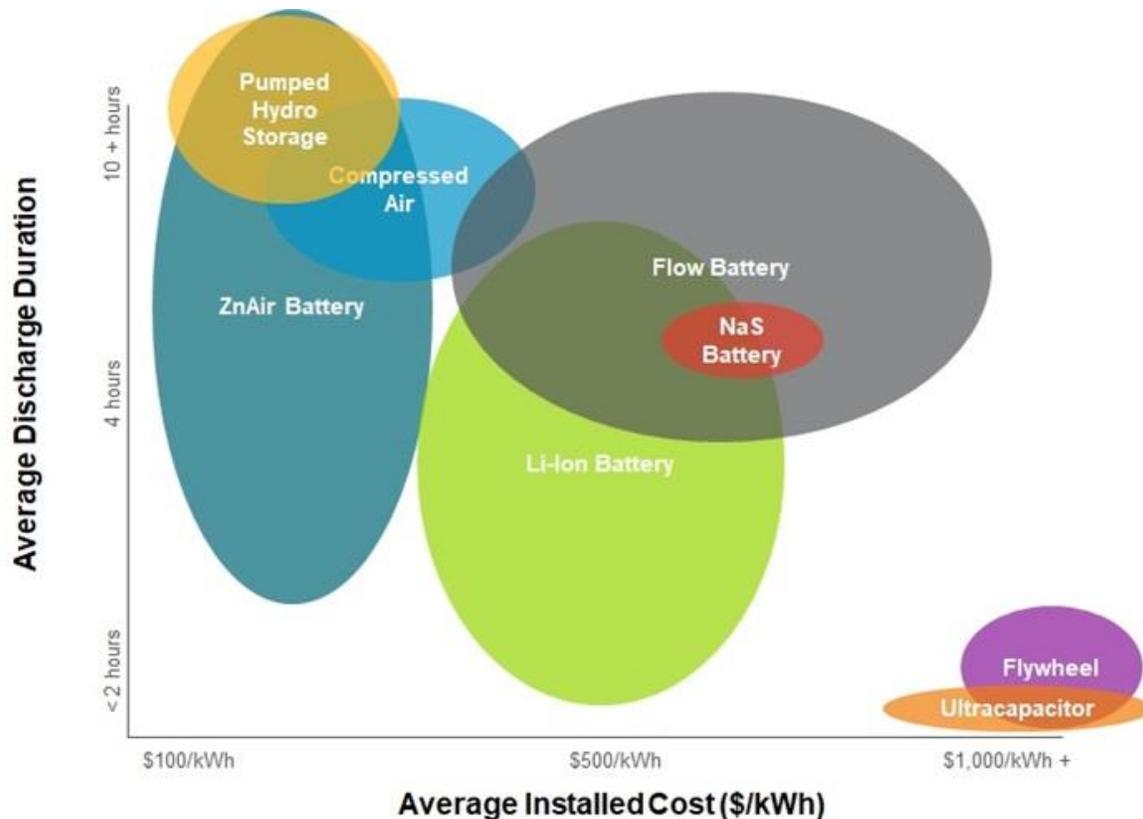
Required Course Materials:

- Galvin, Kurt et al., "PERFECT POWER: How the Microgrid Revolution Will Unleash Cleaner, Greener, More Abundant Energy", McGraw-Hill Education; 1 edition (September 16, 2008)
- S Al-Hallaj, G Wilk, G Crabtree, M Eberhard, " Overview of distributed energy storage for demand charge reduction", MRS Energy & Sustainability, 2018
- S. Al-Hallaj, S. Wilke, B. Schweitzer, "Chapter 2: Energy Storage Systems for Smart Grid Applications", The Triangle: Energy-Water-Food Nexus for Sustainable Security in the Arab Middle East' Editors: A. Badran and S. Murad, Springer Publishing, in publication
- S. Al-Hallaj and K. Kiszynski, "Hybrid Hydrogen Systems for Stationary and Transportation Applications", 1st Edition, 2011, Springer Publishing, ISBN 978-1-84628-466-3
- Huggins, Robert, Energy Storage: Fundamentals, Materials, and Applications (2016).
Selection to be assigned
- Selected Lazard materials such as "Energy Storage Systems: Disrupting the Power Sector, Again¹"
- P. Zhang, Networked Microgrids. Cambridge University Press 2020.
- Spector, Julian. "What Would It Take for the US to Become an Energy Storage Manufacturing Powerhouse?" GTM, Greentech Media, 13 Jan. 2020, www.greentechmedia.com/articles/read/can-the-us-claim-dominance-in-energy-storage-manufacturing.
- Lacey, Stephen et al., The New Normal for the Grid: Batteries, The Energy Gang. Green Tech Media 2019.

¹ <https://microgridnews.com/energy-storage-disrupting-power-sector/>



- 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>



Source: Navigant Research

Additional Course Materials:

- Spector, Julian. "Cheaper Than a Peaker": NextEra Inks Massive Wind+Solar+Storage Deal in Oklahoma", GTM, Greentech Media, 26 July 2019, www.greentechmedia.com/articles/read/nextera-inks-even-bigger-windsolarstorage-deal-with-oklahoma-cooperative#gs.yaljsn.
- Spector, Julian. "Dominion Energy Plans to Build 4 Storage Pilots and Study Them for 5 Years." GTM, Greentech Media, 7 Aug. 2019, www.greentechmedia.com/articles/read/dominion-energy-plans-to-build-four-storage-pilots-and-study-them-for-five-#gs.yaloay.
- Spector, Julian. "Can Newcomer Energy Vault Break the Curse of Mechanical Grid Storage?" GTM, Greentech Media, 14 Nov. 2018, www.greentechmedia.com/articles/read/energy-vault-stacks-concrete-blocks-to-store-energy#gs.yaltpk.
- John, Jeff St. "Energy Vault Lands \$110M From SoftBank's Vision Fund for Gravity Storage." GTM, Greentech Media, 15 Aug. 2019, www.greentechmedia.com/articles/read/energy-vault-lands-110m-from-softbanks-vision-fund-for-gravity-energy-stora#gs.yaly99.
- Lacey, Stephen et al., Watt It Takes: Form Energy's Mateo Jaramillo on His Mission to Build Long-Duration Batteries, The Energy Gang. Green Tech Media 2019.

CLASS OUTLINE

Weekly Topic	Description
<p>1: <i>Introduction to course & Energy Storage Technology Basics</i></p>	<ul style="list-style-type: none"> • Overview of storage technologies: electrochemical, thermal, hydrogen, CAES etc. • How do energy storage technologies operate? • Batteries • Fuel cells/Supercapacitors <p><u>Response Paper #1:</u> Discuss a material challenge or new opportunity with battery technology</p>
<p>2: <i>Assessing Storage Technologies + Key Market Applications</i></p>	<ul style="list-style-type: none"> • 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? <p><u>Response Paper #2:</u> Outline an ideal market or customer for deployment of battery technology</p>
<p>3: <i>Microgrids</i></p>	<ul style="list-style-type: none"> • What are microgrids and how do they work? • Microgrid power electronic interfaces <p><u>Response Paper #3:</u> Provide an assessment of the strengths and weaknesses of your “favorite” microgrid</p>
<p>4: <i>Microgrid Control and Integration</i></p>	<ul style="list-style-type: none"> • Microgrid architecture and control • Grid integration <p><u>Response Paper #4:</u> Discuss an emerging solution in microgrid software / control architecture</p>
<p>5: <i>Market Applications of Microgrids + Final Project Presentations</i></p>	<ul style="list-style-type: none"> • Where do microgrids fit into the US and global economy today? In the future? <p><u>Final Project:</u> 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)</p>