AEV 5020 CONTROLS MODELING AND DESIGN FOR AEV

Term III Summer 2012-2013
Lecture: Online
Discussion: Wednesdays 5:00-8:00 pm
Ford Rotunda Campus, Dearborn

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Prerequisites: AEV 5010: Introduction to AEVs

Textbook: Ogata, K., System Dynamics, 4th Edition, Pearson Prentice Hall, 2004.

Additional References: Mohan, N., Electric Drives: An Integrative Approach, Mnpere, 2003.
Mi, C., Masrur, M.A., and D.W. Gao. Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives, Wiley, 2011.

Course homepage: You will be automatically enrolled to the course website on "Blackboard." The web address of Blackboard is http://knowledge.udmercy.edu/. You can also login through the TitanConnect portal, http://tc.udmercy.edu/.

Office Hours: By appointment. Students are also encouraged to post questions to Blackboard so that answers can be seen by the entire class.

Course Description:
Introduction to modeling and simulation of various elements of the powertrain of Advanced Electric Vehicles (AEV), time and frequency domain analysis techniques, introduction to classical controller design techniques for Single Input Single Output (SISO) Linear Time-Invariant (LTI) systems with an emphasis on PID controller design, advanced topics pertinent to AEVs will be addressed as time allows.

Course Content:

1. Modeling and Simulation: Modeling of the dynamics of the various elements of the powertrain of AEVs. Possible elements include IC engines, DC motors, AC motors, power electronics, batteries, and sensors. Forms for the mathematical models will include differential equation and transfer function models. Only a high level understanding of the underlying dynamics will be required with detailed instruction left to more specific courses on E-drives, Power Electronics, and Batteries. Emphasis will be placed on identifying the proper level of model detail for analysis and design as compared to simulation. MATLAB/Simulink will be used for the simulation exercises in the course. Techniques for achieving reduced order and linearized models will also be presented.
2. Time and Frequency Domain Analysis: Time and frequency domain analysis techniques will be covered. Bode plots will be employed for the frequency response analysis. Understanding dynamic systems in terms of their transient performance, steady-state performance, and robustness characteristics will be taught.
3. Controller Design: Pole placement and frequency domain design techniques will be introduced for SISO LTI systems. The effect of the three terms of the traditional PID controller will be taught. Different control architectures and their effect on performance will also be investigated, as well as the actual implementation of the resulting controllers.
4. Advanced Topics: Possibilities include how to design control systems with multiple loops, how to design control for systems with multiple inputs and/or multiple outputs, how to design for robustness, understanding the effect of specific nonlinearities like actuator saturation and coulomb friction, integrator anti-windup, switching between different power plants in the control system, and sensorless control.

Course Outcomes:

After taking this course, students will be able to:

1. Derive mathematical models for the various elements of the powertrain of AEVs (differential equations and transfer functions).
2. Describe the principles of the operation of sensors necessary for the feedback control of AEVs and will be able to model the relevant dynamics.
3. Describe and evaluate simplifying assumptions made in the modeling process (nonlinearities, higher order dynamics).
4. Determine and describe quantitatively the time response of systems based on the pole locations of their models (transient and steady state).
5. Model a system of components by block diagram and determine the input/output behavior of the system based on such a model (reduction of multiple loops, effect of inputs entering at different places in the feedback loop).
6. Determine and describe the robustness properties of a system based on its frequency response (stability margins).
7. Use frequency domain techniques (Bode plots) to analyze and design control systems.
8. Describe and tune the effect of the three terms of a PID controller.
9. Evaluate the trade-offs inherent in the design of a controller (different gains, different architectures).
10. Design the torque and speed control of a DC motor with mechanical load (cascade structure).
11. Qualitatively describe the principles of control of AC motors (vector control).
12. Qualitatively describe and heuristically design necessary nonlinear elements of an AEV control system like switching between system components and limiting signal magnitudes.
13. Use MATLAB/Simulink for the analysis and design of control systems (including the discrete logic), as well as describe the different approaches to numerical simulation (forward and backward looking) and their inherent tradeoffs.

Class Elements:

Homework – Problem sets will be assigned approximately every one to two weeks over the course of the semester.
Quizzes – Two extended quizzes will be given during the course of the semester.
Laboratories – Two lab exercises will be performed with an assignment associated with each.
Exams – One midterm will be given during the semester in addition to a cumulative final.

Class Policies:

Late work – Homework must be turned in at the beginning of class. Late homework is not accepted. Your lowest homework score will be dropped thereby allowing for emergencies.
Exams – Exams and quizzes will in general be closed book and closed note.
Academic Integrity – Any suspected cheating will be dealt with according to the College policy - see the Engineering Science Student Handbook. In the case of homework, working together is encouraged, but you must write your own solutions that reflect your own understanding of the material.

Grading:

Homework	20%
Quizzes	10% (5% each)
Laboratory	10% (5% each)
Midterm exam	25%
Final exam	35%

Grading Scale:

Grade:	A	A-	B+	B	B-	C+	C	D	F
Percentage:	93-100	90-92	87-89	83-86	80-82	77-79	70-76	60-69	<60

AEV5020 Schedule

(note: all elements of this schedule are subject to change)

DATES	TOPICS	DUE
Week 1 (5/6-5/10)	**Module 1:** Course overview (introduction to control) **Module 2:** Introduction to modeling **Module 3:** Mathematical modeling part I (differential equations, the Laplace transform)	HW #1 due 5/10
Week 2 (5/11-5/17)	**Module 4:** Modeling mechanical systems **Module 5:** Mathematical modeling part II (transfer functions, intro to block diagrams and time response)	HW #2 due 5/17
Week 3 (5/18-5/24)	**Module 6:** Modeling electrical systems (power electr.) **Module 7**: Modeling challenges (black-box modeling, batteries, numerical simulation)	HW #3 due 5/25
Week 4 (5/25-5/31)	**Quiz 1 (in discussion section, 5/29)** **Module 8:** Electromechanical systems – sensors **Module 9:** Electromechanical systems – actuators (motors)	HW #4 due 5/31
Week 5 (6/1-6/7)	**Module 10:** First-order systems **Module 11:** Stability, second-order systems **Module 12:** Non-canonical systems (higher-order, effect of zeros, nonlinear systems)	HW #5 due 6/7
Week 6 (6/8-6/14)	**(discussion section won't be held 6/12)** **Module 13:** Intro to control, block diagram manipulation **Module 14:** Control specifications, PID Control	HW #6 due 6/14
Week 7 (6/15-6/21)	**Module 15: Laboratory Activity 1 (in discussion, TBD)***	
Week 8 (6/22-6/28)	**MIDTERM (in discussion section, 6/26)**	
Week 9 (6/29-7/5)	**No modules or discussion section this week**	Report #1 due 7/5
Week 10 (7/6-7/12)	**Module 16:** Steady-state error **Module 17:** Root locus basics **Module 18:** Root locus for controller design	HW #7 due 7/12
Week 11 (7/13-7/19)	**Module 19:** Introduction to frequency response **Module 20:** How to plot Bode diagrams **Module 21:** Relative stability, system identification	HW #8 due 7/19
Week 12 (7/20-7/26)	**Quiz 2 (in discussion section, 7/24)** **Module 22:** Frequency response for controller design **Module 23:** More advanced architectures	HW #9 due 7/26
Week 13 (7/27-8/2)	**Module 24: Laboratory Activity 2 (in discussion, TBD)*** **Module 25:** System-level considerations **Module 26:** Implementation and advanced topics	Report #2 due 8/2
Week 14 (8/3-8/8)	**FINAL EXAM (in discussion section, 8/7)**	

* We will meet on the UDM McNichols campus on these days
** The last day to withdraw is July 17