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Publication Date
2012-07-30

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Environmental Energy Technologies Division

January 22, 2012

http://eetd.lbl.gov/EA/EMP/emp-pubs.html

presented in the Campus Microgrids Panel, 2012 IEEE PES General Meeting
22-26 Jul 2012, San Diego, CA USA

This work described in this paper was funded by the Office of Electricity Delivery and Energy Reliability, Distribution System Integration Program of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. It also builds on work previously supported by the Consortium for Electric Reliability Technology Solutions with funding provided by the California Energy Commission, Public Interest Energy Research Program, under Work for Others Contract No. 500-03-024.

A Green Prison: The Santa Rita Jail Campus Microgrid

Chris Marnay, *IEEE Member,* Nicholas DeForest, and Judy Lai

Index Terms**-- buildings, cogeneration, dispersed storage and generation, microgrids, PV, fuel cells, power quality, power system economics, energy efficiency.**

I. Introduction

A large microgrid project is nearing completion at Alameda County's twenty-two-year-old 45 ha 4,000-inmate Santa Rita Jail, about 70 km east of San Francisco. Often described as a *green prison,* it has a considerable installed base of distributed energy resources (DER) including an eight-year old 1.2 MW PV array, a five-year old 1 MW fuel cell with heat recovery, and considerable efficiency investments. Fig. 1 is an aerial depiction of the Jail with the PV rooftop modules clearly visible.

Fig. 1. Jail Aerial View

A current US$14 M expansion adds a 2 MW-4 MWh Li-ion battery, a static disconnect switch, and various controls upgrades. During grid blackouts, or when conditions favor it, the Jail can now disconnect from the grid and operate as an island, using the on-site resources described together with its back-up diesel generators. In other words, the Santa Rita Jail is a true microgrid, or µgrid, because it fills both requirements, i.e. it is a locally controlled system, and it can operate both grid connected and islanded. The substation where the static switch is installed is at the top corner of the Jail as pictured. The battery's electronics includes Consortium for Electric Reliability Technology (CERTS) Microgrid technology. This enables the battery to maintain energy balance using droops without need for a fast control system. A future project that will add concentrating solar thermal collectors.

The Santa Rita Jail microgrid demonstration is one of nine supported by the U.S. Department of Energy, whose goal is reduction of local feeder peak by 15%. To achieve this goal, the campus must operate away from its optimal operating point, which would typically be the bill minimizing point.

II. Economic Environment

Santa Rita Jail currently purchases its electricity under Pacific Gas and Electric's E-20 tariff for industrial and general service customers. In addition to daily customer and meter charges, the Jail is subject to time of use (TOU) rates for both consumed electricity and peak power demand. These latter demand charges tend to comprise the bulk a larger share of monthly electricity bills as efficiency and on-site generation lowers energy purchases. Current E-20 TOU rates are summarized in Table 1 below. The stiff demand charges are currently a third of summer bills.

Table 1: PG&E E-20 Industrial Rate

Summer	Max Peak	$11.04	$0.14	12:00-18:00, M-F
	Part-Peak	$2.59	$0.10	8:30-12:00 and 18:00-21:30, M-F
	Off-Peak	-	$0.08	21:30-8:30, M-F and Weekends
	Maximum	$7.45	-	
Winter	Part-Peak	$0.82	$0.09	8:30-21:30, M-F
	Off-Peak	-	$0.08	21:30-8:30, M-F and Weekends
	Maximum	$7.45	-	

III. Equipment Underperformance

Historically, the PV arrays at Santa Rita Jail have never met their 1.2 MW rating. The maximum power output observed

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from the PV system, with the exception of a single month in 2007, has not exceeded 700 kW in recent years.

Fig. 2. The 1 MW Fuel Cell at Santa Rita Jail

The fuel cell at the jail was intended to provide a consistent base load of 1 MW. The fuel cell's performance has not been good. In fact, it produced at a 100% capacity factor in only one month over the 2007-2009 period. The missed 2009 bill savings resulting from less-than-perfect performance are shown in Figure 3.

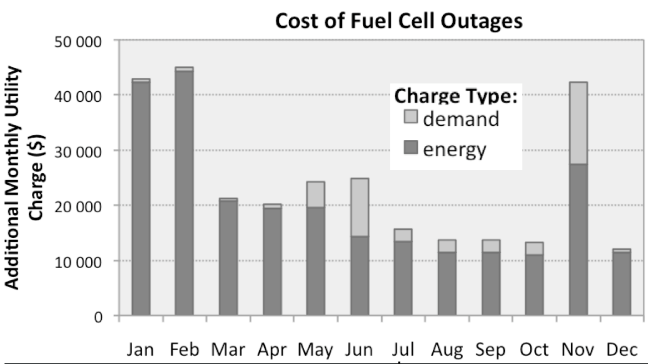

Fig. 3. Foregone 2009 Electricity Bill Savings from Sub-100% Fuel Cell Capacity Factors

IV. Battery Not Chosen

The addition of a battery to preexisting resources at the Jail enables its operation as a μgrid. During islanding, the battery can be a load balancing resource, as well as a transitional source while back-up generators start. By enabling rapid and, if necessary, frequent islanding, it is hoped that fuel cell performance can be improved by avoiding power quality trips.

One of the battery technologies considered for the μgrid, but not ultimately adopted was a 2 MW-12 MWh NaS battery. Considerable analysis was conducted of possible Jail operations using this battery, which is summarized here. Figure 4 shows optimal, i.e. maximally bill reducing, operation of the NaS battery during a brief fuel cell outage. The optimum battery schedule was found using Berkeley Lab's Distributed Energy Resources Customer Adoption Model, (DER-CAM).

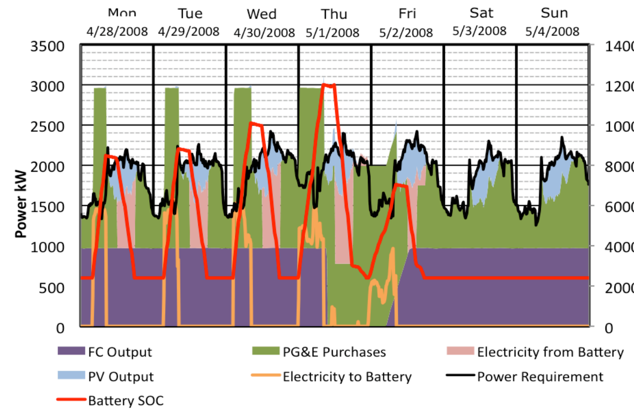

Fig. 4 Optimized May 2008 Week NaS Battery Operation

Notice that the battery is left discharged over the weekend. Round-trip losses are significant for NaS batteries, and 30% is the average here. In general, the battery is charged in the early morning hours and discharged during the following afternoon. Strangely the state-of-charge is considerably lower during a fuel cell outage, a surprising result driven by the off peak demand charges.

V. Potential Reduction in Feeder Peak

DER-CAM was run for a peak summer week in 2009. Rather than minimizing electricity costs during this week, DER-CAM tried to reduce the approximately 14 MW local feeder peak of as much as possible, in keeping with the U.S.DOE program. The result was a roughly 8.6% reduction in the peak, well shy of the 15% goal; however, if the Jail claims credit for all of the load reducing investments it has made over the last decade, or so, then peak reduction is about 20%. In addition to the PV system and fuel cell installations, the Jail has made a number of efficiency improvements, the most significant being a chilled water plant upgrade and major lighting retrofits. Notably, these feeder peak reductions are achieved with little impact on the Jail's electricity bill. The additional cost for the 2009 summer peak week was around $400, insignificant compared to the Jail's annual electricity costs of about one million dollars. This analysis did not consider export of power to the grid, which is now technically possible, although the net effect would be minor.

VI. Conclusion

The many energy supply and efficiency investments made by Alameda County at its Santa Rita Jail have enabled the installation of a true campus μgrid using CERTS technology. The μgrid can seamlessly disconnect and island, and by altering its control strategy, it can have a significant impact on the local feeder peak. Addition of a hypothetical 2 MW-12 MWh NaS battery alone could lower the peak by almost 9%, and considering all the Jail's investments, the net effect is around 20%. And this change of strategy would incur modest cost. Analysis of the actual 2 MW- 4 MWh battery installed, but peak reduction will likely be 6-7 % and the total effect about 18%, but the cost is expected to be around an order of magnitude higher.