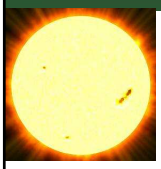
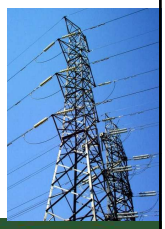


Smart Grid: Transforming the US Power Grid

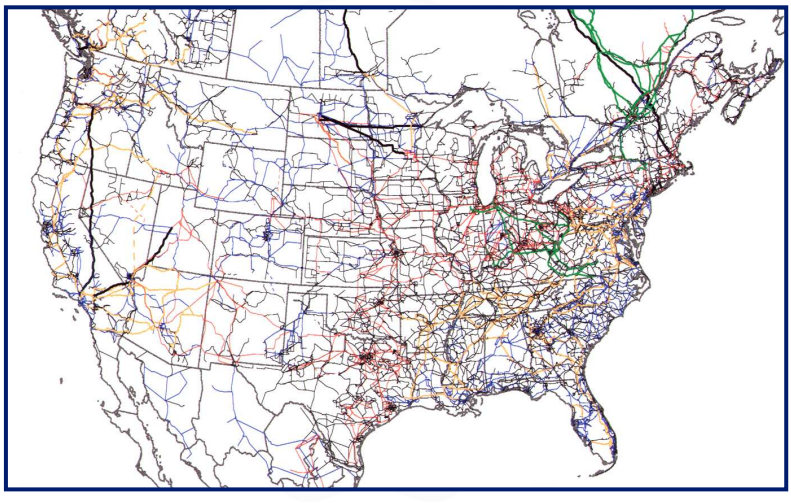
Wade O. Troxell

Associate Dean for Research and Economic Development

College of Engineering



U.S. Electric Power Transmission Grid



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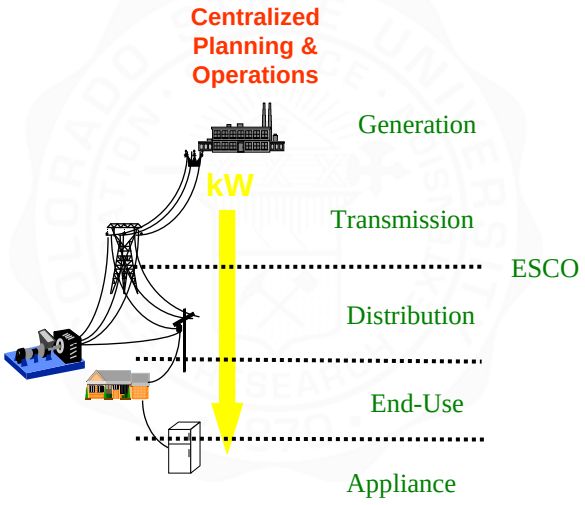
Centralized Infrastructure

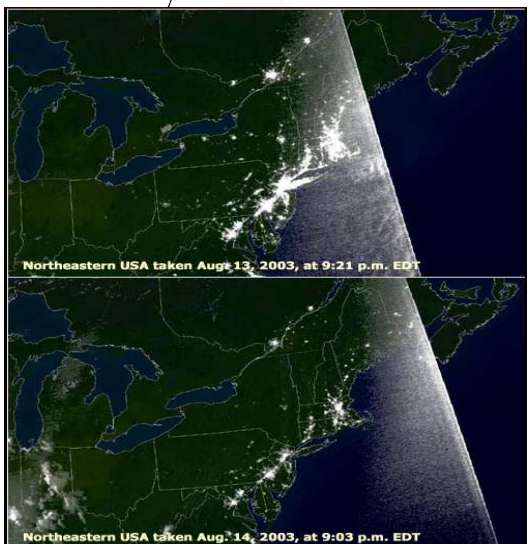


Central Power Generation

- Average U.S. generating plants are old (avg. 35 years)
- Wasteful (33% delivered efficiency) and
- Dirty (50 times the pollution of the best new distributed generation)

Fundamental flaw in the excessive reliance on central generation of electricity

Vulnerability of Centralization



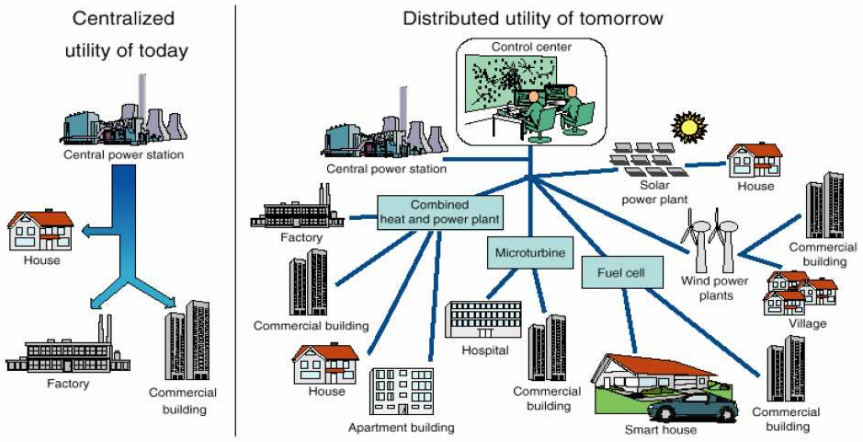
August 14th, 2003
Northeast USA Blackout

End-User v. Utility: The debate around the meter

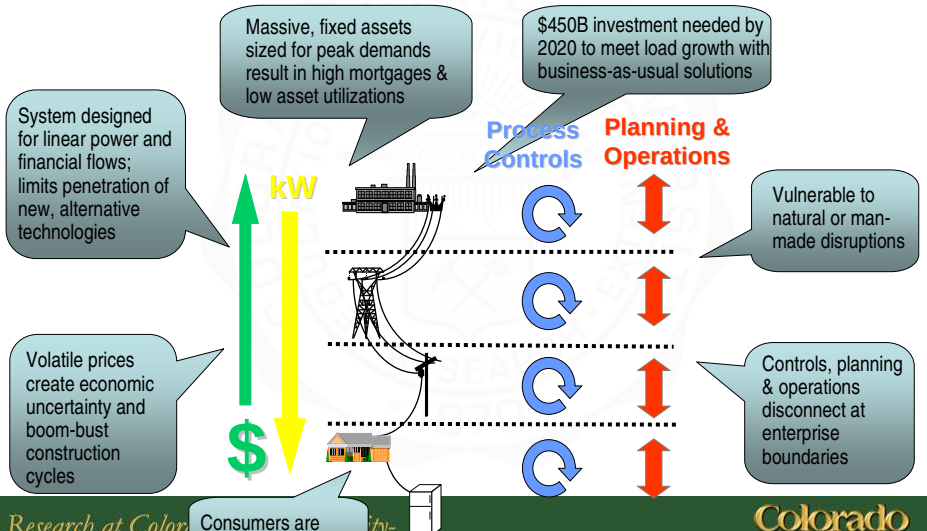
Customer's side of the meter

Utility's side of the meter

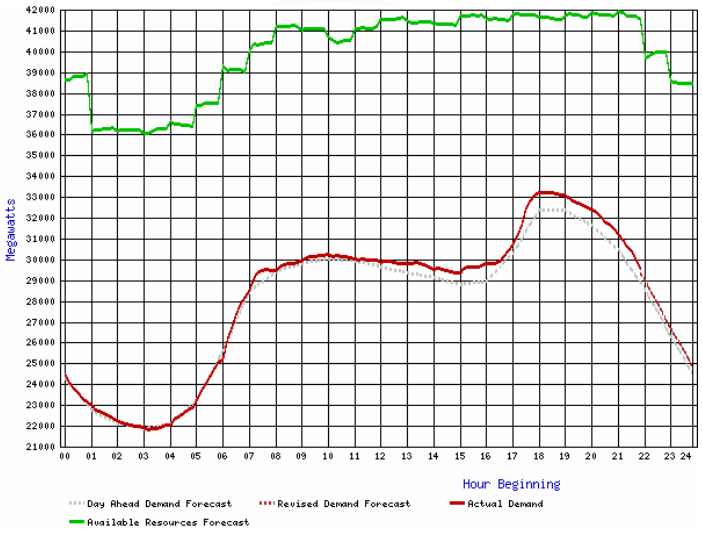
Electric Power System Transformation



Issues & Uncertainties Surround Today's US Electric Power Infrastructure



01/24/08 CAISO Snapshot of Power Supply and Demand



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Transforming the US Electric Power Infrastructure

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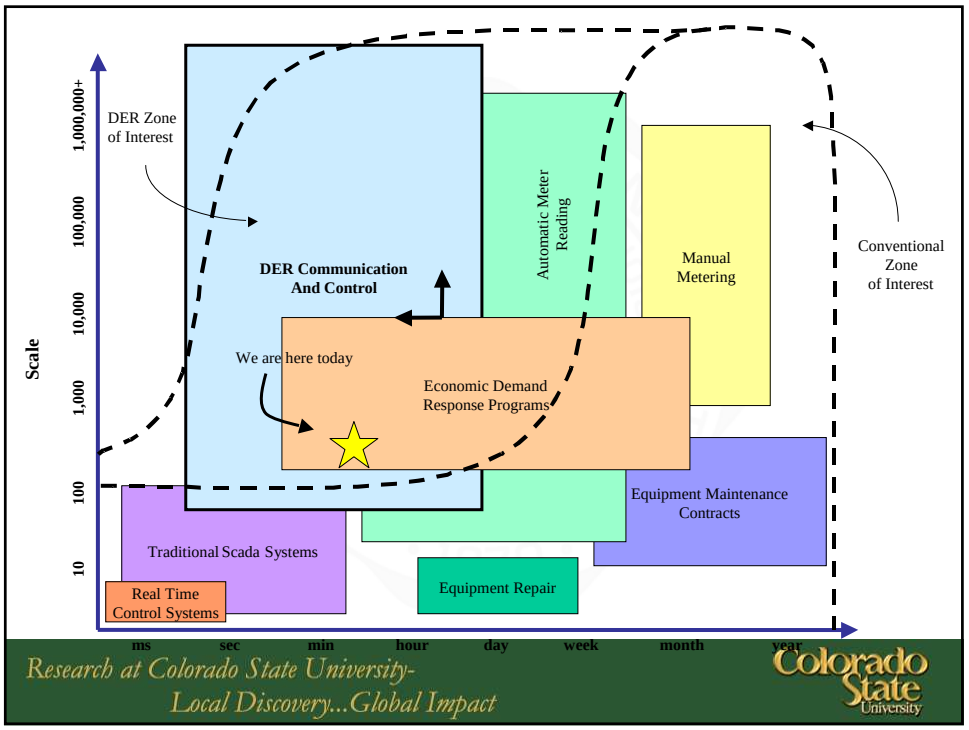
Distributed Energy Resources

- DER can be characterized as
  - Energy recycling (e.g., combined heat and power)
  - Energy producing (e.g., generators)
  - Energy consuming (e.g., building control systems)
  - Energy monitoring (e.g., meters)
  - Energy routing and switching (e.g., switch gear)
  - Energy conditioning devices (e.g., power electronics)
- Network them together for value-added products and services



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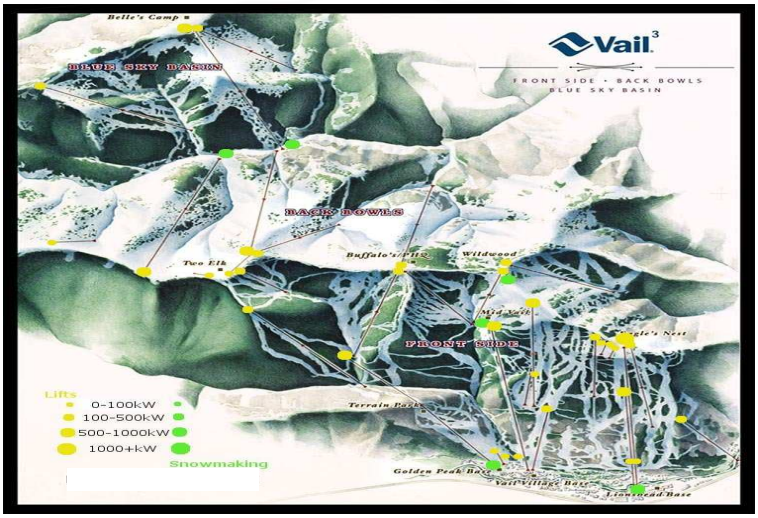
Networked Distributed Energy Project



Develop a portfolio of energy management options:

- Device-level efficiency optimization – base load reduction
- Optimize energy use based on rate structure
- Demand-side management (DSM)
- Distributed generation/CHP
- Fuel arbitrage
- Renewables
- Economic demand response (EDR)
- Purchase optimization
- Regional aggregation

Energy Management is best viewed as portfolio optimization

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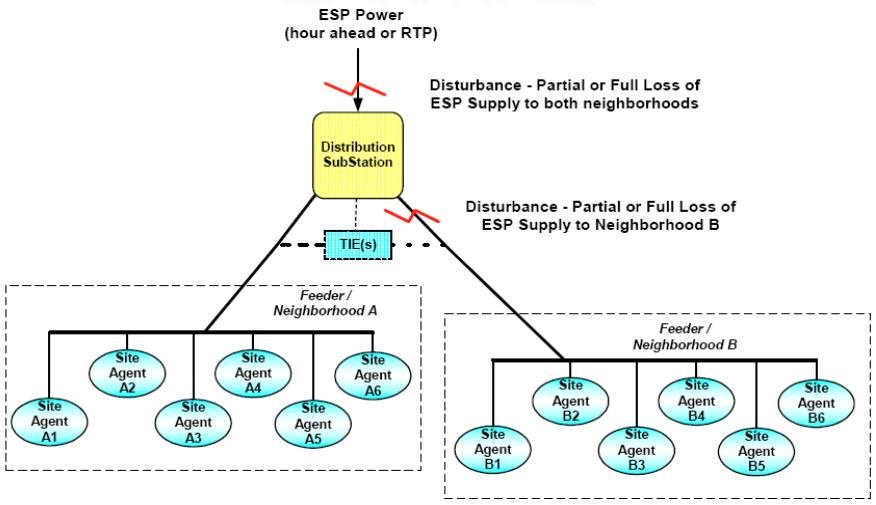
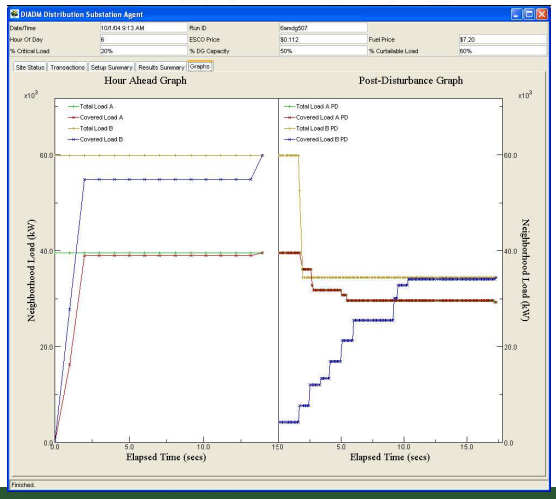
Distributed Power Neighborhood Project



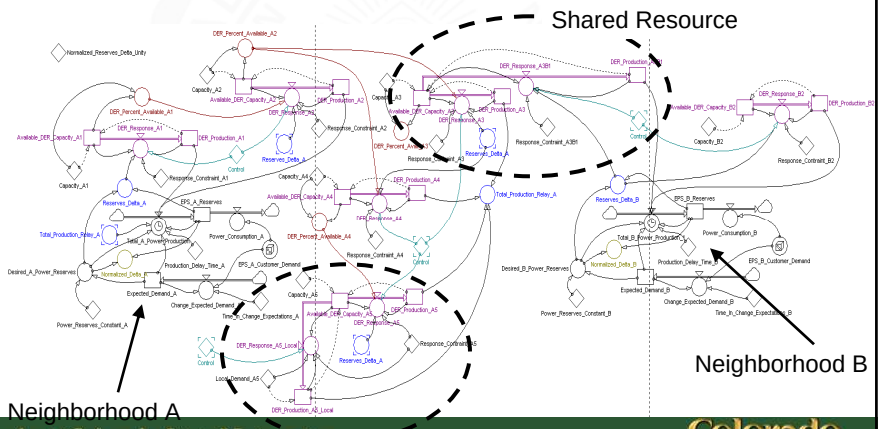
Response to System Failure



Neighborhood Response to System Failure

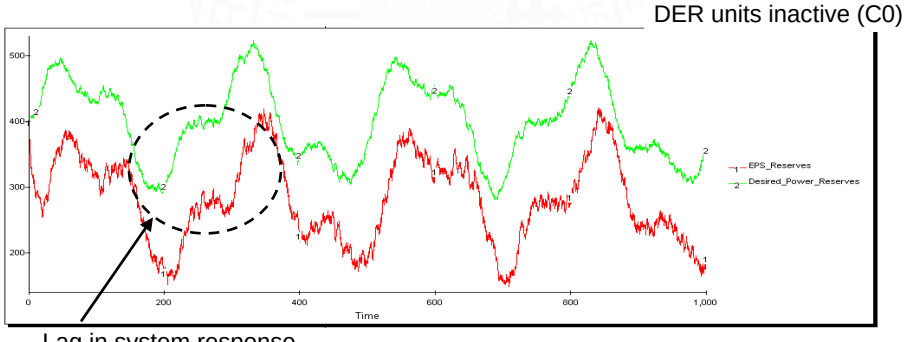
Two Power Neighborhoods

- A two-neighborhood SD model



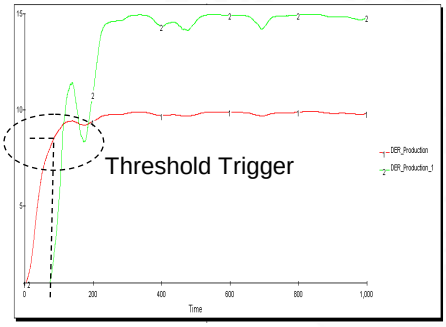
Qualitative results

- Actual power reserves vs. desired power reserves

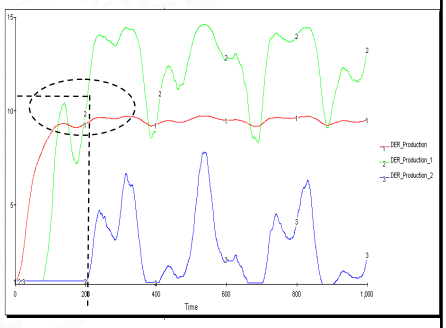


Qualitative results

- Description of DER Behavior



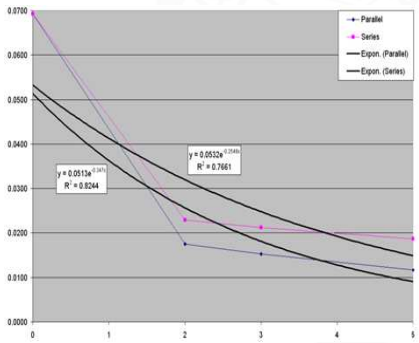
Two DER units connected in series
n=2

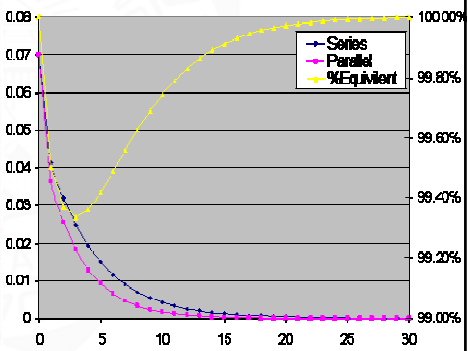


Three DER units connected in series
n=3

Quantitative Results

- Positive Effect of DER Connectivity Structure





Variance reduction is faster in parallel-connected systems, but this difference is transient

Information and DER

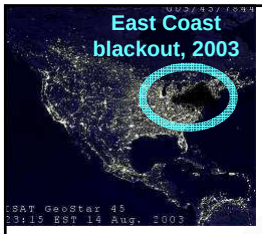
- Firming renewable DG sources with information (and w/o storage)
- Real time emissions monitoring in load centers.
- Grid stability by aggregating large numbers of heterogeneous DER sources.
- Power grid security for critical power applications.
- Market based models using real time pricing, demand response and other information dependent rate structures enabled by DER.
- Power quality and performance contracting including improvement verification.
- Power grid constraint relief using DER.

Basic Smart Grid Tenets

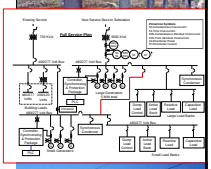
- Information technology is an enabler to unlock the value of distributed energy devices
- Better information leads to better decision making at all levels of the electrical system
- Transparency of value allows market participants to develop and deploy economical solutions that cross enterprise and regulatory boundaries
- Distributed decision making provides resilience of complex systems to avoid system-wide failures
- Timely information and decisions enhances the security and reliability of the system

Why Smart Grid Matters…

- Smart Grid provides for
  - less reliance on vulnerable centralized power generation, transmission and distribution systems,
  - Integration of renewable generation,
  - an increase in the overall system efficiency,
  - the ability to match power quality to end user needs,
  - a more robust electrical system, and
  - ability to recover under utilized and wasted energy.



Working Towards a Robust and Reliable Electric Grid



- **InteGrid** – Grid Simulation Laboratory
  - Megawatt-scale *in situ* physical grid simulation capability.
  - Tests and validates computer simulations with actual physical system dynamics when renewable generation sources (e.g., wind and solar) and other forms of distributed generation and loads are integrated into the electric power grid.
  - Partnership with Spirae - a Colorado business, CSU's Engines & Energy Conversion Laboratory, and the Northern Colorado Clean Energy Cluster.
- **FortZED**
  - Zero energy demonstration of DER for demand management from two substation feeders located in Fort Collins Old District that feeds a variety of users including commercial, CSU facilities, and city and county government offices.
  - FortZED system will demonstrate the ability to reduce peak demand by engaging a variety of distributed generation and load shedding practices through comprehensive dispatch and control.

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CSU Green Power Project

- Research test bed integral to production wind plant
- Power Plant
  - 100MW + capacity with proximity to energetic resource and transmission
- 11,000 acre Maxwell Ranch NW of Fort Collins and Windsor
- May provide renewable power supply to CSU and other higher education institutions in Colorado.

Smart Grid Colorado

- FortZED – PRPA and FCU
- Smart Grid Boulder – Xcel
- Solar City Denver – Xcel
- Renewable Energy Communities - NREL