ET 332b
AC Electric Machines and Power Systems

Instructor:  Dr. Carl Spezia, PE

Office:  Engr. D110  
Phone: 453-7839  
E-mail: powerguy@siu.edu

Office Hours:  9:00 am - 10:00 am  M-W-F  
2:00 pm - 3:00 pm M-W-F


References:  Electric Machinery and Transformers, Irving L. Kosow

Grading Scale:

100-90%  A  
89-80%  B  
79-70%  C  
69-60%  D  
59-below  F

Hour Exams (3 at 100 points each)  50%  
Final Exam (200 points)  20%  
Homework  10%  
Laboratory Experiments/Activities  20%

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Total  100%

Course Policies

1.  Late Work and Makeup Exams  
No make-up exams. All homework handed in at the beginning of the period it is due.  No late homework accepted without prior approval. Late lab grades reduced by 5% per working day starting from due date.

2.  Attendance Policies  
Class attendance is required and attendance will be taken at the beginning of every period. Students are allowed four unexcused absences. Any further absences will reduce the TOTAL grade by 5% per day absent.

Note: the final exam is optional for all students that have a 90% or higher average on the hour exams, homework, and experiment/activities
Course Description and Prerequisites
This course introduces the theory and operation of DC and AC machines with an emphasis on the testing and measurement of machine characteristics and parameters. Laboratory exercises will demonstrate the theoretical concepts and give experience using various types of measurement devices and software.

Prerequisite: Engineering Technology 304a

Course Performance Criteria
At the end of this course, you will be able to:
1.) Find the voltage current and power in a single phase ac circuit using phasor analysis,
2.) Construct a power triangle for an ac load,
3.) Compute the power factor of an ac load,
4.) Compute the voltages and currents in three-phase delta and wye connected loads and sources,
5.) Solve simple balanced three-phase ac systems,
6.) Identify the types of mechanical loads attached to motors in industry,
7.) Draw the equivalent circuit model of single phase transformers,
8.) Conduct open circuit and short circuit tests on transformers to find circuit parameters,
9.) Use the per unit system to perform power system calculations,
10.) Compute transformer efficiency and voltage regulation,
11.) Interpret nameplate data on transformers and ac motors,
12.) Make three phase transformer connections,
13.) Compute load division between parallel transformers,
14.) Explain the operation of three-phase induction motors
15.) Calculate motor currents, power, speed and torque using an equivalent circuit model,
16.) Measure and calculate motor losses and efficiency,
17.) Connect power meters and measure ac power and power factor,
18.) Conduct no-load and locked-rotor tests to find motor circuit parameters,
19.) Explain how synchronous motors operate,
20.) Perform motor calculation using and equivalent circuit model,
21.) Explain how induction generators operate.
22.) Explain how synchronous motors can be used for power factor correction and calculate their impact,
23.) Explain how synchronous alternators operate,
24.) Perform alternator calculations,
Performance Criteria (cont.)

25.) Make three-phase power and energy metering connections and interpret a watt-hour meter reading.

Emergency Procedures

SIUC is committed to providing a safe and healthy environment for study and work. Because some health and safety circumstances are beyond our control, we ask that you become familiar with the SIUC Emergency Response Plan and Building Emergency Response Team (BERT) program. Emergency response information is available on the BERT website at www.bert.siu.edu, Department of Public Safety’s website www.dps.siu.edu (disaster drop down) and in the Emergency Response Guidelines pamphlet. Know how to respond to each type of emergency.

Instructors will provide guidance and direction to students in the classroom in the event of an emergency affecting your location. It is important that you follow these instructions and stay with your instructor during an evacuation or sheltering emergency. The Building Emergency Response Team will assist your instructor in evacuating the building or sheltering within the facility.

Final Examination Schedule Policy

This course will follow the University schedule for final examinations. The course instructor will not administer the final exam prior to the published University date.

Academic Dishonesty Policy:

Students may be subject to disciplinary proceedings resulting in an academic penalty or disciplinary penalty for academic dishonesty. Academic dishonesty includes, but is not limited to, cheating on a test, plagiarism, or collusion. References to the Student Conduct Code, (e.g. plagiarism policy).
ADA Statement for Students Requiring Special Accommodations:

As per Section 504 of the Vocational Rehabilitation Act of 1973 and the American Disabilities Act (ADA) of 1990, if accommodations are needed, inform the instructor as soon as possible.
Fundamentals of Ac Analysis

**Single phase ac analysis**
- Time and phasor representations
- Series circuits
- Parallel circuits
- Power triangle
- Power Factor

**Three phase ac analysis**
- Double subscript notation
- Wye connected sources
- Delta connected sources
- Phase sequence
- Solution of three phase circuits
  - balanced and unbalanced

**Review of Basic Mechanics**
- Physical of mechanical motion, force,
  - Torque, transformation of energy.
  - Torque-speed relationships for mechanical loads

**Transformer Principles**
- Construction and classification
- Transformer action with sinusoidal input voltages
- Ideal transformer model
- Equivalent circuit for transformers
- Voltage regulation
- Per unit/percent system
- Per unit/percent transformer impedances
- Transformer efficiency
- Open circuit/short circuit tests

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Spring 2014
# ET 332b
## Electromechanical Principles and Devices
### Course Outline

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<td>Phase sequence identification</td>
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<tr>
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<td>Equivalent circuit of the Induction motor</td>
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<td>NEMA Classifications</td>
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<td>Induction motor parameters</td>
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Electromechanical Principles and Devices
Course Outline

Induction Generator Operation

Synchronous Motors

Synchronous Generators (Alternators)

Chapter 8

Chapter 9

Section 5-15
TEST 2

Construction and motor starting
Equivalent circuit model
Synchronous motor power equation
Load changes effects on motor
Effects of field excitation changes
Synchronous motor losses and efficiency
Synchronous condenser operation of synchronous motors

Motor to generator transition
Synchronous generator power equation
Generator loading
Paralleling Synchronous generators
Prime mover and generator control
Motoring of synchronous generators
Safe paralleling of alternators
Loss of field excitation effects
Load division between Alternators

Test 3

Final review

Final exam (comprehensive)
ET 332b
Electromechanical Principles and Devices
Course Outline

ET 332b
Homework Assignments

1. cpmathhw.wp5*
2. sglepwhw.wp5
3. spqhw.wp5
4. pfhw.wp5
5. hw3phs1.wp5
6. hw3phs4.wp5, hw3phs3.wp5
7. hw3phs2.wp5, pfcorr.wp5
8. wyedhw.wp5, tqpdpd.wp5
9. 2-9
10. 2-11
11. 2-13
12. 2-15
13. 2-25
14. 2-17
15. 2-39
16. 3phtxhw.wp5
17. 3-11
18. 3-1, 3-9**
19. meterhw.wp5
20. 4-4, ind-hw1.wp5
21. 4-6
22. 4-10
23. 4-16
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28. 8-1, 8-2, 8-3
29. 8-5
30. 8-7
31. 8-17
32. 9-1, 9-5

*Homeworks with this type of label come from the homework packet.
**Misprint in problem statement. Use a voltage value of 482 instead of 432.
ET 332b
Electromechanical Principles and Devices
Course Outline

Syllabus Attachment
Spring 2014

We emphasize student achievement and success because achievement and success are essential if we are to shape future leaders and transform lives.

IMPORTANT DATES
Semester Class Begins: 01/14/2014
Last day to add a class (without instructor permission): 01/24/2014
Last day to withdraw completely and receive a 100% refund: 02/26/2014
Last day to drop a course using SalukiNet: 08/23/2014
Last day to file diploma application (fee required to appear in Commencement):
Spring 2014
Final Examinations: 05/05 – 05/09 2014

*Note: For outreach, online, and short course drop deadlines, visit Registrar’s Academic website http://registrar.siu.edu/

SPRING SEMESTER HOLIDAYS
Martin Luther King, Jr.’s Birthday 01/20/2014
Spring Vacation: 03/08 – 03/16/2014

WITHDRAWAL POLICY – Undergraduate only
Students who officially register for a session may not withdraw merely by the stopping of attendance. An official withdrawal form needs to be initiated by the student and processed by the University. For the proper procedures to follow when dropping courses and when withdrawing from the University, please visit registrar.siu.edu/pdf/undercatalog114.pdf

INCOMPLETE POLICY – Undergraduate only
An INC is assigned when, for reasons beyond their control, students engaged in passing work are unable to complete all class assignments. An INC must be changed to a completed grade within one semester following the term in which the course was taken, or graduation, whichever occurs first. Should the student fail to complete the course within the time period designated, that is, by no later than the end of the semester following the term in which the course was taken, or graduation, whichever occurs first, the incomplete will be converted to a grade of F and the grade will be computed in the student’s grade point average. For more information please visit: http://registrar.siu.edu/grade/incomplete.html

REPEAT POLICY
An undergraduate student may, for the purpose of raising a grade, enroll in a course for credit no more than two times (two total enrollments) unless otherwise noted in the course description. For students receiving a letter grade of A,B,C,D, or F, the course repetition must occur at Southern Illinois University Carbondale. Only the most recent (last) grade will be calculated in the overall GPA and count toward hours earned. See full policy at http://registrar.siu.edu/pdf/undercatalog114.pdf

GRADUATE POLICIES
Graduate policies often vary from Undergraduate policies. To view the applicable policies for graduate students, please visit http://prodschool.siu.edu/about-us/grad-catalog/index.html

DISABILITY POLICY
Disability Support Services provides the required academic and programmatic support services to students with permanent and temporary disabilities. DSS provides centralized coordination and referral services. To utilize DSS services, students must come to the DSS to open cases. The process involves interviews, reviews of student-supplied documentation, and completion of Disability Accommodation Agreements.

http://disabilitys.siu.edu/

STUDENT CONDUCT CODE
http://policies.siu.edu/other_policies/chapter3/conduct.html

1 Southern Illinois University Carbondale (SIU), Pathways to Excellence: A Strategic Plan
   Retrieved from http://siu.edu/about/policies/strategic-plan/

SAUKINET: https://saukine.siu.edu/home/displaylogin
ADMINISTRATION: http://admin.siu.edu/
PROVOST & VICE CHANCELLOR: http://provost.siu.edu/
SIU ONLINE: http://online.siu.edu/
ET 332b
Laboratory Activities and Experiments

1.) **Power Laboratory Safety and Work Procedures/Delta and Wye Voltage Connections**
   (Hampden Experiment 3)

   Students learn safety rules for working with high (above electronic board level) voltages. Avoiding electric shock and other safety hazards encountered in the power lab are covered. This lab covers the basic operation of the transformers, fractional-horsepower ac motors and alternators. Students perform lab experiments to prove voltage relationships for fundamental three phase connections. Students observe three-phase alternator operation.

2.) **Wye Connected Alternators**
   (Hampden Experiment 4)

   Students observe the effects of load balance on a wye-connected alternator. Students see a practical application of Kirchhoff's current law for ac systems. Phasor addition of currents produces a net current of zero in the neutral conductor of a wye-connected load. The experiment demonstrates the effect of unbalance on the current flow in the neutral.

3.) **Transformer Voltage, Current and Impedance Ratios**
   (Handout Experiment 2)

   This experiment examines ideal and non-ideal operation of a transformer. The turns ratio is used to determine how a transformer changes voltage, current and impedance levels. The experiment shows how to derive the ratios for each of these quantities. The effects of adding load on the ideal transformer ratio formulas are experimentally determined.

4.) **Transformer Open Circuit Test**
   (Handout Experiment 3)

   The effects of magnetizing the iron core of a transformer are included in the basic theory of the transformer. The exciting current of a small transformer is measured. The power losses of a transformer core are measured. These values are used to determine an equivalent circuit that accounts for the magnetizing effects of the iron core.
5.) **Transformer Short Circuit Test**  
(Handout Experiment 4)

The series impedance effects of a transformer are identified and measured experimentally. The leakage reactance and the series winding resistances are measured using a method called the short circuit test. These effects are included in a model that more accurately represents the actual operation of a transformer under load.

6.) **Direction of Rotation of Three-Phase Motors**  
(Hampden Experiment 12)

The effects of phase sequence on the direction of motor rotation are examined. Students will be able to correctly connect a three-phase motor to a voltage supply and have it rotate in the desired direction. The relationship between motor poles and synchronous speed is explained.

7.) **Starting Characteristics of Squirrel-cage Induction Motors**  
(Hampden Experiment 13)

The electrical and mechanical characteristics of a squirrel-cage induction motor during start-up are explored experimentally. The maximum torque of a three-phase motor is estimated from reduced voltage tests. The mathematical relationships between motor terminal voltage and torque are used to make this calculation.

8.) **Running Characteristics of Squirrel-cage Induction Motors**  
(Hampden Experiment 14)

Students will observe the changes on motor speed and terminal current as it is loaded. The two-wattmeter method of active power and power factor measurement is introduced and used to measure quantities in this experiment.

9.) **Losses and Efficiency of Induction Motors**  
(Hampden Experiment 16)

The power losses are measured and an operating efficiency is computed for a fractional horsepower motor. The types of losses incurred in induction motor operation are identified and measured either directly or indirectly. A locked rotor test is performed to find the equivalent resistance of the motor.
10.) **Starting and Synchronizing Synchronous Machines**  
(Hampden Experiment 19)

The synchronous machine can operate as either a generator or motor. In either case, procedures must be followed to safely connect the machine to the system. Synchronous machines must be rotating at nearly synchronous speed before they are connected to the power system. The experiment shows how the synchronous machine is started and how it operates under load.

11.) **Load Characteristics of Ac Generators**  
(Hampden Experiment 5)

The load-terminal voltage characteristics of an alternator are experimentally determined. Resistive and reactive load combinations are connected to the terminals of a small alternator. The effects of armature resistance, reactance, and armature reaction are discussed and the observed in practice. The effects of capacitive and inductive loads on the terminal voltage and power factor are also observed.

If time permits

12.) **Paralleling Alternators**  
(Hampden Experiment 7)

The necessary conditions for the parallel operation of alternators are examined. An alternator is synchronized with an infinite bus using phasing lamps. Two alternators are paralleled using phasing lamps. The factors that affect power flow and operating frequency are observed.
ET 332b
Electromagnetic Principles and Devices
Laboratory Experiment Format

You will perform several experiments on different topics during the course of the semester. The following information outlines the format used to document the experiment results and the procedures used to find the results. Type all experiment reports submitted this semester. Use this format on Experiments 3, 4, and 5.

The first page of every experiment report will be a cover page that will include the following items:

- Experiment number
- Experiment title
- Course number
- Student name.

Center these items in the middle of the page. An example cover page is attached. This template is available from the course website.

The following section describes the body of the experiment report. Number the pages in the body of the report at the bottom center. Do not number the first page of the report. This page displays the title information described above.

The body of the experiment has four sections:

1.) Objective
2.) Procedure
3.) Data and discussion of results
4.) Conclusion.

In the objective, you will explain the purpose for doing the experiment. You will also identify the major points you wish to learn about in the experiment.

Example: Find the resistance and inductance of a separately excited dc motor.

In the procedure section, give a summary of the methods used to measure and collect the data required in the experiment. Make this section in the form of numbered steps.

Example: 1. Connect a variable ac voltage source to the motor terminals.

2. Adjust the supply until motor stator current value is equal to motor rating.

Combine several small tasks into a single numbered topic to reduce the number of numbered subsections.
The data and results section documents the information collected during the experiment. Represent all data in a clear concise form. Use tables and graphs to collect and display the data into a presentable form. Use the correct units on all experimental quantities. Label the axis of the graphs and give them appropriate titles. Discuss the significance of the data and graphs contained in this section.

Software tools, such as Excel and MathCAD, make graphs and calculations simple to produce. Use these tools whenever possible. MathCAD makes it possible to produce an entire lab report that includes all sample calculations graphs and supporting procedures and discussions without using many other software packages.

Show sample calculations in the body of the report. Large data tables and other supporting calculations not directly related to the main topics of the experiment should be included in an appendix located after the main report. An appendix is not required when data tables are short. (10 entries or less)

Use figures to show how test setups were connected. Schematics of the models and circuits constructed for the experiment should also be included. Various software packages make drawing figures for lab experiments less laborious. AutoCAD, Visio, Paintbrush, Pspice, Multisim or any other graphic program can create images. Use cut/paste tools to transfer the graphic from one application to another.

In the conclusion section of the report, summarize the knowledge gained in the experiment.

The report body should be double-spaced and typewritten.
ET 332b
Lab Report Grading and Attendance Policies

Grading

The following table shows the point distribution and graded items for the ET 332 lab report. You will receive maximum points if all listed items are included and correct.

For all experiments EXCEPT 3, 4, and 5, only include the pages from the lab handout that show data and have answers to questions. For the format of these labs see the handout labeled, Laboratory Experiment Format. This includes both the De-Briefing and Quick Quiz sections. Produce all graph and figures using a computer program such as Excel. Include the graphs required by the lab procedures and any additional ones specified by the lab instructor.

Late labs will have point totals reduced by 5 points per working day. After one week, late labs will not be accepted.

Attendance

Students are expected to be seated in the lab at the scheduled starting time. An attendance sheet will be circulated at the beginning of the lab period. Everyone is responsible for signing this sheet. Anyone entering the lab after the scheduled starting time will be considered late and the work that they are intending to hand in will be considered late by one day. The lab instructor will be available before the lab period begins to answer questions and assist in experimental setups.

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<tr>
<th>Item</th>
<th>Points</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Title Page</td>
<td>5 pts</td>
<td>The title page must follow the given format exactly to receive credit. See the examples in the syllabus and from the lab T.A.</td>
</tr>
<tr>
<td>De-Briefing Questions</td>
<td>20 pts</td>
<td>Complete all short answer questions correctly and completely. You should print question responses clearly. Unreadable responses will be considered wrong. Use complete sentences and good grammar. Graphs are sometimes included in this section. Always use a computer program to generate these plots. Additional tables of the collected data can be included with the graphs, but are not required.</td>
</tr>
<tr>
<td>Experimental Results</td>
<td>10 pts</td>
<td>All data tables must be filled and contain reasonably accurate values. Write all values clearly. The data tables must be signed by the T.A. before leaving lab. Unsigned data will receive no credit.</td>
</tr>
<tr>
<td>Quick Quiz</td>
<td>20 pts</td>
<td>Correctly answer all multiple choice questions listed in the lab handout. Include these pages in the report.</td>
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<tr>
<td>Discussion</td>
<td>45 pts</td>
<td>To receive maximum credit for the discussion section, each topic in the discussion point handout must be included and thoroughly explained. The discussion can be up to three pages in length. It must be typed with no greater than a 12 point font and double spaced.</td>
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</table>