



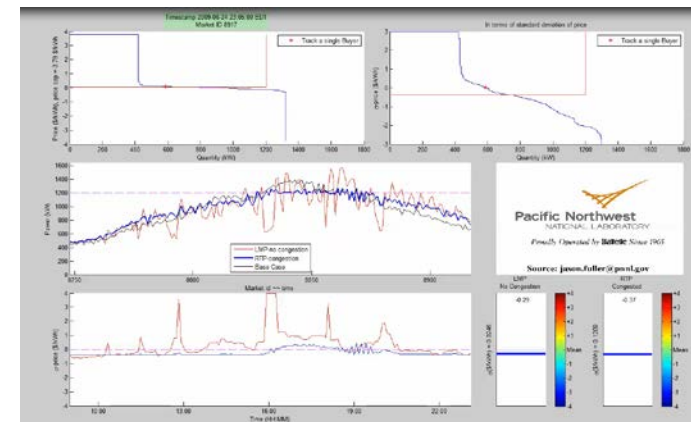
AEP gridSMART[®] RTP Demonstration

Transactive Energy Workshop
Westminister, CA
10 Dec 2013

STEVE WIDERGREN
Energy & Environment Directorate
Richland, WA

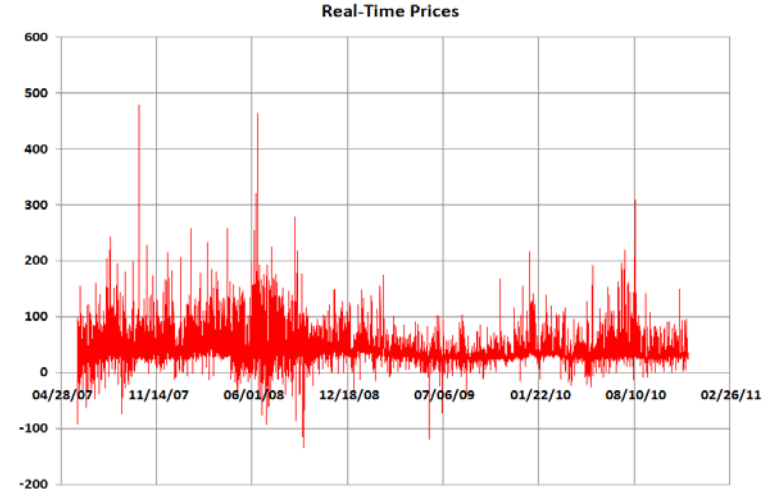
gridSMART® RTP Demo Summary

- ▶ First real-time market at distribution feeder level with a tariff approved by the PUC of Ohio
- ▶ Value streams
 - Energy purchase benefit: function of PJM LMP
 - Capacity benefits: distribution feeder and system gen/trans limitations, e.g., peak shaving
 - Ancillary services benefits: characterized, but not part of the tariff
- ▶ Uses market bidding mechanism to perform distributed optimization – transactive energy
 - ~200 homes bidding on 4 feeders
 - Separate market run on each feeder
 - “Double auction” with 5 minute clearing
- ▶ HVAC automated bidding
 - Smart thermostat and home energy manager
 - Homeowner sets comfort/economy preference
 - Can view real-time and historical prices to make personal choices

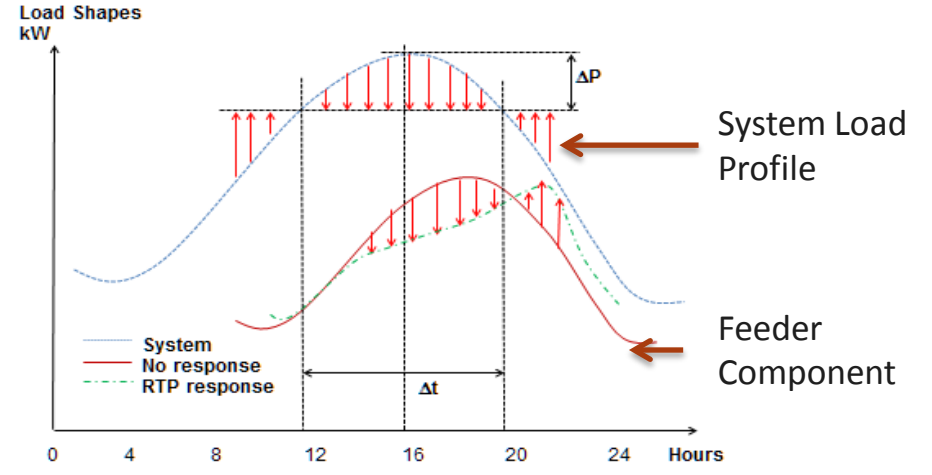
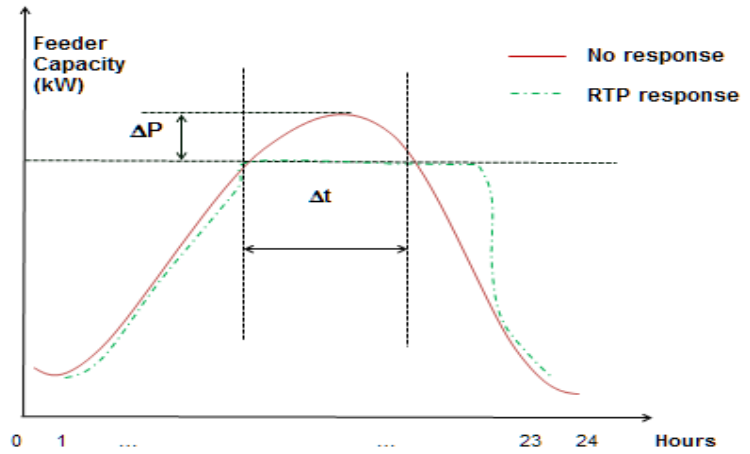


RTP Value Streams

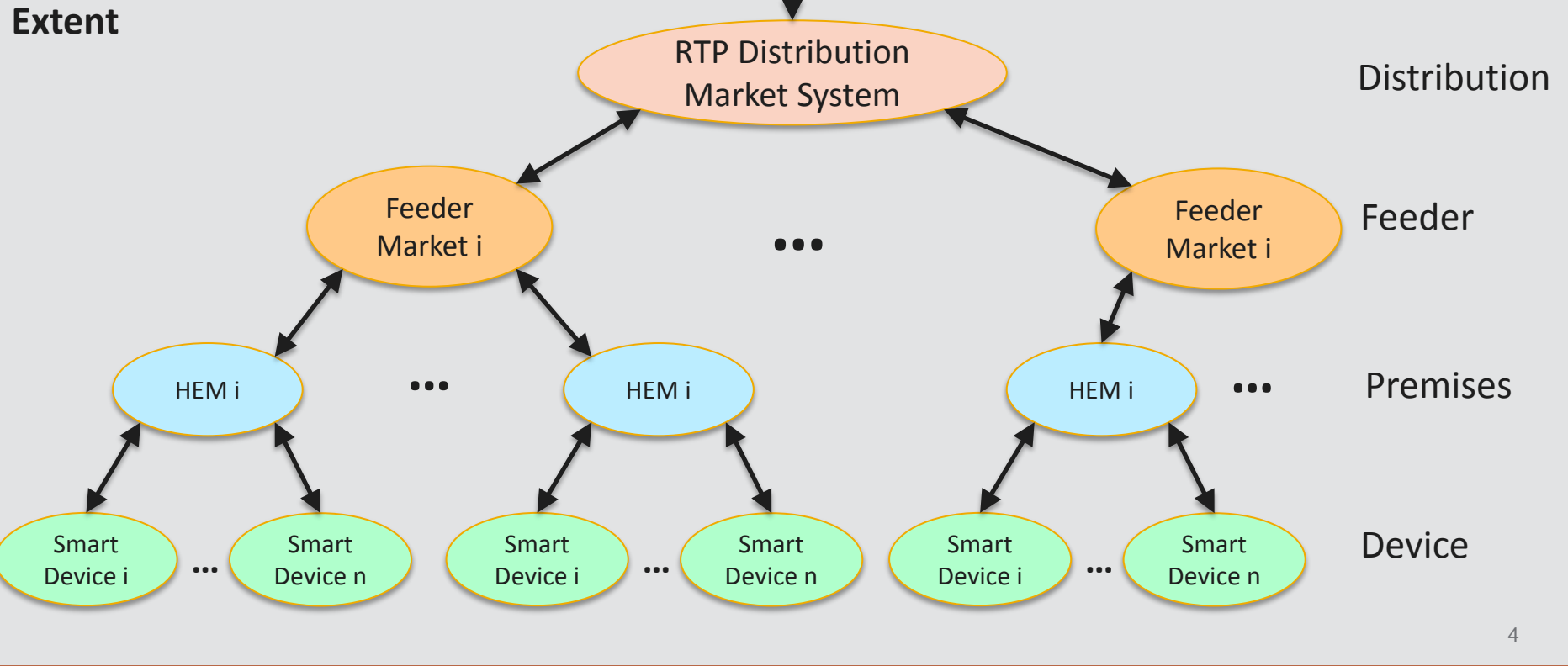
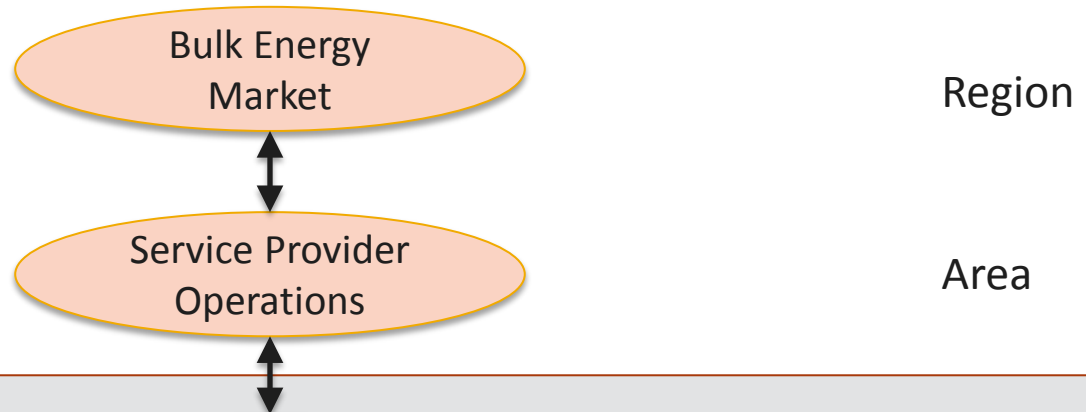
- ▶ Energy purchase benefit
 - Respond to whole energy market price fluctuations
- ▶ Capacity benefits
 - Local constraints: distribution feeder capacity
 - System constraints: generation or transmission equipment limitations
- ▶ Ancillary services benefits
 - Spinning reserves, ramping, regulation
 - No direct experiment in the demonstration



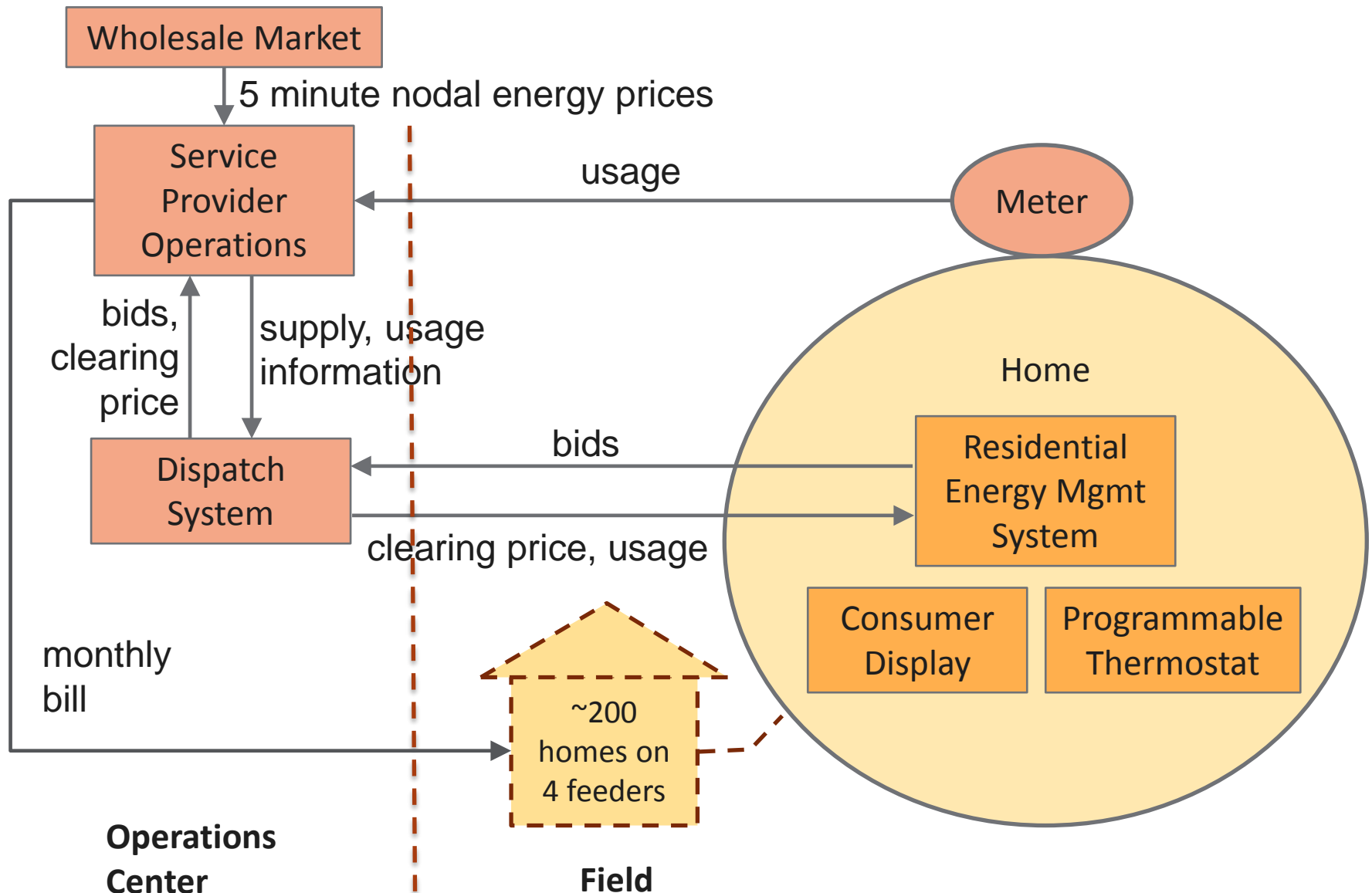
PJM LMP for the period June 2007 to November 2010.



Architecture



Extent



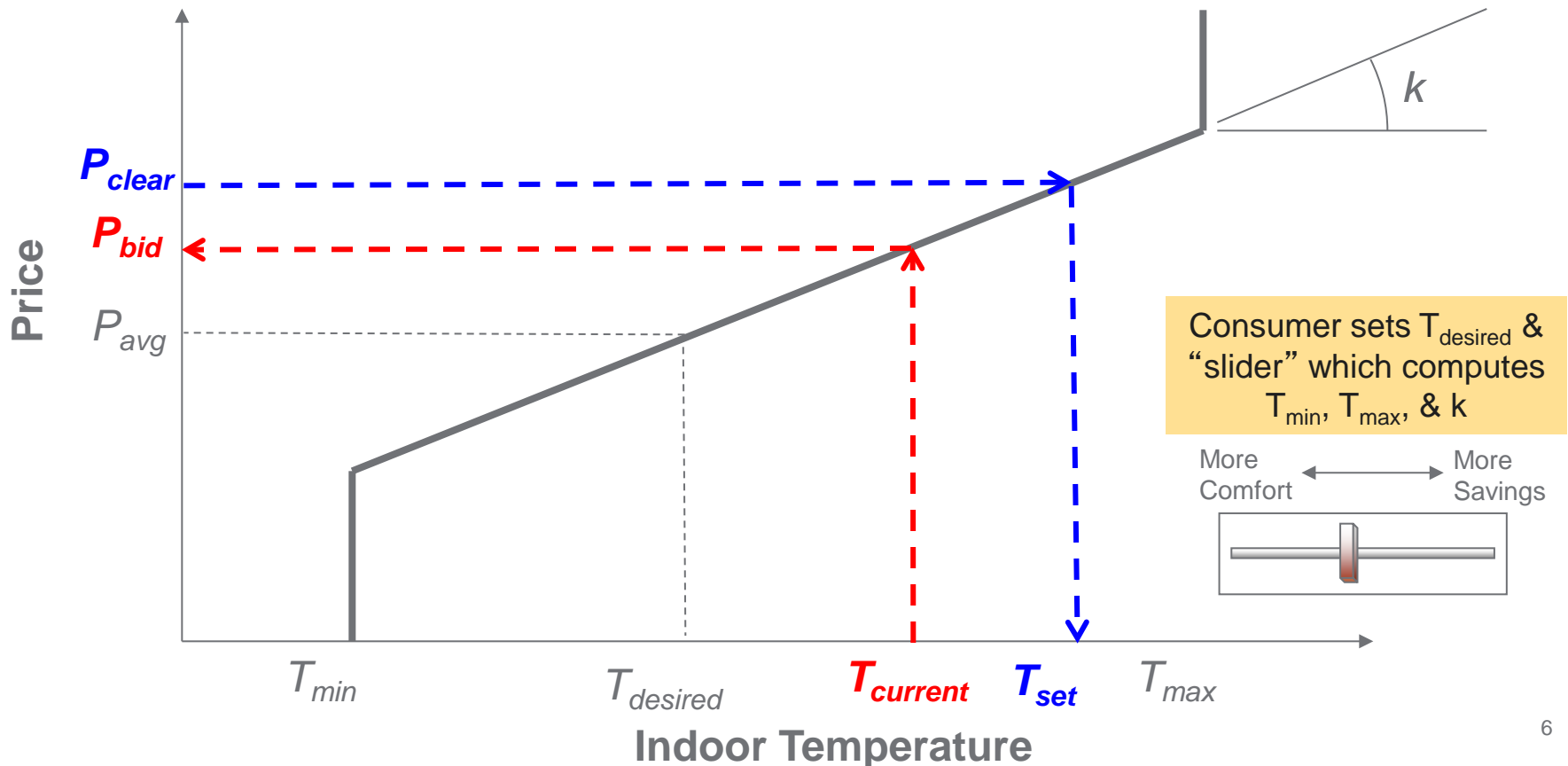
Thermostat Agent in Double-Auction Market

Cooling Example

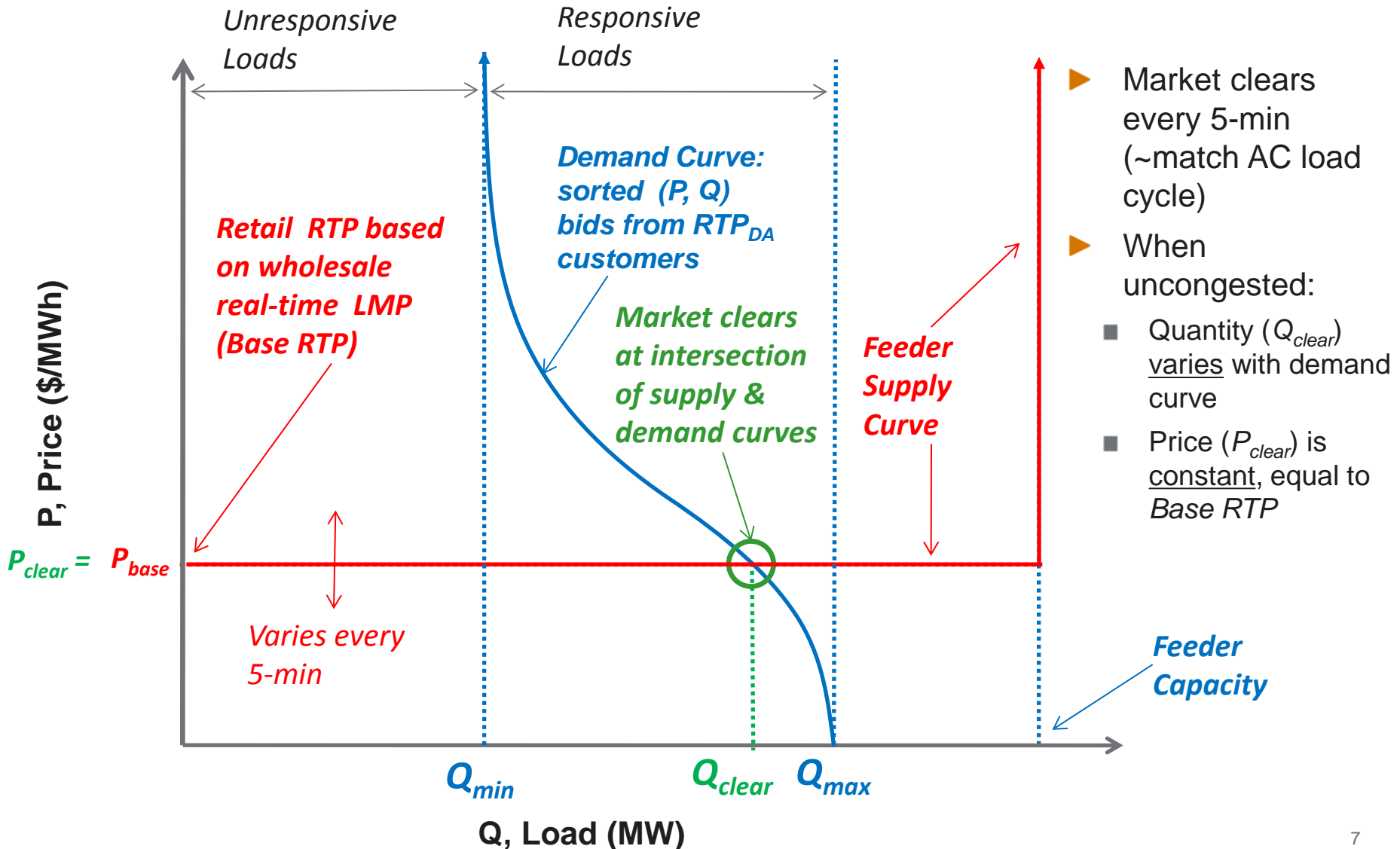
Tstat: bids quantity (power of AC) & price at which AC will “run” based on $T_{current}$

Market: sorts bids & quantities, clearing price set to manage quantity to any capacity limit

Tstat: adjusts setpoint to reflect clearing price

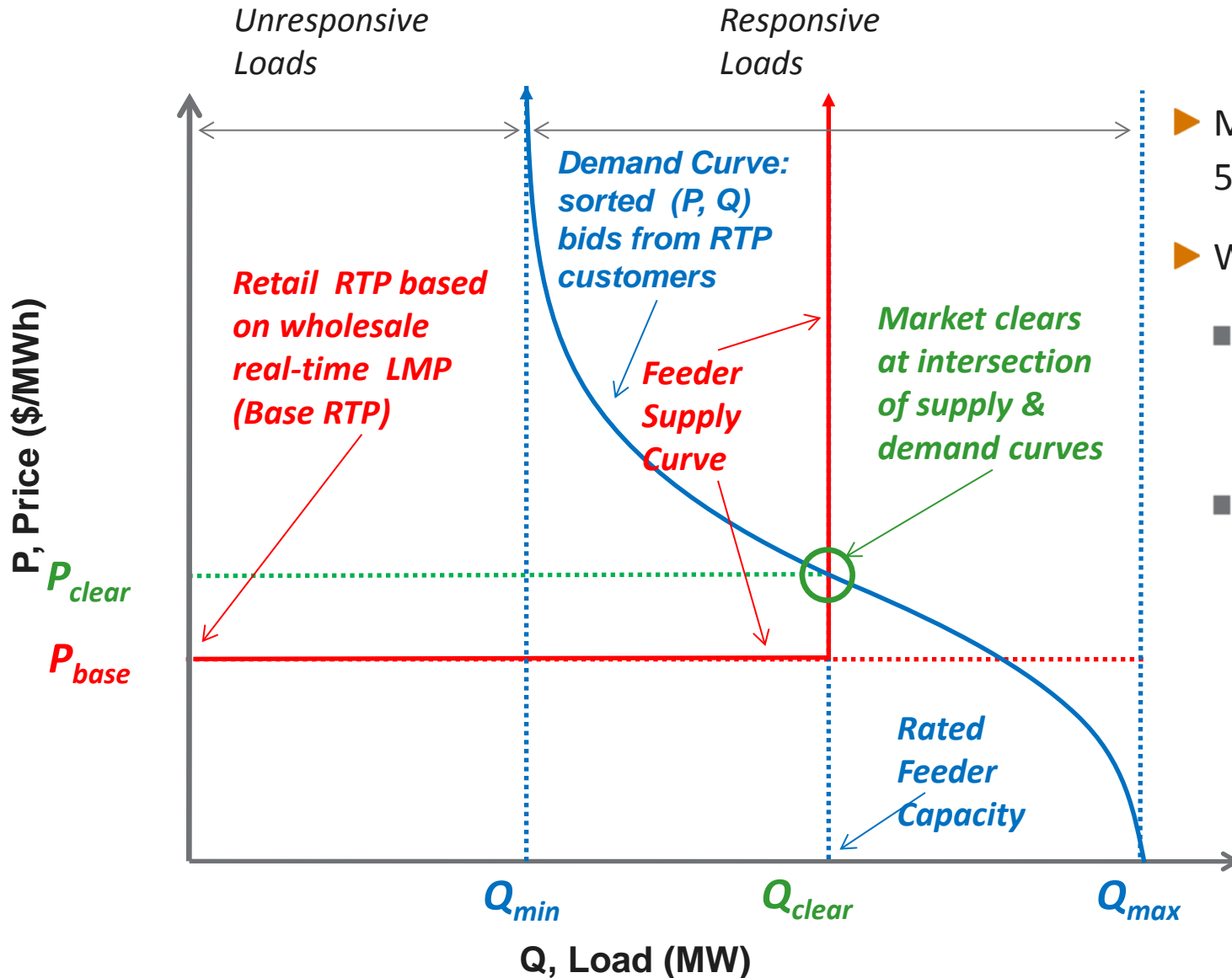


RTP Uncongested Conditions



- ▶ Market clears every 5-min (~match AC load cycle)
- ▶ When uncongested:
 - Quantity (Q_{clear}) varies with demand curve
 - Price (P_{clear}) is constant, equal to Base RTP

RTP Distribution Congestion

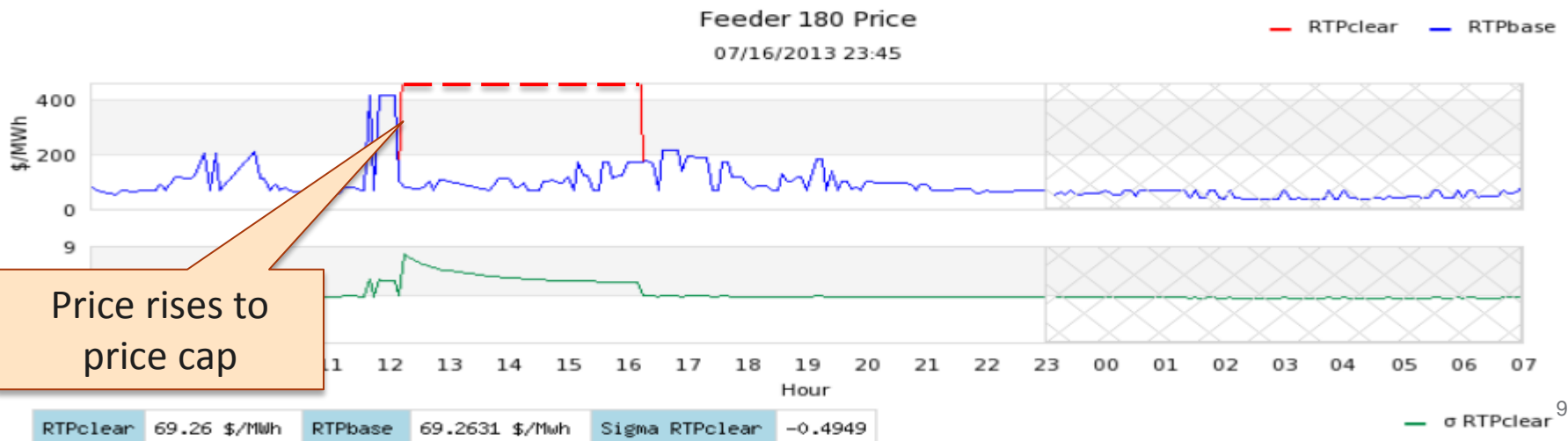
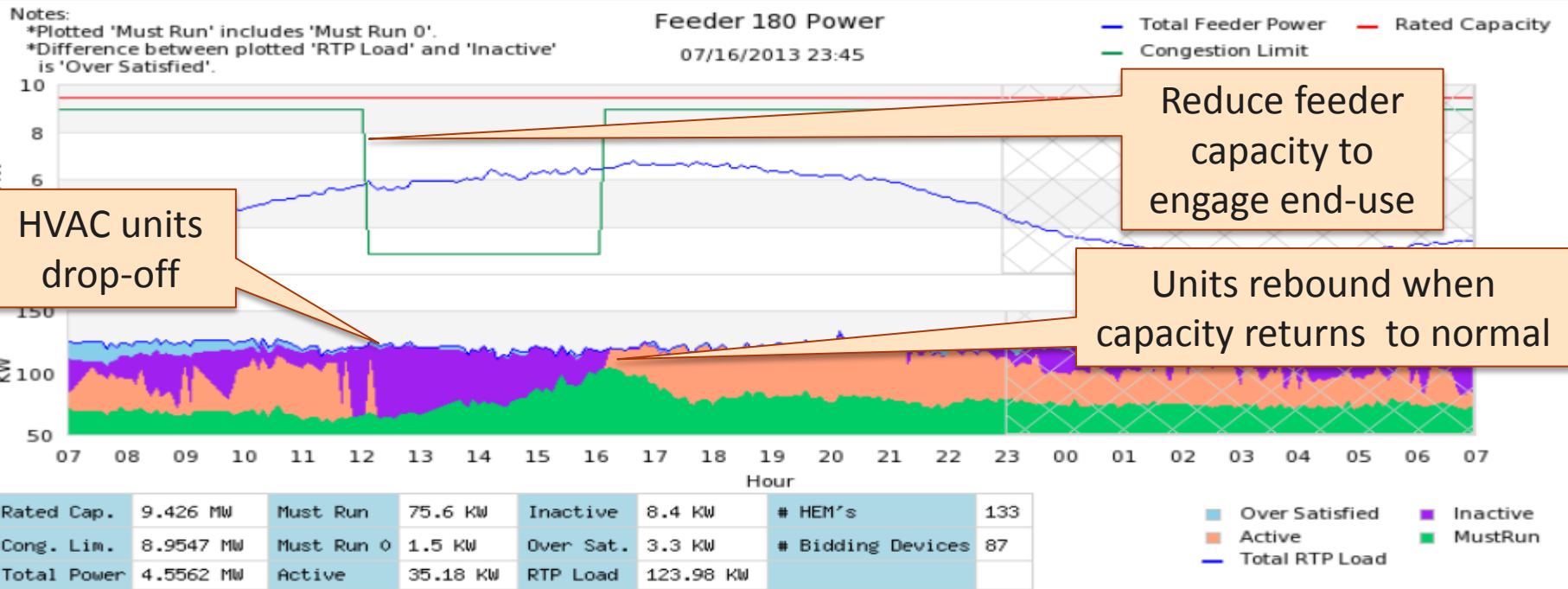


▶ Market clears every 5-min

▶ When congested:

- Quantity (Q_{clear}) is constant at rated feeder capacity
- Price (P_{clear}) varies to keep load at rated capacity

gridSMART® RTP in Action



- ▶ Transactions and parties
 - Smart thermostat bids price and quantity to HEM
 - HEM aggregates price and quantity bids from smart thermostat agents
 - Feeder market system clears market based on
 - Price quantity bids from HEMs
 - Supply bid from system operations
 - Feeder capacity limit
 - Feeder market system communicates cleared market price to HEMs
 - HEM communicates cleared market price to smart thermostat
 - Smart thermostat sets HVAC set point based on cleared market price
- ▶ Temporal variability
 - Demonstration runs on 5 minutes periodic clock
 - If PJM price is not available, a default is used
 - If bid not received from a HEM, the household is not included in the market clearing
 - If market clearing not received by HEM, device uses last cleared price

- ▶ System interoperation was under the control of AEP Ohio
- ▶ All systems and device firmware had some level of customization
- ▶ Messages to smart meter use Zigbee SEP1.x
- ▶ Communications with HEM use a leased cellular network
- ▶ HEM and thermostat firmware is remotely upgradeable
- ▶ Operations systems followed AEP interoperability and cybersecurity procedures
- ▶ System components went through unit and system tests prior to deployment
- ▶ RTP system to HEM communication includes
 - RTP transaction: straightforward price/quantity and clearing price messages
 - Experiment monitoring information: measured household meter data, thermostat settings, internal household temperature

▶ Value discovery

- Smart thermostat agents determine bids based on their determination of the moving average clearing price of energy and their owners' price to comfort flexibility
- RTP market clearing system assembles all supply and demand bids and knowing the feeder capacity clears the market for that feeder
- The cleared price is the discovered value for that auction

▶ Value assignment

- Smart thermostat agents use a 24 hour moving average of a filtered price to determine if energy is expensive or cheap
- Customers price sensitivity and thermostat settings are used with the average price to determine the bid
- HVAC quantity is configured into the thermostat
- Service provider calculates the value to supply energy on the tariff that is a function of the PJM 5 minutes wholesale price
- Service provider can engage the resources by reducing the feeder limit to address other value streams (e.g., critical system peak)

- ▶ Customers
 - Have choices for reducing their bills by being more flexible to price fluctuations
 - Can override or reconfigure their settings at will
- ▶ Service providers
 - Can engage end-use resources for aforementioned value streams
- ▶ RTO/ISO and market operators
 - Engage end-use resources through market mechanisms that can be applied to suppliers and consumers
- ▶ Regulators
 - Can drive greater efficiency in system operations
 - Engage end-use resources for other policy objectives, e.g., reduce emissions, maintain reliability

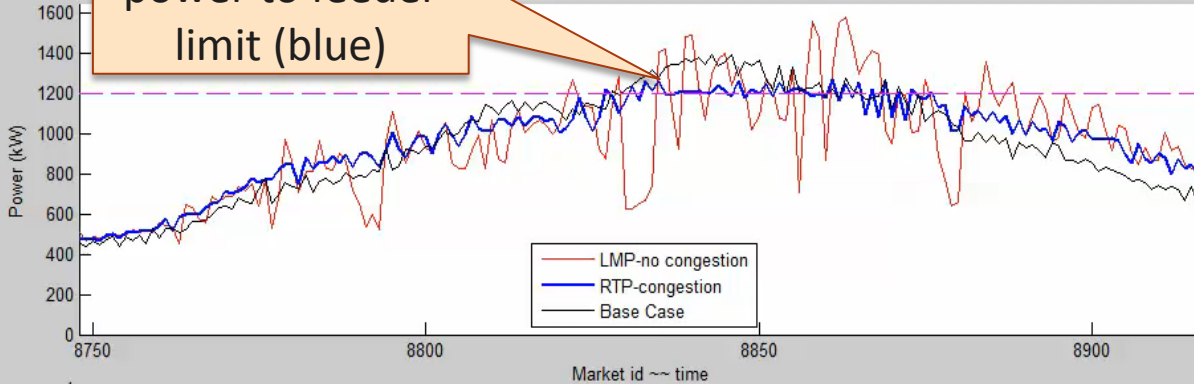
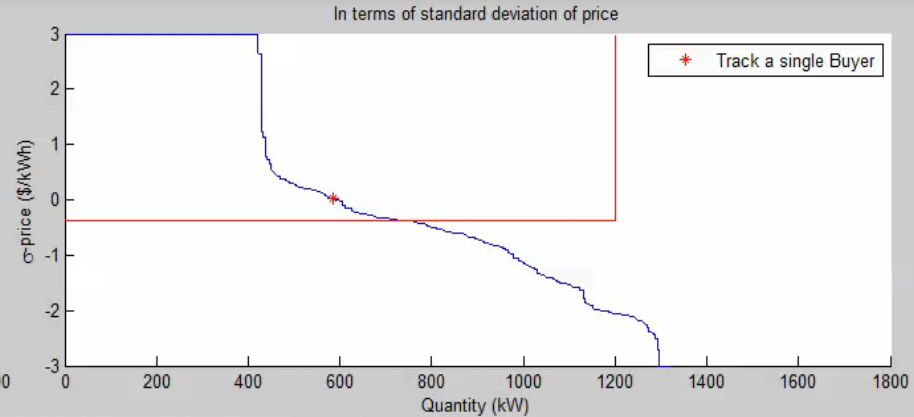
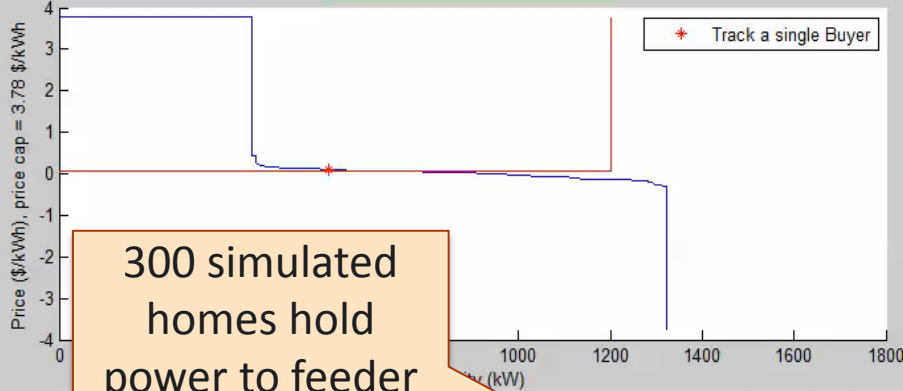
Stability Assurance: RTP Simulation – GridLAB-D



Pacific Northwest
NATIONAL LABORATORY

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Timestamp 2009-06-24 23:05:00 EDT
Market ID 8917



300 simulated homes hold power to feeder limit (blue)

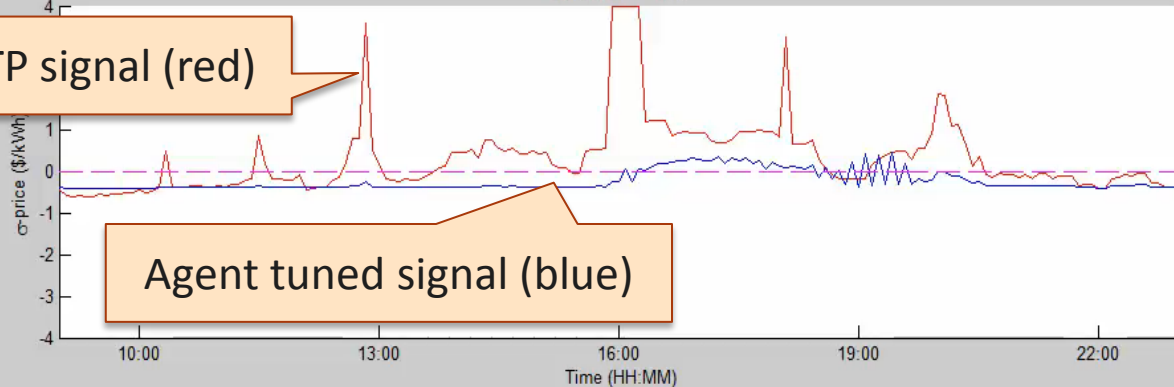


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Source: jason.fuller@pnnl.gov

RTP signal (red)



Agent tuned signal (blue)

σ(\$/kWh) = 0.0246

- Used to analyze
- tariff design
 - agent algorithms
 - Market interactions

Participating Agencies and Organizations

- ▶ Primary funding agencies: AEP Ohio, US-DOE
- ▶ Regulator: Public Utility Commission of Ohio
- ▶ Wholesale market: PJM 5 minute energy LMP market
- ▶ Service provider: AEP Ohio
- ▶ Household participant: AEP Ohio RTP program customers
- ▶ RTP system and device actors
 - System specification: PNNL
 - System design and implementation: Battelle
 - Home Energy Management: AEP contractor
 - Smart thermostat: AEP contractor
 - Smart meter: AEP contractor
 - Customer recruitment: AEP contractor
 - Hardware installation and maintenance: AEP contractor

Acknowledgement & Disclaimer

- ▶ Acknowledgment: This work is supported in part by the Pacific Northwest National Laboratory operated for the U.S. Department of Energy by Battelle under Contract DE-AC65-76RLO1830.
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Thank you!

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