Open Automated Demand Response Communications in Demand Response for Wholesale Ancillary Services

Sila Kiliccote
Mary Ann Piette
Girish Ghatikar

Lawrence Berkeley National Laboratory
1 Cyclotron Rd. 90-3111
Berkeley CA 94720

SKiliccote@lbl.gov
MAPiette@lbl.gov
GGhatikar@lbl.gov

Ed Koch
Dan Hennage

Akuacom
25 Bellam Blvd. St 215
San Rafael CA 94903

Ed@akuacom.com
Dan@akuacom.com

John Hernandez
Albert Chiu
Osman Sezgen

Pacific Gas and Electric Company
245 Market St.
San Francisco CA 94105

J6H6@pge.com
AKC6@pge.com
OXS6@pge.com

John Goodin

California Independent Systems Operator
P.O. Box 639014
Folsom, CA 95763

JGoodin@caiso.com

Keywords: demand response, automated demand response, OpenADR, ancillary services

Abstract

The Pacific Gas and Electric Company (PG&E) is conducting a pilot program to investigate the technical feasibility of bidding certain demand response (DR) resources into the California Independent System Operator's (CAISO) day-ahead market for ancillary services non-spinning reserve. Three facilities, a retail store, a local government office building, and a bakery, are recruited into the pilot program. For each facility, hourly demand, and load curtailment potential are forecasted two days ahead and submitted to the CAISO the day before the operation as an available resource. These DR resources are optimized against all other generation resources in the CAISO ancillary service. Each facility is equipped with four-second real time telemetry equipment to ensure resource accountability and visibility to CAISO operators. When CAISO requests DR resources, PG&E's OpenADR (Open Automated DR) communications infrastructure is utilized to deliver DR signals to the facilities' energy management and control systems (EMCS). The pre-programmed DR strategies are triggered without a human in the loop. This paper describes the automated system architecture and the flow of information to trigger and monitor the performance of the DR events. We outline the DR strategies at each of the participating facilities. At one site a real time electric measurement feedback loop is implemented to assure the delivery of CAISO dispatched demand reductions. Finally, we present results from each of the facilities and discuss findings.

1. INTRODUCTION

The Participating Load Pilots (PLP) were authorized by the California Public Utilities Commission (CPUC) as a first step towards allowing DR programs to participate in the CAISO markets as Participating Loads (PL). The objective of these pilots was to assess the technical and financial feasibility of using retail loads for PL. Various retail load classes and technologies participated in the pilots. The key requirements under the PLP is that the PL resources have to meet the non-spinning reserve requirements, which means the resources have to deliver energy within 10 minutes, be available for two hours, and provide real-time telemetry to the CAISO. All three investor-owned utilities in California conducted PLPs with various customer segments. Southern California Edison utilized small aggregated loads, leveraging real-time telemetry at the feeder with two-way communicating switches and air conditioning loads. This was an extension of the prior work done on spinning reserve demonstration [1] [2]. San Diego Gas and Electric Company worked with aggregators with small commercial and industrial customers. CPUC allowed a portion of the PL to be dispatched manually, granted it still met the dispatch criteria.

The PG&E's pilot program investigates the technical feasibility of bidding large commercial and industrial DR resources into the CAISO's day-ahead market for ancillary services non-spinning reserve. PL resources provide demand that can be curtailed at the direction of the CAISO in the real-time dispatch of the CAISO controlled grid. PL model relies on a simple price-sensitive demand curve submitted in the day-ahead market, and an accompanying pseudo-generator supply curve for use in the Real-Time Market that represents the demand response resource's real-time energy dispatch capability [3]. PG&E's additional goals for the pilot is to identify and investigate potential barriers such as forecasting load and demand reduction, bidding and settlements, locational resource management and testing telemetry technologies. This research is significant because three individual sites that participated in price-responsive automated DR (Auto-DR) programs utilized the same technologies, DR strategies and infrastructures, and with no additional costs to each facility, participated successfully in the wholesale non-spinning ancillary services. While there is a clearly defined application and certification process that outlines the agreements as well as PL implementation plan approval, metering and telemetry requirements and ancillary service testing, this paper concentrates on the operational process.

The project team includes PG&E, Itron, Akuacom, Metrum Technologies, Bow Networks, Lawrence Berkeley National Laboratory (LBNL) and the CAISO. LBNL developed a set of site selection criteria. Responsibilities of the team members are:

- PG&E – Project management
- LBNL – Pre- and post- event analysis, recruitment of sites, evaluation of building controls issues and DR control strategies
- ITRON – Forecasting of loads and load reductions
- Metrum Technologies – Four-second telemetry technology provider
- Bow Networks – Four-second telemetry communications provider
- Akuacom – Automation of PLP dispatch signals, conversion from ADS specific format to OpenADR
- CAISO - Dispatch of PLP event signals.

This paper is organized as follows. The next section describes the PLP system architecture. This is followed by the **Methodology** section, in which we describe the site selection criteria, development of forecasts, data and data collection methods as well as the DR strategies at each facility that participated in the pilot. In the **Results** section we present a comparison of forecasts with actual loads, the findings from test and actual events as well as the cost for telemetry and enablement. Finally in the **Discussion and Conclusion** section, we point out issues that had come up during the pilot, resolution of these issues and identify next steps.

2. PARTICIPATING LOAD PILOT (PLP) ARCHITECTURE

In the Day-Ahead Market, PG&E submits two bids through the CAISO's Scheduling Infrastructure Business Rules (SIBR) web-based user interface for each of the PL: a load bid (an offer to buy or self-schedule demand) and a generating (pseudo generating resource) bid (an offer to sell demand reductions). Load bid consists of hourly loads of the resource. Pseudo generating bid represents the demand reduction portion of the non-spinning reserve provided by the PL. Both Load and Pseudo Generating bids are hourly bids generated by PG&E by averaging 5-minute forecasts submitted by Itron's MetrixIDR™[1]. Any operational changes within the facilities are communicated to PG&E either directly by the facility operator or through LBNL before 5 am one day before the trading day. Between 5 am and 9 am, there is a second window of opportunity for the facilities to announce changes to their bids. Bids and prices are submitted to CAISO by 9 am. The day-ahead market closes at 10 am one day before the trading day. The CAISO publishes schedules and award results no earlier than 1 pm on the same day. Figure 1 outlines the pre-analysis process flow starting two days prior to the operation date for each day. The real-time market closes 75 minutes before the trade

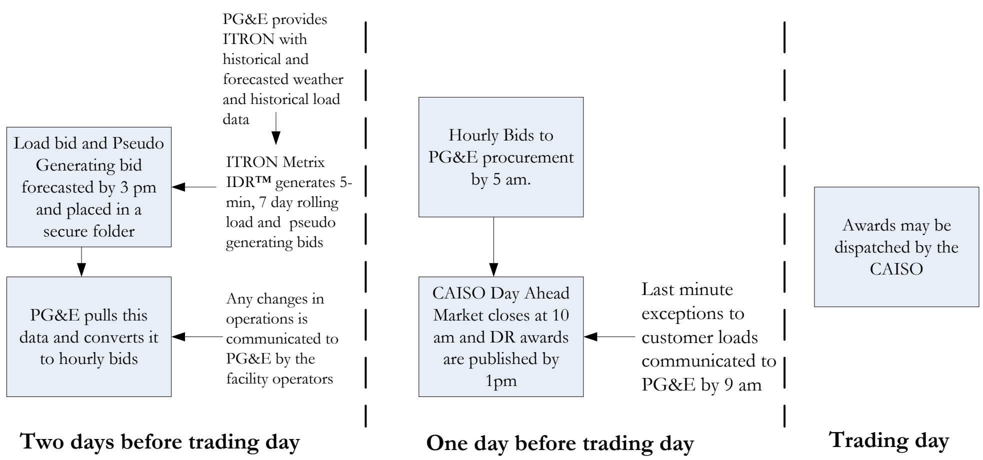

Figure 1 Load and pseudo generation schedule submission process

hour and the PL resources are settled based on 5 minute dispatches that are based on the PL's day-ahead schedule. A typical settlement time for PL resources takes 38 to 56 days after the resource request date. At the time this paper was written no settlements were completed for the PLP dispatches. Therefore, in this paper, no site specific earnings or losses are reported for the facilities that participated in the PLP.

Three facilities, a retail store (IKEA), a local government office building (Contra Costa County) and a bakery (Svenhard's Swedish Bakery) participated in Auto-DR programs with PG&E in previous years, were recruited into the pilot program [4]. CAISO's Automated Dispatch System (ADS) linked the ISO operators dispatching DR resources to DRAS. When CAISO dispatched awards for the participants (Figure 2, 1) PG&E's OpenADR (Open Automated DR) messaging infrastructure was utilized (Figure 2, 2) to deliver DR signals to the facilities' energy management and control systems (Piette et al. 2009). This is the same infrastructure that is currently being used for PG&E's price-based Auto-DR programs such as Automated Critical Peak Pricing and Demand Bidding programs. Pre-programmed DR strategies were triggered without a human in the loop at each facility utilizing the Client Logic with Integrated Relay (CLIR) box[2]. This device communicates price and reliability signals with facility EMCS by mapping DR program information to dry contact relay closures. On the metering side, dual meter socket installations allowed the facilities to keep their revenue meter (RM) and facilitated the installation of another meter with a Code Division Multiple Access (CDMA) chip provided by Metrum Technologies to transfer four-second electric load data for this pilot (Figure 2, 3). CDMA technology transmits radio signals over a cellular-based wireless network. This four-second telemetry infrastructure was installed at each of the participating facilities and data were communicated by Bow Networks to CAISO (Figure 2, 4), PG&E (Figure 2, 5) and Akuacom (Figure 2, 6).
CAISO uses the telemetry data to have visibility to the operating reserves on the grid and to ensure that it it meeting its minimum operating reliability criteria at all times. PG&E stored these data in a secure shared folder for access by the team. Itron used the data for the load and shed forecasting. Akuacom used the four-second data for real-time feedback to dispatch various pre-programmed control strategies at the government office building to sustain the shed amount dispatched by the CAISO. **Figure 2** displays the architecture of the participating load pilot. The dashed arrows represent meter data communications, while solid arrows represent communication of the resource request parameters. In **Figure 2**, the entities to the left grouped with dashed lines are involved in pre- and post-analysis. Others to the right, including PG&E, are involved in the actual resource request and/or delivery.

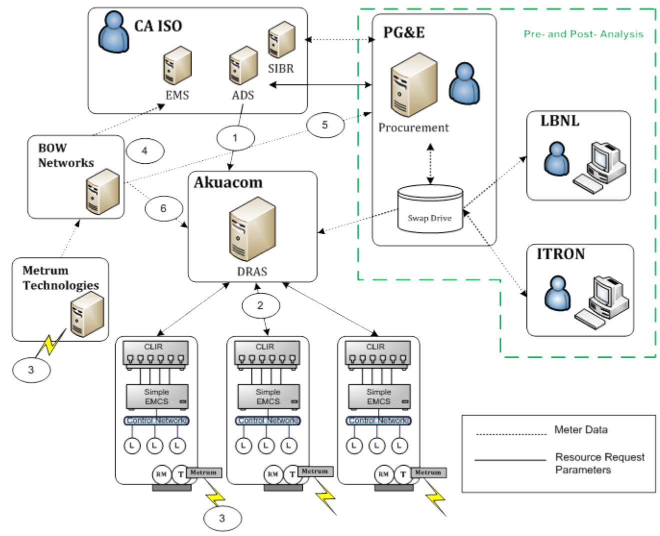

Figure 2 Participating load pilot system architecture

3. METHODOLOGY

LBNL worked with PG&E to develop pre- and post analysis methods as well as electrical data sharing methods for this pilot. Pre-analysis methods include development of site selection criteria, analysis of loads for sites in the AutoDR [5] programs as compared to the criteria, DR shed strategies as well as forecasting loads for recruited facilities. Forecasting of individual building loads were done by MetrixIDR™ and is out of the scope for this paper. Post-analysis methods include the development of ramp time and shed calculations methods as well as evaluation of accuracy of forecasts. Finally, timely and secure communication and data sharing by all the team members is a major undertaking. However, this discussion is not included in this paper.

3. 1. Site Selection

Sites that participated in PG&E's AutoDR programs in previous years were considered for this pilot. Selection criteria were as follows:

- Low load variability – enhances load forecasting accuracy
- Ability to deliver resource in 10 minutes – preferably a site with both fast (lighting) and slow (Heating Ventilation Air Conditioning) response

[2] Technical guide is available at
http://drrc.lbl.gov/pubs/CLIR-UserGuide_6-R3.pdf

- Low shed variability – enhances shed forecasting accuracy
- Minimum of 10 kW of load shed

Historical electrical 15-minute interval meter data is available for all the AutoDR sites. Due to the low resolution of the meter data, it was difficult to determine the response time of the sites. However we grouped the sites that yielded the initial shed within the first 15 minutes and those that yielded additional shed within the second 15 minute period. If a site continued to shed after the first 15 minutes, we considered these sites as having "slower" response.

All sites met the minimum demand shed requirement. Only three of the sites in Auto-DR consistently shed lighting loads. However, these sites are recently equipped with solar panels. Therefore their load shape and load variability prohibited their participation. For the remaining sites, load statistical summaries (LSS) and load variability (VAR) calculations [6] were completed. DR participation and load shape statistical summary. VAR is a measure of coefficient of variance; it is the ratio of standard deviation to average demand, for each hour during the time period of interest, as defined in Equation 1. The bigger the load variability, the more difficult it is to accurately forecast load. LSS shows the average, minimum, maximum and standard error of 15-min demand across each day in the period of interest. LSS and VAR both reflect DR potential as they indicate when and where peak loads occur, or the extend to which loads vary or can be reliably predicted.

$$VAR = \frac{\sqrt{\dfrac{\sum_{i=1}^{N}\left(x_i - \bar{x}\right)^2}{N-1}}}{\bar{x}} \qquad (1)$$

where $\bar{x}$ is the average hourly load in the period, and N is the number of days in the period

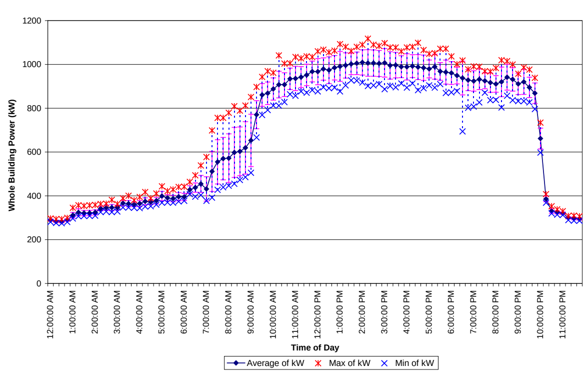

Figure 3 Load statistical summary (LSS) of IKEA

As a result of the pre-analysis, four sites were recommended to participate in the pilot. Two of these sites agreed to participate in the study. A third site, which did not fit the initial load variability criteria, was requested to participate in the study to so as to evaluate a variety of sites. The final three facilities that participated in the study were a retail store (IKEA), a local government office building (Contra Costa County) and a bakery (Svenhards Swedish Bakery).

3. 2. DR Strategies

Each facility had participated in PG&E's Automated Critical Peak Program (Auto-CPP) for at least two years. Therefore, two-level DR strategies were pre-programmed in their energy management and control systems (EMCS). Each site was asked to re-evaluate their strategies and decide how long they would be willing to participate and with which DR strategy.

- IKEA responded to PLP events the same way they respond to Auto-CPP: noon to 6pm with shutting off a small portion of their roof-top units and raising temperatures 2 ºF for the first three hours and alternating the shut-off roof-top units and increasing temperature setpoints additional 2 ºF for the last three hours.
- Svenhards automatically turned off their pan washer for the duration of the event between 3 pm and 5 pm.
- Contra Costa County allowed the team to experiment with adjusting DR strategies depending on the load feedback received from 4 second telemetry. 4 ºF temperature setpoint adjustment with one degree increments was pre-programmed into the EMCS. During the resource request period, forecasted bid level and the actual load shed were compared and adjustments to temperature setpoints were requested automatically in order to sustain the forecasted bid levels.

3. 3. Ramp Rate Calculations

Non-spinning reserve resources must ramp to full capacity within 10 minutes. Ramp rate is the bid component that indicates the load drop rate and load pick-up rate for participating loads, for which the scheduling coordinator is submitting energy bids or ancillary services bids[3]. It is the measured rate, expressed in megawatts per minute, of a participating load's ability to adjust its demand. For each participating load resource, a ramp rate is entered into the CAISO's master file. The average, best and worst ramp rates for the participants were 0.25, 0.05 and 0.1 MW/min.

[3] http://www.caiso.com/240d/240dbdee2c0c0.pdf

For each event and resource, ramp rate is calculated as the load drop over the first 10 minutes of the PL event.

3. 4. Data Collection

Data collection and secure sharing among the seven entities that participated in the operation and analysis of the PLP events was a major effort in this project. An additional meter with a Code Division Multiple Access (CDMA) chip was installed at each facility to communicate four-second real-time telemetry data wirelessly. This real-time data was used by CAISO to ensure resource availability and by Akuacom as a feedback to sustain the reduction bid level at Contra Costa County building. A swap drive with strict security guidelines was established by PG&E for archiving and sharing both four-second telemetry and forecast data.

The electrical data for each site collected (or calculated) and shared for this project is as follows:

- 15 minute interval data from the revenue meter
- 5 minute data from the pulse output of the revenue meter
- 4 second telemetry data from the meter with CDMA chip
- 5 minute load forecasts (calculated by Itron/Metrix IDR)
- 5 minute load reduction forecasts (calculated by Itron/Metrix IDR)
- Hourly load forecasts (calculated by PG&E using 5 minute load forecasts) also known as Load Schedule
- Hourly load reduction forecasts (calculated by PG&E5 minute load reduction forecasts) also know as Generator Schedule

3. 5. Demand Shed Calculations

Forecasted loads are considered as baseline for all calculations. Demand shed calculations are completed by subtracting actual 5-minute loads from forecasted five-minute loads and compared to the forecasted hourly demand reduction.

3. 6. Settlement Calculations

The real-time settlement is based on the deviation of the real-time revenue meteragainst the day-ahead schedule. The settlement is calculated as:

(Actual meter – Day-Ahead Schedule) x Real-Time Price

This may result in a charge to PG&E if positive (+) or a credit if negative (-).

3. 7. Dispatch Signal Propagation

The DRAS is directly interfaced to the CAISO Automated Dispatch System (ADS). It polls the ADS Server to receive dispatch instructions as depicted in the following general pseudo code from the "ADS API Specification. The connection to the ADS Server is secured using SSL with both client and server side certificates.

Instructions from the ADS arrive in the form of XML documents. The following fields from the XML document are examined by the DRAS to determine the appropriate course of action:

<batchType>0</batchType> - This is the type of instruction. The two types that are relevant are "5 minute dispatchable[4]" and "OOS Instructions[5]".

- <startTime>2006-10-13T14:10:00Z</startTime> - This is the start time of the instruction
- <endTime>2006-10-13T14:15:00Z</endTime> - This is the end time of the instruction
- <dot>12.0</dot> - This is the level in MW that the resource is being instructed to go to.

When a valid instruction is received an OpenADR event is created that has the same start time and end time as that in the instruction. Note that for 5 minute dispatchable instructions, an end time is not explicitly given and it is assumed to be 5 minutes after the start time. The notification time for DR event is the same as the start time and the event is immediately published to all the DRAS Clients so they can achieve their instructed levels within the required 10 minute ramp period.

Figure 4 display the Auto-CPP mapping on OpenADR specification. Issue Time is either day ahead of two hours

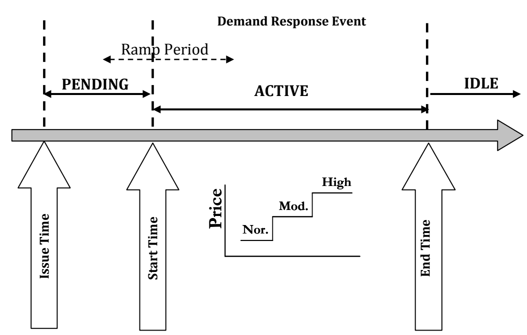

Figure 4 Automated critical peak pricing (Auto-CPP) mapping on OpenADR specification

---

[4] Indicates 5 minute dispatchable event

[5] Out of Sequence (OOS) instruction is associated with exceptional dispatches.

before the DR event time on the day of the Auto-CPP event. The implicated Ramp Time is either before or at the Start Time and is determined by the facility operator. During the Active Period, DR event contains simple price levels (NORMAL, MODERATE or HIGH).

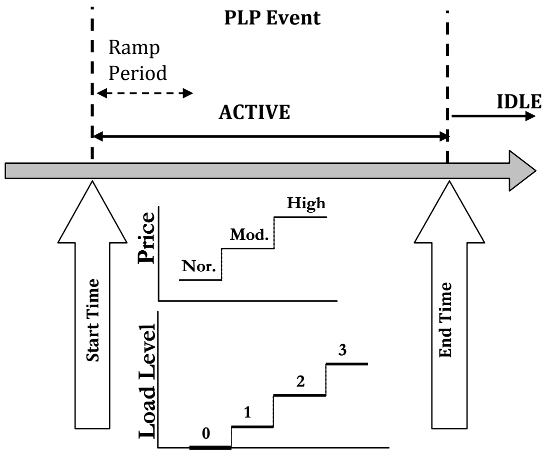

Figure 5 PLP event mapping on OpenADR specification

Figure 5 displays the PLP Event mapping on OpenADR messaging model. In this application, Issue Time field and PENDING signal is not being utilized. The implicated Ramp Time is within the PLP Event Active period. The DR event also contains a simple price level (NORMAL, MODERATE, or HIGH). In addition the DR event also contains an enumerated load level (0-3) that is used for doing closed-loop monitoring.

For Contra Costa County Building, which is using closed loop monitoring, if the facility is not achieving its instructed level then a higher shed level is sent to that facility. Likewise if the facility is shedding more than the instructed level, a lower shed level may be sent.

4. RESULTS

By the time this paper was written, a total of eight PLP events were dispatched. The first event in July was a test event and was dispatched to ensure that the automation worked and that sample messages from CAISO's ADS were received and processed. All the buildings were "live" in the wholesale market on the CAISO's production systems on July 29, 2009. The remaining PLP events were actual dispatches called by the CAISO's ADS. Table 2 shows the dates of each event and the duration of participation for each facility. Some of the dispatched events did not meet the initial PLP rules such as one event per day and minimum event duration of one hour.

Table 1 PLP events and duration of participation for each facility

Site/Date	17-Jul	6-Aug	27-Aug	31-Aug	11-Sep	18-Sep	21-Sep	22-Sep
IKEA EPA	15:00 - 17:00				14:40 - 14:43	16:00 - 16:25, 16:35 - 16:50		
CCC	15:00 - 17:00	17:00 - 18:00		14:00 - 15:00	14:40 - 14:43	16:00 - 16:25, 16:35 - 16:50	14:00 - 16:30, 16:40 - 17:55	
Svenhards	15:00 - 17:00	15:00 - 16:00	15: 25 - 15:30			16:00 - 16:25, 16:35 - 16:50	16:30 - 16:40	16:55 - 17:00

For each of the sites, a representative event is selected and presented in this paper. For each event, the load shape is presented in two ways: 1) Actual 5 minute electrical load data is displayed with the hourly load forecast for the event day, and 2) The difference between the actual 5 minute electrical load data and the forecasted 5 minute load data with the hourly forecasted bids. The first graphic representation shows how the actual load profile follows the hourly bids averaged and submitted by PG&E. The second representation shows a comparison of actual versus forecasted 5 minute load data and how the sheds compare to the difference between forecasted and actual data. A table that summarizes the ramp time and average load shed is also presented for each facility.

4.1. Contra Costa County Office Building

Load variability and weather sensitivity calculations indicate that this is a highly weather sensitive building with low hourly load variability. As a result, LBNL recommended the use of outside air temperature data in forecasting algorithms. While this site participated in all PLP events that were dispatched by the CAISO for this resource, the test on September 21st was the only one where the PLP event was long enough to test the feedback algorithm for this facility. Figure 6 displays the actual 5 minute load data with the hourly forecasts. The PLP event was dispatched between 2 pm and 6 pm. The DR strategy for this facility is programmed such that four load levels are mapped onto four 1ºF incremental temperature adjustment strategies. At the PLP event start, a 2ºF adjustment is dispatched. The 4-second data is used to monitor the performance of the strategy and evaluate if it meets the bid requirements. If the initial strategy did not meet the bid requirements, than the strategy is adjusted by the DRAS by sending another load level information that adjusts the temperature setpoints up or down within the initial parameters set and programmed by the participant. On September 21, the initial adjustment for the first hour exceeded the bid. This is partly because there was a problem with the algorithm and instead of calling for the strategy with 2 ºF, the system called for 4 ºF strategy that was carried out for 1 minute before it was adjusted. Part of reason why the shed is so deep is because of the nature of response by the heating, ventilation and air conditioning (HVAC) systems. When initial adjustments are made, the fans go to their minimum setting and the chillers unload resulting in transient savings resulting in high ramp rate.

Therefore, the bids for the first hour for this facility have to be increased to match the response.

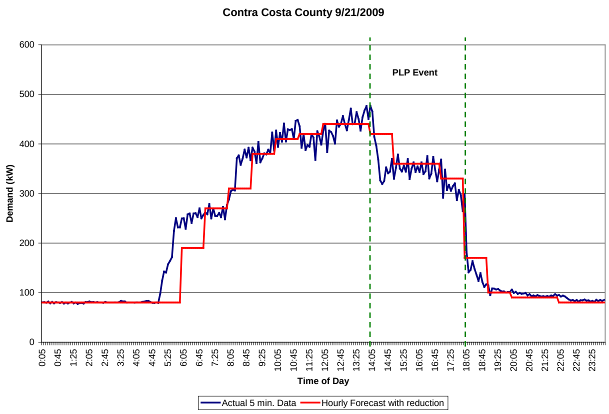

Figure 6 Contra Costa County hourly load forecasts and actual load data on September 21, 2009

Figure 7 presents the difference between the forecasted and actual 5 minute load data. When the loads are less variable, in this case early morning and late evening periods, the forecasted load matches the actual load. However, during occupied hours, even this low load variable building's load is harder to predict.

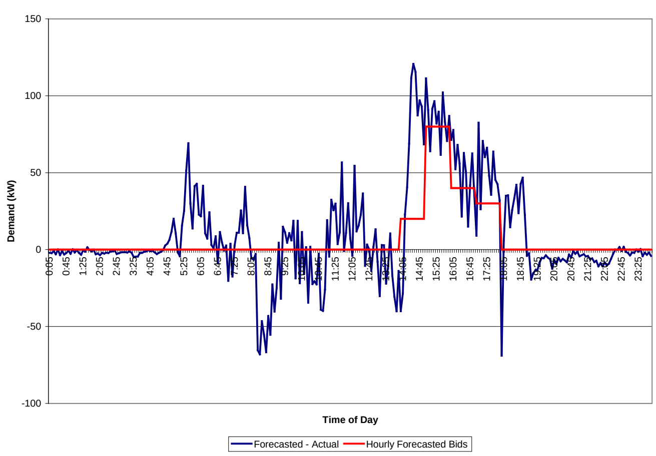

Figure 7 The difference between the forecasted and actula 5-minute load data

Table 2 Contra Costa County - Summary of performance, September 21, 2009

Forecasted vs. Actual Ramp Rate (MW/min)	Forecasted vs. Actual Average Load Reduction			
	HE 15:00	HE 16:00	HE 17:00	HE 18:00
0.002/0.006	20/72	80/86	40/51	30/49

Table 2 summarizes the forecasted and actual performance measurements for the Contra Costa County building. Forecasted ramp time is much lower than actual ramp time and will be adjusted when the bid level for the first hour is increased for this facility. The hourly forecasts with hour ending (HE) presentation show again that the initial reduction is lower than the initial bid, confirming an adjustment of the bid. While in many cases excess delivery of load may be considered acceptable, any excess performance in this pilot is considered "uninstructed" by the CAISO and is settled at as uninstructed energy.

4.2. IKEA Building

This building is a low variable and high weather sensitive building. September 18th was selected as a representative day since two out of three events this site participated in was either a test event or too short (only 3 minutes). While the duration of the PLP event (see Table 2) is still not long enough to calculate the performance of the site, ramp rate calculations were completed using the 4 second telemetry data. Also, the 5-minute load data obtained from this site's meter indicates low resolution readings which complicates the forecasted and actual load comparison for the event period (**Figure 8**).

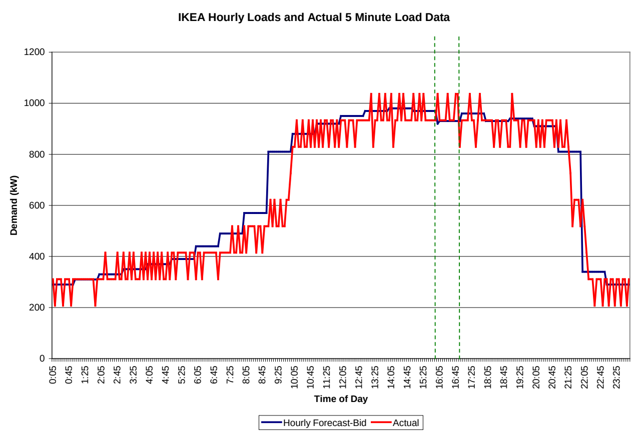

Figure 8 Actual and forecasted load shape for IKEA on September 18, 2009

The forecasted load data for this site on this date (Figure 9) is higher especially before store opening and after store closing suggesting there may be change in the store hours or operations during these periods that is not considered in the forecasting algorithm.

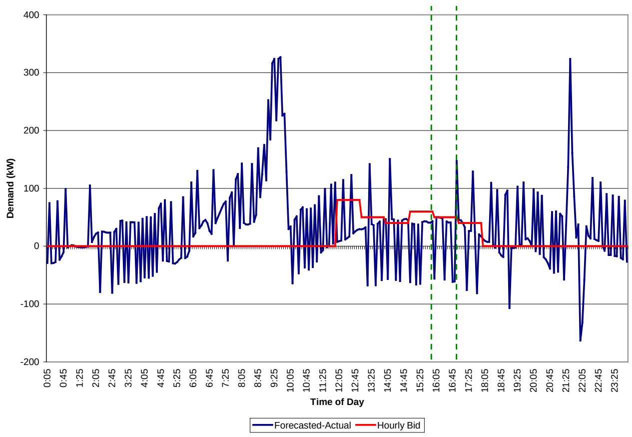

Figure 9 The difference between forecasted and actual loads on September 18, 2009

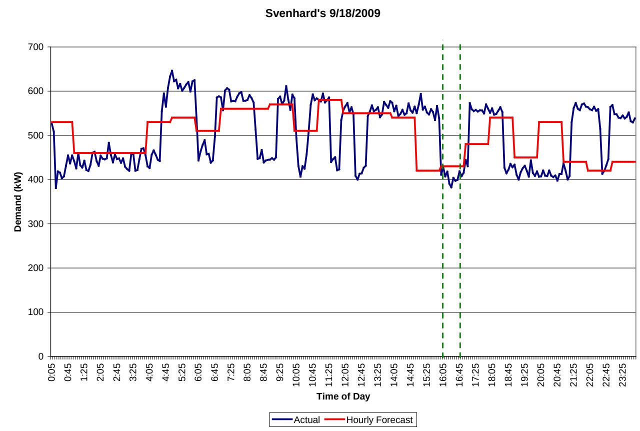

Figure 10 . Svenhard's actual load and forecasted hourly load on September 18, 2009

The actual ramp rate for this PLP event is ten times higher than the forecasted ramp rate and the average load shed is less than half of the forecasted reduction (Table 3). One PLP event does not provide enough data to evaluate the performance of this site. Poor resolution of the electric load data is also complicates the analysis.

Table 3 IKEA's summary of performance on September 18, 2009

Forecasted vs. Actual Ramp Rate (MW/min)	Forecasted vs. Actual Average Hourly Shed (kW)			
	HE 15:00	HE 16:00	HE 17:00	HE 18:00
0.001/0.01	-	-	50/20	-

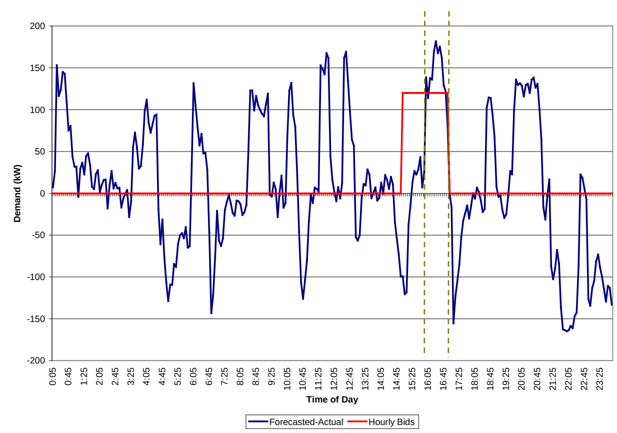

Figure 11 The difference between forecasted and actual loads at Svenhards on September 18, 2009

4.3. Svenhards Facility

Svenhards was not one of the facilities that was initially recommended by LBNL for this study since this facility has high load variability and low weather sensitivity indicating that the loads are dominated by the process loads. September 18th is selected as a representative date for this site since the rest of the events were test events, their duration was short, or the pan washer was not operational at the time the event was dispatched. Due to the high variability of the loads, the actual loads do not closely follow the forecasted hourly loads for the event date (Figure 10) and the difference between the forecasted loads and actual loads vary as much as the actual bid (Figure 11).

The forecasted and actual ramp rate is the same because the strategy, which is automated shutdown of the pan washer, yields same results each time it is deployed. Actual demand reduction is higher than the forecasted reduction bid. While the forecasting of loads is difficult for this facility, as long as the pan washer is operational when the PLP event is called, the ramp rate and the load reduction is consistent for each event.

Table 4 . Svenhard's summary of performance on September 18, 2009

Forecasted vs. Actual Ramp Rate (MW/min)	Forecasted vs. Actual Average Load Reduction			
	HE 15:00	HE 16:00	HE 17:00	HE 18:00
0.012/0.012	-	-	120/143	-

5. CONCLUSION AND DISCUSSIONS

The PLP events conducted by PG&E have been successful in proving that buildings in PG&E's price-based Auto-DR programs can participate in wholesale ancillary services with fully automated communication infrastructure using OpenADR and existing DR control strategies. Traditionally, Auto-DR has been applied to price-responsive slow DR programs with notifications varying from 24 hours to 2 hours before the DR event [7]. The load shed calculations for slow DR have been using 15-minute electric load data gathered from the revenue meter 24 hours after the DR events. Overall significance of the results of the PLP is summarized as follows:

1. HVAC as an end use and global temperature adjustment as a DR strategy meet the 10-minute response time and two-hour duration requirements for wholesale ancillary services.
2. OpenADR specification can be used to communicate wholesale DR events in an open and interoperable way. From a customer's perspective the transition from Auto-DR programs to PLP was seamless; they used the same infrastructure with no additional costs.
3. Internet can be used for fast DR to dispatch non-spinning ancillary services and still meet the 10 minute load response time.

From PG&E's perspective, each site's load had to be forecasted and bid into the CAISO's system; 4-second telemetry had to be installed at each facility; automated communication between the ADS and DRAS had to be established; a secure file sharing system had to be set up; and settlements had to be incorporated into customer billing. A summary of the lessons learned from the pilot are:

- *Forecasting loads* is a complex process and highly variable loads are extremely difficult to forecast. There is a need to develop better forecasting methods where load characteristics and changing in loads are better incorporated in the forecasting algorithms.
- *Cost of telemetry* for each site needs to be analyzed and scalability issues need to be explored.
- *Settlements* were not completed by the time this paper was written. Various value streams should be investigated.
- *Dispatch rules* were assumed to be sorted at the CAISO system and little intelligence was programmed into the DRAS in terms of program rules. DRAS can be used as a second check point for dispatch rules.
- *Maximum duration of dispatch and number of events* for the PLP sites is not sufficient to test sustainability of sheds.

6. ACKNOWLEDGEMENTS

Authors would like to thank all the participants, especially Andy Green and David Nyberg from Contra Costa County, Rick Betten and Oliver Babor from IKEA East Palo Alto and Allen Herman from Svenhard's Swedish Bakery for their continuing support. This work was sponsored in part by the Demand Response Research Center which is funded by the California Energy Commission (Energy Commission), Public Interest Energy Research (PIER) Program, under Work for Others Contract No.150-99-003, Am #1 and by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

References

[1] Eto, J., J. Nelson-Hoffman, C. Torres, S. Hirth, B. Yinger, J. Kueck, B. Kirby, C. Bernier, R. Wright, A. Barat, D. Watson. 2006 Demand Response Spinning Reserve Demonstration. LBNL-62761.

[2] Eto, J., J. Nelson-Hoffman, E. Parker, C. Bernier, P. Young, D. Sheehan, J. Kueck, and B. Kirby 2008. Demand Response Spinning Reserve Demonstration—Phase 2 Findings from the Summer of 2008. LBNL-2490E.

[3] CAISO. MRTU Release 1 Participating Load Users Guide (Participating Load Technical Standards)

[4] Piette, M. A., G. Ghatikar, S. Kiliccote, E. Koch, D. Hennage, P. Palensky, and C. McParland. CEC OpenADR-Version 1.0 Report 2009. Open Automated Demand Response Communications Specification (Version 1.0). California Energy Commission, PIER Program. CEC-500-2009-063 and LBNL-1779E

[5] Piette, M.A., D. Watson, N. Motegi, S. Kiliccote. Automated Critical Peak Pricing Field Tests: 2006 Pilot Program Description and Results. LBNL-62218. August 2007.

[6] Coughlin, K., M.A. Piette, C. Goldman, and S. Kiliccote Statistical Analysis of Baseline Load Models for Non-Residential Buildings. Energy and Buildings 41 (2009) 374–381

[7] Piette, M.A., S. Kiliccote, and G. Ghatikar Linking Continuous Energy Management and Open Automated Demand Response. Presented at the Grid Interop Forum, Atlanta, GA, November 11-13, 2008. LBNL-1361E. November 2008

Sila Kiliccote is a Senior Scientific Engineering Associate in the Building Technologies Department at Lawrence Berkeley National Laboratory. She has been a part of the

Automated Demand Response team developing an automated demand response communication infrastructure, integrating it with building control systems and working with stakeholders to standardize the information model. She has a master's degree in Building Science from Carnegie Mellon University and a Bachelor of Science in Electrical Engineering from University of New Hampshire.

Mary Ann Piette is a Staff Scientist at Lawrence Berkeley National Laboratory and the Research Director of the PIER Demand Response Research Center. She has at LBNL since 1983 and has extensive experience evaluating the performance of energy efficiency and demand response in large facilities. The DRRC plans, manages, conducts and disseminates DR research for the California Energy Commission. Ms. Piette has a BA in Physcial Science and a MS Degree in Mechanical Engineering from UC Berkeley and a Licentiate from the Chalmers University of Technology in Gothenburg, Sweden.

Girish Ghatikar is a Systems and Business Analyst with DOE's Lawrence Berkeley National Laboratory who oversees OpenADR technology evaluation and Open Auto-DR standards activities related to Smart Grid. Mr. Ghatikar also has working experience of working with wireless and energy information systems and related technical and policy issues. Mr. Ghatikar has Masters degrees in Telecommunication Systems and Computer Technologies, and Infrastructure Planning.

Ed Koch is founder and CTO of Akuacom. Akuacom specializes in enterprise systems for automated energy control and monitoring in commercial and residential buildings, especially as it applies to Demand Response Programs. Prior to that Ed was the founder and CTO of Coactive Networks which specialized in creating solutions for linking distributed control networks used in energy management systems to IP networks and enterprise applications.

Dan Hennage is the chief architect of the Akuacom Demand Response Automation Server (DRAS). Prior to Akuacom, Mr. Hennage was Co-founder and Vice President of Product Development of Coactive Networks where he guided the implementation of Coactive's products and was instrumental in transitioning Coactive's gateway products into high volume production. He was also the project manager of Coactive's major residential deployments. Mr. Hennage has an extensive background in product development including Building Control, Machine Control, and Vehicle Route Guidance Systems.

John Hernandez is a Senior Program Manager in the Demand Response Product Development Department at Pacific Gas & Electric (PG&E). His responsibilities include the design, development and implementation of demand response programs for retail electricity customers with the intent of integrating with the wholesale market. In his 5 years in the energy market, 3 years were spent tackling Demand Side Management's (DSM) retail DR sector. He has a BS in Business Management from the University of San Francisco with concentration in Accounting and Strategic Management.

Albert Chiu is a Senior Program Manager in the DR Department at Pacific Gas & Electric (PG&E). In his 8 years in DSM, he has worked on the design and implementation of residential, low income, commercial and local government DSM programs for utility customers. He is the lead of the Emerging Technology Team in the Demand Response Operation Department at PG&E and is also responsible for the implementation of the Auto DR Program. He has a BS in Environmental Study from San Jose State University and concentrated in Energy Efficiency and Renewable Energy.

Osman Sezgen is a Manager in the Demand Response Department at PG&E. His responsibilities include evaluation of emerging DR technologies and administration of technical incentive programs that enable customers for DR. He also manages the development of DR programs and contracts from regulatory applications, through pilots, to full scale implementation. Before joining PG&E in 2004, Mr. Sezgen was with Lawrence Berkeley National Laboratory working in several departments/groups including Building Energy Analysis, End-use Forecasting, Building Technologies, and Electricity Markets and Policy. He holds a BS Degree and a MS Degree in Mechanical Engineering from University of Manchester (UK) and a MS Degree in Industrial Engineering and Operations Research from UC Berkeley.

John Goodin is the California Independent System Operator Corporation's ("CAISO") lead for demand response. John's current responsibilities lie in development of demand response policy and products for the CAISO. Prior to joining the CAISO's Market and Product Development department, John was part of the External Affairs team where he served as an Account Manager for the CAISO for seven years, developing key corporate relationships and learning and explaining the many aspects of "ISO" business and markets. John has a B.S. degree in Mechanical Engineering from the California Polytechnic State University, San Luis Obispo.