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A. Document Title and Summary

1. Today's Date: 05/25/16
2. Document Title: Southern California Edison Company's (U 338-E) Smart Charging Pilot Final Report
    3. Document Summary (Executive Summary, Brief Description, Background, and Introduction): Attached is the Final Report for SCE's Smart Charging Pilot. This Report is being served at the request of Energy Division, and was presented at the May 2016 Demand Response Measurement and Evaluation Council meeting, in compliance with the disposition letter for Advice Letter 2749-E and 2749-E-A.

B. Sender Contact Information

1. Sender Name: Mark Martinez
2. Sender Organization: SCE
3. If Utility, Utility Number: (U 338-E)
4. Sender Phone: 626-302-0975
5. Sender Email: Mark.S.Martinez@sce.com

C. Documents Submitted that Reference Proceedings

If the document attached is submitted as a compliance document because of a Commission Decision, identify:

1. Proceeding numbers: A.14-10-014, R.13-09-011
2. Name of report: Southern California Edison Plug-In Electric Vehicle (PEV) Smart Charging Pilot

D. Documents Submitted that Reference other requirements

1. If the document submitted is in compliance with (i) something other than a Commission decision identified in Section C above or (ii) something in addition to the Commission decision identified above, please identify the original source of the compliance filing: (Examples may include a Resolution on an Advice Letter, Ruling Proceeding, General Order, Staff Letter, Public Utilities Code, or sender's own motion): N/A

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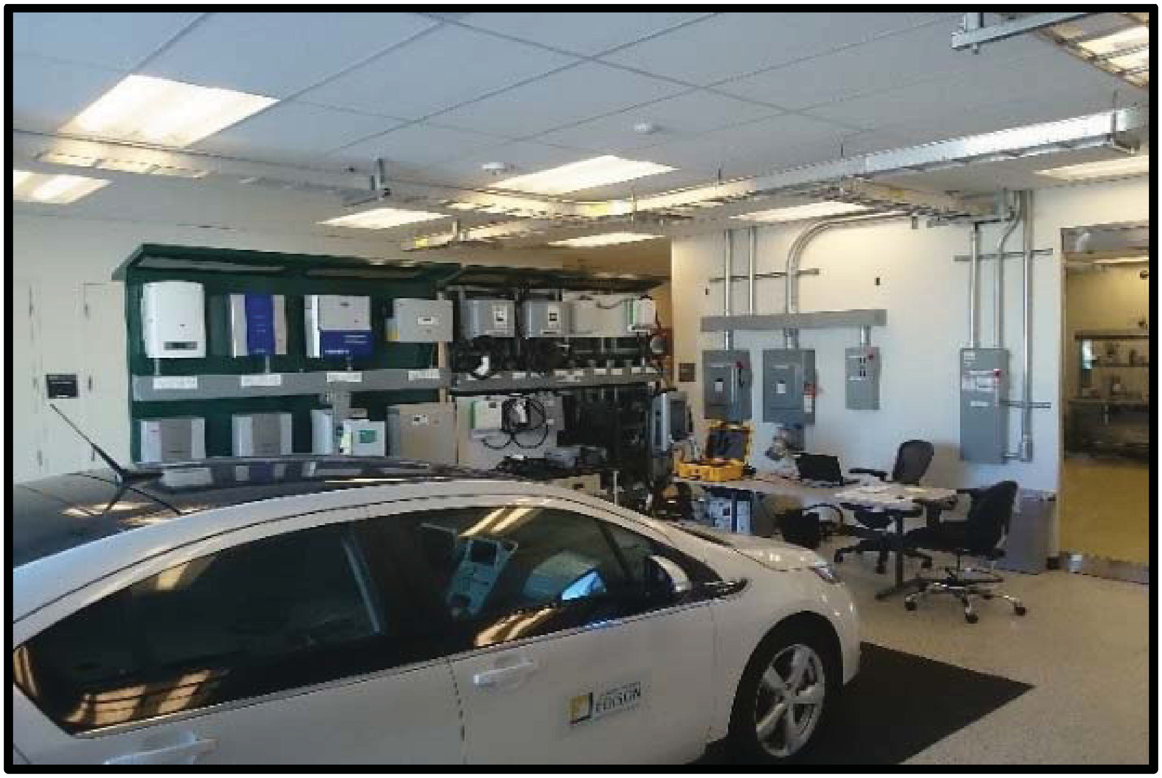
Southern California Edison
Plug-In Electric Vehicle (PEV)
Smart Charging Pilot



Final Report

May 2016 revision

SOUTHERN CALIFORNIA
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Executive Summary

According to the Plug-in Electric Vehicle Collaborative, over 123,000 Electric Vehicles (EV) have been sold in California since December of 2010. [1] This equates to roughly 41% of total EV sales in the United States for this time period. While California's rapid adoption of EVs can be seen as a positive for sustaining the environment and meeting regulatory and government policies, it presents two needs that will both have to be met for EV adoption to become as ubiquitous as gasoline-powered vehicles.

Firstly, consumers must be able to charge at home with low cost and low stress, while meeting all their travel needs. Secondly, utilities must be aware of and be able to manage residential charging in order to integrate EVs onto the distribution grid. This integration should not cause undue stress on the infrastructure, while continuing to provide safe and reliable energy for all customers.

The alignment of these issues can be termed "Smart Charging" and using tools like Demand Response (DR) and sub-metering will enable utilities, vendors, and consumers to work together in order to achieve the true benefits of transportation electrification. This report summarizes a Smart Charging pilot conducted by SCE that evaluated some technologies that could be deployed by SCE and vendors in order to achieve this common vision.

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[1] http://www.pevcollaborative.org/sites/all/themes/pev/files/CPEV_annual_report_web_0.pdf

Overview

Regulatory Background

The Plug-In Electric Vehicle (PEV) Smart Charging Pilot was authorized in the California Public Utilities Commission (CPUC) Demand Response Decision (D.) 12-04-045 dated April 30, 2012. D.12-04-045 authorized funding for Southern California Edison Company (SCE) to conduct the pilot contingent upon the submittal and approval of the required pilot plans discussed in Ordering Paragraph 80. The details of the pilot were proposed and approved via Advice Letter (AL) 2749-E and 2749-E-A.

Scope

From the middle of 2013 until the end of 2014, Southern California Edison's (SCE) Advanced Technologies Organization (ATO) conducted a CPUC-approved smart charging pilot called Augmenting AMI with Broadband (hereafter known as the Pilot). The Pilot acquired and evaluated a variety of technologies, both in the lab and in the field, supporting newly developed communications standards for load management of EV charging. This report details the results of the Pilot and makes some recommendations about future pilots or program implementations.[2]

Goals

The goals of the Pilot were twofold:

1- Evaluate and possibly recommend a variety of residential-based smart charging technologies that utilize non-AMI communications — including the internet and standardized protocols — in order to sub-meter EV charging, provide real time demand and interval energy data, manage EV loads, and enable customer control (opt-in/opt-out functionality); and

2- Create a common set of requirements and technologies SCE can leverage for future EV or other load management pilots or programs.

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[2] It is important to note a couple of limitations of the Pilot and thus the contents of this report. Firstly, as the technologies evaluated in the Pilot could all be considered prototypes, either developed specifically for the pilot or off-the-shelf technologies that were modified, a cost/benefit evaluation is not included. Secondly, as the field deployment portion of the Pilot was necessarily limited to a small number of EV drivers, this report does not attempt to evaluate customer charging behavior.

Pilot Architecture

The Pilot evaluated two possible ‘paths’ of over the internet communication that could be deployed for residential EV load management programs: Direct and Business to Business (B2B), represented by Figure 1 below. SCE used OpenADR 2.0 to communicate to the 3rd party and Smart Energy Profile 2.0 (SEP 2.0; also known as IEEE 2030.5)[3] to communicate to the customer devices. Further information on the architectures and technologies are provided below.

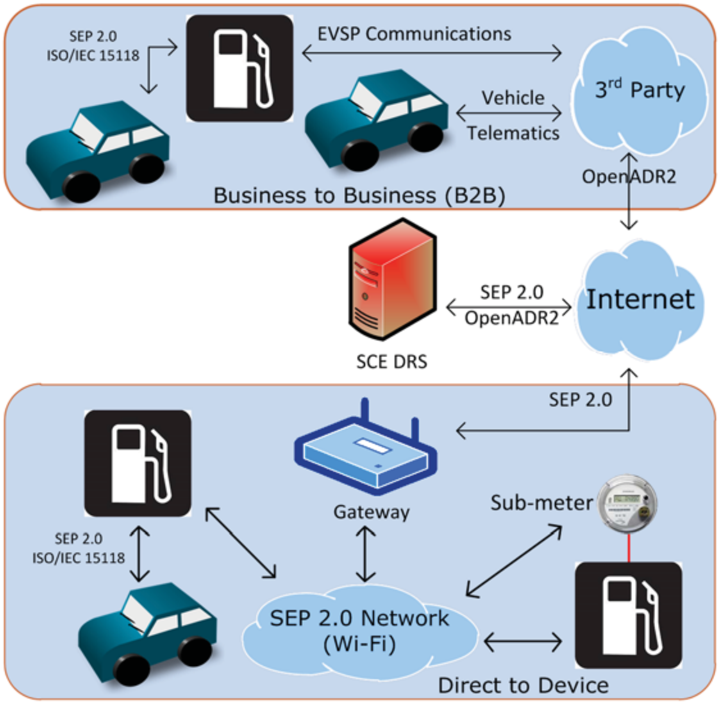

Figure 1- Smart Charging Pilot Architecture- This diagram depicts the communication paths (Business to Business at the top and Direct at the bottom), protocols, and technologies deployed in the Smart Charging Pilot Demonstration.

Cloud-based Demand Response Server (DRS)

The pilot used a demand response server to support both the 3rd party OpenADR 2.0 (Business to Business) and the SEP 2.0 (Direct) interfaces. The server provided an operator portal that was common to both protocols and could be used to manage events; register devices per the standards described method; and collect, display and provide data.

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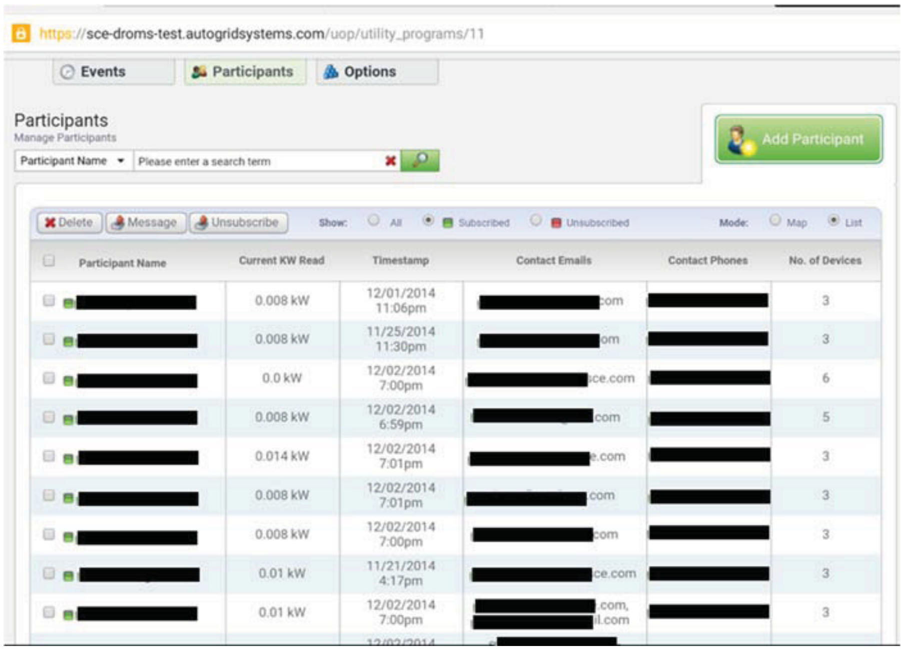
[3] https://standards.ieee.org/findstds/standard/2030.5-2013.html

On the OpenADR side, a certified implementation was required; however, on the SEP 2.0 side, nothing was yet commercially available, so SCE specified requirements for a full (support for all function sets) SEP 2.0 implementation. Though much of the SEP 2.0 functionality would not be used for the pilot, it was determined that by requiring a full implementation, the server could also be used for other pilots, including upcoming Distributed Energy Resources (DER) projects.

The DRS also provided the required customer notification (email, text, voice mail) and opt-out capabilities. After Request for Proposal (RFP) and procurement processes, SCE eventually licensed the Autogrid[4] Demand Response and Optimization Management System (DROMS).



☐ Participant Name	Current KW Read	Timestamp	Contact Emails	Contact Phones	No. of Devices
☐ 🟩 [redacted]	0.008 kW	12/01/2014 11:06pm	[redacted]com	[redacted]	3
☐ 🟩 [redacted]	0.008 kW	11/25/2014 11:30pm	[redacted]om	[redacted]	3
☐ 🟩 [redacted]	0.0 kW	12/02/2014 7:00pm	[redacted]sce.com	[redacted]	6
☐ 🟩 [redacted]	0.008 kW	12/02/2014 6:59pm	[redacted]com	[redacted]	5
☐ 🟩 [redacted]	0.014 kW	12/02/2014 7:01pm	[redacted]e.com	[redacted]	3
☐ 🟩 [redacted]	0.008 kW	12/02/2014 7:01pm	[redacted]com	[redacted]	3
☐ 🟩 [redacted]	0.008 kW	12/02/2014 7:00pm	[redacted]com	[redacted]	3
☐ 🟩 [redacted]	0.01 kW	11/21/2014 4:17pm	[redacted]ce.com	[redacted]	3
☐ 🟩 [redacted]	0.01 kW	12/02/2014 7:00pm	[redacted].com, [redacted]l.com	[redacted]	3

Figure 2- Autogrid DROMS screenshot showing participants in the SCE SEP 2.0 Smart Charging program, current (near real-time) demand reading from the sub-meter, and other data. Note that this screenshot was taken post pilot so the devices were off-line.

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[4] www.auto-grid.com

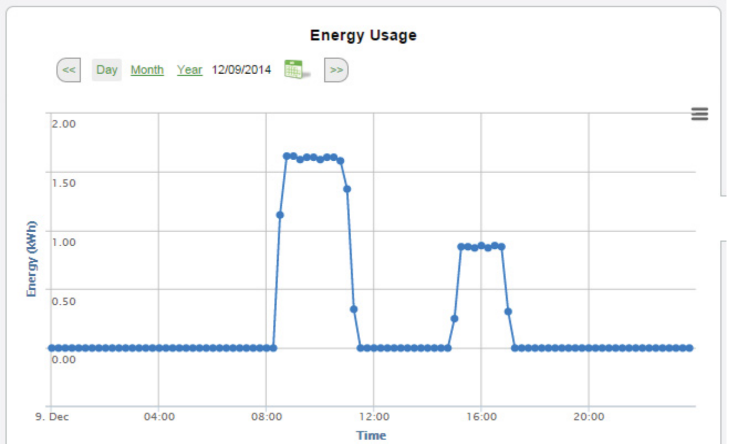
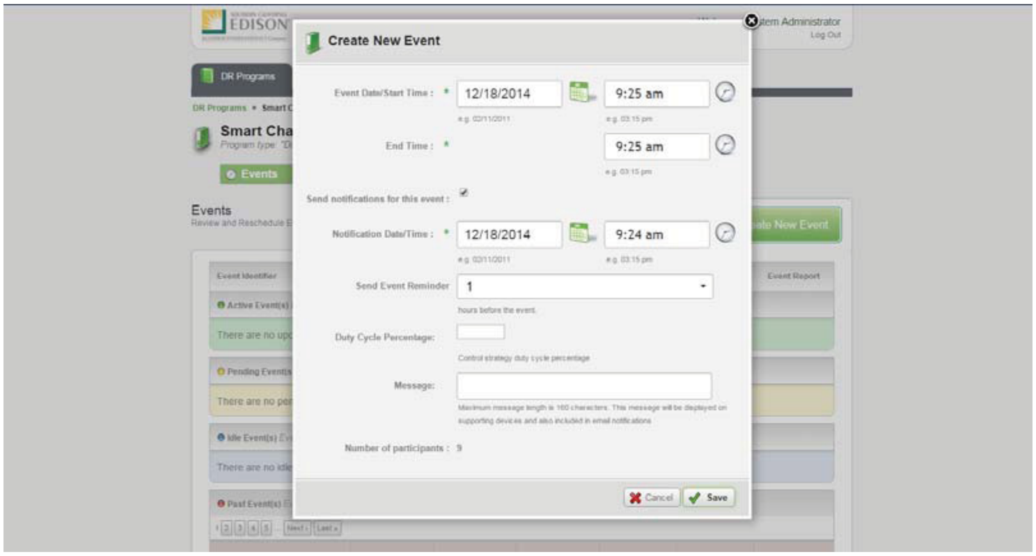


Figure 3- The screenshots above are from the Autogrid DROMS showing 15 minute intervals collected via OpenADR 2.0. This data could also be downloaded in .csv or .pdf formats. It could presumably also be passed on to a utility for customer billing.



Create New Event

Event Date/Start Time : * 12/18/2014 9:25 am

End Time : * 9:25 am

Send notifications for this event : ☑

Notification Date/Time : * 12/18/2014 9:24 am

Send Event Reminder 1

hours before the event

Duty Cycle Percentage:

Control strategy duty cycle percentage

Message:

Maximum message length is 160 characters. This message will be displayed on supporting devices and also included in email notifications

Number of participants : 9

Figure 4- The screenshots above shows DR Event creation screen. Note the options including when notifications go out, how many reminders to be sent, Duty Cycle percentage, and message.

Direct Communications

Direct communications is meant to denote an architecture whereby SCE communicates directly to customer devices, without a 3rd party being involved. For the Pilot, SCE communicated DR signals directly to EVSEs via an internet gateway (GW) that was an Ethernet/SEP 2.0 client on the Wide Area Network (WAN) side and Wi-Fi access point/SEP 2.0 server on the Local Area Network (LAN) side. The GW was an essential part of the pilot as it allowed for separation of SCE's test network and existing customer networks.

For future program implementation, it is assumed a Gateway-based architecture is necessary when doing load management with EVs and EVSEs, as SCE would not directly manage EVSE loads in the future. Eventually there would need to be additional intelligence in-between (e.g., an energy management system (EMS) or a 3rd party) in order to integrate utility DR requests and the driver needs since drivers need to be insured that they will have sufficient battery range for EVs used primarily for transportation. The basic GW functionality would be necessary to communicate to that EMS application, whether built into the GW, into the EVSE, or as a standalone device.

Additionally, this architecture is similar to how SCE conducts some AutoDR building management system (BMS) programs.[5] Though those programs use OpenADR 2.0, SEP 2.0 was chosen as the utility and device DR protocol for several reasons: SEP 2.0 had recently been released with the support of SCE; SCE had been active in getting SEP 2.0 integrated into Society of Automotive Engineers (SAE) smart charging standards for communications between EVs and the grid[6]; and SEP 2.0 has other functionality including Distributed Energy Resources (DER) and Flow Reservation (FR) that might be desired to be demonstrated with the same GWs in a different pilot in the future. Finally, should SCE or another entity desire to use another DR protocol on the WAN or LAN side, different applications and support for other protocols could be added.

Wi-Fi Enabled SEP 2.0 Home Gateway

The SEP 2.0 GW's were acquired in a similar procurement process as the DRS, with Sumitomo[7] Electric Industries ending up being the supplier. As mentioned previously, the gateways were standard 802.11n Wi-Fi access points on the LAN side and also provided several Ethernet ports and a Universal Serial Bus (USB) port. Though not used, the gateway was also an *Application Layer Gateway* (ALG) that with the insertion of a ZigBee dongle into the USB port, could translate pricing, DR, and metering clusters from ZigBee Pro Smart Energy 1.x[8] to SEP 2.0. The GWs featured a webpage that, in addition to the normal router settings, also allowed SCE to enable/disable security, register customer devices, view logs, reset the device, and point the gateways to the DRS.

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[5] https://www.sce.com/wps/portal/home/business/savings-incentives/demand-response

[6] http://standards.sae.org/j2847/1_201311/ and http://standards.sae.org/j2847/3_201312/

[7] http://global-sei.com/

[8] http://www.zigbee.org/zigbee-for-developers/applicationstandards/zigbeesmartenergy/

To commission devices on the utility DR server, the GWs were pre-provisioned to point to SCE's SEP 2.0 server IP address and the Short Form Device Identifiers (SFDIs) and Pins of the GWs, sub-meters, and EVSEs were entered. Once completed, IPv6 and SEP 2.0 defined service discovery were used on the LAN side for automated joining of devices to the GW. A larger implementation might use the Long Form Device Identifier (LFDI) to avoid duplicate IDs resulting in collisions. Full encryption per the SEP 2.0.0 standard was used.

EVSEs and apps polled the GW server for events and the GW client in turn polled SCE's SEP 2.0 DRS for DR events and other SEP 2.0 communications. Polling rates were set for 5 minutes. Similarly, meters posted data to the GW server and the GW server posted meter data to SCE's SEP 2.0 server. Posting rates were 5 seconds.

Figure 5- Sumitomo SEP 2.0 Gateway

Wi-Fi Enabled SEP 2.0 EVSE and Meters

Kitu Systems,[9] a developer who was heavily involved in the SEP 2.0 standardization activities, was retained to integrate SEP 2.0/Wi-Fi into the level 2 EVSEs and meters (they also provided a GW that was tested in the lab). Both the EVSEs and the meter were off-the-shelf devices, with 4 EVSE models and 2 meters eventually being used. A Raspberry Pi with attached Wi-Fi dongle was used for the communications and DR integration (see Figure 6). On some EVSEs, communications were integrated into the J1772 pilot to enable changes (see findings section) to the pilot duty cycle. This allowed SCE to throttle (reduce the power) provided by the EVSE to the EV (see Figure 2). On others, a relay already integrated into the EVSE was used to curtail the charging completely (see Figure 7).

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[9] http://kitu.io/

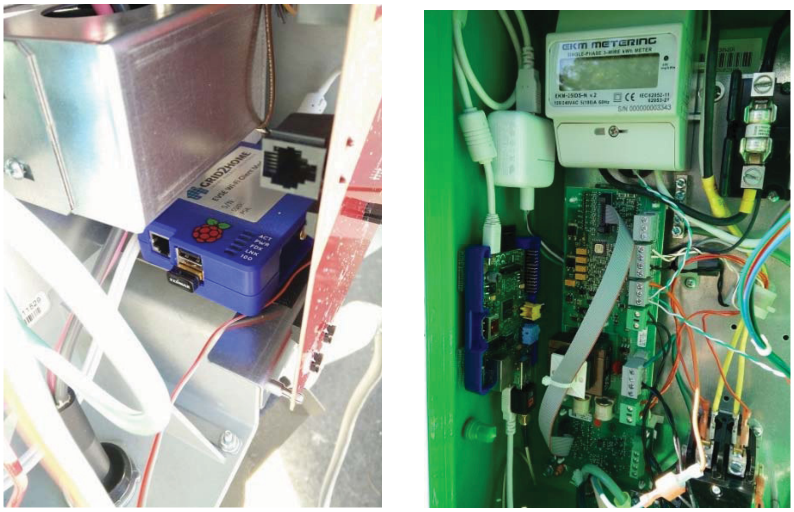

Figure 6- Raspberry Pi Integrated with EVSE (left) and Meter (right- without cover)

SEP 2.0 Electric Vehicle

Though not deployed to a pilot participant, a prototype Smart Charging enabled PHEV was loaned to SCE by an auto Original Equipment Manufacturer (OEM) during the course of the pilot and underwent lab testing at SCE. This evaluation of onboard vehicle communications using SEP 2.0 and Power Line Communications (PLC)[10] was based on extensive work within SAE (See footnote 6) by SCE and others. The implementation involved an Electric Power Research Institute (EPRI) provided gateway capable of translating between SEP 2.0 and the internal vehicle Controller Area Network (CAN) bus communications. Through EPRI testing, it was demonstrated that the vehicle was able to intelligently manage charging schedules based on DR and Pricing communications. No OEM, however, has actually included nor indicated their desire to implement these capabilities on a vehicle (see Telematics discussion below), thus EVSE communications for vehicle load management will be most prevalent for direct architecture implementations.

Business to Business (B2B)

B2B, also known as cloud to cloud, denotes an architecture whereby a 3rd party (e.g., an aggregator) enrolls in a DR program and manages loads based on SCE called events. SCE currently has similar C&I based programs.[11] Though not originally intended to be part of the pilot, testing and demonstration of this architecture was included in order to show a complete

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[10] http://www.homeplug.org/tech-resources/green-phy-iot/

[11] https://www.sce.com/wps/portal/home/business/savings-incentives/demand-response

‘suite’ of solutions. In the end, unless SCE deploys EVSEs or other load control capable devices for customers, it will be up to vendors to provide these capabilities along with open interfaces. As yet, the industry is not moving in this direction. The alternative is for SCE to manage these and other smart grid devices through 3rd parties or through another method (e.g., storage, tariffs, etc.).

In the EV space, the 3rd parties currently only consist of Electric Vehicle Service Providers (EVSPs), which aggregate EVSEs. SCE is working with the EVSPs in its Workplace Charging Pilot. However, Auto OEMs have existing telematics (e.g., cellular) interfaces on many vehicles and are exploring using these communications for load management and other services. For this pilot, with the help of EPRI, the OEMs provided a *Central Server* with an OpenADR 2.0b interface that could receive SCE’s DR signal and translate to each of the OEM’s proprietary APIs. The OEMs in turn communicate the DR signal to the EVs.

Central Server

SCE demonstrated in the lab the use of EPRI’s Central Server to aggregate load management signals to EV loads. EPRI describes its Central Server as follows:

> The OEM Central Server is a server-based application that enables utilities to manage charging for the entire installed base of Plug-in Electric Vehicles (PEVs) as controllable loads. The application uses a set of open, interoperable standards-based interfaces – either via aggregated, indirect Demand Response (DR) programs using Open Automated Demand Response (OpenADR) profile 2.0b or via ‘direct-to-customer’ pricing and DR signals delivered through Automated Metering Infrastructure (AMI) or public internet-connected Home Area Networks (HAN) using Smart Energy Profile 2.0 (SEP 2.0) connectivity.[12] This server-based application also allows the DR signals to be routed through OEM servers, such as Telematics servers, to reach the vehicle. The unique feature of this concept is that it enables a continuum of technologies, which utilities are already implementing, to be incorporated into the DR framework. It provides utilities with a single, common interface to address a wide variety of globally manufactured PEV products – a much

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[12] The overarching reason OEMs state for use of the supplied Telematics systems, besides minimized costs for OEMS as these communications are already being included on some vehicles, is that each OEM can manage grid requests (e.g., from the *Central Server*) based on customer preferences and EV State Of Charge (the latter is not provided by OEMs otherwise) in the cloud. Thus, in order to still provide this service and use the telematics interfaces in Direct-to-Device architectures, signals from AMI or GWs not going through the Central Server would have to be ‘intercepted’ and sent up to OEM servers to take actions on the EV, instead of the EVSE. Further comment on this can be found in the Findings section.

> more powerful proposition compared to interfacing with several different proprietary OEM server interfaces. [13]

SCE tested this capability with several vehicles from different OEMs in the lab, participated in a large demonstration to the public, but did not deploy for the Field Testing portion of the pilot. The OEMs and this 3rd party interface can be considered somewhat analogous to the EMS mentioned above as they use additional, inputs not easily available otherwise, to manage a DR request, such knowledge of the EV's state of charge (SOC), the customer preferences, and the EV capabilities.

The architecture diagram also shows communications between the 3rd party server and the EVSE. As mentioned previously, this was not demonstrated in the Pilot, but rather will be deployed for SCE's PEV Workplace Charging Pilot.

Electric Vehicle

In order to demonstrate the use of 3rd party communications for EVs, EV's must be capable of both telematics communication and load management (e.g., the ability to stop charging remotely). Some vehicles tested already had these capabilities, while others were *engineering* (e.g., prototype) vehicles provided by the OEMs, with either communications, controls, or both.

The architecture diagram also shows the possibility of ISO/IEC 15118 communications between the EVSE and the EV. The IEC 15118 is an application layer protocol that was designed for communications between EVSEs and EVs. It is actively supported (and mandated) in some places in Europe and by some European OEMs. It is also being used for communications in SAEs DC Fast Charging standards.[14] It was not evaluated as part of this Pilot, though it could possibly be used in place of SEP 2.0 for EVSE to EV load management signaling, which would require translation from the utility or other device protocol unless the interface out from the EVSE was to a 15118 server in the cloud.

Pilot Results

The Pilot was deployed in three phases and culminated with this report. The first phase, Design, involved pilot design, stakeholder outreach, the creation of Request for Information

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[13] http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002000665

[14] http://standards.sae.org/wip/j2847/2/

(RFIs) and Request for Proposals (RFPs), and concluded with the procurement of the desired technologies. The second phase, Lab Testing, consisted of test plan development and lab testing and concluded with a lab report. The third phase, Field Testing, entailed the installation of the technologies at ten employee homes, conducting nine DR test events, and the collection of data.

Due to the evolving nature of technologies, and vendor and SCE strategies, the phases were not all conducted in a linear fashion. The scope of the pilot grew from the original EVSE-based DR evaluation (communications to the EVSE to curtail or throttle charging) to also include EV-based DR (through both vehicle telematics and through the J1772 charging cable to the vehicle). However, only the former was demonstrated as part of the employee Field Testing phase. The latter technology's field demonstration was conducted elsewhere.[15]

Lab Testing

Lab testing took place in SCE's Advanced Technology (AT) Garage of the Future lab in Westminster, CA. Both individual device testing and full end-to-end testing were conducted. SCE acquired a SEP 2.0 test tool from Quality Logic to aid in testing both clients and servers. Test cases were created based on the Smart Charging use cases. Use cases evaluated are as follows:

- Commissioning, Registration, and Enrollment (CRE)- This involves the manual registration of devices on servers, automated service discovery, and network joining
- Demand Response and Load Control (DRLC)- DRLC is the ability to send and respond to DR events
- Pricing- Pricing is the ability to send and respond to pricing events
- Measurement and Monitoring (MM)- This involves the ability to measure, communicate, and disseminate data
- Managed Charging (MC)- Managed charging means the ability to schedule charging based on pre-set or real time information
- Human Machine Interfaces (HMI)- HMI includes the ability for users to be notified and respond to DR events

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[15] http://www.energy.ca.gov/research/notices/2014-11-19_workshop/presentations/Sunil_Chhaya_VGI_Presentation_2014-11-19.pdf

	CRE	DRLC	Pricing	MM	MC	HMI
DRS	X	X	X	X		X
Gateway	X	X	X	X		
EVSE	X	X				
SEP 2.0 EV	X	X			X	
Sub-meter	X			X		
Telematics EV		X				
3rd Party Server	X	X	X	X	X	X

Table 1- This table shows the functionality tested and validated per devices acquired

An SCE lab report was completed for this project and this report is not intended to go into all of the details of lab testing. However, as is usual when working with multiple vendors on prototypes involving new interfaces, there were many iterations of development and evaluations between SCE and the vendors before acceptance of all devices was complete. Once lab testing was completed, all devices (except the SEP 2.0 EV and the Telematics EVs) were deployed for Field Testing.

Field Testing

A total of ten participants were chosen for the Field Pilot. Each was required to have internet service, sufficient panel capacity for the EVSE installation, and an EV (all but two as SCE loaned two EVs for the pilot). After deployment and prior to beginning DR testing two of the EVSEs were removed due to a safety concern (non-pilot related) resulting in a total of eight pilot participants. All deployments included a GW, EVSE and sub-meter. Throttling and curtailable EVSEs were randomly installed so that the participants – either battery electric or plug-in hybrid owners - had one or the other. By necessity, the GWs were installed next to customer modems.

After installation, it was determined that because of either distance or interference, the Wi-Fi signal from three of the GWs to the EVSEs/Sub-meters was insufficient. For two of those installations, SCE deployed Power Line Carrier (PLC) modules at both locations and placed the GW in the garage. For the other location SCE used a Wi-Fi range extender as no outlet for a PLC module was available.

Figure 7- In this customer installation, the EVSE did not have enough space to place the Raspberry Pi (left) inside. The sub-meter on the right could be placed anywhere on the branch circuit, including next to the panel. This unit had a relay allowing only on/off capability (the small wire from the Raspberry Pi to the EVSE).

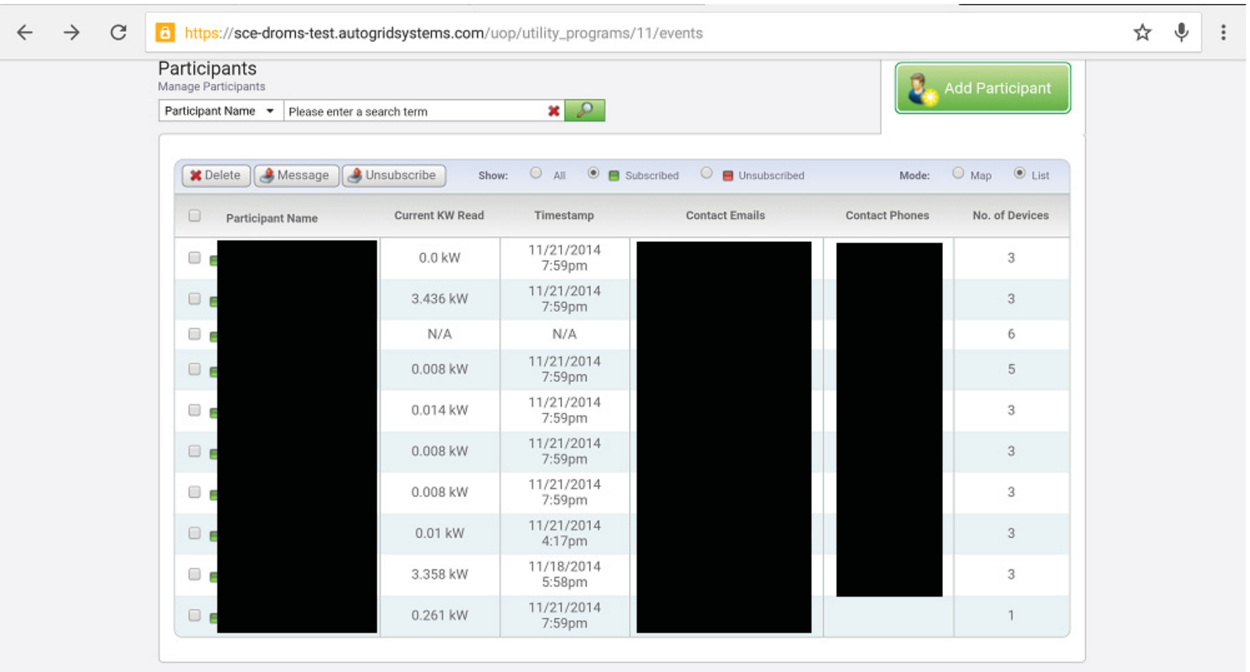
After installation and validation, SCE conducted a total of nine DR events (see Figure 8). In an effort to replicate a real-life DR event scenario, users were only contacted through the standard DRS email and text notification systems (Voicemail was not used). They were also given the option to opt-out by responding to the notification. Notifications were sent out a maximum of one day and a minimum of one hour prior to events being called.

Three events occurred when no vehicles were charging. Five of the events were throttling events and four were complete curtailment. If any duty cycle was set on the DRS, EVSEs that could not throttle curtailed completely. Two total opt-outs occurred and were processed by the DRS effectively (during lab testing, only opt-outs made within approximately 3 minutes of event start were not applied). During the testing, one gateway had to be replaced after it kept dropping off-line and being reset. The reason for the failure was never pinpointed.

	Day	Start Time	Opt Outs	Duty Cycle
Test 1	Sat	2:15 PM	0	50%
Test 2	Fri	6:30 PM	1	0%
Test 3	Mon	9:00 PM	0	46%

Test 4	Tue	10:00 PM	0	0%
Test 5	Fri	11:00 PM	0	46%
Test 6	Mon	6:00 PM	1	0%
Test 7	Tue	7:00 PM	0	23%
Test 8	Wed	10:00 PM	0	23%
Test 9	Fri	8:00 PM	0	0%

Figure 8- Field Tests Conducted



https://sce-droms-test.autogridsystems.com/uop/utility_programs/11/events

Participants
Manage Participants

Show: ○ All ● Subscribed ○ Unsubscribed Mode: ○ Map ● List

☐	Participant Name	Current KW Read	Timestamp	Contact Emails	Contact Phones	No. of Devices
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☐	[redacted]	3.436 kW	11/21/2014 7:59pm	[redacted]	[redacted]	3
☐	[redacted]	N/A	N/A	[redacted]	[redacted]	6
☐	[redacted]	0.008 kW	11/21/2014 7:59pm	[redacted]	[redacted]	5
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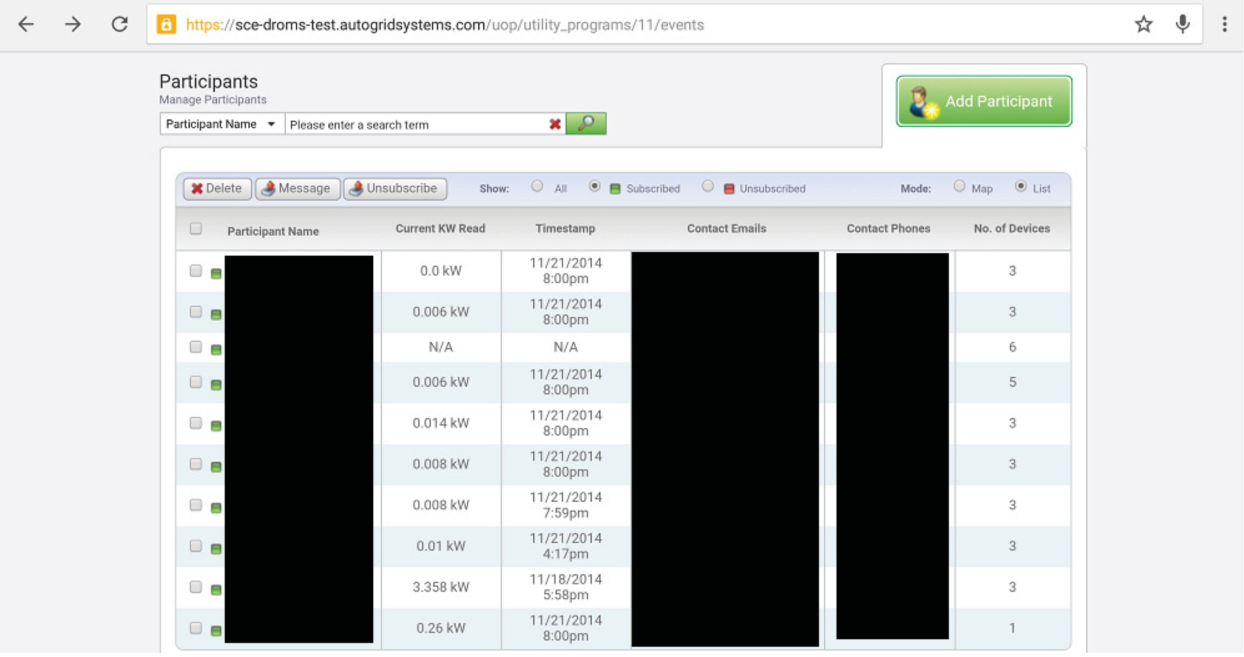
☐	[redacted]	3.358 kW	11/18/2014 5:58pm	[redacted]	[redacted]	3
☐	[redacted]	0.261 kW	11/21/2014 7:59pm	[redacted]		1

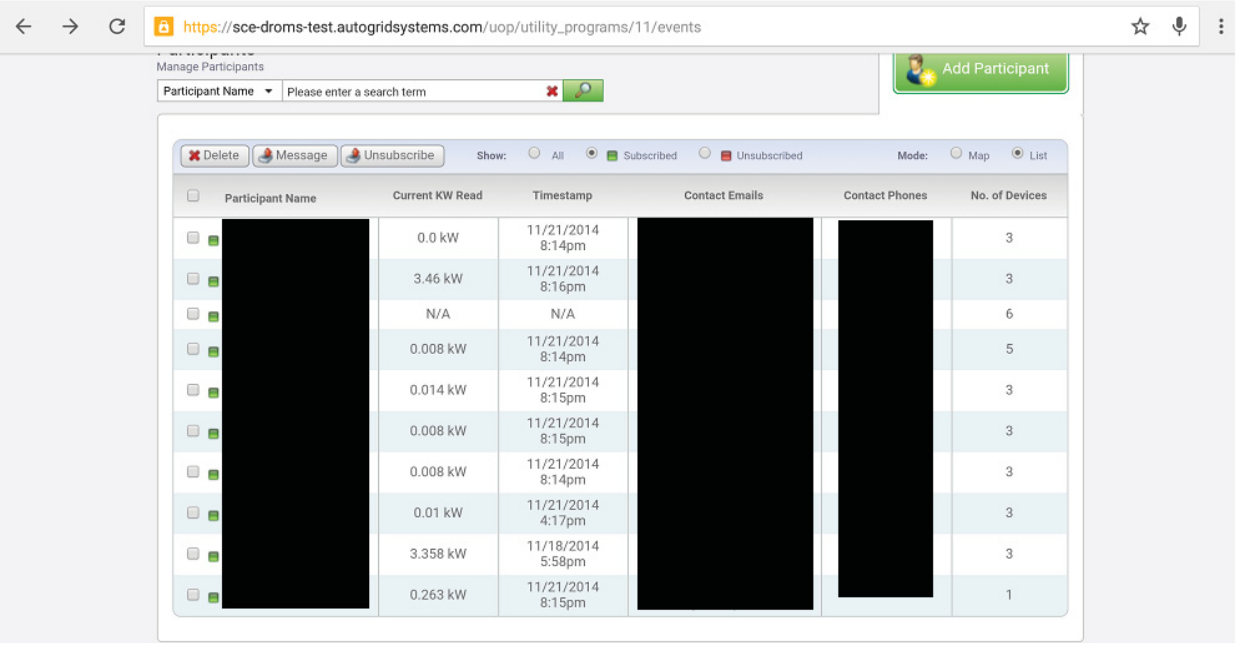
Figure 9- Test #9: 15 minute curtailment event. Before event. Participant in second row charging at 3.436 kW. Note that data in Row 3 and 9 were lab equipment not online.



Show: ○ All ● Subscribed ○ Unsubscribed Mode: ○ Map ● List

☐	Participant Name	Current KW Read	Timestamp	Contact Emails	Contact Phones	No. of Devices
☐ 🟩	[redacted]	0.0 kW	11/21/2014 8:00pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	0.006 kW	11/21/2014 8:00pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	N/A	N/A	[redacted]	[redacted]	6
☐ 🟩	[redacted]	0.006 kW	11/21/2014 8:00pm	[redacted]	[redacted]	5
☐ 🟩	[redacted]	0.014 kW	11/21/2014 8:00pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	0.008 kW	11/21/2014 8:00pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	0.008 kW	11/21/2014 7:59pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	0.01 kW	11/21/2014 4:17pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	3.358 kW	11/18/2014 5:58pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	0.26 kW	11/21/2014 8:00pm	[redacted]	[redacted]	1

Figure 10- Test #9: 15 minute curtailment event. Event Started. Participant in second row charging at 0.006 kW. Note that data in Row 3 and 9 were lab equipment not online.



Show: ○ All ● Subscribed ○ Unsubscribed Mode: ○ Map ● List

☐	Participant Name	Current KW Read	Timestamp	Contact Emails	Contact Phones	No. of Devices
☐ 🟩	[redacted]	0.0 kW	11/21/2014 8:14pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	3.46 kW	11/21/2014 8:16pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	N/A	N/A	[redacted]	[redacted]	6
☐ 🟩	[redacted]	0.008 kW	11/21/2014 8:14pm	[redacted]	[redacted]	5
☐ 🟩	[redacted]	0.014 kW	11/21/2014 8:15pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	0.008 kW	11/21/2014 8:15pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	0.008 kW	11/21/2014 8:14pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	0.01 kW	11/21/2014 4:17pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	3.358 kW	11/18/2014 5:58pm	[redacted]	[redacted]	3
☐ 🟩	[redacted]	0.263 kW	11/21/2014 8:15pm	[redacted]	[redacted]	1

Figure 11- Test #9: 15 minute curtailment event. Event Concluded. Participant in second row charging at 3.466 kW. Note that data in Row 3 and 9 were lab equipment not online.

Upon completion of Field Testing, electricians removed the test equipment and replaced it with EVSEs supplied by SCE.

Findings, Recommendations, and Next Steps

Findings and Recommendations

The following findings and recommendations can be extrapolated from the pilot:

SEP 2.0 Implementation- As a new standard, no gaps or issues with SEP 2.0 were uncovered for the demonstrated use cases. Also, though it is often stated that it is a Home Area Network (HAN) protocol as opposed to OpenADR or others, if device vendors support it in the future or other functionality (DER, Flow Reservation, etc.) is desired, it would be suitable as a head end communication protocol (or combined with others). If used in a much larger pilot or program, however, it may be more proper to use LFDIs, as opposed to SFDIs, for device enrollment.

DRS- The cloud-based DRS used in the Pilot will be useful to support many other pilots as a flexible, extensible, multi-protocol enabled platform (Autogrid offers support for many custom and vendor provided APIs). Such a system would allow for a variety of different protocol-enabled devices to be enrolled in a single program. If supporting more than one interface or many aggregators/devices, a cloud-based system makes sense architecturally. This is because it would have to support many interfaces, while SCE would only need to support one to the DRS from its back office system(s) (e.g., Distribution Management System, Network Management System, Advanced Load Controls System, etc.). For the Pilot, SCE enrollment of customer devices on the DRS was a simple process because of the above mentioned SFDIs and the small customer participation. If a larger pilot or program was implemented, a way for automated enrollment should be enabled.

Automated discovery and registration - SEP 2.0 prescribed mDNS/DNS-SD worked well and allowed devices to join the SEP 2.0 easily. One can envision a *whole house* type program whereby SCE registers a single GW or EMS and allows customers to self-register. This could be the simplest and easiest program to enable.

DR Signal Types - If SEP 2.0 or some other similar DR protocol is used, EVSE load management events need to be carefully implemented. With SEP 2.0, if directly communicating DR signals to EVSEs or EVSEs management devices, it is important to note several things:

1. SEP 2.0 provides either duty cycle % or load adjustment & signals. The former was supported by Autogrid and Kitu for this Pilot. Semantically, for EV charging, the latter might make more sense.

2. If throttling via the J1772 Duty Cycle,[16] different vendors might determine how different SEP 2.0 signals are interpreted into pilot duty cycles, which could result in some vehicles not reducing charge.
3. Throttling can either be done based on EVSE capacity (e.g., 50% reduction = 30A EVSE reduced down to 15A) or, with measurement, based on current EV charging rate (e.g., 50% reduction = vehicle charging at 20A reduced to 10A). With the former, as many vehicles charge at limited rates (Chevrolet Volt max charge rate is 3.3 kW or ~14A), some vehicles will not reduce charging. With the latter method, it was noted in lab testing that at least one model of vehicle does not have a linear charge profile and sometimes reduces charge for a very short durations (<1 sec). This means that if a throttling event is applied during one of the valleys, the vehicle might error out and stop charging.

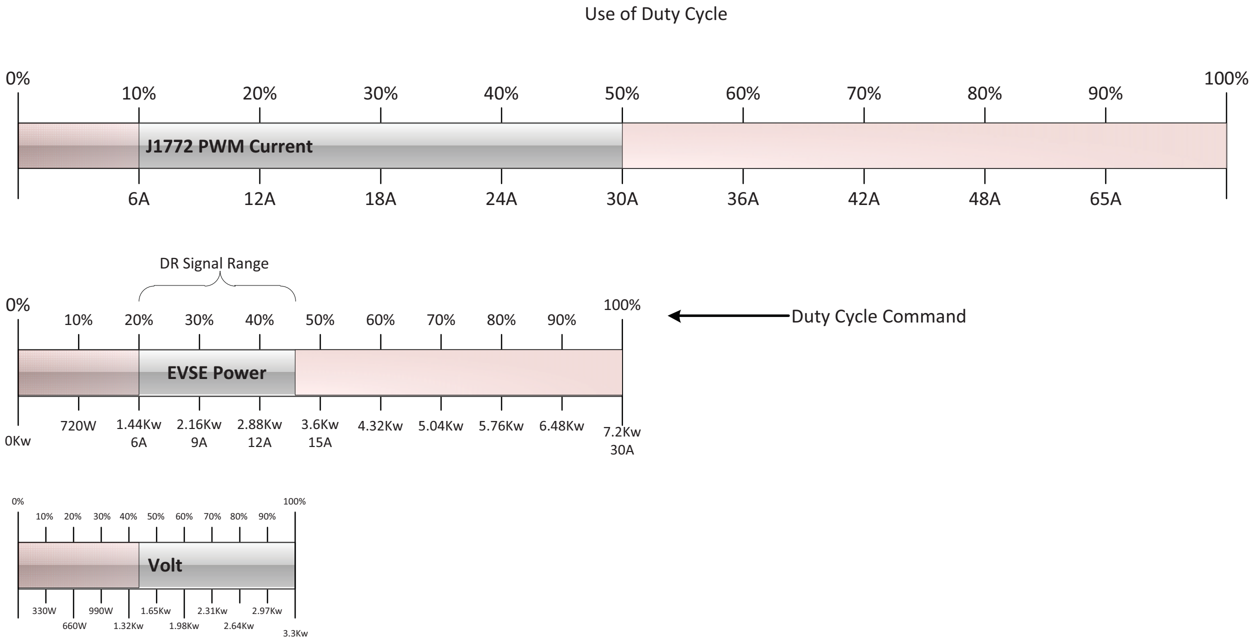


Figure 12- DR Interpretations for a 240V/30a (7.2 kW) EVSE.

The above Figure 12 represents further how these DR commands might be interpreted. The top bar represents the Pilot Duty Cycle per SAE J1772 specifications. If a 50% SEP 2.0 duty cycle DR signal is directly mapped to the pilot duty cycle percent, a 30A EVSE would remain charging at a maximum rate. The middle bar represents the EVSE and percentages of full

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[16] http://standards.sae.org/wip/j1772/

charging capacity. If a 50% SEP 2.0 duty cycle DR signal is intended to effect the capacity to 50% (15A or 3.6 kW), the Volt (~13.7A or 3.3 kW max) shown on the bottom bar would not be effected. It is also important to note that EVSEs have different charging rates (20A, 30A, and 40A are common). The best case scenario would be for the above to be standardized for EVSE DR, most likely through a future SEP 2.0 certification process or through an SAE; however, as that is unlikely to occur, each of the above should be determined prior to any pilot or program implementations.

Customers and DR strategies - Even with a small sample size, 22% of events had an opt-out. Though more investigation is needed, this might point to the necessity to give customers flexibility with EV load management programs. Whether that is simply based on automation (e.g., set and forget), pricing, only throttling-based events, or the use of other technologies, this points to the fact that capturing EV loads are not going to be as simple as HVAC programs. Vehicle batteries are meant to be used for travel and customers might not be as comfortable with other entities interrupting their charge. Also, as SCE observed latencies ranging into the minutes, real time events using internet based technologies are not recommended.

Signal Speed - Although measuring the time it took for DR signals to reach control equipment and shed electric load was not part of the pilot, there were some observations made that may help in determining the type of DR programs that EVs could participate in. In controlled lab conditions, communication with the architecture utilizing the public internet and a gateway connected to EVSE equipment had some variability, but always responded in less than a minute. However, when using the central server architecture, times were longer and more variable due to the processing of multiple inputs, applying algorithms, and issuing commands. In this environment, times varied from 3 to 10 minutes.

Future projects should focus on optimizing round trip communication and evaluating latency in a variety of use cases. Test events were always initiated at least five minutes prior to the load reduction. Generally, when using EVs as a DR resource with the architectures tested, events dispatched with a five minute notification could react within ten minutes.

Next Steps

The following are some next steps recommended based on this Pilot:

Larger pilots – The current PEV Workplace Charging pilot report, when completed, should be able to inform SCE how to accomplish DR for workplace and commercial charging scenarios.

A similar large pilot based on this Pilot, but including 3rd parties and other off-the-shelf technologies, is also suggested on the residential side. This will inform SCE of costs for deploying technologies vs relying on 3rd parties and provide more information on charging behaviors and program possibilities. Some suggestions for further investigations include:

- Real-time pricing signals
- Load up signals (for excess generation scenarios)
- EMS/3rd parties and SEP 2.0 Flow Reservation which is a SEP 2.0 function that was derived with help from SAE and SCE that allows for dynamic management of charging based on multiple inputs (see 6). This adds automated intelligence into load management scenarios
- The use of OpenADR 2.0 and SEP 2.0 home server (or other protocols)
- Evaluation of OEM telematics-based solutions that communicate directly to EVs. Such a program needs to be well thought out, but adding the SOC to EV management scenarios is worth exploring, comparing these services to SCE Direct programs. However, as vehicles travel and are owned by an employee or customer, and workplace and commercial charging are owned, operated, and paid for by the site host, telematics services probably are most closely aligned to residential programs

New Charging Technology Explorations - DC Fast Charging and Vehicle to Grid are more disruptive technologies and services than AC charging, and it may be worthwhile for SCE to explore in future residential EV pilots how to safely and cost effectively enable these, especially from the Distribution Grid perspective.

SCE-provided Sub-metering Pilot - SCE is currently involved in a CPUC prescribed sub-metering pilot due to the costs of deploying a separate meter (due to trenching, new panels, etc). The 3rd party devices are often not very accurate, can add significant costs to the purchase of an L2 EVSE, usually require the customer to pay for network services, and could possibly lead to stranded assets. In the pilot, simple, inexpensive, certified, revenue grade, and off-the-shelf devices were placed on a branch circuit of the EVSE and communicated effectively over the internet to the DRS and SCE back office. A pilot to further explore the use of similar technologies may be worthwhile to enable simple and cost-effective sub-metering and billing.

SEP 2.0 Testing and Certification - SCE has been involved in SEP 2.0 development for some time. If SCE deploys SEP 2.0 technologies, it would be worthwhile for SCE to push for a very strong testing and certification program, so as not to experience some of the interoperability issues seen with HAN In Home Displays and other similar programs.

Bring Your Own Device (BYOD) Options - SCE should further explore partnerships with set top box manufacturers (Cisco, Tivo, etc.) and service providers (ISPs, cable providers, security companies, etc.) to bundle utility interfaces and services directly into customer purchased devices, cloud service, and energy management systems. In addition, enabling standard protocols will allow customers to choose products that are plug and play, meet environmentally conscience customer preferences, and can save money on energy bills while meeting distribution and programmatic needs of utilities. However, regulatory or governmental support of standard protocols is necessary to allow utilities to focus on implementation of energy saving programs rather than driving standards development.

A potential strategy is for devices to also be the home Wi-Fi Access Point or Home Automation Gateway. Whatever the implementation, devices must be rigorously tested before being deployed and provide a remote reset option (if serving non-critical services or with customer permissions) should the device go offline.

Appendix A- Acronyms

ALG- Application Layer Gateway- A gateway that provides services up to the Application Layer (e.g., as a client or server, application translation, etc.)

API- Application Programming Interface- A set of programming instructions and standards for accessing a Web-based software application or Web tool.

ATO- Advanced Technologies Organization- SCE organization that "monitors, identifies, tests, and evaluates technologies that support SCE efforts to maintain a safe, reliable, affordable, and secure electric grid while empowering the customer with more options and greater control to manage their energy use."

B2B- Business-to-Business- Refers to a relationship between two businesses, typically in regard to a transaction or communication from one business to another. With respect to the communication architecture presented on page five, B2B refers to the third party design in which SCE sends the DR event to a third party prior to any interaction from the end device / user.

BMS- Building Management System- Sometimes referred to as an Energy Management System. A system used by commercial and industrial customers typically to manage a variety things including lighting and HVAC systems. A modern BMS could include the management of PV inverters, energy storage, and EV infrastructure.

DCFC- DC Fast Charging- A method for charging an EV battery using DC power from the EVSE (off board charger). DCFC charges at much higher power than AC charging which goes to a maximum of 19.2 kW.

DER- Distributed Energy Resources- Refers to devices that can both absorb and export energy, as well as an SEP 2.0 function set designed to monitor and control DER devices

DR- Demand Response- a voluntary program in which customers reduce their electricity consumption, often during peak usage times, in order to ensure grid reliability.

DRLC- Demand Response and Load Control- Used interchangeably with DR. DRLC more specifically mentions that a load is often controlled during a DR event.

DROMS- Demand Response and Optimization Management System- An OpenADR 2.0b certified DRS from Autogrid. Provides prototype SEP 2.0 services.

DRS- Demand Response Server / System- A backend or cloud based system used for DR event creations, registration, and data exchange.

DSM- Demand Side Management- According to the US Energy Information Agency, DSM is the "planning, implementing, and monitoring activities of electric utilities which are designed to encourage consumers to modify their level and pattern of electricity usage."

Duty Cycle- DR signal within energy management protocols like SEP 1.x and SEP 2.0. It reduces the load of an intelligent device based on the maximum potential of the device. For example, if an intelligent EVSE can provide a maximum of 7.2 kW, then a 50% Duty Cycle communication would reduce the EVSEs potential to 3.6 kW.

EMS- Energy Management System- Often used interchangeably with BMS. A system that monitors and optimizes the use of energy.

EPRI- Electric Power Research Institute- EPRI conducts research, development and demonstration (RD&D) relating to the generation, delivery and use of electricity for the benefit of the public.

EV- Electric Vehicle- A vehicle which uses one or more electric motors for propulsion.

EVSE- Electric Vehicle Supply Equipment- commonly referred to as an "electric vehicle charger", provides "energy for the recharging of electric vehicles".

EVSP- Electric Vehicle Service Provider- An aggregator and service provider of EVSEs.

GW- Gateway- At its most basic, a GW converts from one protocol to another (e.g., from Ethernet to Wi-Fi). See ALG.

HPGP- Home Plug GreenPhy- Method of networking communications via power lines.

IEEE 2030.5- The official name of SEP 2.0 after IEEE standardized it. See SEP 2.0.

ISO / IEC 15118- Specifies the communication between Electric Vehicles (EV), including Battery Electric Vehicles and Plug-In Hybrid Electric Vehicles, and the Electric Vehicle Supply Equipment (EVSE).

SAE J1772- North American standard for electrical connectors for electric vehicles, maintained by the Society of Automotive Engineers.

LFDI- Long Form Device Identifier- Forty digit device identifier used when a globally unique identity is required, for example in sending an event back to a service provider that is associated with a particular device.

Load Adjustment Percentage (Appliance Load Adjustment Percentage) - Function Set within energy management protocols like SEP 1.x and SEP 2.0. It reduces the load of an intelligent device based on the current amount of power being provided / consumed.

OEM- Original Equipment Manufacturer- In this document, solely refers to EV manufacturers

OpenADR 2.0b- Open Automated Demand Response 2.0b- An Open and interoperable information exchange model and emerging Smart Grid standard. OpenADR standardizes the message format used for Auto-DR so that dynamic price and reliability signals can be delivered in a uniform and interoperable fashion among utilities, ISOs, and energy management and control systems.

PLC- Power Line Communication- A communication technology that enables sending data over existing power cables.

QL- Quality Logic- Provider of the official test harness for SEP 2.0. Also provides OpenADR testing, consulting and other services.

RFI/RFP- Request for Information/Request for Proposal- A specification, usually including requirements, that is used to gather information and costs about available technologies or the development of new technologies

SAE- Society of Automotive Engineers- A global association of more than 138,000 engineers and related technical experts in the aerospace, automotive and commercial-vehicle industries.

SCE- Southern California Edison- The primary electric utility for southern California.

SEP 2.0- Smart Energy Profile 2.0- Open standard communication protocol. It provides a variety of benefits including the following smart energy features: pricing, DRLC, energy usage information / metering data, text messaging, and distributed energy resources. These features can be used by utilities to manage both residential and commercial customer devices. SEP 2.0 can be used locally with a residential Energy Management System (EMS) or a Building Management System (BMS).

SFDI- Short Form Device Identifier- Twelve digit number "used to identify a device within a HAN or site domain. It should not be used in a truly global context…"

SOC- State of Charge- The equivalent of a fuel gauge for the battery pack in a battery electric vehicle, hybrid vehicle, or plug-in hybrid electric vehicle. The units of SOC are percentage points (0% = empty; 100% = full).

USB- Universal Serial Bus- A common standard for device connection supported by most operating systems.

VEN- Virtual End Node- OpenADR name for a software or hardware client.

VTN- Virtual Top Node- OpenADR name for a server.

ZigBee- A specification for a suite of high level communication protocols used to create personal area networks built from small, low-power digital radios, based on IEEE 802.15.4.

ZIP- ZigBee Internet Protocol- the first open standard for an IPv6-based full wireless mesh networking solution and provides seamless internet connections to control low-power, low-cost devices.