NSF-Sponsored Workshop on
Electrical Energy Education & Research

December 13-16, 2009, Doha, Qatar

Energy Engineering Education
and Smart Grid Test-Bed

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EPE at RPI

• Electric Power Engineering was a Separate Department at RPI
  – Established in 1962
  – Offered One-Year MS Program without Thesis
  – Undergraduate Student Body was Small
    • So was the Number of PhD Students

• Merged into ECSE Department around 2000
  – Education for Working Professionals Concentrated at RPI-Hartford
SOME 20 years ago, the students’ interests were concentrated on space related topics which resulted in their neglect to consider other more established technologies, including power and energy. Philip Sporn realized that such preferences would lead to serious shortages in the necessary power oriented professionals which had to be avoided. He encouraged a group of industrial leaders to join the American Electric Power Company in the sponsorship of a professorial chair whose occupant would lead the development of a professional program in electric power engineering. Such chair was established at Rensselaer in the Spring of 1962. This was the start of a program that has now become well known for its quality and achievements, both nationally and internationally.

# Undergraduate EPE Curriculum

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tr>
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Core Undergraduate Courses

Major in EPE

- Electromechanics
- Semiconductor Power Electronics
- Power Engineering Fundamentals

EPE Laboratory
New Energy Systems Curriculum

- EE Major with Concentration in Energy Systems
- Lab Activities in Each Course
- Modular Curriculum Allows Focus on Different Subjects
Focus on Fundamentals

• For Example, in Power Electronics
  – Steady-State Circuit Analysis Based on Inductor Voltage-Second and Capacitor Amp-Second Balance
  – PWM Spectral Analysis Using Double Fourier Series

\[
\sum_{m=1}^{\infty} \frac{4}{m\pi} J_0 \left( \frac{m\pi M}{2} \right) \sin \frac{m\pi}{2} \cos[m(\omega_c t + \theta_c)] + \sum_{m=1}^{\infty} \sum_{n=\pm 1}^{\infty} \frac{4}{m\pi} J_n \left( \frac{m\pi M}{2} \right) \sin \frac{(m+n)\pi}{2} \cos[m(\omega_c t + \theta_c) + n(\omega_t + \theta_1)]
\]

• Renewable Energy?
Challenges

• Plug and Play
• Copy and Paste
• Storage is Cheap
Smart Grid Test-Bed

Local Distribution Grid

Wind

Solar

Fuel Cell

Utility
Test-Bed Design

• Grid Simulator
  – Variable Voltages and Frequency (Weak Grid)
  – Programmable Harmonic Contents
  – Controllable Impedance and Other Dynamic Characteristics
  – Transient and Fault Conditions

• Sources, Loads, Energy Storage Devices
  – Constant-Power and Other Actively Controlled Loads
  – Battery Bank, Hybrid Vehicles (to be Added)
Grid Simulator

• Single or Three-Phase
  – 70 kW Three-Phase Operation
  – 40 kW Single-Phase Operation

• Two Back-to-Back Voltage-Source Converters
  – Input Stage Uses a Generative Drive with Line Filter
  – Output Formed by Three PWM Inverters in Parallel

• Internal Development Focus on Control
Solar and Fuel Cell Simulation

- Sampling Period < 0.1 ms
  - ADC 2 μs
  - Computation 50 μs
  - DAC 30 μs
Wind Power Simulator

Commercial Motor Drives with Custom-Made Control Software

Variable Speed Drive → PM Motor → PM Gen → PWM Rectifier → Grid-Parallel Inverter
Programmable Loads

- AC and DC Inputs
- Resistive, Inductive, Capacitive
- Constant Current
- Constant Instantaneous Power (DC)
  - As Load for Rectifiers
- Constant Average Power
- Control Bandwidth Limitations
Use of the Test-Bed

• Research
  – Renewable Energy Grid Integration
  – Distribution System Voltage Stability and Control
  – Impedance Matching, Harmonic Resonance
  – Energy Storage and System Energy Management

• Education and Outreach
  – Renewable Energy (Undergraduate & Graduate)
  – Advanced Power Electronics (Graduate)
  – System Demonstration, Industry Collaboration

• Future Expansion – RTDS, PMU, Smart Meters