Fall 2015 – EE 394V (16960) Analysis of Power Systems with Renewable Energy Sources

MW 9:00 – 10:15 am

Instructor: S. Santoso (ssantoso@mail.utexas.edu)

Office Hours: UTA 7.229, M 1:30 – 2:30 pm, W 12:30 – 1:30 pm, or by appointment

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Course Objective: This objective of this course is to provide students with technical background in modeling and analysis of integration of renewable energy sources, particularly photovoltaic (PV) and distributed energy storage (DES), into utility distribution systems. The course focuses on the following topics: distribution system load flow, feeder voltage regulation, short-circuits, system protection, grid impacts, and accommodation limits.

Pre-requisites: Graduate standing and instructor's consent.
This course assumes understanding and mastery of the following topics in power system analysis: per-unit quantities, balanced and unbalanced three-phase systems, steady-state, dynamic, and time-domain models of power system apparatuses (such as transformers, overhead lines, synchronous and induction machines, and loads), symmetrical components and sequence networks, short-circuit analysis, distribution system protection, linear algebra and numerical analysis, power system simulations.

Textbooks (Optional)

- T. A Short, Electric Power Distribution Handbook, 2014
- T. Gonen, Electric Power Distribution System Engineering, 2014
- J. J Burke, Power Distribution Engineering, 1994
- H. L Wills, Power Distribution Planning Reference Book, 2004
- W. H Kersting, Distribution System Modeling and Analysis, 2012.
- J. A Momoh, Electric Power Distribution, Automation, Protection, and Control, 2007
- J. Grainger, W. Stevenson, Power System Analysis, McGraw-Hill, 1994
- H. Saadat, Power System Analysis, 3rd, PSA Publishing, 2010
- P. Kundur, Power System Stability and Control, McGraw-Hill, 1994
- Electrical Transmission and Distribution Reference Book, Westinghouse Electric & Manufacturing Company, 1942

Course website https://canvas.utexas.edu//

Course structure Two 75-minute class time with problem assignments and projects

Topical Outline

1. Distribution Circuit Modeling
    - Network matrices: admittance matrix, network solution and reduction, admittance matrix structure and manipulation, bus impedance matrix, inverse elements.
    - Distribution circuit elements and modeling: voltage and current sources, capacitor, line, reactor, transformer, generator, load, PV, DES, inverters.
    - Three-phase distribution-circuit load flow: circuit load shape, characteristics, and allocation, voltage controls, modeling and solution in Matlab, and applications of EPRI® OpenDSS.
    - Three-phase short-circuit analysis: modeling and solution in Matlab and OpenDSS.

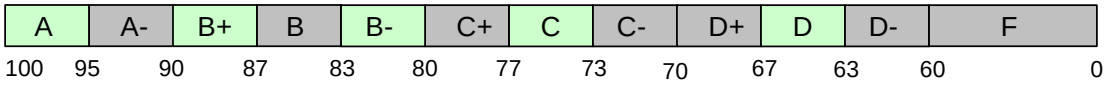
2. Feeder PV Accommodation Limits and Grid Impact Analysis
    - Distribution circuit planning, feeder circuit characteristics, load analysis and allocations
    - Grid impacts: voltage, current, and system protection.
    - PV accommodation: framework, large- and small-scale PV deployments, grid impacts and voltage limit criteria, cloud coverage, generation variability, analysis effects of minimum loads, locational dependence of PV generation, application of smart inverters and volt/var controls.
    - PV accommodation using current and other criteria.

3. Distributed Energy Storage Use Cases and Accommodation Limits
    - Energy storage modeling and control elements.
    - Operational use of DES: system level applications for transformer N-1 contingency, frequency regulation; feeder-level applications for voltage, power quality; stacked benefits, and edge of grid applications.
    - Accommodation limits: system and bus levels based on voltage, thermal current, short-circuit protection, and short-circuit strength.

4. Distribution System Protection
    - Overcurrent protection coordination: fuse-fuse, recloser-fuse, recloser-recloser.
    - PV and DES models for short-circuit conditions.
    - PV and DES impacts: delayed tripping, miscoordination, reverse current flow.
    - Reduction of relay reach: analysis considering fault types (SLG, 3LG), resistance, location, and mitigation.
    - Sympathetic tripping: analysis considering fault types (SLG, 3LG), resistance, location, and mitigation.

Grading Policy: Numerical grades (*g*) are as follows, with a total of 100 points
Assignments and minor/supporting projects: 60 points (5 – 7 projects)
Major projects: 40 points (2 – 3 projects)

The correspondence of letter to numerical grade (*g*)



Computing Tools Matlab, PSCAD/EMTDC, and OpenDSS

Classroom behavior: Class meets on MW between 9 and 10:15 am except during University designated holidays. Although I do not take class attendance, all students are encouraged to be present in all scheduled classes. Late arrivals are indicative of lack of commitment and disruptive to everyone in the class. Be sure to arrive at least 5 minutes before the start of class. I reserve the right to refuse entry to students arriving 10 or more minutes late. Repeat offenders will be subjected to a 25% total grade reduction. The use of all handheld devices (phones, tablets, Ipads) unrelated to the learning process is strictly prohibited. Laptop computers may be used for taking notes and running simulation models.

Policies for submitting assignments, projects, take-home exams, computer scripts: All assignments must be submitted on the due date. Missed exams may be made up due to illness or other emergencies;

otherwise a zero is assigned. Grades for late assignments without instructor consent will be reduced by 25%/day.

Academic Integrity: Any scholastic dishonesty will not be tolerated. Please review this link: http://deanofstudents.utexas.edu/sjs/acint_student.php

Accommodations for Student with Disabilities: The University of Texas at Austin provides, upon request, appropriate academic adjustments for qualified students with disabilities. For more information, contact the Office of Dean of Students at 471-6259 and visit this link:
http://www.utexas.edu/diversity/ddce/ssd/for_cstudents.php

Q drop Policy: The State of Texas has enacted a law that limits the number of course drops for academic reasons to six (6). As stated in Senate Bill 1231:
"Beginning with the fall 2007 academic term, an institution of higher education may not permit an undergraduate student a total of more than six dropped courses, including any course a transfer student has dropped at another institution of higher education, unless the student shows good cause for dropping more than that number."

Emergency Evacuation Policy: Occupants of buildings on the UT Austin campus are required to evacuate and assemble outside when a fire alarm is activated or an announcement is made. Please be aware of the following policies regarding evacuation:

- Familiarize yourself with all exit doors of the classroom and the building. Remember that the nearest exit door may not be the one you used when you entered the building.
- If you require assistance to evacuate, inform me in writing during the first week of class.
- In the event of an evacuation, follow my instructions or those of class instructors.

Do not re-enter a building unless you are given instructions by the Austin Fire Department, the UT Austin Police Department, or the Fire Prevention Services office.

Religious Holy Days: By UT Austin policy, you must notify me of your pending absence at least fourteen days prior to the date of observance of a religious holy day. If you must miss a class, an examination, a work assignment, or a project in order to observe a religious holy day, I will give you an opportunity to complete it within a reasonable time after the absence.