EE 362R (16930) – Renewable Energy and Power Systems
Class Time: Fall 2011, MWF 10:00 – 11:00 am
Class Location: ART 1.120
The University of Texas at Austin

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Renewable energy has become an increasingly important source of energy in electricity generation. In addition to hydropower, wind and solar (photovoltaic and thermal) energy represent two most viable forms of renewable energy sources. The 2011 total installed wind power capacity in the U.S is over 42 GW. Nearly one quarter of this capacity is installed in Texas, making it rank first in the U.S. The state's projected wind power capacity is expected to increase several folds in the next few years. Solar photovoltaic energy has been used primarily on a smaller scale such as in residential and small community establishments. A few utility-scale solar photovoltaic and thermal power plants have been constructed in recent years. Although they are mostly in Europe, notable installations in the U.S are Copper Mountain Solar Facility (48 MW in Nevada) and Cimarron Solar Facility (30 MW in New Mexico). In Texas, two utility-scale PV projects are under constructions, 30-MW and 60-MW plants in Webberville (east of Austin) and Pflugerville, respectively. These sources of renewable energy provide a pathway to achieve energy sustainability and security.

Course Objective: The purpose of this course is to provide students with a rigorous introduction to electric power generation systems with intermittent and variable renewable energy sources and their technical challenges in grid integration. Major emphasis is placed on wind energy resource assessments, elements of conversion systems, generation technology, and grid interconnection and integration issues. Minor emphasis is placed on fundamental and engineering concepts of photovoltaic and concentrated thermal generation systems. This course complements ME379 Introduction to Renewable Energy and Sustainability. It also serves as the introductory course to EE 394V Modeling and Simulation of Wind Power Plants and ChE/ME 384 Energy Policy and Technology.

Course Pre-requisite: Upper-level standing in Engineering, and EE 411 or 331 with a grade of at least C-.

Course Format and Structure: Course format is predominantly lecture, presentation, and discussion. To allow more class time, it is important to note that a few book chapters and technical papers/reports will be assigned for self-study. Although they will not be presented in class, they will be included in homework assignments and exams. Students are encouraged to participate in classroom discussions and ask questions for further information or clarification.

We will run a few computer simulation models of wind turbines and wind power plants in class or computer labs. In addition to two mid-term exams and a final exam, there will be three class projects and a series of assignments. Workload is moderate to heavy. Students are expected to spend on average about 8 to 12 hours per week outside the classroom.

Planned Course Outline:

1. Overview of Renewable Energy Sources and Trends
   - 1.1. Sources of renewable energy
   - 1.2. Renewable energy trends
   - 1.3. Key factors affecting renewable energy supply and prospects
   - 1.4. U.S wind and solar energy outlook

2. Wind Resource Characteristics and Assessment
   - 2.1. Wind speed characteristics and variations
     - 2.1.1.Annual, seasonal
     - 2.1.2.Synoptic, diurnal
     - 2.1.3.Height
   - 2.2. Wind speed and power relation
     - 2.2.1.Available power and power extracted from the wind
     - 2.2.2.Rotor swept area
     - 2.2.3.Air density
   - 2.3. Wind speed distribution and statistics
     - 2.3.1.Weibull pdf
     - 2.3.2.Mean, mode, root mean cube
   - 2.4. Wind energy production

3. Fundamentals of Wind Turbines : Aerodynamics of Blades
   - 3.1. System components
   - 3.2. System design features: number of blades, rotor upwind /downwind, vertical and horizontal axis rotors, tower spacing
   - 3.3. Elementary momentum theory and Betz Limit
   - 3.4. Airfoils and general concepts of aerodynamics
   - 3.5. Aerodynamics of wind turbines: drag and lift
   - 3.6. Aerodynamic power controls: pitch, stall, active stall
   - 3.7. Blade shape for ideal rotor without wake rotation
   - 3.8. Tip speed ratio and rotor power characteristics C_P-λ
   - 3.9. Power curves

4. Fundamentals of Wind Turbines: Drive trains
   - 4.1. Drive trains
   - 4.2. Drive train models

5. Fundamentals of Wind Turbines: Fixed speed (Type 1)
   - 5.1. Induction generator
   - 5.2. Direct-coupled fixed speed wind turbines
   - 5.3. Steady-state analysis of energy conversion: from wind kinetic, to mechanical, and electrical.
   - 5.4. Reactive power requirements
   - 5.5. Islanded operation
   - 5.6. Modeling and simulation
   - 5.7. Effects of tower shadow and wind shear

6. Fundamentals of Wind Turbines: Variable speed (Type 2 – 4)
   6.1. Induction generator with slip control (Type 2): steady-state analysis, slip and pitch control, modeling and simulation
   6.2. Doubly-fed induction machine (Type 3): current-regulated model, independent active and reactive power controls, modeling and simulation
   6.3. Full converter turbines (Type 4): converter configuration and topology

7. Impacts of wind farm interconnections
   7.1. Distribution system impacts: short-circuit capacity, voltage regulation, protection coordination, voltage fluctuations
   7.2. Transmission system operation impacts: inertia and frequency, operating limits
   7.3. Transmission system planning impacts: reliability analysis, capacity value.

8. Photovoltaic power Systems
   8.1. The solar resource: spectrum, earth's orbit, altitude angle, position, tracking systems, insolation
   8.2. PV materials and electrical characteristics: a generic PV cell, equivalent circuits, cells, modules, arrays, IV curve under standard test conditions
   8.3. PV systems: IV curves, maximum power point trackers, grid connected systems, capacity factors

Reading Materials and Textbooks: (1-7 available electronically from UT Libraries)

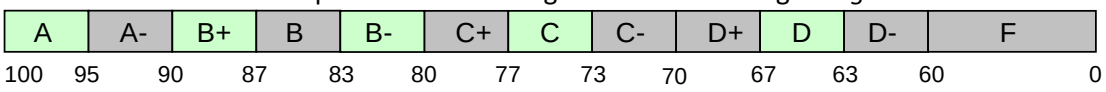
1. E. Hau, *Wind Turbines: Fundamentals, Technologies, Application, Economics*, Springer-Verlag, 2005, Chapters 2, 3, 4, 5, 9, and 14.
2. J.F Manwell, J.G McGowan, A.L Rogers, *Wind Energy Explained: Theory, Design, and Application*, Wiley, 2002 or 2009 (Chapters 1, 2, 3, and 5).
3. G. M Masters, *Renewable and Efficient Electric Power Systems*, Wiley, 2004, Chapters 6 - 9.
4. R. Strzelecki, G. Benysek, *Power Electronics in Smart Electrical Energy Networks*, Springer, 2008, Chapters 11 and 12.
5. T. Ackermann, *Wind Power in Power Systems,* Wiley, 2005, Chapters 3 and 4.
6. M. Stiebler, *Wind Energy Systems for Electric Power Generation*, Springer 2008, Chapters 2 and 5.
7. P. A Lynn, *Electricity from Sunlight, An Introduction to Photovoltaics*, Wiley 2010, Chapter 3.
8. G. Johnson, *Wind Energy Systems*, Electronic Edition, download from this location: *http://www.eece.ksu.edu/~gjohnson/*
9. Technical papers and reports

Course Interface: Course materials are available in this course site, https://courses.utexas.edu/

Grading Policy: Distribution of grades and numerical grades (*g*) are as follows:

- Assignments and small projects: 15 + 20 points,
- Midterm exam: 2 x 15 points – Exam dates: Mondays 10/3 and 11/7.
- Class participation and behavior: 5 points
- Final exam: 30 points
- Total *g* = 100 points

The correspondence of letter grade to numerical grade *g* is:



Classroom behavior: Class meets on MWF between 10 and 11 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 not 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 the missed work within a reasonable time after the absence.