Smart Grid - The Convergence of Information, Communications, Telecommunications and Electrical Technology

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Smart Grid – requires the integration of many technologies

- The Smart Grid requires many technologies
  - Information Technology
  - Wired and Wireless Communications
  - IP Networking
  - Electrical Power Systems
  - Electronics
  - Digital Circuits
  - Sensors
  - Alternative Energy Systems
  - Control Systems
Smart Grid – a multi-disciple multi-technology challenge for education

- A system solution to the modernization of the power grid
- A multi-disciple, multi-technology approach must be taken
- Courses and programs require a systems approach
- An understanding power utility industry and regulation issues is important
- Students must understand electrical power systems, instrumentation, networking, security and control technologies.
- The smart grid could be the ultimate-killer-app for the electro-IT industry and a compelling challenge for community college technology programs.
The many views of the Smart Grid?

- Edison-Westinghouse-Tesla view
- The US starting point view
- Sources of US energy view
- The Department of Energy view
- Gridwise Alliance view
- The IEEE view
- Cisco view
- Siemens, IBM, GE… view
The Power Grid – Edison-Westinghouse-Tesla

- Edison – DC grid
- Westinghouse – AC grid
- Tesla – Components for the AC grid
- Power grid is the world’s largest network
- The most important achievement of the twenty century.
- Mostly one-way communications

North American Grid Today
Sources of US Electrical Energy

- Coal: 48.9%
- Natural Gas: 20.0%
- Nuclear: 19.3%
- Petroleum: 1.6%
- Hydroelectric Conventional: 7.1%
- Other: 0.7%
- Other Renewables: 2.4%

Sources of US electrical generation by percentage in 2006. (image: wikipedia.org)
Start with the DOE View—a report

Smart Grid - Makes a distributed utility Possible

This material is based upon work supported by the Department of Energy under Award Number DE-0000070.
DOE lists five fundamental technologies that will drive the Smart Grid:

- Integrated communications, connecting components to open architecture for real-time information and control, allowing every part of the grid to both ‘talk’ and ‘listen’
- Sensing and measurement technologies, to support faster and more accurate response such as remote monitoring, time-of-use pricing and demand-side management
- Advanced components, to apply the latest research in superconductivity, storage, power electronics and diagnostics
- Advanced control methods, to monitor essential components, enabling rapid diagnosis and precise solutions appropriate to any event
- Improved interfaces and decision support, to amplify human decision-making, transforming grid operators and managers quite literally into visionaries when it comes to seeing into their systems
GRIDWISE Alliance

And then there was...

http://www.gridwise.org/

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COMMUNITY COLLEGE OF RHODE ISLAND
IEEE Transactions on Smart Grid

JOURNAL TO BE LAUNCHED BY IEEE

The IEEE Transactions on Smart Grid is intended to be a cross-disciplinary and internationally archival journal aimed at disseminating the results of research on smart grid that relates to energy generation, transmission, distribution and delivery. The journal will publish original research on theories, technologies, design, policies, and implementation of smart grid. The Transactions will welcome manuscripts on design, implementation and evaluation of energy systems that include smart grid technologies and applications. Surveys of existing work on smart grid may also be considered for publication when they propose a challenging perspective on the future of such technologies and systems. The initial topical issues considered by the Transactions include:

- Smart sensing, communication and control in energy systems
- Wireless communications and advanced metering infrastructure
- Smart grid for energy management in buildings and home automation
- Phasor measurement unit applications for smart grid
- Smart grid for plug-in vehicles and low-carbon transportation alternatives
- Smart grid for cyber and physical security systems
- Smart grid for distributed energy resources
- Smart grid for energy savings and financial management
- Smart grid in interdependent energy infrastructures
- Smart grid for intelligent monitoring and outage management

If you are interested in reviewing papers and assisting in the launch of this journal, please sign up as a reviewer on the Manuscript Central site at: http://mc.manuscriptcentral.com/pes-ieee.

http://smartgrid.ieee.org/ieee-smartgrid-news
Cisco Smart Grid Solutions

Cisco Solutions for Utilities/Smart Grid

- **Substation Automation**
  Cisco solutions include ruggedized routers and switches to handle the most demanding substation environments.

- **Home Energy Management**
  Cisco solutions help enable utilities and their customers to more effectively monitor and control energy use.

- **Business Energy Management**
  Cisco EnergyWise and Network Building Mediator technologies help businesses reduce their costs and carbon footprint.

- **Grid Security**
  Cisco solutions include physical and cyber security technology and services to address regulatory compliance and threat mitigation.

- **Data Center Operations**
  Cisco solutions provide highly secure, scalable data management and storage options for grid operations.

Cisco Smart Grid Elements

Elements of a Smart Grid

Observable
Full awareness of grid state—transporting sensor data and control commands

Controllable
Driving the grid to any desired state

Automated
Adapting rapidly to changing conditions without human intervention

Integrated
Connecting utility systems and processes—greater intelligence and efficiency in the grid

http://www.youtube.com/watch?v=yGk13U_kgGM&feature=related
Video-Cisco View

http://www.cisco.com/web/strategy/energy/external_utilities.html
Cisco Smart Grid View
Siemens – Energy from anywhere is reaching everywhere


Energy from anywhere is reaching everywhere.

Austin homes and businesses weather the sweltering Texas summers with fewer costly outages, thanks to Siemens Smart Grid solutions. Elsewhere, we're helping utilities integrate new, alternative sources of energy into the conventional grid. And we've developed HVDC transmission systems to efficiently deliver this clean power where it's needed, even hundreds of miles away.
IBM – Information processing will save energy

video  http://www-03.ibm.com/innovation/us/thesmartercity/index_flash.html#energy_and_utilities/ch1/

Energy and Utilities

With the emergence of the technologies that make smart grids possible, companies can provide their customers with the information and control they need to actually change their behavior and reduce usage and costs.

These smart grids use sensors, meters, digital controls and analytic tools to automate, monitor and control the two-way flow of energy across operations—from power plant to plug. A power company can optimize grid performance, prevent outages, restore outages faster and allow consumers to manage energy usage right down to the individual networked appliance.

Many Smart Grid Videos

Smart Grid

Our electric grid is a marvel of 20th-century engineering, but it's showing signs of strain. Can a "smart grid" help? Aired February 23, 2011 on PBS

Posted 02.23.11

Watch Smart Grid

8:53
Aired February 23, 2011 on PBS

http://www.pbs.org/wgbh/nova/tech/power-grid.html
http://www ecs csus edu/CASmartGrid/index php?content=video & PHPSESSID=b8dd400f9773ff6b6cae8f2b209822108

Courses in Network Security

- CSC 114 Digital Evidence & Computer Crime
- CSC 115 Internet Security and Law
- CSC 138 Computer Networks
- CSC 153 Computer Forensics Principles and Practices
- CSC 154 Computer Attacks & Countermeasures
- CSC 250 Computer Security & Privacy
- CSC 252 Cryptography
- CSC 253 Computer Forensics
- CSC 254 Network Security

Courses in Power Engineering

- EEE 141 Power System Analysis
- EEE 142 Energy Systems Control and Optimization
- EEE 144 Electric Power Distribution
- EEE 100 or 200 level Power Elective Course
- EEE 100 or 200 level Power Elective Course
- EEE 131 Electromechanical Laboratory
- EEE 135 Renewable Electrical Energy Sources and Grid Integration
- EEE 136 Smart Electric Power Grid
- EEE 143 Power System Laboratory
- EEE 192A Electrical Power Design Project 1
- EEE 192B Electrical Power Design Project 2
- EEE 255 Introduction to Future Power Systems and Smart Grids
Why teach energy? - Job Opportunities

Retirements and attrition estimates in electric and gas utilities through 2013
(source: Center for Energy Workforce development)

<table>
<thead>
<tr>
<th>Job Category</th>
<th>Attrition and Retirement- % workforce</th>
<th>Replacements Needed</th>
<th>Retirees</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Engineers</td>
<td>44.7</td>
<td>14,500</td>
<td>10,000</td>
</tr>
<tr>
<td>Technicians</td>
<td>49.0</td>
<td>27,000</td>
<td>20,500</td>
</tr>
<tr>
<td>Line Workers</td>
<td>40.2</td>
<td>29,000</td>
<td>19,000</td>
</tr>
<tr>
<td>Nonnuclear plant operators</td>
<td>47.6</td>
<td>12,000</td>
<td>9,000</td>
</tr>
<tr>
<td>Pipe fitters</td>
<td>45.0</td>
<td>8,500</td>
<td>6,500</td>
</tr>
</tbody>
</table>
Topics that we must teach

- Electrical Technology
- Power Systems
- Power Electronics
- Digital Systems
- Sensors
- Networking
- Security
Smart Grid Technology

- Integrated Communications
  - Real-time information and control
  - Every part of the grid will ‘talk’ and ‘listen’

- Sensing and measurement
  - Accurate remote monitoring, Time-of-use pricing
  - Demand-side management

- Advanced components
  - Superconductivity, storage, electronics, diagnostics

- Advanced control methods
  - Monitoring, rapid diagnosis, precise solutions

- Improved Interfaces
  - Amplify human decision-making, views of the grid and systems

Teach Technology

- Telecommunications
  - Networking, wireless

- Voltage, Current, power
  - Phasors, frequency
  - Current and voltage transformers

- Electrical, electronics
  - Troubleshooting

- Computer, algorithms
  - Security

- Displays, information management
Energy/Generation, Transmission and Distribution Competency Model

Bulk Energy Generation

- Non-Renewable: Non-Variable
  - Nuclear
  - Coal
  - Gas

- Renewable: Non-Variable
  - Hydro
  - Biomass
  - Geothermal
  - Pump Storage

- Renewable: Variable
  - Wind
  - Solar

Source: IEEE
Energy Distribution

- Distribution of Bulk
- Distribution of Storage
- Capacitor Bank Distribution
- Control, Measure, Protection
- Record and Optimization

Source: IEEE
Energy Customers

- Residential
- Commercial
- Industrial
- Smart meters
- Two-way communications
- Customer generation
- Energy Domains

Source: IEEE
Energy Operations

- Domain Flow Control
- Substation two-way communications
- Monitoring and reporting control
- Customer network data gathering and control

Source: IEEE
The Markets domain operates and coordinates all the participants in electricity markets within the smart grid. It provides the market management, wholesaling, retailing and trading of energy services. The Markets domain interfaces with all other domains and makes sure they are coordinated in a competitive market environment. It also handles energy information clearinghouse operations and information exchange with third-party service providers. For example, roaming billing information for inter-utility plug-in-vehicles falls under this domain.
Power Engineering Components

- Generators
- Transmission lines
- Current Transformers (CT)
- Voltage Transformers (VT)
- Switches
- Capacitors
- Current and Voltage Protection
- Fusing
- Sensors
- Flash suppression devices
Sensors and Measurement

- Electric Current
- Voltage
- Power
- Voltage-Current Phase angle (Power Factor)
- Temperature
- Harmonics
- Frequency
Community College Equipment Challenges

- High power equipment
  - Cost
  - Size
  - Safety issues

- Specialized equipment

- Solution partner with local energy provider
Learning Tools and Simulation Applications

- Power World - free
- PSCAD - $
- Mutisim - $
- Automation Studio - $
- LabVolt Simulation - $
- LabVIEW - $
- Wireshark - free
Power World-high voltage power simulator

- Free education version
- Minutes to days times
- Up to 10,000 buses
- Transmission power flow analysis
- Define generations systems
- Define transmission characteristics
- “Take mystery out of transmission systems”

Power World-Details

Bus Voltage (magnitude and angle)

Line Current

Shunt Capacitor Output

Generator Output

Transformer Current H-Side

Transformer Current L-Side

Load Parameters

Co-Gen

Source

Load

0.9950 pu -1.46 Deg

97.56 AMP

0.9924 pu -1.56 Deg

5.91 Mvar

5.0110 MW -0.6405 Mvar

2.00 MW 1.1761 Mvar

42.27 AMP

213.47 AMP

1.0000 pu 0.0000 Deg

7.00 MW 6.30 Mvar

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PSCAD – Power System Simulator

- Free limited file size ($2500 site license.)
- Time domain analysis
- Similar to MultiSim
- Power transients
- Construct schematics
- Transmission systems
- Wind turbine simulation

https://pscad.com/products/pscad/
Multisim Electrical Circuit Simulator

- Simulates electrical circuit element with Spice
- Basic to complex
- Compare simulated and measured
- 3D breadboarding environment
- Interface to LabVIEW

http://www.ni.com/multisim/
Automation Studio Simulator

- Visual Simulation of
  - Electrical systems
  - Electromechanical systems
  - Power networks
  - Digital controllers
  - Hydraulic controls
  - Pneumatics controls
  - Programmable logic controllers (PLC)
- Library of systems and components

LabVIEW Programming and Testing

- Hardware, software and test equipment simulation and control
- Drag and drop programming
- Test equipment programming
- Equipment simulation
- Industry standard for advanced testing
- Design test environments
- Extensive analysis and display
- Large library

http://www.ni.com/labview/whatis/
Wireshark Testing and Analysis

- Wired and wireless network analysis
- Sniff and analyze
  - Zigbee
  - Heart
  - WiFi
  - WiMax
- Free open source

http://www.wireshark.org/
Onset HOBO Data Logger-
For Student Labs and Projects

- Monitor energy usage
- Measure renewable energy,
  - Wind, Solar, Hydro
- Monitor wireless or wired
- Set alarms
- Send to iPhone
- Capture and display data with Onset web interface
- CCRI project
  - Monitor all solar and wind energy at four campuses
  - Measure all energy used at all campuses
  - Display all information on website

http://www.onsetcomp.com/
Home energy monitor systems measure and log the total amount of energy use in the home. Plug the system into your home network and you can view the details of home energy use on any computer. On line applications allow you to view energy consumption from anywhere on the Web. There are even iPhone applications that will connect you to your home energy use. Clever graphics are used to display information making energy use easy to understand.
TED – The Energy Detective-Home System

• Current and voltage clamps to measure power consumption
• Interfaces to Google PowerMeter (until September)

http://www.theenergydetective.com/
CCRI Energy Utility Technology Certificate

- Mostly electrical power technology
- Introduction to smart grid
- Potential National Grid employment
- Job-Energy utility technician
- Job-Power equipment installation
- Job-Power systems maintenance technician
- Job-Lineman and cable technician
- Job-Electrical utility subcontractor technician
CCRI Energy Utility Technology Certificate

- Training for the electrical and gas energy sector
- Full-time 27 credit certificate
- Transfers to A.S. degree
- 64-hr Ngrid practicum
- Energy utility technician
- Power equipment installation
- Power systems maintenance technician
- Lineman and cable technician
- Electrical subcontractor technician
- Starting pay $26/hr, $40/hr after 42 months (Ngrid)

This two-semester, 27-credit certificate program provides students with a core set of skills and competencies the energy industry requires. ETUT coursework covers energy industry technology and operations, technical math, AC and DC circuits and controls, and computer applications. The program emphasizes safety issues, critical thinking and problem-solving skills as well as teamwork, time management, workplace behavior and business ethics.

Students will spend one eight-hour day per week in an eight-week energy industry practicum with a regional energy provider that will give students hands-on training and experience as they apply classroom theoretical knowledge in a practical, real-world environment. Students also will be required to complete a program portfolio containing key learning outcomes, practicum reports, lab reports and projects.

This program is offered only as a full-time, day program that begins in the fall semester. All credits earned for the certificate will apply towards the Engineering Systems Technology A.S. degree. This program is limited to 20 enrollees, and the admission process includes an interview with department faculty and math placement examination.
CCRI Energy Utility Technology Certificate

- Coursework covers
- energy industry technology and operations
- technical math
- electrical circuits
- digital systems
- power electronics
- power generation, transmission and distribution
- introduction to renewable energy
- Industry practicum
CCRI Engineering Systems Technology A.S.

- Core courses-electronics, digital, robotics, electromechanical
- Concentrations-electrical, mechanical, energy, automation
- 63 credit A.S. degree
- Full-time and part-time
- Seamless certificate transfer from ETUT certificate
References
References – the 40 watt light bulb as a reference – 1 KWh/day