Recent Curricular Revisions in the Energy Systems Area at University of the Pacific

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Department Information (pre – 2009)

- Small department with 8 faculty members
- No power / energy faculty member
- One energy conversion course was offered
- Taught by faculty member whose expertise was in another area (Prof. Khoie)
- Observed in 2007 / 2008 that co-op employers were hiring students in the power area.

Timeline of Events

- Developed and offered a power systems course during spring 2009 (Mathews)
- Attendance at 2009 Napa conference confirmed workforce shortage (Electric Boat / Sundstrand)
- Fall 2009: graduate renewable energy class offered (Khoie)
- Fall 2010: Univ. of Minnesota led DOE consortium grant received
- Fall 2011: power electronics class with lab offered (Mathews)

DOE Grant

- $25k over 3 years to Revitalize Electric Power Engineering by State of the Art Laboratories
- U. Minnesota developed lab equipment acquired
    - 2 stations of power electronics lab
    - 1 station of electric drives lab
- Used UMN resources (lab manuals, textbook, video-based lectures) to develop power electronics course and lab
- Power electronics course with lab offered Fall 2011 to 5 students
- Details of implementation follow:

SPICE-based labs

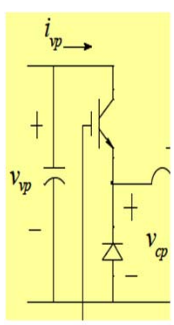
- Characteristics of ideal switching power pole with output filter
- Switching Characteristics of MOSFET and Diode in a Power Pole
- Characteristics of capacitors: ESR, ESL, Resonant frequency
- Frequency Response of Buck Converter
- Designing the feedback control for a buck converter using voltage-mode control
- Flyback converter simulation

Hardware-based labs

- Introduction to the Power Pole board & Differential Oscilloscope Probes
- Buck Converter
- Boost Converter
- Feedback control of buck converter
- Full bridge converter for DC motor drive (use electric drives lab equipment)

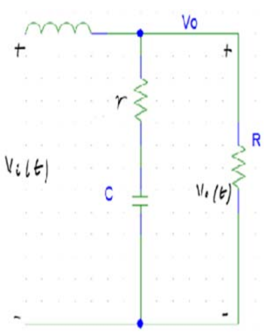
Course Development

- Lots of preparation needed as material was new to instructor. UMN developed materials helped greatly
- Spice-based labs were tailored to mesh with the class
- Will focus on lessons learned in implementing closed loop control of buck converter
- Linearizing the power stage of the buck converter: Text takes 3 pages to derive the transfer function.
- Was able to avoid the derivations and get transfer function via analysis of the output filter and coupling this with dynamic average model behavior of the switching power pole



Duty cycle d

Switching power pole



Output Filter

- Vcp = dVin   all voltages are dynamic averages
- For sinusoidal duty cycle perturbation $\tilde{d}$ output voltage perturbation is $\tilde{d}$ Vin.
- Switching power pole is followed by a filter whose transfer function is $H(s) = \frac{1}{LC}\frac{1+sRC}{s^2+s\left(\frac{1}{RC}+\frac{R}{L}\right)+\frac{1}{LC}}$
- Overall power stage transfer function is $\frac{\tilde{V}_o}{\tilde{d}} = \frac{V_{in}}{LC}\frac{1+sRC}{s^2+s\left(\frac{1}{RC}+\frac{R}{L}\right)+\frac{1}{LC}}$

Lab Modification

- PSPICE lab 10 was modified: Prelab involved derivation of the output filter transfer function.
- The filter magnitude response plot scaled by Vin gave the magnitude response of the power stage.
- Software lab also included use of Matlab scripts to design a feedback controller to provide desired phase margin at the selected crossover frequency.
- Controller was implemented on a breadboard and coupled to the power electronics circuit board.

Outcomes

- Power electronics course was successful. Student rating of the course was an average of 4.8/5
- On average one class in power / energy area is expected to be offered every semester.
- Since 2009 we have graduated 16 students who have had the power systems or power electronics classes. A number of them have gone on to work in the power / energy sector.
- Around 5 co-op employers regularly hire in the power / energy area.

Acknowledgments

- Thanks to Ned Mohan and the University of Minnesota Energy Systems Group
- Meetings and workshops organized by them have been invaluable. They have helped a small program (without much faculty expertise in the area) build up its energy systems offerings
- Opportunity to participate in the DOE consortium to revitalize electric power engineering education by state of the art laboratories helped greatly. Allowed us to acquire lab equipment and develop the power electronics course.