California Independent System Operator

Integration of Energy Storage Technology in Power Systems

Northwest Wind Integration Forum's Pumped Hydro Storage Workshop – October 17, 2008

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Identification of Issues, barriers and alternatives for Integration of Energy Storage Technology in Power Systems

Types of Storage Technology Available

Pumped hydro, which generates electricity by reversing water flow between reservoirs, is the most widespread energy storage system on power networks. With an efficiency rate of more than 70%, pumped storage accounts for over 90GW worldwide, according to the Electricity Storage Association (ESA).

Flywheel systems, which utilize a massive rotating cylinder, can provide fast regulation services. New high speed flywheel designs are based on clustering forty 25kW units that can store 1MW for one hour.

Battery Storage, lithium Ion batteries and Sodium Sulfur batteries can provide 15 to 60 minutes of energy storage and provide regulation services

Compressed Air Storage, takes advantage of the many abandoned gas and oil wells in the state as a cavern to store compressed air and recover it for use in a turbine.

Super capacitors*,* or electrochemical capacitors, possess swift charge and discharge capabilities. More powerful than batteries, they can be cycled tens of thousands of times. Those with energy densities under 20kWh/m3 have been successfully developed, and work is underway to expand the effectiveness of larger units.

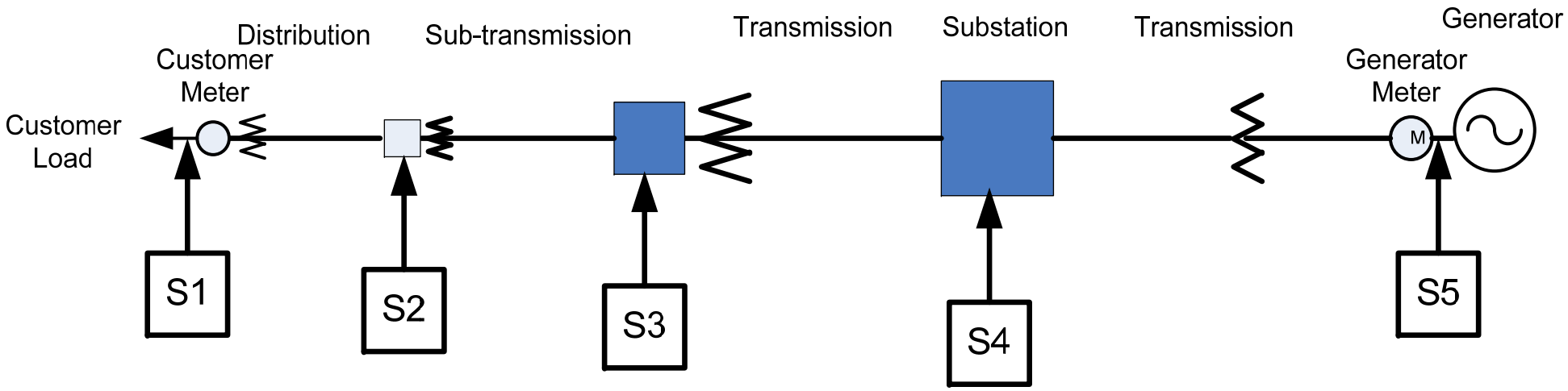
Flow batteries have low energy density, but they offer high capacity and independent power and energy ratings. Technologies in use include polysulfide bromide (PSB), vanadium redox (VRB), and zinc bromide (ZnBr).

Plug in Hybrid Vehicles, The idea of using the batteries of plug-in hybrid vehicles as an energy storage resource -- a concept called Vehicle to Grid (V2G)

#1 Issue – Transmission facility or market facility?

- When is a storage facility a transmission facility and therefore included in Transmission Rates (or Distribution Rates)?
  - Location criteria?
  - Voltage criteria?
  - Services it provides? Operated as a transmission device?
- When is it a market based facility?
  - Bids into energy and A/S markets
- Could it be a hybrid and have both transmission and market based funding? Probably unlikely

Connectivity Process

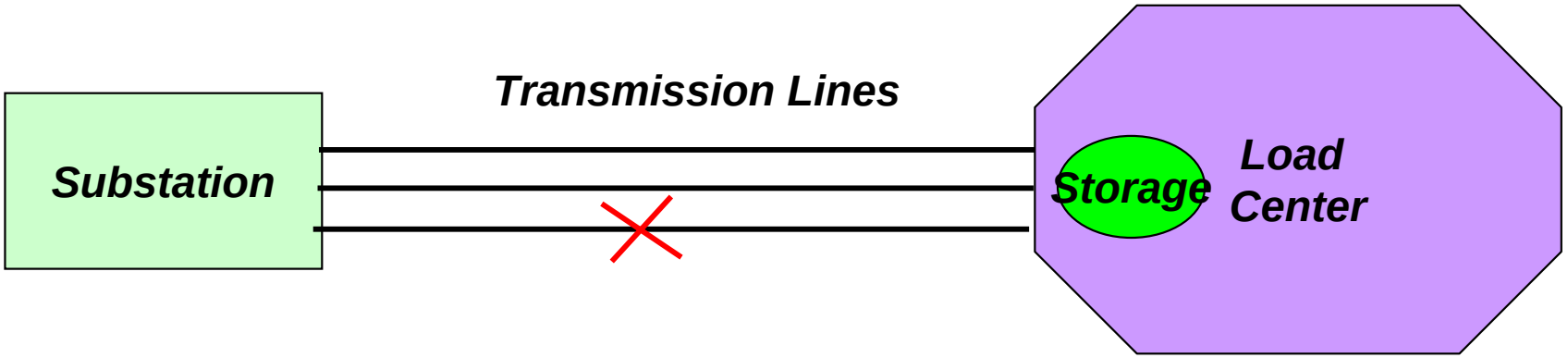


- Five potential interconnection locations:
  - S1 – Customer sites
  - S2 – Distribution substations
  - S3 – Sub-transmission substations
  - S4 – Transmission substations
  - S5 - Generating stations

Potential storage facility services

- Transmission device – voltage support, VAR source, mitigation of transmission loading, etc. – and therefore storage is financed through transmission rates.
- Distribution device – power quality improvement, voltage support, load relief, load leveling, etc. –included in distribution rates.
- Customer device – demand peak reduction, power quality, uninterruptible power supply, plug-in hybrid vehicles, etc. – paid for by the customer or a curtailable load provider.
- Market services – Ancillary Services such as regulation and operating reserves, arbitrage of energy prices (shifting of energy from low cost periods for deliver during higher cost periods). Obviously these services are financed though the energy and capacity markets.

Other uses of Energy Storage



In the event a transmission line is lost, or a generator in the Load Center Area is lost, the storage system could inject energy into the load center area to temporarily help unload the overloaded lines. It could also provide voltage support and potentially reduce the need for some RMR contracts.

Storage Facilities – Are they economical?

- Strategies for financing and implementing storage systems
- What services do they provide and who would pay for them?
- How would they be dispatched? ACE/Freq? AGC? ASC?
- Assessment of the storage technologies
  - Pump Storage
    - Operation of 3rd pump at Helms; LEAPS, Other PS Units
  - Hydrogen Storage - Fuel Cells
  - Plug-in Hybrid Vehicles
  - Compressed Air Storage
  - NAS Batteries – LI Ion Batteries
  - Flow Based Battery Storage
  - High Speed Flywheel Storage

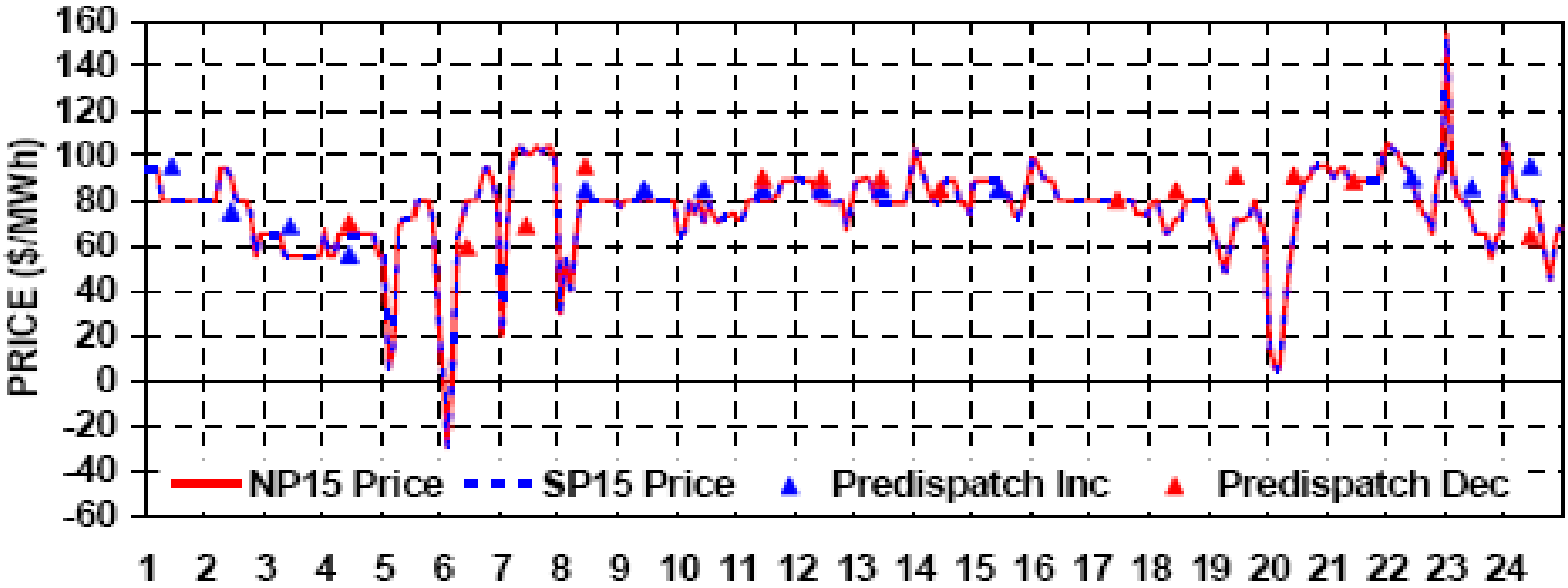
Battery Enclosure

Success factors for participating in energy markets

- The key question is whether the storage facility can operate at a profit by buying energy from the market when the price is low or negative and sell it back to the market when the price is high. For this strategy to be successful, it would be useful to have
  - significant volatility in real-time energy prices,
  - a volume of energy storage that is at least 3 times the capacity rating of the unit (a 10 MW facility should have at least 30 MW Hrs of storage capability),
  - a very efficient storage technology with low round trip energy losses, and
  - a capital cost per MW of energy storage that is competitive.

Example of real-time 5 minute prices

Prices vary from -$30 at 6 AM to $80 at 6:30 AM



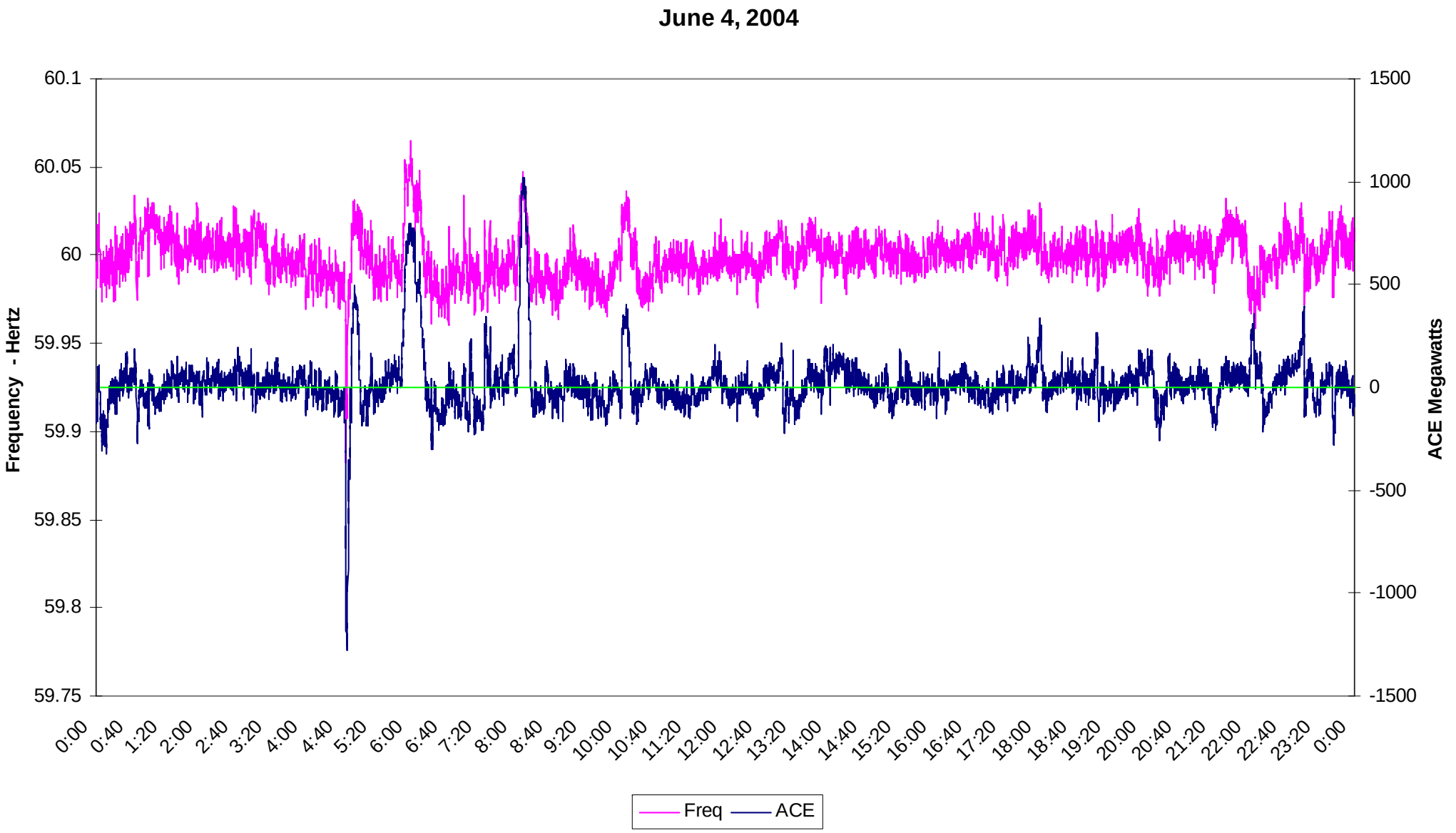
	NP15				SP15			
	Min	Max	Avg	Δ Avg.	Min	Max	Avg	Δ Avg.
	RTMA MCP							
Peak	$ 5.00	$ 105.47	$ 79.67	$ (2.33)	$ 5.00	$ 105.47	$ 79.67	$ (2.33)
Off-Peak	$ (29.89)	$ 154.00	$ 69.36	$ 8.54	$ (29.89)	$ 154.00	$ 69.36	$ 8.54

Potential value of storage facilities

A Control Area Operator's Perspective

- Fast response to control signals, frequency response, and automated dispatch commands
- High ramp rates
- High reliability and stability, environmentally friendly
- Easy to start and stop
- Lower cost energy but limited energy supply,
- Units are frequent suppliers of Regulation Services in generation mode
- Pump storage facilities have added advantage of providing night time loads to help balance system
- Pump Storage Disadvantage – difficult to site and take an estimated 10-12 years to permit, license, and construct

Potential use of Energy Storage for ACE and Frequency Control



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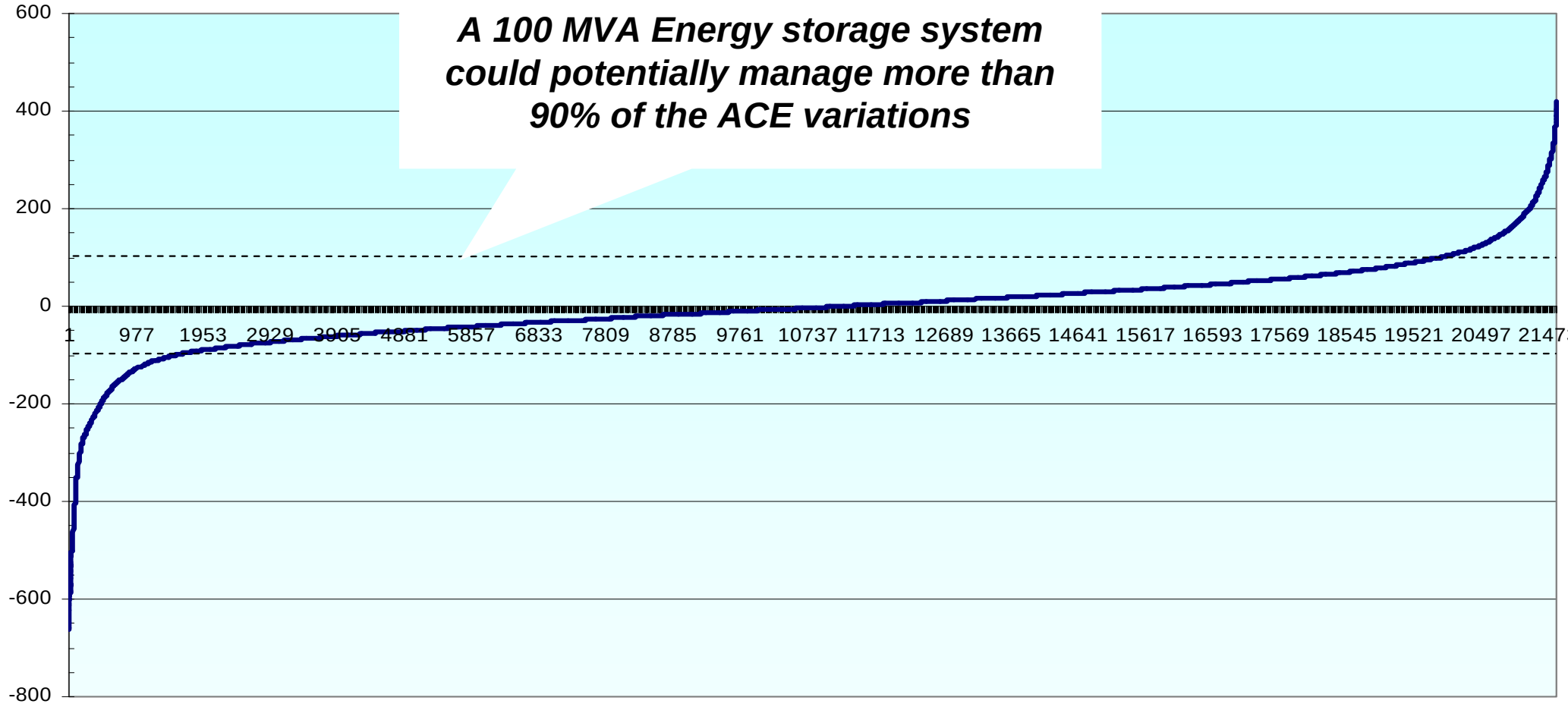
Potential use of Energy Storage for ACE and Frequency Control

Variation of 4 Second ACE over a 24 hour Period sorted by MW value



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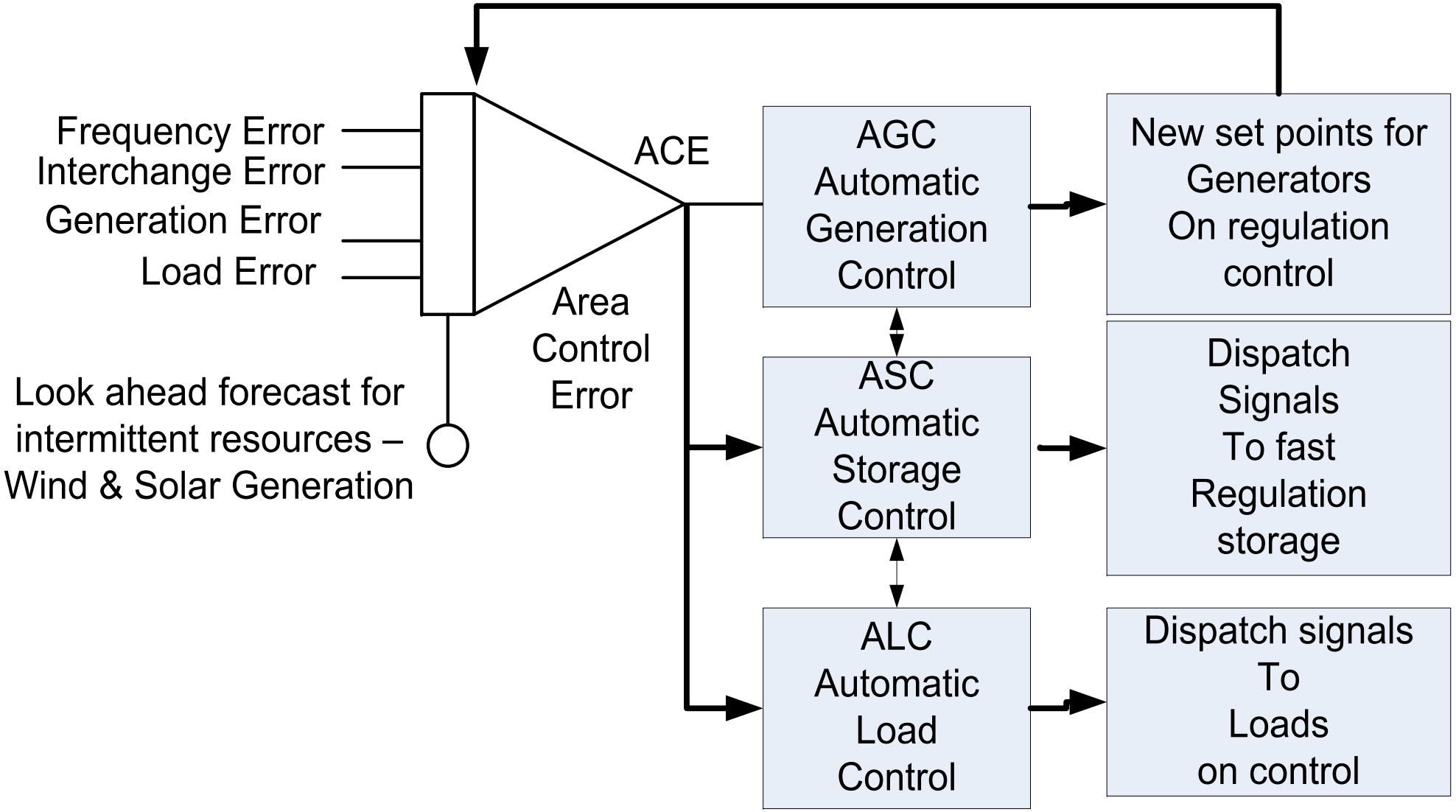
Future Energy Management System Control System



Barriers to Deployment of Storage Facilities

#1 A good economic model for making storage payoff. Is the differential between off-peak prices and on-peak prices large enough or sustained to make a compelling business case?

#2 Identification of value added services that storage can provide to improve the economic model? Fast ramp rates? High Speed Regulation? FRR-Frequency Responsive Reserves?

#3 Tariff issues?

#4 Market knowledge?

#5 FERC decision on whether storage is a transmission facility or a market facility? LEAPS Pump Storage facility is treated as a market resource and not included in transmission rates

#6 Other?

Next Steps

- Document issues, barriers, and opportunities for energy storage facilities
- Internal CAISO review of project plan and timeline
- Installation of a 2 MW LI Battery facility for regulation in October-November 2008
- Develop proposed pilot test of storage facilities for regulation services – potential implementation in Q2 2009
- Discussion with Stakeholders on the detailed pilot test plan