The Use of Responsive Load for Spinning Reserve and Regulation

ORNL

Power and Energy

Systems Group

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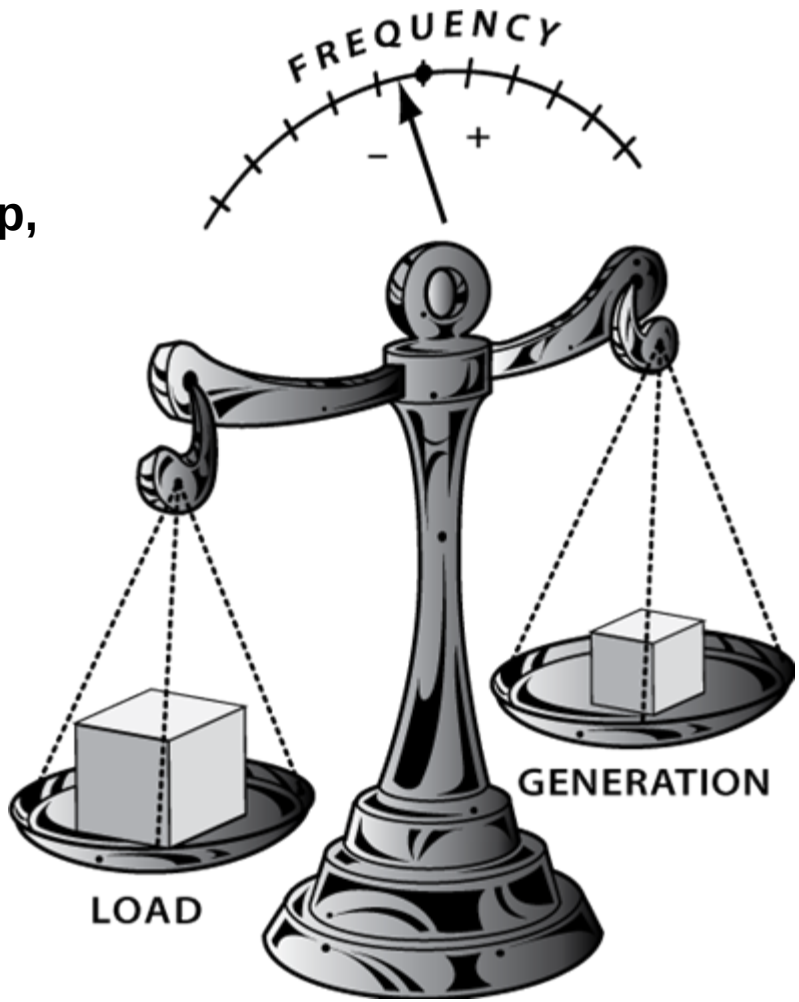
July 2009

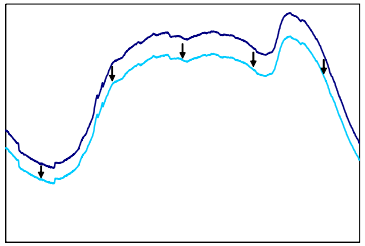
Generation and Load Must Always Be Balanced (Supply and Demand)

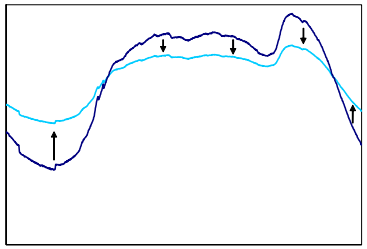
- **If load is greater, frequency will drop, if generation is greater, frequency will rise.**
- **BUT, it is nearly impossible to control on frequency, when frequency moves, it is too late.**
- **Instead, the system operator constantly does bookkeeping to ensure that load and generation are balanced, we measure power flows, and control the balance in our balancing area.**

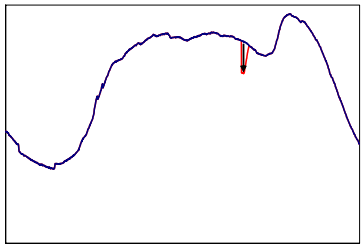


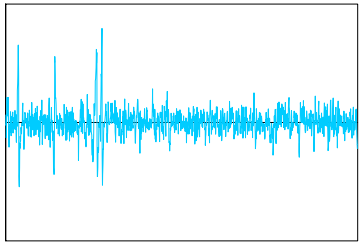
There Are Five Basic Types of Responsive Load

1. Energy Efficiency **programs reduce electricity consumption and usually reduce peak demand.**
2. Price Response **programs move consumption from day to night. (real time pricing or time of use)**
3. Peak Shaving **programs require more response during peak hours and focus on reducing peaks every high-load day.**
4. Reliability Response **(contingency response) requires the fastest, shortest duration response. Response is only required during power system "events." –** ***This is new and slowly developing.***
5. Regulation Response **continuously follows the power system's minute-to-minute commands to balance the aggregate system –** ***This is very new and may have the potential to dramatically change electricity costs.***



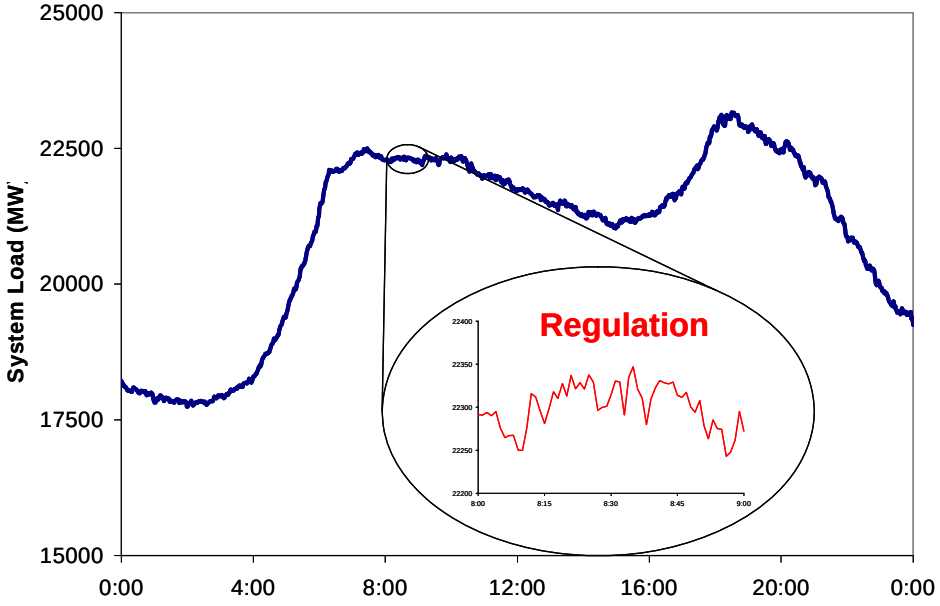




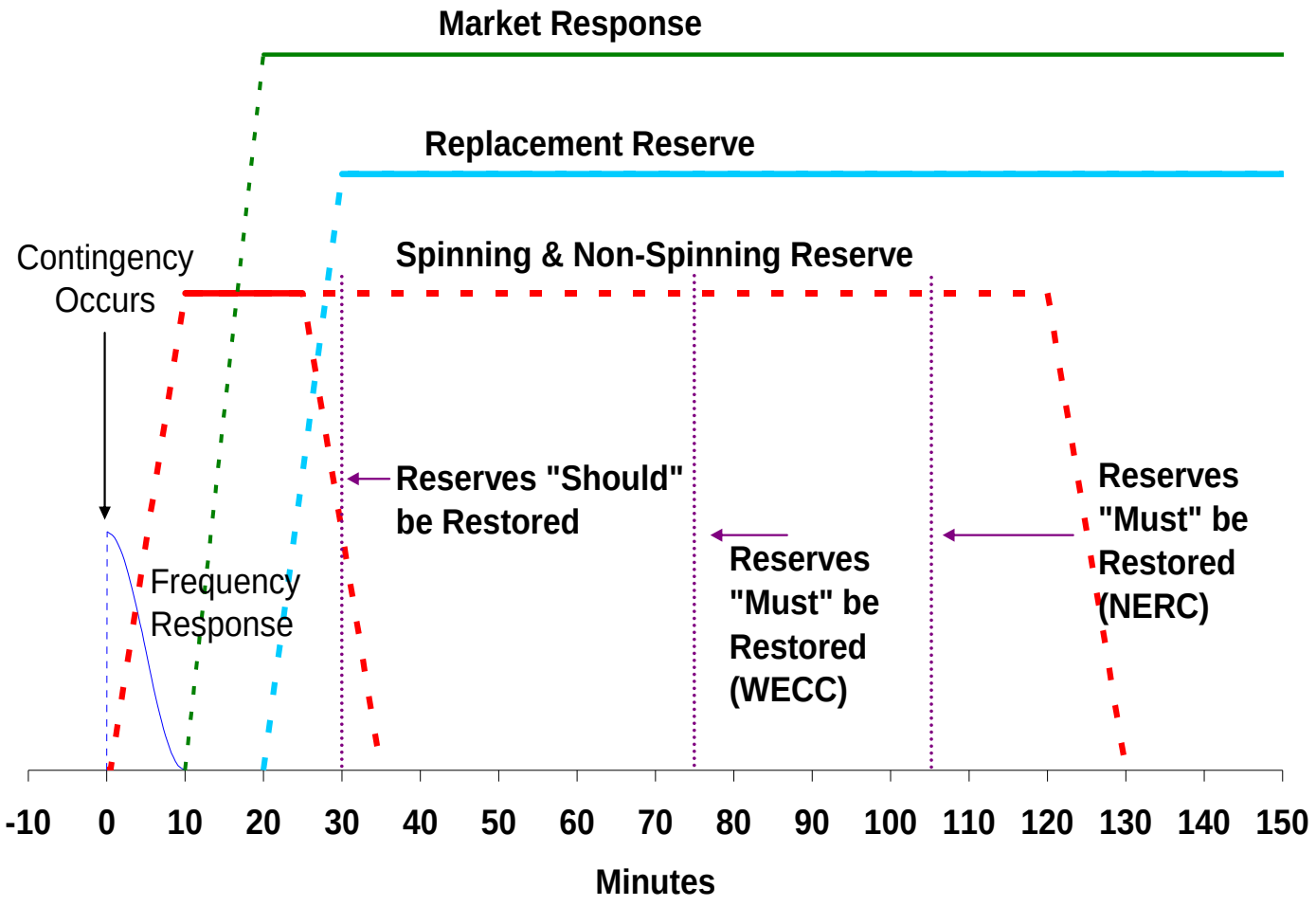


Markets, Responsive Load and Storage

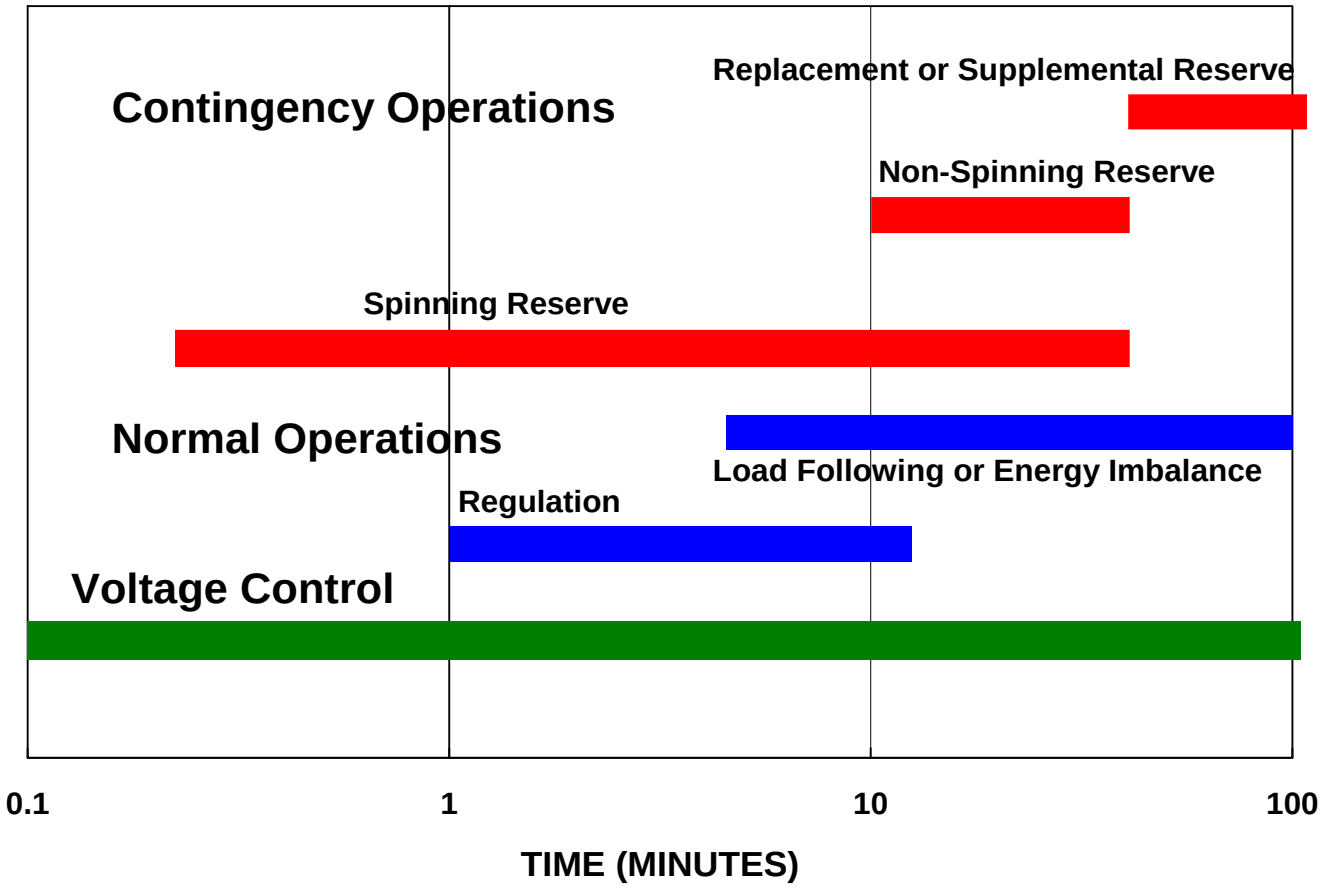
- **Today, 5 minute energy markets are responsive to system variability.**
- **Responsive load is just beginning to provide regulation – the minute to minute energy balancing of the system.**
- **Storage is also being used to supply regulation**
- **Regulation integrates to zero**

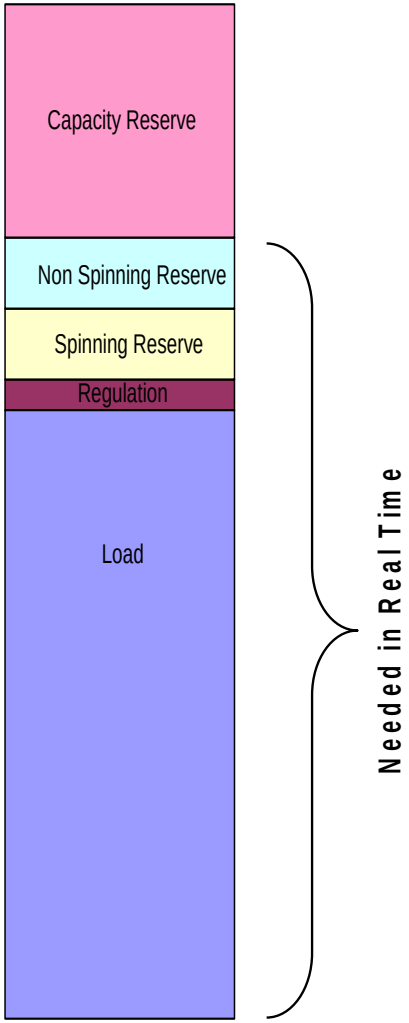


Regulation provides the minute-to-minute balancing of generation and load


Market Response
Replacement Reserve
Spinning & Non-Spinning Reserve
Contingency Occurs
Frequency Response
Reserves "Should" be Restored
Reserves "Must" be Restored (WECC)
Reserves "Must" be Restored (NERC)
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Minutes

Response Time and Duration for Ancillary Services



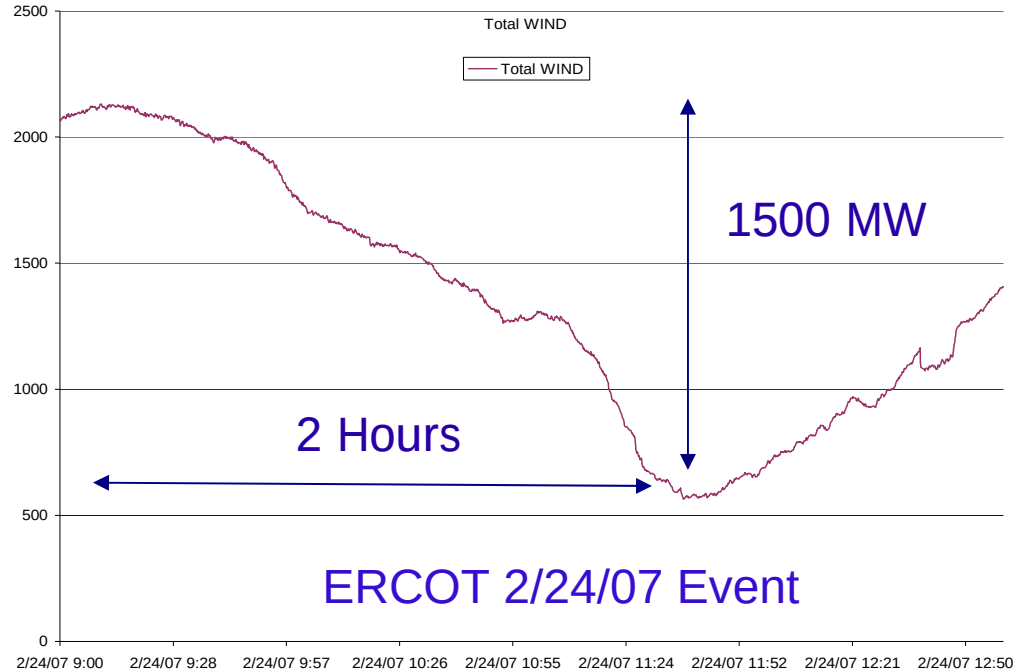


Ancillary service providers contribute capacity just as peak and base load generators do.

Renewable Generation is Variable, But, this Challenge Can be Overcome

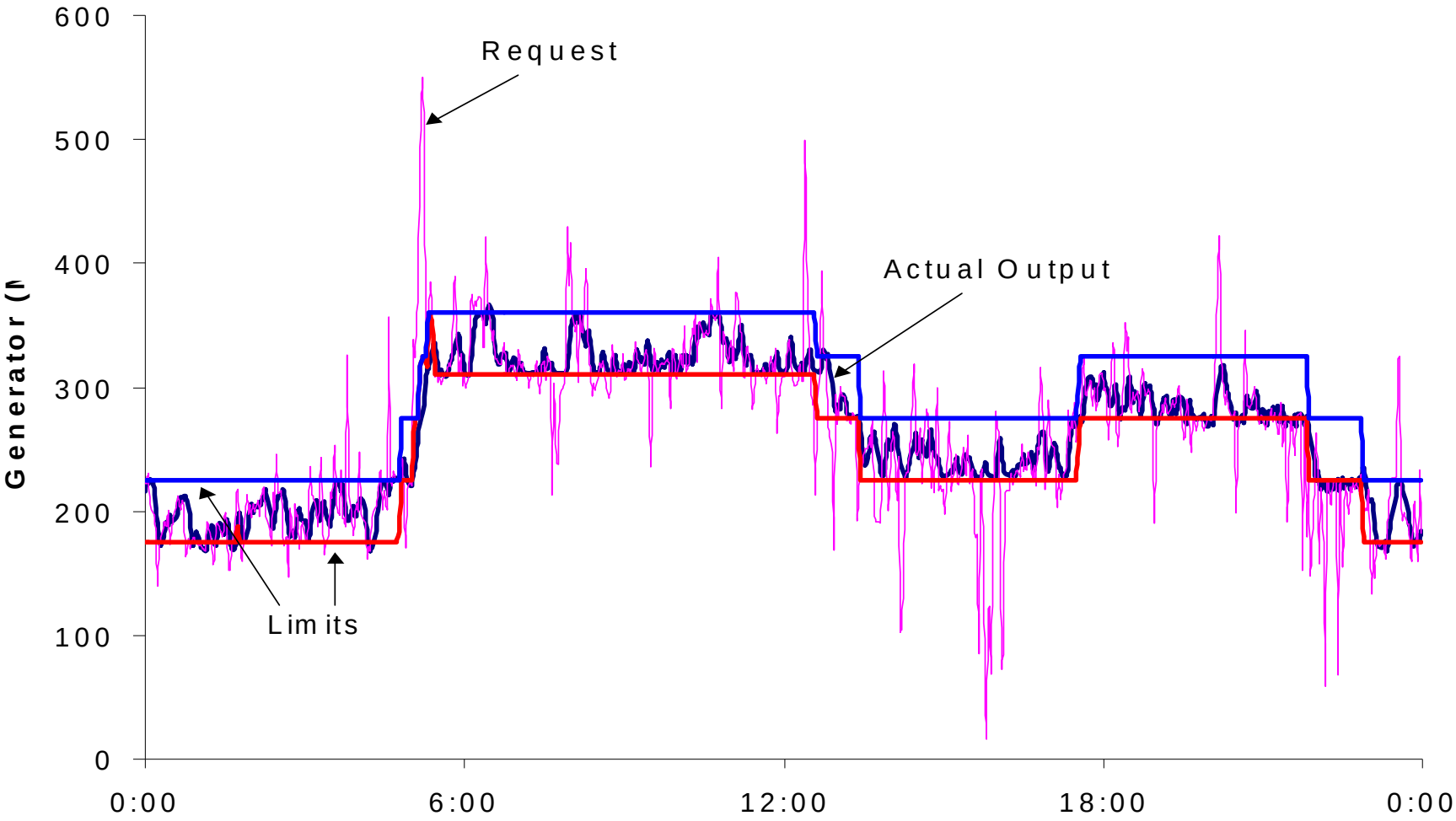
- **We can improve day ahead and hour to hour planning by developing a method for probabilistic analysis of renewable generation aggregations.**
- **Supply forecasts can be done statistically as a function of weather and time over areas as large as a balancing area.**
- **Larger areas will be "smoother" and will include responsive load and storage resources in their operation**

Extreme Wind Events Are Typically Not Rapid Like Generator Failures

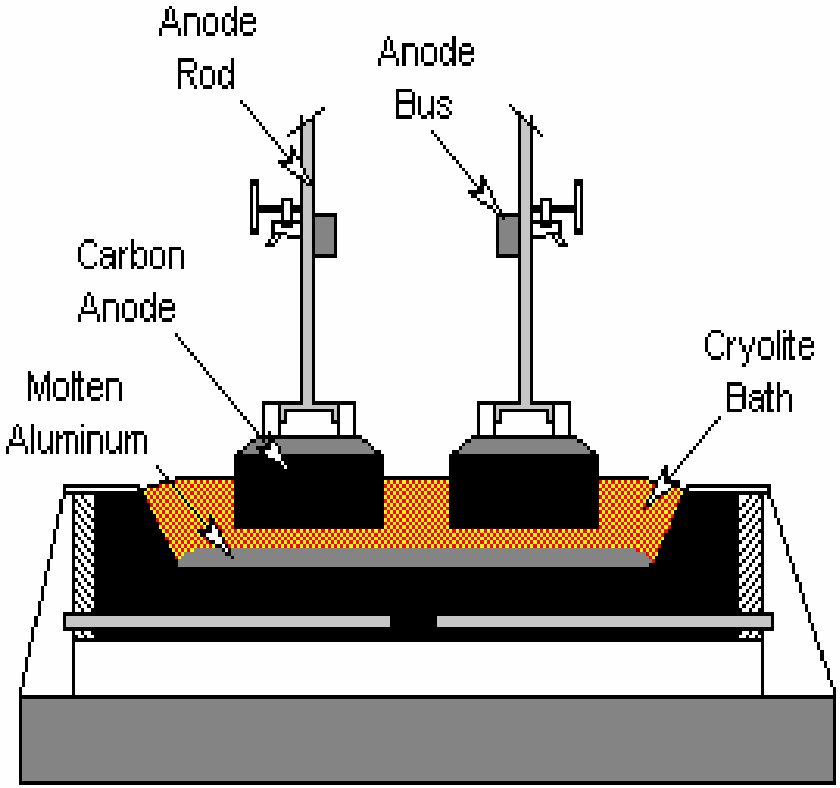


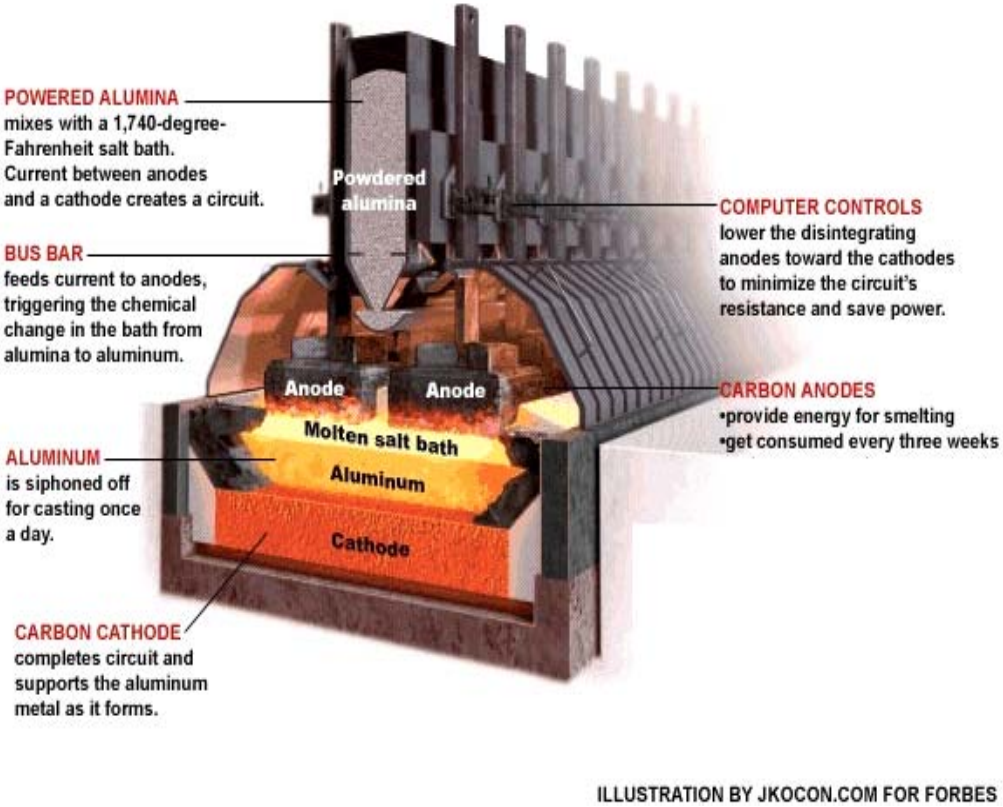
- **Extreme wind events are ramping events, not contingency events**
  - **Electrical events are still contingencies (single feeder…)**
  - **Geography prevents all turbines from seeing *wind* events simultaneously and spreads the response**
- **Increasing the amount of wind increases the ramp duration, not the ramp speed**
- **Responsive load and large aggregations will provide the solution**

Thermal Generators often Fail to Follow Regulation Commands Closely

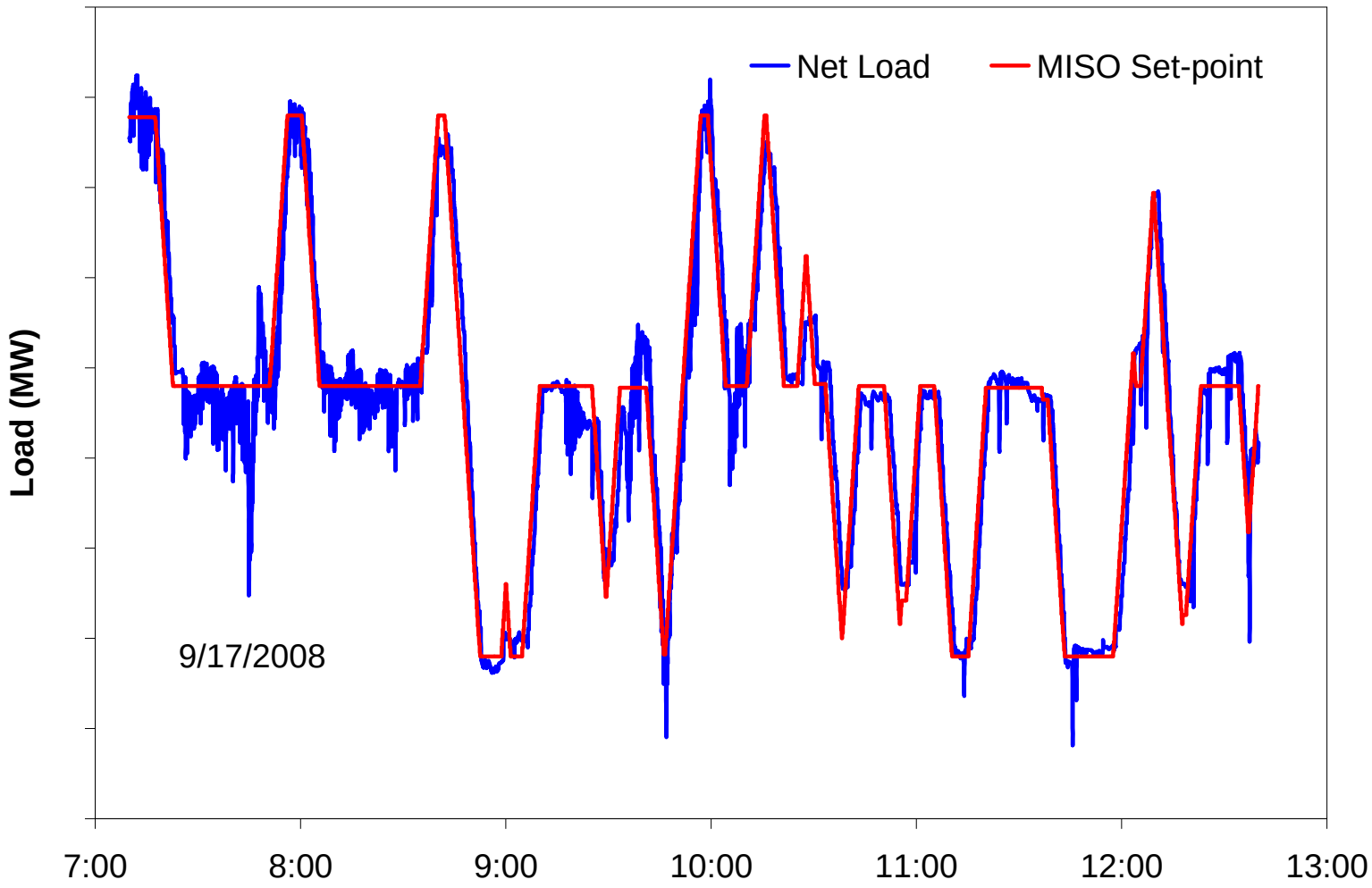


In aluminum smelting, the cryolite must remain frozen at the edges and molten in the center



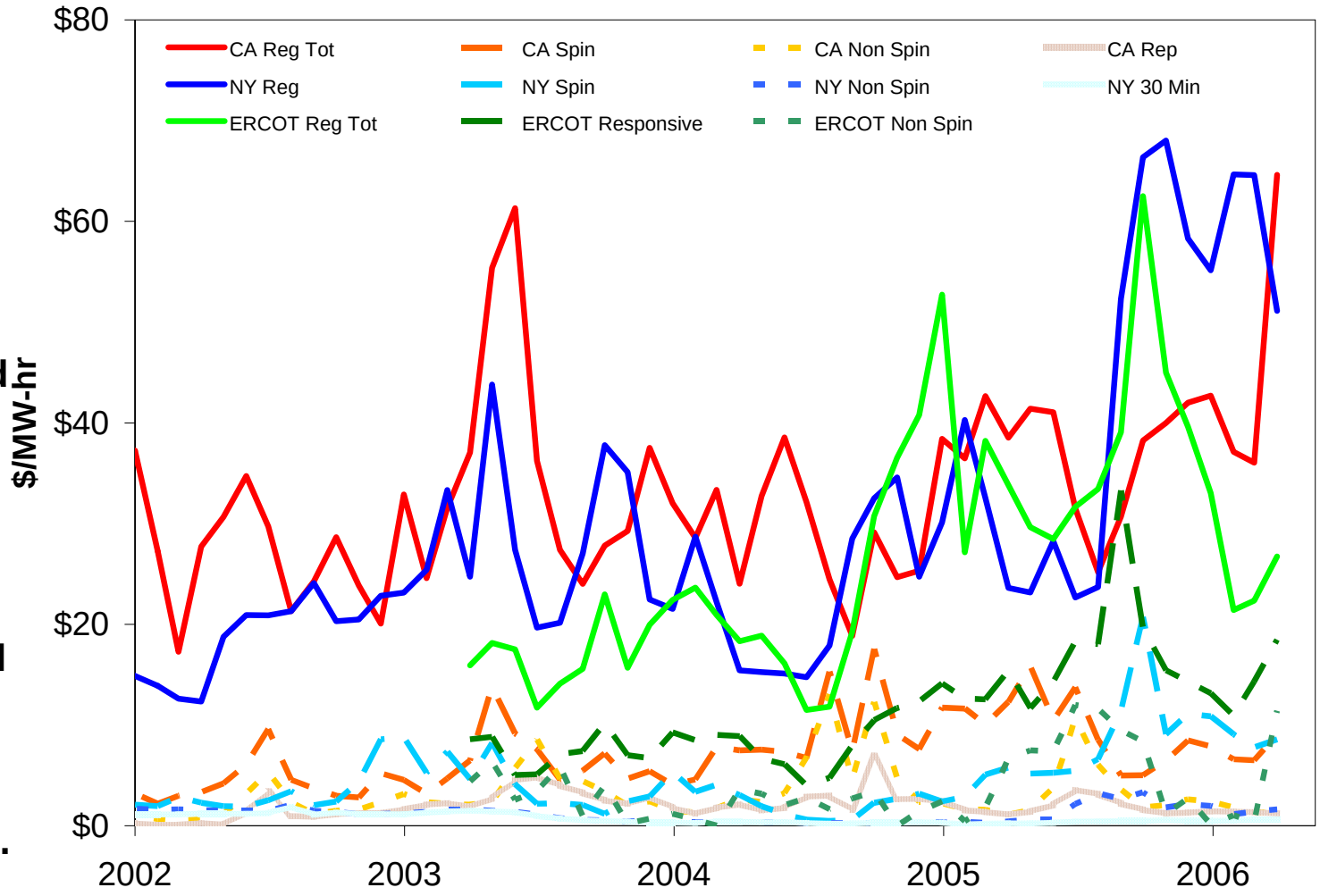


Supplying 15 MW of Regulation from Aluminum Smelter



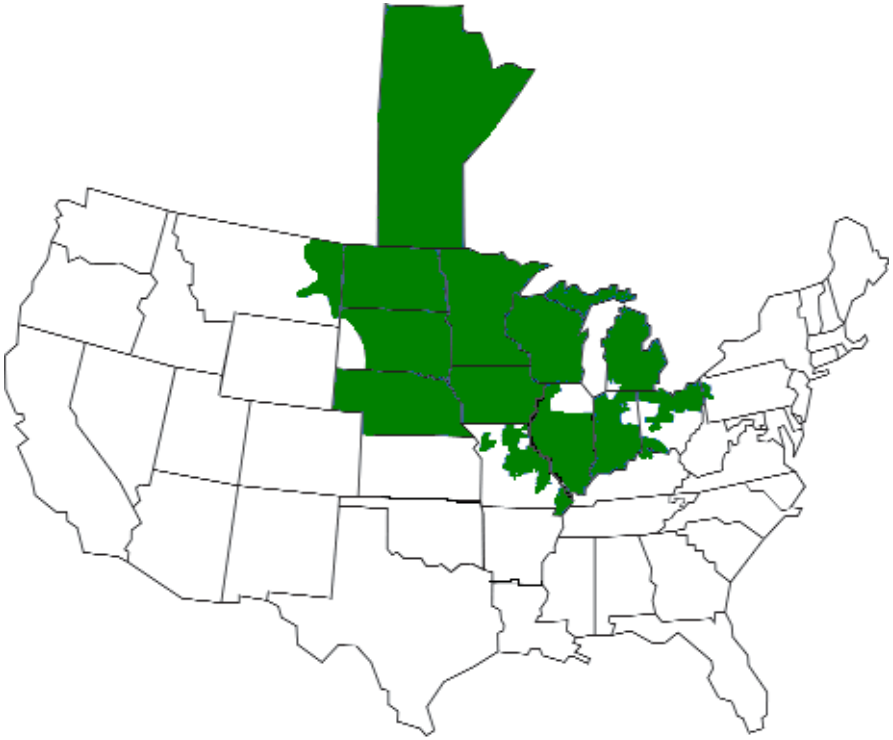
Ancillary service pricing - regulation is most expensive and replacement reserve is least expensive in all markets

- **Aggregations of responsive load, renewable generation and storage will be modeled using probabilistic methods.**
- **Renewables and load will respond to the market.**
- **This will greatly increase transmission efficiency because transmission will not have to be kept unloaded in order to supply reserves from distant locations.**



Storage, Responsive Load and Renewables Will Work Together Over the Whole Balancing Area

- **Ancillary services, (regulation, spinning reserve, voltage regulation) supplied from loads and renewable resources.**
- **Statistical planning of responsive load and renewable generation.**



Midwest ISO Footprint,

The MISO will be one BA soon.

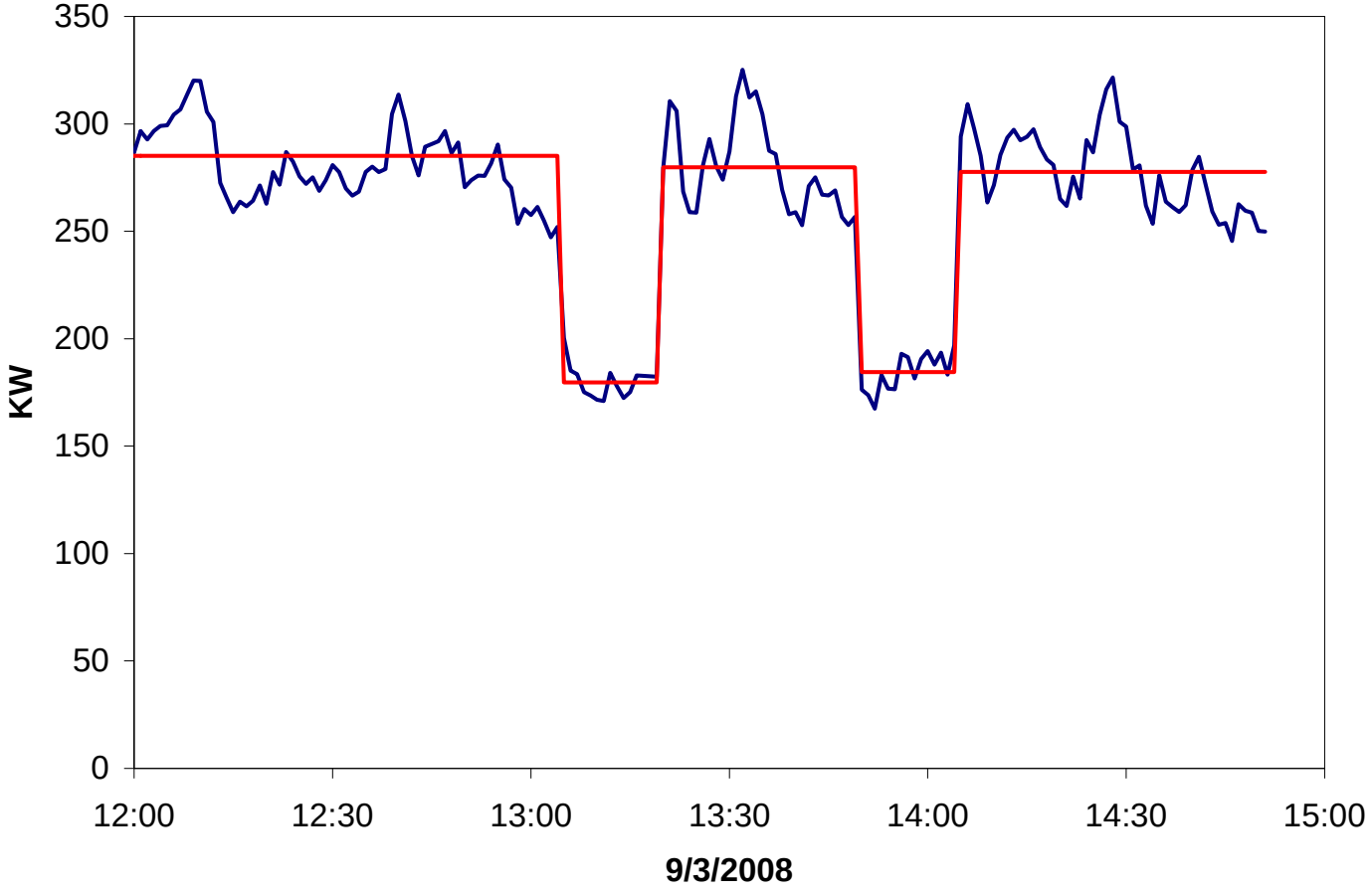
Midwest ISO Previous Balancing Authorities

MIDWEST ISO	MIDWEST ISO Member		MIDWEST ISO Member
MRO	Yes	**RFC**	Yes
Alliant Energy – CA –ALTE	Yes	Cinergy Corporation	Yes
Alliant Energy – CA – ALTW	Yes	City Water Light & Power	Yes
Dairyland Power Cooperative	Yes	DECA, LLC – Vermillion	Yes
Great River Energy	Yes	First Energy Corp.	Yes
Lincoln Electric System	Yes	Hoosier Energy	Yes
Madison Gas and Electric Company	Yes	Indianapolis Power & Light Company	
MHEB, Transmission Services	Yes	LG&E Energy Transmission Services	
MidAmerican Energy Company	Yes	Michigan Electric Coordinated Systems	
Minnesota Power, Inc	Yes	Northern Indiana Public Service Company	
Muscatine Power and Water	Yes	Ohio Valley Electric Corporation	
Nebraska Public Power District		Southern Indiana Gas & Electric Co.	
Northern Sates Power Company		Wisconsin Energy Corporation	
Omaha Public Power District			
Otter Tail Power Company			
SaskPower Grid Control Centre			
Southern Minnesota Municipal Power Agency			
Upper Peninsula Power Co.			
Western Area Power Administration – Upper Great Plains East			
Wisconsin Public Service Corporation			
SERC	Yes	**SPP**	Yes
Ameren Transmission	Yes	Aquila networks – MPS	
Illinois Power Co.	Yes		
Central Illinois Light Co.	Yes		
Southern Illinois Power Cooperative	Yes		
Columbia Water & Light			

Testing Hotel Spin Response

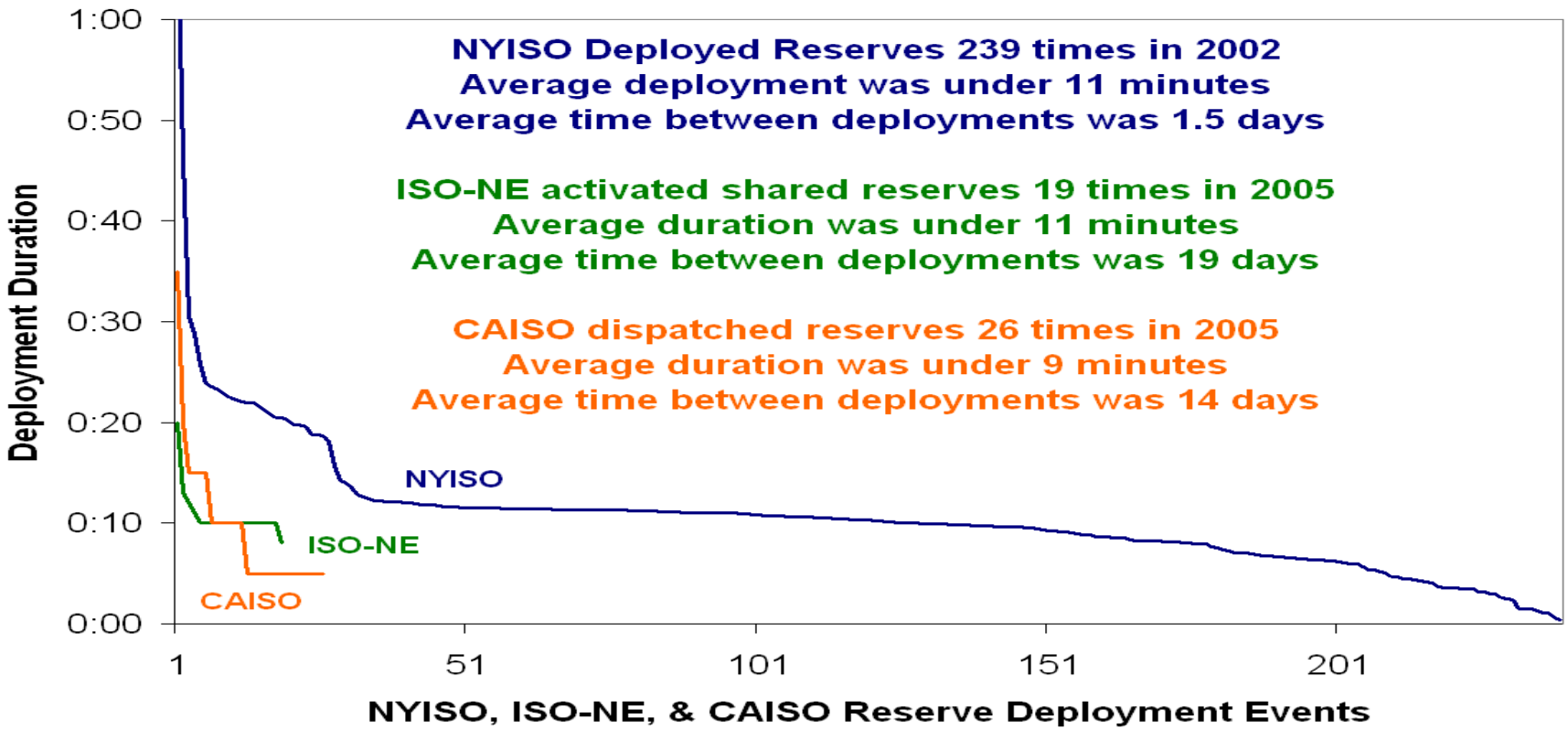
- **Digital Solutions Inc PTAC and central unit controllers**
- **Primary function is energy savings**
- **Modified to respond to system operator commands, frequency, and voltage**
- **Control of 162 rooms & 14 hallway PTACs**

Response is Fast and Accurate – Much Faster Than Generation



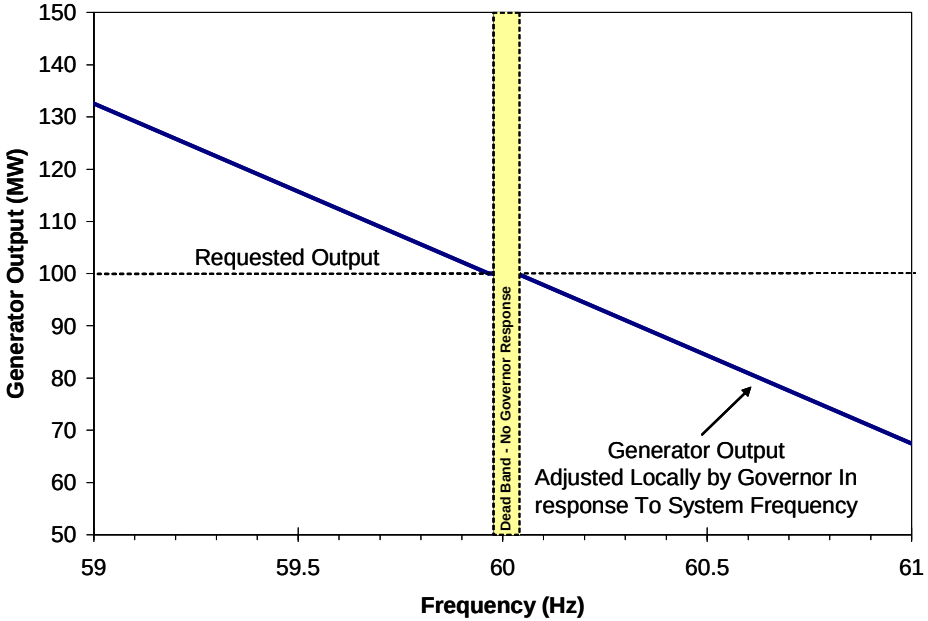
Reserve Deployments Typically Short But Occasionally Long

Power System Need Matches Load Response Capability

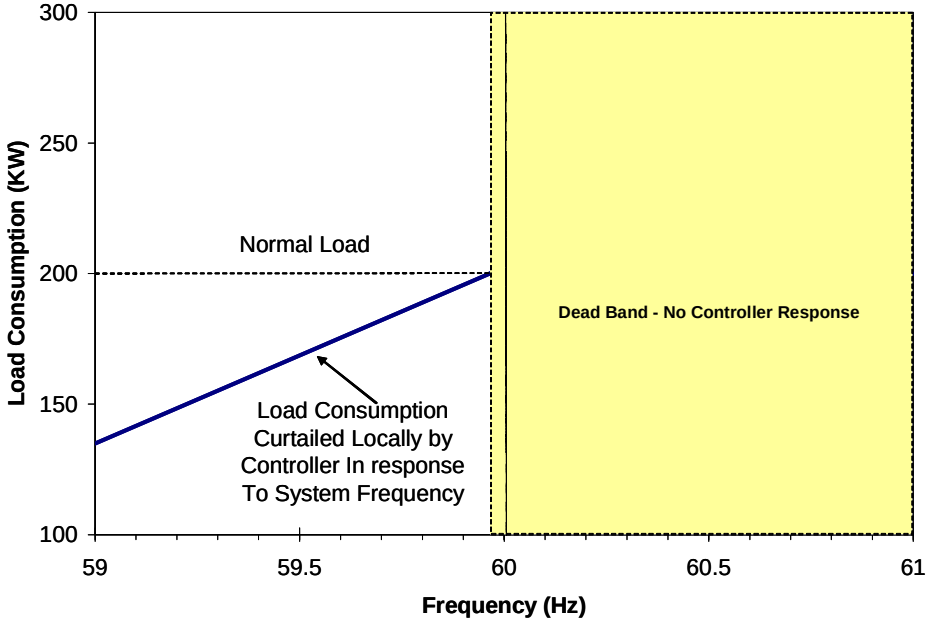


Frequency Response

Generator

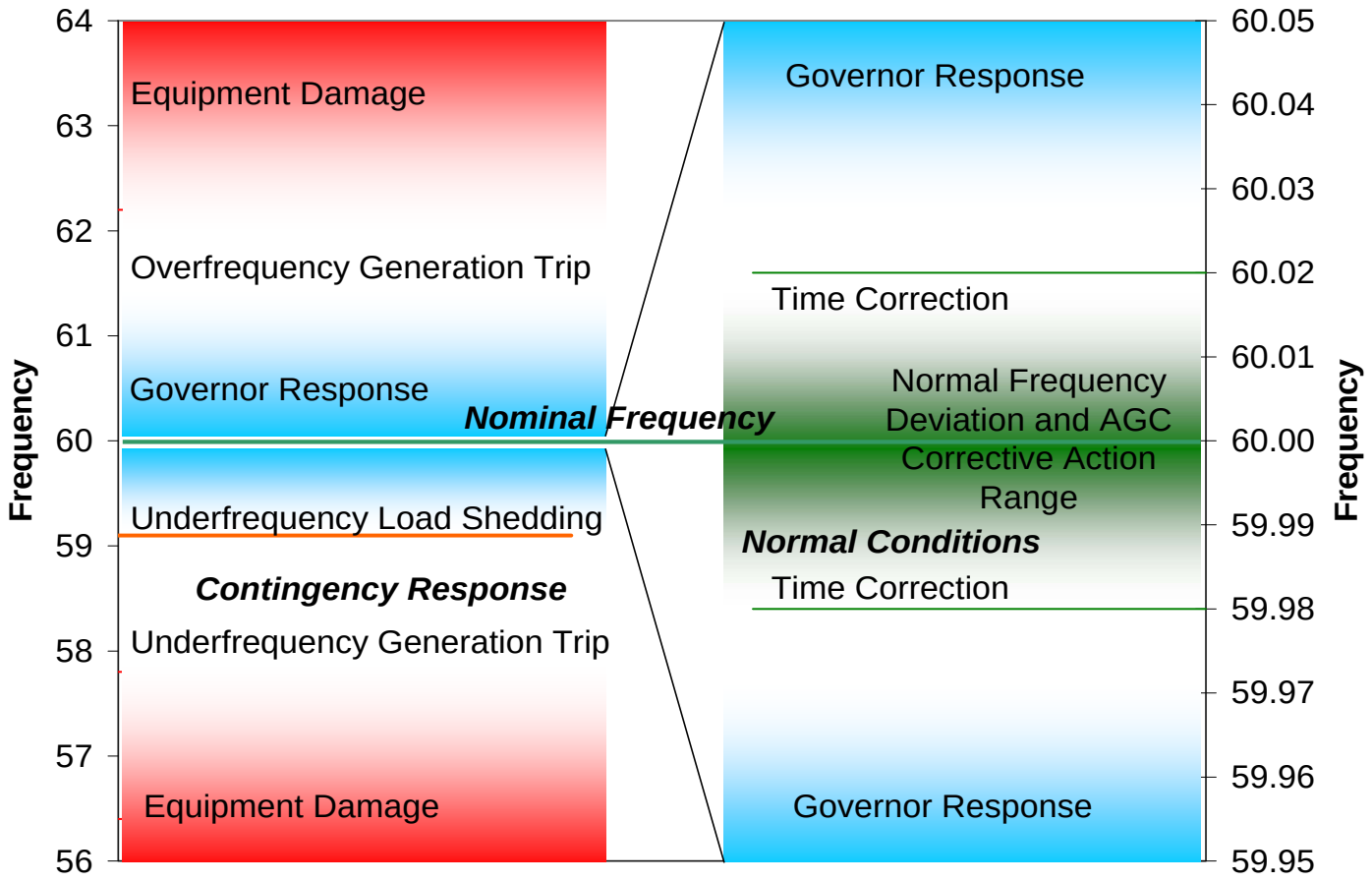


Load



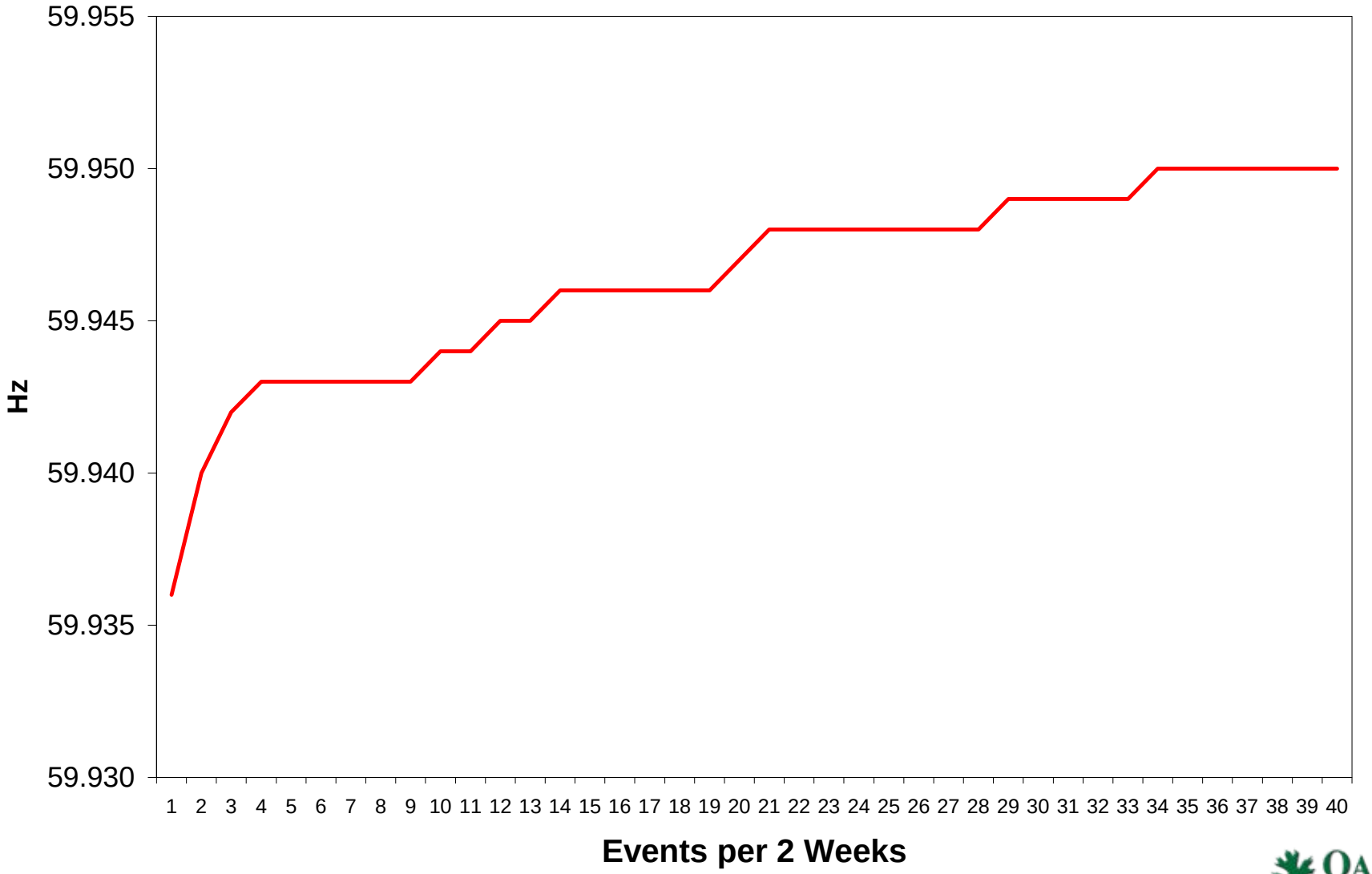
For loads to supply spinning reserve, they too must respond to power system frequency deviations.

Power System Frequency Is Tightly Controlled



Responsive loads must respond in the governor response range.

Eastern Interconnection Frequency History 6/24/08 to 7/8/08



The Fast Response of Load Actually Improves System Response to Contingencies

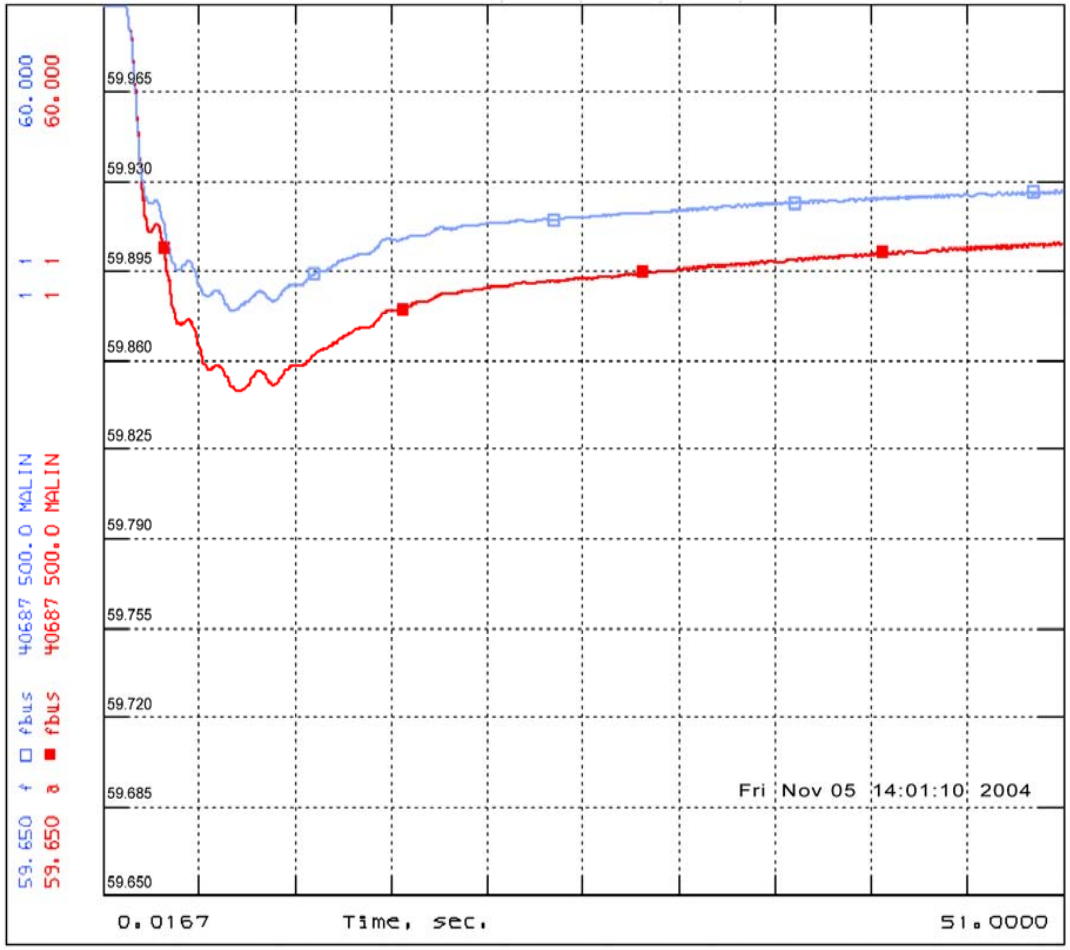


Fig. . WECC system stability is enhanced when 300 MW of responsive load (upper blue curve) replaces an equal amount of generation (lower red curve). Stability runs performed by Donald Davies of WECC.