Residential Real-time Pricing Experience

Steve Widergren
Pacific Northwest National Laboratory

Workshop on DSM Potentials, Implementations and Experiences
Graz, Austria
20 May 2014
Transactive Grid Control Overview

1. Automated, price-responsive device controls express customer’s flexibility (based on current needs)

2. Customer system aggregates responses to form overall price flexibility curve

3. Utility aggregates curves from all customers

4. Aggregator determines price at which grid objective achieved, broadcasts to consumers

Price-Discovery Mechanism

Supply Limit

Aggregate Demand Curve (all customers)

Load (kW)

Price ($/kWh)

Load (kW)

Price ($/kWh)

Customer Price-Flexibility Curve*

Max Load

Base Load

AC

Water heater

Charge battery

Discharge battery

Price ($/kWh)

* Labels removed before sending to utility
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 market 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 System

Wholesale Market

5 minute nodal energy prices

Service Provider Operations

bids, clearing price

Usage

Dispatch System

supply, usage information

Home

Meter

Clearing price

Residential Energy Mgmt System

bids

Consumer Display

Programmable Thermostat

Field

~200 homes on 4 feeders

Operations Center

monthly bill
RTP Market Uncongested Conditions

Market clears every 5-min (~match AC load cycle)

When uncongested:
- Quantity ($Q_{\text{clear}}$) varies with demand curve
- Price ($P_{\text{clear}}$) is constant, equal to Base RTP

Retail RTP based on wholesale real-time LMP (Base RTP)

Unresponsive Loads

Responsive Loads

Demand Curve: sorted ($P$, $Q$) bids from RTP$_{\text{DA}}$ customers

Market clears at intersection of supply & demand curves

Feeder Supply Curve

Feeder Capacity

$P_{\text{clear}} = P_{\text{base}}$

Varies every 5-min

$Q_{\text{min}}$, $Q_{\text{clear}}$, $Q_{\text{max}}$

Q, Load (MW)
RTP Market Congestion Conditions

Unresponsive Loads

Responsive Loads

Demand Curve: bids from RTP households

Retail RTP based on LMP

Feeder Supply Curve

Market clearing

Feeder Capacity

Congestion Surplus

P\text{\tiny clear}

P\text{\tiny base}

Q\text{\tiny min}

Q\text{\tiny clear}

Q\text{\tiny max}

q\text{\tiny bid}

P\text{\tiny incentive}

P, Price ($/MWh)
gridSMART® RTP in Action

Reduce feeder capacity to engage end-use

HVAC units drop-off

Units rebound when capacity returns to normal

Price rises to price cap
Summary of RTP Demo Analysis

- Experiments analyzed Jun – Sep 2013
- Electric system impacts
  - Wholesale purchases: energy use and cost reduced by ~5%
  - System peak shaving: ~6.5% peak load reduction at 50% simulated RTP household penetration
  - Feeder peak management: ~10% peak feeder load reduction at 50% simulated household penetration
- Household impacts
  - Bills: ~5% average reduction (includes peak management incentive)
  - Thermostat overrides over 4 month duration
    - 2 hr events < 10 overrides
    - 4 hr or greater events < 20 overrides
  - Customer satisfaction
    - Over 75% satisfied (40% very satisfied)
    - Perceived monthly bill impact: 51% savings, 39% same, 10% increase
Sensitivity of Load to Price

The trend line illustrates the systemic response of lower load to higher price.

Actual load response versus LMP for about 12,000 5-min data points covering the period June–September 2013. Bottom shows histogram of the frequency of LMPs up to $100/MWh.
**Pacific Northwest Demonstration Project**

**What:**
- $178M, ARRA-funded, 5-year demonstration
- 60,000 metered customers in 5 states

**Why:**
- Develop communications and control infrastructure using incentive signals to engage responsive assets
- Quantify costs and benefits
- Contribute to standards development
- Facilitate integration of wind and other renewables

Only project of its kind integrating resources across multiple utilities to achieve regional benefits.
Operational objectives

- Manage peak demand
- Facilitate renewable resources
- Address constrained resources
- Improve system reliability and efficiency
- Select economical resources (optimize the system)

Aggregation of Power and Signals Occurs Through a Hierarchy of Interfaces
Generic Transactive Control Node
Inputs & Outputs

- **Aggregate incentive or quantity estimate inputs from multiple adjacent nodes**
- **Calculate output incentive & load estimate for adjacent nodes**
- **Implement local control of assets at the node**

Local data & info
Control signals for node’s assets

- Input Incentive or price
- Output Incentive or price
- Input Quantity
- Output Quantity
Realizing Transactive Grid Control

Purpose

- Transactional frameworks are established to incentivize and coordinate the response of millions of smart energy assets

Characteristics of a Good Solution

- Privacy, free will, and cyber-security concerns are mitigated
- Simple cyber-interaction paradigm, applicable at all levels of the system and supported by standards
- Offers a viable transition path that co-exists with traditional approaches
- Smooth stable, predictable, and graceful failure

Outcomes

- Accepted by business and policy decision-makers as a valid, equitable, and advantageous revenue/investment recovery mechanism
- Vibrant vendor community supplies transactional products and services, e.g., operating systems and system- & device-level controls