GRID 2020 Discussion: Transactive Energy & Distributed Markets

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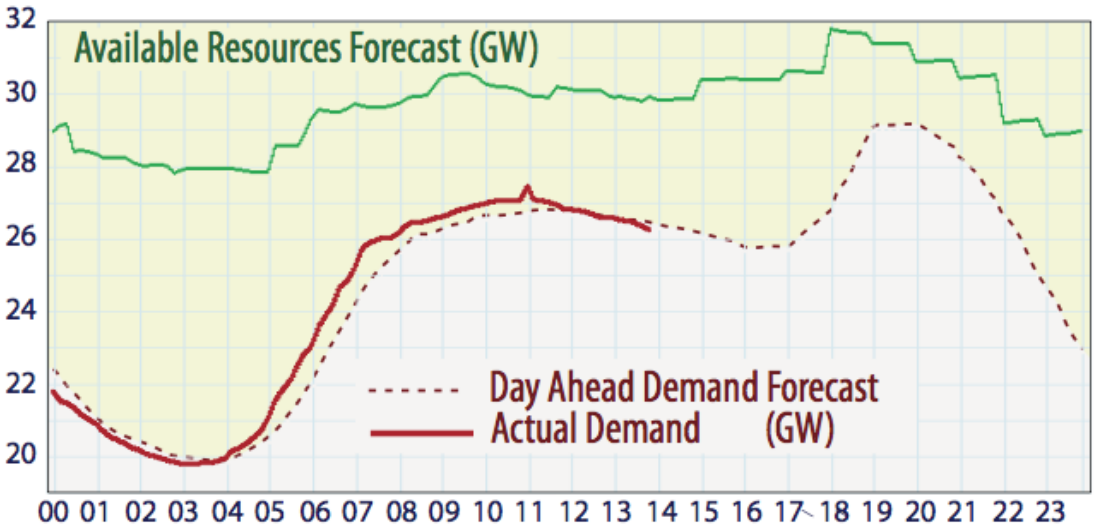
Why we are here

Certain Generation

"Inelastic" Load



California ISO
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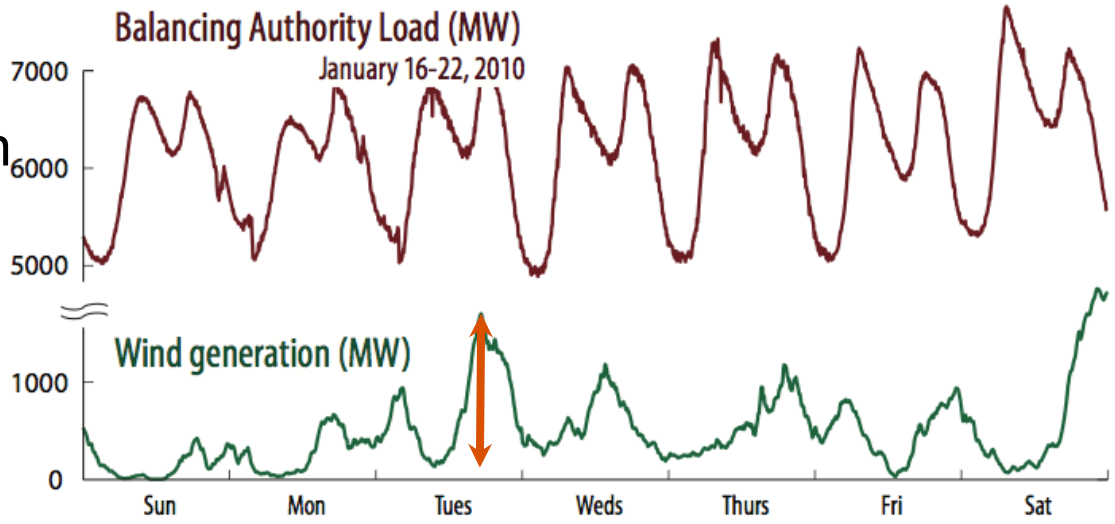
Uncertain Generation

"Elastic" Load



Introduction

- To prevent a loss in social welfare, better control systems and better demand responses are required.

- The Goal: Economic efficiency and Robust control.
  - E: maximize benefits – costs
  - R: a 99.9999% reliable system

- There have been two basic policy approaches in wholesale markets.
  - One is a control-based approach: focused on R
  - The other is a market-based approach: focused on E

- Do they apply to distribution networks?

The market-based approach
(if reliability is not sacred)

- "Let there be markets and there will be economic efficiency."
  - A strong belief the first welfare theorem of economics.

- The policy recommendation for distribution:
  Let consumers face market prices and participate in RTM.

- The good news:
  with enough markets and competitive behavior
  - E: The equilibrium allocation maximizes surplus
  - R: load = generation; no need for reserves
    - This simplifies the control.

The bad news

- There never are "enough markets."
  - Some missing markets can be replaced with contingent bidding but that is informationally and computationally complex.
- Market equilibrium is not instantaneous.
  - The assumption that market equilibrium is realized at every instant of time and in every state is totally unrealistic.
- The model is not robust to frictions.
  - Unanticipated events after equilibrium computation
  - Lags in the price discovery process
  - Can easily lose reliability; require more reserves.

The control-based approach
(if efficiency is not paramount)

- "Let there be control and there will be reliability."
  - A strong belief in the ability to know everything and control everything appropriately on time.

- The policy recommendation for distribution:
  Directly control consumers' devices.

- The good news:
  with enough control devices and communication
  - R: Tight control provides robust reliability
  - E: Smart meters allow consumer input; no need for markets
    - This simplifies the economics.

The bad news

- There is never "enough communication."
  - Consumers may be unwilling (due to incentives) or unable (due to complexity) to provide needed information.
- Ignores two types of information that are key to improving surplus and efficiency.
  - Closing markets a day ahead of time (or even 5 minutes ahead of time) ignores all new, last-minute cost and benefit information.
  - A "phase lag" controller ignores information required for "efficient rationing".
- Provides little incentive for innovation to improve economic efficiency.

Summary to here

- The Market based approach
  - The primary goal is economic efficiency.
  - Tries to mimic competitive markets and pass wholesale prices through to the consumer.
  - Affords insufficient attention to reliability, information processing, and computation issues.

- The Control based approach
  - The primary goal is robustness.
  - Tries to mimic airplanes and pass controls through to the consumer.
  - Affords insufficient attention to efficiency issues, market responses, and incentive compatibility constraints

A Case study: Prices to Devices

- Passes both controls and prices through to consumers in real time.

- Sounds like a good idea
  - For the market advocate:
    - Reduces the need for operating reserves
    - Increases benefits, reduces costs
  - For the control advocate:
    - Real time demand response on a short time scale
    - Direct access to new reserves

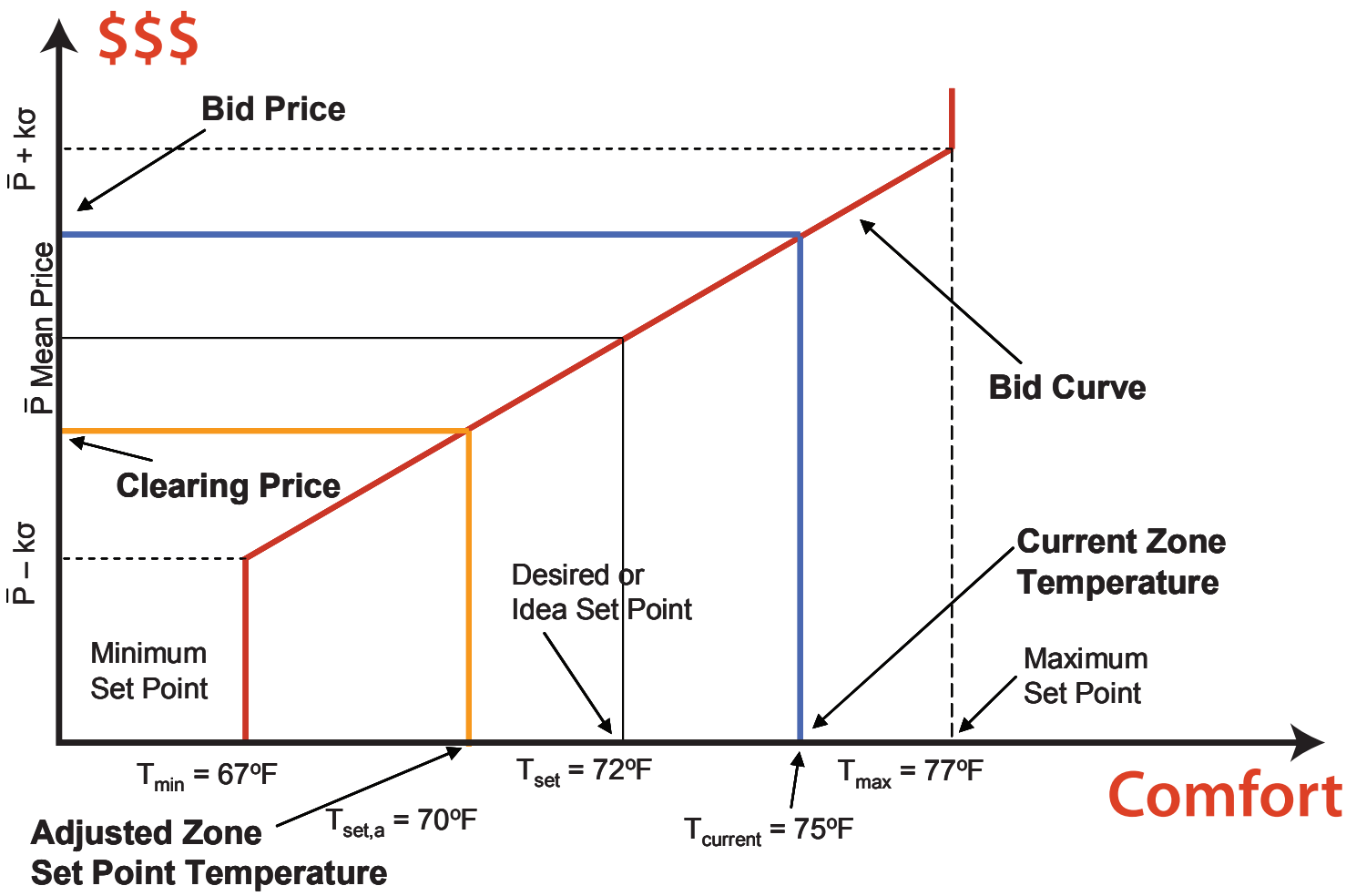
- Let's consider an example:
  - Thermostatically controlled HVAC

How it works

- The user programs the thermostat to set the temperature to T(p) when the market sends the price p.
- The RTM computes p' and sends to device.
- The device resets the temperature by T(p').
- The new demand, e(T(p')), hits the grid and must be supplied.
- The RTM computes new p" and sends to device.

- In equilibrium, the market is responsive to consumer preferences and demand responses help reliability.

Automated "trading" in the market



Transactive Controls: Market-Based GridWiseTM Controls for Building Systems
Pacific Northwest National Laboratory 2006

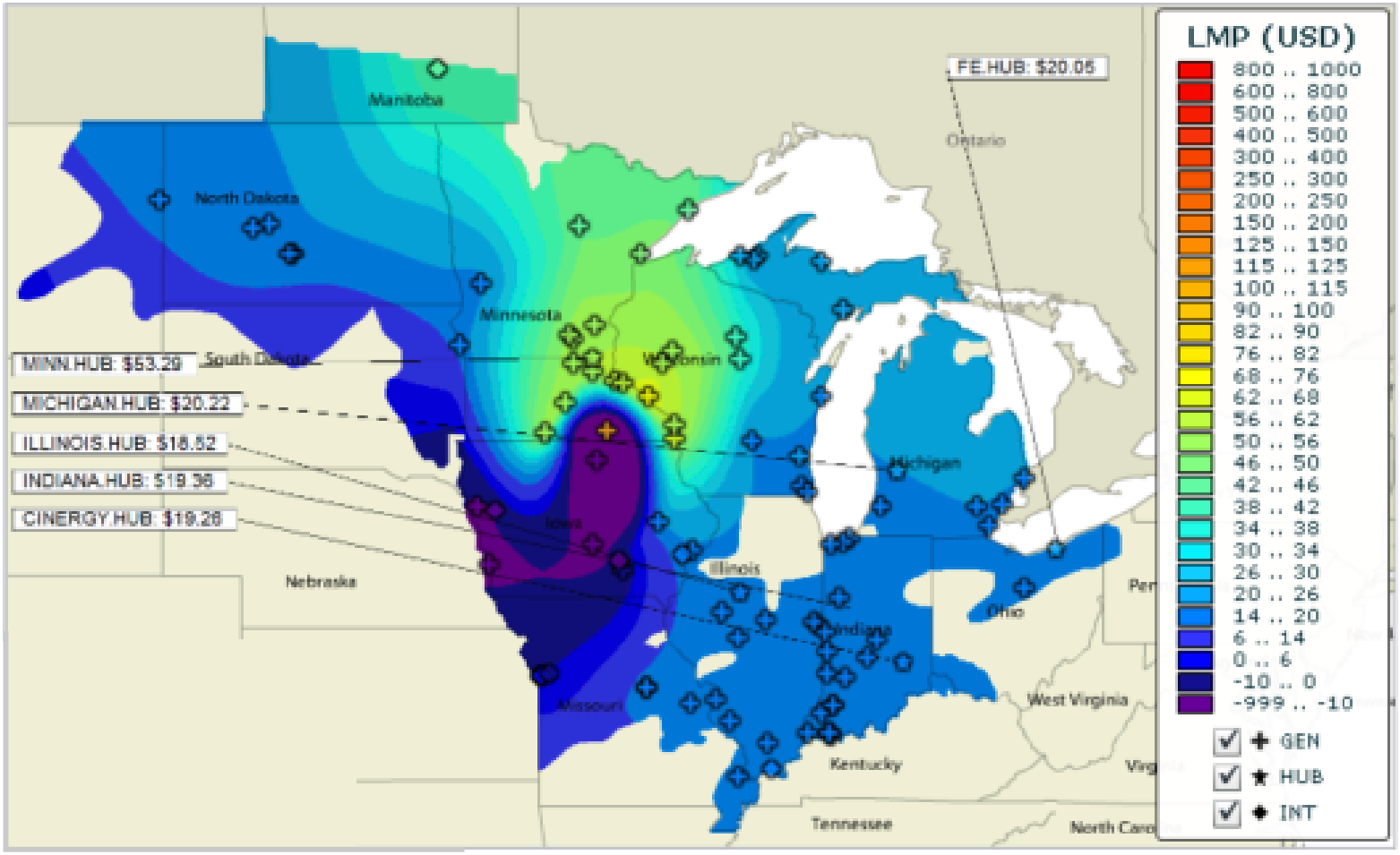
Prices to devices

- In equilibrium, the market is responsive to consumer preferences and demand responses help reliability.

- The problem: volatility and lagged response.

Winds Cause Price Spikes

Midwest ISO today: Friday afternoon, March 4, 2011 3:30 p.m.



Winds Cause Price Spikes

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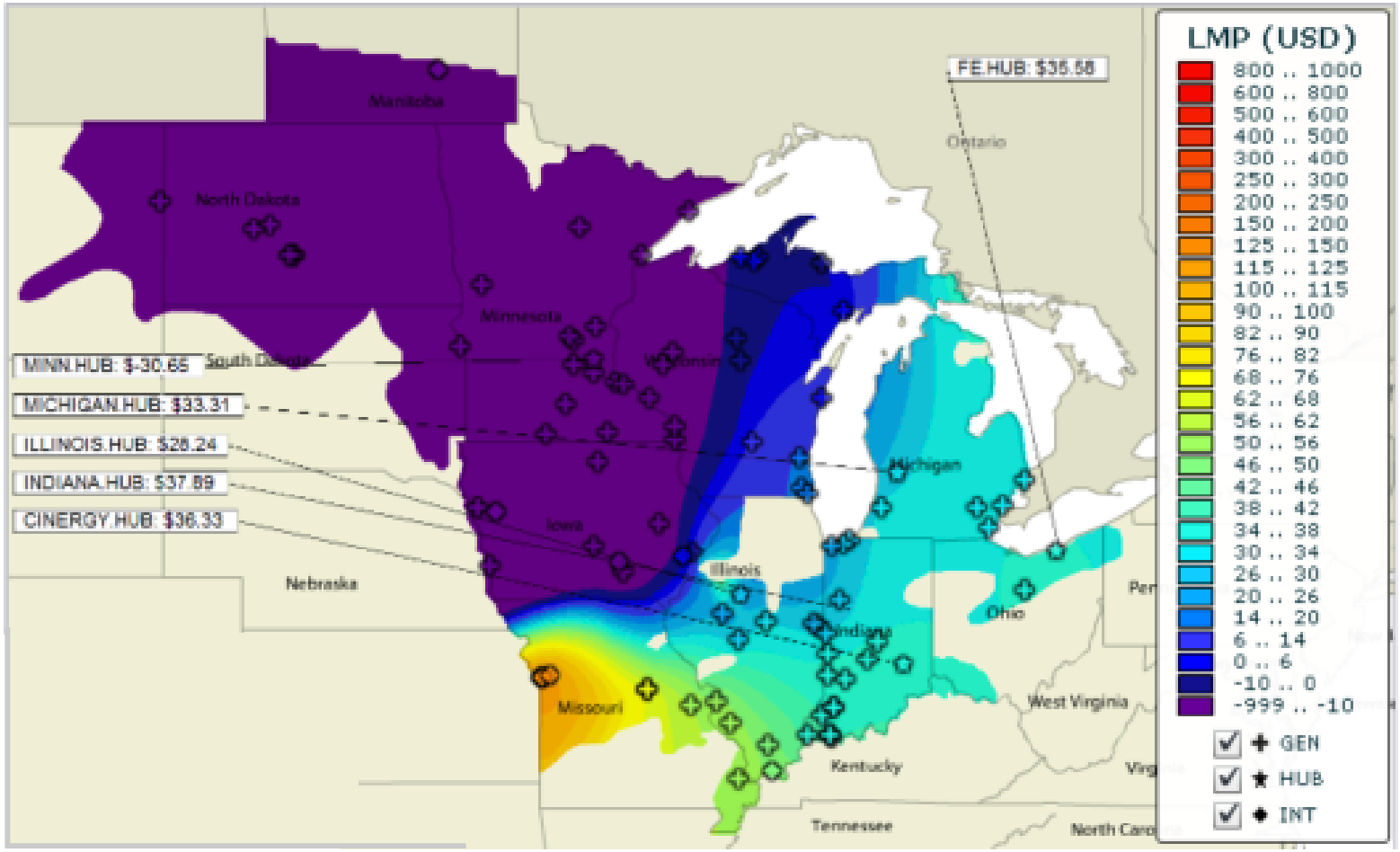

Winds Cause Price Spikes

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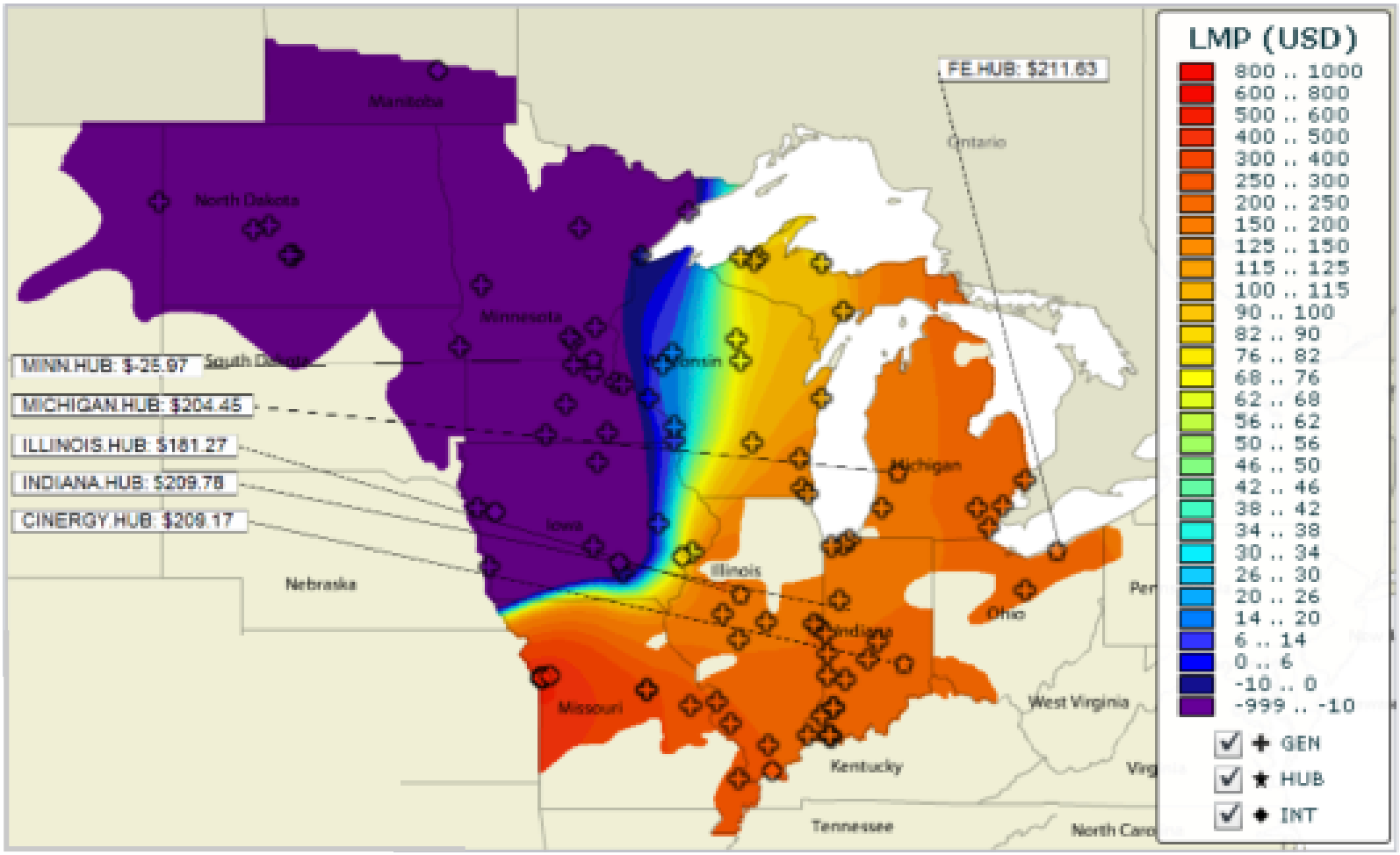

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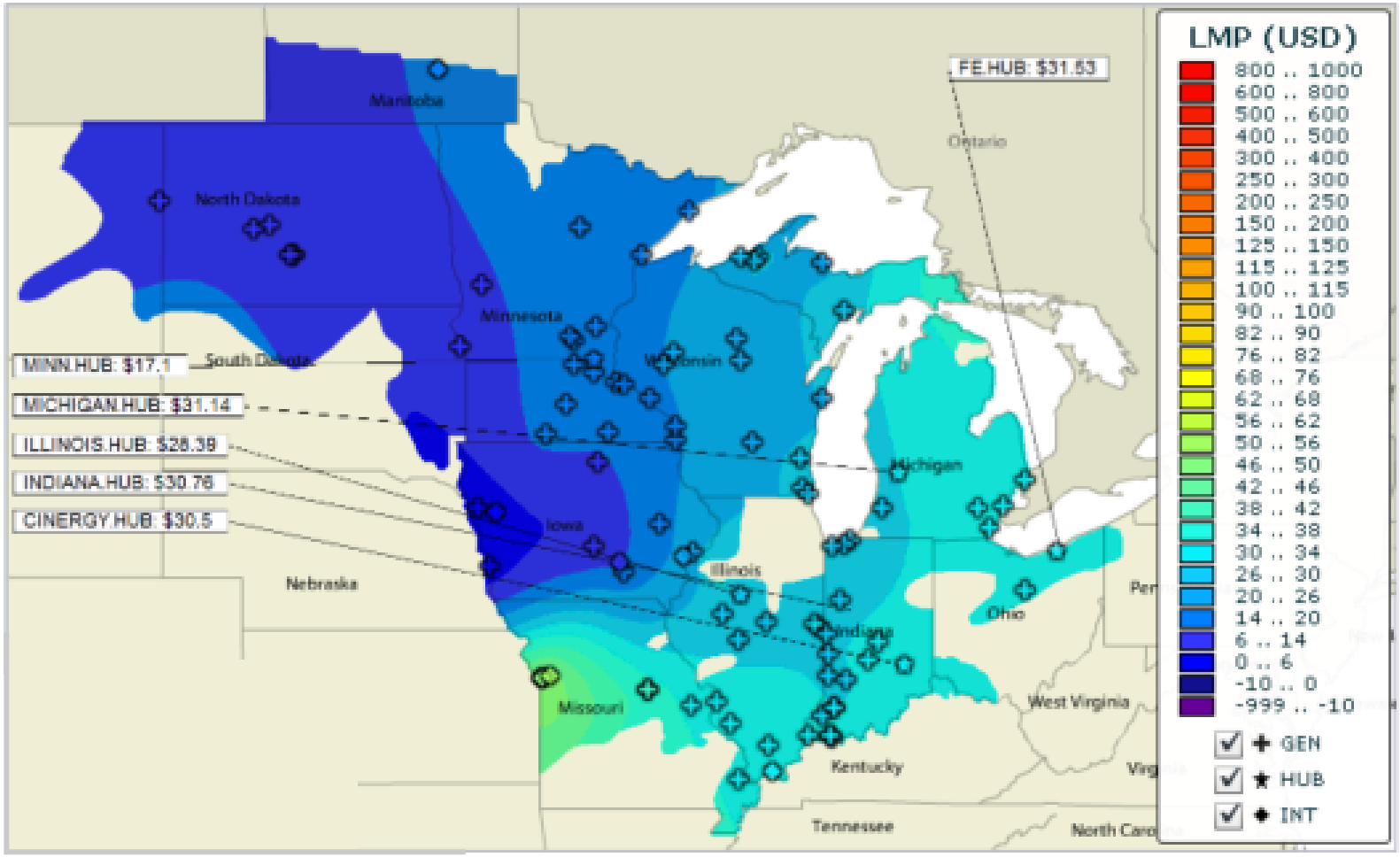


The analysis of dynamics

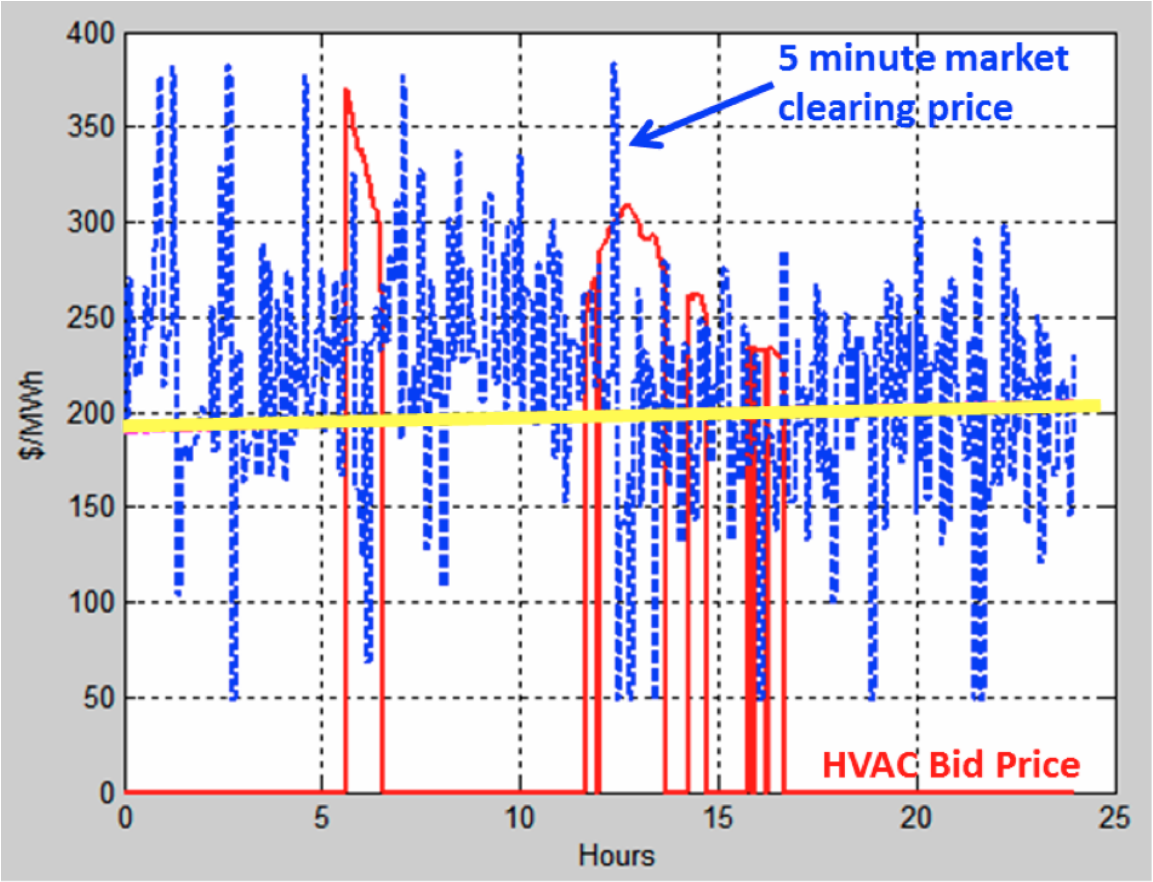
- Let P_{t-1} = price in the most recent RTM (5 min).
- $E(T(P_{t-1}))$ is the Demand Response.
- The price in the next RTM satisfies $E(T(P_{t-1})) - S(P_t) = 0$.

- A linear approximation of the price dynamics is

$$P_t = P^* + (E'/S')(P_{t-1} - P^*)$$

- This is stable iff $|E'/S'| < 1$.

- It is <u>unstable</u> if the distribution market is more price responsive than the wholesale market.
  - E(p) = Ne(T(p)) so as N grows, problem becomes worse.



Source: PNNL Transactive Control

Price Volatility from Responsive Demand under Real-time Pricing

The bad news

- The problem – proportional control
  - Price increase implies immediate drop in load, which can create an undesirable phase imbalance in the distribution circuit since many loads are connected to only one or two phases
  - Price drop triggers resumption in consumption, creating the oscillations a control theorist would expect from a high gain feedback loop.

- As currently conceived, this is bad for both market-based and control-based approaches.
  - Market failure
    - Never in equilibrium, lower surplus
  - Control failure
    - More volatility, lower reliability

- This would be a disaster.

The RTM paradigm must be reconsidered.

- Current policy patterns have applied wholesale spot market principles, developed for balancing large centralized and transmission connected resources, to distributed resources.
  - This is questionable.

- Need an integrated energy policy.
  - A smart market design that respects the timing and dynamics of price discovery and the constraints of network control.
  - A smart control design that respects the preferences of human participants and the constraints of incentive compatibility.

- At Caltech, a team of economists and control engineers is working on this.

End