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Storage and Grid Reliability

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U.S. DEPARTMENT OF ENERGY

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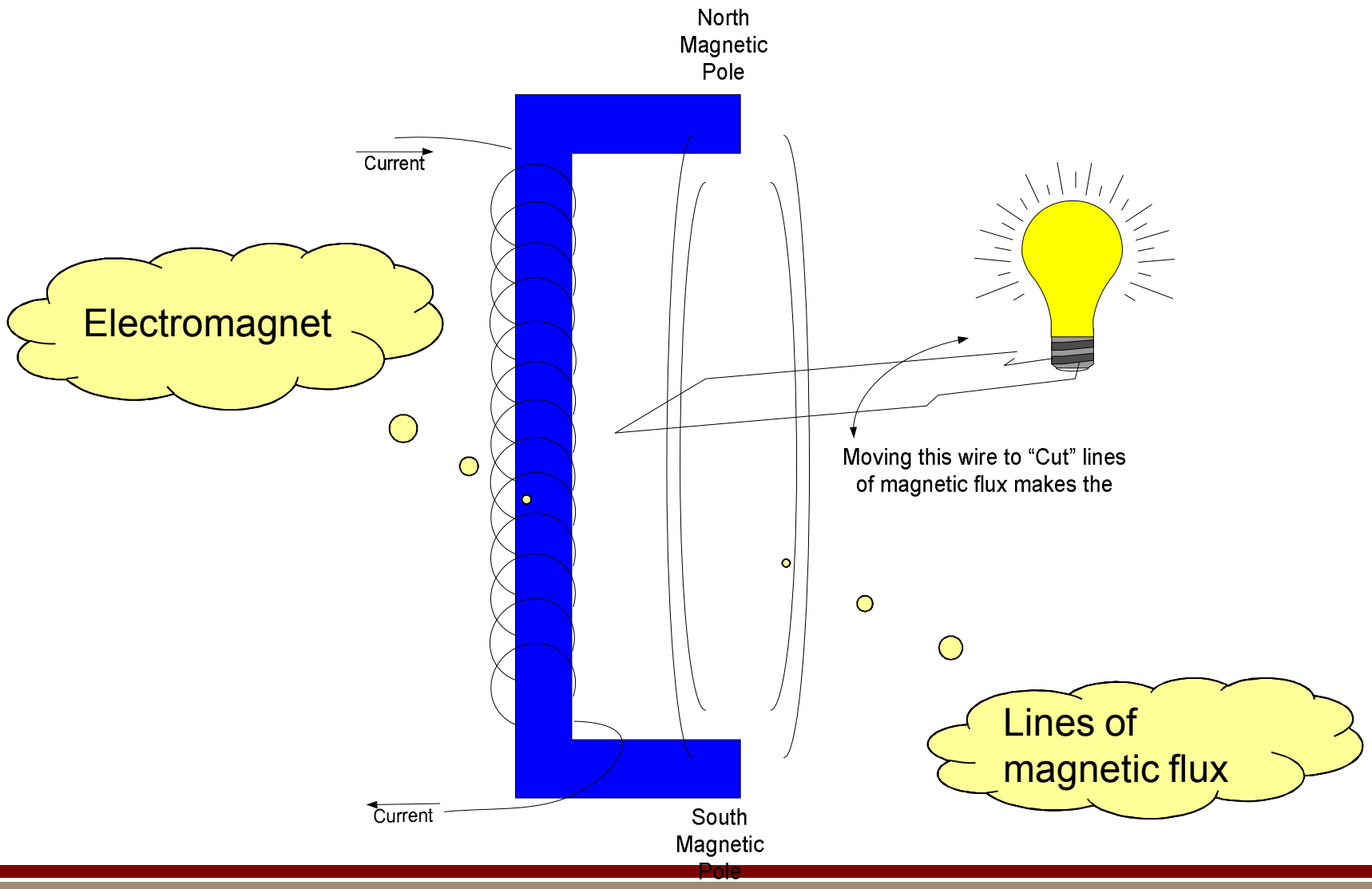
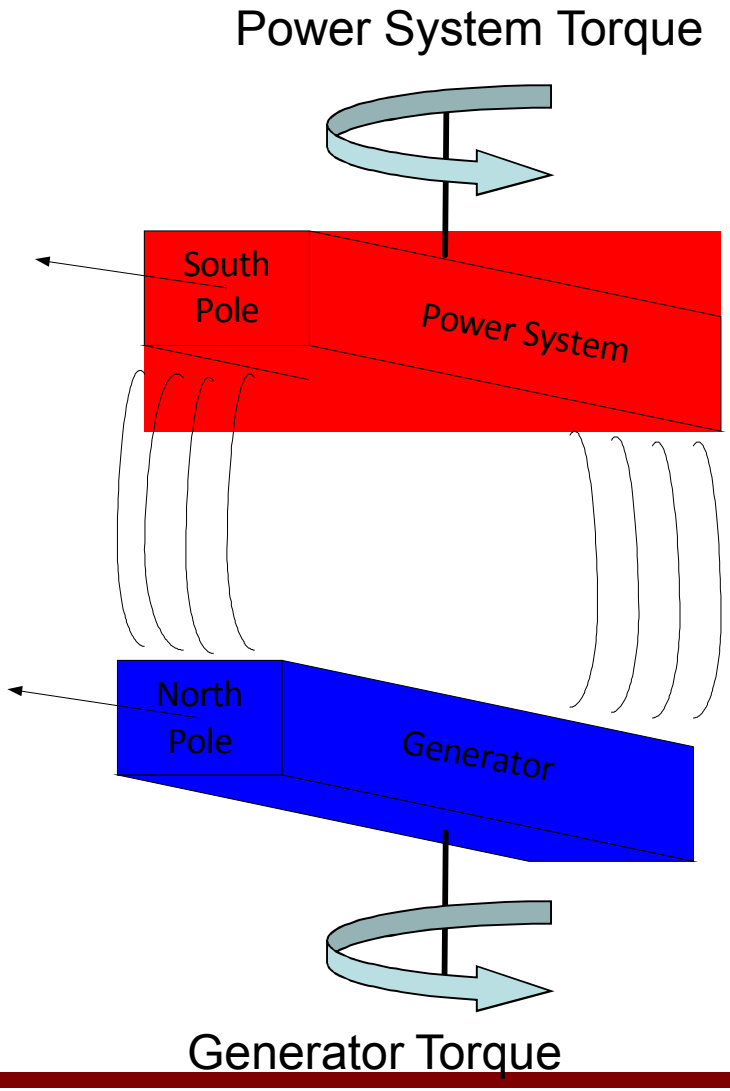
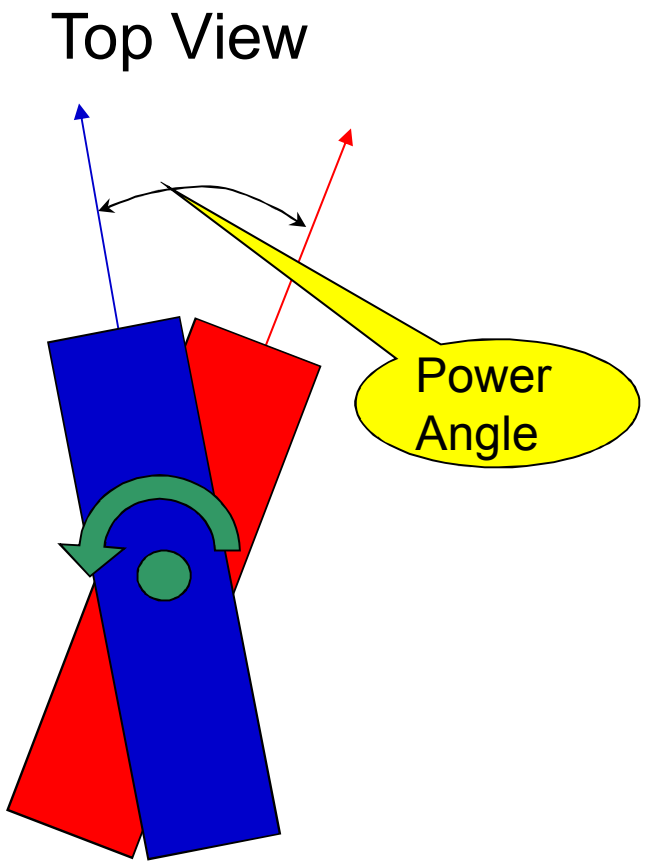
A Simple Generator

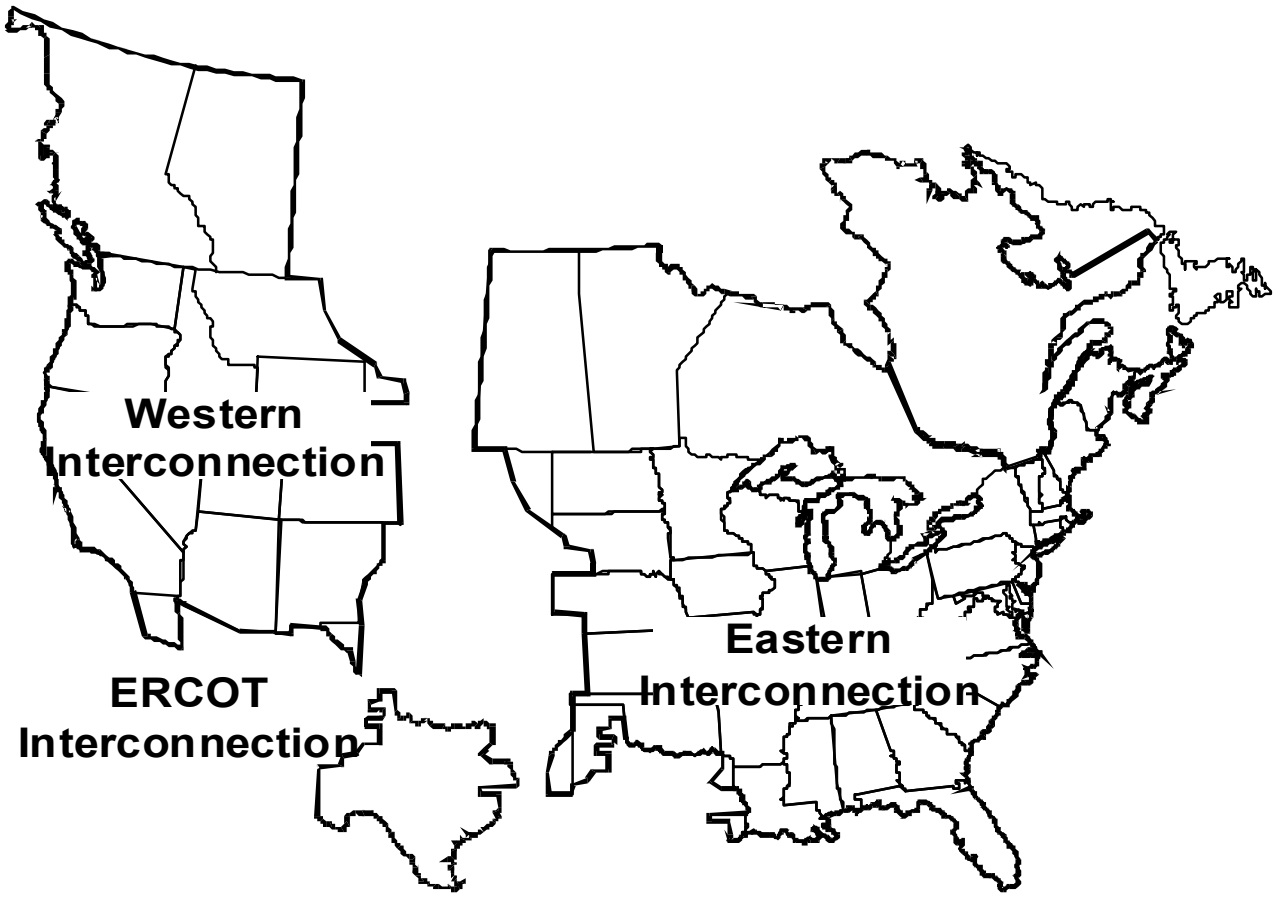


Generator Synchronism

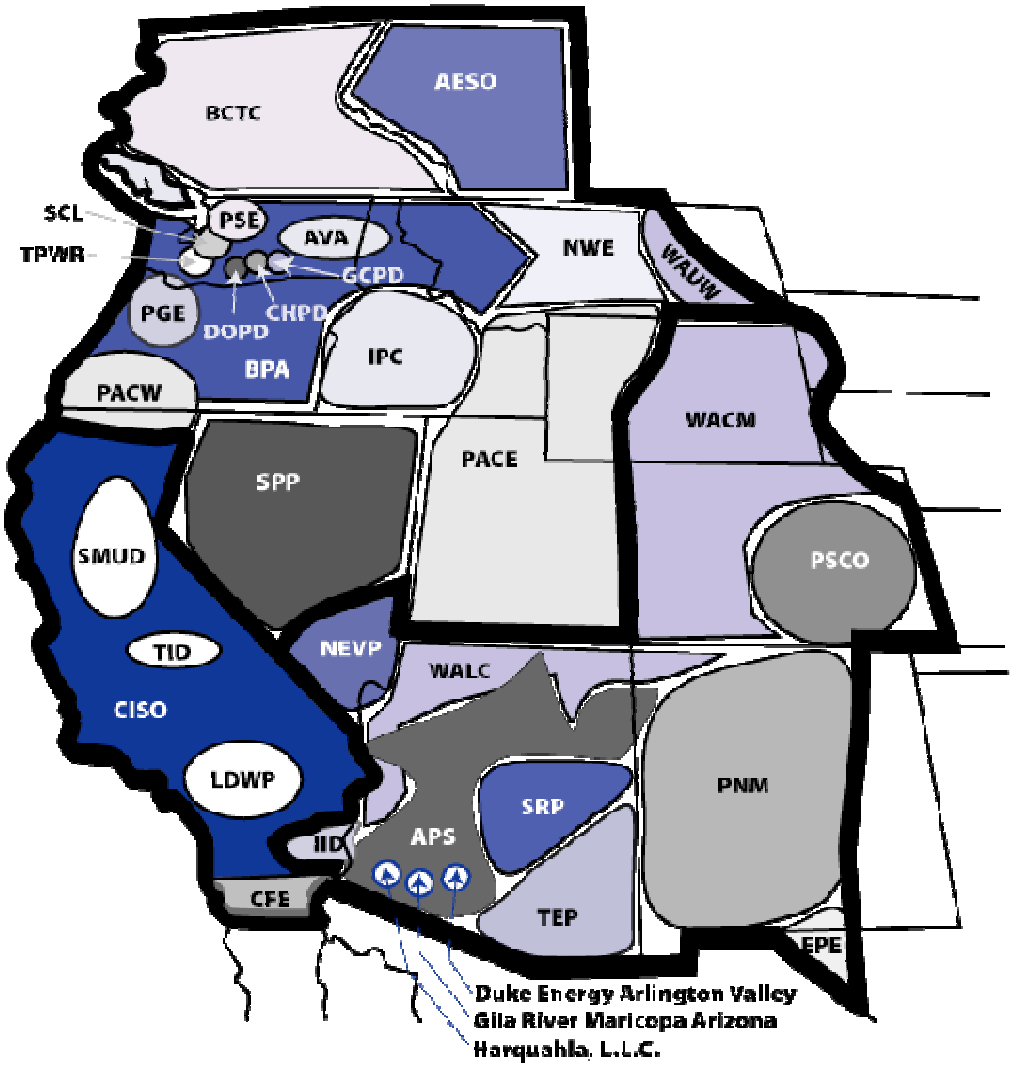




Major Grid Systems in North America



Interconnected Power System Operation

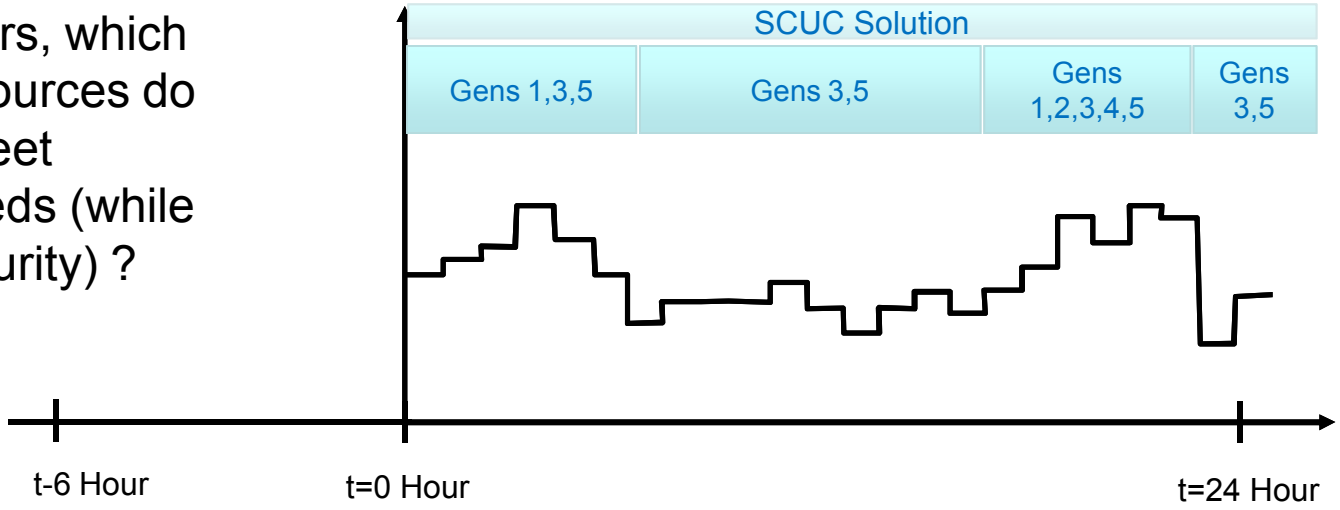


~37 in the WECC, 140 Control Areas in North America

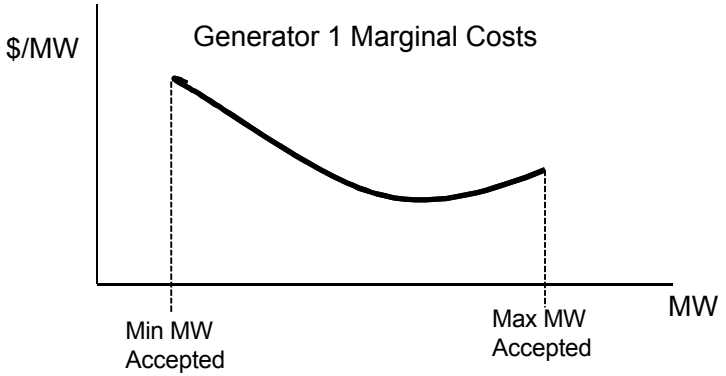
Graphical View of a Unit Committment

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

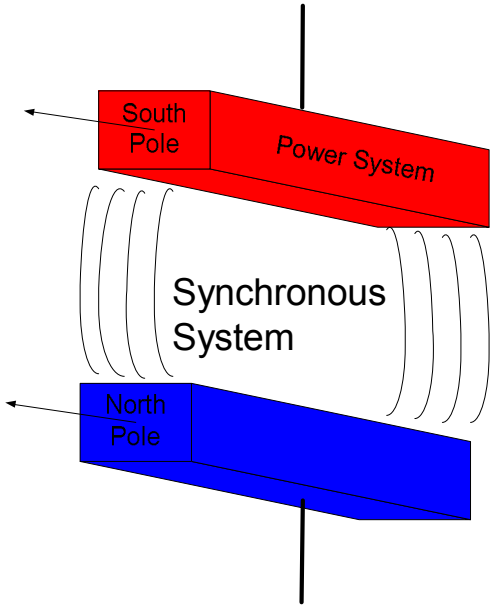
At time t-6 Hours, which generating resources do we select to meet tomorrow's needs (while preserving security) ?

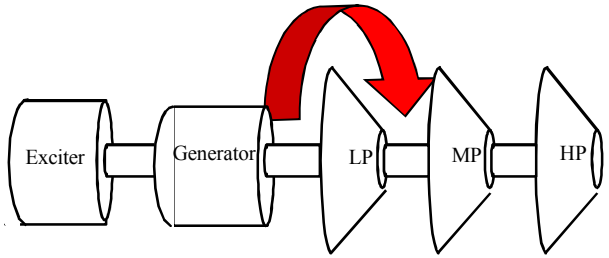


Generating Resources 1-5 Available (Offers)



System Frequency Indicates Mismatch Between Load and Generation





Inertia, or "mass" of the system

$$\text{Stored Kinetic Energy} = \frac{1}{2} J\omega^2$$

Speed of rotation (also the system frequency)

Conservation of Energy

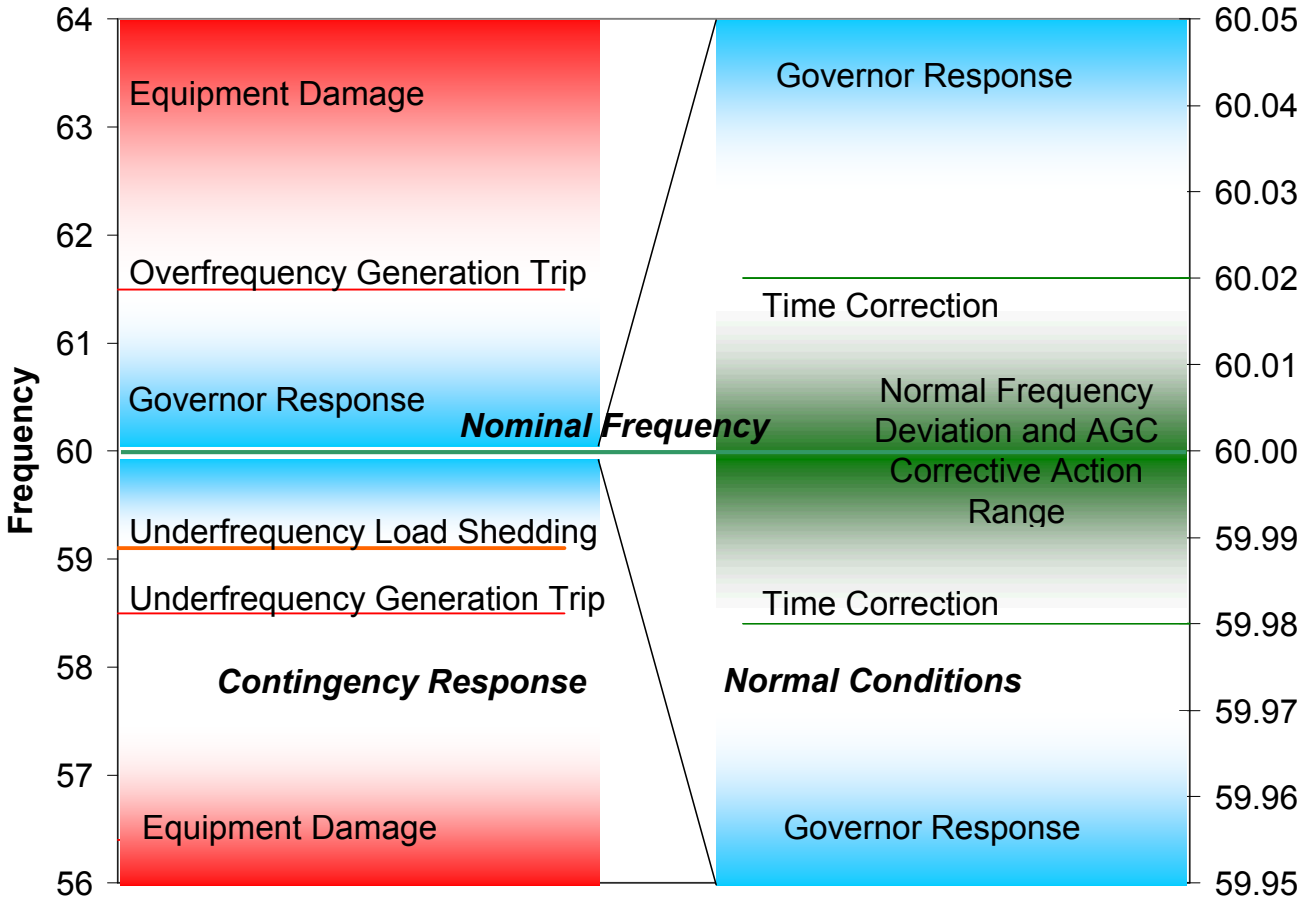
- If there is more load than generation, stored kinetic energy will decrease, and frequency will fall.

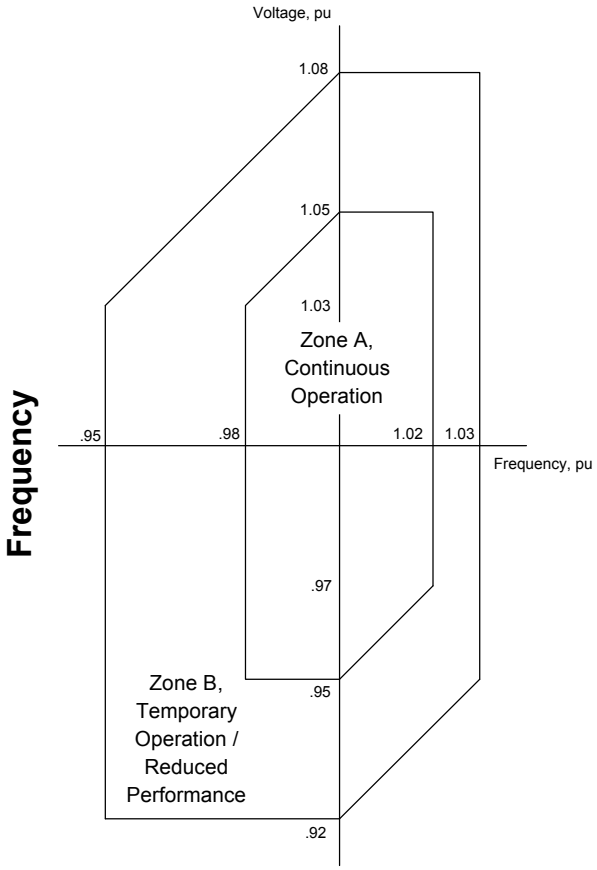
- If there is more generation than load, stored kinetic energy will increase, and frequency will raise.

Q. When a load is instantly light turn on turned on, where does the power come from?

A. Initially from the stored kinetic energy of the system, followed by increased turbine power

Hz & V/Hz Regulation Bands

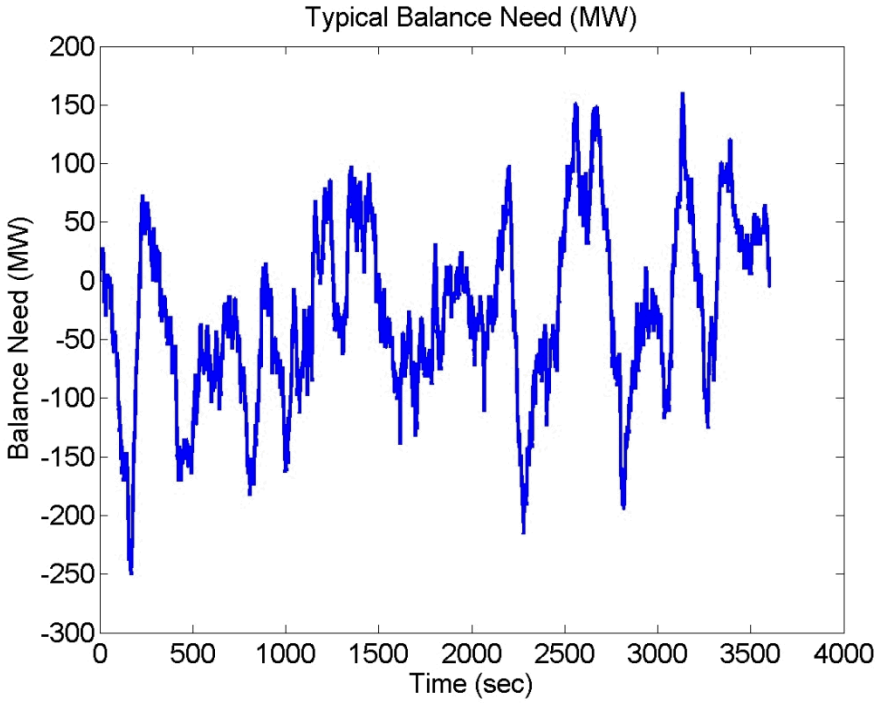


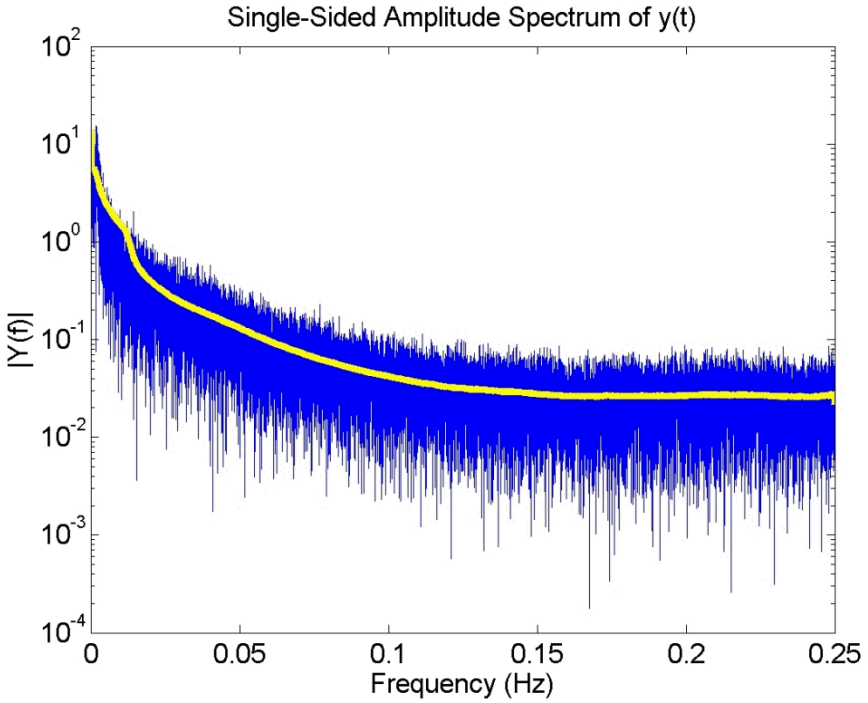


IEC 34-1 Voltage-Frequency Limits for Industrial Generators

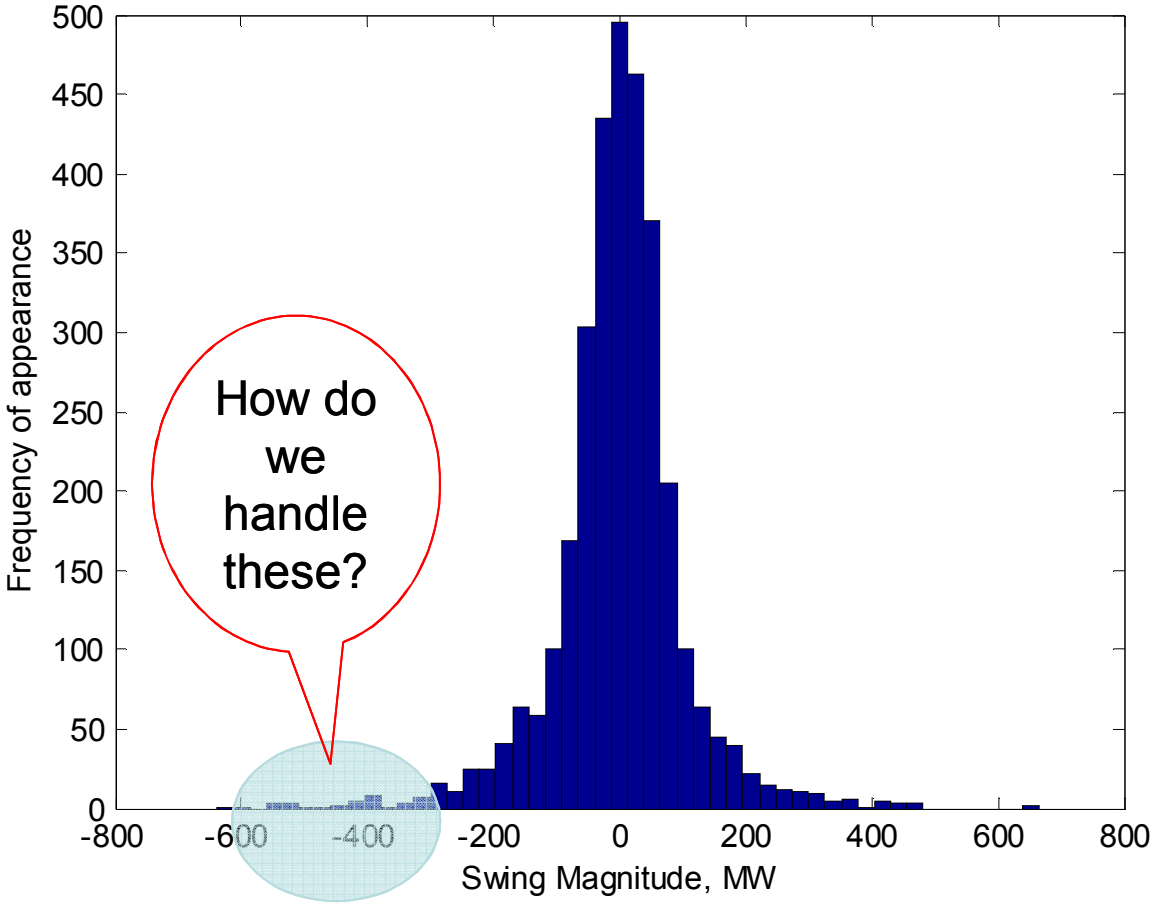
Sample Balance Data – PJM

Load is never exactly as we forecasted



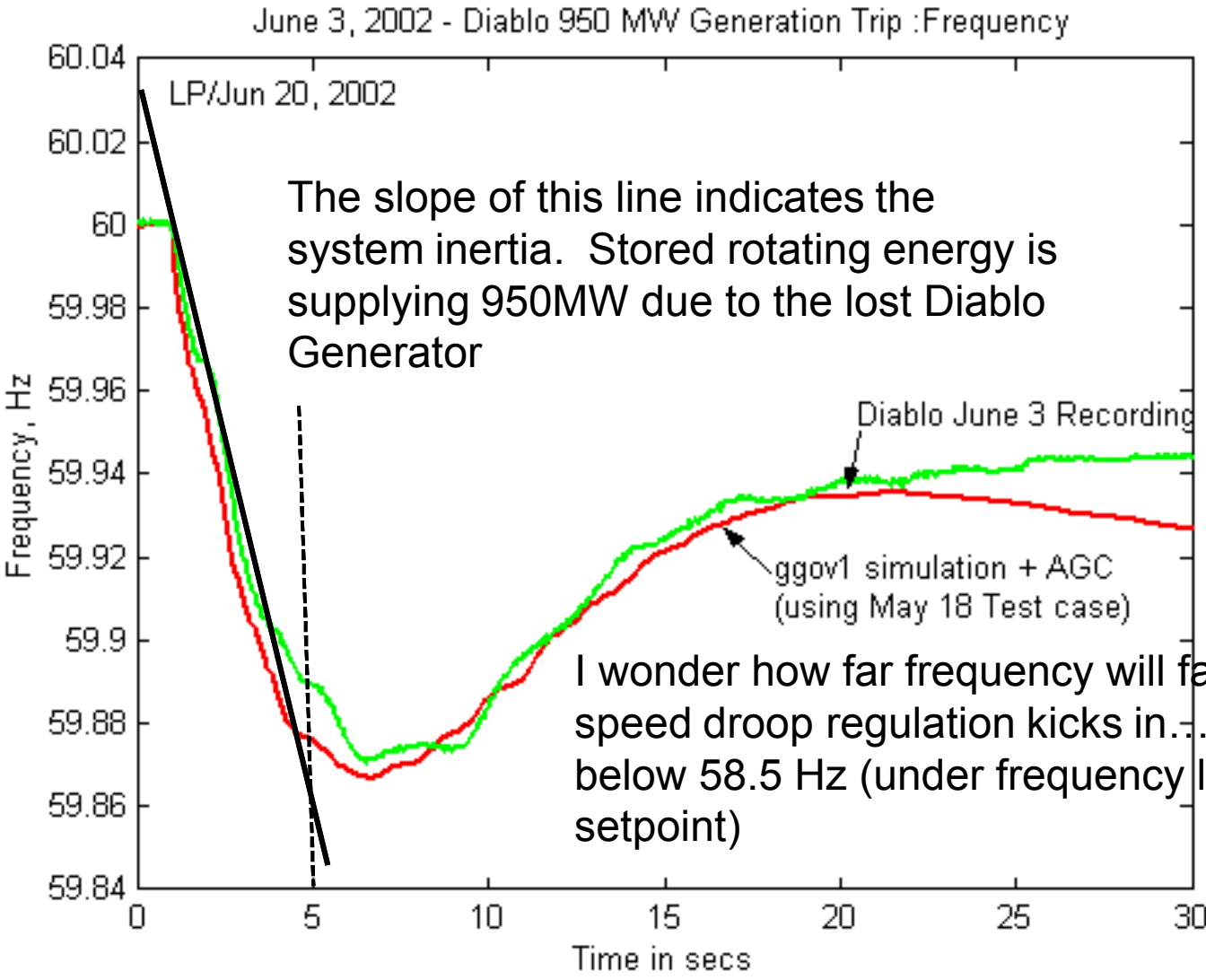


Tail Events from BPA System Wind in 2010



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.

Frequency Excursion



Common Means of Managing System Imbalance

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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)

Grid Reliability

- What is reliability?
  - It's "the lights coming on when I need them on"
    - This definition doesn't care why they didn't come on, nor does it care what part of the system didn't do its job.
  - Two components
    - Adequacy- is there enough generation?
    - Security- is the grid robust enough to withstand a disturbance?
- System reliability is often thought of from two perspectives:
  - Transmission level reliability
  - Distribution level reliability
  - The distinction between the two helps to focus solutions
- From a PUC perspective, what is the right amount of reliability and how do we measure it?

Grid Reliability

- From a transmission point of view, there are several possible metrics that can be used for system reliability.
- Measured
  - ACE (CPS1 and CPS2) – N/A for Hawaii
  - TLR levels on transmission line loading- N/A for Hawaii
  - Substation voltage fluctuations
  - Raw frequency deviations, beyond specified limits
  - Amount of MW Hours of under frequency load shedding per year
- Analyzed
  - N-1 contingency analysis
    - Voltage, stability, line overload
  - Available reserves
  - Loss of Load Probability

Grid Reliability

- From a distribution perspective
  - SAIDI- System Average Interruption Duration Index [Hours]
    - "I have 4-nines of reliability! Power is served all by one hour per year! Yeah!
  - SAIFI- System Average Interruption Frequency Index [interruption/customer]
    - "Oops, I had 3600 interruptions, each lasting one second"
  - Voltage regulation
  - Harmonics

Grid Reliability *EQUALS* Money

The Reliability Yin-Yang:

If you give me money, I will give you reliability

(Reliability is a choice… safety, not so much)