What is the Controllable Electrical Demand from Residential EVSE in the San Diego Region?

April 2015

Key Conclusions

- The aggregated EV Project's residential electric vehicle supply equipment (EVSE) charging demand in San Diego exceeded 100 kW from 4 p.m.to 4 a.m. during the third quarter of 2013.
- This aggregated demand during the third quarter of 2013 was sufficient for bidding into controllable demand response activities in the San Diego region.
- The positive adoption of plug-in electric vehicles (PEVs) in the San Diego region increases the probability of enlisting sufficient PEV owners in demand response activities. However, the numbers of residential EVSE must grow by a factor of 18 to make direct control minimally worthwhile at all hours of the day.
- The incentive programs promoted by San Diego Gas and Electric (SDG&E), coupled with easily programmable EVSE, are highly effective in moving residential charging to off-peak hours.
- For the foreseeable future, direct utility control of residential EVSE is not beneficial, whereas indirect control through rate incentives is beneficial.

Introduction

The EV Project enrolled over 8,000 residential participants. These participants purchased or leased a Nissan Leaf or Chevrolet Volt. The Blink Level 2 EVSE used to recharge the PEVs were installed by the EV Project at PEV owner residences. The power required to charge a PEV can be a significant electrical load for a residence and, when all PEVs in an area are aggregated, a significant load on the electric grid.

Electric utilities seek ways to reduce their generating costs by managing the maximum (i.e., peak) load on their system. Managing residential PEV charging activity provides an opportunity for minimizing, or eliminating, any impact of PEV charging on peak load. This management may be achieved indirectly through rates that incentivize PEV owners to charge their vehicles during off-peak hours or may take the form of direct utility control of residential EVSE. What insight can EV Project data provide relating to the magnitude of this impact and the potential controllable demand? This paper quantifies the total controllable electrical load imposed on the electric grid by residential PEV charging in the San Diego region of the EV Project.

Why is Controllable Demand Important?

The electric utility is responsible for providing power to customers within its service territory. SDG&E is solely responsible for providing electricity for all customers within the San Diego region of the EV Project. SDG&E publishes its dynamic load profile, showing the power required by its customers during a specific period of time. This profile for June through August 2014 is shown in Figure 1, showing the maximum, median, and minimum power demand over the 3-month period for each hour of the day.

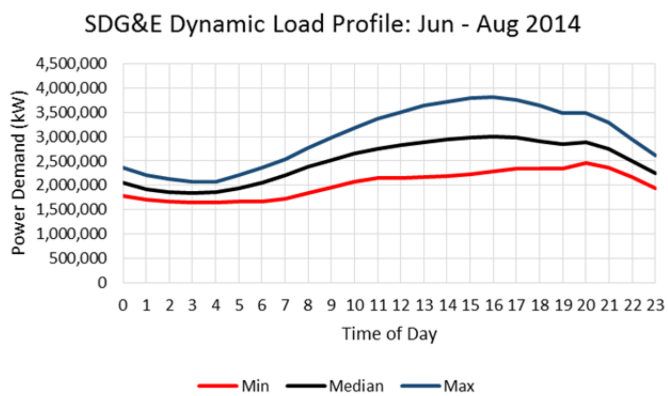

Figure 1. SDG&E hourly demand.[1]

SDG&E must provide power generation to match the power demand, which, during this 3-month period, varied from a minimum of 1,649 MW to 3,814 MW. Generation is provided by first operating "base-load" generating stations. These base load power plants are generally the cheapest units to operate and are most efficient when operating at full power. Thus, these units are typically fully loaded to provide power all day. Once this base-load capability is fully utilized, other generating plants are brought into service. The last plants to be utilized are "peaking" units that are more expensive to operate, but whose output can be modulated more rapidly and used only when necessary to handle the peak loads. In some situations, utilities may need to purchase power from other sources to fulfill peak load requirements. If the utility can shift peak power demand to other times, the cost of operating peaking power plants and purchasing power from other utilities during peaks can be avoided.

In anticipation of power demand increases or problems on the grid causing a reduction in power generation, utilities typically operate "spinning reserve" generation. These are generating stations that are fully operational and, although not loaded, are fully prepared to rapidly supply power to the grid in order to "follow" the demand. During transitional increases or decreases in demand, these spinning reserves may cycle on and off. If the demand can be controlled, this cycling may be avoided and the reserve unit operated in a more stable state.

In addition to managing total power generation to match demand, the electric grid must maintain voltage and frequency. This regulation can be achieved by controlling small amounts of generation or by controlling small amounts of power demanded by customers on the electric grid.

Figure 2 illustrates these three major situations. Controlling the demand, even in minimal amounts, in these three areas helps the electric utility to reduce costs.

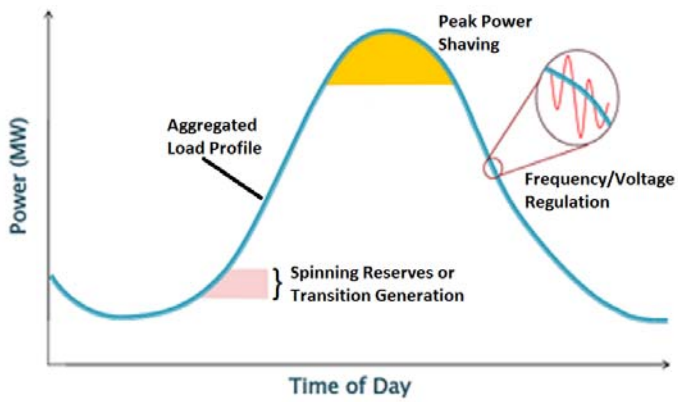

Figure 2. Controllable demand situations.

Residential Controllable Demand Options

The electric utility has several tools available for assisting in management of its peak power requirements. For this paper, controlling demand from residential PEV charging is of interest, including determining the effectiveness of; controlling residential EVSE demand to reduce peak power requirements, assisting in loading and unloading generation, and providing frequency and voltage regulation.

Through use of rate incentives (such as time-of-use or TOU), customers are encouraged to shift their power demand to off-peak times. Figure 3 shows the SDG&E EV-TOU-2 rate schedule for residential PEV charging. The rates charged for electricity incentivize the residential PEV customer to charge during off-peak times, especially during super off-peak times.

The EV Project installed Blink EVSE in the homes of each of its participants in the San Diego area. The Blink EVSE provides an intuitive touch screen interface that allows the PEV owner to easily schedule a window of time during which the EVSE will provide charge power, allowing the PEV owner to schedule charging to take advantage of the SDG&E off-peak and super off-peak rates. The Blink EVSE also allows the EV Project to collect EVSE usage data and report information derived from these data in its quarterly reports. The report for the third quarter of 2013 for residential EVSE usage in the San Diego region includes charging demand by time of day and is shown in Figure 4.

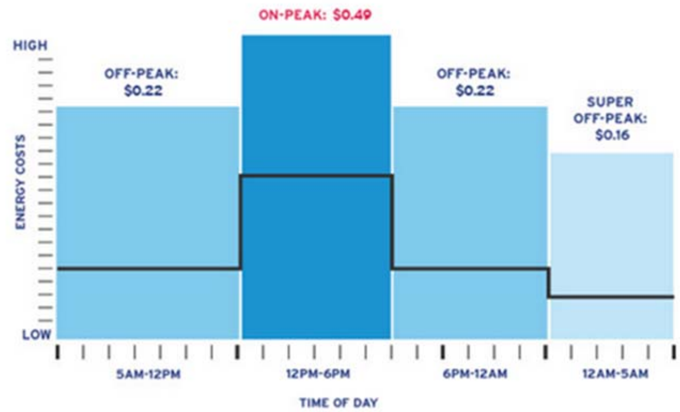

Figure 3. SDG&E residential peak schedule.[2]

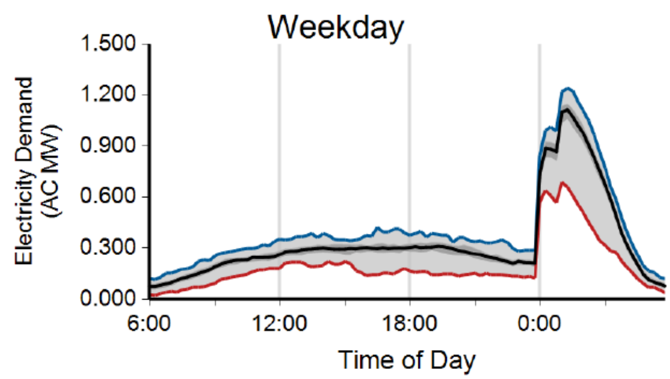

Figure 4. Residential charging demand for San Diego in the third quarter of 2013.[3]

The blue curve shows the maximum electricity demand over the 3-month period for each hour of the day; the red curve shows the minimum demand for each hour; and the black curve shows the median demand. The peak at midnight reflects the effectiveness of the SDG&E time-of-use rate incentive program in shifting the start of PEV charge to the super off-peak times. As a result, direct control of EVSE charging during on-peak times will have little effect in shifting the utility's overall demand, because the total peak daytime load for EVSE is about 0.4 MW, which is insignificant compared to the total SDG&E system demand of 3,000 MW. Rate incentives and readily programmable EVSE appear highly effective in reducing on-peak demand of residential EVSE; therefore, this negates any need for direct utility control of residential EVSE. Providing direct control can provide other benefits to utilities.

SDG&E offers a reduce-your-use voluntary program for residential customers. After enrolling in the program, residential customers receive notification the day before an event is identified by the utility and, when reducing their demand between 11 a.m. and 6 p.m., they receive reward credits on their utility bill.

Incentive programs like reduce-your-use are indirect and rely on the customer to take or not take action. In addition, they are not available for immediate actions on the day needed. For an electric utility to authoritatively use residential customer load to mitigate peak demand, greater positive control of the customer load is required. Control of PEV charging in near real-time provides this opportunity.

Utility Control of Residential Plug-In Electric Vehicle Charging

To be effective in controlling demand, a minimum of 100 kW of controllable power is generally required. For residential PEV charging, this requires aggregating many EVSE that are connected to vehicles where both the vehicle and EVSE are available for charging. Because there are financial incentives for providing this demand control, there are frequently penalties for failing to provide adequate control. Thus, this system will require the following:

- EVSE capable of remote control and monitoring
- Aggregation systems and programs
- Sufficient numbers of EVSE providing demand for aggregation
- Communication signals from the utility to the aggregator of service
- Enlistment and communications methods for participating EVSE owners.

Smart EVSE that allow for monitoring, control, and communication through the internet (such as the Blink unit deployed in the EV Project) are also capable of aggregation. Demonstrations of controllable demand from the utility through EVSE have occurred in several forms, including those conducted by the California Energy Commission grant ARV-09-005 involving SDG&E.[4]

Control of charging may include starting and stopping charging (or regulating the rate of charging) or in some cases, discharging the PEV battery through the EVSE back to the grid. The later example, called vehicle-to-grid or V2G, requires additional PEV features and is an advanced capability that is currently being tested; however, it is not the focus of this paper. For this consideration, only curtailment or restoration of charging (i.e., frequently called V1G) is of interest.

Residential Electric Vehicle Supply Equipment Controllable Demand

Controllable demand from EVSE requires the EVSE to be connected to and charging the PEV. Unless the EVSE is actually charging the PEV (i.e., is not just connected), there is no demand to curtail.

The EV Project's quarterly reports identify the time of day the residential EVSE are connected and available for charging. Charge availability (i.e., vehicle is connected to EVSE) for San Diego in the third quarter of 2013 is shown in Figure 5.

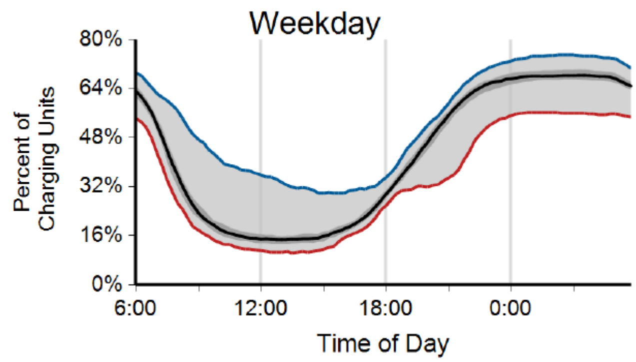

Figure 5. Charging availability in San Diego for the third quarter of 2013.[5]

As might be anticipated, charging availability generally follows the typical work schedule, where PEVs begin to depart for work at approximately 6 a.m. and gradually return home and are connected to EVSE at the end of the work day until about midnight, when most are available for charging. However, it does indicate that a minimum of 10% of monitored EVSE are connected at all times of the day. It is noted that these may not be the same EVSE every day, but aggregated over the entire San Diego region, at least 10% of residential EVSE were connected at all times during the quarter.

Figure 4 indicates that at least some of the connected EVSE during on-peak times are, in fact, charging the PEV.

While one may suppose that the maximum number of EVSE connected would produce the maximum demand, it is not necessarily the case. The most conservative scenario in estimating available controllable demand would be using the maximum number of EVSE available and the minimum charging demand that was observed. Figure 6 overlays these on the same graph to more clearly see what EVSE are available and what the related demand is at the same time of day.

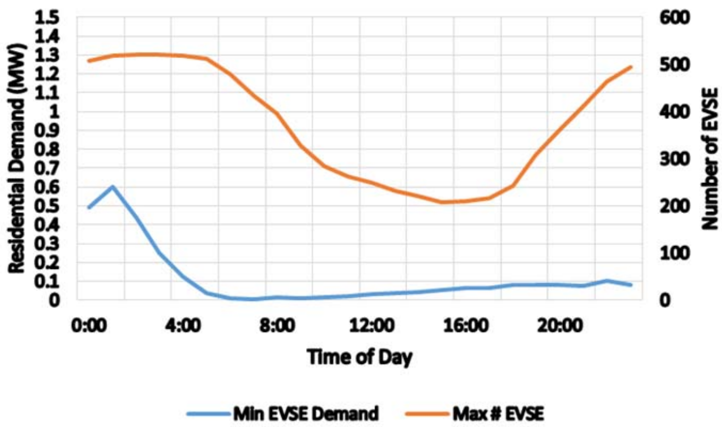

Figure 6. Residential EVSE availability and demand for the third quarter of 2013.

According to the third quarter 2013 report, the minimum aggregated charging demand exceeded 100 kW from midnight to 4 a.m. and again at 10 p.m. During this time, the population of EV Project residential EVSE in that analysis presented in the San Diego region was 696. During the day, the maximum number of EVSE connected was 521 or 75% of those EVSE reporting.

For analysis purposes, several qualifying factors were placed on the residential EVSE data in reporting the quarterly data, which resulted in exclusion of data from some EVSE. In addition, some EVSE, though functional, fail to report data. In the third quarter of 2013, the EV Project had installed 963 EVSE in the San Diego region. Thus, the 521 EVSE represented only 54% of the installed residential EVSE.

The results for the first quarter 2013 are similar. In both cases, the maximum number of EVSE connected at any time is approximately 75% of all reporting EVSE utilized in the quarterly report. Assuming the effects of the whole population of residential EVSE is the same as those reporting, the entire population would be expected to produce the results shown in Figure 7.

Therefore, with the full population of residential EVSE in the EV Project in the third quarter of 2013, the minimum aggregated charging demand exceeded 100 kW and occurred from 4 p.m.to 4 a.m. As seen in Figure 1, these are times of changing load; therefore, services related to spinning reserve and transitional generation may be possible. In addition, regulation services may be performed. However, this does assume all these EVSE are enrolled in an aggregation program.

Because the minimum adjusted EVSE demand is just over 5 kW at 7 a.m., the total inventory of residential EVSE would need to be increased by a factor of 18 to produce 100-kW demand at all hours of the day.

However, third party aggregators may bid specific times or SDG&E may elect to provide services when sufficient EVSE are enrolled. SDG&E has already shown success in enlisting residential customers to select the super off-peak rate and, with the proper incentives, could enlist a significant number of residential PEV owners in a direct control demand reduction program.

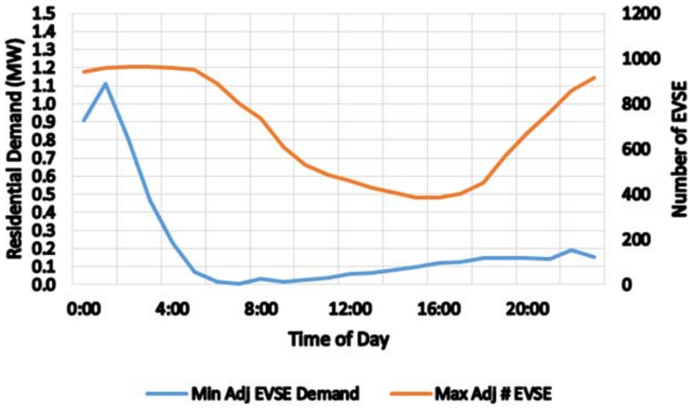

Figure 7. Extrapolated availability and demand.

Conclusions

A residential customer, who purchases and installs a Level 2, 240-volt alternating current EVSE, is required to obtain an electrical permit. SDG&E receives notification of this during the permitting process and has information on the total numbers of PEV owners with 240-volt EVSE. Some PEV drivers elect to charge their PEV with a 120-volt EVSE for which permitting is not generally required. In these cases, the EVSE typically will not contain the necessary control and monitoring features to be included in a controllable demand program.

The EV Project enlisted 963 residential participants in the San Diego region by the end of 2013. The Blink EVSE provided to these participants by the EV Project incorporate the necessary control and monitoring functions to implement remote control of charging. The controllable demand represented by the EV Project residential EVSE in San Diego, if fully aggregated, was capable of over 100 kW of demand response in the third quarter of 2013. This capability was at hours of the day when demand reduction was not a priority for SDG&E. However, these are times of changing load; therefore, services related to spinning reserve and transitional generation may be possible.

As PEVs continue to be added to the San Diego area, the potentially controllable load from residential charging will continue to grow and may be attractive to SDG&E or third-party aggregators as a demand reduction tool. However, EVSE installed by new PEV purchasers will require remote control capability if aggregation is to be effective.

The incentive programs promoted by SDG&E, coupled with easily programmable EVSE, are highly effective in moving residential charging to off-peak hours. This minimizes the need for directly controllable demand. However, as the number of residential EVSE continues to grow, there may be benefit to the utility having direct control. This analysis shows the population would need to grow by a factor of 18 to make direct control minimally worthwhile at all hours of the day. For the foreseeable future, direct utility control of residential EVSE is not beneficial, whereas indirect control through rate incentives is beneficial.

About The EV Project

The EV Project was the largest PEV infrastructure demonstration project in the world, equally funded by the U.S. Department of Energy (DOE) through the American Recovery and Reinvestment Act and private sector partners. The EV Project deployed over 12,000 alternating current Level 2 charging stations for residential and commercial use and over 100 dual-port direct current fast chargers in 17 U.S. regions. Approximately 8,300 Nissan LEAFs™, Chevrolet Volts, and Smart ForTwo Electric Drive vehicles were enrolled in the project.

Project participants gave written consent for EV Project researchers to collect and analyze data from their vehicles and/or charging units. Data collected from the vehicles and charging infrastructure represented almost 125 million miles of driving and 4 million charging events. The data collection phase of The EV Project ran from January 1, 2011, through December 31, 2013. Idaho National Laboratory is responsible for analyzing the data and publishing summary reports, technical papers, and lessons learned on vehicle and charging unit use.

Company Profile

Idaho National Laboratory is one of DOE's 10 multi-program national laboratories. The laboratory performs work in each of DOE's strategic goal areas: energy, national security, science, and the environment. Idaho National Laboratory is the nation's leading center for nuclear energy research and development. Day-to-day management and operation of the laboratory is the responsibility of Battelle Energy Alliance.

For more information, visit avt.inl.gov/evproject.shtml.

References

[1] http://www.sdge.com/customer-choice/customer-choice/dynamic-load-profiles accessed January 9, 2015.

[2] http://www.sdge.com/clean-energy/ev-rates accessed January 19, 2015.

[3] EV Project Quarterly Report, Q3, 2013, http://avt.inl.gov/pdf/EVProj/EVProjInfrastructureQ32013.pdf accessed January 31, 2015.

[4] California Energy Commission

http://www.energy.ca.gov/drive/projects/ARV-09-005.html.

[5] ibid.