Transactive Control

Real-Time Pricing Double-Auction

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An Economically Rational, Real-Time Price-Responsive Thermostat
Thermostat with a Simple Economic Response to Price (Cooling Example)

User sets: \( T_{\text{desired}} \) and comfort vs. savings (on thermostat, by time & day-of-week)

These imply: \( T_{\text{max}}, T_{\text{min}}, k \) (price response parameters); \( T_{\text{set}} = T_{\text{desired}} @ \text{avg. price} \)

Price* is expressed as std. deviation from mean (over period of days to a year)

Tstat setpoint: automatically adjusts to current price (\( P_{\text{current}} \))

Pre-cooling: will occur when \( P_{\text{current}} < P_{\text{avg}} \) (unless forbidden by user)
Thermostat (Today)

Cooling Thermostat with an Economic Response to a Double-Auction Retail Congestion Market

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

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

*Tstat: adjusts setpoint to reflect clearing price

Manages variable demand to maintain desired load, maximizes total comfort of participants

Two-way communication is required

\[ T_{\text{stat}} \]

Indoor Temperature

\[ T_{\text{min}} \quad T_{\text{desired}} \quad T_{\text{current}} \quad T_{\text{set}} \quad T_{\text{max}} \]

Price*

\[ P_{\text{bid}} \quad P_{\text{clear}} \quad P_{\text{avg}} \]

More Savings

More Comfort
Customers can be recruited, retained, and will respond to *dynamic pricing* schemes if they are offered:

- Opportunity for significant savings (~10% was suggested)
- A “no-lose” proposition compared to a fixed rate
- Control over how much they choose to respond, with which end uses, and a 24-hour override
  - prevents fatigue: reduced participation if called upon too often
- Technology that automates their desired level of response
- A simple, intuitive, semantic interface to automate their response

*Translates to control parameters:*

\[ K, \ T_{\text{max}}, \ T_{\text{min}} \] (see Virtual Thermostat)
Double-Auction Retail Market Sets Real-Time Price Based on Capacity
RTP Double Auction Market – Uncongested Conditions

- Market clears every 5-min (~matches AC load cycle)
- Cleared load ($Q_{\text{clear}}$) varies with demand curve
- Clearing price ($P_{\text{clear}}$) will be the Base RTP
RTP Double Auction Market – Distribution Congestion

- **Base RTP**, based on PJM 5-min real-time market

**Unresponsive Loads**

- **Demand Curve**: sorted \((P, Q)\) bids from RTPDA customers

**Responsive Loads**

- **Feeder Supply Curve**

- **Feeder Capacity**

- **\(P_{\text{clear}}\) is set to make the \(Q_{\text{clear}}\) equal to feeder capacity**

- **When congested, \(P_{\text{clear}} > \text{Base RTP}\)**

- **\(P_{\text{clear}}\) varies every 5-min to try to keep load at feeder capacity**
RTP Double Auction Market – Distribution Congestion

- Clearing price ($P_{\text{clear}}$) set to clear the total load ($Q_{\text{clear}}$) at feeder capacity.
- When congested, $P_{\text{clear}} >$ Base RTP.
- $P_{\text{clear}}$ varies every 5-min to try to keep load at feeder capacity.

Diagram:
- Unresponsive Loads
- Responsive Loads
- Demand Curve: sorted $(P, Q)$ bids from RTP DA customers
- Feeder Supply Curve
- Congestion Surplus
- Feeder Capacity
- $P_{\text{clear}}$, $P_{\text{base}}$, $Q_{\text{clear}}$
A share of the system-wide load reduction target is allocated to each feeder based on the number of RTP customers and feeder load. $Q_{\text{clear}}$ is less than the feeder capacity.
RTP Double Auction Market – Rewarding Customers for Response to Congestion Prices

Customer bid price & quantity provide the basis for reward in response to congestion prices.
Design Basis for a Revenue-Neutral RTP Tariff
What is Congestion?

Two types of congestion not reflected in LMP:

- Distribution congestion – a distribution feeder’s load exceeds its capacity; localized to a single substation or feeder
- System congestion – a system-wide need for load reduction
  - allocated across feeders as a reduction in capacity
  - in proportion to RTP$_{DA}$ customers on them

Congestion is managed by the double-auction (DA) market

- DA clearing price rises during a congestion event to match load to capacity
- RTP$_{DA}$ customers respond by reducing load to target level

Congestion can be:

- Natural, due to limited distribution or feeder capacity
- Declared, to manage system congestion
  - peak system load
  - grid contingencies
  - spinning reserve event
Simple CPP Does **Not** Manage Capacity Well

- Limited by lack of response after first hour
- Rebound effect after CPP results in new, even **higher** peak
RTP + double-auction retail market manages a capacity constraint with precision.
Design Principles for a RTP Double-Auction Tariff

- Revenue neutrality
  - Revenue neutral prior to any load shift by customers
  - I.e., for a customer with:
    - the average annual energy consumption and load shape
    - no change to their load shape or consumption in response to RTP
  - their electric bill under RTP$_{DA}$ is the same as under the standard tariff

- Manage congestion with a double auction

- Opt-in by customer, hold-harmless clause (one year)

- Response is voluntary, but must reduce customer’s bill

- Customer incentive proportional to the value provided

- Congestion surplus rebated to maintain revenue neutrality

- Appropriate split of cost savings between utility & participants