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

Textbook: Electrical Machines, Theory, Operation, Applications, Adjustment, and Control, 2nd Edition, Charles I. Hubert

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%
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

ET 332b
Ac Electric Machines and Power Systems

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.) Find transformer parameters using open circuit and short circuit tests
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,
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.

ET 332b
Ac Machines and Power Systems
Course Outline

Fundamentals of Ac Analysis

Single phase ac analysis	Appendix A
Time and phasor representations	Class Notes
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	
Physic of mechanical motion, force,	Class Notes
Torque, transformation of energy.	
Torque-speed relationships for mechanical loads	

Power and Energy Measurements	Class Notes and Handouts
Phase sequence identification	
Single phase power measurements	
Three phase power measurements	
Two-Wattmeter method	
Reactive power metering	
Load characteristics and demand	
Energy Metering	

Transformer Principles	Chapter 2
Construction and classification	Sections 2-2 to 2-5
Transformer action with sinusoidal input voltages	Sections 2-7 to 2-14
Ideal transformer model	
Equivalent circuit for transformers	
Voltage regulation	
Per unit/percent system	
Per unit/percent transformer impedances	
Transformer efficiency	

ET 332b
Ac Machines and Power Systems
Course Outline

Open circuit/short circuit tests	**TEST 1**
<u>Transformer Connections and Operation</u>	Chapter 3
Terminal markings and connections	Sections 3-1 to 3-4
Nameplate ratings	Sections 3-6 to 3-7
Autotransformer connections	Sections 3-10, 3-11, 3-12, 3-14
Parallel operation of transformers	
Load division between transformers	
Three phase transformer connections	
Instrument transformers	
<u>Three Phase induction motors</u>	Chapter 4
Induction motor action	Sections 4-1 to 4-15
Rotating Magnetic field	
Equivalent circuit of the Induction motor	
Developed power and torque	
Losses and efficiency	
<u>Application of three phase induction motors</u>	Chapter 5
NEMA Classifications	Sections 5-1 to 5-3
Locked rotor inrush currents	Sections 5-6 to 5-7
Wound-rotor motors	Sections 5-9 to 5-14
Effects of voltage unbalance	Sections 5-16 to 5-18
Induction motor parameters	
Determination of Induction motor parameters	
Blocked rotor tests	
No-load tests	
Dynamic braking of induction motors	Section 5-15
Induction motor starting and control	**TEST 2**
Induction Generator Operation	

ET 332b
Ac Machines and Power Systems
Course Outline

Synchronous Motors	Chapter 8
Construction and motor starting	Sections 8-1 to 8-9
Equivalent circuit model	Sections 8-11 to 8-12
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	
Synchronous Generators (Alternators)	Chapter 9
Motor to generator transition	Sections 9-1 to 9-13
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)**

SIU Southern Illinois University
CARBONDALE

Syllabus Attachment

Spring 2016

http://pvcaa.siu.edu/

IMPORTANT DATES *

Semester Class Begins.....01/19/2016
Last day to add a class (without instructor permission):.....01/24/2016
Last day to withdraw completely and receive a 100% refund: 01/31/2016
Last day to drop a course using SalukiNet:..... 04/03/2016
Last day to file diploma application (for name to appear in Commencement program): 02/12/2016
Final examinations: 05/09--05/13/2016

Note: For outreach, internet, and short course drop/add dates, visit Registrar's Academic webpage http://registrar.siu.edu/

SPRING SEMESTER HOLIDAYS

Martin Luther King, Jr.'s Birthday Holiday 01/18/2016

Spring Break 03/12—03/20/2016

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 http://registrar.siu.edu/catalog/undergraduatecatalog.html

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/grades/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/catalog/undergraduatecatalog.html

GRADUATE POLICIES

Graduate policies often vary from Undergraduate policies. To view the applicable policies for graduate students, please visit

http://gradschool.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://disabilityservices.siu.edu/

PLAGIARISM

Student Conduct Code http://sr.siu.edu/student_conduct_code/

Guidelines for Faculty http://pvcaa.siu.edu/_common/documents/Plagiarism/Guide%20to%20Preventing%20Plagiarism.pdf

MORRIS LIBRARY HOURS

http://www.lib.siu.edu/about

SAFETY AWARENESS FACTS AND EDUCATION

Title IX makes it clear that violence and harassment based on sex and gender is a Civil Rights offense subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories such as race, national origin, etc. If you or someone you know has been harassed or assaulted, you can find the appropriate resources here: http://safe.siu.edu

SALUKI CARES

The purpose of Saluki Cares is to develop, facilitate and coordinate a university-wide program of care and support for students in any type of distress—physical, emotional, financial, or personal. By working closely with faculty, staff, students and their families, SIU will continue to display a culture of care and demonstrate to our students and their families that they are an important part of the community. For Information on Saluki Cares: (618) 453-5714, or siucares@siu.edu,

http://salukicares.siu.edu/index.html

EMERGENCY PROCEDURES

Southern Illinois University Carbondale is committed to providing a safe and healthy environment for study and work. We ask that you become familiar with the **SIU Emergency Response Plan** and **Building Emergency Response Team (BERT)** programs. Emergency response information is available on posters in buildings on campus, available on BERT's website at www.bert.siu.edu, Department of Safety's website at www.dps.siu.edu (disaster drop down) and the Emergency Response Guideline pamphlet. 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.***

INCLUSIVE EXCELLENCE

SIU contains people from all walks of life, from many different cultures and sub-cultures, and representing all strata of society, nationalities, ethnicities, lifestyles, and affiliations. Learning from and working with people who differ is an important part of education as well an essential preparation for any career. *For more information please visit:* http://www.inclusiveexcellence.siu.edu/

LEARNING AND SUPPORT SERVICES

Help is within reach. Learning support services offers free tutoring on campus and math labs. To find more information please visit the Center for Learning and Support Services website:

Tutoring : http://tutoring.siu.edu/

Math Labs http://math.siu.edu/courses/course-help.php

WRITING CENTER

The Writing Center offers free tutoring services to all SIU students and faculty. To find a Center or Schedule an appointment please visit http://write.siu.edu/

AFFIRMATIVE ACTION & EQUAL OPPORTUNITY

Our office's main focus is to ensure that the university complies with federal and state equity policies and handles reporting and investigating of discrimination cases. *For more information visit:*

http://diversity.siu.edu/#

Additional Resources Available:

SALUKINET: https://salukinet.siu.edu/cp/home/displaylogin

ADVISEMENT: http://advisement.siu.edu/

PROVOST & VICE CHANCELLOR: http://pvcaa.siu.edu/

SIU ONLINE: http://online.siu.edu/

Spring 2016 R.O'Rourke

332B Homework list

Homework #	Source	Assignment	Date Due	Turned in?	Grade Received
1	Handout	cpmathhw.wp5			
2	Handout	sglephhw.wp5			
3	Handout	spqhw.wp5			
4	Handout	pfhw.wp5			
5	Handout	hw3phs1.wp5			
6	Handout	hw3phs4.wp5, hw3phs3.wp5			
7	Handout	hw3phs2.wp5, pfcorr.wp5			
8	Handout	wyedhw.wp5, tqspd.wp5			
9	Handout	meterhw.wp5			
10	2	2-9			
11	2	2-11			
12	2	2-13			
13	2	2-15			
14	Handout	puprob.docx			
15	2	2-23, 2-25			
16	2	2-17			
17	2	2-39			
18	Handout	3phtxhw.wp5			
19	3	3-11			
20	3	3-1, 3-9[1]			
21	4 & Handout	4-4 ind-hw1.wp5			
22	4	4-6			
23	4	4-10			
24	4	4-16			
25	Handout	indhw1.wp5			
26	5	5-22			
27	5	5-31, 5-32			
28	5	5-35			
29	8	8-1, 8-2, 8-3			
30	8	8-5			
31	8	8-7			
32	8	8-17			
33	9	9-1, 9-5			

[1] Mistake in problem statement. Use a voltage of 482 V instead of 432V.

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.

ET 332b
Laboratory Activities and Experiments

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.

ET 332b
Laboratory Activities and Experiments

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 and 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
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 vale 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, CircuitMaker, 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.

Southern Illinois University at Carbondale
Department of Technology

ET 332b
Electromagnetic Principles and Devices

Experiment #

Experiment Title

Reported by: name of student

Performed By: student name 1
student name 2
student name 3

Date Performed:

ET 332b
Laboratory 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.

Item	Points	Comments
Title Page	5 pts	The title page must follow the given format exactly to receive credit. See the examples in the syllabus and from the lab T.A.
De-Briefing Questions	20 pts	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.
Experimental Results	10 pts	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.
Quick Quiz	20 pts	Correctly answer all multiple choice questions listed in the lab handout. Include these pages in the report.
Discussion	45 pts	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.