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Abstract

This paper describes the concept for and lessons from the development and field-testing of an open, interoperable communications infrastructure to support automating demand response (DR). Automating DR allows greater levels of participation and improved reliability and repeatability of the demand response and customer facilities. Automated DR systems have been deployed for critical peak pricing and demand bidding and are being designed for real time pricing. The system is designed to generate, manage, and track DR signals between utilities and Independent System Operators (ISOs) to aggregators and end-use customers and their control systems.

1. INTRODUCTION

California utilities have been exploring the use of critical peak pricing (CPP) and other DR pricing and program strategies to help reduce peak day summer time electric loads. Recent experience with DR has shown that customers have limited knowledge of how to operate their facilities to reduce their electricity costs under CPP or in a DR Program [1]. While the lack of knowledge about how to develop and implement DR control strategies is a barrier to participation in DR programs like CPP, another barrier is the lack of automation of DR systems. Most DR activities are manual and require building operations staff to first receive emails, phone calls, and pager signals, and second, to act on these signals to execute DR strategies.

The various levels of DR automation can be defined as follows. **Manual Demand Response** involves a labor-intensive approach such as manually turning off or changing comfort set points at each equipment switch or controller. **Semi-Automated Demand Response** involves a pre-programmed demand response strategy initiated by a person via centralized control system. **Fully-Automated Demand Response** does not involve human intervention, but is initiated at a home, building, or facility through receipt of an external communications signal. The receipt of the external signal initiates pre-programmed demand response strategies. The authors refer to this as Auto-DR. One important concept in Auto-DR is that a homeowner or facility manager should be able to "opt out" or "override" a DR event if the event comes at time when the reduction in end-use services is not acceptable.

From the customer side, modifications to the site's electric load shape can be achieved by modifying end-use loads. Examples of demand response strategies include reducing electric loads by dimming or turning off non-critical lights, changing comfort thermostat set points, or turning off non-critical equipment. These demand response activities are triggered by specific actions set by the electricity service provider, such as dynamic pricing or demand bidding. Many electricity customers have suggested that automation will help them institutionalize their demand response. The alternative is manual demand response -- where building staff receives a signal and manually reduces demand. Lawrence Berkeley National Laboratory (LBNL) research has found that many building energy management and controls systems (EMCS) and related lighting and other controls can be pre-programmed to initiate and manage electric demand response.

This paper provides an overview of the AutoDR field tests and implementation activities from 2003-2007. A companion paper describes the technology in greater detail. This paper focuses on the automation design history and does not cover the shed strategy or shed measurement details which are covered in previous papers [2,3,4,5].

2. TECHNOLOGY HISTORY

The automated demand response project began in 2002 following California's electricity market crisis with the goal of addressing three key research questions. First, is it possible using today's technology to develop a low-cost, fully automated infrastructure to improve DR capability in California? Second, how "ready" are commercial buildings to receive common signals? Third, once a building receives a signal, what type of strategies are available that can be readily automated?

Research planning began in 2002 and a series of field tests and implementation programs were organized to advanced the technology from the initial conceptual design to the status today where it has been designed for use with over 100 facilities over 200 kW.

2.1. 2003: Initial Development and Tests

The 2003 technology development began with the design of a fictitious price signal and automation server that could be represented in XML (Extensible Markup Language) to support interoperable signaling. The automation uses a client server architecture and has been tested with both pull and push communications designs. Five facilities were recruited: 1) a large office, 2) supermarket, 3) pharmaceutical research campus including a cafeteria and a small office, 4) data center/office, and 5) a university campus library. Criteria for recruitment includes evaluating different types of facilities, multiple vendor Energy Information Systems [6], multiple vendor Energy Management and Control systems, multiple technology gateways, difference types of ownership, and a variety of end-use load reduction strategies [2].

All of these sites had participated in DR and had been equipped with new communications and monitoring systems as part of California's Enhanced Automation program [7]. Preparations for the test involved the development of an automation server and the XML software client installations at each of the client sites. The client listens to the signal continuously and replies with the price level. The test resulted in fully automated shedding during two events with an average peak reduction of about 10%.

2.2. 2004: Scaled Up Tests with Relay

The design of the 2004 tests began with the consideration that many facilities did not have EIS and EMCS that could support XML. We reviewed existing technologies and modified the DR automation price server to interoperate with a low-cost Internet relay. The Internet relay is a device with relay contacts that can be actuated remotely over a local or wide area network or the Internet using Internet Protocols (IP). The 2004 technology development and field tests were similar to the 2003 tests in that they were purely fictitious, with no real payment for DR performance. Eighteen sites were recruited to participate in a series of tests. To help in recruiting, the facility managers were offered the assessment of how "ready" their automation systems were to receive common signals for the future's dynamic tariffs and DR program opportunities.

Figure 1 shows the geographic distribution of the participant sites along with the development sites and price-server clients. Many development sites for the XML software client were located outside of California. The price clients listening to the signals could be implemented outside California, as the figure shows. Energy managers out of state can monitor the automation system communications in real time from any web browser.

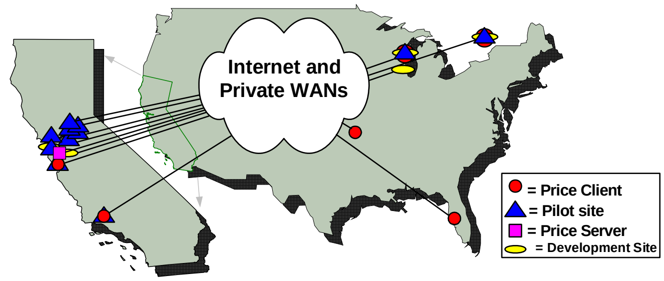


Figure 1. Geographic location of Auto DR facilities, automation clients, and server.

Fifteen facilities participated in the 2004 tests with about half using the XML software client and half using the Internet relay. The average demand reduction for these 15 sites was 0.53 W/ft^2 or about 14% of the whole building electric-peak demand. Table 1 shows an example of how a building would pre-program a response to general DR mode information. A facility manager can decide how to translate the general DR modes into whatever response strategy they choose.

Table 1. Sample DR building control strategies by mode

Building Type	End-Use	Normal	Shed Level 1 Moderate	Shed Level 2 High
Large Office	HVAC	Zones - 72 F	Zones - 76 F	Zones - 78 F
Supermarket	Lighting, Refrig	All On	Lights Down 35%	Anti-Sweats Night Mode

Note: HVAC – Heating, ventilation, and air conditioning

2.3. 2005: Critical Peak Pricing

In 2005 we began our initial collaboration with the Pacific Gas and Electric Company to offer AutoDR as part of the Critical Peak Pricing (CPP) Program. To participate, a site had to be willing to go onto PG&E's CPP tariff. The tariff offers a rate discount during most summer days, but prices increase on CPP days as shown in Figure 2. Fifteen facilities participated in the Automated CPP tests. CPP usually is called 12 times in each summer but because the automation systems took time to install, the tests were not conducted until late in the summer. For the eight sites participated in the fully automated CPP event on September 29th, 2005 the average demand response ranged from 0 to 24% per site for the medium price period and 4 to 28% per site during the high price period, with an average of 9% and 14% overall for the two price periods.

The 2005 automated CPP test used a new automation server renamed as the DRAS – DR Automation Server. This server was operated at a secure industrial grade hosting facility designed to accommodate scaling up the technology in future years.

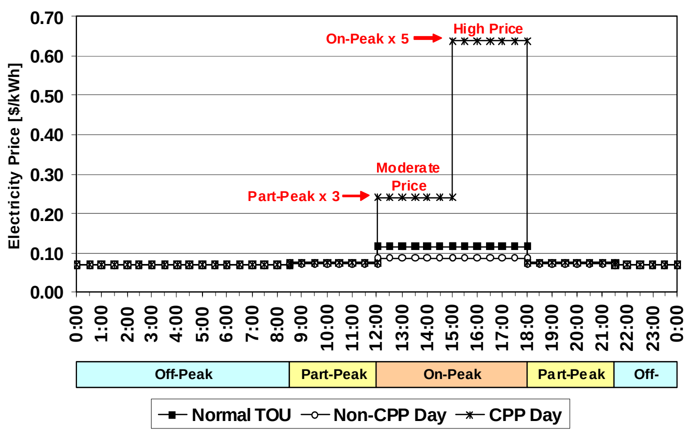


Figure 2. Critical peak price tariff compared with TOU

2.4. 2006: Scaled Up Automated CPP

Following the pilot automated CPP test in 2004 we began a more formal partnership with PG&E's Emerging Technologies Program. In an effort to transfer the expertise of the automation system installation efforts from LBNL to a third party, we developed a qualifications procedure for third-party engineering services. Initially named the DR Integration Services Company, or DRISCO, this service company was renamed in 2007 to an AutoDR Technical Coordinator.

In addition to recruiting new sites into the program, we had about eleven sites that had fully automated CPP response for the entire summer with 12 events. More importantly, we provided this automation system through a severe heat wave in July 2006. Each site continued to reduce their loads over many days during this 1.5-week event. None of the sites opted out or overrode the automation capability, although that option was available. Figure 3 shows an automated demand response shed at an office building in Martinez California. The shed shows a classic response with the first level of response based on resetting the zone temperatures up a few degrees, and second level reset response during the three-hour high price period. Over 100 kW was shed during the high price period with no rebound when the building goes into unoccupied mode after 6 pm.

Among the Auto-CPP sites, site responses to 125 events were fully automated and evaluated in this study. The average peak demand reduction was 14% of the whole-facility load based on the three-hour high-price period.

As we brought the technology out to a large customer base we found that the Internet relay had some communications security issues for some customers. A hole in the corporate firewall was some times needed to allow the relay onto the network. As a result of that finding, a new client was developed. This technology, known as the Client and Logic with Integrated Relay or CLIR was developed as an IT friendly "plug and play" automation client. It is typically installed inside of the secure enterprise network and "polls" for CPP event information using 128 bit secure socket layer (SSL) encryption and authentication using HTTPS protocol. HTTPS is also used for most online financial transactions. No modification to corporate enterprise firewalls is required.

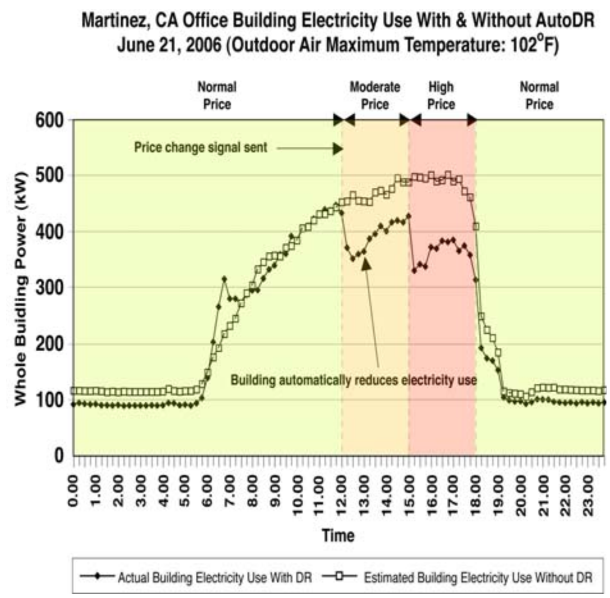


Figure 3. Example of load shape change with AutoDR

2.5. 2007: Commercialization and Program Expansion

Following the hot summer of 2006 the California Public Utilities Commission requested the three California Investor Owned Utilities to partner with the Demand Response Research Center to begin using AutoDR technologies. As part of that effort we developed a more formal definition of AutoDR to outline the principles for the automation system design. **Automated Demand Response for commercial and industrial facilities can be defined** as fully automated DR initiated by a signal from a utility or other appropriate entity and provide full-automated connectivity to customer end-use control strategies.

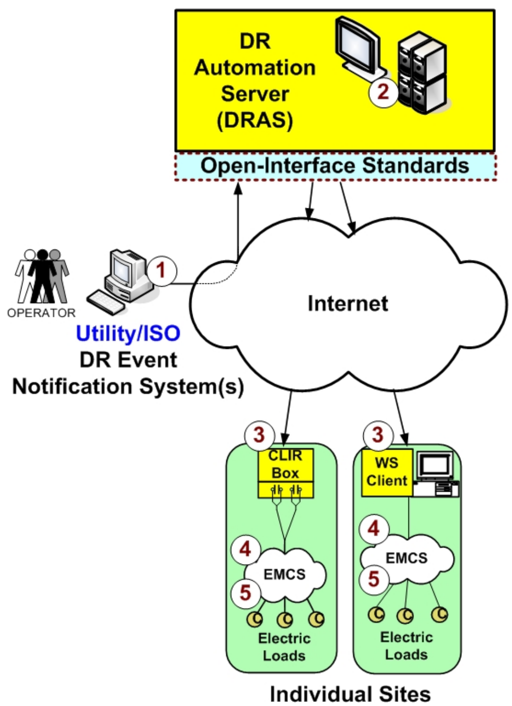
Signaling - AutoDR technology should provide continuous, secure, reliable, two-way communication with end-use customers to allow end-use sites to be identified as listening and acknowledging receipt of DR signals.

Industry Standards - AutoDR consists of open, interoperable industry standard control and communications technologies designed to integrate with both common energy management and control systems and other end-use devices that can receive a dry contact relay or similar signals (such as internet based XML).

Timing of Notification - Day ahead and day of signals are provided by AutoDR technologies to facilitate a diverse set of end-use strategies such as pre-cooling for "day ahead" notification, or near real-time communications to automation "day of" control strategies. Timing of DR automation server (DRAS) communications must consider day-ahead events that include weekends and holidays.

The AutoDR architecture has five steps (Figure 4).

Figure 4. Automated Demand Response Architecture



The steps are as follows:

1. The Utility or ISO defines DR event and price signals that are sent to the DRAS.
2. DR event and price services published on the DRAS.
3. DRAS Clients (CLIR or Web Service Software) request latest event information or price from the DRAS every minute.
4. Customized pre-programmed DR strategies determine action based on price.
5. Facility EMCS carries out shed based on DR signals and strategies.

The San Diego Gas and Electric collaboration is focusing on a demonstration with DR aggregators. The Southern California Edison demonstration is similar to the 2006 PG&E Automated CPP project except that a third-party program manager, Global Energy Partners, is managing it

The PG&E AutoDR program was expanded to include both CPP and demand bidding. Demand bidding allows a larger population of customers to participate because they do not need to go onto the PG&E CPP tariff. The bidding automation uses a standing DR bid that triggers an automated response whenever the program is called. The 2007 PG&E AutoDR program also included recruitment coordinators and technical coordinators to market, evaluate, configure, and manage the automation systems. Over 22 MW have been recruited into the program.

3. RELATED DR BUILDINGS RESEARCH

The DRRC has been actively evaluating the capability of large customers to respond to automated DR signals. While the focus was initially on commercial buildings, we are beginning to examine end-use control strategies that can be automated in industrial facilities as well. Key commercial building research projects have included the following

3.1. Pre-Cooling Field Demonstrations

One of the most important DR strategies for hot summers is to reduce cooling electricity use during DR events. Research. The DRRC has sponsored several years of field trials in both small and large commercial buildings to understand of pre-cooling can be successfully deployed to improve comfort and demand responsiveness [8]. Shifts over 2 W/ft^2 have been conducted, and in some cases energy use can be reduced along with peak demand. The AutoDR day-ahead and event pending signals have been used to automate pre-cooling.

3.2. Demand Responsive Lighting

Lighting systems can be an excellent end-use for DR. The DRRC has funded a scoping study to characterize existing strategies for DR lighting and emerging and advanced technologies. Addressable and dimmable lighting systems with centralized control can offer daily energy efficiency and excellent dispatchable, year-round DR capability. Further research is needed to explore how to design and control such systems. Advances in software are needed to ensure usability and performance [9].

3.3. DR Control Strategy Tools and Guides

Two significant barriers toward scaling up DR participation in commercial buildings are a) the lack of knowledge regarding what strategies are feasible for DR and b) estimating the size of the peak load reduction. To address the first barrier the DRRC created a guide to DR control strategies that is based on engineering principals and lessons from the implementation of AutoDR in over 40 buildings [10]. We have developed two downloadable whole-building simulation tools help estimate the peak demand reduction for different HVAC strategies. One tool is for single zone packages HVAC and the other is for built-up HVAC systems. Further work is needed to make the tool generalizable to a larger set of buildings, climates, and DR strategies.

4. NEXT STEPS AND FUTURE DIRECTIONS

This paper has presented the history and status of automated demand response research and initial commercialization activities in California. The research began with advanced control and energy information systems that could host XML-based signals. Recent work has included automating relay signals with Internet based communications in a secure, open web services architecture. Research on commercial buildings control strategies has also shown good potential for wide spread demand response. Future efforts include standardization of the communications and signaling systems, and efforts to move the technology into future building codes and standards. This technology is also described in a companion paper [11].

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