Implementation of the UMN Power Electronics Laboratory at Northern Arizona University

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### NAU Power Engineering = UMN Southwest, Sponsored by APS

<table>
<thead>
<tr>
<th>Course</th>
<th>Term</th>
<th>Final Enrollment</th>
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</thead>
<tbody>
<tr>
<td><strong>EE401/490: Power Systems</strong></td>
<td>Fall 2007</td>
<td>13</td>
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<tr>
<td>Senior technical elective</td>
<td>Fall 2008</td>
<td>18</td>
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<tr>
<td>(3 credits lecture)</td>
<td>Spring 2010</td>
<td>31</td>
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<td></td>
<td>Fall 2011</td>
<td>24</td>
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<tr>
<td><strong>EE484: Power Electronics</strong></td>
<td>Fall 2010</td>
<td>22</td>
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<tr>
<td>Senior technical elective</td>
<td>Spring 2013</td>
<td>39</td>
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<tr>
<td>(3 credits: 2 lecture, 1 lab)</td>
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<tr>
<td><strong>EE490: Electric Drives</strong></td>
<td>Spring 2012</td>
<td>28</td>
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<tr>
<td>Senior technical elective</td>
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<tr>
<td>(3 credits: 2 lecture, 1 lab)</td>
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**Increasing NAU EE enrollment:**

<table>
<thead>
<tr>
<th>AY6-7</th>
<th>AY7-8</th>
<th>AY8-9</th>
<th>AY9-10</th>
<th>AY10-11</th>
<th>AY11-12</th>
<th>AY12-13</th>
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<tbody>
<tr>
<td>128</td>
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<td>157</td>
<td>171</td>
<td>219</td>
<td>211</td>
<td>227</td>
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Main Causes for High Enrollment

- Industry support, job opportunities
- Hardware labs
- Renewable energy / sustainability
What I Like Most about the Hardware Lab

- Students “know the difference between a transistor and a transformer”
- The lab addresses practical, modern issues: heating, switching oscillations, component behavior changing with frequency
- “Oh!” Increased motivation – problems based on lab component specs, students continue working after lab, students analyze the circuit diagrams
- Students develop more sophisticated skills using test bench equipment
What I Like Most about the Hardware Lab

- Content challenging yet within reach

1. Laboratory and Power-pole Board Familiarization
2. Buck Converter
3. Switching Characteristic of MOSFET and Diode
4. Boost Converter
5. Buck-Boost Converter
6. Voltage-Mode Control
7. Peak Current Mode Control
8. Flyback Converter
9. Forward Converter
Main Lab Challenges

- Cost (Help from APS, DOE, alumni, department, dean’s office)
- Quality test bench equipment
- Space, sharing lab facilities with other courses
- Staffing, lab assistants
PSpice Simulations

- Alternative or supplement to hardware lab
- Use in “active learning” classrooms
1. Pulse-Width-Modulation (PWM) and Filter Characteristics
2. Switching Characteristics of MOSFET and Diode in a Power-Pole
3. Frequency Characteristics of Capacitors
4. Step-Down (Buck) DC-DC Converters
5. Step-Up (Boost) DC-DC Converter
6. Step-Down/Up (Buck-Boost) DC-DC Converter in CCM
7. Comparison of the Dynamic Response of the Switching Model with the Average Model: Buck-Boost Converter
8. Step-Down/Up (Buck-Boost) DC-DC Converter in DCM
9. Comparison of the Dynamic Response of the Switching Model with the Average Model: Buck-Boost Converter
10. Frequency Response Analysis of a Buck Converter using an Averaged Model
11. Designing the Feedback Control for a Buck Converter using the Voltage-Mode Control
12. Frequency Response Analysis of Buck-Boost Converter using Averaged Model
13. Current Mode Control of Buck-Boost Converter with Slope Compensation
14. Comparison of Frequency Response of a Buck-Boost Converter in CCM and DCM
15. Single-Phase Diode-Bridge Rectifiers
16. Three-Phase Diode-Bridge Rectifiers
17. Power Factor Correction (PFC) Circuit
18. Flyback DC-DC Converter
19. Forward DC-DC Converters
20. Full-Bridge DC-DC Converters
21. Zero-Voltage-Switching in a Synchronous Buck Converter
22. Three Phase PWM Inverters
23. Single-Phase Thyristor-Bridge Rectifier
Impact in 2012 – Jobs, Careers

• Employment for current students and recent graduates
  ◦ APS Palo Verde nuclear plant, Cholla and Four Corners coal plants
  ◦ APS subcontractors (e.g., Electrical Consultants, Inc. and Abeinsa)
  ◦ Hawaiian Electric Company, Bonneville Power, Puget Sound Energy
  ◦ Southwest Windpower, Swinerton, Saudi Electric Company, Maxim

• Graduate (M.S.) students, Power engineering research
  ◦ Santosh Chalise, “An Investigation of the Maximum Penetration Level of a Photovoltaic (PV) System into a Traditional Distribution Grid,” now at South Dakota State Univ.
Humanitarian Power Engineering

- ~18,000 Navajo families without electricity
- Large number of off-grid systems with varying levels of functionality
- Failing electronics, appliances – harsh environment
- 50% unemployment (avg. income ~$7,000), 50% graduation rate
- Wells contaminated from uranium tailings
- Communities in northeast Arizona could use your and your students’ knowledge, skills, creativity, and enthusiasm
Questions?

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