

Spring 2026

ELEN6593: Distributed Energy Resources (DERs) and Smart Grid System (Formerly ELEN4510)

Description: This graduate-level course provides an immersive exploration into the dynamic forces reshaping our electric grid, transforming it from a traditional one-way central supply structure into a sophisticated network with bidirectional, flexible power flows. You will gain a comprehensive understanding of how the integration of large-scale Distributed Energy Resources (DERs), such as solar and storage, alongside other firm power systems and advanced smart grid components, fundamentally alter grid operating characteristics, driving the energy transition. Through a hybrid approach that combines classroom lectures with presentations from leading industry Subject Matter Experts (SMEs), students will learn about the essential concepts, tools, and technologies needed to measure, analyze, predict, protect, and control the grid of the future. The course offers unparalleled exposure to current issues and challenges confronting the grid and the broader energy landscape, including an exclusive tour of Con Edison's Advanced Metering Infrastructure (AMI) control center to witness real-world applications. Furthermore, this course actively encourages cross-registration with other sustainability programs, fostering an interdisciplinary learning environment and expanding professional networks. Join us to analyze, innovate, and prepare to lead in the rapidly evolving clean energy future.

Prerequisite: General understanding of the electric power system.

Instructor: Dr. Mohamed Kamaludeen, Electrical Engineering.

Office: Mudd 1342.

Office Hours: Online (by appointment) and/or after class. You can email me at mkk2178@columbia.edu to setup an appointment. Please, include "[ELEN6593]" (without the quotes) in the subject line.

Academic Load: 3 hr./wk.; 3 cr.

Time: Thursday, 4:10pm – 6:40pm. This class will adapt to an asynchronous learning schedule. The first session will be in-person, followed by ad-hoc virtual session via Zoom. See the course timeline below for more details. I reserved the right to adjust the schedule.

Location/Classroom: TBD

Zoom Meeting ID: Will be posted in Courseworks prior to Lecture.

Textbook: There is no textbook for this course. Relevant articles, journals and resources will be posted on Courseworks.

Course Structure and Expectations:

- **Mandatory Off-Campus Sessions:** This course includes essential, hands-on learning experiences conducted at designated off-campus facilities. A mandatory component involves **travel to the Con Edison of New York headquarters for a practical tour of their Advanced Metering Infrastructure (AMI) control center**. This session will provide direct exposure to operational smart grid technologies and real-world applications. Specific dates, logistical details, and safety protocols for these required off-campus activities will be communicated well in advance.
- **High-Engagement Learning Model:** This course employs a high-engagement, project-based learning model to cultivate a comprehensive and practical understanding of Distributed Energy Resources (DERs) and Smart Grid Systems. A cornerstone of this learning experience is the **direct, front-line exposure to current industry practices through presentations by leading Subject Matter Experts (SMEs)** on selected topics. These industry experts will provide invaluable insights, offering real-world perspectives and addressing current challenges in the field. The course emphasizes self-initiative, collaborative teamwork, and a flipped classroom approach. Students are expected to commit significant time to independent research, self-directed learning, and team-based activities beyond scheduled class hours. Active participation and thorough preparation are fundamental to success in this dynamic learning

environment.

- **Prerequisite Knowledge:** General understanding of the electric power system.

Course Topics:

- Grid Modernization techniques and investments.
- Renewable Energy (such as Wind and Photovoltaics) and Storage.
- Climate Change and Grid Resilience.
- Advance Metering Infrastructure (AMI).
- Electric Vehicles (EVs).
- Geothermal Energy and Resources.
- Data Centers.
- Distributed Energy Resource Management (DERMS) and Advance Distribution Management Systems (ADMS).
- Building Decarbonization.
- Smart Inverters and new Grid Topology.

Student Learning Outcomes: Having successfully completed this course, you will be able to:

- **Command a profound and practical understanding** of the multifaceted challenges and opportunities inherent in DER integration and global grid modernization.
- **Navigate and articulate the pivotal shifts** currently redefining the power industry, particularly the accelerated transition towards an intelligent Smart Grid and a cleaner energy future.
- **Leverage invaluable insights from leading industry experts**, gaining direct exposure to real-life projects, critical challenges, and burgeoning opportunities that shape the energy landscape.
- **Differentiate and critically evaluate** the diverse array of renewable and firm power energy sources, mastering the complexities and integration hurdles associated with their deployment onto the electric power grid.
- **Rigorously analyze and assess** power system stability dynamics and the intricate components driving comprehensive grid modernization efforts, positioning you as an indispensable contributor to its evolution.

Required Readings:

These research papers and others will be posted in Courseworks under reading materials.

- Das, A., Wu, D., Bhatti, B. A., Kamaludeen, M. K. (2024, June 21). Approximate Dynamic Programming with Enhanced Off-Policy Learning for Coordinating Distributed Energy Resources. *IEEE Transaction and Sustainable Energy*, 15(3), 1614-1626. <https://doi.org/10.1109/TSTE.2024.3361674>
- Kamaludeen, M.K., et al.: Common direct current (DC) bus integration of DC fast chargers, grid-scale energy storage, and solar photovoltaic: New York City case study. *IET Smart Grid*. 115 (2024). <https://doi.org/10.1049/stg2.12154>.
- Kamaludeen, M.K., et al.: Grid-Scale Battery Systems for VAR Support in Con Edison Distribution Substations via Bi-Directional Smart Inverters. *IET Smart Grid*. 115 (2024). STG-2024-02-0029.
- Kamaludeen, M. K., Mohamed, A. A., Zafar, K., Esa, Y., Nyemah, E., Salmeron, L., Odie, S. (2023, December 21). Common direct current (DC) bus integration of DC fast chargers, grid-scale energy storage, and solar photovoltaic: New York City case study. *IET Smart Grid*. <https://doi.org/DOI: 10.1049/stg2.12154>

- Mohamed, A. A., Zafar, K., Vaidya, D., Salmeron, L., Kanwhen, O., Esa, Y., Kamaludeen, M. K. (2023, December 11). Grid Impact of Wastewater Resource Recovery Facilities-Based Community Microgrids. *IET Smart Grid*. <https://doi.org/10.3390/smartcities6060152>
- J. Kassakian, R. Schmalensee, "The Future of the Electric Grid," MIT, 2011, available online at: <http://mitei.mit.edu/publications/reports-studies/future-electric-grid>.
- Kamaludeen, Mohamed K., et al. "Dissecting the Levelized Cost of Storage — “Adders” for New York City." *Sustainability - MDPI Journal*, 23 Mar. 2022, pp. 1-18. <https://www.mdpi.com/journal/sustainability>, doi: Sustainability 2022, 14, 3768. <https://doi.org/10.3390/su14073768>.
- Kamaludeen, Mohamed K, et al. “Common DC Bus Integration for Energy Storage, Solar Photovoltaic, and Electric Vehicle Fast Chargers at ConEdison's Cedar Street Substation” – IEEE
- Kirn Zafar, Mohamed K. Kamaludeen, Yusef Esa, Ahmed Ali A. Mohamed, and Simon Odie, “Fault Analysis for DC Bus-Integrated ESS, EVSE, and PV,” submitted to Energy Reports (EGYR-D-23-02193), 2023.
- Ahmed Mohamed, Kirn Zafar, Dhavalkumar Vaidya, Lizzette Salmeron, Andrea Kanwhen, Yusef Esa, and Mohamed Kamaludeen, “Grid Impact of Wastewater Resource Recovery Facility Based Community Microgrids,” submitted to Energy Reports (EGYR-D-23-02189), 2023.
- Kamaludeen, M.K., et al.: Common direct current (DC) bus integration of DC fast chargers, grid-scale energy storage, and solar photovoltaic: New York City case study. *IET Smart Grid*. 1每15 (2024). <https://doi.org/10.1049/stg2.12154>
- Kamaludeen, M.K., et al.: Approximate Dynamic Programming with Enhanced Off-policy Learning for Coordinating Distributed Energy Resources. *IEEE-PES* (2024).
- DOE Pathways to commercial liftoff Reports: [Pathways to Commercial Liftoff - Pathways to Commercial Liftoff](#)
- New Geothermal Heating & Cooling and Virtual Power Plants (VPPs) Liftoff Reports [Geothermal Heating and Cooling - Pathways to Commercial Liftoff](#)

Software Packages[†]:

- MS office suite.

[†] Instructions on how to install these software packages will be given in the class.

Academic Integrity Policy:

Academic integrity is paramount and strictly enforced within this course. Any form of plagiarism or cheating is unequivocally prohibited. During all examinations, mobile phones must be powered off and stowed away; their use as calculators or for any other purpose is strictly forbidden.

Engaging in academic dishonesty, including but not limited to copying content from the internet, collaborating inappropriately with peers, or unauthorized use of artificial intelligence platforms, places your academic standing in severe jeopardy. It is important to understand that instructors possess effective methods for detecting instances of plagiarism or unoriginal work.

Should you be found guilty of plagiarism or cheating on an examination, the minimum consequence will be a failing grade for the entire course. Furthermore, such infractions may lead to more severe penalties as outlined by University policy, including permanent notations on your academic transcript, suspension from the University, or even expulsion.

For a comprehensive understanding of the university's expectations and policies, you are required to review the Academic Integrity Policy of Columbia University at <https://www.cc-seas.columbia.edu/integrity/policy>. Adherence to these principles is not merely a recommendation but a fundamental requirement for all students.

Attendance Policy:

Consistent attendance is a critical component of success in this course, particularly for sessions involving Challenge presentations and mandatory in-field visits. Your presence and punctuality for all classes are not merely encouraged but are essential to your learning and the collaborative environment.

Punctual arrival for all classes is expected. Please be aware that I reserve the right to deny entry to the classroom for students who are late, as their delayed arrival can disrupt the learning experience for others and impede the flow of instruction.

Regarding **challenge presentations**, rescheduling is not automatically granted. Any request to reschedule a presentation is subject to my sole approval. To facilitate this process and demonstrate your commitment, you must notify me of your need to **reschedule at least 24 hours in advance**, to the extent that it is possible. Failure to adhere to these attendance and notification policies may result in significant academic disadvantages, including missed crucial information, inability to participate in practical components, and potentially adverse impacts on your grade. Your proactive engagement with these requirements is fundamental to your successful completion of the course.

Missed Assignments:

“Life Happens Pass”- For one written assignment this semester you can get an automatic 48-hours extension on the due date, no questions asked. **You MUST inform Dr. Kamaludeen and the TA in writing (email) to get this pass.** All other assignments will get a 10% deduction per day of being late. It is to your benefit to turn in assignments on time. Most of the points are better than no points.

Courtesy Policy:

The use of unauthorized handheld electronic equipment is not allowed in the classroom.

Disability Policy:

The university is committed to providing appropriate academic accommodation to ensure all students have an equitable learning experience. If you have a disability that impacts your academic participation, the university strongly encourages you to register with the Disability Services office. This enables them to work with you to determine and implement reasonable accommodations in accordance with the Americans with Disabilities Act. Proactively connecting with the Disability Services office at Columbia University will help you access the support and resources available to facilitate your academic success.

Evaluation and Grading Policy:

Mid-Term	10%
Challenges (4 projects at 10pts. each)	40%
Homeworks (8 HWs)	25%
Final	15%
Attendance & Challenge Presentation	10%

Grading Scale

Grade	A+	A	A-	B+	B	B-	C+	C	C-	F
%	≥95	91-94	87-90	83-86	79-82	73-78	69-72	65-68	60-64	≤59

Challenges: (40%)

There will be multiple expert lectures followed by a “challenge” discussion and/or homework assignment. The challenge will be a problem posed by the professor and/or industry expert. At the end of each challenge, the class will be allowed to form teams of 4-5 students, who will then work with the industry expert and professor on developing questions that will address the challenge. Each student is expected to participate and make a significant contribution to the discussion. Once questions are formulated, each group is expected to address each question via a written report and in-class presentation at the next scheduled class time (based on the established schedule). Project reports will be submitted in the form of a technical paper, using a standard template that will be available on the Courseworks. I reserve the right to modify the teams, and/or reassign an individual to a certain team.

Due date for presentation and reports is outlined in the table below. I reserve the right to change these dates.

Changes to the syllabus:

I reserve the right to amend all policies stated above. Please make sure to check the class page on coursework regularly, where I will post announcements and any changes to the syllabus.

Course Timeline:

<u>Week #</u>	<u>Date</u>	<u>Synchronous Learning</u>	<u>Topics</u>	<u>Challenge / Homework</u>	<u>Deliverables</u>
1	1/22/2026	In-Person	Syllabus + Evolution of the Electric Grid	N/A	N/A
2	1/29/2026	In-Person	Challenge 1 (Group Work): Data Center	Challenge 1	N/A
3	2/5/2026	Virtual	Challenge 1 finalization & Photovoltaics (Solar PV) + Energy Storage lecture	HW 1	N/A
4	2/12/2026	In-Person	Challenge 1 Presentations & Climate Change and Grid Resilience	HW 2	Challenge 1
5	2/19/2026	Virtual	Challenge 2 (Group Work): Grid Modernization	Challenge 2	HW 1
6	2/26/2026	In-Person	Advance Metering Infrastructure (AMI) Lecture & Tour - Con Edison	HW 3	HW 2
7	3/5/2026	In-Person	Challenge 2 Presentations & Electric Vehicles	HW 4	Challenge 2 + HW3
8	3/12/2026	Mid-Term Exam	Mid-Term Exam	N/A	N/A
9	3/19/2026	No Class - Spring Break	No Class - Spring Break	N/A	N/A
10	3/26/2026	In-Person	Challenge 3 (Group Work): Distributed Energy Resource Management - DERMS	Challenge 3	HW 4
11	4/2/2026	Virtual	Challenge 3 Finalization & Wind Energy Lecture	HW 5	N/A
12	4/9/2026	In-Person	Challenge 3 Presentations & Geothermal Lecture	HW 6	Challenge 3 + HW 5
13	4/16/2026	In-Person	Challenge 4: Building Decarbonization	Challenge 4	HW 6
14	4/23/2026	Virtual	Challenge 4 Finalization & Cybersecurity for the Electric Grid Lecture	HW 7	N/A
15	4/30/2026	In-Person	Challenge 4 presentations & Smart Inverters and New Grid Topology	HW 8	Challenge 4 + HW 7
16	5/7/2026	Study Week - No Class	Study Week - No Class	N/A	HW 8
17	5/14/2026	Final Exam	Final Exam	N/A	N/A

* I reserve the right to change these topics based on the progress and interest of the class.