The Electric Power Grid in Transition: Technologies, Markets, and Investments

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Energy and Electricity – Critical to Our Productivity and Quality of Life
Electricity – the Life Blood of Modern Society
What is the Power Grid?
The U.S. Power Grid
Power Grid Infrastructure (U.S.)

**Transmission**
- High voltage
- 400,000 miles
- 16,000 substations

**Distribution**
- Lower voltage
- 5,000,000 miles
- 60,000 substations
Today’s Electric Power Systems
(AC Networks, One-Way Flow)

Generation ➔ Transmission ➔ Distribution ➔ Consumption

Generating Station
(Low Voltage)

Transmission Lines
(Ultra High Voltage)

Substation
Step-Down Transformer

Customer Transmission Lines
(High Voltage)

Subtransmission Customer
(Medium Voltage)

Primary Customer
(Medium to Low Voltage)

Secondary Customer
(Low Voltage)
Challenges for Today’s Power Grid

Resource Transition

Consumer Participation
Electricity demand is expected to more than double by 2050.

- 4.3 trillion kWh (World)
- 6 trillion kWh (US)

2010-2050 timeline
U.S. Electricity Generation

Graph showing U.S. electricity generation from select fuels in billion kilowatthours from 1980 to 2040. Key fuels include coal, natural gas, nuclear, renewable energy, and petroleum. The graph indicates historical data and projections for 2016 and beyond.
Energy Mix has Evolved Over Time
US Electricity Generation

Plant capacity by power source

- Natural Gas
- Coal
- Nuclear
- Hydroelectric
- Oil
- Wind
- Solar
- Other

(Washington Post)
Regional energy flow: production, consumption, net imports/exports and losses

Energy Source (Trillion BTU)
- Coal: 2,080
- Solar: 0.9
- Nuclear Import: 160
- Hydro: 4.1
- Wind: 4.0
- Geothermal: 0.7
- Biomass: 22
- Biomass Import: 14
- Petroleum: 15
- Petroleum Import: 440
- Natural Gas: 661

Energy Outcome (Trillion BTU)
- Coal Export: 790
- Unused Energy: 1,400
- End-Use Electricity Export: 310
- Useful Energy: 520
- Natural Gas Export: 370

Power of 32 Region: uniting Pittsburgh and 32 counties across western Maryland, eastern Ohio, southwestern Pennsylvania and northern West Virginia. 2011 data.

Source: Sustainable Pittsburgh
Consumer Participation is Increasing
Four primary consumer sectors (electrical consumption)

Source: Edison Electric Institute (EEI)
Grid Impacts from Extreme Weather Events
Distributed Energy Resources and Microgrids

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

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Transmission Lines
(Ultra High Voltage)

Subtransmission Customer
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Primary Customer
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(Low Voltage)

Generating Station
(Low Voltage)

Generator Step Transformer

Customer Transmission Lines
(High Voltage)

Substation Step-Down Transformer
The 21st Century Grid and Its “Interactions”

DER, Storage, μ-Grid, DC

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

DER, EV, Storage, μ-Grid, DC

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DER, EV, Storage, DC
Projected Global Energy Supply Investments (by type: 2014-2035)

- Power dominates the projected investment
- Distribution-level spending is increasing
- Renewables are roughly comparable with (95% of) Upstream Gas

Impact on SWPA Economy

- SWPA has a strong energy-economy and energy industry nexus
- Opportunities for resource development, manufacturing, technology R&D
- Needs remain for workforce development in some areas
- Job creation and regional economic strength
- Importance in diversification of energy resources, delivery infrastructure, and end-use technologies
- Policy and regulation are key drivers
A Brighter Future with Global Implications

THANK YOU
The University of Pittsburgh’s Role

New Laboratory/Facilities Plans for the Pittsburgh Energy Innovation Center (EIC)

Establishing “The Energy GRID Institute”

(Grid Research and Infrastructure Development)
The Pitt Center for Energy

• University-wide Research Center
  • $48 Million R&D portfolio ($23.5-M new grants, FY-2016)
  • 100+ Faculty and 250-300 Graduate Student Researchers

• Dedicated to improving energy technology research, development, and implementation, including:
  • Resources
  • Delivery and Infrastructure
  • Utilization
  • Materials and Storage
  • Markets
  • Education and Training
The Pitt Center for Energy

• **Areas of Strategic Growth**
  - INDUSTRY and COMMUNITY PARTNERSHIPS
  - Power Electronics and Energy Storage Technologies
  - Microgrids and Resilient / Secure Energy Systems
  - Renewable Energy Technology Development and Integration
  - Direct Current (DC) Infrastructure, Technologies, and Standards
  - Hybrid AC/DC Systems and Integrated Energy Networks
  - Electric Vehicle-to-Grid / Transportation Electrification Concepts
  - Power Systems Operation, Control, and Security
  - Energy Materials Development and Testing
  - Energy Policy, Regulation, and Economics

• **Need for New/Expanded Facilities and Operations**
  - On-Campus and Off-Campus Options
  - **Off-Campus focus at the Pittsburgh Energy Innovation Center**
    - Establishing the Energy GRID Institute (June 2016)
The Energy GRID Institute

• The GRID Institute was announced in June 2016.

• This new entity, grounded in research from Pitt’s Center for Energy, the SSOE and the Electric Power System Laboratory (ECE Dept.), will leverage the University’s public and private partnerships with new labs and facilities at the off-campus Energy Innovation Center building in downtown Pittsburgh, to create a unique and comprehensive international solution center for the entire electric utility industry.

• The Energy GRID Institute will serve as the nexus for collaborative research that encourages economic growth and job creation for the region and with its partners; enhances Pitt’s incubator, start-up, and commercialization potential; facilities cross-disciplinary and multi-functional activities; and enables a broad range of service offerings and partnership models.
The Energy GRID Institute (est. June, 2016)

University research & development; and independent industry/community activities

– Focus will be on the ELECTRIC UTILITY INDUSTRY

– **Key Facility/Lab:** High-voltage and high-capacity capability and multiple use facility
  
  • 15 kV-ac, 5 MVA and 1.5 kV-dc, 1 MVA capacity
  
  • Ring-Bus configuration and dedicated DC area
  
  • AC and DC Energy Environments at Utility Distribution Level
  
  • Distributed Energy Generation, Grid, and Load Integration
  
  • Operation and Control Center, Smart Grid Interfaces
The Energy GRID Institute
- 20,000 ft² of new labs/facilities
- Electric Power Technologies Lab
- High voltage AC/DC capabilities
Proposed EPTL Layout

Power Distribution Areas
- **MV Grid Lab**: Reconfigurable lab for traditional or microgrid projects. Designed using utility-grade distribution equipment.
- **Test Lab**: Isolated testing facility for safe testing of industry technologies, and EPTML research projects.
- **AC and DC**: Flexible power architecture capabilities – AC, DC, and hybrid systems.

Specialty Areas
- **Rapid Prototyping**: Advanced machine shop for development of professional grade components and projects.
- **SCADA Center**: Automation, metering, and control for distribution network.
- **Relaying and Controls**: Protective relaying technologies, Phasor-measurement, and advanced control.
- **RTDS Center**: Real-Time Digital Simulator and hardware in the loop capabilities – research and testing on industry leading equipment.

Laboratory Ratings and Features
- 15 kV-ac, 5 MVA and 1 kV-de, 1 MVA capacity
- Micro-Grid/Micro-Energy Environment at Electric Utility Distribution Level
- Distributed Energy Resource and Load Integration
- Renewable Technologies (Solar PV, Wind, etc.)
- Energy Storage, Electric Vehicle-2-Grid
- Distribution Feeder Infrastructure
- Real Time Digital Simulator (RTDS)
- SCADA and Systems Operations
- Protective Relaying and Substation Automation
- Advanced Control and Communications, PMU
- Modeling, Simulation, and Analysis
- FACTS and HVDC Control Systems
- Power Electronics Converters (and other power technologies development, prototyping, and testing -- e.g., IEEE 1547 certification)
- DC standards development (IEC SG 4)
- Integration of feeder analytics
- Technology testing and certification
GRID Institute / Pitt Facilities at the EIC Building

- **Electric Power Technologies Lab**
  - Dr. Gregory Reed – ECE (PI)
  - High-Voltage/High-Capacity AC and DC Grid Facility and System Operations Center

- **Energy Storage Technologies Lab**
  - Dr. Prashant Kumta – BioE, ChemE (PI)
  - Nano-Materials for Conversion and Energy Storage

- **High-Temperature Corrosion Testing Lab**
  - Dr. Brian Gleeson – MEMS (PI)
  - Harsh-Environment, High-Temperature Materials Testing

- **Energy-Related University Incubator Space**
  - Dr. Rob Rutenbar – VC for Research and ECE (PI)
  - Lab Spaces for Start-up/Commercialization Activities
The Energy GRID Institute
- Service Offerings

- Testing, Certification & Evaluation
- Training
- Roadmapping
- Development Partnership
- Industry Consortia
- Vertical Collaboration
- Center of Excellence
- Data & Analytics
- Government R&D
- Graduate Course R&D
- Graduate Student R&D
- U-LAB
- I-LAB
The Energy GRID Institute

Current (Initial) Industry and Community Partners

($5.7-M in total in-kind and programmatic support, to-date)

ABB
Dominion VP
Eaton, Electrical
EPRI
Mitsubishi Electric
Pitt-Ohio Express
Sargent Electric
Universal Electric

ANSYS
Duquesne Light Co.
Emerson Process Management
FirstEnergy Corp.
OPAL-RT
RTDS
Siemens

RK Mellon and HL Hillman Foundations
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