MECHENG 499-001/599-001/599-881
Battery Systems and Control
Winter 2015, MW 10:30-12:00 (+12:00-12:30)
Room 151 CHRYS – 3 Credits

Instructor: Professor Anna Stefanopoulou (annastef@umich.edu)
Graduate Student Instructor: Shankar Mohan (elemsn@umich.edu

Required: ME360 equivalent
Concurrent: ME461/EE460 equivalent (can be taken concurrently with the Battery Controls)

Course statement: This course covers battery modeling, control and diagnostic methodologies associated with battery management systems. Practical examples from automotive and consumer electronics are used throughout the course. Emphasis is placed upon system-level modeling, equivalent circuit models and surrogate models for estimation and on-board parameterization of the electric and thermal Lithium-Ion battery behavior. Distributed spatiotemporal models of coupled Li concentration, potential, and thermal phenomena are reviewed and then we highlight their analogies with the equivalent circuit models introduced in the first part of the course. We then venture to apply these models in State of Charge (SOC), State of Power (SOP), and State of Health (SOH) estimation using Kalman filtering and recursive least-squares estimation to augment classical coulomb counting techniques. Cell balancing in a pack is then discussed and practiced in a realistic simulation. Battery cooling, thermal evolution and run-away behavior will be the last course section. Estimation of battery core temperature will finally be developed that will guide thermal management and used for an improved SOP and SOH.

The course does **not** require extensive background in battery chemistry and materials, but does require a basic background (undergraduate level) in signals and systems ME 360 equivalent or controls (Laplace transforms, time/frequency analysis, state space and control design tools) ME 461 equivalent.

Mathworks Matlab/Simulink will be used in course instruction and projects. We do not have copies to give away, but students who registered can access "virtual sites" to use the software. (http://virtualsites.umich.edu). You can also buy the Matlab/Simulink student version.

Email list:
You can email your questions or use piazza at ctools but you must come (or webex) to office hours to get a fast reply. **Always use MEx99bat in your message subject and indicate which office hours you will be attending**.
First describe the problem you are facing in the text of your e-mail. This will help us when we travel and cannot open attachments. You could **attach ONE pdf with your question including necessary figures, m-file, sml-file, and resulting graphs in one PDF. If we need more info, we will e-mail and ask you to send us your working m or sml file.
***Expect at least one day delay in email communication. Our ability to help declines as e-mail volume increases, so please be considerate and concise. Also do NOT wait till the last HW day. We **will not help outside the office hours during the HW due-day**.

Textbook: There will be no textbook. Lecture notes and handouts will be distributed in class or through Ctools.

Honor Code: No discussion or collaboration is allowed in the Examination periods. You may discuss the homework assignments with each other and with the instructor, but you **must write your own m-files, code, create your own figures, and provide answers** which reflect your own understanding of the material. No copying and pasting of any kind.

Grade: Homework 5% Midterm A 45%, Midterm B 50%
Graduate students will be typically given extra assignments in homeworks and examinations. The 599 students include in-campus and on-line students. The 499 students will have a slightly less load (specific HW & Exam problems can be skipped) than the 599 students. Frankly, I think all students can register in the 599 section if they satisfy the requirements.

Homework:
There will be approximately one HW per week. Homework problems in this course are hard but rewarding because they are derived from real world problems.

Homework counts for very small % of your grade, because we cannot grade it in detail. If you submit your HW with almost all the questions seriously attempted, then the assigned grade will be "2." If we see many gaps in your answers then the assigned grade will be "1." If your submission is mostly blank or missing, then we will grade it with "0." Thus, the HW grade is unimportant and it will up to you to work on the homework, submit your best version and study the posted solutions.

Finally, your HW will be submitted to the ctools by the specified time and date. No late homework will be accepted! The lowest grade will be dropped.

Office Hours
All of them in AL 2044; available through Webex with slight higher priority to the off-site students
Monday 5-6pm GSI
Tuesday 12-1pm GSI, 4:30-5:30pm Prof, 8:30-9:30pm GSI
Friday 2:30-3:30 GSI

Exams: 2 hours in class time. Open notes. Bring only a regular Calculator. No computers or other electronics will be allowed. Distance-learning students are welcome to take the exam in campus, otherwise they will need to organize a proctor.
Midterm A: TBD
Midterm B: TBD
Back-up Exam: Wed April 29th 4:00-6:00 (if any of the regular midterms have been missed)

MATH and Dynamics notions we will be using a lot in the class:
1. Ordinary Differential equations, Linearization, Stability, characteristic equation, eigenvalues
2. Laplace Transforms, Transfer functions (poles, zeros, DC gain)
3. Time responses, overshoot, undershoot, settling time, damping ratio, time constant, rise time
4. States, state-space representation
5. Frequency Representation of systems and signals: bandwidth, roll-off rate, DCgain, natural, damped frequencies ...
6. Basics of PID controllers, Root locus ...

Items 1.-7. are a must! You can probably study items 8.-9. and catch up while taking this class.

Syllabus:

Chapter 1: Equivalent Circuit Models
Overview Li Chemistries
Voltage, Power, and the Electrical point of view
Parameterization of Equivalent Circuit Models
Constant Current Constant Voltage (CCCV)

Chapter 2: Electrochemical Control-Oriented Models
Butlet-Volmer, Kinetics
Diffusion (electrolyte & solid)
Numerical Approximations
Electrode-Averaged Model
Single Particle Model

Chapter 3: Battery Controls
State of Charge (SOC) Estimation
Observability, Estimation, Kalman filters
State of Power (SOP) estimation
State of Health (SOH) Estimation (optional)

Chapter 4: Stack Management
Cell thermal Dynamics, thermal Run-Away
Pack thermal dynamics
Monitor, Management,
Cell Balancing: Passive & Active