PowerDirect® Revisited

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ABSTRACT

A paper presented for the 2002 ACEEE Summer Study on Energy Efficiency in Buildings Conference described PowerNet and PowerDirect®, innovative Sacramento Municipal Utility District (SMUD) demand response programs that used the Internet, evolving technology platforms, and program design as key elements of a new way of delivering demand response (Fryer, Schiller, and Coomes 2002). The programs ended in 2007 and the infrastructure was abandoned.

Fast-forward to 2013 and PowerDirect is once again an innovative program, this time with the Internet, OpenADR, automated metering infrastructure, a sophisticated demand response management system, and a new and exciting program designed to encourage reliable, predictable, and sustainable automated demand response. Four program options are offered, along with technical incentives, technical assistance, and energy information.

This paper describes the reintroduction and evolution of the program under the Department of Energy (DOE) Smart Grid Investment Grant, and discusses the program elements, infrastructure, systems, processes, and results of SMUD's 2013 PowerDirect Automated Demand Response Pilot Program.

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Disclaimer

Introduction

In 2002, SMUD worked with the State of California, Stonewater Controls (Energy 1st ®), Apogee Interactive (The Demand Exchange®), and Energy Interactive (Energy Profiler Online®)

to test the forerunner of automated demand response in a large commercial building in the 2002 version of the PowerDirect pilot program (Fryer, Schiller, and Coomes 2002).

The modest project involved retrofitting one floor with dimmable lighting ballasts and controls, and an HVAC temperature reset through the facility energy management system connected to the Internet through a Stonewater Controls gateway. The project proved the concept, but was prohibitively expensive to implement for the lighting component at $45,000. The HVAC component, employing a 2° and 4° temperature reset, was very cost effective at $5,000 (Fryer, Schiller, and Coomes 2002).

The projection at that time (2002) for enabling AutoDR in a facility that was already equipped with the necessary controls was approximately $100/kW (Fryer, Schiller, and Coomes 2002). The 2013 PowerDirect pilot program demonstrated an overall cost to enable AutoDR of $83/kW, including the site assessment. This represents a mix of facilities, some already fully capable, some requiring extensive control system installation, programming, and commissioning. The installed cost per kW for the customer in the 2013 program ranges from a low of $7.00/kW to a high of $217/kW, very consistent with the projections from 2002 (U.S. Department of Energy 2014).

This paper presents the results of the pilot program, the program design, supporting systems, and key innovations that contributed to the success of the pilot program.

Background

SMUD has a history of demand response program operation beginning in 1977 with direct load control of residential air conditioners using one-way radio controlled switches. SMUD expanded the breadth of the program to encompass over 100,000 participants by the mid-1990s, along with program offerings for commercial, industrial, and agricultural customers. The programs offered load reduction of approximately 9% of SMUD's peak load, until California's passage of AB 1890 and the restructuring of California's electric utility landscape.

The demand response programs were changed, scaled back, and in many cases, eliminated as the perceived need for the programs waned and potential for stranded investment dominated the utility environment. SMUD continues to operate pilot programs, and maintain the Residential Air Conditioning Load Management program and the Voluntary Emergency Curtailment Program through the present day.

In 2009, SMUD was awarded the Smart Grid Investment Grant through the American Recovery and Reinvestment Act. SMUD launched the SmartSacramento Smart Grid project including funding and projects for a new demand response management system (DRMS), demand response pilot programs for residential and commercial customers, and Automated Demand Response (AutoDR).

The Author created two definitions for describing AutoDR to explain and incorporate the definitions into projects and program designs, as nothing existed that adequately captured the concepts. The definitions describe AutoDR "Capable" and AutoDR "Enabled".

- AutoDR "Capable": A device is considered to be AutoDR capable if it's connected, able to communicate, programmable, configurable and controllable for Automated Demand Response. (https://www.smud.org/powerdirect/faqs.htm March 2014)

- AutoDR "Enabled": A device is considered to be AutoDR Enabled if it's connected, equipped, programmed, configured, controlled and tested for Automated Demand Response. (https://www.smud.org/powerdirect/faqs.htm March 2014)

Research

The program development occurred over approximately a year and a half, while a parallel set of activities were undertaken that included the automated meter reading infrastructure, demand response management system procurement and integration, and the SmartSacramento Partner AutoDR projects.

SMUD formed a cross-organizational team called the Demand Response Working Group to get input from all stakeholders within the company, help determine the value of DR, and determine the parameters necessary for a program to meet SMUD resource needs. The group produced an internal set of documents with a common language for demand response and resource requirements that included the avoided cost, value, and characteristics of the resources.

Extensive review of publications, program information, and interviews with the California Investor –owned utilities personnel was conducted to determine what program elements are working, which are applicable to SMUD, and where opportunities for improvement in program design and operation for both the customer and the utility are present. The review of demand response programs from across the country and California, and working with the Demand Response Research Center at Lawrence Berkeley National Lab, help form an idea for a new type of AutoDR program that became the 2013 PowerDirect program (Piette et al. 2009; Piette, Kilicotte, and Ghatikar 2007; Kilicotte et al. 2010; Motegi et al. 2007; FERC 2010; Rosenstock 2010; Violette, Freeman, and Neil 2006).

Program Design

The key elements of the program are based on achieving reliable, predictable and sustainable load reduction.

The program development turned conventional program design thinking on its head and pursued what customers are capable of providing day-in, day-out, for short and long durations, with day-of to day-ahead notification. Key program innovations include:

- Simple and straightforward programs: Designed to balance SMUD and customer business needs, and provide a high degree of customer acceptance.
- Four program options: Each option is based on a different allocation of performance risk and financial risk to the participant and SMUD.
- Open arms approach to working with customers: Customers are allowed to aggregate smaller loads within one contract, giving them the ability to participate in higher value programs and manage their load reduction across multiple sites.
- Demand Response Management System (DRMS): SMUD uses the Lockheed-Martin SEEload DRMS. SEEload is a very capable, scalable platform that is highly integrated across multiple SMUD business systems, including the Silver Spring Network automated metering system, SAP (SMUD's enterprise software), an enterprise service bus, and the Itron Enterprise meter data management system. Installed in 2012, SEEload is will be the system used to manage all the SMUD demand response programs. SEEload functions

include customer, program, and operations management functions; analysis and reporting of events; device availability and client communication; and predicted and actual load reduction impacts. SEEload allows visibility and control capability of loads all the way down the to the distribution transformer level. (http://www.lockheedmartin.com/us/products/energy-solutions/seesuite/seeload.html 2014).

- Voluntary: The program has no penalties or liquidated damages – customers earn compensation by participating in events. Opt-out of an event carries contractual and financial impacts, however customers are not dropped or excluded from program on a future date if they opt-out of an event.
    - Opt-out allowed through the client that is automatically processed by the DRMS from the client and the customer is removed from the capacity matrix and if an event is in progress, removed from the event. The SMUD DRMS is the only system known to SMUD to have enabled the opt-out capability directly from the client in 2013. Other AutoDR programs require the customer to interact with the demand response automation server to opt-out from an event.
- Automated notification, dispatch, settlement: Key processes are automated to the extent practical, with manual actions required to ensure process control is maintained and include:
    - Accurate, timely settlement process that significantly reduces the time required to settle an event. The event settlement process requires just minutes to go from analyzing an event to posting a bill credit to a customer account, controlled as required at key points in the process.
    - The AMI system and the meter data management systems are leveraged to provide the data for the participants and used in calculating the baselines and settlement.
    - Customers are provided the data through Energy Profiler Online, an online energy information platform originally adopted by SMUD to support the PowerDirect program in 2001.
- Simplicity: The programs are supported with a simplified contract that is designed to reach the best fit for customer. During program operation, no bidding or other human interaction between SMUD and the customer is required to notify, participate in, and post a settlement for an event.
- Customers are responsible for client procurement, maintenance, and communication with the SMUD DRMS. SMUD assists with the monitoring and troubleshooting of client communication issues.
- High level of response predicted to actual: Computer modeled, calculated target load reduction profiles provide a predicted load reduction for each participant, by hour, by month.
- "First-hour" dispatch model: The first-hour dispatch model is a key innovation that delivers a predicted load profile for each customer, by hour, by month, for each of the four summer months. The load reductions are temperature, occupancy, and system dependent, typically decreasing over time from the first hour of dispatch. The program operation began with one set of load profiles, by participant, by month, based on a 2 – 6 pm dispatch window. It became readily apparent after the first two events that this approach would not work and support accurate predicted load reduction and an

automated settlement process. The load reduction profile for each program type (i.e. MinDLR) is represented by four sub-programs in the DRMS capacity matrix, corresponding to the first hour the program is dispatched. (See Figure 1)

- For example, the program is available from 2 pm to 6 pm, weekdays, June – September. A load reduction profile is created for 2-6 pm, 3-6 pm, 4-6 pm, and 5-6 pm for the month of June for each customer. When an event is called, the system operator selects the desired hours for the dispatch that correspond to the start time of the event, from 1 to 4 hours in duration. This produces a very accurate load profile for the duration of the event.
- Without the "first-hour" dispatch model and corresponding capacity matrix in the DRMS, there would be no way to reflect an accurate load reduction, since the load reduction is a function of when the event is initiated and the duration. A single static profile for 2-6 pm across the season will not work, as it is only valid for a 2 pm dispatch.

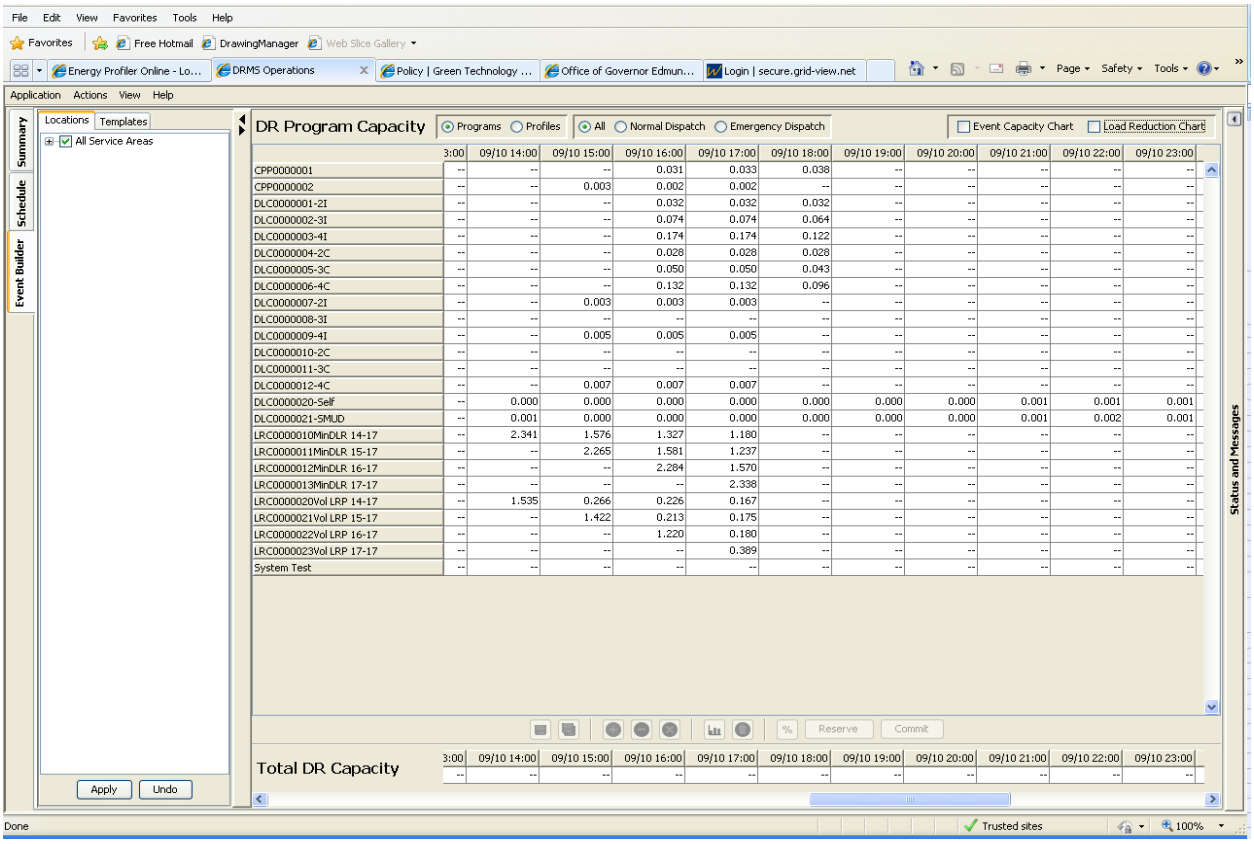

Figure 1. SEEload DRMS Capacity Matrix. The programs are represented by the letter and number combinations under the "DR Program Capacity" header. Note the sub-program distinction identified by the 14-17, 15-17, 16 -17, and 17-17 showing the associated first hour of dispatch. *Source:* SMUD SEEload system screenshot.

Recruitment

SMUD's PowerDirect program is designed to be an operational asset, considered along with other resources for both economic and reliability resource needs. In order to compete in the SMUD resource mix, customer compensation, incentive payments, enablement costs, and overhead costs are managed to keep the total cost of the program as low as possible. To attract reliable and sustainable program participants, removing the penalties and liquidated damages became a key recruitment selling point. SMUD received feedback from only one potential recruit that payment levels were not sufficient after explaining penalties were removed from the program.

SMUD's recruitment showed there are 2 main subsets of customers enrolling in the program. Facilities familiar with automated demand response (most were enrolled in programs at a national level) and those who wanted to be part of the pilot program, mostly unfamiliar with AutoDR and eager to be an early adopter.

The greatest difference between the two subsets was the cost of integration. SMUD's DRMS used OpenADR 1.0 for 2013, providing 2 options for customer systems to connect (SOAP and ReST) to either hardware or software clients. Without a national standard, OpenADR 1.0 presented a learning curve integrating with customer systems, as the SEEload OpenADR syntax differed slightly from the other previously established Demand Response Automation System providers. The cost difference between groups can mostly be attributed to the amount of hardware needed for implementation. Programming was required for all installations. Additional hardware, either for connection or control, was not usually required for customers who had national DR systems already operational. National retailers often have a centralized operations center allowing them to propagate the SMUD event signal automatically to multiple sites within minutes of posting.

Early on, recruitment focused on customers within SMUD's territory who had large peak demands, where small changes to their operations could lead to greater load reduction potential. SMUD's market analysis showed the top 1500 largest customers could yield 40 MW of AutoDR, or about 1% of SMUD's 3300 MW summer peak load.

Recruitment targeted customers who participated with SMUD in the advanced controls programs during the SmartSacramento project, SMUD's energy efficiency programs, and national retailers. These customer control systems under consideration had both the potential to be re-programmed to include demand response strategies, and had the communication capability to interact with the DRMS.

Early recruitment of national retailers showed this segment could produce very predictable, easily enabled, and very consistent load reduction. SMUD's smart meter infrastructure allowed the PowerDirect program to aggregate multiple sites into a single load, thus qualifying customers who previously have been excluded from a similar program and managing their participation with one contract.

Penalties and liquidated damages present challenges and obstacles to participation. Utilities want a guarantee of performance and a mechanism to be made whole if that guarantee is not fulfilled. Customers are wary of penalties, especially for participation in unfamiliar programs that have operational and economic impact.

SMUD eliminated penalties and liquidated damages to encourage participation by allowing program parameters to limit risk for both parties and found that eliminating penalties became a driving force for participation. Customers are free to work cooperatively with SMUD

to optimize their DR capability without risk of large financial consequences. In a specific case, the first question posed to program managers about PowerDirect was: "What are the penalties for non-performance?" In SMUD's experience, removing penalties allowed for greater acceptance of lower program payments, thus reducing the risk and exposure to the utility.

Participants

The program participants consisted of 9 contracts, with 126 facilities. Customers ranged from small and large retail, to large office buildings, and included 3 of the 6 the SmartSacramento Partners: a school district, state office buildings, and county office buildings.

- 6 contracts were represented in MinDLR and 3 in the Voluntary Load Reduction program.
- Each facility is typically one metered point. An individual contract can correspond to one or more meters and facilities.

Program Description

The PowerDirect program offers four program options to help best meet customer and SMUD business needs. The programs are available to operate June – September, 2 to 6 pm, weekdays.

Firm load reduction program. The Firm Load Reduction Program (FLR) is the most aggressive option presented to customers in the program. In FLR, the customer must reduce total site load to a pre-determined level for each hour, no matter what their load is at the time of the demand response event. FLR poses the greatest risk to the customer because until their load level reaches this point, they do not qualify for an event payment. The incentive for the customer to choose FLR is earning more compensation for over-performance. Once the customer reduces their load to the pre-determined level, they receive energy payments for all load reduced to their commitment, and the potential to reduce load even further and receive additional energy payment without a cap. Only one customer signed up for PowerDirect in the FLR option. After analyzing the load and demand response strategies, too much of the demand response was based on temperature dependent loads and the Minimum Dependable Load Reduction option was determined to be a better fit. FLR Guidelines:

- Reduce energy consumption by a minimum of 50kW, to a predetermined maximum consumption level, for at least two consecutive hours during peak usage hours.
- Receive an incentive of $2.30/kW per month and 12¢/kWh for energy reduction from baseline on Conservation Days.

Minimum dependable load reduction. Minimum Dependable Load Reduction (MinDLR) was the most subscribed option in the program. MinDLR has less risk associated than FLR because instead of reducing total load to a pre-determined level, customers reach a pre-determined level of load reduction below their baseline. Once 50% of the load reduction target is reached, participants start receiving energy payments up to 150% of the load reduction target. MinDLR gives customers a "working range" to operate within and still be compliant and receive energy

payments. The tradeoff is the compensation capped of 150% of the load reduction and limiting the potential risk of program abuse to the utility. MinDLR Guidelines:

- Reduce energy consumption by a minimum of 50kW for at least two consecutive hours during peak hours.
- Achieve 50% to 150% of the load reduction goal each hour of the event on a Conservation Day.
- Receive an incentive of $2.30/kW per month and 12¢/kWh for energy reduction from baseline on Conservation Days.

Demand response peak pricing. This program option is similar to a Critical Peak Pricing rate, where the peak price for electricity is increased during event hours. The difference is this program creates a dynamic critical peak period, set by the event duration at time of dispatch. The program is applicable to customers on SMUD's GS-TOU1, GS-TOU2, and GS-TOU3 rates (https://www.smud.org/en/business/customer-service/rates-requirements-interconnection/your-rates.htm).

- On peak price for electricity is increased with a $0.50/kWh on peak "adder" to the customer's existing rate.
- Off-peak price for electricity is discounted $0.02/kWh from June 1 through September 30, 2013.
- No customers enrolled in this program in 2013. All felt it was too risky and not a good fit for their operations.

Voluntary load reduction. Voluntary Load Reduction is the "learning" option. There is no minimum load reduction commitment, with the customer receiving energy payments for all load reduction provided below their baseline. This option removes any risk for the customer and allows them to optimize their systems for load reduction without having to reach a committed load level. The goal is to give customers the ability to participate in events and learn how their systems respond, while receiving a financial incentive for participation. The hope is customers learn how there systems respond and move up to higher value program option that provides higher financial incentives (monthly capacity payments) and a more predictable load reduction, delivering greater value for SMUD and the customer. The Voluntary program allows customers that would normally be excluded from an AutoDR program to participate. For example, SMUD enrolled a school district with 60 facilities and a modest 2°global temperature reset. Throughout the summer, the district delivered modest load reduction for about 2 hours. Once school was back in session, the one-hour load reduction delivered during an event topped 1 MW for about 1 ½ hours before tapering off dramatically (U.S. Department of Energy 2014). Voluntary Load Reduction program guidelines:

- No contractual or minimum load reduction commitment.
- Receive 11¢/kWh for the energy reduction delivered from the baseline.

Program Operating Parameters

The program operates June 1 through September 30, with a minimum expectation of 8 to 12 Conservation Day events called during peak hours (2:00 p.m. to 6:00 p.m., weekdays). Events

last from one to four hours, with notifications sent out either the day of or the day before an event, with a minimum 30 minutes notification. Events may be run more frequently than once per day. (See Figure 2)

- Day-of notification is typically sent two hours, and at least 30 minutes prior, to an event.
- Maximum of 12 Conservation Day events more than two hours long. Exception is the Voluntary Load Reduction option.
- Maximum of three consecutive days with events more than two hours long within a 14-day period.
- No limit on consecutive days with events two hours long or less.

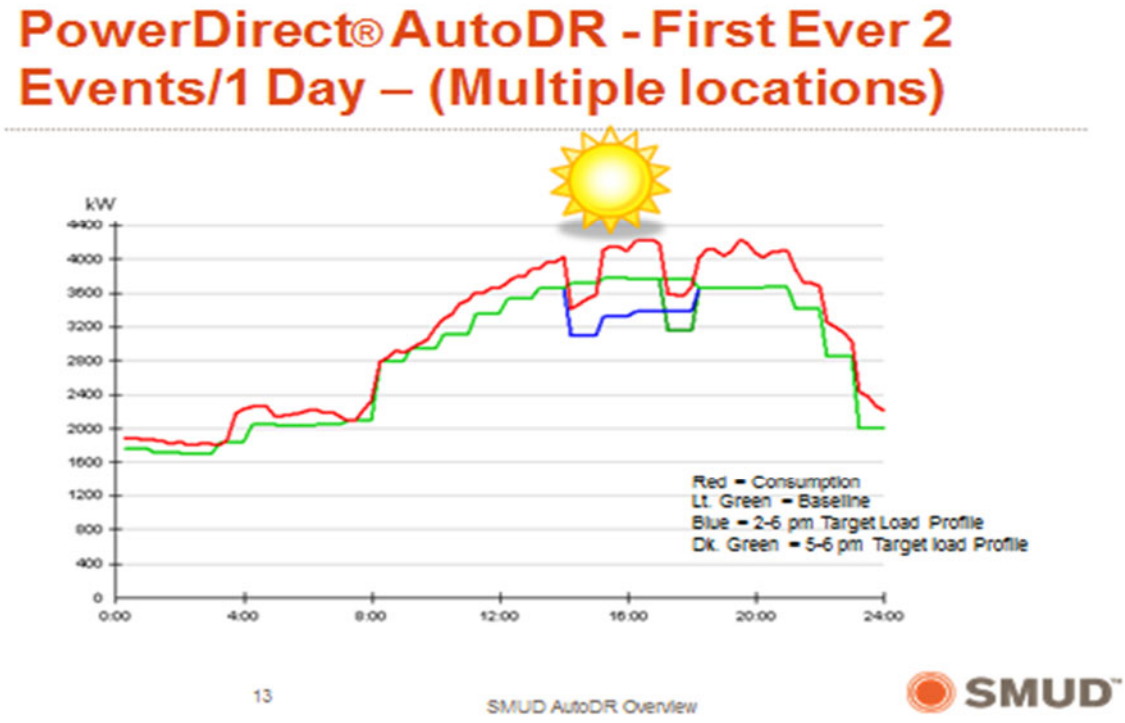

Figure 2. PowerDirect AutoDR Event Day example. *Source:* Energy Profiler Online screenshot of actual event on September 9th, 2013.

Technology Incentive

The incentive pays $125/kW of enabled AutoDR up to a maximum of 100% of AutoDR project cost. The incentive is calculated based on the facility's highest one-hour average electrical load reduction over the four program months as determined from a detailed site assessment performed by SMUD and its contractor. The incentive payout is planned in two steps: $50/kW at project completion, then $75/kW at testing and verification of demand reduction. In practice, SMUD paid the full incentive in one step, based on the calculated load peak reduction. One customer performed significantly better in events than predicted, and was paid additional technology incentive to provide fair compensation for their project based on the

demonstrated load reduction capability. To be eligible for the incentive, work must be complete and functionally tested by program deadlines.

Site Assessment

SMUD contracted with Global Energy Partners to perform site assessments, assist with the implementation of AutoDR strategies and perform the load reduction profile analysis. The site assessment and implementation assistance is provided at no cost to the customer. Typically, a high-level preliminary site assessment is done, followed by a detailed site assessment.

Customer Experience

With the design of the PowerDirect program, customer experience through the entire process was a priority. By providing technical analysis, hardware and software support, and a transparent process at no cost to the customer, SMUD earned the trust of participants, helping lead to reliable load reduction and a successful program outcome.

The PowerDirect contract, the first step in program enrollment, differed greatly from SMUD's usual program process. The cost of the technical site assessment and requirement of reserving technical incentive funds required a firm commitment from the customer, instead of the usual letter of intent. The unique structure of the PowerDirect contract did not detour any participants from joining, as the flexibility in the contract allowed SMUD and the customer to feel confident in a positive outcome.

Once the contract was signed, the technical site assessment was scheduled. The site assessment included verification of existing equipment, facility square footage, current controls strategies, and planned demand response strategies. National retailers typically did not require detailed site assessments as demand response strategies and expected results were available from participation and experience in other AutoDR programs. The most important result of the site assessment for SMUD was an accurate model of expected load reduction, by hour, by month.

With the site assessment complete and load reduction strategies decided, controls and mechanical contractors, selected by the customer, can begin project work. The SMUD technical incentive level was the deciding factor for several enrollments after the site assessment, however SMUD had several customers who wanted to participate regardless of the incentive limit.

Connection between the site controls systems and SMUD's DRMS was different for each site. Encouraging participation meant SMUD needed to be flexible in allowing options for connecting to the DRMS. The SEEload system supports both ReST and SOAP protocols. All connections follow the OpenADR 1.0 protocol (2013). SMUD is implementing OpenADR 2.0a protocol in 2014 and will maintain compatibility with OpenADR 1.0.

Once the customer systems were operational and communication with SMUD's DRMS was complete, a demand response test was performed to verify technical incentive requirements were satisfied. With a successful test, the load reduction validated, and all invoices received, the technical incentive payment is processed and the site is now ready for the DR season.

Outcome

The pilot operated very successfully from June – September, with 10 structured events delivering approximately 41,500 kWh of energy and 3.4 MW of peak load reduction. The

Minimum Dependable Load Reduction (MinDLR) program delivered 93% of predicted demand reduction at $0.61/kWh, and the Voluntary program delivered 81% of predicted load reduction at $0.11/kWh, for a combined effective performance of 91% overall at $0.53/kWh (excluding revenue impacts). A total of $22,250 was paid in performance incentives. (U.S. Department of Energy 2014)

- Technology Incentives totaled $ 96,296. SMUD provided site assessments and technical assistance at no charge to the customer. Customers were provided Energy Profiler Online as their tool to view the energy information associated with their program participation including displaying the baseline, target load profiles, and actual energy consumption data.
- The customer project cost ranged from about $7/kW to $217/kW. The customer enablement cost to SMUD, including the technology incentive and technical assistance was $83/kW, well under budget estimates (about 40% lower) and cost-competitive with supply-side capacitor options on the 230 kV system.
- 100% of the participants have agreed to continue participation in 2014 with some adding additional sites. During the 2013 season only one site opted out of an event. There were no complaints registered from participants regarding the load reduction measures.
- A comprehensive survey was provided to all participants and AutoDR controls implementers. 90% of participants indicated that they are satisfied with the pilot program.

Baseline Experience

SMUD utilized a baseline algorithm for each participant that calculated an average load profile of the 10 previous non- holiday, non-event, weekdays (10 of 10) with a 45-day look back to gather the consumption data, and additive day-of adjustment. This was chosen due to the types of load present in the program, SMUD's familiarity with the methodology, and the inherent limit of exposure from baseline correction error in the additive method.

SMUD began the program with a 30-day look back and a +/- 20% cap on the baseline adjustment, typical of the California IOU AutoDR programs. The weather was unseasonably cool for the first two events, and very hot on the event day, resulting in a gross under-correction of the baselines on the event day. The look back was subsequently extended to 45 days and the adjustment cap was removed, and the event settlements were rerun, allowing the program parameters to control the financial exposure and provide a fair settlement for the customer. A comparison for all customers in all events was performed for the additive and scalar methods. An example of the comparison is represented in Table 1.

Table 1. Comparison of additive and scalar baseline adjustment methods

	Time	Baseline	Adjusted Baseline	Actual	% Adjustment	% Error from Actual	Value of Error
Additive	16:00	4,037.31	5,752.80	4,671.04	142.49%	123.16%	1,081.77
Scalar	16:00	4,037.31	8,629.05	4,671.04	213.73%	184.74%	3,958.02

The above analysis is for Participant 5 on August 30, 2013. The table shows the variation between the additive and scalar methods when calculating the day-of adjustment to the baseline. Note the value of the error in this example is much greater for the scalar method. *Source:* (U.S. Department of Energy 2014).

Conclusion

The 2013 PowerDirect AutoDR pilot program demonstrated that an innovative program, designed to offer ease of compliance through automation, eliminating penalties and liquidated damages, and structured to encourage consistently achievable performance will provide reliable, predictable, and sustainable load reduction. Key innovations include the use of the "first-hour" dispatch matrix, modeling predicted load reduction profiles, eliminating bidding and other human interaction required to participate in events, and a simplified, flexible contract.

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