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Energy Storage, Transmission, and Policy

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Sandia National Laboratories

Exceptional service in the national interest

U.S. DEPARTMENT OF ENERGY

NNSA

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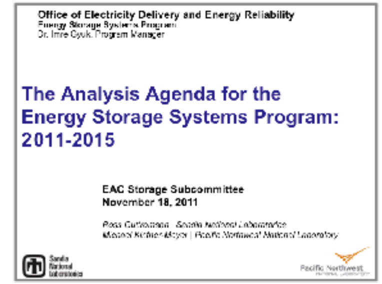
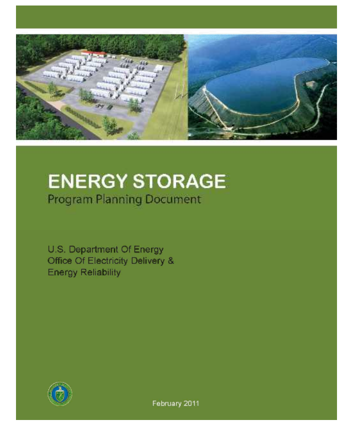
Sandia Strategy for DOE/ESS Program

DOE/OE

- Determine where to put energy storage for the best value
- Develop and drive performance targets
- Use RD&D to understand the value chain… use feedback to guide the science
- Use RD&D to lower the cost
- Include engineering that is necessary for manufacturing





SNL's Program Mission: <u>Lower the cost of reliably delivered electricity through applied RD&D of stationary energy storage system technologies</u>

SNL's Adds a Few Principles to the Joint SNL/PNNL Strategy, Including:

- Prepare for Imre's inevitable departure (currently relationship based)
- Ensure feedback between analytics component and S&T design component

Major Drivers of Energy Policy

- Independence from Foreign Oil
- Environmental Concerns (CO_2, water use, SO_x, NO_x, and others)
- Other National and State Policies
  - Renewable Portfolio Standards
  - CO_2 Tax or Cap and Trade
- Ancillary Markets such as Renewable Energy Credits (RECs)
  - FERC Order 755 (Pay for Performance)
  - FERC Order 1000 (Must consider non-wires solutions to transmission)

Legislative/Policy/Market Needs

- Financial Incentives are needed (e.g. tax credits, load guarantees, etc)
- Transparency of costs – proper allocation of costs (e.g. balancing costs due to wind attributed to wind energy cost)
- Help state PUCs understand the technical and policy implications of new technology solutions (smart grid, demand response, energy storage, etc)
- FERC policy changes to allow assets to recover their full value for service provided (e.g. binning new resources into Transmission or Generation assets)
- Development of new energy market structures that are unbiased against any participating resource
- Introduction of Futures Markets for Energy and AS to spur investment.

Legislative/Policy/Market Needs (continued)

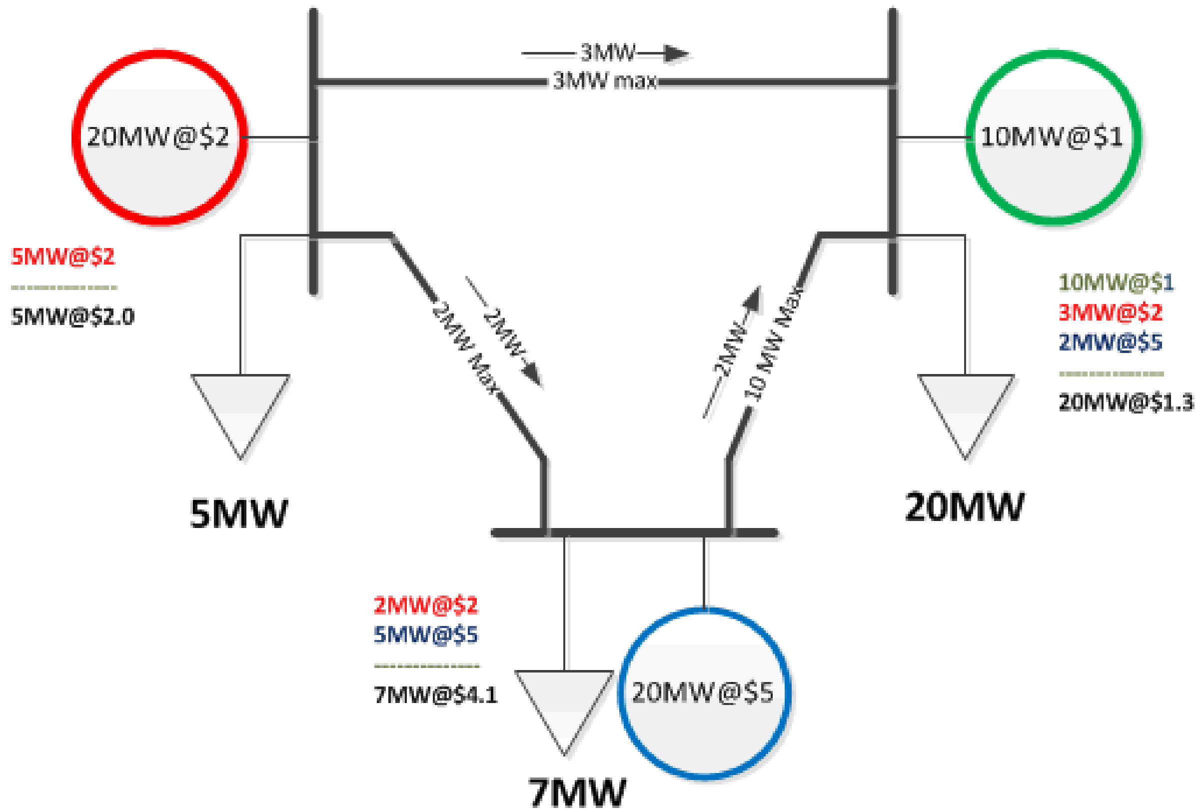
- Sustained Federal investment is needed in R&D and Demonstrations
- Introduction of new markets for services that are emerging due to the integration of variable generation (primary frequency response, reactive support, RAS, etc)
- Unbundling of reliability services into structured markets

Current Storage Legislation

- S 1845, Sent to Committee Nov, 2011: **Senators Wyden (D-OR), Bingaman (D-NM) and Collins (R-ME) have introduced bi-partisan legislation that would create an ITC for energy storage.**
- S 1520, Sent to Committee Aug, 2011: **The Senate Energy and Natural Resources Committee approved S. 1510, co-sponsored by Chairman Bingaman (D-NM) and Murkowski (R-AK), a bill that creates a Clean Energy Deployment Administration (CEDA) to finance the development and deployment of innovative breakthrough clean energy technologies.**
- S 1351 (Stabenow): **A bill to promote the development, manufacturing, and use of advanced batteries**

Basics of Locational Marginal Pricing

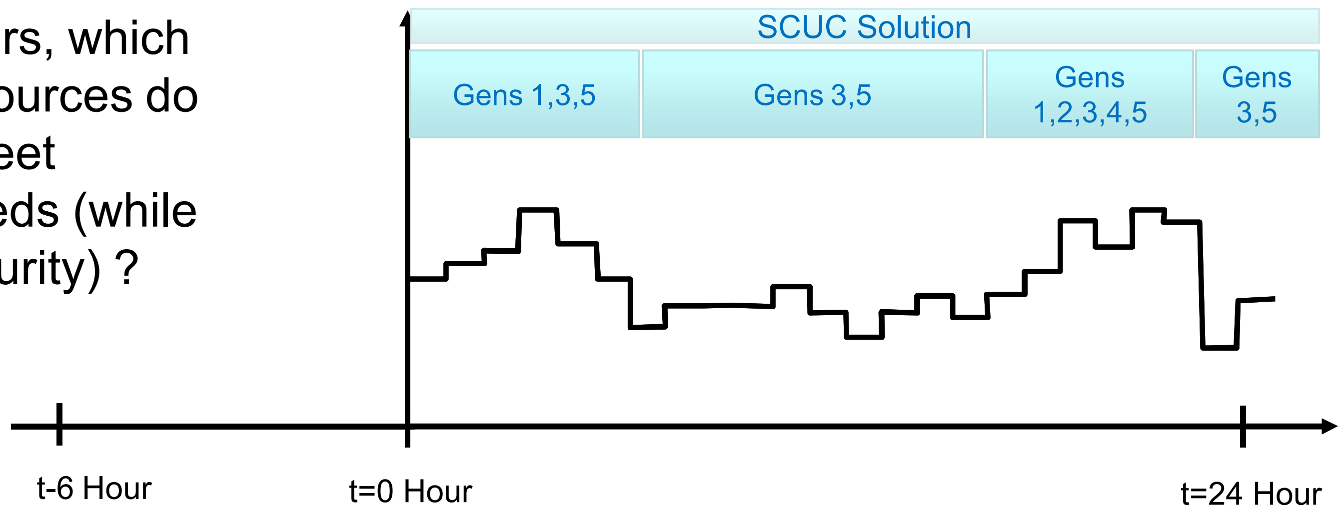
LMP come from a Security Constrained Unit Commitment (SCUC) optimization



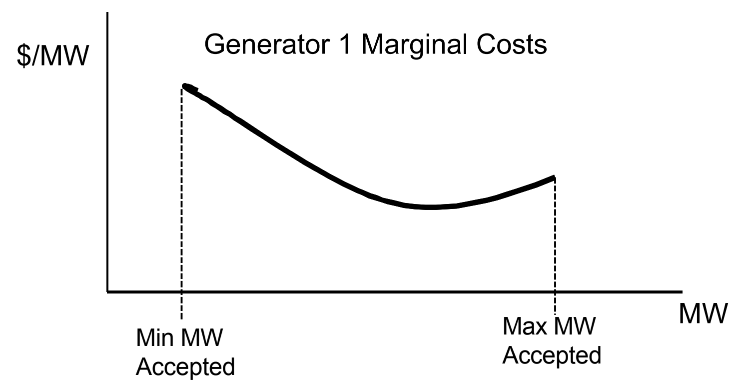
Graphical View of a Traditional SCUC

- Forecasted Power Needs for time t (Bids). Forecasts made at time t-6 Hours

At time t-6 Hours, which generating resources do we select to meet tomorrow's needs (while preserving security) ?



Generating Resources 1-5 Available (Offers)

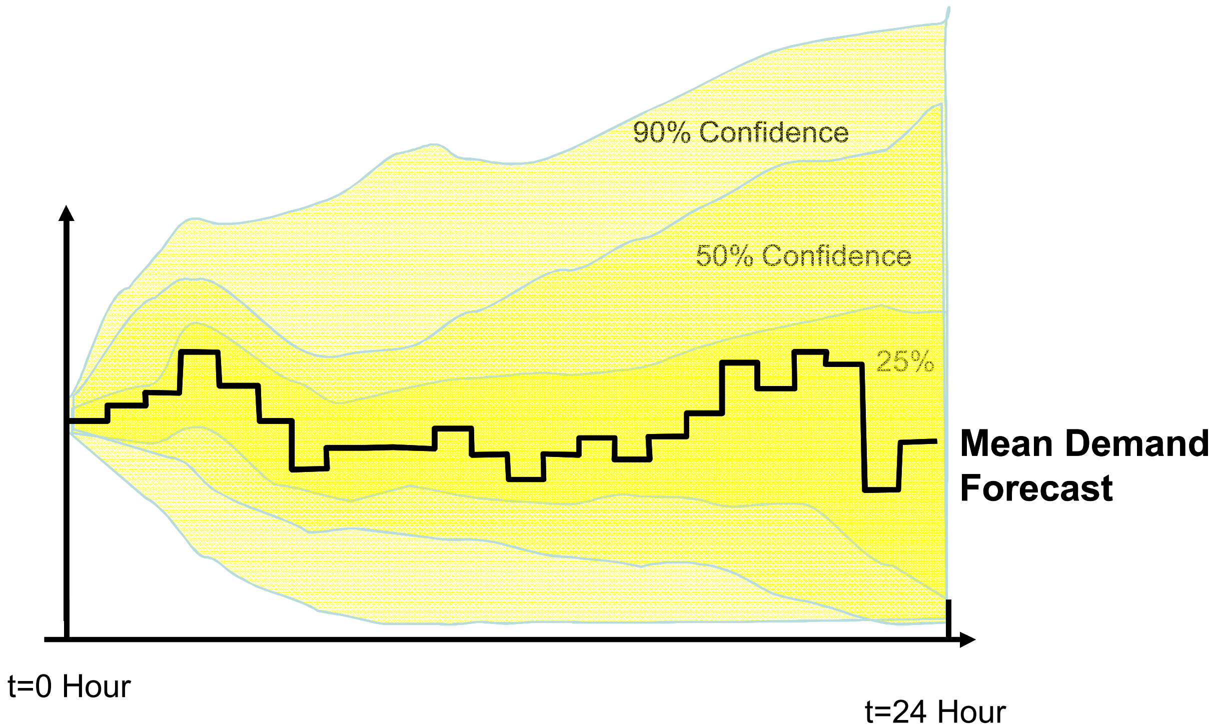


What is Imbalance and Where Does it Come From?

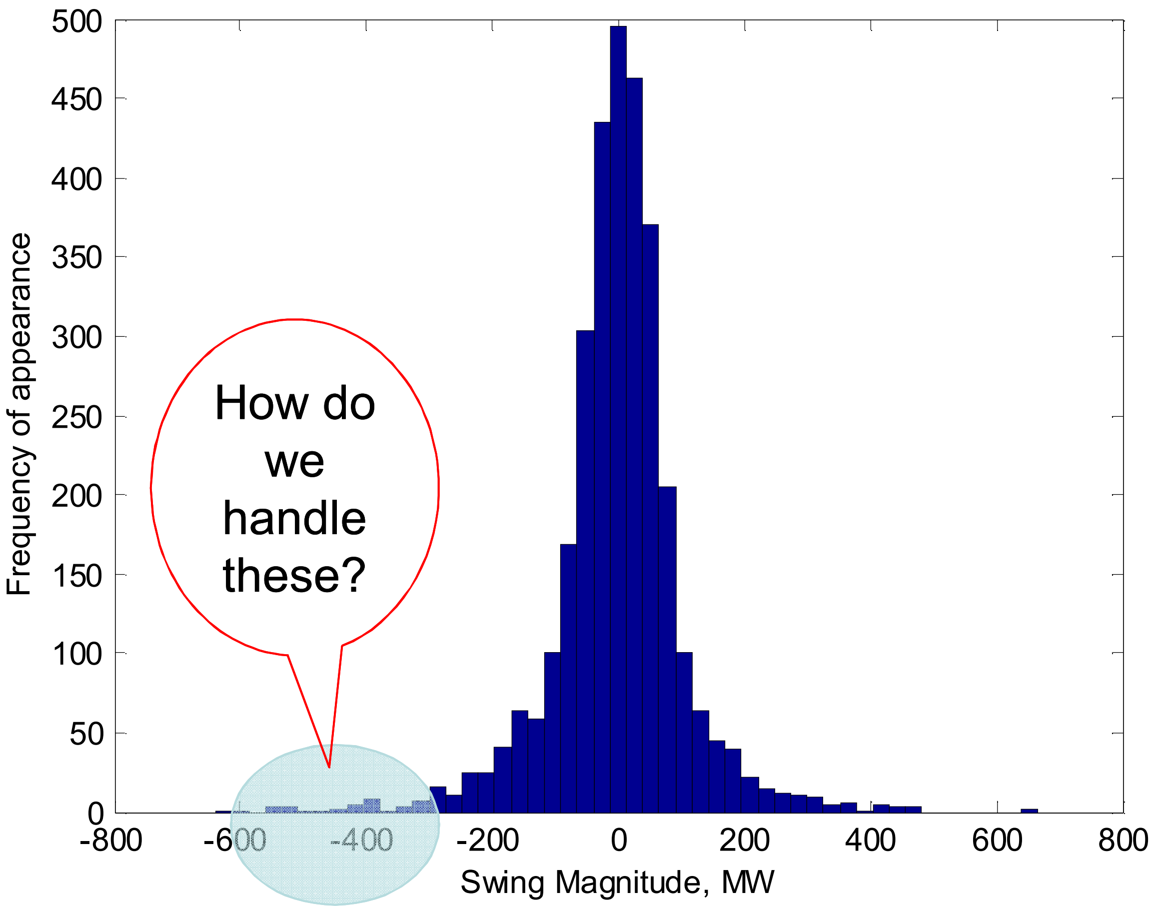
Imbalance is a difference between scheduled generation and actual demand

It comes from:

1. Inability to perfectly forecast load and generation
2. Finite Markets: Day Ahead, Hour Ahead, 5 Min Ahead
   -There would still be variability with perfect forecasts

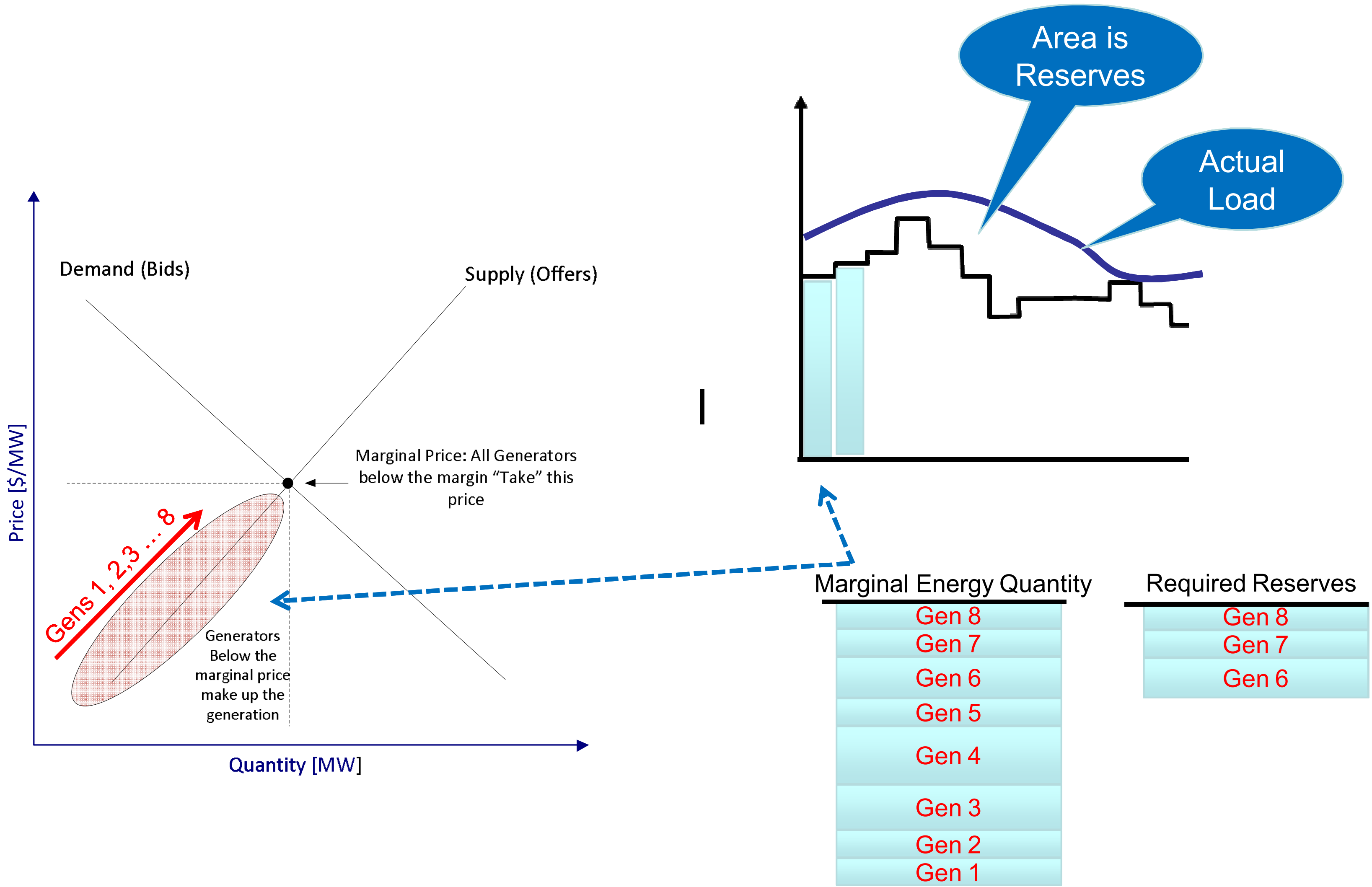


Tail Events from BPA System Wind in 2010



On Feb 26, 2008, Industrial load tripping in Texas worked well to manage a 1400 MW wind power loss in a 5 minute time frame.

Energy and Reserves Co-optimization



Common Means of Managing System Imbalance

Resources	Operations	Flexibility

• Storage
• Demand response
  • Smart Charging EVs
  • Residential
  • Industrial
  • Commercial
• Traditional generation
• Additional transmission
	• Balancing Area Consolidation (ISO formation)
	• Generator Schedule Compression
	• Dynamic scheduling of loads and resources
	• Improved forecasts for wind, solar, and load
	• Improved (stochastic) commitment process
		• The variable resource itself (regulation down and up if spilling)
		• Expansion of system flexibility (expanded ramp rates, start up times, etc)
		• Optimization of hydro resources (in coordination with environmental constraints)

How Should We Value Storage:

Compare Resources or Compare Services?

Example: Transmission… what services does it provide?

- Delivers power to the loads
- Sufficient transmission keeps nodal price spreads low
- Maintains reliability

Q. What's more important; transmission, or the services it provides?

A: Obviously, the services it provides are more important

The Point: A cost comparison of resource types is largely irrelevant. A more relevant question is how to cost compare methods which reliably meet the needs of the grid.

Challenge: Select the Least Cost Resource Portfolio which Results in Each Grid Need Being Fulfilled

Grid Services (that need to be fulfilled)

Resources that can be used to provide services

	Within hour balancing	Frequency Regulation and Inertia	Voltage Support	Stability Support	Scheduled short-term Capacity	Scheduled long-term capacity	Lowering nodal prices
Combustion Turbine	■	■	■	■	■	■	■
Flywheel Storage	■	■	■	■			■
Flow Battery	■		■		■		■
FACTS Power Electronics			■				
Transmission Lines			■				■
Demand Response	■		■	■	■		■

Orange cells indicate that the resource can meet the need. Cost information is absent

This table is not complete, and intended only to demonstrate the principle stated in the title

Project: Hawaii Regulatory Analysis

Goals

- How do we define a Gold, Silver, and Bronze plated system? And How do we choose which is in the best interest of the public?
- Identify reliability metrics pertinent to the conditions of the Hawaii system.
- Make recommendations on reliability standards for electrical systems located and operating in Hawaii.
- Seek feedback of metrics by National Regulatory Research Institute or other appropriate regulatory bodies.

Project: PUC Regulatory Analysis

Goals

Produce a guidebook for regulators & utilities:

- Summarize recent energy storage rate recovery cases

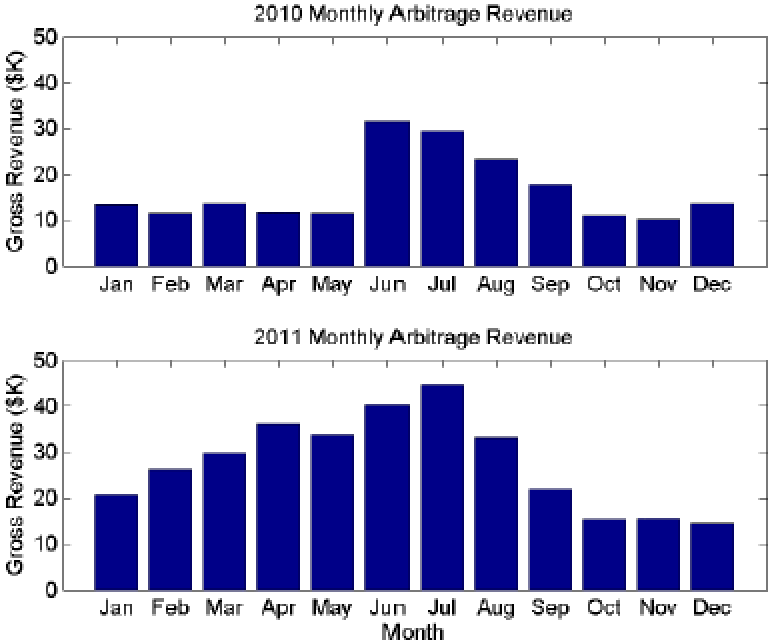
- Develop example ESS rate recovery requests, and provide the PUC with a credible means of evaluating them

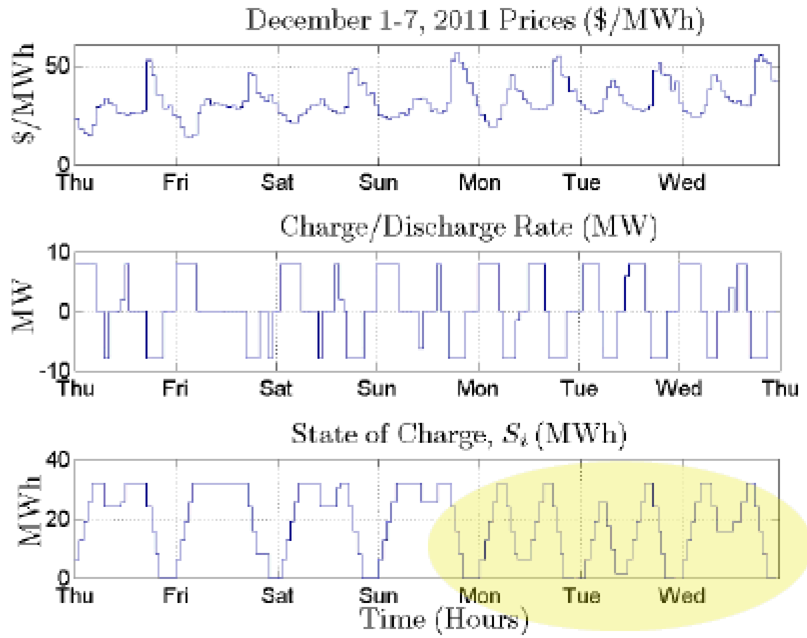
Project: Market Design

Responsive to FERC Order 755

- Project Goals
  - To develop a market structure that would allow:
    - all resources capable of providing a service to the grid to do so, and
    - provide for compensation based on the benefits provided to the grid
  - To base such a structure on the fundamentals of what the grid needs to operate reliably
    - as opposed to making incremental changes as new technologies and challenges arise

How to Optimize Use of Energy Storage (From Arbitrage to A/S)





Year	Charge Time (%)	Discharge Time (%)	Revenue
2010	20.88%	16.70%	$198,330
2011	25.36%	20.29%	$331,992

Transmission Expansion

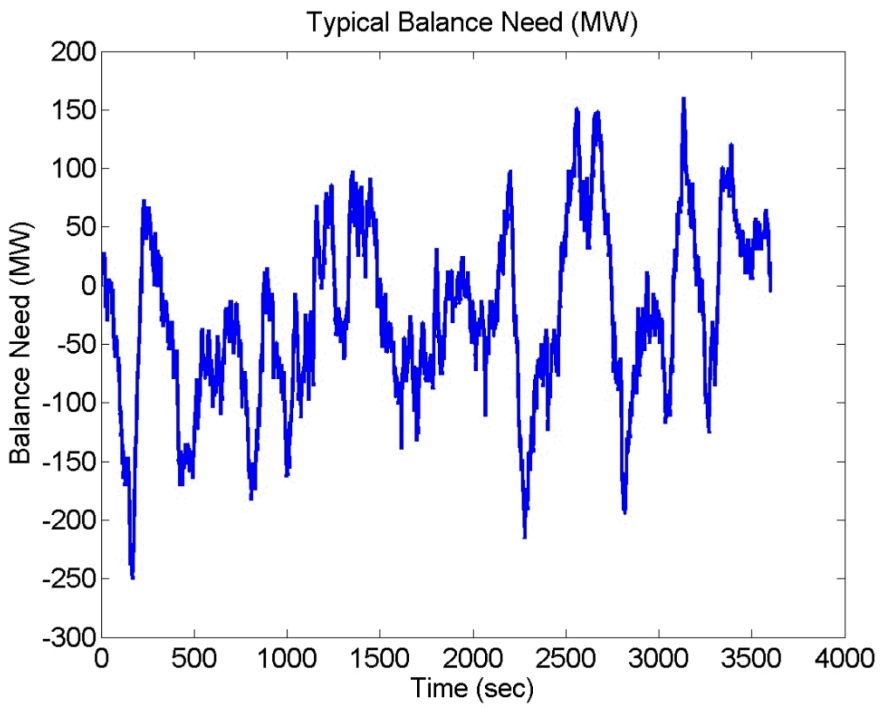
Probabilistic Expansion is Needed

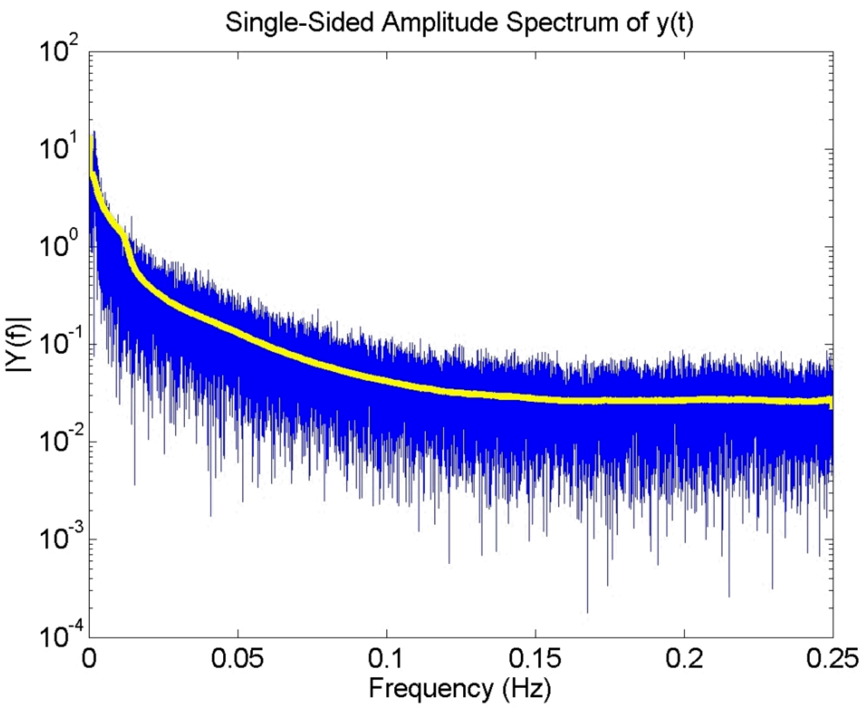
- Historically, transmission expansion has been done using a 10 year planning process.
- Stochastic transmission planning has not occurred
- Until recently, stochastic operation (e.g. conditional firm transmission) has not been utilized, and is still not widely used

How should we optimally expand transmission based on our expectation of future generation build-out and load growth? Should we optimize incrementally? Optimize based on 5, 10, 20 year outlook? What’s the financial risk of making a wrong decision?

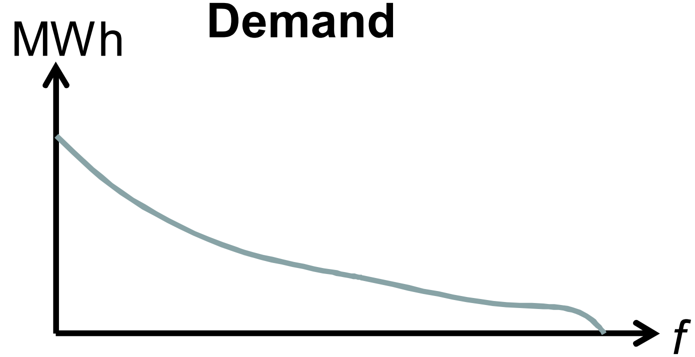
Wholesale Market Design Project

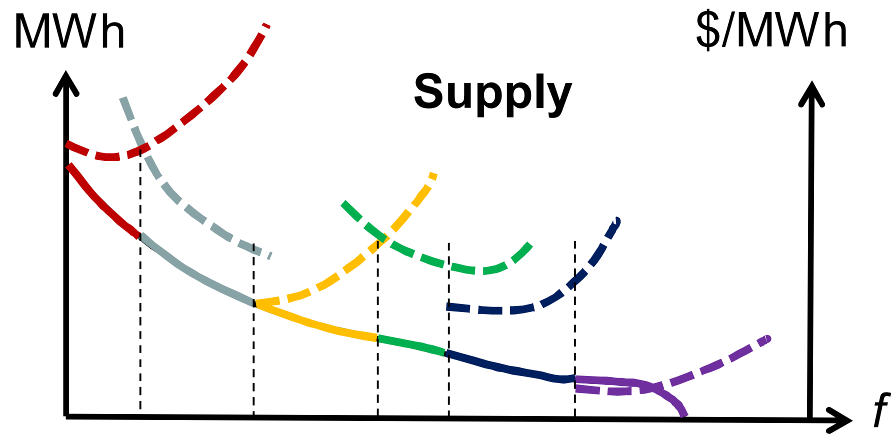
Sample Balance Data - PJM



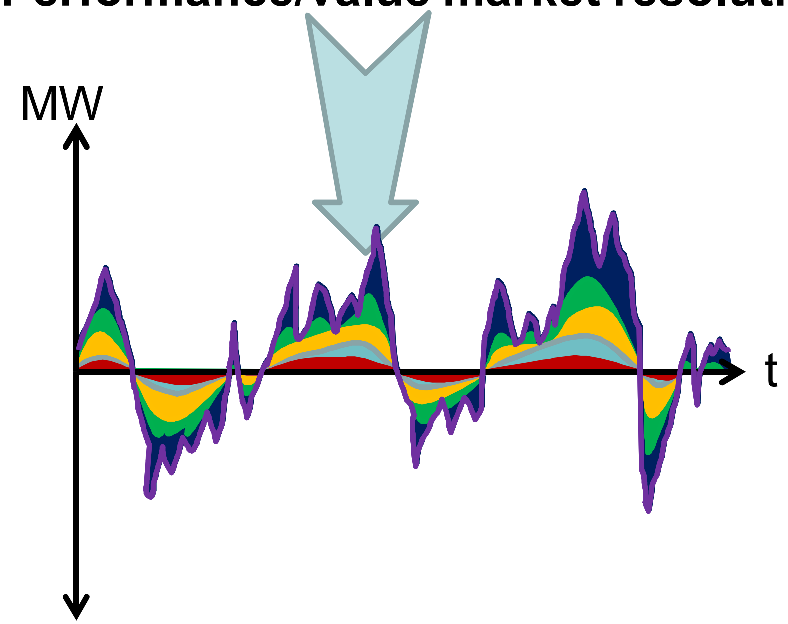


Project: Market Design
(Continued)





Performance/value market resolution



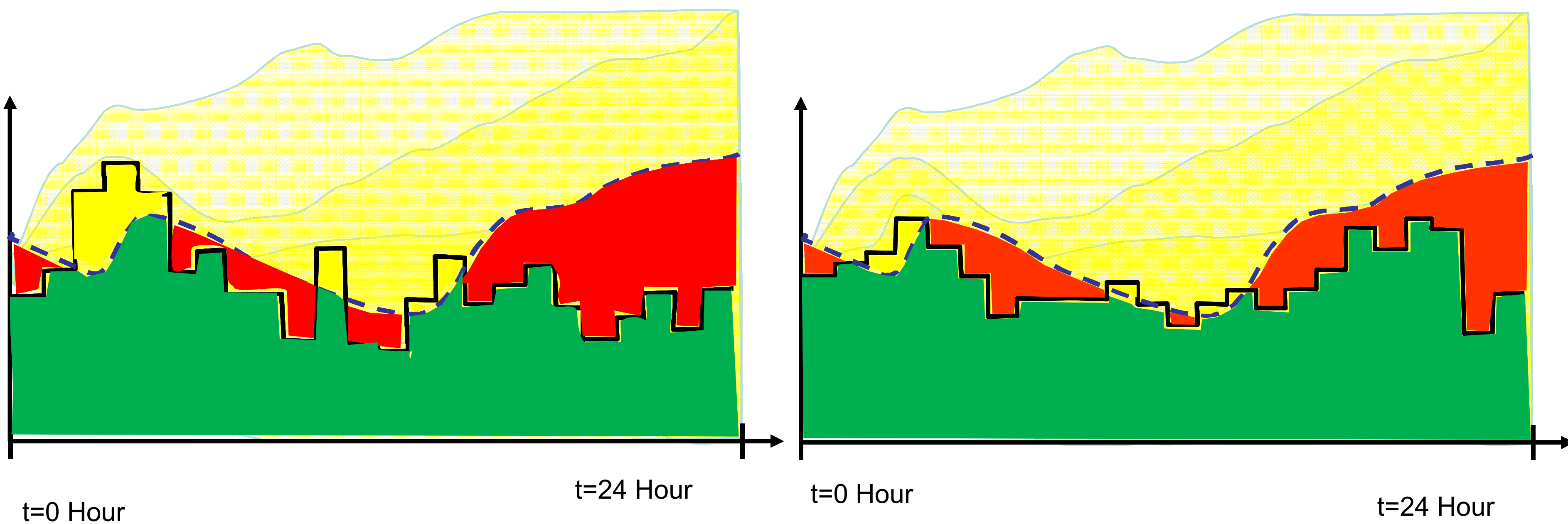
Project: Stochastic SCUC/SCED

- Improved Power System Operation for Using Advanced Stochastic Optimization
  - This award:
    - Enables efficient use of variable generation on the grid by using advanced stochastic optimization
    - Allows the use of new complex energy market structures which can take advantage of large amount of demand response, energy storage, and other variable (or steady) resources
  - Team:
    - Sandia (Lead)
    - Alstom
    - ISO-NE
    - IA State University
    - UC Davis

How Does Stochastic SCUC Save Money?

Two Ways:

1. By moving regulation services into energy markets
2. By making the dispatch stack more efficient



Green= Cheapest DAM Energy

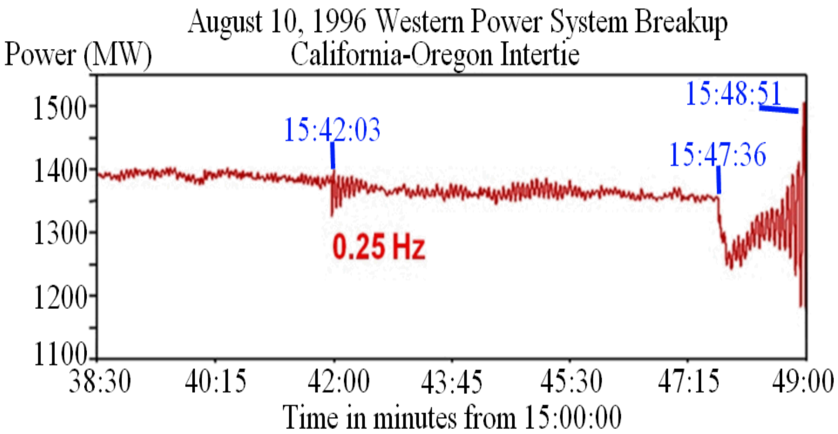
Yellow= Down Regulation

Red= Most Expensive Up Regulation

Project: Controls for Grid Stability

Motivation:

- Studies indicate that approximately 300MW (total) of real power modulation would benefit transient and small signal stability.



Project:

Develop controls for energy storage devices to concurrently provide Ancillary Services, manage transient stability, small signal stability, and primary frequency response.

The following areas will be addressed:

1) Assess storage technologies as to their adequacy to meet the grid requirements developed by previous work by BPA and Montana Tech.
2) Develop "do no harm" safeguards
3) Develop ESS controls that concurrently provide grid stability and AS.
4) Analyze mass deployment using a WECC dynamic model (PSLF).
5) Deploy a pilot project with BPA and others

Energy Storage System Testing and Evaluation

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Motivation:

Provide impartial, third party testing for components and systems from the cell to the MW battery level.

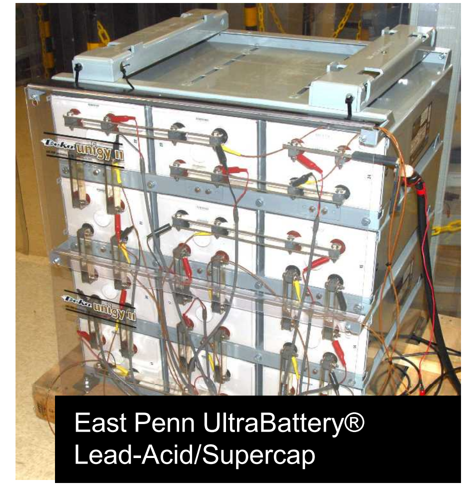
FY11/12 Activities:

- *Cell level testing* of International Batteries, Altairnano Batteries, East Penn Batteries
- *Module level testing* of the East Penn and Furukawa Ultrabatteries
- *System level testing* of the Redflow flow batteries
- *MW battery testing capability* available at the ESTP
- *Battery testing methodologies* to determine if multiple Depth of affect battery life

Cell Testing

14,000+ cycles and counting with only 10% loss in capacity

Module Testing



12,000+ cycles and counting with no loss in capacity

1 MW System Capability

FY12 Plans

- Bring online MW system testing at ESTP
- Implement advanced testing using autoregression modeling and historical utility data in protocols
- Initiate testing of CUNY Zn-Ni flow battery
- Continue ongoing test projects with 10s of thousands of cycles

Defining Battery Testing For Specific Applications

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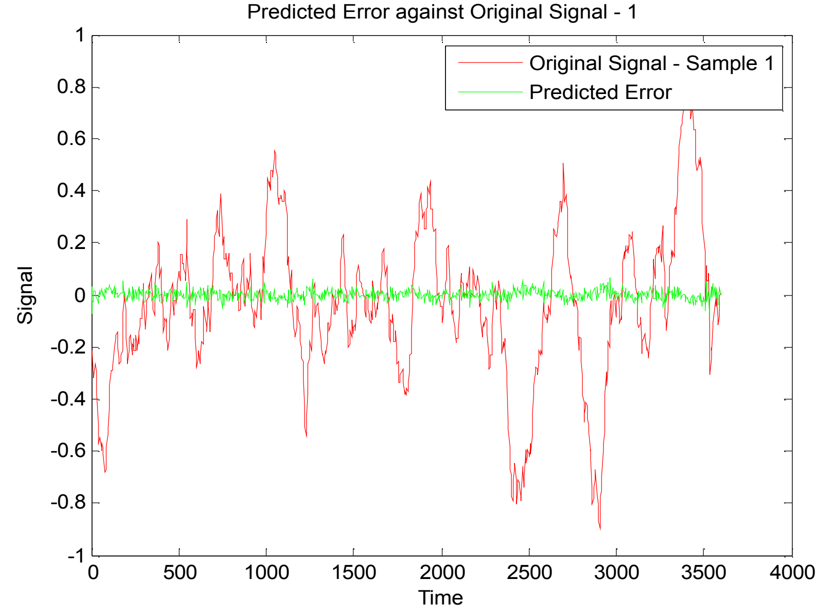
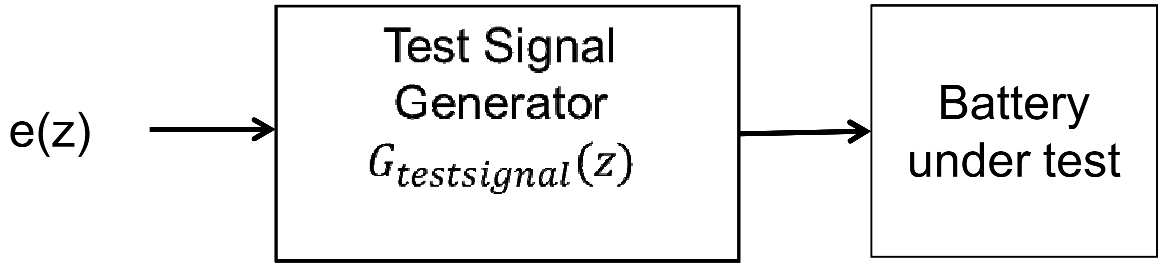
Measure the needed output for application to create Gapp(z)

$$G_{app}(z)=\frac{1}{1-a_1z-a_zz^2-a_3z^3-a_4z^4}$$

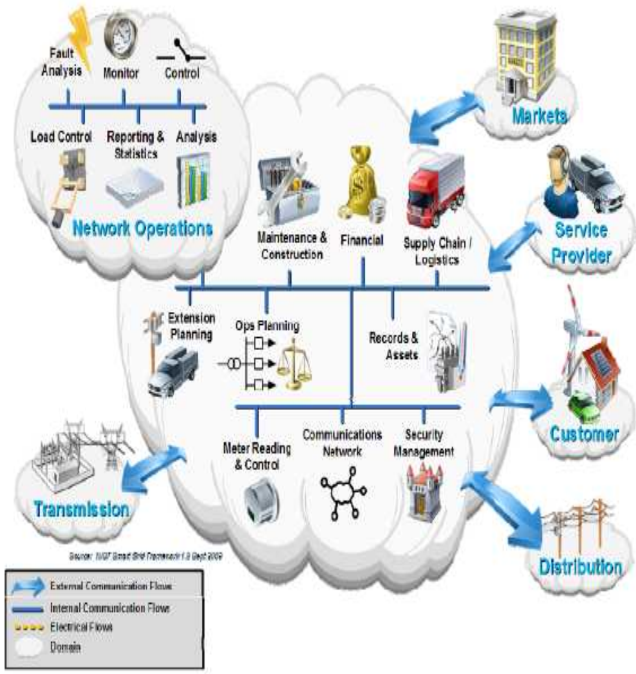
$$G_{test\ signal}(z)=\frac{G_{app}(z)}{G_{Power\ Electronics}(z)}$$





System Studies: NV Energy, Southern Co, Maui

- **Motivation:**
  - Determine whether grid-level storage is more cost effective than the next-best alternative at supplying the needed amount of energy and reserves:
    - To reduce the delivered cost of electricity for consumers.
    - Especially with projected increases in renewables.
    - Pumped-storage hydro, flywheels, and batteries (as well as combinations of these) are among the options to be studied.
  - Determine where storage can be implemented.
  - Calculate the needed level of operating reserves, as well as quantifying the benefits of storage in providing operating reserves.



- **FY11 Activities:**
  - Develop project scopes and study methodologies.
  - Obtain necessary data.
  - Develop modeling competency.

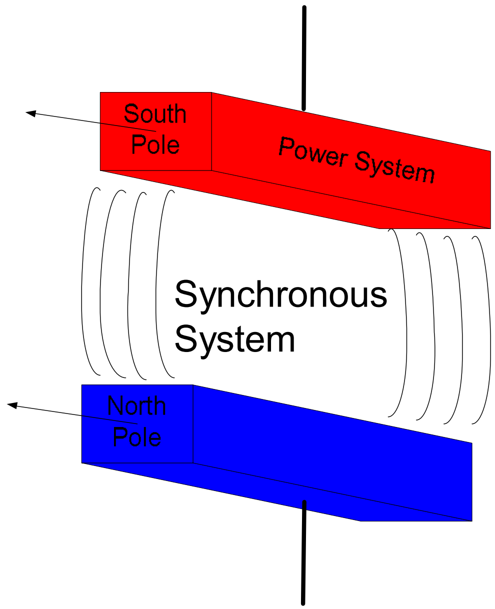
- **FY12 Plans:**

Complete system studies in the following Balancing Areas:

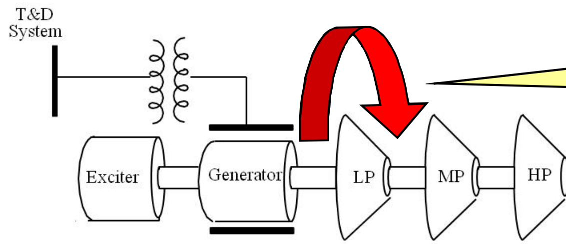
- NV Energy *for 2025 | 25% RPS*
- Southern Company *for 2020 | 2% renewable penetration*
- Maui *grid level storage and stability analysis*

Extras

# Indicates Mismatch Between Load and Generation

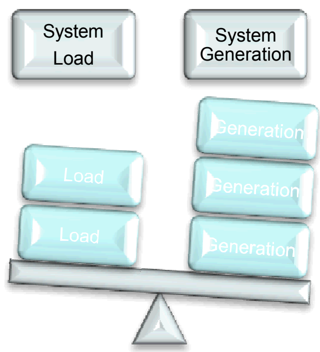


"Stack"

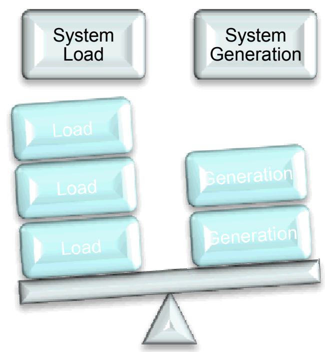


Speed of rotation (also the system frequency)

Stored Kinetic Energy

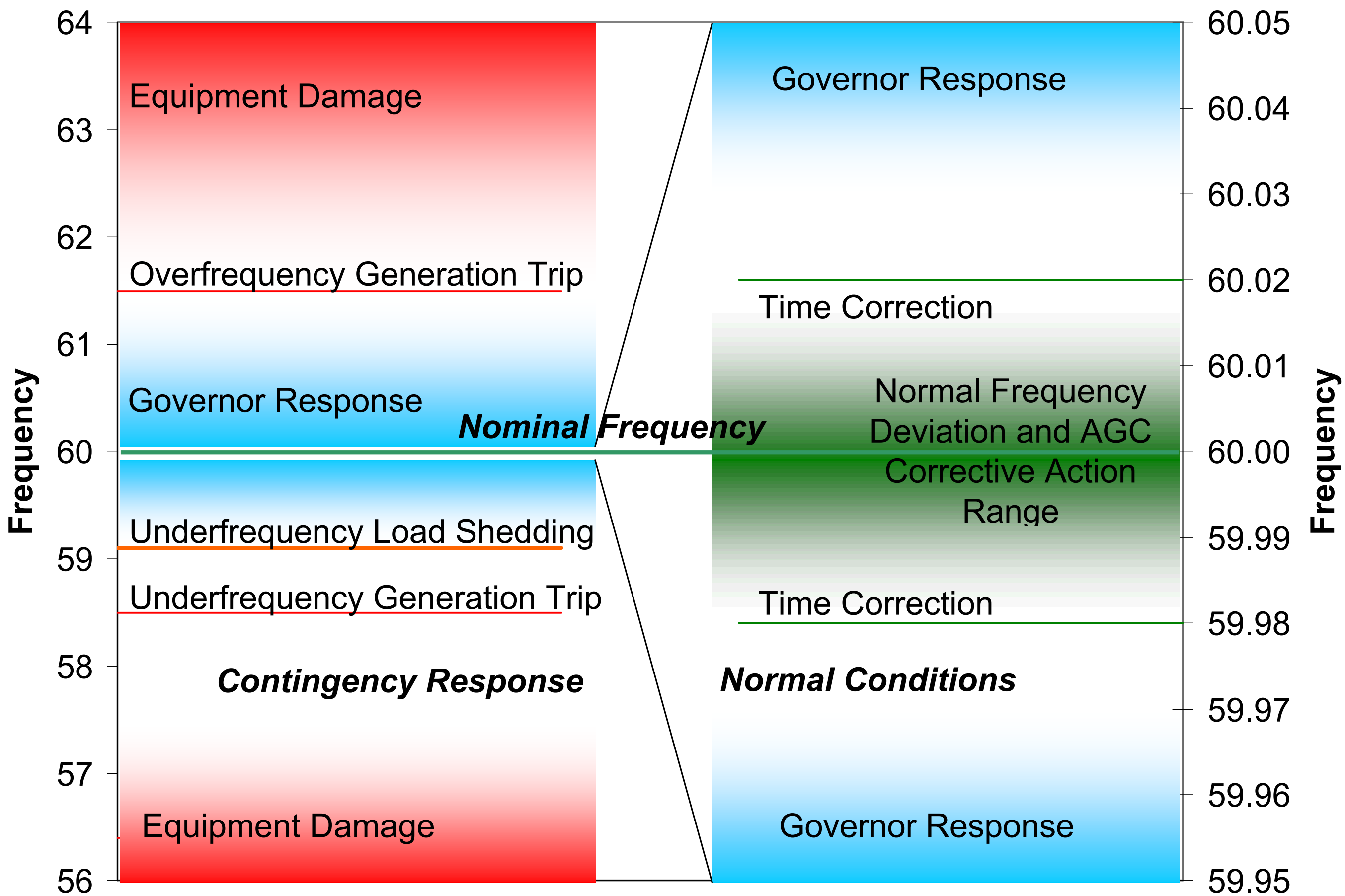


Frequency Goes UP



Frequency Goes DOWN

Frequency Regulation Bands



Frequency Excursion