Demand Response and Research Activities in California

Mary Ann Piette
IEEE Smart Grid Workshop
November 3, 2008

Lawrence Berkeley National Laboratory
Demand Response Research Center

http://drrc.lbl.gov

Sponsored by California Energy Commission
Public Interest Energy Research Program
Presentation Outline

- **Demand Response Basics and Introduction**
- **DR Research Center Overview**
- **Automating Demand Response**
  - Introduction
  - Status
  - Future Directions
- **Additional DR Research in California**
Integrated Smart Grid Considerations

Transmission
- Real time system improvements
- Congestion control
- Intelligent Agent integration and application
- Implementing RPS
- Advanced grid communications and control
- Extreme event planning and response
- CA ISO market redesign (MRTU)
- Automatic network reconfigurations
- Rapidly deployable systems
- Self healing grid

Distribution
- Distribution automation
- Advanced grid communications and control
- Congestion control
- Self healing grid
- Implementing Microgrids
- Integration of DER
- Reliability, availability, PQ improvements
- Reduce peak demand
- Low carbon network benefits

DER Integration
- Integrating renewables
- Integration of DER
- Implementing Microgrids
- Advanced grid connected power electronics
- Advanced communications and control

Demand Response
- AMI systems and implementation
- CAISO MRTU Implementation of DR
- Advanced communications and control
- Integration of DR automated technologies
- Development of enabling DR technologies

Energy Storage
- Renewable firming and dispatchability
- Reduce peak demand
- Low carbon network benefits
- Advanced grid connected power electronics
- Advanced communications and control

Security
- Wireless Network Field Demo
- Network survivability
- Self healing systems
- Rapidly deployable systems
- Automatic network reconfigurations
Demand Response Definition

- **Demand Response (DR)** is the action taken to reduce load when:
  - Contingencies (emergencies & congestion) occur that threaten supply-demand balance, and/or
  - Market conditions occur that raise supply costs

- **DR typically involves peak-load reductions**
  - DR strategies are different from energy efficiency, i.e., transient vs. permanent
Policy Context

- **Supply-side solutions** to provide peak power cost more than load reduction solutions
- A **real-time control and communications infrastructure** is needed to support price and emergency signals
- **It doesn’t take much** “automated” load reduction to avoid blackouts
- **Air conditioning** is the low-hanging fruit
Demand Response Options

❄ **Reliability programs (utility operated)**
  - Air conditioning cycling
  - Interruptible/curtailment

❄ **Economic programs (customer choice)**
  - Demand bidding
  - Demand reserves

❄ **Signals (price and emergency)**
  - Automatic demand response
Demand Response R&D Vision

Create a real-time, automated DR infrastructure that is simple to use and can adaptively respond to changing contingency and market conditions.

A DR infrastructure must coexist with legacy systems, allow for future technology and tariff improvements, and have near-, medium-, and long-term benefits to California ratepayers.

California Daily Peak Loads -- 2006

- Residential Air Conditioning
- Commercial Air Conditioning

Date: Jan-06 to Nov-06

Graph showing the daily peak loads with peaks in July and September.
What Are We Trying to Achieve?

- Previous proceedings – CEC and CPUC (R.02-06-001)
  - Early goal for price sensitive DR: 5% of peak by 2007
    - Residential Default CPP
    - Small Commercial (< 200 kW) Default CPP
    - Medium Commercial (< 999 kW) Default CPP
    - Large C&I (> 1 MW) 2-part RTP
- IOU business plans for Automated Meter Infrastructure
- Long term success \(\rightarrow\) DR as business as usual
- Research needs
  - DR value, potential, technologies, programs, policies
  - How much DR do we need? Relation between price response and reliability?
CAISO Ancillary Services

- CAISO procures regulation, spinning reserve and non-spinning reserve ("ancillary services") in day-ahead and hour-ahead markets.

- CAISO market participants can self-provide any or all of these A/S products, bid into CAISO markets, or purchase them from CAISO.

- Spinning Reserves: A contingency reserve provided by generation that is running ("spinning") with additional capacity that is capable of ramping over a specified range within 10 minutes and running for at least 2 hours.

- Future - Fast Demand Response may be a significant portion of future A/S products.
Demand Response Research Center
Research Areas

* **Energy Systems and Strategic Issues**
  - Valuing Demand Response
  - Dynamic Tariffs and Rate Design
  - *Communications Infrastructure*

* **Buildings**
  - *Automation, Communications and Control*
  - *End-Use Control Strategies and Models*
  - Behavior –response to dynamic tariffs

* **Industry**
  - Automation, End-Uses and Controls
### “Buildings” Side of Demand Side Management

<table>
<thead>
<tr>
<th>Motivation</th>
<th>Efficiency and Conservation (Daily)</th>
<th>Peak Load Management (Daily)</th>
<th>Demand Response (Dynamic Event Driven)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Environmental Protection</td>
<td>- TOU Savings</td>
<td>- Economic</td>
</tr>
<tr>
<td></td>
<td>- Utility Bill Savings</td>
<td>- Peak Demand Charge savings</td>
<td>- Reliability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Grid Protection</td>
<td>- Emergency</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Grid Protection</td>
</tr>
<tr>
<td>Design</td>
<td>- Efficient Shell, Equipment &amp; Systems</td>
<td>Low Power Design</td>
<td>Dynamic Control Capability*</td>
</tr>
<tr>
<td>Operations</td>
<td>- Integrated System Operations</td>
<td>Demand - Limiting and Shifting</td>
<td>Demand - Limiting, Shifting, or Shedding</td>
</tr>
<tr>
<td>Initiation</td>
<td>Local</td>
<td>Local</td>
<td>Remote</td>
</tr>
</tbody>
</table>

*Prefer closed loop strategies, granular control*
Automation Goals and Definition

Recent Research Goals

- **Cost** - Develop low-cost, automation infrastructure to improve DR capability in California
- **Technology** - Evaluate “readiness” of commercial buildings to receive signals
- **Capability** - Evaluate capability of control strategies for current and future buildings

**Auto-DR Definition** - Fully automated signals for end-use control

- **Signaling** – Continuous, secure, reliable, 2-way comms; listen and acknowledge
- **Industry Standards** - Open, interoperable communications to integrate with both common EMCS and other end-use devices that can receive a relay or similar signals (such XML)
- **Timing of Notification** - Day ahead and day of signals facilitate diverse strategies
Manual DR - Common Practice

Utility Owned

Utility

Utility Messaging & Settlement System

Interval Meter

Dial-Up Communication

Utility

Consumer Owned

Facility Manager

Lighting Controls

EMCS/Interface

Lighting

HVAC

BACnet LonWorks Zigbee (RF) DALI, etc.

BACnet LonWorks Modbus Etc.
DR Automation Server and Client

Utility Owned

- Utility
- Utility Messaging & Settlement System
  - DR Event Signals, Price, Reliability, Acknowledgement
  - Communication Device
  - AutoDR
  - DRAS
- Electric Meter
- Secure Web Service
- Dial-Up Communication

Consumer Owned

- Facility Manager
- Lighting Controls
  - BACnet
  - LonWorks
  - Zigbee (RF)
  - DALI, etc.
- EMCS/Interface
- Lighting
  - BACnet
  - LonWorks
  - Modbus Etc.
- HVAC

DRAS Clients –
1. Software only (Smart)
2. Software & Hardware (Simple)

1. Utility sends DR notification to DRAS
2. Price-Level and DR event signals sent on DRAS
3. Polling clients request price level and event data every minute
4. Energy Management Control System (EMCS) and other systems carry out shed based on pre-programmed strategies.
DR Automation Server Event Architecture

- **Web Client**: Connects to DRAS UI Web Server
- **DRAS UI Web Server**: Initiates DRAS
- **Participant Site**: Initiates DR Event
- **Utility/ISO**: Provides necessary information
- **Web Server**: Interacts with DRAS
- **DRAS Client**: Sends RTP Info to Utility/ISO
- **Utility Information System**: Manages program operators
- **Client Connection**: Configures DRAS
- **Program Operator**: Manages DR events
- **Web Client**: Updates RTP Info
- **DRAS**: Sends Event Info to DRAS Client
- **Set Load Status**: Manages load status
- **Exception Alarms**: Notifies participants
- **Voice mail, Email, Page, etc.**: 3rd Party Notification System
- **Participant Manager**: Manages participant site

The diagram illustrates the flow of data and interactions between various components in the DR Automation Server Event Architecture.
Demand Response Automation Architecture
Features of Open Automated DR Communications (OpenADR) Standards

- **Continuous and Reliable** - Provides continuous, secure, and reliable communications infrastructure
- **Translation** - Translates DR event information to continuous internet signals
- **Automation** - Receipt of the signal is designed to initiate automation
- **Opt-Out** - Provides opt-out or override function
- **Complete Data Model** – Describes model and architecture to communicate price, reliability, and other DR activation signals.
- **Scalable** – Provides communications architecture scalable to many forms of DR programs and tariffs
Commercialization of OpenADR Client

Client-server architecture with

- Single DR Automation Server (DRAS)
- Several client designs
  - Software (XML)
  - Hardware software – Client and Logic with Integrated Relay (CLIR)
Critical Peak Pricing (CPP) with additional curtailment option

- **CPP Price Signal**: 10x per year
- **Extraordinary Curtailment Signal**: < once per year

![Graph showing CPP Price Signal and Extraordinary Curtailment Signal](image)
Auto-DR in 130,000 ft² County Office
Current Practice

Martinez, CA Office Building Electricity Use with and without AutoDR
June 21, 2006

Graph showing the comparison of Whole Building Power, Baseline, NetWatts, and CAT with different temperature levels.
Aggregated Auto-DR Results – June 26, 2006

1.3 MW reduction during high price period
Results From PG&E Auto-DR
2008 CPP Event
## Comparison of End-Use Strategies

<table>
<thead>
<tr>
<th>Building use</th>
<th>HVAC</th>
<th>Lighting</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Global temp. adjustment</td>
<td>Duct static pres. increase</td>
<td>SAT Increase</td>
</tr>
<tr>
<td>ACWD</td>
<td>Office, lab</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>B of A</td>
<td>Office, data center</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Chabot</td>
<td>Museum</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>2530 Arnold</td>
<td>Office</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>50 Douglas</td>
<td>Office</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>MDF</td>
<td>Detention facility</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Echelon</td>
<td>Hi-tech office</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Centerville</td>
<td>Junior Highschool</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Irvington</td>
<td>Highschool</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Gilead 300</td>
<td>Office</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Gilead 342</td>
<td>Office, Lab</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Gilead 357</td>
<td>Office, Lab</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>IKEA EPaloAlto</td>
<td>Furniture retail</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>IKEA Emeryville</td>
<td>Furniture retail</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>IKEA WSacto</td>
<td>Furniture retail</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Oracle Rocklin</td>
<td>Office</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Safeway Stockton</td>
<td>Supermarket</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solectron</td>
<td>Office, Manufacture</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Svenhard's</td>
<td>Bakery</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Sybase</td>
<td>Hi-tech office</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target Antioch</td>
<td>Retail</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Target Bakersfield</td>
<td>Retail</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Target Hayward</td>
<td>Retail</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Walmart Fresno</td>
<td>Retail</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

- **Global temperature reset migrating to State Energy Code**
Global Zone Temperature Adjustment
Widely Implemented

Customer

Temperature (F)

68.0 69.0 70.0 71.0 72.0 73.0 74.0 75.0 76.0 77.0 78.0 79.0 80.0 81.0 82.0

CPP two-level GTA
CPP one-level GTA
DBP

Average
Retail 1A
Office 3
Government 1
Retail 2
School
Lab/Office 2
Average
Government 2
Government 3
Retail 3
Government 4
Retail 3
Office 4

Average

CPP
Ave. temp. increase (mod): 2.75 F
Ave. temp. increase (high): 1.88 F
DBP
Ave. temp. increase: 2.3 F

Normal
Moderate
High
Target

Control:  Auto-CPP  Opt Out (NORMAL)  Forced Moderate  Forced High

Save

Upcoming Automated CPP Events for PGE_CPP_ZONE2

<table>
<thead>
<tr>
<th>Received Event</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fri Nov 10 09:22:23 PST 2006</td>
<td>Wed Nov 15 12:00:00 PST 2006</td>
<td>Wed Nov 15 19:00:00 PST 2006</td>
</tr>
</tbody>
</table>

Communication

<table>
<thead>
<tr>
<th>Comm. Method</th>
<th>Event Level</th>
<th>Last Contact</th>
<th>Comm. Status</th>
<th>Event Pending</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOFTWARE</td>
<td>normal</td>
<td>Fri Nov 10 09:24:55 PST 2006</td>
<td></td>
<td>NONE</td>
</tr>
</tbody>
</table>

Preparation Status

<table>
<thead>
<tr>
<th>CPP Program</th>
<th>CPP sign.up</th>
<th>InterAct setup</th>
<th>Notify test</th>
<th>Activate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Antioch</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>06/01/2006</td>
</tr>
<tr>
<td>Target Bakersfield</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>06/01/2006</td>
</tr>
<tr>
<td>Target Hayward</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>05/01/2006</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical Prep</th>
<th>Site survey</th>
<th>EMCS program</th>
<th>Server comm. test</th>
<th>Control test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Antioch</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Target Bakersfield</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Target Hayward</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

LBNL Auto-CPP Newsletters
Results by Utility for 2007
Over 40 MW for 2008

<table>
<thead>
<tr>
<th>Participants 2006</th>
<th>13 CPP</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Load Reduction (MW)</td>
<td>1.1</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Peak Load Reduction (%)</td>
<td>13%</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2007 Peak Reduction Goal</th>
<th>15MW</th>
<th>5MW</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants 2007</td>
<td>29 CPP</td>
<td>52 DBP</td>
<td>8 CPP</td>
</tr>
<tr>
<td>Peak Load Reduction (MW)</td>
<td>1</td>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>Peak Load Reduction (%)</td>
<td>14%</td>
<td>35%</td>
<td>49%</td>
</tr>
<tr>
<td>2007 Peak Reduction (MW)</td>
<td>22MW</td>
<td>2MW</td>
<td>1MW</td>
</tr>
</tbody>
</table>

* Includes in-production and estimated impacts of in-process sites
Auto-DR Customer CPP Performance

Average Shed

Retail-Inland  Retail-Valley  Retail-Coast  Office-Inland  Biotech-Coast  Public-Inland  Indus-Inland  School-Inland

Auto CPP  Non-Auto CPP

Average CCP
Peak Load Reduction
- 8% w/ Auto-DR
- 1% w/o Auto-DR
CALIFORNIA ENERGY COMMISSION

Scales of Demand Side Energy Management

- Daily Energy Efficiency
- Time-Of-Use Energy
- Daily Peak Load Managed
- Day-Ahead (slow) DR
- Real-Time DR

Service Levels Optimized

Time of Use Optimized

Service Levels Temporarily Reduced

Increasing Levels of Granularity of Controls

Increasing Speed of Telemetry

Spinning Reserve (fast) DR
Ideal start - good commissioning, retro-commissioning, advanced/new controls

- HVAC - Direct digital control (DDC) global temperature adjustment
  - In process for Title 24 2008
  - Closed loop
- Lighting Continuum - Zone Switching, Fixture Switching, Lamp Switching, Stepped Dimming, Continuous Dimming
- Maybe you “can” use a strategy every day?
Multi-Objective Optimization

**Energy**
- On/off mode/control
- Weather/solar/wind
- Occupancy/comfort/schedule
- Equipment loads
- Continuous diagnostics

**Operating Costs**
- Rate $/kWh, TOU, demand charges
- Dynamic – critical, variable peak, RTP
- DR program – shed frequency, duration
- Maintenance and operations

**Emissions**
- Real-time CO$_2$/kWh (time of day)
- Grid or on-site power
- Energy source

**Demand Response/Grid**
- Loads to limit, shift, shed
- Service level control capability
- Service level requirements
  - Duration, frequency of DR participation
- Spinning reserve participation

<table>
<thead>
<tr>
<th>Energy (kWh)</th>
<th>Operating Costs ($)</th>
<th>Emissions (CO$_2$)</th>
<th>Demand Response ($)</th>
<th>kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Variable Air Volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice/Chilled Water Storage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAV with Pre-Cooling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Future Directions
DR strategies as a “Mode” in Optimized Control

- Orchestrating modes using schedules, signals, optimization algorithms:
  - Occupied/Unoccupied
  - Maintenance/Cleaning
  - Warm up/Cool down
  - Night purge/Pre-cooling
  - Low power DR mode

- Intelligence needed for decision making
- Customized, simple and transparent interface
- Financial feedback systems need to present operational value
- Embed DR Communications in EMCS
- Need more sensors, algorithms, real-time simulations, feedback!
Related OpenADR Projects

- **Embedding** Auto-DR Clients in control systems
- **Piloting small commercial** Auto-DR systems using low-cost communicating thermostats
- **Developing large commercial pre-cooling** field studies and simulation tools
- **Testing dimmable lighting systems**, designs to provide efficiency and DR
- **Evaluating industrial processes** - case studies on refrigerated warehouses, wastewater, controls
- **Planning implementation** of OpenADR in Title 24
Automation by Sector

Programmable Communicating Thermostat

Demand Response Automation Client

Demand Response Automation Client

Internet

CALIFORNIA ENERGY COMMISSION
Auto-DR System Architecture – Possible Integration with Residential

Commercial and Industrial Customers

Residential – Small Commercial Customers
UCB Technologies for Lower-Power Wireless Sensing

Energy Scavenging

From vibration
(10 – 80 μW/cm²)

From flow
(3 mW/cm² at 1200 fpm)

From light
(15 mW/cm² in sunlight; 6 μW/cm² indoors)

From heat transfer
(8000 mW/cm² from steam pipe)
UCB Distributed Thermostats

Ad Hoc Wireless Networking
CERTS Demand Response Demonstration

This website provides real-time and archived information from a precise, statistically significant test of demand response for a representative SCE distribution circuit (see project overview). The next test is scheduled for dynamic update.

The test is intended to demonstrate the capabilities of load management technologies to provide spinning reserve to the California ISO and to defer distribution enhancements for SCE. In the test, residential air conditioning clustered within a single SCE distribution circuit is being curtailed using a dispatch signal from a central control location (see topology). Daily tests are being planned for the entire month of September.

The test has two basic goals (see Test Plan):
1. Demonstrate that the load can be curtailed reliably and quickly on the issuance of a dispatch signal. The load shed is expected to start within 10 seconds of the signal and be fully implemented within two minutes.
2. Demonstrate that when load is curtailed by a dispatch signal, the available MW demand response of a specific circuit can be precisely predicted with a 95% statistical confidence level using three variables: time of day, day of week, and temperature.

This project is coordinated by the Consortium for Electric Reliability Technology Solutions and the California ISO under a research grant from the CEC PIER program. Contact John Kueck, Oak Ridge National Laboratory, for more information about this project. Contact Joe Fito, Lawrence Berkeley National Laboratory for more information about CERTS.
Thank You

Mary Ann Piette
mapiette@lbl.gov
http://drrc.lbl.gov