

## EE 459/559

# Electromechanical wind energy conversion and grid integration Fall, 2016

*M, W, 5:10-6:30 am, 1242 Howe*

*Professor James McCalley*

## Course Overview

**Course:** EE 459/559 – Electromechanical wind energy conversion and grid integration

**Instructor:** Professor J. McCalley, Room 1115 Coover

**Office Hours:** Tuesdays 4-5. Fridays 4-5 pm.

**E-mail & Phone :** [jdm@iastate.edu](mailto:jdm@iastate.edu); 515-294-4844 (v)

**Administrative Assistant:** to be named soon, 515-294-8057, Room 1130 Coover

**Grader:** Ashraf Radaideh, [radaideh@iastate.edu](mailto:radaideh@iastate.edu), 1132 Coover Hall. Office hours: Friday: 8-10 am.

**Course Web Page:** There is a Blackboard page (<https://bb.its.iastate.edu/webapps/portal/frameset.jsp>), to which all of you should have access with your ISU net ID and password. However, I will mainly use a public website to post materials and homeworks. This website is at [home.eng.iastate.edu/~jdm/ee559/schedule.htm](http://home.eng.iastate.edu/~jdm/ee559/schedule.htm).

### Catalog description:

E E 459/559: Electromechanical Wind Energy Conversion and Grid Integration  
(3-0) Cr. 3.

Prereq: Credit or enrollment in E E 452, E E 456

Summary of industry status and expected growth; power extraction from the air stream; operation and modeling of electric machines, and power electronics topologies for wind energy conversion; analysis of machine-grid power electronic circuits, controller interface, and collector (distribution) networks; treatment of harmonics, flicker, over/under-voltages, filters, low-voltage ride-through, and reactive compensation; relaying; effects on transmission expansion, planning and grid operation and coordination including variability, frequency control, reserves, and electricity markets; overview of storage technologies and hybrid configurations.

### Course Topics:

#### A. Introduction (about 1 week):

- Industry status
- Wind energy technology
- Levelized cost of wind energy

#### B. Electric machines & power electronics topologies for wind energy conversion (EMPE) (about 7 weeks):

- Fixed-speed induction generator wind energy conversion systems (WECS)
- Doubly-fed induction generator WECS
- Variable speed WECS with synchronous generator

#### C. Grid integration issues (GII) (about 6 weeks):

- Transmission and collection
- Localized issues
- Off-shore technologies
- Grid operation
- Interaction with electricity markets
- Storage technologies

**Course Prerequisite:** Familiarity with power system analysis methods at the level of one of the standard text books on this subject, including the ones by Bergen & Vittal, Grainger & Stevenson, Glover & Sarma, Gross, del Torro, Saadat, and Elgerd. Familiarity with the following topics is essential: matrix algebra, calculus, network analysis theory, electromagnetics.

### Required Student Materials:

1. None. All course materials will be posted to the course webpage.
2. Some useful resources are listed below. None of them are required, but some of the materials I will use will come from these references. You can probably purchase most of them on-line if you would like to have one. If a resource

has an asterisk, it means the library has a copy, but I have it checked out. I would appreciate it if you would not place a recall on it but rather just ask me for it and I can arrange for you to borrow it from me.

General:

- \*E. Hau, “Wind Turbines, Fundamentals, Technologies, Application, Economics,” 2<sup>nd</sup> edition, Springer, 2006.
- J. Manwell, J. McGowan, and A. Rogers, “Wind energy explained: theory, design and application,” 2<sup>nd</sup> edition, Wiley 2009.

Electric machines and converters:

- G. Abad, J. Lopex, M. Rodriguez, L. Marroyo, and G. Iwanski, “Double fed induction machine: modeling and control for wind energy generation,” Wiley, 2011.
- B. Wu, Y. Lang, N. Zargari, and S. Kouro, “Power conversion and control of wind energy systems,” Wiley, 2011.

**Class Attendance:** You are strongly encouraged to attend class, but role will not be called. However, you are responsible for all information presented in-class. Although effort will be made to post in-class coverage to the website, class time is the primary means of communicating material; if a student misses class, there is no guarantee it will be possible to obtain the material in another way, and the instructor is under no obligation to provide another way. The bottom line is this: do not miss class, but if you do, make arrangements with a fellow classmate to provide you with any material that was not posted to the website. For off-campus students, this is less of an issue because you will have access to the archived recordings of class. I do not make these recordings available to on-campus students because experience has it that doing so results in decreased class attendance.

**Class Preparation:** A schedule of topics is given below. Although we may deviate from this schedule a little, if you are attending class regularly, you should still be able to use it to tell where we are and how best to prepare for class. Reviewing all posted materials is strongly encouraged. I suggest that you check the website 15 minutes before class, print out any newly posted material, and bring it to class with you; alternatively, bring your laptop to class and access the material just before class begins. Please note: I frequently work on the materials right up to the beginning of class, and so accessing it 15 minutes before class begins is a good approach to guarantee you have that day’s materials in front of you. You might maintain the materials in electronic form (and not hard copies) throughout the semester; however, you will need hard copies for the final exam (see comment below on final exam).

**Course grading policy:**

Final scores will be determined by the following allocation:

	EE 459	EE 559
<b>Exam 1</b>	25%	20%
<b>Exam 2</b>	25%	20%
<b>Final Examination</b>	25%	20%
<b>Homework</b>	25%	15%
<b>Project proposal</b>	0%	5%
<b>Project presentation</b>	0%	5%
<b>Project technical paper</b>	0%	15%
<b>Total</b>	100%	100%

Letter grades will be determined by the following guidelines:

<b>90 and above</b>	A
<b>80 to 90</b>	A- / B+ / B
<b>70 to 80</b>	B- / C+ / C
<b>60 to 70</b>	C- / D+ / D
<b>60 and below</b>	D- / F

The above guidelines are guaranteed in that they will not change it in a way that is not in your favor, e.g., if your final average is 90 or above, you will definitely receive an A. It is possible, though not guaranteed, that the above guidelines could be changed in your favor, e.g., if your final average is 89.7, you might still get an A. However, any change in your favor of this nature is entirely the decision of the instructor and is not guaranteed.

**Communication:** Feel free to communicate with the instructors in any way that is convenient to you (after class, during office hours, phone, e-mail), for questions about the course material or assignments. E-mail is an especially good way, but response time here is variable, typically ranging from a minute to about 24 hours, depending on the nature of your question and the instructor’s schedule. If you send mail and do not respond within 24 hours, then it means that somehow your email was missed, and so in this case, please re-send.

**Exams 1 & 2:** There will be two 75-minute exams during the semester and a final exam. No make-up exams will be given, unless there is a legitimate reason for missing the exam that is not under the student's control, and the student makes appropriate arrangement with the instructor in advance of the scheduled exam.

**Final exam:** The final exam will be 2 hours, comprehensive, open-book/open notes, covering the material from the entire semester. Having hard copies of all materials in a binder will facilitate your ability to perform well on the final exam.

**Exams for off-campus students:** Off-campus students (those enrolled in EE 550 XE) have three options regarding taking exams (on-campus students must take exams via option 1):

1. Option 1: Come to campus and take the exam with the rest of the class during normal class time (4-5:30).
2. Option 2: Come to campus and take the exam at one of the ISU testing center locations during the allowed scheduled time. The ISU testing center locations are 2552 Gilman Hall, 60 Carver Hall, and 139 Durham Center. In this case, your proctor will be the "Gilman Testing Center," which you can implement by following the instructions for finding a proctor here: <http://www.testcenter.iastate.edu/need-a-proctor/>.

If you do not live in or reasonably close to Ames, Iowa, then Options 1 and 2 may not be realistic for you.

3. Option 3: Take the exam via the proctoring and testing system. This option is probably the one most off-campus students will need to select. This option requires that you find a proctor yourself which you can do by following the instructions for finding a proctor here: <http://www.testcenter.iastate.edu/need-a-proctor/>.

**IMPORTANT:** Off-campus students choosing options 1 or 2 need to identify a proctor by week 4 of class.

**Assignments:** There will be homework assignments that students work outside of class and turn in for a grade. Late assignments will not be accepted, unless there is a legitimate reason that is not under the student's control, and the student communicates with the instructor in advance.

**Laboratory:** The Iowa State University Electrical and Computer Engineering department has a Wind Energy Systems Laboratory, managed by Nick David. Nick will give four laboratory demonstrations during this course, focused on the following topics:

1. Wind turbine components
2. Characterizing the wind resource
3. The doubly-fed induction generator (DFIG)
4. Back-to-back power converter used in DFIG

You will be asked to prepare for the demonstration in advance, to watch it, and then to turn in your responses to some questions.

**Project:** Students enrolled in EE 459 do not need to complete a course project. Each student enrolled in EE 559 is required to complete a course project. The end result of the course project will be a 5-8 page technical paper (written in the format of an IEEE technical conference paper – see the "MSWord Template" located at <http://www.ieee-pes.org/templates-and-sample-of-pes-technical-papers>), and a 10-minute recorded presentation. The presentations will be played to the class during the last three classes. (We will extend these three classes by 15 minutes each, ending them at 6:45pm, to give us 90 minutes per class, so that we can have 90/8≈11 minutes per presentation.) All presentations should be pre-recorded using the voice-over in powerpoint. (All technical papers and recorded presentations are due on Wednesday, November 30, 2016 and should be posted to the course Cybox on that day; presentations will be shown in-class on Wednesday, November 30, Monday December 5, and Wednesday December 7. Some additional information about the project follows:

1. Some guidelines on project content will be given soon.
2. Subject to the given guidelines identified in item #1, EE 559 students are responsible for identifying their own project objective.
3. Each EE 559 student should send to Dr. McCalley, by Friday, September 16, 2016, a two-page (11 pt font, standard margins) *project proposal* which states project objective and why the objective is important, previous work related to the objective (on which you will build), the approach you will take, what will be the project deliverable(s), and the project work schedule. You should start on this immediately after receiving the guidelines.
4. Your project proposal will count 5% of your overall course grade. Grading criteria for the project proposal will be (a) significance of the objective; (b) capture of previous work; (c) creativity of the identified approach; and (d) usefulness of the final deliverable.
5. The work you report should not be work you have already performed previous to enrolling in this class. It can be work that you end up using in the future in your job or your research.
6. Expectations are that the technical papers would be at least 5 pages in length and not to exceed 8 pages in length (including bibliography). Suggested sections for the technical paper are "Abstract", "Introduction," "Basic concepts," "Recent work in advancing state-of-art," "Industry applications," "Conclusions," and "Bibliography." You should post your paper to the Cybox.

7. Presentations must not exceed 10 minutes; this is a hard constraint! Your presentation should identify the project objective, any basic concepts, recent work in advancing state-of-art, and industry applications.
8. For the voice-over powerpoint, make sure the audio is embedded and NOT linked; you can test this by making sure the audio works on another device). Include your picture and e-mail address on slide 1.
9. For each project, a group of four students in the class will be identified to ask one question per student and then email their question to the presenter. The presenter must then prepare a response to each question (identifying the person who asked the question) and upload to the Cybox by Friday, December 7, 2016. Assignments for the groups of student questioners is provided below.

**Identification of Questioners for each Presenter**

Presenter No.	Presenter name	Student groups to ask questions
1	Rajaz Amitava*	Chartouni, Cao, Chiluka, Huang
2	Zhelun Cao	Dugan, Jones, Kancheria, Sarangan, P. Sharma
3	Vikram Chiluka	Haq,R. Sharma, S. Sharma, Singh
4	Yija Huang	Heinen, Ahmed, Zapata, Dellasandro
5	Rory Jones	Mirza, Feltes, Gnesda, Karim
6	Sameera Kancherla *	Riedl, Kekeocha, Klyn, Lewis
7	Srikrishna Sarangan	Szostak, Near, Zuluaga, Rust
8	Pranav Sharma	Trischan, Watkins, Amitava, Cao
9	Rishi Sharma	Zaou, Chiluka, Huang, Jones
10	Shikha Sharma	Chartouni, Kancherla, Sarangan, P. Sharma
11	Vivek Singh	Dugan, R. Sharma, S. Sharma, Szostak
12	Hassan Ahmed	Haq, Trischan, Singh, Zapata
13	Carlos Borda Zapata	Heinen, Zaou, Ahmed, Dellasandro
14	Jesse Dellasandro	Mirza, Feltes, Gnesda, Karim
15	Daniel Feltes	Riedl, Kekeocha, Klyn, Lewis
16	John Gnesda	Szostak, Near, Zuluaga, Rust
17	Srijan Karim	Trischan, Watkins, Amitava, Cao
18	Samuel Kekeocha	Zaou, Chiluka, Huang, Jones
19	Aric Klyn	Chartouni, Kancherla, Sarangan, P. Sharma
20	Steven Lewis	Dugan, R. Sharma, S. Sharma, Singh
21	Joseph Near	Haq,Ahmed, Zapata, Dellasandro
22	Maria Pareja Zuluaga	Heinen, Feltes, Gnesda, Karim
23	Matthew Rust	Mirza, Kekeocha, Klyn, Lewis
24	Benjamin Watkins *	Riedl, Near, Zuluaga, Rust

**Disability Statement:**

Please address any special needs or special accommodations with me at the beginning of the semester or as soon as you become aware. Those seeking accommodations based on disabilities should obtain a Student Academic Accommodation Request (SAAR) from the Disability Resources (DR) office. Any student who feels s/he may need an accommodation based on the impact of a disability should contact me privately to discuss the specific need.