Advanced Scientific Computing The Electric System

March 4 , 2009

Patricia Hoffman
Principal Deputy Assistant Secretary
Office of Electricity Delivery and Energy Reliability
US Department of Energy

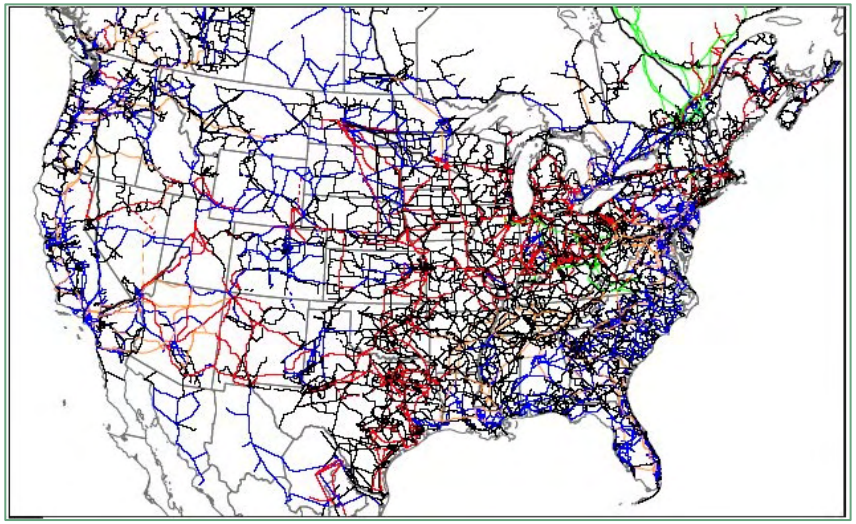
The Electric Grid is a Complex System with Unique Characteristics

Physically

- Never holistically designed, grid developed incrementally in response to local load growth Today, there are:
  - 30,000 Transmission paths; over 180,000 miles of transmission line
  - 14,000 Transmission substations
  - Distribution grid connects these substations with over 100 million loads, i.e. residential, industrial, and commercial customers
- Diverse industry w/o a common voice
  - 3,170 traditional electric utilities
  - 239 investor-owned, 2,009 publicly owned, 912 consumer-owned rural cooperatives, and 10 Federal electric utilities

Technically

- Electricity flows within three major interconnections along paths of lowest impedance (at the speed of light); yet the grid is operated in a decentralized manner by over 140 control areas
- Demand is uncontrolled; electricity is the ultimate “just-in-time” production process



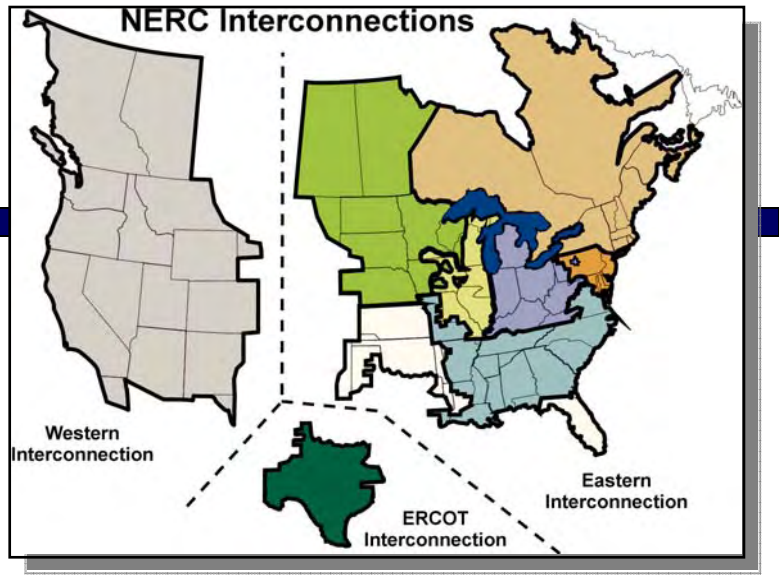
Uniqueness

- Two things make electricity unique:
  1. Lack of flow control
  2. Lack of large-scale energy storage

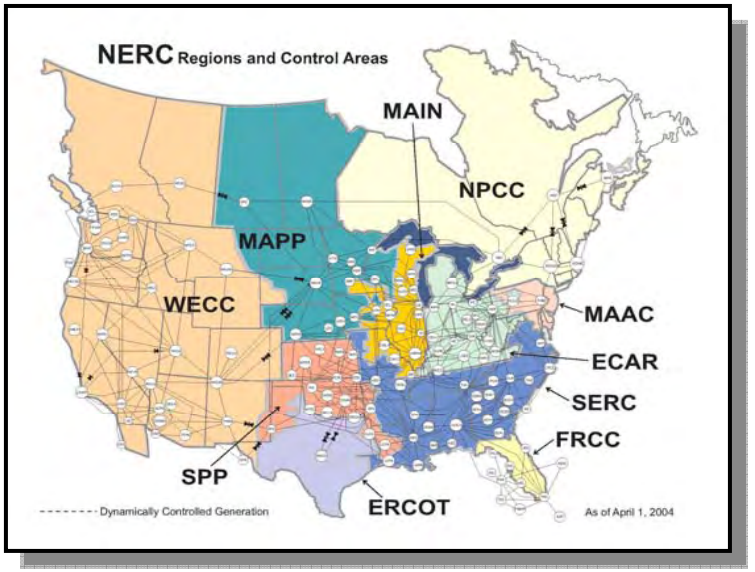
The Electric Grid is Well Developed but very complex

- Real-time power system analysis is a well developed field
  - Much works well
  - Significant data collection infrastructure exists
  - We must fully understand the existing systems before we can improve them

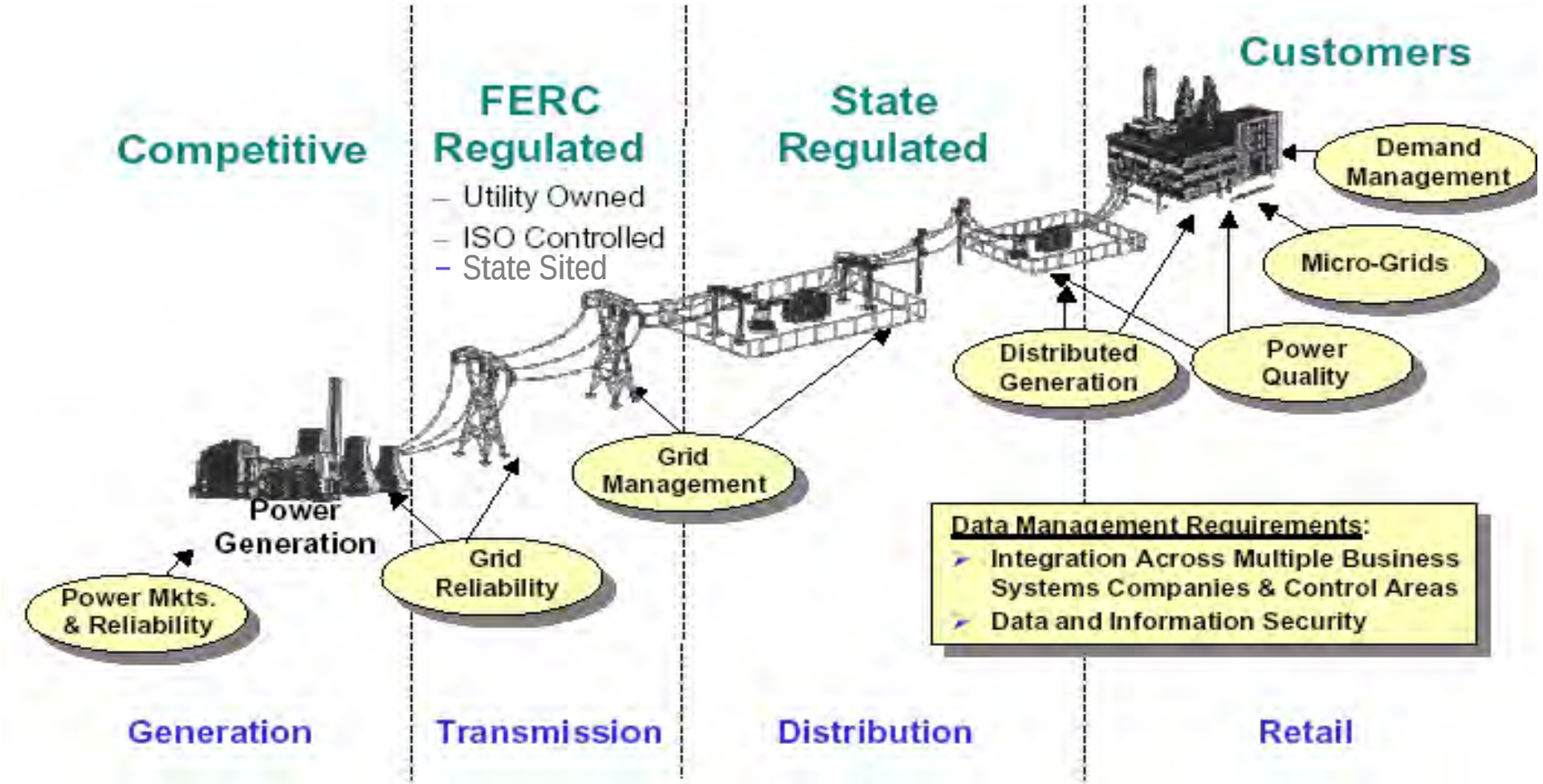
3 Interconnections, 139 Control Areas (105 in the East), 18 Reliability Coordinators, & 10 Regions



We are moving to a scale that is well beyond anything currently being done

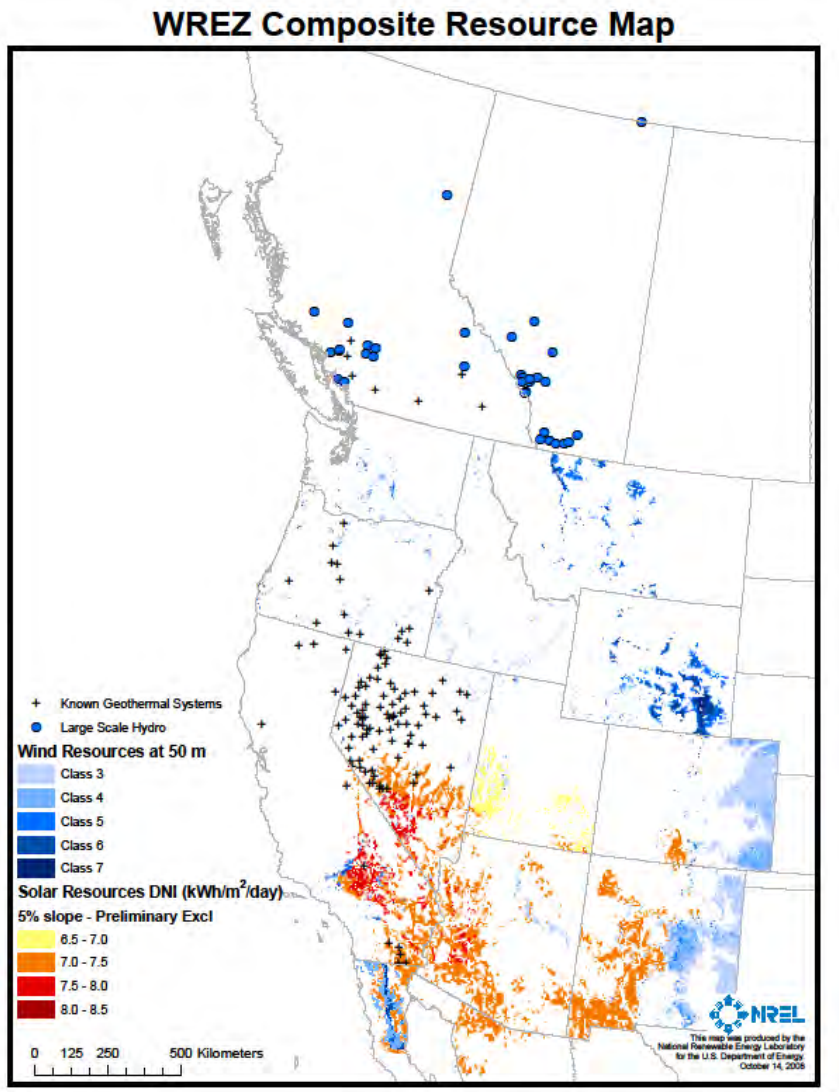


Electric Power Infrastructure



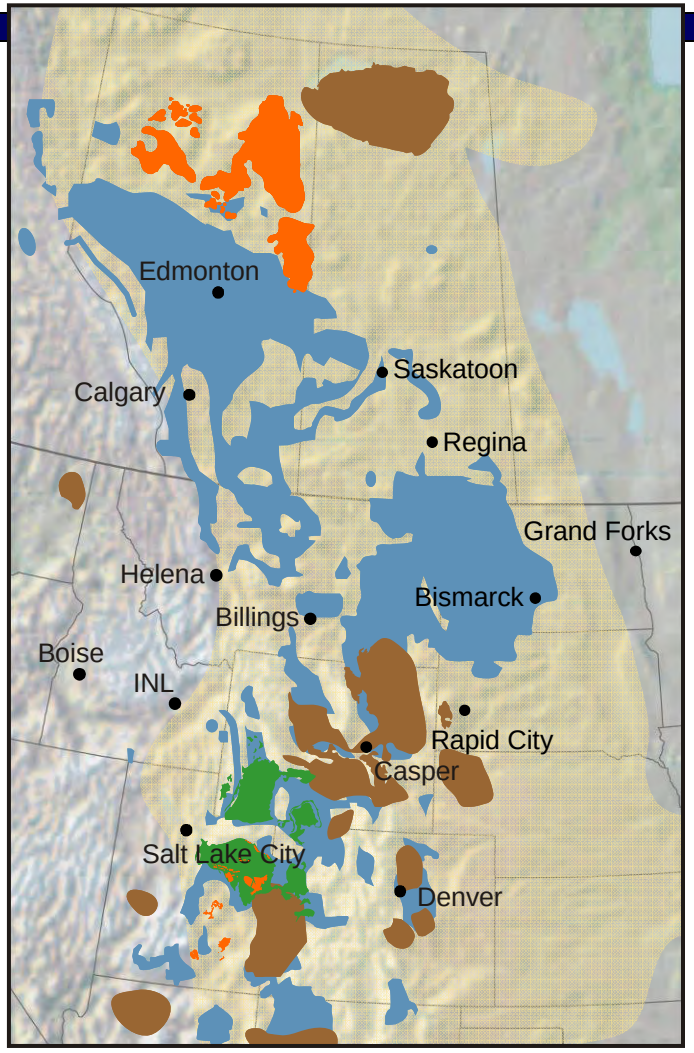
Opportunity and Challenge: Accessing Renewables

Western Gov Assn Western Renewable Energy Zones Project



Opportunity and Challenge: Remote Resources

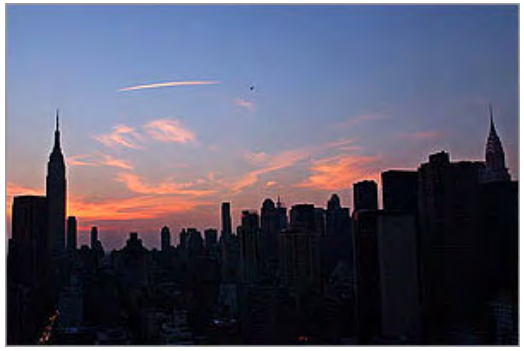
Source: Idaho National Lab



Investment Priorities: Long-term

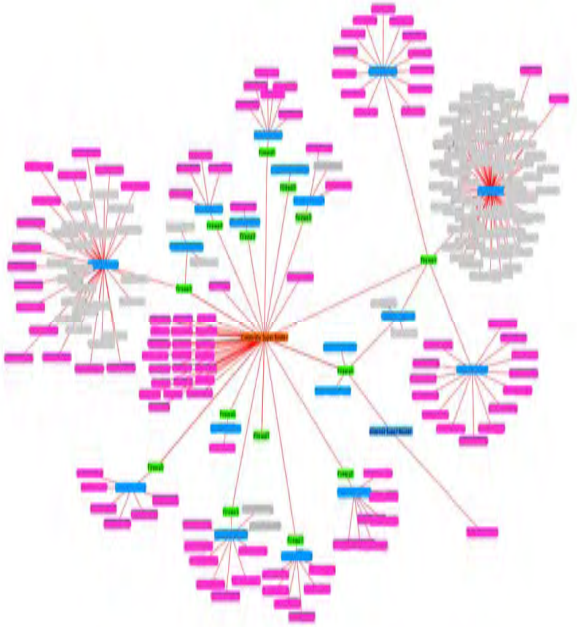
- Adapting the electric grid to a low carbon future
  - Generation Diversity (size and make-up): developing & deploying abundant affordable zero/low carbon *domestic* resources
  - System Efficiency: catching up to today's grid needs *and* enabling a low-carbon future
- Consumer Energy Management
  - Demand-side: *enabling the customer* to participate (energy efficiency, demand response, energy storage, distributed energy -CHP, plug-in hybrids)
- Smart Grid (sensing-data collection- monitoring- automation)
  - Advanced monitoring and analysis (phase measurement units, real-time data simulators- operational modeling, advanced metering)
- Transportation – hybrids to plug in hybrids
- Security (availability and integrity)
  - Control System Security (vulnerabilities)
  - Diagnostics (intrusion detection, anomalies)
  - Recovery (resiliency)

Driving Forces Grid Advancement



Blackout 2003

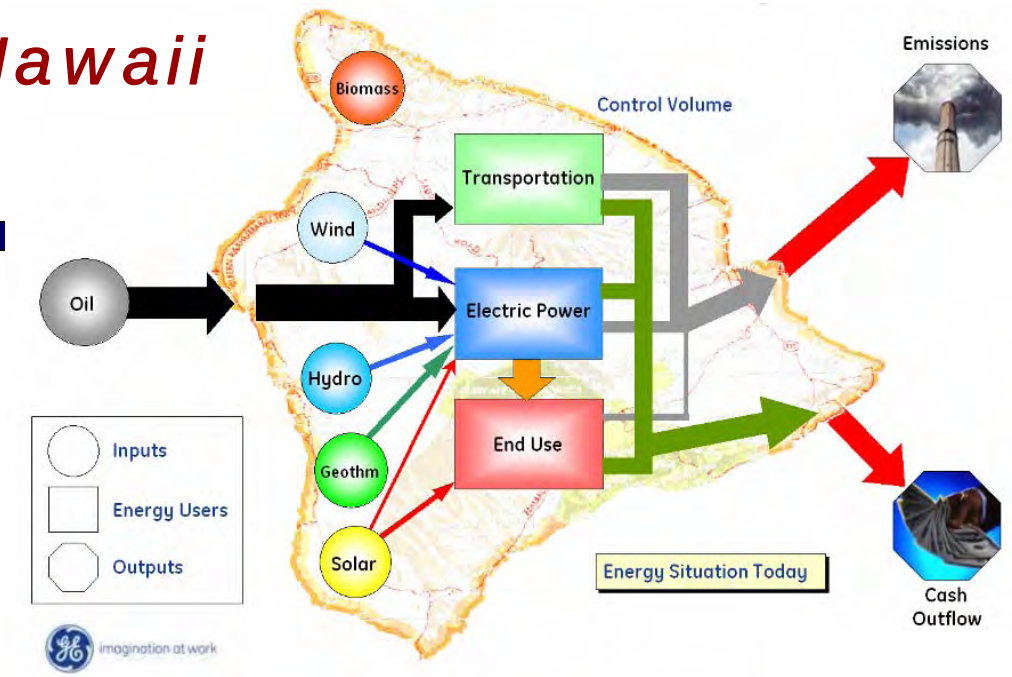
Hurricanes 2005

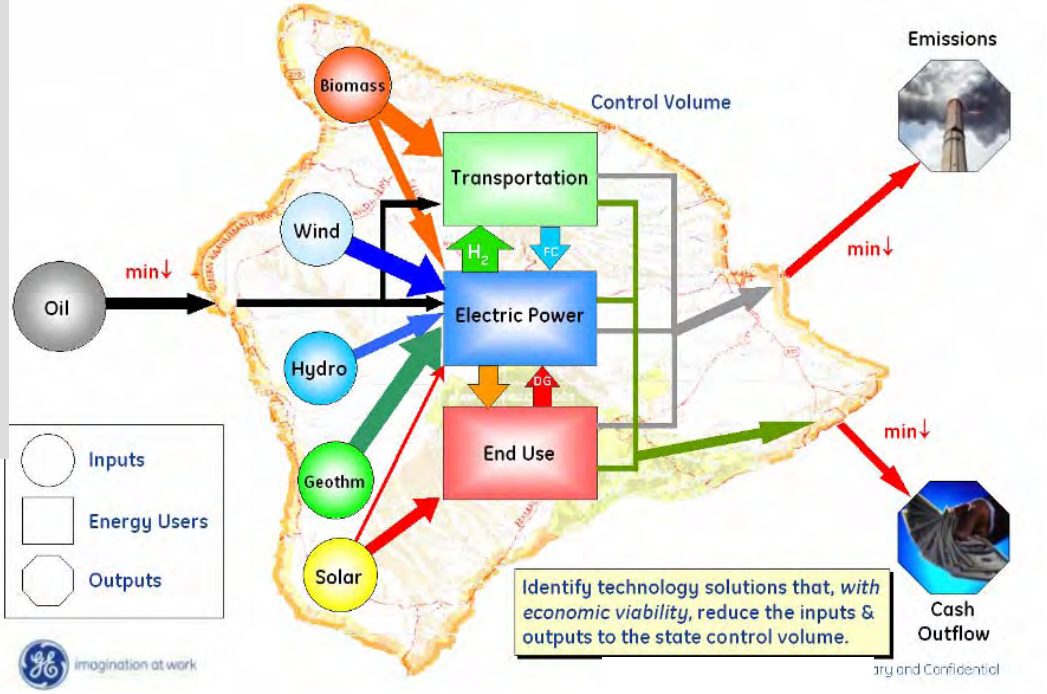


Cyber Vulnerabilities

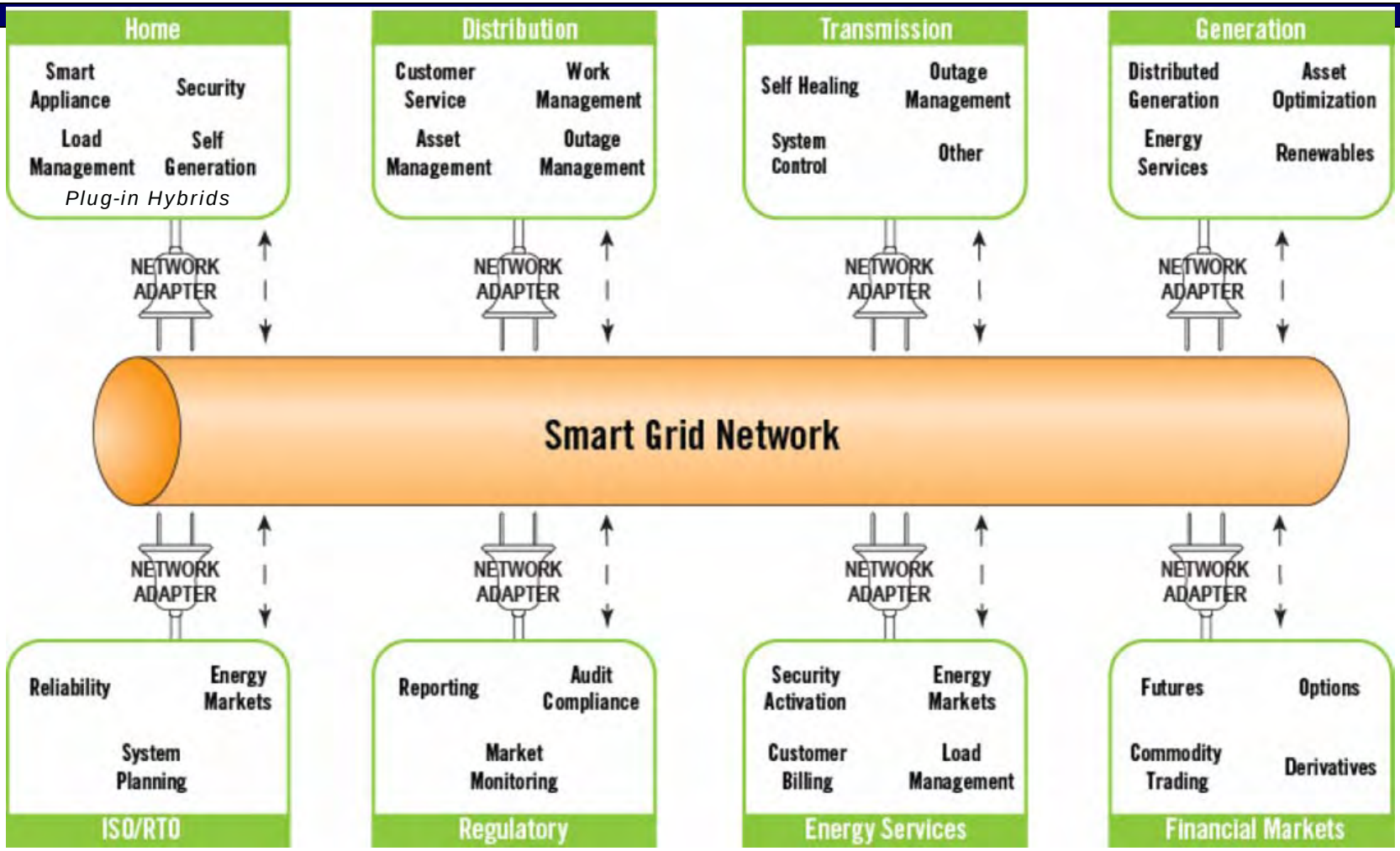
Getting it Right - Hawaii

- *70% Renewables*
- *Use of distributed resources to reduce peak power (minimum of 15% reduction) on distribution feeder or substation) - Distribution Management System for peak load reduction*



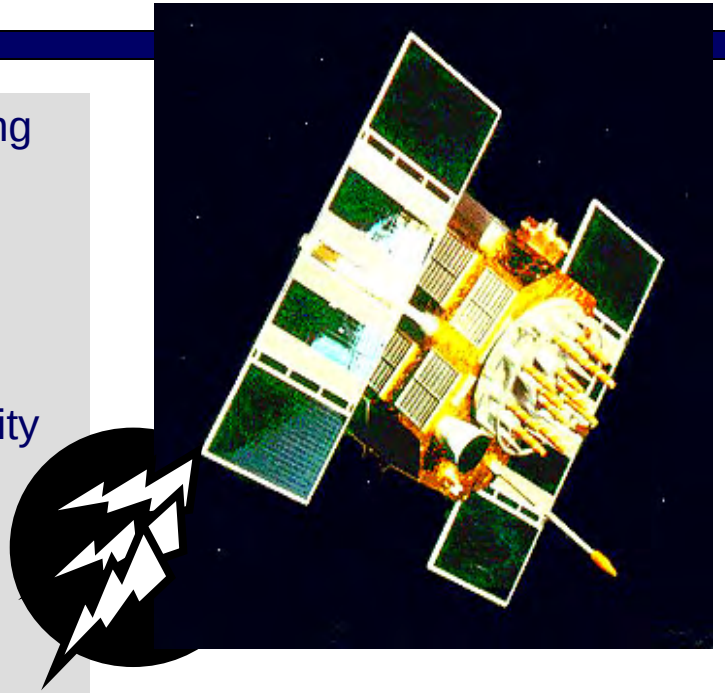


Communications Integration

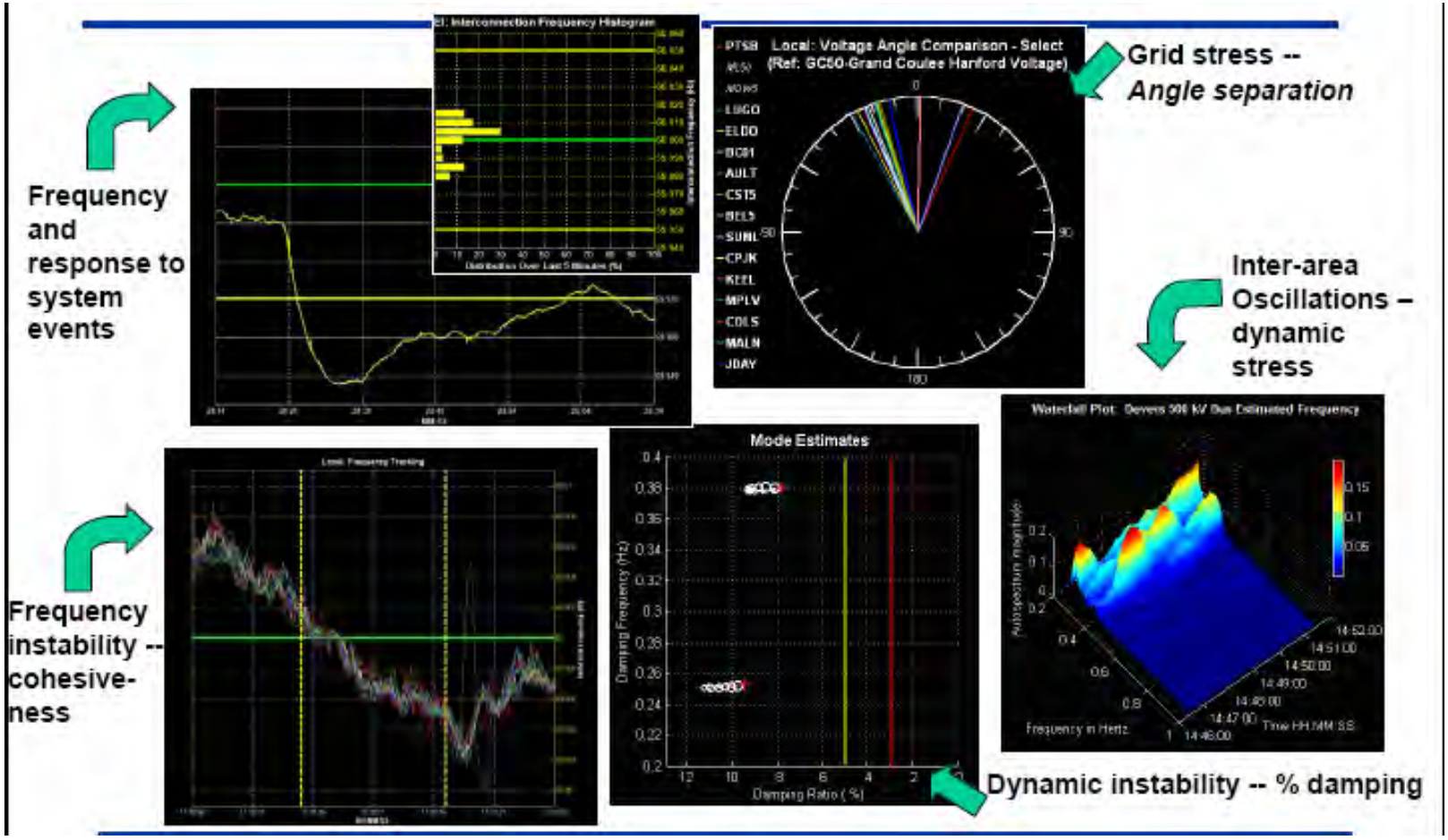


Phasor Technology – Key for the Future

- Phasor Measurement Units – Mature Hardware, Emerging Networks and Applications
  - Supplements 50-year old SCADA technology
  - GPS time synchronized high resolution data
  - Wide coverage
- Provides MRI of Power System Compared to X-ray Quality Visibility From Traditional SCADA
  - Wide-area situational awareness
  - System dynamics monitoring
  - Improved modeling
- Addresses Current Industry Problems
  - Blackout prevention – early warning - and restoration
  - Visualization – wide area, common data, common displays
  - Reliability standards monitoring
  - Security Assessment – safe operating zones
  - Renewables integration



Information



Visualization and Controls Transmission Reliability

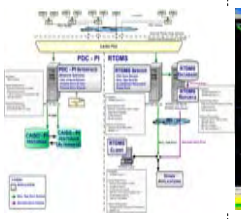
Phasor Measurements, Real Time Wide-Area Situational Awareness, Visualization, Infrastructure Monitoring, Alarming, and Control

PROBLEM IDENTIFICATION

- 1996 Western Interconnection Blackouts
- 2003 Northeast Blackout

INFRASTRUCTURE DEVELOPMENT

- TVA Super PDC
- IEEE 37.118
- NIST SynchroLab

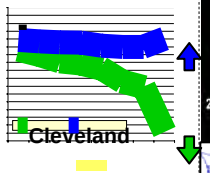


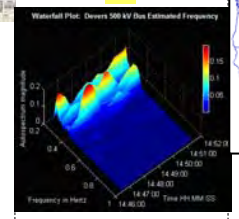
VISUALIZATION FOR WIDE-AREA SITUATIONAL AWARENESS

- Real Time Dynamics Monitoring System

FORENSIC ANALYSIS/ BASELINING

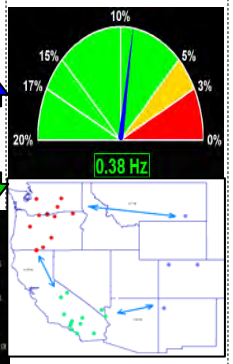
- CAISO Operating Engineers Workstation
- Baselining Static Angles in East





APPLICATIONS

- Small Signal Stability Monitoring
- Intelligent Alarming
- State Estimation
- Adaptive Islanding



INDUSTRY ADOPTION

- EIPP -> NASPI
- WECC WAMTF
- Research Roadmap

GOAL

Industry Approach to Phasor Technology Research and Applications:

- Visualization
- State Estimation
- Mode Monitoring
- Alarming
- Real Time Controls

Science Based Collaborations

- 1. New algorithms that are scalable and robust for solving large nonlinear mixed-integer optimization problems and methods for efficiently (real-time) solving large sets of ordinary differential equations with algebraic constraints, that include delays, parameter uncertainties, and data as input.
- 2. A new mathematics for characterizing uncertainty in information created from large volumes of data and for characterizing the uncertainty in models used for prediction.
- 3. New methods to enable efficient use of high bandwidth networks by dynamically identifying only the data relevant to the current information need and discarding the rest. This would be especially useful for wide area dynamic control where data volume and latency are barriers.
- 4. New software architectures and new rapid development tools for merging legacy and new code without disrupting operation. Software should be open source, modular, and transparent. Security is a high priority.

Computational Techniques for Electric Systems

- **Wide-area visualization**
- **Spatio-temporal representation**

Decision Support

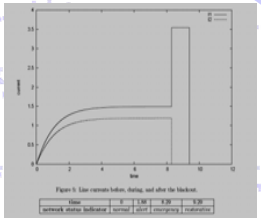
Simulation-based discovery

Scenario-steering

User-discovery

Application scenarios: grid-state, outages

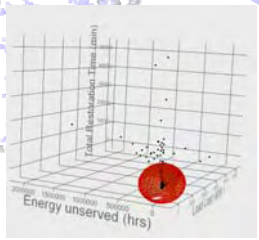
Modeling and Simulation



Algorithm parameters

Specifications

Data-analysis



- **Hybrid simulation**
- **Parallel contingency evaluation**

- **Distributed control and communication**
- **Data-directed discovery**