Fundamentals of Electric Drive Systems
EEL 5934   Section XXXX
Class Periods: MWF, Period 3, 9:35 AM – 10:25 AM
Location: NEB 0102
Academic Term: Spring 2024

Instructor:

Name:	Prof. Baoyun Ge (he/him/his)	
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Office Phone Number:	(352)294-3926	
Office Hours:	Office Hour 1: Online, See Canvas for the Link	Tuesday, 8:30 pm to 9:30 pm
	Office Hour 2: Larson 221	Thursday, 2:00 pm to 3:00 pm

Teaching Assistant/Peer Mentor/Supervised Teaching Student:
Please contact through the Canvas website
- David Blow, david.blow@ufl.edu, LAR 122, office hours (TBD)

Course Description
Electric drive systems (EDS) are used extensively in a wide range of applications, including electric vehicles, drones, electric aircraft, robots, wind generators, satellites, spacecraft, etc. This course will introduce the fundamentals of electric drive systems, with a special focus on the steady-state analysis of permanent magnet AC drives, which are used extensively in these applications.

Course Pre-Requisites / Co-Requisites
1. EEL 3472 – Fundamentals of Electromagnetic Fields (or equivalent)
2. EEL 3135 – Introduction to Signals and Systems (or equivalent)

OR

1. EEL 3211C – Basic Electric Energy Engineering (or equivalent)
2. EEL 3135 – Introduction to Signals and Systems (or equivalent)

Course Objectives
The main objective of this course is to expose students to the three pillars of electric drive systems:
1. Electric machines (EM): we will start with reviewing the operating principles of DC machines and then switch to permanent magnet AC machines with the introduction of AC windings, traveling waves, and brushless concepts. Steady-state analysis, magnetic circuit analysis, and finite element analysis will be covered.
2. Power electronics (PE): we will base our discussion on the classic two-level three-phase voltage source inverter. The concepts of pulse width modulation (PWM) and modulation depth will be taught to understand its steady-state characteristics. In addition, limitations due to parasitic and thermal will be introduced.
3. Feedback control (FC): we will model electric machines and inverters on the dq-axis and build high-performance feedback control for them. A physics-based approach will be used to show how to build torque and speed regulators step by step. The concept of the estimator/observer will be introduced as well.

It is expected that students will gain knowledge on how to perform steady-state analysis on electric drive systems and get familiar with CAD tools like Matlab/Simulink, COMSOL, LTSpice, and PLECS to virtual prototype sub-components of electric drive systems and evaluate their performance. The students are also expected to complete a project and document the results.

Materials and Supply Fees
NA

Required Textbooks and Software
- Fitzgerald & Kingsley's Electric Machinery, 7th Edition ([Amazon Link](#))
  Authors: Stephen D. Umans
  Publisher: McGraw-Hill
- Software:
  - Mathcha (for homework assignments)
  - Blockpad or Mathcad (for engineering calculations)
  - Matlab or Python (for computation and plotting)

Recommended Materials
If students would like to explore advanced topics on electric drive systems, we refer to:
- Introduction to Electric Machines and Drives, 1st Edition ([Amazon Link](#))
  Authors: D. W. Novotny, T. A. Lipo, T. M. Jahns
  Publisher: University of Wisconsin
- Vector Control and Dynamics of AC Drives, 1st Edition ([Amazon Link](#))
  Authors: D. W. Novotny, T. A. Lipo
  Publisher: Clarendon Press

Course Schedule

Module	Topic	Reading Materials	Assignments	Day	Date
EM/PE/FC	Introduction, Demo			Monday	1/8
EM	Magnetic Circuit	1.1, 1.2	Quiz 1 Due	Wednesday	1/10
EM	Magnetic Circuit	1.1, 1.2		Friday	1/12
EM	Electromechanical Energy Conversion	3.1—3.5		Wednesday	1/17
EM	Electromechanical Energy Conversion, DC Machines	3.1—3.5, 7.1—7.3		Friday	1/19
EM	DC Machines	7.1—7.3	Quiz 2 Due	Monday	1/22
EM	DC Machines	7.1—7.3		Wednesday	1/24
EM	DC Machine Inside Out	Slides		Friday	1/26
EM	Winding Functions	Handout 1	HW 1 Due	Monday	1/29
EM	Winding Functions	Handout 1, 4.5		Wednesday	1/31
EM	AC Machines	4.1, 4.2		Friday	2/2
EM	BLAC Steady State Modeling (abc-axis)	5.1, 5.2, 5.8	Quiz 3 Due	Monday	2/5
EM	BLAC Steady State Characteristics	5.1, 5.2, 5.8		Wednesday	2/7
EM	Magnetic Circuits in BLAC	1.1, 1.2, 5.8		Friday	2/9
EM	Magnetic Circuits in BLAC	1.1, 1.2, 5.8		Monday	2/12
EM	Finite Element Analysis	Handout 2		Wednesday	2/14
EM	Synchronous Machines	5.6		Friday	2/16
EM	Transformers	2.1—2.4	HW 2 Due	Monday	2/19
EM	Asynchronous Machines	6.1, 6.2		Wednesday	2/21
EM	Asynchronous Machines	6.1, 6.2, 6.3		Friday	2/23
EM	Electrostatic Machines	Slides	Quiz 4 Due	Monday	2/26
EM	**Midterm Exam 1**		**Exam 1**	**Wednesday**	**2/28**
PE	Switch Mode Power Supply	Handout 3		Friday	3/1
PE	From DC/DC to DC/AC Converters	Handout 4		Monday	3/4
PE	Two Level Three Phase Inverter	Slides		Wednesday	3/6
PE	Two Level Three Phase Inverter	Slides		Friday	3/8
PE	Sinusoidal Pulse Width Modulation	Slides	HW 3 Due	Monday	3/18
PE	Sinusoidal Pulse Width Modulation	Slides		Wednesday	3/20

PE	$\alpha\beta$-axis Modeling	Slides		Friday	3/22
PE	Space Vector PWM	Slides		Monday	3/25
PE	Space Vector PWM	Slides	Quiz 5 Due	Wednesday	3/27
PE	SPWM vs SVPWM	Slides		Friday	3/29
PE	Power Electronics Circuit Simulation	Handout 5		Monday	4/1
PE	**Midterm Exam 2**		**Exam 2**	**Wednesday**	**4/3**
FC	Control Diagram of DC Machines	10.1		Friday	4/5
FC	Control of DC Machines	10.1	HW 4 Due	Monday	4/8
FC	Control of DC Machines	10.1		Wednesday	4/10
FC	Control of AC Machines and dq-axis Modeling	10.2, C.1		Friday	4/12
FC	dq-axis Modeling	C.1, C.2	Quiz 6 Due	Monday	4/15
FC	Back on Control of AC Machines	10.2, Slides		Wednesday	4/17
FC	Torque/Current Regulator	Slides		Friday	4/19
FC	Control of Cascaded Energy States	Slides		Monday	4/22
FC	Current and Rotor Position Sensors	Slides	HW 5 Due	Wednesday	4/24
EM/PE/FC	**Final Exam**		**Final Exam**	**Tuesday**	**4/30**

Attendance Policy, Class Expectations, and Make-Up Policy

Excused absences must be consistent with university policies in the Graduate Catalog (https://catalog.ufl.edu/graduate/regulations) and require appropriate documentation. Additional information can be found here: https://gradcatalog.ufl.edu/graduate/regulations/

ATTENDANCE is required. Each missed class results in a deduction of one point (out of 100) from the overall course total. There are no excuses for missed classes, but <u>four classes can be missed without penalty</u>. (There are 41 classes this semester, missing three classes is ~10%!)

Late homework policy for the homework sets:

Late by	Point Reduction Percentage
1 day	5%
2 days	10%
Beyond 2 days	100% (thus not accepting anymore)

Exam/Test makeup policy: (1) the instructor shall be notified at least **one week** before the exam/test date; (2) the makeup exam/test will be held **before** the official one and the exact time will be determined between the student and the instructor.

Evaluation of Grades

Assignment	Total Points	Percentage of Final Grade
Homework Sets (5)	100 each	30%
Quizzes (6)	varies, 1.67% each	10%
Midterm Exam (2)	100 each	27%
Project	100	20%
Final Exam	100	13%
		100%
These weights are subject to changes. Please always refer to the Welcome Module in the Canvas Course Home Page for the most updated syllabus.		

Homework and exam problems are designed to test students' ability to apply equivalent circuit and magnetic circuit models, conduct *dq*-axis analysis, and formulate closed-loop motion control. There are homework problems involving the usage of CAD tools to virtually prototype electric drive systems, evaluate performance, and determine the effectiveness of the design.

This course is co-listed with the undergraduate course EEL 4930, for which these assignments will be graded differently.

The graduate section also includes a project assignment. The graduate and undergraduate sections will be graded separately. The graduate section will have different weights for the exams.

NOTICE that the aggregated scores on Canvas are not reliable. Canvas simply uses the same weight for any assignments and does not follow the grading policy laid out here.

Project
A final project will be assigned for the students to work on an electric drive system. The evaluation is based on the simulation files and the project report. The distribution of points is listed below.

Project Work	Total Points	Component Points		
		Simulation Completeness	Engineering Insight	Report Quality
Project Report & Simulation Files	100	40	30	20

Grading Policy
The following is given as an example only.

Percent	Grade	Grade Points
93.4 - 100	A	4.00
90.0 - 93.3	A-	3.67
86.7 - 89.9	B+	3.33
83.4 - 86.6	B	3.00
80.0 - 83.3	B-	2.67
76.7 - 79.9	C+	2.33
73.4 - 76.6	C	2.00
70.0 - 73.3	C-	1.67
66.7 - 69.9	D+	1.33
63.4 - 66.6	D	1.00
60.0 - 63.3	D-	0.67
0 - 59.9	E	0.00

More information on UF grading policy may be found at:
UF Graduate Catalog
Grades and Grading Policies

Students Requiring Accommodations
Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting https://disability.ufl.edu/students/get-started/. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Course Evaluation

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/.

In-Class Recording

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A "class lecture" is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To "publish" means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

University Honesty Policy

UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (https://sccr.dso.ufl.edu/process/student-conduct-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values varied perspectives and lived experiences within our community and is committed to supporting the University's core values, including the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of race, creed, color, religion, age, disability, sex, sexual orientation, gender identity and expression, marital status, national origin, political opinions or affiliations, genetic information, and veteran status.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:
• Your academic advisor or Graduate Program Coordinator

• HWCOE Human Resources, 352-392-0904, student-support-hr@eng.ufl.edu
• Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
• Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: https://registrar.ufl.edu/ferpa.html

Campus Resources:

Health and Wellness

U Matter, We Care:
Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: https://counseling.ufl.edu, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence
If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)
Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.

Academic Resources

E-learning technical suppor*t*, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Connections Center, Reitz Union, 392-1601. Career assistance and counseling; https://career.ufl.edu.

Library Support, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

Student Complaints Campus*:* https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/;https://care.dso.ufl.edu.

On-Line Students Complaints*: https://distance.ufl.edu/getting-help/; https://distance.ufl.edu/state-authorization-status/#student-complaint.*