Spring 2018 ECE 622
Energy Networks and Power Distribution Grids

Instructor: Prof. Siddharth Suryanarayanan
Office: Engineering B116
Office hours: 300pm–500pm Wednesday
Other times by appointment only (for Prof. Suryanarayanan's calendar, see: `https://goo.gl/Uu9VbV`)
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Lecture time and venue: 515pm–800pm Wednesday, Room: Engineering B4

Textbook:
None. Notes and technical papers will be supplied by the instructor as deemed fit.

Prerequisites:

- *ECE 461 (or) ECE/ENGR 508 (or) ECE/ENGR 565

Course description: Energy networks: generation, storage, consumers. Systems approach to analysis of distribution networks and transition to intelligent grid systems.

Course objectives: Electric power distribution systems and networks are undergoing hitherto unprecedented changes in design, asset portfolios, operation, management, and active customer engagement. These critical delivery systems are evolving from passive to active roles driven by the Smart Grid Initiative. This graduate-level course is designed to provide an introduction to the emerging concept of smart electric power distribution systems. The emphasis of the course is on topics related to microgrids; smart customers, homes, and neighborhoods; topology and assets management; and, demand response and resource allocation.

In this course students will:

1. Identify the characteristics of a smart electric distribution system
2. Translate the above characteristics to study specific innovations in contemporary electric distribution systems such as microgrids, demand response, and asset management
3. Prepare an annotated bibliography of no less than three references for the material learned in each week
4. Examine and evaluate emerging trends in smart customers, homes, and neighborhoods vis-à-vis electric energy
5. Compare and contrast the state-of-the-art to the newly evolving topology and technologies in smart electric distribution systems
6. Explain via a term paper the future of a contemporary topic in smart distribution systems
7. Defend a position as a panelist on a contemporary topic in smart distribution systems.

*OR instructor's approval.

Assignment of course grade: The grade will be based on the weighted index as shown below.

Homework	25 %
Annotated bibliography	25 %
Term paper	25 %
Panel presentation	25 %

Course outline and reading material: Tentative schedule †

Week 1	Introduction to course and overview of the Smart Grid Initiative in the US
Week 2	Characteristics of a smart distribution system [1], [2]
Week 3	Distributed generation and IEEE 1547 family of standards [3], [4]
Week 4	Microgrids 1: definition, design, and deployment
Week 5	Microgrids 2: lessons learned in dispatch [5]
Week 6	Microgrids 3: lessons learned in data collection and analysis [6]
Week 7	Microgrids 4: relief and recovery activities [7]
Week 8	Smart customers, homes, and neighborhoods 1: *a)* engaging the end-user [8] and *b)* enabling technologies for smart homes [9]
Week 9	*Spring recess*
Week 10	Smart customers, homes, and neighborhoods 2: energy management in smart neighborhoods [10]
Week 11	Topology modifications and assets management 1: reliability improvement in distribution systems [11], [12]
Week 12	Topology modifications and assets management 2: *a)* intelligent distribution substation [13] and *b)* short-term load forecasting and energy management [14]
Week 13	Demand response and resource allocation 1 [15], [16],
Week 14	Demand response and resource allocation 2 [17]
Week 15	Electric vehicles and energy storage in distribution systems [18], [19], [20]
Week 16	Advanced topics & Panel presentations

†The instructor may be on business-related travel on some of the lecture dates. In such cases of a conflict in schedule, the

Week	Course objectives	Objective level
Week 1	1	Introduction
Week 2	1	Engagement
Week 3	2	Engagement
Weeks 4–7	2	Mastery
Weeks 8–10	4	Mastery
Weeks 11 and 12	5, 6	Mastery
Weeks 13 and 14	2	Mastery
Week 15	5	Engagement
Week 16	3, 6, 7	Mastery

Important dates:

Term paper assigned ..... Week 8
Drop course without W ..... Week 9
Term paper due ..... Week 12
Panel presentation topic and panelists assigned ..... Week 13
Panel presentations ..... Week 16
Full annotated bibliography due ..... Week 16

Course Policy:

Attendance: Regular attendance is strongly encouraged. Instances of two successive absences will result in a decrease of the final grade by 5% and will accumulate for every repeated occurrence. In specific, this course will include a frequently assigned (weekly) reading assignment that typically requires studying the course material equivalent to a book chapter, which includes reading and understanding the theoretical narrative of the text and relating this material to the class lectures, performing independently (by the student) the associated derivations from the textbook, and carrying out independently (by the student) the examples (worked-out problems and exercises) from the textbook and/or reference sources. The reading assignments are essential for the successful and efficient performance on projects and class participation, and as such are evaluated and assessed through all assessed/graded items included in the course outline.

Canvas use policy: The instructor will exclusively use the Canvas facility to communicate with the individual and the class regarding the course. So, it is imperative that the student has a functioning email (usually, it is the colostate.edu email id) associated with the Canvas website to receive all notifications. The instructor does not take any responsibility for sending information to students via any other means or to another email id than the one associated with Canvas.

respective lecture will be recorded sans audience and made available via the class URL on Canvas or a guest lecturer may be invited to substitute or the lecture may be canceled.

Make-up: Except under documented cases of extenuating circumstances, there will be no opportunity for a make-up for any portion of the class component towards the final grade.

ADA Statement: Students with disabilities are encouraged to register with the Office for Student Services to determine the appropriate classroom accommodations. Any student with verification of a disability should contact the instructor as soon as possible, and will be accommodated in an appropriate manner.

Term paper: Each student enrolled in the course is required to choose a contemporary topic of research interest in the field of smart electric distribution systems. The instructor will assign this project in the 8^{th} week of classes in the semester. The student is expected to perform high quality literature search and draw conclusions about state-of-the-art and the future of the topic chosen. A technically sound research paper on the topic of choice written in the form of a conference paper (according to the IEEE PES template) is a required deliverable from each student/team in the 12^{th} week of classes in the semester. The template will be provided to the students or can be obtained at the following link (`https://goo.gl/8iKeQ9`).

Annotated bibliography: Each student (or team of no more than two students) enrolled in the course is required to deliver an annotated bibliography consisting no less than three references sources for each week's lecture topic. The full annotated bibliography is due on the 16^{th} week of classes in the semester. For more information on what constitutes an annotated bibliography, visit `https://goo.gl/M6XLxX`.

Panel presentation: Each student enrolled in the course is required to participate on a panel and defend a position. This is scheduled on the 16^{th} week of classes in the semester. Each panel will have three (or four) student participants. The topics of the panels will be decided by the instructor and conveyed to the class during the 13^{th} week of the classes in the semester. Each student panelist will present a lecture for 15 minutes followed by a Q&A session of 10 minutes.

Academic Honesty: Academic integrity is of utmost importance. For a description on practicing academic integrity, go to: `http://tilt.colostate.edu/integrity/`
Colorado State University's Writing Center defines plagiarism as "the unauthorized or unacknowledged use of another person's academic or scholarly work. Done on purpose, it is cheating. Done accidentally, it is no less serious. Regardless of how it occurs, plagiarism is a theft of intellectual property and a violation of an ironclad rule demanding credit be given where credit is due."
Departures from accepted norms of academic integrity will be dealt with full compliance to CSU principles published in the CSU General Catalog. Visit `http://goo.gl/6opQt7` for information on the CSU policies pertaining to this.
The instructor may use a CSU designated resource for verification of plagiarism in any work that is submitted by a student for grade in this course.
Visit `http://tilt.colostate.edu/integrity/pledge/` for familiarizing with the CSU Honor Pledge.

Reading material

[1] H. E. Brown, S. Suryanarayanan, and G. T. Heydt, "Some characteristics of emerging distribution systems considering the Smart Grid initiative," *The Electricity Journal*, vol. 23, no. 5, pp. 64–75, June 2010.

[2] H. E. Brown and S. Suryanarayanan, "A survey seeking a definition of a smart distribution system," in *41st North American Power Symposium*, Oct. 2009, pp. 1–7.

[3] "IEEE standard for interconnecting distributed resources with electric power systems," *IEEE Std 1547-2003*, pp. 1–28, Jul. 2003.

[4] "IEEE standard for interconnecting distributed resources with electric power systems - amendment 1," *IEEE Std 1547a-2014 (Amendment to IEEE Std 1547-2003)*, pp. 1–16, May 2014.

[5] M. Panwar, G. P. Duggan, R. T. Griffin, S. Suryanarayanan, D. Zimmerle, M. Pool, and S. Brunner, "Dispatch in microgrids: Lessons from the fort collins renewable and distributed systems integration demonstration project," *The Electricity Journal*, vol. 25, no. 8, pp. 71 – 83, 2012. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1040619012002151

[6] M. Panwar, D. Zimmerle, and S. Suryanarayanan, "Data analysis and visualization for electric microgrids: A case study on the FortZED RDSI microgrid," in *2013 IEEE Green Technologies Conference (GreenTech)*, Apr. 2013, pp. 330–337.

[7] C. Abbey, D. Cornforth, N. Hatziargyriou, K. Hirose, A. Kwasinski, E. Kyriakides, G. Platt, L. Reyes, and S. Suryanarayanan, "Powering through the storm: Microgrids operation for more efficient disaster recovery," *IEEE Power and Energy Magazine*, vol. 12, no. 3, pp. 67–76, May 2014.

[8] A. Zipperer, P. A. Aloise-Young, and S. Suryanarayanan, "On the design of a survey for reconciling consumer behaviors with demand response in the smart home," in *2013 North American Power Symposium (NAPS)*, Sep. 2013, pp. 1–6.

[9] A. Zipperer, P. A. Aloise-Young, S. Suryanarayanan, R. Roche, L. Earle, D. Christensen, P. Bauleo, and D. Zimmerle, "Electric energy management in the smart home: Perspectives on enabling technologies and consumer behavior," *Proceedings of the IEEE*, vol. 101, no. 11, pp. 2397–2408, Nov. 2013.

[10] B. Celik, R. Roche, S. Suryanarayanan, D. Bouquain, and A. Miraoui, "Electric energy management in residential areas through coordination of multiple smart homes," *Renewable and Sustainable Energy Reviews*, vol. 80, pp. 260 – 275, 2017. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1364032117307554

[11] H. E. Brown, S. Suryanarayanan, S. A. Natarajan, and S. Rajopadhye, "Improving reliability of islanded distribution systems with distributed renewable energy resources," *IEEE Transactions on Smart Grid*, vol. 3, no. 4, pp. 2028–2038, Dec. 2012.

[12] J. Giráldez, A. Jaiantilal, J. Walz, S. Suryanarayanan, S. Sankaranarayanan, H. E. Brown, and E. Chang, "An evolutionary algorithm and acceleration approach for topological design of distributed resource islands," in *2011 IEEE Trondheim PowerTech*, Jun. 2011, 8 pp.

[13] P. Kadurek, A. Zipperer, S. Suryanarayanan, and S. Cobben, "An application of a decision-making algorithm for an intelligent distribution substation," in *2013 IEEE Power Energy Society General Meeting*, Jul. 2013, 5 pp.

[14] D. Palchak, S. Suryanarayanan, and D. Zimmerle, "An artificial neural network in short-term electrical load forecasting of a university campus: A case study," *Journal of Energy Resources Technology*, vol. 135, no. 3, pp. 1–6, 2013.

[15] T. Hansen, R. Roche, S. Suryanarayanan, H. J. Siegel, D. Zimmerle, P. M. Young, and A. A. Maciejewski, "A proposed framework for heuristic approaches to resource allocation in the emerging Smart Grid," in *2012 IEEE PES International Conference on Power Systems Technology (POWERCON)*, Oct. 2012, 6 pp.

[16] T. Hansen, R. Roche, S. Suryanarayanan, A. A. Maciejewski, and H. J. Siegel, "Heuristic optimization for an aggregator-based resource allocation in the Smart Grid," *IEEE Transactions on Smart Grid*, vol. 6, no. 4, pp. 1785–1794, July 2015.

[17] T. M. Hansen, R. Roche, S. Suryanarayanan, A. A. Maciejewski, H. J. Siegel, and E. K. P. Chong, "Customer modeling and pricing-mechanisms for demand response in smart electric distribution grids," in *Cyber-Physical-Social Systems and Constructs in Electrical Power Engineering.* The Institution of Engineering and Technology (IET), London, UK, 2016, pp. 135–160.

[18] J. Giráldez, R. Roche, S. Suryanarayanan, and D. Zimmerle, "A linear programming methodology to quantify the impact of PHEVs with V2G capabilities on distribution systems," in *2013 IEEE Green Technologies Conference*, Apr. 2013, pp. 8–15.

[19] S. Suryanarayanan, F. Mancilla-David, J. Mitra, and Y. Li, "Achieving the smart grid through customer-driven microgrids supported by energy storage," in *2010 IEEE International Conference on Industrial Technology (ICIT)*, Mar. 2010, pp. 884–890.

[20] M. E. Samper, A. Vargas, F. Eldali, and S. Suryanarayanan, "Assessments of battery storage options for distribution expansion planning using an OpenDSS-based framework," in *2017 IEEE PowerTech Manchester*, Jun. 2017, 6 pp.

Resources for technical writing

- Purdue Online Writing Lab (OWL), [Online Available]: `https://owl.english.purdue.edu/owl/`, Last accessed on: 25/7/2017.

- M. Derntl, "Basics of research paper writing and publishing," *International Journal of Technology Enhanced Learning*, vol. 6, no. 2, 2014, pp. 105–123, [Online Available]: `http://dbis.rwth-aachen.de/~derntl/papers/misc/paperwriting.pdf`, Last accessed on: 25/7/2017.