Systems Challenges and Opportunities for Sustainable Energy Solutions

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Outline

■ Significance of the Electric Power Industry
■ Security of Supply and System Stability
  Requirements: Energy Balance, T&D Congestion, Reserves
■ Barriers to Adoption of Environmentally Friendly
  Sustainable Technologies: Wind, PV, HEV, Distributed Res.
■ The Cyber Physical System: Multiple-Competing
  Developers and Users
■ A Systems Approach: Technology-IT-Regulatory
  Policy-Markets-New Business Models for
  Consumer and Institutional Behavior, Risk Sharing
  and Contract Design
Electricity and Sustainable Energy Future

- Best Strategy to Conserve Fossil Fuels is to stop using them for heating (heat pumps up to 3-4x more efficient)
- Electrification of transportation sector a must
- New load should come from Clean generation not fossil fuel powered generation!
System Security: Energy Balance and T&D Goals

- Assure system integrity and security through contingency planning that assures robustness to uncertainties that may threaten system stability (possibly cause a blackout!)

- This is done by securing sufficient reserve capacity resources to avoid congestion in:
  A. Transmission capacity (Schedule Gen and Loads => LMP)
  B. Generation/Demand Balance in Real Time.

- Achieved today by:
  A. Long term contracts,
  B. Real Time Markets
  C. Central Planning (conventionally regulated, vertically integrated utilities)
Transmission System/Whole Sale Markets in the US today: >50% of consumers

Source: FERC
Generation Capacity Reserves

- **Primary Reserves** (Frequency Control); respond to real-time distributed monitoring of frequency

- **Secondary Reserves** (Regulation Service); Commands sent in 5-8 sec intervals, full reserve deployment response required within 60-90 seconds

- **Tertiary Reserves** (Spinning or Operating Reserves); scheduling commands sent in 5 minute intervals, full reserve deployment response required within 15 minutes

- **Slower Tertiary Reserves**; required response in 0.5 to 2+ hours
Congestion Costs Appear in:

- **TRANSM. SYSTEM/WHOLESALE MARKET**
  - Energy (MWh) needed to meet demand
  - Transmission Equipment capacity needed for N-1 contingency planning
  - Capacity Reserves (MW)

- **RETAIL/DISTRIBUTION (Potential Market)**
  - Distribution network equipment (transformers) utilization constraints.
The Unbundled Cost of Electricity: Averages

Source: EIA
The Cyber/Physical Electricity System **Platform**: The Smart Grid Broadly Construed!

- Generation-Transmission-Distribution-Consumption Assets
- The Embedded Automation, Information Technology
- The Decision Support and Control Software
- The Market or Regulatory Framework

Source: FERC
Issues with Renewable Generation (Wind, PV,..)

- Wind Output Forecast Error (at 90% confidence interval)
  - Day ahead ~20% (stand. Dev ~10%)
  - Hour Ahead ~ 5% (stand. Dev ~2.5%)
- Reg. Serv. currently on the order of .5-1% of Peak Load, at an average cost of $20-30 per MW per hour
- Operating Reserves higher at lower cost
- Wind Generation~20% of energy=> Regulation Service 2-3% of Peak Load. SHOW STOPER?
- Similar Issues with PV. Current Rates Inappropriate! California Utility Example…
Issues with Mass Adoption of Hybrid Electric Vehicles (EVs)

- Full conversion to EVs => ~20% increase in load
- Even if Wind generation supplies additional Load, will the distribution network require expensive expansion?
Is a Resilient Infrastructure Possible through Competitive and Innovative Cyber Investments?

- Are there Synergies between Renewable Generation and EV Battery Charging?
- Can EV battery charging be managed so as to decrease charging costs while mitigating
  - (i) reserve capacity cost of Intermittent generation and
  - (ii) mitigate distribution network congestion!!!
- Can Smart Retail Markets distribute costs fairly and elicit innovative development and use of the Cyber/Physical - Smart Grid Platform?
Multi-Disciplinary Systems Approach Required Synthesizing

- Power Engineering
- Information Technology
- Cyber Physical Interface Development
- Decision Support, OR, Stochastic Control
- Finance, Risk Management, Contract Design
- Market Design, Regulatory Economics
- Social Science and Human Behavior
- Organizational Behavior
- Climate/Environment Science