## Syllabus: ECE 451 Power System Analysis – Fall 2014

Instructor: Dr. Ning Lu, Associate Professor, Department of ECE, North Carolina State University

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Course Time: Monday & Wednesday 8:05AM – 9:20AM Room: 01228 Engineering Building 2

Office Hours: Monday 3:00 – 5:00 pm, or by appointment

# **Course Description**

The course will help students understand how power systems are modeled both at the distribution and transmission levels. The course covers long-distance transmission of electric power with emphasis on admittance and impedance modeling of components and system, power-flow studies and calculations, symmetrical and unsymmetrical fault calculations, economic operation of large-scale generation and transmission systems. Emphasis is on applications of computer-based methods to power-system problems.

#### **Prerequisites**

ECE 305 or equivalent coverage of the following prerequisite topics:

- 1. Steady-state analysis of single-phase and three-phase circuits
- 2. Elements of transient analysis and rudimentary electromagnetic field theory
- 3. Principles of electric machines, transformers, and transmission lines
- 4. Per-unit system and representations
- 5. Please also review ECE 301 (Linear Systems) for definition of a vector, a matrix, matrix sum and products, determinants, matrix inverse

#### **Textbooks**

Grainger, John J., and William D. Stevenson. Power system analysis. New York: McGraw-Hill, 1994.

## **Course Learning Objectives**

Upon completion of this course, students will be able to:

- Build basic understandings on modern power system operation and protection
- Master basic modeling technics for power system analysis
  - o Modeling of power system apparatus (transformers, motors, transmission lines)
  - Single and three phase systems
- Power flow analysis
  - o Bus admittance matrix
  - Power flow solution
- symmetrical and unsymmetrical fault calculations
- Economic Dispatch and Unit Commitment

## **Grading Policy**

Attendance is expected at each lecture of this course. There will be weekly problem assignments. Fold your homework papers together (stapling is recommended) and print your name on the outside. Homework papers will be collected at the beginning of class on their due dates. Late homework will not

be accepted. Students are encouraged to collaborate sensibly on homework keeping in mind that quizzes and exams are **closed-book**.

There will be one class project, a midterm and a final exam. The weight for each is as follows: Homework: 24%; Class Project: 12%; Midterm: 24%; Final: 40%. Homework will be graded by the Teaching Assistant (TA) if one is assigned; questions regarding homework should be directed to the instructor. The instructor will also grade quizzes and Final Exam and the design project. Please see your instructor if you have questions about grading.

Only the University approved reasons will be accepted for missing an exam (See <a href="http://www.ncsu.edu/policies/academic affairs/pols regs/REG205.00.4.php">http://www.ncsu.edu/policies/academic affairs/pols regs/REG205.00.4.php</a>). A make-up exam will be administered at the mutual convenience of the student and the Instructor. In all cases, signed documentation must be provided to the Instructor and attached to the make-up exam in order to obtain credit.

## **Reading Assignments**

The reading assignments are given in the Lecture Schedule. Reading the assignments before coming to the lectures can be very helpful.

#### Software needed

Matlab and *Power World* will be the main computational tool for both the homework and the project. Each student may also be required to use a general-purpose analysis computer program for either power flow or fault analysis and design of a representative electric-power transmission network.

#### **Academic Integrity**

Work in this course is to be done under the Academic Integrity Honor Pledge: "I have neither given nor received unauthorized aid on this test or assignment." Students must abide by the Code of Student Conduct, <a href="http://www.ncsu.edu/policies/student\_services/student\_discipline/POL11.35.1.php">http://www.ncsu.edu/policies/student\_services/student\_discipline/POL11.35.1.php</a>
Evidence of copying, including copying of source code, or any other use of unauthorized aid will be investigated and potentially referred to the University judicial system as a violation of the *Code of Student Conduct*. The *minimum sanction* for a violation is a zero on an assignment. Recycling of projects from another class will be considered an academic integrity violation.

#### Students with disabilities

Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 515-7653. For more information on NC State's policy on working with students with disabilities, please see this page (<a href="http://www.ncsu.edu/provost/hat/current/appendix/appen">http://www.ncsu.edu/provost/hat/current/appendix/appen</a> k.html.)

## Civility in the classroom

Students are expected to assist in maintaining a classroom environment that is conducive to learning. Inappropriate behavior in the classroom that leads to the distraction of others shall not be tolerated under any circumstances.

# Course Outline (This is a tentative schedule that is subject to minor changes)

		Date	Course Description	Section	Pages	
1	W	8/20/2014	Introduction			
2	М	8/25/2014	Balanced 3-phase systems; power calculations	1-14		
3	W	8/27/2014	Balanced 3-phase systems; per-unit quantities 1.8 – 1.14		14 - 37	
	М	9/1/2014	Labor Day Break (No class)			
4	W	9/3/2014	3-phase transformers and connections 2.4 - 2.5		56 - 64	
5	М	9/8/2014	3-phase transformers and connections 2.4 - 2.5		56 - 64	
6	W	9/10/2014	Transformers: phase shift, per-unit calculations	64 - 82		
7	М	9/15/2014	Impedance diagrams, per-unit calculations 3.1 - 3.3		87 - 105	
8	W	9/17/2014	Synchronous machines and equivalent circuits 3.4, 3.5		105 - 117	
9	М	9/22/2014	Synchronous generator; control of P&Q output 3.4, 3.5		105 - 117	
10	W	9/24/2014	Y <sub>bus</sub> formation and modification 7.1 – 7.6		238 - 263	
11	М	9/29/2014	$Y_{bus}$ formation and modification $7.1 - 7.6$		238 - 263	
12	W	10/1/2014	Gaussian elimination and triangular factorization 7.7 – 7.8		263 - 279	
13	М	10/6/2014	Z <sub>bus</sub> matrix; formation and modification 8.1 - 8.3		283 - 301	
	W	10/8/2014	Midterm			
14	М	10/13/2014	Z <sub>bus</sub> matrix; formation and modification 8.1 - 8.3		283 - 301	
15	W	10/15/2014	Z <sub>bus</sub> matrix; formation and modification 8.4 - 8.5		301 - 310	
16	М	10/20/2014	Equivalent circuits from Zbus matrix			
17	W	10/22/2014	The power flow problem	9.1 - 9.2	329 - 342	
18	М	10/27/2014	Newton-Raphson calculations 9.3 - 9.4		342 - 353	
19	W	10/29/2014	Power- flow case studies Chap. 9			
20	Μ	11/3/2014	Power-flow summary Chap. 9			
21	W	11/5/2014	Symmetrical faults, Z <sub>bus</sub> equivalent circuits	10.1 - 10.4	380 – 402	
22	М	11/10/2014	Symmetrical components 11.1 - 11.4		416 - 429	
23	W	11/12/2014	Sequence circuits; Y/ $\Delta$ loads; t- lines, synchronous machines 11.5 - 11.7		429 - 449	
24	М	11/17/2014	Sequence networks; Y and ∆ transformers 11.8 - 11.9		449 - 467	
25	W	11/19/2014	Single-line-to-ground faults 12.1 - 12.2		470 - 488	
26	М	11/24/2014	Problem-solving session Chaps. 11-12			
	W	11/26/2014	Thanksgiving Break (No Class)			
27	М	12/1/2014	Line-to-line and double-line-to-ground faults	12.3 - 12.5	3 - 12.5 470 - 488	
28	W	12/3/2014	Solutions of typical fault problems (last class)	Chap.12		
	W	12/10/2014	Final exams (1:00-4:00 p.m.)		(40 points)	

ECE 451 Homework Assignments: Fall 2014

HW Set	Due Date	Sections of Text	Homework Problems from Class Text	
1	8/25	1.8 – 1.14	1.13, 1.15, 1.16, 1.17, 1.18, 1.20, 1.22, 1.23, 1.24	
2	9/01	2.4 – 2.5	1.25, 1.26, 2.12, 2.14, 2.17	
3	9/08	2.6 - 2.10 3.1 - 3.3	Handouts: Transformers: 1,2,3 & Per-Phase System Equivalents 4,5,6	
4	9/15	3.4 – 3.5	3.3, 3.4, 3.5, 3.6, 3.13	
5	9/22	7.1 – 7.8	In all problems of this assignment, assume no mutual coupling exists 7.1 (find Ybus), 7.2, 7.13, 7.14, 715, 7.19	
-	9/29		Test No. 1 Lectures 1 - 11	
			Fall Break October 6 - 7	
6	10/18	8.1 – 8.5	8.1 – 8.6 inclusive	
7	10/25	8.1 – 8.5	8.8 – 8.10 inclusive	
8	11/01	9.1 – 9.4	9.4 - 9.7 inclusive and Special Problems 1, 2, and 3	
9	11/08	10.1 – 10.4	10.3, 10.5, 10.6 ( word "motor" should be "bus"), 10.8, 10.11, 10.12	
10	11/15	11.1 – 11.7	11.2 – 11.6	
11	11/22	11.8 – 11.9	11.8, 11.9, 11.10, 11.12	
	11/22		Test No. 2 Lectures 12 - 25	
	11/24		Thanksgiving Holiday	
12	11/29	12.1 - 12.5	12.1, 12.3, 12.4, 12.8 - 12.10, 12.12	