ECE 4630/ECE 5630 Electric & Hybrid Drive Systems

Course previously offered as: **ECE 477/ECE 577 Electric & Hybrid Drive Systems**

1 Catalog Course Description ECE 4630/ECE 5630

Introduction to electric drives and their applications including mobile robots, electric vehicles, plug-in EV and hybrid EV. Brush and brushless DC, AC synchronous and induction, stepper motors. Load torque-speed-current profile, losses. Power processing units, dc-dc converters, H-bridges, 3-phase inverters. Clarke and Park transform, field oriented control, pulse width modulation and space vector modulation. Torque, speed and position control synthesis and analysis. Battery types, state-of-charge models, heat issues. Regenerative braking, alternative energy. Computer simulation and visualization of principles.
Prerequisite: ECE 3600, ECE 4400 and ECE 4610

2 Prerequisite: ECE 351, 429 and 431

ECE 3600 (ECE 351) - Electrical Machines (4)
Magnetic circuits, transformers, magnetic energy, force/torque and heat dissipation. DC and AC machines and their equivalent circuits, torque analysis and power efficiency. Three phase transformers, synchronous and induction machines. Per unit system and introduction to power distribution. With Laboratories in transformers, DC and AC machines.
Prerequisite(s): ECE 2005 (ECE 276) Electric Circuits and major standing

ECE 4400 (ECE 431) - Automatic Control Systems (4)
Mathematical modeling of dynamic systems, transfer functions and block diagrams. State-space representations and local linearization of nonlinear systems. Transient and steady-state analysis, stability criteria and state-feedback control. The root-locus method and frequency-response method for control systems analysis and design. Design of PID controllers and compensation networks. Controllability and observability for linear time invariant system2. Computer simulations using Matlab. With laboratory.
Prerequisite(s): ECE 3204.

ECE 4610 (ECE 429) Introduction to Power Electronics (4)
Power semiconductor devices and circuits. AC/DC Converters. Thyristors and commutation techniques. Phase-controlled rectifiers, choppers and inverters. AC voltage controllers and cycloconverters. Introduction to novel power electronic devices, such as IGBT and power MOSFET. Some industrial applications. With laboratory.
Prerequisite(s): ECE 3105 and major standing

ECE 3204 (ECE 335) Signals and Systems (3 cr hrs)
Laplace transform, transfer function, pole-zero pattern, and introduction to state-space concepts in the analysis of electrical and mechanical lumped-parameter linear systems. Systems modeling in differential equation and Laplace transform domains. Natural and forced responses of first-order, second-order, and higher order linear time-invariant systems. Introduction to frequency response analysis. Introduction to Fourier analysis of signals and systems. Bode plots. Offered fall, winter.
Prerequisite(s): ECE 2005.

ECE 3105 (ECE 327) Electronic Circuits and Devices (4 cr hrs)
Characteristics and models of nonlinear circuit elements, such as diodes, BJTs and MOSFETs. Analysis and design of circuits employing these devices, including power supplies, voltage regulators, and amplifiers; Biasing and circuit stability issues. Use of Operational amplifiers, discrete circuit elements; and PSPICE software for circuit design is emphasized in the lab. Offered fall, winter.
Prerequisite(s): ECE 2005.

EXE 2005 (ECE 276) Electric Circuits (4 cr hrs)
Modeling and analysis of circuits with dependent sources; non-ideal operational amplifiers. Transient and forced responses in RC, RL and RLC circuits. Series and parallel resonant circuits. AC power, three-phase circuits, magnetically coupled circuits. Wye-delta transforms. Introduction to frequency response. Use of PSPICE. With laboratory. Offered fall and winter.
Prerequisite(s): EGR 240. Prerequisite or corequisite: APM 255

3 Useful Background

Matlab, Simulink & Toolboxes

- Matlab programing
- Simulink modeling
- Simscape Toolbox
- Control Toolbox

Mathematics

- Vectors, Matrices
- Rotation operations
- Differential equations
- Laplace transform

Mechanical systems

- Newton law of motion
- Kinematics
- Statics
- Dynamics

4 Course Topics

After taking this course, you should be able to understand, discuss and/or apply the following with breadth & depth.

4.1 Alternative Energies & Vehicles

- Alternative energies and their influence future world climate and resources
- Potential impact of electric drive vehicles
- Intro to superconductors, graphene batteries,

4.2 Vehicle Mechanics

- Math models for describing dynamics of longitudinal motion of vehicle
- Simulation of vehicle dynamics in Matlab, Simulink and Simscape
- Power split devices (PSD) such as planetary gears for hybrid vehicles

4.3 Electric motors

- Ampere's law, Faraday's law, Lorentz's law in electromagnetics to motor & braking actions
- Math & simulation models for
    - Permanent magnet DC (PMDC)
    - Separately excited DC (SEDC) motors
- Math & simulation models for three-phase motors including
    - 3-phase circuits, Clark transform,
    - Permanent magnet synchronous machine (PMSM)
    - Brushless DC (BLDC) motors, Park transform
    - AC induction squirrel cage motors
- Math & simulation models for
    - Single phase vs 3-phase AC motor
    - Stepper motor
    - Variable reluctance motor
    - Linear motors

4.4 Power Conversion Units

- Why switching is widely used

  - Efficiency & conversion
  - Power transistors (BJT, MOSFET, IGBT, thyristors)
  - Electromagnetic interference (EMC) issues
- Heat transfer, thermal resistance, heat sinking, component temperature
- Pulse width modulation (PWM) principle
- Space vector modulation (SVM) for three phase BLDC motor
- Electronic power conversion circuits
  - Boost (step up), buck (step down) & buck-boost converters
  - Simple power switching and diode protection
  - H-bridge circuit
  - 3-phase inverter circuits
  - Transformers

4.5 Vehicle control

- Control strategy and scheme for controlling the following action in a of a drive or vehicle system
  - Torque
  - Speed
  - Position
- Park transform, d-q control for BLDC motors
- Simulation motors incorporating loads and vehicle dynamics
- Load & dynamometer

4.6 Battery

- Modeling & simulation of a battery SOC using an equivalent electrical model
- Regenerative braking
- New battery technologies
- Battery management

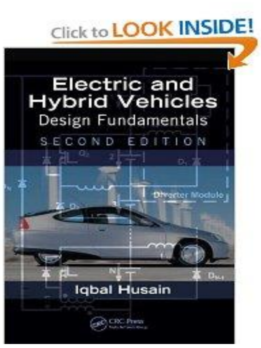
5 Textbook & References

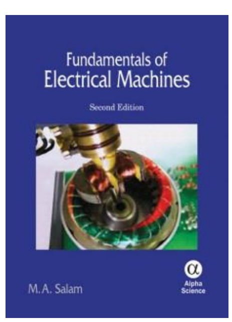
I post lecture notes & references on the Moodle site for this course. They would be necessary and sufficient as class materials.

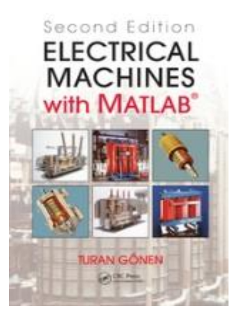
You may purchase the following textbook and reference books for further reading & references.

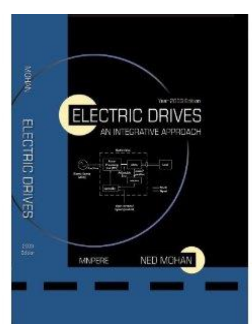
Textbook: ***Electric and Hybrid Vehicles – Design Fundamentals – 2nd Edition*** by Iqbal Husain, CRC Press – Taylor & Francis Group 2011, ISBN 978-1-4398-1175-7

Reference textbooks: *Fundamentals of Electrical Machines, Second Edition*, 2012, M. A. Salam
Electrical Machines with MATLAB®, Second Edition, 2011, Turan Gönen
Electric Drives: An Integrative Approach, 2003, Ned Mohan









6 Moodle Course Site

Course notes and materials will be posted on the course site on http://moodle.oakland.edu website. However the site for a merged ECE4630 & ECE5630 course is still under construction. (Has to do with OU Banner setting.)

I will email detail of the Moodle course page as soon as it is ready,

7 Homework & Simulation Assignments, Quizzes, Exam

There will be
- About seven homework assignments,
- About three Matlab/Simulink simulation assignments
- About 2 quizzes & 1 final exam

All assignments, quizzes & exams must be submitted online through Moodle. There will be penalty for late submissions. See the "Rules for Submission of All Assignments" link on Moodle.

Grade allocation (subject to slight variations)

Homework assignments	35%
Simulation assignments	30%
Quizzes & Exams	35%