Electric Power Grid Reliability in a New Era of Energy Development

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The Pitt Center for Energy

• University-wide Research Center
  • $30+ Million R&D portfolio
  • 90+ Faculty and 250+ Graduate Student Researchers

• General Areas of Research Focus:
  • Energy delivery and reliability (Electric Power)
  • Advanced materials for energy-related applications
  • Energy efficiency and sustainability
  • Clean energy development and integration
  • Unconventional gas resources
  • Carbon management and utilization
  • Direct energy conversion and recovery
  • Various non-engineering areas
Electricity – the Life Blood of Modern Society
Example of energy lost during conversion and transmission. Imagine that the coal needed to illuminate an incandescent light bulb contains 100 units of energy when it enters the power plant. Only two units of energy eventually light the bulb. The remaining 98 units are lost along the way, primarily as heat.
Power Grid Infrastructure and Reliability
Today’s Electric Power Systems
(AC Networks, One-Way Flow)

Generation ➔ Transmission ➔ Distribution ➔ Consumption
The U.S. Power Grid
T&D (the Grid) Delivers Electricity

Transmission
• High voltage
• 400,000 miles
• 16,000 substations

Distribution
• Lower voltage
• 5,000,000 miles
• 60,000 substations
In the late 1800s and early 1900s, Pittsburgh was at the center of the war of the currents — AC vs. DC electricity

Edison  Westinghouse  Tesla
Challenges for Today’s Power Grid

Resource Transition

Consumer Participation
Energy Utilization

Primary Energy Use by Fuel (quadrillion Btu) (U.S. DOE EIA, 2014 report)

- Petroleum and other liquids: 36% (2011) to 32% (2040)
- Coal: 20% (2011) to 19% (2040)
- Natural gas: 26% (2011) to 28% (2040)
- Nuclear: 8% (2011) to 2% (2040)
- Liquid biofuels: 1% (2011) to 2% (2040)
- Renewables (excluding biofuels): 8% (2011) to 9% (2040)

(U.S. DOE EIA, 2014 report)
Electricity Generation

Figure 13. Electricity generation by fuel, 1990-2040

(trillion kilowatthours)

<table>
<thead>
<tr>
<th>Year</th>
<th>History</th>
<th>2012</th>
<th>Projections</th>
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<tbody>
<tr>
<td>1990</td>
<td>52%</td>
<td>1%</td>
<td>1%</td>
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<tr>
<td>2000</td>
<td>19%</td>
<td>12%</td>
<td>30%</td>
</tr>
<tr>
<td>2010</td>
<td>9%</td>
<td>16%</td>
<td>35%</td>
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<tr>
<td>2020</td>
<td>16%</td>
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<tr>
<td>2030</td>
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<td>2040</td>
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- Natural gas: 35%
- Renewables: 16%
- Nuclear: 16%
- Coal: 32%
- Oil and other liquids: 1%
Electricity Generation Portfolios are Changing
Future Energy Supply and Demand Trends
Grid Impacts from Powerful Weather Events

Hurricane Sandy
Distributed Energy Resources and Microgrids

Evolving DC-based Loads and Resources
Consumer Participation is Increasing
Tomorrow’s electric power systems will have hybrid AC-DC networks and multi-way flow

Generation → **Transmission** → **Distribution** → Consumption

- **Generation**
  - Generating Station (Low Voltage)
  - Generator Step Transformer
- **Transmission**
  - Transmission Lines (Ultra High Voltage)
- **Distribution**
  - Substation Step-Down Transformer
  - Subtransmission Customer (Medium Voltage)
  - Primary Customer (Medium to Low Voltage)
  - Secondary Customer (Low Voltage)
- **Consumption**
  - Customer Transmission Lines (High Voltage)
Opportunities – Grid Modernization

DC Solutions and Power Electronics Technology

Large-Scale Renewables

Cleaner Fossil Resources

Power Conversion Technologies

Micro-Energy Developments
Advantages of DC and Power Electronics

- HVDC -- Greater Capacity per Right of Way (x6)
- Improved Controllability of T&D Networks
- Less Costly Infrastructure – both O/H and U/G
- Increased Efficiency and Lower Losses
- Reduced Risk of Major Blackout Events
- Enhanced Resiliency of Grid Infrastructure and Integration of Micro-grid Solutions
- Better Match of Supply (renewables/storage) and Demand (consumer devices)
- **Technology Development and Economic Growth, U.S. Leadership, and Workforce / Jobs**
The 21st Century Grid and Its Interactions

DER, Storage, μ-Grid, DC

Power Plants

Large-Scale Renewables (all types)

DER, Storage, μ-Grid, DC

Communications, Control, Security, Power Conversion, ‘N’-Way Interface, Automation, etc.

Transmission Distribution

Communications, Control, Security, Power Conversion, ‘N’-Way Interface, Automation, etc.

Transportation

Commercial

Residential

DER, EV, Storage, μ-Grid, DC

DER, EV, Storage, DC
DC and Power Electronics Development
Pittsburgh Leadership, Again, in the 21st Century

Univ. of Pittsburgh / Government, Industry, and Community Partners

AC-DC Power/Energy Laboratories
A Brighter Future with Global Implications
Thank You
Contact Information

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