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Results and Commissioning Issues from an Automated Demand Response Pilot

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Synopsis

This paper describes a research project to develop and test Automated Demand Response hardware and software technology in large facilities. We describe the overall project and some of the commissioning and system design problems that took place. Demand Response (DR) is a set of activities to reduce or shift electricity use to improve the electric grid reliability purposes, manage electricity costs, and ensure that customers receive signals that encourage load reduction during times when the electric grid is near its capacity. There were a number of specific commissioning challenges in conducting this test including software compatibility, incorrect time zones, IT and EMCS failures, and hardware issues. The knowledge needed for this type of system commissioning combines knowledge of building controls with network management and knowledge of emerging information technologies.

About the Authors

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Introduction and Goals

This paper describes a research project on Automated Demand Response hardware and software technology in large facilities. We describe the overall project and a number of commissioning and system design problems. Demand Response (DR) is a set of activities to reduce or shift electricity use to improve the electric grid reliability purposes, manage electricity costs, and ensure that customers receive signals that encourage load reduction during times when the electric grid is near its capacity. The two main drivers for widespread demand responsiveness are the prevention of future electricity crises and the reduction of average electricity prices. Additional goals for price responsiveness include equity, through cost of service pricing, and customer control of electricity usage and bills. The technology developed and evaluated in this report could be used to support numerous forms of DR programs and tariffs. Kintner-Meyer et al recently evaluated DR economics for commercial buildings (Kintner-Meyer et al, 2003).

Levels of automation in DR can be defined as follows. **Manual Demand Response** involves a labor-intensive approach such as turning off unwanted lights or equipment. **Semi-Automated Response** involves the use of controls for load shedding, with a person initiating a pre-programmed load shedding strategy. **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. We 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 desirable.

While the emphasis of the research was on technology development, testing, characterization, and evaluation, we also sought to evaluate the decision-making perspectives of the facility owners and management. This project also sought to improve understanding of the feasibility and nature of DR strategies in large facilities. The six facilities recruited for this project received government funds for new DR technology during California's 2000-2001 electricity crises. Another goal of this project was to develop and test a real-time signal for automated demand response that provided a common communication infrastructure for diverse facilities.

This paper begins with an overview of the Auto-DR project, which includes a description of the Internet information technology the project was built upon. Next, we present the test results, reporting on the actual demand savings. The commissioning issues are then discussed, followed by a summary that includes a brief discussion of future directions. A complete description of the project is presented in Piette et al, 2004.

Project Overview

This project builds on previous work at LBNL to characterize emerging technology such as Energy Information Systems (EIS), web-based Energy Management and Control Systems (EMCS), and Demand Response systems (Motegi et al, 2002, Motegi et al, 2003). The building controls industry, like other industries, is undergoing a series of dramatic changes that are enabling new features that take advantage of advanced computing and communications systems. LBNL and others have conducted recent research to evaluate the capabilities, features, and costeffectiveness of new technologies for building energy efficiency and demand response. Energy Information Systems have evolved out of the electric utility industry in order to manage time-series electric consumption data. EIS products have been developed quickly with various features and complexities in order to satisfy the wide variety of client needs. Web-base Energy Information Systems have evolved out of the electric utility industry in order to manage time-series electric consumption data. However, energy management technologies have also expanded their functionalities, and may often overlap with EIS technology. Since EIS products are relatively new, they are changing quickly as the market unfolds. Figure A shows the relationships between the EIS and related systems. The "demand response" field has developed systems that enable utility-operated demand response programs or other demand curtailment measures (e.g. responsive thermostat[1], direct load control devices[2]). Energy management and control systems are beginning to incorporate Internet linkages for remote control, remote monitoring, and enterprise wide system integration.

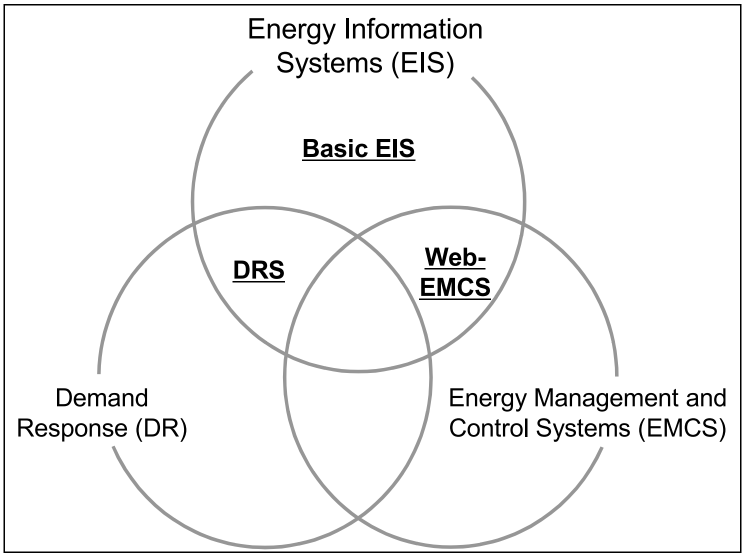

Figure A. Overlapping Features in Emerging Monitoring and Control Technology

The Auto-DR project concept was to perform a two-week test of fully automated DR in four to six facilities. The test consisted of providing a single fictitious continuous electric price signal to each facility. The technology used for the communications is known as Extensive Markup Language (XML) with "Web Services". Control and communications systems at each site were programmed using Web Wervices to listen to the price signal provided by a Web Services server. All of the facilities had Energy Information Systems and Energy Management and Control Systems that were programmed to automatically begin shedding demand when the price rose from 10 cents/kWh to 30 cents/kWh. The second stage price signal increased to $75 cents/kWh. Five sites participated in the test. The test kept the fictitious prices elevated for 3 hours. Figure B shows the price signal sent on Wednesday, November 19.

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[1] A thermostat that can receive external signals and respond by adjusting temperature settings.

[2] Devices that can interrupt power supply to individual appliances or equipment on consumer premises by the utility system operator.

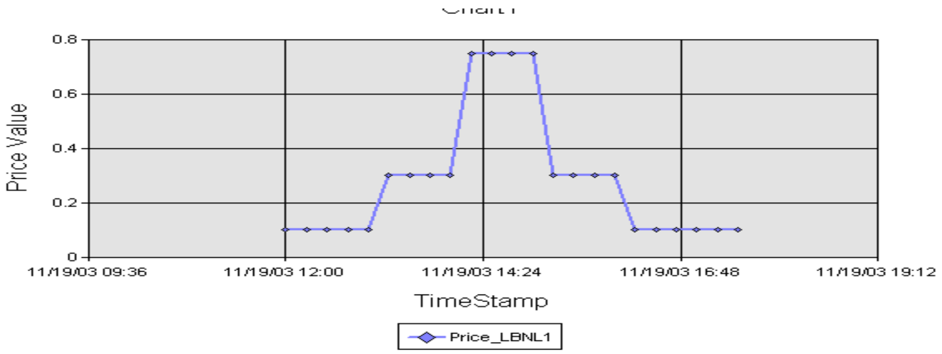

Figure B: Fictitious Electric Price Signal Sent to Five Facilities

The five project test sites represent a diverse set of facilities, control and communications systems, utilities, ownership types, and DR strategies (Table 1).

Table 1: Summary of Test Sites

	A **Albertsons**	**B** **Bank of America**	**C** **GSA Oakland**	**D** **Roche**	**E** **UCSB**
Location	Oakland	Concord	Oakland	Palo Alto	Santa Barbara
Use	Supermarket	Office (Retail)	Office	Two Office, Cafeteria	Library
	Engage /eLutions™	Webgen Intelligent Use of Energy™	BACnet Reader and BACnet controller	Tridium Vykon™	Itron Enterprise Energy Management Suite™
Area	50,000	211,000	1,100,000	192,000 *	289,000
Whole-Building peak demand (Nov)	401 kW	999 kW	2710 kW	706 kW	866 kW
Peak W/ft^2 (Nov)	8.0	4.7	2.8	3.6	3.0

*Office Building A2 is 101,078 ft^2, FS is 23,159 ft^2, SS is 67,862 ft^2.

The Automated Demand Response System generated an XML price signal from a single source on the Internet. Each of five disparate commercial building sites monitored the common price signal and automatically shed site-specific electric loads when the price increased. Other than price signal scheduling, which was set up in advance by the project lead researchers, the system was designed to operate without human intervention during two one week pilot periods. The diagram titled Auto-DR Network Overview below shows the system functionality from the highest level. Researchers at LBNL define the price schedule. The schedule is sent to the Price Server (but schedule is not viewable by the client computers). The current price is then published on the server in an interface viewable by the client computers. Client computers poll the server to get the latest price every few minutes (clients also send their current price to the server) and the client computers and EMCS receive latest price. Business logic software commands HVAC & lighting (via the EMCS system) to enter various shed modes based on price (normal mode, shed stage1, shed stage2).

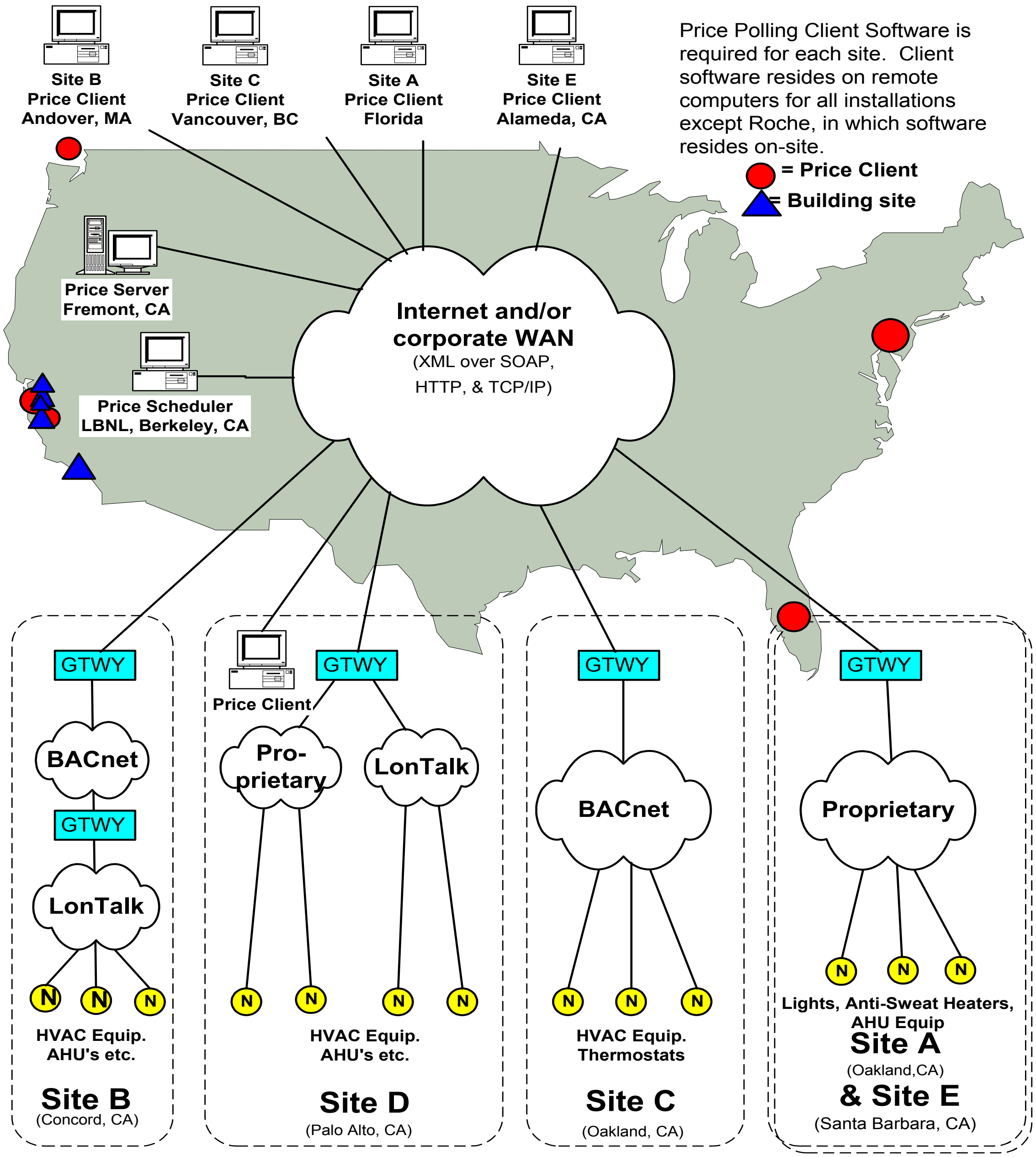
Price Polling Client Software is required for each site. Client software resides on remote computers for all installations except Roche, in which software resides on-site.

Figure C: Auto-DR Network Overview

The figure above shows some of the control and communications features of the Auto-DR systems at each site. Each site used a gateway (GTWY) to connect incompatible networks with different protocols. The figure also shows that multiple building communications protocols were used among the five sites, including both open and proprietary systems. All of the test sites were in California, but their servers and Energy Information Systems included systems in several other states and in Canada.

Test Results

The two-week test period begin on Monday, November 10, 2003. LBNL sent the first high price event on Wednesday, November 12. Three of the sites had technical problems during the first test, so minimal analysis was conducted. The second test on Wednesday, November 19, was successful, with all five buildings simultaneously reducing their electric demand, as shown in Figure C. The shed strategies consisted of the following type of control changes: zone set-point change, direct control of fans, resetting duct static pressure, reset of cooling valves, reduction of overhead lighting, and reduction of anti-sweat heaters.

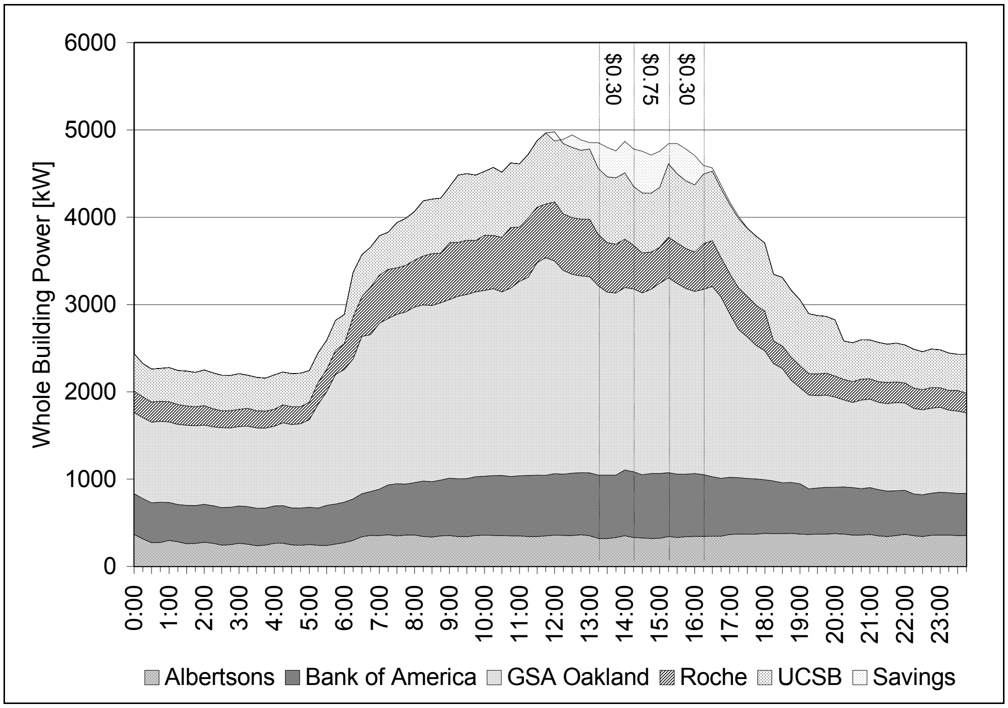

Figure D. Aggregated Auto-DR Load Shed from five sites on Nov. 19, 2003.

The aggregated total demand for the five facilities was nearly 5000 kW. The maximum peak savings was about 10% of the load, or about 500 kW. The maximum load reduction at each site ranged from 8 kW (at Bank of America) to 240 kW (at GSA). Area normalized maximum savings ranged from 0.04 (at Bank of America) to 0.83 W/sqft (at Albertsons). Hourly average electric load reductions for each of the five sites are shown in Figure C. There were no tenant or other complaints at any of the sites, but this was not surprising given that the sheds were not aggressive.

Commissioning Issues

There were a number of specific commissioning challenges in conducting this test. This section describes five key issues: software compatibility time zones, IT and EMCS failures, and hardware issues. The knowledge needed for this type of system commissioning combines knowledge of building controls with network management and knowledge of emerging information technologies.

Software Compatibility

Platform independence is one of the key attributes of well-designed Web Services. However, platform dependencies are not always easy to spot. In the Auto-DR pilot, there were some compatibility issues associated with the Web Services Server (WS Server) which was developed within the Microsoft ".Net " environment and two of the clients that were developed in other environments (Java, Delphi). These problems were not caused by inherent platform incompatibilities per se, but by the indiscriminate use of a text format rather than another format more commonly used to display data. The problems were resolved by modifying the WS Server to use a format that is more commonly used for data. In some cases, IT infrastructures required software upgrades in order to enable new features to be implemented. This is a common occurrence in the software development process.

Time zones

The developers, users, servers and clients were distributed across 3 time zones in continental North America. Thus, a common universal time zone was required for use by all parties. UPT was selected as the standard. While all parties used UPT, most users of the system prefer to see their local time zone when interacting with the system on a Human Machine Interface. In the pilot, programmers often converted UPT to local time to improve the usability of time related data (e.g. XX:15 UPT was converted to 2:15 PM PST). But since this work was done without regard for users in other time zones, some problems occurred in viewing and logging time at various sites. These problems were resolved by adopting a two-pronged approach; UPT for low level software and PST were used where time data would be viewed or logged. Similar inconsistencies occurred when different client software programmers took slightly different approaches to the project requirement of returning "current" value for electricity pricing to the server. Unless defined otherwise, several different approaches can all be "correct", but the resulting system would be inconsistent

IT Failures

In several cases, portions of the IT infrastructure failed for various reasons. At Albertson's the polling client software stopped polling (i.e. "requesting") inexplicitly just prior to the start of the pilot test window. It was restored minutes later after system administrators were alerted by phone. An upgrade of the UCSB EIS software before the pilot left the *gateway* software out of synch. Since the *remote control* functionality was not functional in time for the pilot (*remote monitoring* was OK), a remotely controlled IP Relay was used to provide the control interface to the EMCS. At BofA in the first pilot test, the buildings were not commanded into shed mode for unknown reasons. This was probably a result of recent EMCS programming upgrades that resulted in the EMCS not "listening" to the network during the first test.

EMCS Failures

In the first test window, two sites failed to properly enter shed mode due to failures in the EMCSs. At GSA, an ***I/O controller*** locked up and failed to initiate a change to shed mode by closing contacts on a relay. At UCSB, the first test was marred by some EMCS points being "fixed" in manual mode, unable to automatically respond to remote commands to enter certain shed strategies.

Hardware Issues

During the installation and early testing phase of the project, it was reported by Albertson's management that a chicken cooker powered down when the freezer case lights were shed. Analysis of the data logs and additional testing identified a cause and effect relationship between shedding the freezer case lights and disabling the electric chicken cooker. Though the wires were never visually identified, all evidence indicated that the chicken cooker was connected to the circuit that was labeled case lights. In addition to being disabled when the freezer case lights are turned off, analysis of the electric trend logs show an intermittent load profile that started appearing several times per day several months prior. Albertson's management verified a match between the chicken cooker installation and the daily "cooker-like" load profiles that we observed. Rather than perform costly revisions to high voltage wiring, the EMCS software was modified to remove the chicken cooker and the associated freezer case lights from the shed strategy.

Organizational Challenges

The high level objectives of the project were clear to the project team from the start. In most cases, the project team was able to convey these goals to the key decision makers at each site as part of the recruitment effort. Managers who are in a position to understand and approve of a project of this magnitude and complexity tend to be spread very thin between many important facility management responsibilities. As the project was delegated to the various parties who actually define, design and implement the details of the system, it was very challenging to help keep the original vision intact and on track. The differing organizational structures of each group further exacerbated this issue.

Because Web Services is a relatively new technology, none of the development teams had used it prior to the pilot. But because of the simplicity of this technology, lack of experience was not a major impediment to success for any Auto-DR pilot development team. However, though learning Web Services is simple for most programmers in the IT community, development of this type requires programming skills beyond the ability of most EMCS "programmers". In addition, within most EMCS organizations it is not common for EMCS programmers to broaden their skills to include IT level programming expertise.

Within each Auto-DR pilot team, an IT professional programmed the WS client and business logic and an EMCS professional programmed or configured the shed logic in the EMCS controllers. While this approach ultimately produced successful results, the added organizational complexity made scoping, development, testing and project management more difficult.

Conclusions and Future Directions

This paper described the results from a recent test of automated demand response technology. There were a number of specific commissioning challenges in conducting this test. We described five key issues: software compatibility time zones, IT and EMCS failures, and hardware issues. The knowledge needed for this type of system commissioning combines knowledge of building controls with network management and knowledge of emerging information technologies.

In general, the study showed that Auto-DR is technically feasible, although considerable effort from the research team was needed to guide the development of this technology at several of the case study sites. The study has obtained detailed information concerning numerous topics regarding DR and Auto-DR. The technology presented here offers a glimpse of what may be possible for a large-scale deployment effort. We have also made progress in developing methods to measure the DR sheds.

Future work is needed to support commissioning of Demand Response capabilities in large facilities. Basic knowledge of how to develop, test, and fully operationalize DR strategies is needed. Beyond development of basic demand shedding strategies is the opportunity to develop automated systems. New commissioning methods will be needed to develop these advance features with today's EMCS.

As a technology-research oriented project, the research team developed new knowledge about DR that is not widely available. DR is a complex concept. Facility operators need to understand DR economics, controls, communications, energy measurement techniques, and the relation between changes in operation and electric demand. Such understanding may involve numerous people at large facilities. Facility managers need good knowledge of controls, and current levels of outsourcing of control services complicate understanding of control strategies and system capabilities. Examples of information needed to facilitate DR in general include guides on DR strategies and measurement and analysis tools and techniques to predict and measure DR. These tools should include building operational information and economic analysis tools. DR functional and commissioning tests are needed to guide facility managers through the process of identifying and testing DR strategies. Such techniques should ideally be linked to retro-commissioning guides that link energy savings and control optimization to DR.

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