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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

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Smart Grid Regional Demonstration Program is the final report for the Smart Grid Regional Demonstration Program project (agreement number PIR-11-009) conducted by the Los Angeles Department of Water and Power. The information from this project contributes to Energy Research and Development Division's Energy Systems Integration Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

The Los Angeles Department of Water and Power partnered with the Jet Propulsion Laboratory, University of California, Los Angeles, and University of Southern California to demonstrate innovations in key areas of Smart Grid technologies. In this project, the Los Angeles Department of Water and Power and its partners demonstrated Smart Grid and Energy Storage technologies in the Los Angeles area that present a suite of use cases that are scalable for national implementation and replication. Anticipated benefits of a Smart Grid and energy storage technologies are reduced emissions, lower costs, increased reliability, and greater cyber security and flexibility to accommodate new energy technologies, including renewable, intermittent, and distributed sources.

The California Energy Commission as partial cost-share funded the program with $1 million for the recipient's $60.3 million American Recovery and Reinvestment Act of 2009 award for a total $120.6 million project. This includes demonstrating smart charging, battery aggregation and backfill, a fully functional microgrid, renewables and battery integration, and a car sharing program. The Los Angeles Department of Water and Power is currently in its first year of a two year data collection. Initial studies have yielded positive results and the Los Angeles Department of Water and Power can make preliminary recommendations.

Keywords: Smart Grid, Electric Vehicle, Smart Grid Regional Demonstration Program, Los Angeles Department of Water and Power, Jet Propulsion Laboratory, University of California, Los Angeles, University of Southern California, smart charging, battery aggregation and backfill, microgrid, renewables and battery integration, car sharing program,

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EXECUTIVE SUMMARY

Introduction

The U.S. Department of Energy through a $60.3 million American Recovery and Reinvestment Act of 2009 award (DE-OE0000192) provided funding for a Smart Grid Regional Demonstration Program to the Los Angeles Department of Water and Power. The California Energy Commission provided a $1 million cost share award to fund partially the Electric Vehicle projects portion of the larger regional demonstration program. The Los Angeles Department of Water and Power collaborated with the National Aeronautics and Space Administration Jet Propulsion Laboratory, University of California, Los Angeles, and University of Southern California to complete the objectives of the program with total project funding of $120.6 million.

The Los Angeles Department of Water and Power is developing and demonstrating innovative Smart Grid technologies, identifying sociological and behavioral factors essential for Smart Grid technology adoption by utility customers, and quantifying costs and benefits of these technologies. The Los Angeles Department of Water and Power and its partners expect this program will help open the market for viable, commercially available Smart Grid solutions, representing the state of the industry such that similar large-scale Smart Grid infrastructure projects can be implemented across the nation.

Like the Internet, the Smart Grid consist of controls, computers, automation, and new technologies and equipment working together, but in this case, these technologies will work with the electrical grid to respond digitally to our quickly changing electric requirements.

This report provides insight into the implementation, and progression of the Electric Vehicle Projects. Many of the observations in this report are preliminary as these projects are ongoing. Los Angeles Department of Water and Power will continue to refine impact trends and conclusions beyond the preliminary results presented in this report. Since Los Angeles Department of Water and Power undertook numerous smart technologies simultaneously, data and interpretation adjustments are anticipated as the projects continue and evolve.

Project Purpose

The Los Angeles Department of Water and Power used the funds from the Energy Commission to partially fund the Electric Vehicle project. Under the Electric Vehicle project, the Los Angeles Department of Water and Power will perform six demonstrations: smart charging, battery aggregation and backfill, a fully functional microgrid, renewables and battery integration, a car sharing program, and a grid impact study. These demonstrations will test the aggregation and integration of electric vehicles with transmission and distribution systems.

The Los Angeles Department of Water and Power Electric Vehicle Project Team documented and assessed the impact of electric vehicle integration on such systems accounting for: multiple user demographics, grid specifications, driving patterns, electric vehicles, and a variety of charging equipment. Additionally, the project team documented experiences with the communications and control systems associated with electric vehicle integration, noting the scalability of wireless, sensing, monitoring, and control within the project.

Information was collected and provided so customers, distributors, and generators can change their behavior to reduce system demands and costs, increase energy efficiency, optimally allocate and match demand and resources to meet that demand, and increase the reliability of the grid.

Project Results

Los Angeles Department of Water and Power and its partners successfully implemented smart charging and installed necessary equipment to collect data for the battery aggregation and backfill, the fully functional microgrid, the renewables and battery integration, and the car sharing program. While the project is still in the first year of a two year data collection, enough research was done to make a few preliminary recommendations to the California Energy Commission for California.

Smart charging demonstration. The Los Angeles Department of Water and Power and its partners implemented five use cases. A final recommendation, however, cannot be made until enough data is collected. Therefore, the Los Angeles Department of Water and Power and the University of California, Los Angeles are continuing to collect data from electric vehicle chargers. Initial studies indicate that by using third party applications, different chargers and electric vehicle manufacturers can use the smart grid. Additional work is underway to collate and analyze the data as it is collected.

Battery aggregation and backfill demonstration. All five of use cases are continuing. The Los Angeles Department of Water and Power and the University of California, Los Angeles are collecting data associated with using batteries and electric vehicles in the power grid. While the current data is insufficient to make final recommendations, initial studies indicate that electric vehicles charging or discharging at a large scale at the same time may result in a noticeable frequency change.

Fully functional microgrid demonstration. Three of the four use cases have been partially completed. The Los Angeles Department of Water and Power installed equipment for distribution automation and to collect data. That effort is ongoing. However, initial studies show that distribution automation is possible.

Renewables and battery integration demonstration. Three of the five use cases were partially completed. The University of California, Los Angeles is collecting data on solar panels and battery integration. Because of the lack of data, an initial recommendation cannot be made.

Car sharing program demonstration. The Los Angeles Department of Water and Power and its partners completed one of the two use cases. The Los Angeles Department of Water and Power and the University of California, Los Angeles are collecting data from electric vehicle chargers and electric vehicle and power use. The study on the distribution effects of the car/ride share program will be completed once more data is collected.

Grid impact stability and power study demonstration. There are two use cases to be completed. Since the program is still in its first year of a two year data collection, this demonstration area cannot be discussed at this time due to a lack of data.

Project Benefits

The potential benefits of these smart grid and energy storage demonstrations are reduced emissions, lower costs, jobs creation, increased reliability, greater security, and flexibility to accommodate new energy technologies, including renewable, intermittent, and distributed resources. The Electric Vehicle project created over 75 jobs in California.

CHAPTER 1: Introduction

The U.S. Department of Energy (DOE) through a $60.3 million American Recovery and Reinvestment Act of 2009 award (DE-OE0000192) provided the Los Angeles Department of Water and Power (LADWP) funding for a Smart Grid Regional Demonstration Program (SGRDP) in response to DOE Federal Opportunity Announcement DE-FOA-0000036. Additionally, the California Energy Commission provided LADWP with $1 million in partial co-funding for the Electric Vehicle projects of the SGRDP in response to the Public Interest Energy Research (PIER) program. LADWP is collaborating with its project partners to carry out this demonstration on the designated areas to include two university campuses – the University of California, Los Angeles (UCLA) and the University of Southern California (USC) – surrounding neighborhoods, City of Los Angeles facilities, and LADWP power system test labs, to:

- Develop and demonstrate innovative Smart Grid technologies;
- Identify sociological and behavioral factors essential for Smart Grid technology adoption by utility customers;
- Quantify costs and benefits of these technologies.

The last project partner, Jet Propulsion Laboratory (JPL), is responsible for the Cyber Security aspects of the project.

It is hoped that the SGRDP will help open the market for viable, commercially available Smart Grid solutions, representing the state of the industry such that similar large-scale Smart Grid infrastructure projects can be implemented across the nation.

This report provides insight into the implementation, and progression of the Electric Vehicle Projects. Many of the observations in this report are preliminary as these projects are ongoing. LADWP will continue to refine impact trends and conclusions beyond the preliminary results presented in this report. Since LADWP undertook numerous smart technologies simultaneously, data and interpretation adjustments are anticipated as the projects continue and evolve.

1.1 Background

LADWP is the largest municipal utility in the United States. It was established in 1902 to deliver water to the city of Los Angeles. Electric distribution began in 1916. Its service territory covers 465 square miles and serves 3.8 million residents. LADWP employs more than 8,800 workers and has an annual budget of about $4.9 billion.

In 2010, LADWP produced its Power Integrated Resources Plan (IRP). This plan provides a 20-year framework to ensure LADWP will meet the future energy needs of its ratepayers. Through an IRP, utilities forecast the demand for energy and determine how that demand will be met.

The 2010 IRP was guided by the following key objectives:

- Maintain a high level of electric service reliability
- Maintain competitive rates
- Exercise environmental stewardship.

For the IRP, LADWP's goal—and primary challenge—is to develop a long-term resource plan that is informative, sensitive to the local and regional economy, and adaptable to changes in state and federal regulations, fuel prices, and advances in power generation technologies. An important component in support of this plan will be leveraging opportunities offered by Smart Grid technology. Hence, LADWP has a keen interest in leveraging what functions existing Smart Grid technology can offer and shaping the next generation of Smart Grid technologies.

The SGRDP is comprised of a set of interrelated demonstration projects – Demand Response (DR), Electric Vehicle (EV), Customer Behavior (CB), Cyber Security (CS) and Advanced Metering Infrastructure (AMI).

The key to effectively implementing the SGRDP is creating a secure, scalable, standards-based, and interoperable cyber-physical system architecture; specifically, one that allows relevant-time flow of information between customer and institutional facilities at the demonstration sites, LADWP's AMI communications network, and utility grid.

The goal of SGRDP is to demonstrate Smart Grid technologies that embody essential and salient characteristics and present a suite of use cases for national implementation and replication. These use cases will collect and provide the optimal amount of information necessary for customers, distributors, and generators to change their behavior in a way that reduces system demands and costs, increases energy efficiency, optimally allocates and matches demand and resources to meet that demand, and increases the reliability of the grid.

1.2 Electric Vehicles

The EV Project Team's vision is to satisfy the SGRDP goals by demonstrating EV technology and its role with regard to Smart Charging, Battery Aggregation, Microgrids, Renewables, Car/Ride Share, and Grid Impact Analysis.

The EV Project will document the above EV demonstrations, which test the aggregation and integration of EVs with transmission and distribution systems, and assess the impact of EV integration on such systems, accounting for:

- Multiple user demographics, grid specifications, and driving patterns
- A variety of EV types
- A variety of charging equipment types

The project will also document experiences with the communications and control systems associated with EV integration; noting the scalability of wireless, sensing, monitoring, and control within the project.

Such monitoring and control systems will include the links between charging stations and grid management systems. The EV Project will also incorporate the necessary requirements to ensure cyber security.

Overall, by the end of the project, the project will demonstrate:

- Monitoring of chargers, power usage, and EV use
- Viability of applying charged EVs for maintaining grid integrity related to renewable portfolio and resource planning goals
- Integrating EVs with the LADWP grid, including Smart charging, battery aggregation and backfill, renewables and EV battery integration
- The Smart-charging of EVs and charging stations in the LADWP Service Territory
- Ability of the Smart Grid infrastructure to protect the integrity of customer, configuration, and audit data

The scope of this project is to demonstrate Smart Grid and Energy Storage technologies in the LADWP service territory (specifically, LADWP Smart Grid Power Lab, UCLA Research Labs, Chatsworth substations, and EV chargers at a several different locations) and develop a suite of use cases applicable not only to the study area, but also transferable for national implementation and replication. From these use cases, the goal is to collect and provide the information necessary for customers, distributors, and generators to modify existing usage and behavior patterns to reduce system demands and costs, increase energy efficiency, increase the reliability of the grid, and optimally allocate and match resources with demand.

The anticipated social benefits of EV and energy storage using Smart Grid technologies are reduced emissions, lower costs, increased reliability, greater security and flexibility to accommodate new energy technologies; including renewable, intermittent and distributed resources.

1.3 Summary

For the Electric Vehicle Project, six different demonstration areas are part of the Program Objectives (Table 1). These areas include smart charging, battery aggregation and backfill, a fully functional microgrid, renewables and battery integration, the use of car sharing programs at USC and UCLA, and a grid impact stability/power study. Within each of these areas are use cases that will be executed to satisfy the Program Objectives. In all, there are twenty-three use cases to successfully demonstrate to satisfy the objectives.

Table 1: Electric Vehicle Demonstration Areas and Use Cases

Demonstration Areas	Use Cases
Smart Charging using WINSmartGrid for EV and Existing Charging Stations and EVs in and around Los Angeles and the UCLA Campus	Monitoring of All Chargers
	Reading Power Consumption for Vehicles connected to Chargers
	Control of Chargers
	Disconnection of a Vehicle that is Charging
	Smart Charging through Mobile Interface
Battery Aggregation and Backfill	Use of Batteries in Grid (G2V)
	Use of Batteries in Grid (G2V & V2G)
	Distribution Effects of Battery Aggregation and Backfill (G2B)
	Distribution Effects of Battery Aggregation and Backfill (B2V)
	Distribution Effects of Battery Aggregation and Backfill (B2G)
Fully Functional Microgrid	Inductive Charging
	Various Vehicle Charging
	Distribution Effects of EVs on the Grid
	Local Grid Balancing and Management
Renewables and Battery Integration	Community Storage of EV Batteries and External Storage
	Garage of the Future
	Cycling of the Batteries
	Aggregation of the Batteries
	Integration of EV and Solar
Using Car Sharing Programs at USC and UCLA	Monitoring of Chargers, Power Usage, and Car Usage
	Distribution Effects of Car / Ride Share Program
Grid Impact Stability / Power Study	Generation, Transmission, and Distribution Effects
	Various Loading Scenarios

CHAPTER 2:
Demonstration Areas

2.1 Smart Charging using WINSmartGrid™ for existing charging stations and EVs in and around Los Angeles and UCLA

2.1.1 Methodology

This demonstration area will be responsible for the monitoring of all chargers, the ability to read power consumption for vehicles connected to chargers, the control of chargers, the ability to disconnect vehicles that are charging, and the utilization of a mobile interface. The demonstration of automated smart charging using wireless communications will take into account cyber security concerns, reliability, and result in outcomes to help determine upgrades required to the electric distribution system with fully scale implementation of EVs.

To demonstrate the use cases and meet the success criteria for this demonstration area, the EV Project team will install Level 1, Level 2, and Level 3 charging stations from various vendors at UCLA and LADWP parking structures (Table 2). Additionally, to circumvent proprietary communication protocols that inhibit the EV team from collecting detailed user data and fully controlling the charging operations, the EV team will develop an open-architecture charging station that supports the data collection and circuit control of this project. By using this open-architecture, the EV team will be able to monitor and control (including disconnect) chargers and collect charger data. Lastly, the EV team will develop and implement a web interface and API interface to allow Smart Charging through mobile interfaces.

Table 2: Smart Charging Equipment List

Equipment Overview	Total	Installed/ Acquired
Level 2 EV Charger (DWP)	131	124
Level 3 EV Charger (DWP)	16	13
Level 2 EV Charger (Rebate Program)	898	898
Electric Vehicles	67	67

2.1.2 Success Criteria

The success criteria for Smart Charging include the successful completion of all use cases. Additionally, a report on smart charging infrastructure results will also be generated as a part of the success criteria for the demonstration area.

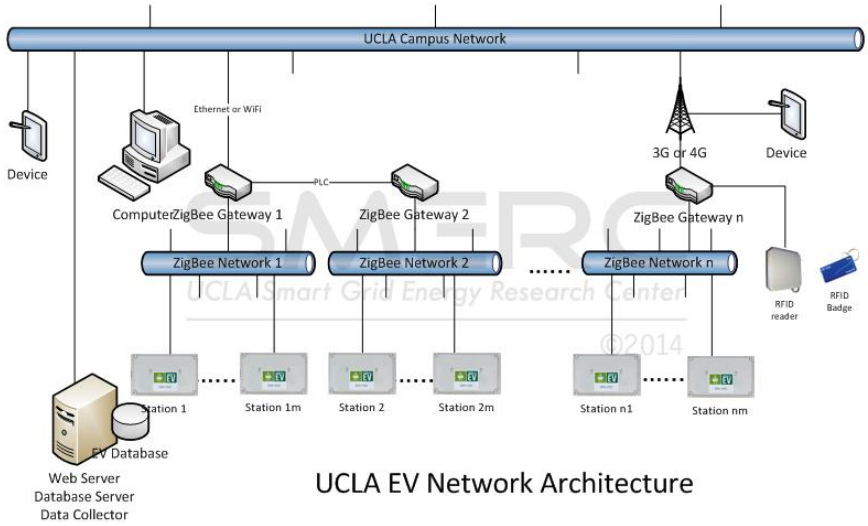
The majority of the chargers for this demonstration area has been installed and these chargers are collecting data. Additionally, the UCLA Smart Grid Energy Research Center (SMERC) developed the mobile interface and can be utilized. The report on smart charging infrastructure results will be generated at the end of the project in 2016.

2.1.3 Observations and Results

The UCLA Smart Grid Energy Research Center (SMERC) has dedicated its efforts on large-scale testing of its smart charging network WINSmartEV™ using UCLA parking structures as the test bed. SMERC tested various communication networks and designed an optimal communication architecture based on the specific characteristics of the parking structures.

The WINSmartEV™ EV charging network utilizes a centralized control system to monitor and regulate the network for real-time smart charging services. This smart charging infrastructure uses standard networking technologies to create a network that facilitates charging services for the end user and monitoring and control tasks for maintainers/operators. The charging services are completely adaptable by way of local or remote charging algorithms. In addition, the architecture incorporates multiplexing capabilities with a unique safety system that integrates safety on all levels of control. Figure 1 shows the topology of the EV network's architecture.

Figure 1: Topology of WINSmartEV™



Source: UCLA

Current commercial EV charging stations provide basic stations without any network features or they use proprietary technologies to connect charging stations to networks. For instance, while Coulomb provides a ChargePoint application programming interface (API) and an OpenCharge protocol for developers, the current application uses the company's own network to locate available charging stations for users. It is possible to build a smart charging system over a closed network with API and protocols; however, it is difficult to determine if such commercial implementations have an integrated safety design. SMERC implemented safety designs in basic, non-networked commercial charging stations, like those provided by Leviton and ClipperCreek. Nevertheless, these stations simply provide basic charging services without power information monitoring and network control features. In addition, the user must take extra steps in order to authorize charging sessions when using a closed system. Finally, commercial implementations like that of Coulomb may use smart charging algorithms in their charging stations, but these stations only have one or two outlets, which are not suitable for sharing electric current.

2.1.3.1 Monitoring All Chargers

UCLA SMERC control center monitoring and control interface shows status of EV chargers.

In Figure 2, the control center shows charging status as “standby” or “charging”. “Standby” means there is currently no EV connected or the charger is not charging. “Charging” means the station is currently charging a vehicle. The corresponding user and latest meter data are displayed.

Under “Station Status”, it shows “online” or “offline”. Online means the control was able to receive data from the EV charger in the past data collection loop. “Offline” means the data retrievals was not successful in the past data collection loop.

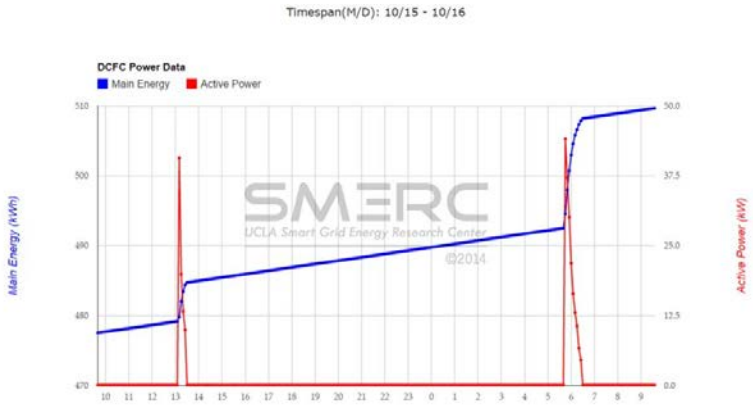
“Plugged-in” shows “yes” if a charging cable is connected to a vehicle. This option is only available for level 2 chargers.

Figure 2: Control Center – EV Status Monitoring

Source: UCLA

Figure 3 shows current data collection of DC Fast Charger (DCFC).

Figure 3: Data Collection on DCFC



Source: UCLA

For data collection, Table 3 shows a sample of collected data.

Table 3: Sample Station Data Record for July 2014

Station ID	Timestamp	Voltage	Current	Frequency	Power Factory	Active Power	Apparent Power	Main Energy
000D6F000072BB56	7/1/2014 0:13	208.09	0	60.09	1	0.83	0.83	3130.526
000D6F000072BB56	7/1/2014 0:29	208.46	0	59.98	1	0.79	0.79	3130.526
000D6F000072BB56	7/1/2014 0:46	208.23	0	59.98	1	0.79	0.79	3130.527
000D6F000072BB56	7/1/2014 1:02	208.58	0	59.98	1	0.83	0.83	3130.527
000D6F000072BB56	7/1/2014 1:19	208.53	0	59.98	1	0.87	0.87	3130.527
000D6F000072BB56	7/1/2014 1:35	207.29	0	59.98	1	0.79	0.79	3130.527
000D6F000072BB56	7/1/2014 1:52	206.91	0	59.98	1	0.83	0.83	3130.528
000D6F000072BB56	7/1/2014 2:08	206.75	0	59.98	1	0.79	0.79	3130.528
000D6F000072BB56	7/1/2014 2:25	206.79	0	59.98	1	0.83	0.83	3130.528
000D6F000072BB56	7/1/2014 2:41	207.8	0	59.98	1	0.83	0.83	3130.528
000D6F000072BB56	7/1/2014 2:58	207.85	0	59.98	1	0.79	0.79	3130.528
000D6F000072BB56	7/1/2014 3:14	207.55	0	60.1	1	0.84	0.84	3130.529

Source: UCLA

As shown in the sample, data are collected in 15 min intervals. The two sets of data that are required for this use case are as follows:

EV Status:

- Timestamp – collected as indicated in Table 3.
- EV charger operating status – collected in Table 3. Offline if voltage field is 0, online otherwise.
- Charging state – collected in Table 3. Charging if current field is greater than 1, standby otherwise.

Accumulative Charging Data:

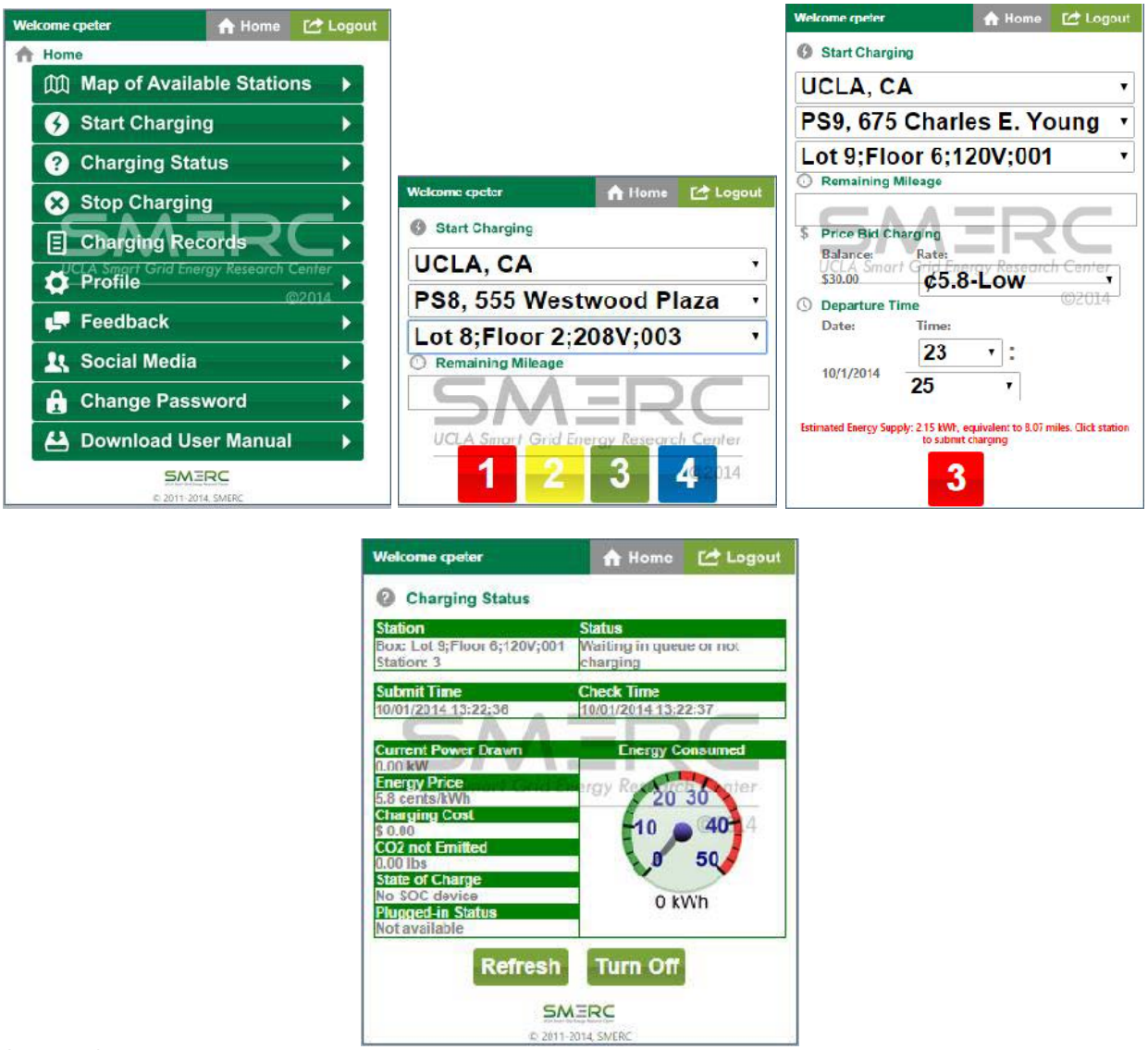
- Timestamp – collected as indicated in Table 3.
- kWh – collected as indicated in Table 3. “Main Energy” field.

- kW – collected as indicated in Table 3. "Active Power field.
- kVARh and kVAR can be obtained by Power factor, kW, and kWh.

2.1.3.2 Reading Power Consumption for Vehicles Connected to Chargers

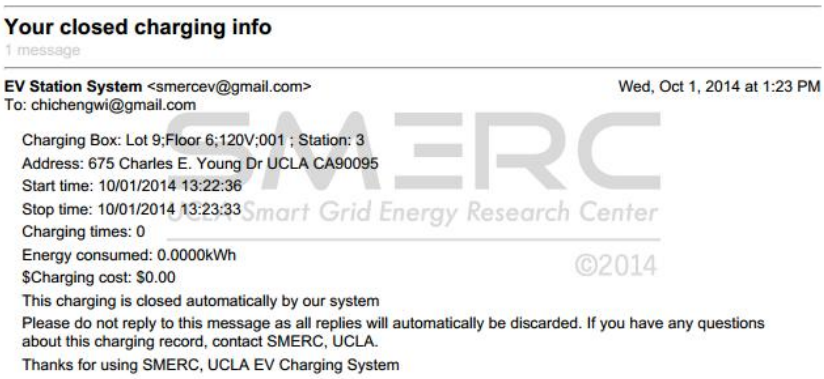
When an EV is plugged into an EV charger, the user can activate a charging session through a smart phone or any Internet-connected device. Once activated, power consumption information is obtained through the EV network mentioned in Use Case EV.1. If a vehicle is equipped with the Status of Charge (SOC) box, the SOC information is also obtained. These operations can be illustrated by the screenshots taken from the mobile app/interface in Figure 4 and sample Email in Figure 5.

Figure 4: Screenshots from Mobile App Web Interface



Source: UCLA

Figure 5: Sample Email when a Charging Session is Closed

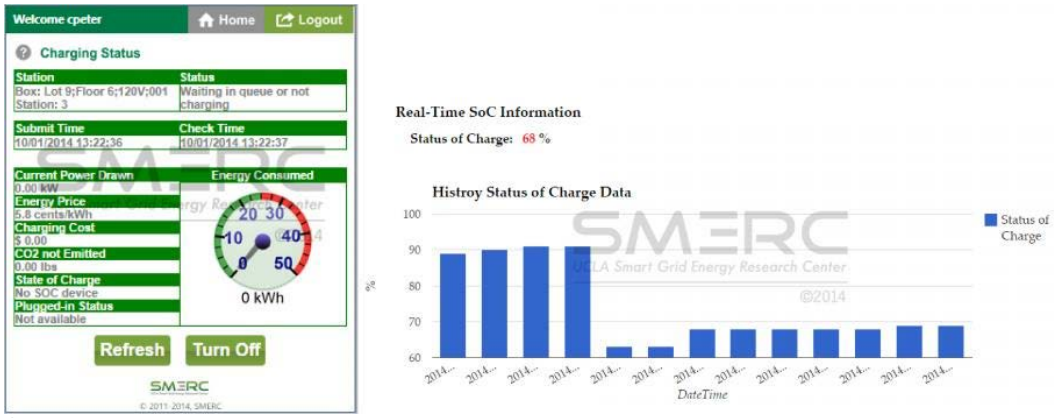


Source: UCLA

The EVSmartPlug™ Fleet application enables clients to charge an electric vehicle that belongs to an organization's fleet using a computer or mobile device and access information related to the charging status corresponding to a particular station. The web application version has already been implemented while the android version is currently under development. Both versions share similar interfaces. The difference being that the android application will obtain charging status information from web-services exposed from the backend. The backend layer of the current website directly queries the database and provides information to be displayed in the asp files. This project will decouple the backend layer with the interface (the android application in this case). The decoupled web-services could then be used by any client including the android application.

Figure 6 shows the screen shot of SOC data collection samples.

Figure 6: SOC Data Collection Samples



Source: UCLA

Figure 7 and Figure 8 show the Ambient Temperature Data Collection.

Figure 7: Ambient Temperature Data Collection

Source: UCLA

Figure 8: Ambient Temperature Data Spreadsheet

Epoch Time	timestamp	Temperature (C)	Humidity (%)
1413413158	10/15/2014 15:45	22.62	58.21
1413413217	10/15/2014 15:46	22.58	58.2
1413413331	10/15/2014 15:48	22.58	58.2
1413414001	10/15/2014 16:00	22.5	58.68
1413414901	10/15/2014 16:15	22.46	59.16
1413415800	10/15/2014 16:30	22.46	58.18
1413416702	10/15/2014 16:45	22.42	58.67
1413417601	10/15/2014 17:00	22.46	58.67
1413418501	10/15/2014 17:15	22.5	58.68
1413419401	10/15/2014 17:30	22.54	58.69
1413420301	10/15/2014 17:45	22.54	58.2
1413421201	10/15/2014 18:00	22.58	58.2

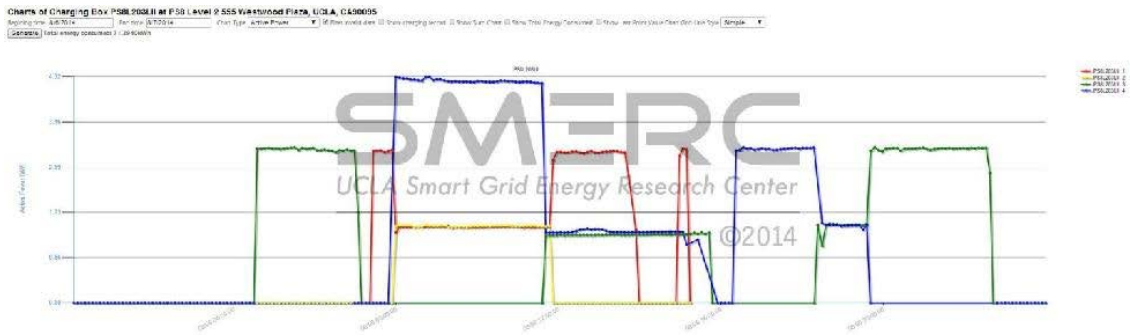
Source: UCLA

One part of the information that was to be collected to determine the EV vitals was the EV battery temperature. However, obtaining this information was not readily available due to the fact that this information was stored in the electric vehicle's battery management system (BMS). Therefore, an alternate solution was found; the EV team collected the ambient temperature in lieu of the battery temperature.

2.1.3.3 Control of Chargers

In addition to the implementation results presented in Use Case EV.1 and EV.2, Figure 9 and Figure 10 show the result of controlling the charging current and on/off state.

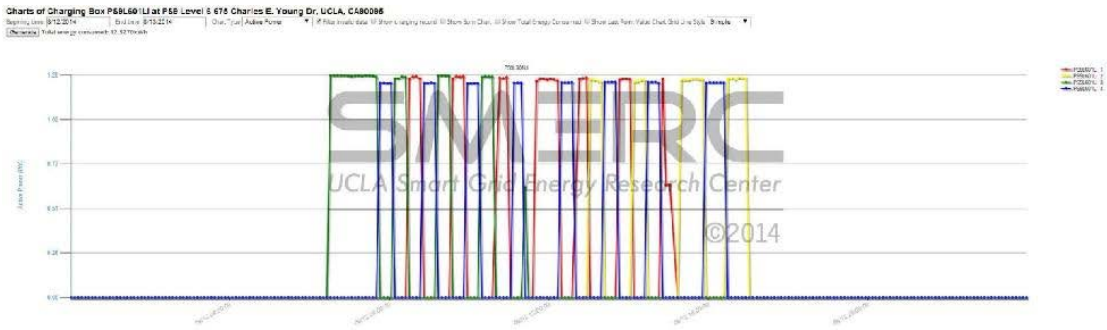
Figure 9: Charging Current Control



Source: UCLA

Figure 9 shows the active power consumptions from four different EV charging plugs that shares two power circuits. The power consumption of each individual plug is represented by the colored curves in the chart – one color corresponding to one individual plug. While charging stations represented by Red and Yellow curves share one power circuit; charging stations represented by and Green and Blue curves share one power circuit. With the second EV plugged into the charging stations, the power (charging current) is reduced to accommodate the maximum capacity of the circuit. Similar current reduction control was also implemented on the power sharing among four EV charging stations.

Figure 10: Control of On/Off State in a Level 1 Round Robin Algorithm



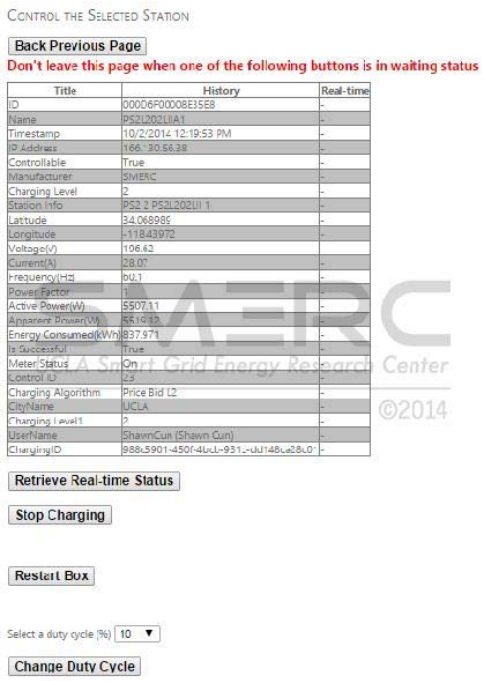
Source: UCLA

Similarly, Figure 10 shows the on/off control of four Level 1 (120 VAC) EV charging stations in the control center. The control center alternatively turns the charging station on and off using round robin charging algorithm.

2.1.3.4 Disconnection of a Vehicle that is Charging

The function of suspending or reducing charging current can be done through control center's web interface as shown in Figure 11. UCLA SMERC control center allows for "Stop Charging" and "Change Duty Cycle" to suspend or reduce charging current of an EV charging station.

Figure 11: Suspend or Reduce Charging Current of an EV Charging Station



CONTROL THE SELECTED STATION

Back Previous Page

Don't leave this page when one of the following buttons is in waiting status

Title	History	Real-time
ID	00006F00008E35E8	-
Name	PS2L202LIIA1	-
Timestamp	10/2/2014 12:19:53 PM	-
IP Address	166.130.56.38	-
Controllable	True	-
Manufacturer	SMERC	-
Charging Level	2	-
Station Info	PS2 2 PS2L202LII 1	-
Lattude	34.068986	-
Longitude	-118.43972	-
Voltage(V)	106.62	
Current(A)	28.07	-
Frequency(Hz)	60.1	-
Power Factor	1	-
Active Power(W)	3507.11	-
Apparent Power(W)	3519.92	-
Energy Consumed(kWh)	837.971	-
Is Successful	True	-
Meter Status	On	-
Control ID	29	-
Charging Algorithm	Price Bid L2	-
CityName	UCLA	-
Charging Level1	2	-
UserName	ShawnCun (Shawn Cun)	-
ChargingID	988c5901-450f-4bcb-931c-dd148ba28c0	-

Retrieve Real-time Status

Stop Charging

Restart Box

Select a duty cycle (%) 10

Change Duty Cycle

SMERC A Smart Grid Energy Research Center ©2014

Source: UCLA

2.1.3.5 Smart Charging through Mobile Interface

EV owners can control the charging sessions of their vehicles through a mobile app or any other device with internet capability. The following are the basic features available in the current mobile app:

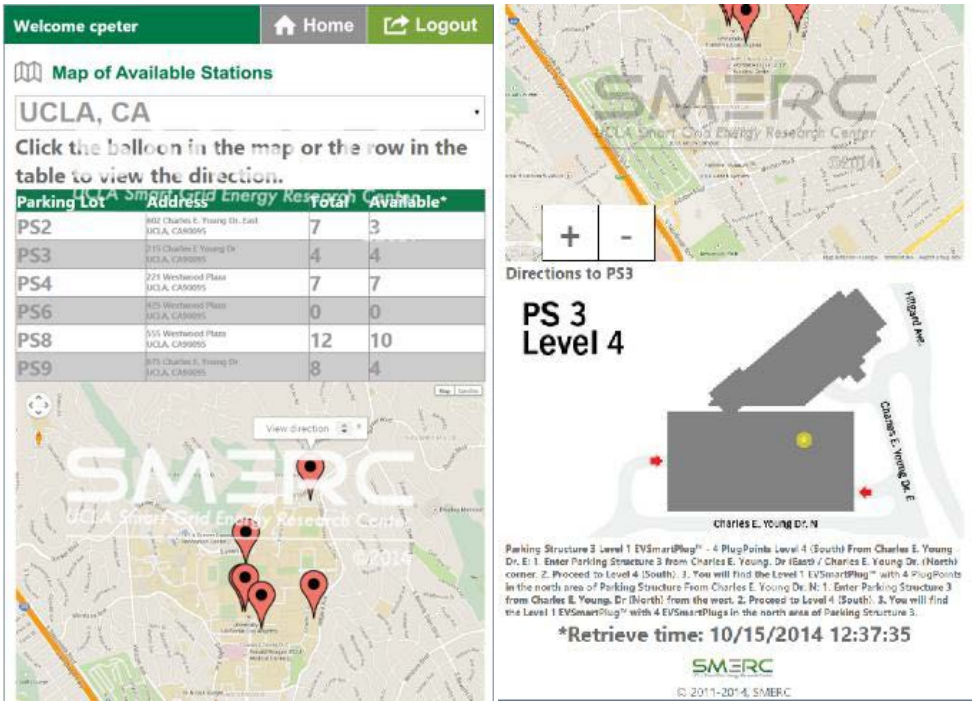
1. Check charging station availability
2. View a map of stations
3. Start and stop charging sessions
4. Check charging status and records
5. Schedule a charging session
6. Check or cancel a scheduled charge
7. Change password or settings under setup

SMERC integrated an updated API 2.0 into the web-based App and are currently working on integrating the third generation Graphical User Interface (GUI) into the EV User Mobile app. SMERC also modified the interface to support the new algorithms in development. Figures 12-17 show the new features available through the web-based app.

Figure 12: Mobile App/Web Interface Menu

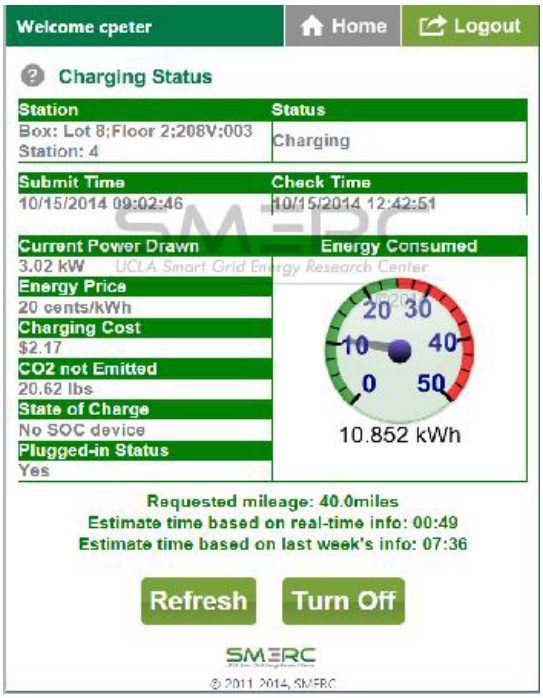
Source: UCLA

Figure 13: Map of Available Stations and Direction



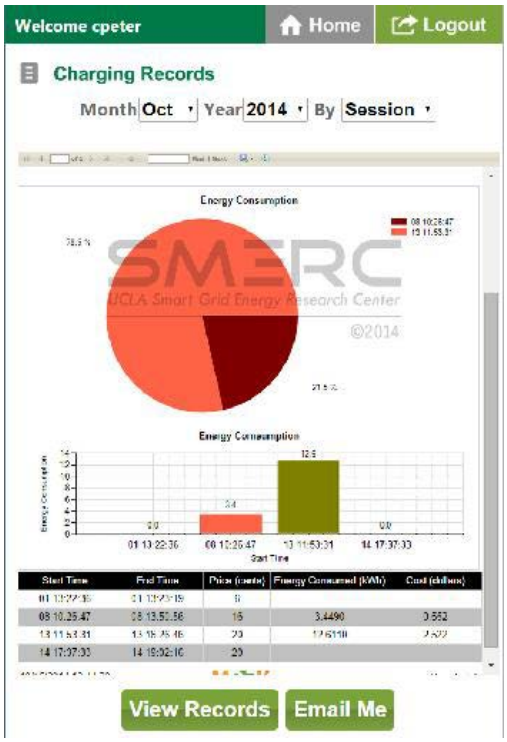
Source: UCLA

Figure 14: Information and User Preference Displayed on Charging Status



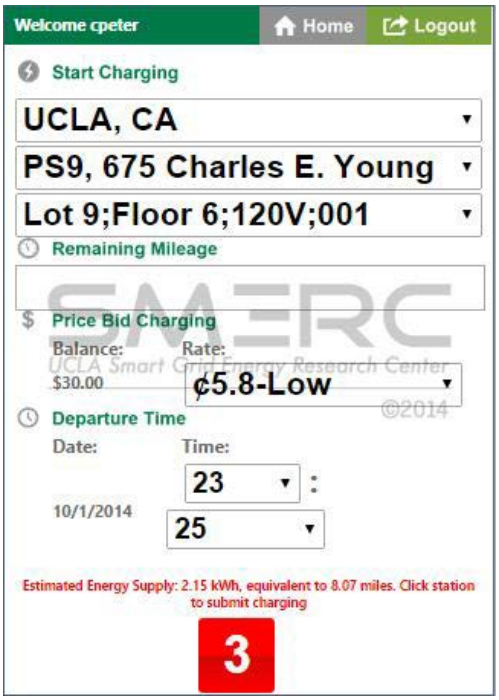
Source: UCLA

Figure 15: Information Display on Charging Record



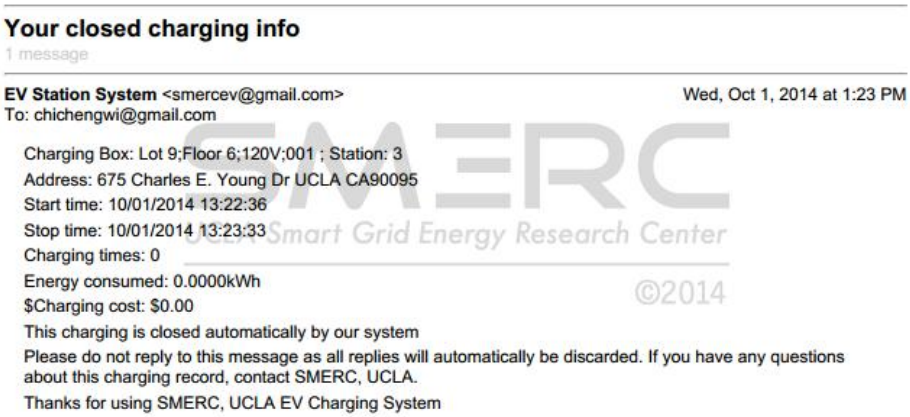
Source: UCLA

Figure 16: User Specified Preference when Starting Charging



Source: UCLA

Figure 17: Example of Notification Message



Source: UCLA

SMERC added web controls in the Start Charging page to support price-based charging algorithms. The charging profile consists of two main components: 1) price preference, i.e. maximum accepted electricity price, and 2) estimated departure time. The system remembers the input from the previous charging session and selects it as a default profile, which saves time for the user. Once the user completes the profile, a prediction algorithm on the control center will automatically compute the predicted energy consumption and equivalent miles according

to the user's profile. The user can start the charging session based on the predicted schedule by clicking a charging station icon.

2.1.4 Recommendations / Future Work

LADWP and UCLA have several recommendations. First, the web-based mobile apps for EV users and fleet vehicle owners have limited capability to provide them with high quality visual effects and interactions from the browser. As such, UCLA will be developing web-services for complicated functional modules within web apps and creating interfaces between web services and native apps in multiple platforms.

Next, due to the difficulties in determining the status of charge, an alternate solution was found; the status of charge for some electric vehicles had to be estimated with the help of the user. However, due to the inaccuracies of this solution, it is recommended that the manufacturer is contacted and request that this information be provided. Alternatively, a third party application that tracks and monitors the electric vehicles could be another solution.

Additionally, when a vehicle is charging, errors in data collection may occur resulting in missing or incorrect data. Because leaving out missing or incorrect data will alter the periodicity of the time series, UCLA will investigate the effect of different processes of substituting missing values in the data.

Lastly, while UCLA is collecting the Charging Record data from anonymized driver profile data, UCLA would like to add an additional layer of privacy to protect EV users. Therefore, UCLA will investigate whether it is possible to achieve the same level of performance and accuracy by extracting data directly from the charging station rather than relying on the EV user's profile.

2.2 Battery Aggregation and Backfill

2.2.1 Methodology

This demonstration area will be responsible for the use of batteries in the Grid (one way, Grid-to-vehicle, G2V), the use of batteries in the Grid (two way, Grid-to-vehicle, G2V, and vehicle-to-Grid, V2G) and the effects of battery aggregation and backfill on distribution (Grid-to-battery, battery-to-vehicle, and battery-to-Grid). This will determine how to locally aggregate EV batteries to serve as backfill into the power grid. This will provide local grid stability, and by ensuring that sub-sections of the grid maintain an available back-up power supply, will serve as a primary prevention against large-scale outages. Backfilling also will provide an effective means of load leveling power supply for customers in the event of a power outage to reduce costs and will improve customer reliability and satisfaction.

To demonstrate the use cases and meet the success criteria for this demonstration area, the EV Project team will design and implement a control system process to schedule EV charging and discharging in a manner that is beneficial for the vehicle and the grid. Additionally, the EV team will install appropriate grid-tie inverters and bi-directional AMI Smart Meters to demonstrate V2G and G2V operations. Lastly, the EV team will collect battery data at fifteen-minute

intervals to study the effects of battery aggregation and backfill on distribution. Table 4, shows battery aggregation and backfill equipment list.

Table 4: Battery Aggregation and Backfill Equipment List

Equipment Overview	Total	Installed/ Acquired
Electric Vehicle (G2V/V2G Capability)	2	2

2.2.2 Success Criteria

The success criteria for Battery Aggregation and Backfill include the successful completion of all use cases. Additionally, a report on the integration and aggregation of EV batteries into the power grid will also be generated as a part of the success criteria for the demonstration area.

UCLA SMERC is collecting data regarding the use of batteries in the Grid. The EV Project team will do research regarding the distribution effects of battery aggregation and backfill. The report on the integration and aggregation of EV batteries into the power grid will be generated at the end of the project in 2016.

2.2.3 Observations and Results

Figure 18 shows a sample of the collected data in CVS format. Important information such as time, voltage, current, frequency, active power, apparent power, power factor and energy are stored in the database as well as the CVS file. The sensor retrieve data passively every 3 min.

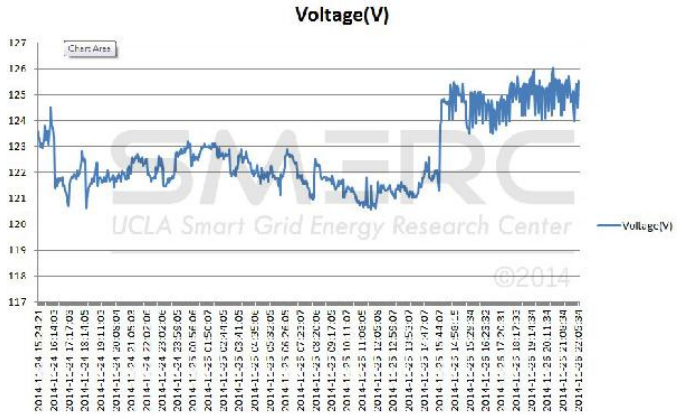
Figure 18: Sample of Collected Data of G2V/V2G

ID	Time	Voltage(V	Current(A	Frequency	Active Po	Apparent	Power fac	Energy(kWh)
1	2014-11-24 15:24	123.58	6.1	59.98	717.79	753.84	0.95	14.529
2	2014-11-24 15:27	123.29	5.76	59.98	659.58	710.15	0.93	14.564
3	2014-11-24 15:30	122.97	5.52	59.98	678.79	678.79	1	14.596
4	2014-11-24 15:33	123	5.92	59.98	709.19	728.16	0.97	14.629
5	2014-11-24 15:36	123.13	6.3	59.98	691.48	775.72	0.89	14.661
6	2014-11-24 15:39	122.96	5.2	59.98	639.39	639.39	1	14.694
7	2014-11-24 15:41	123.03	5.12	59.98	597.92	714.73	0.84	14.714
8	2014-11-24 15:41	123.22	5.33	59.98	603.51	719.25	0.84	14.719
9	2014-11-24 15:44	123.79	6.33	59.98	725.4	783.59	0.93	14.746
10	2014-11-24 15:47	123.26	6.04	59.98	685.29	744.49	0.92	14.779
11	2014-11-24 15:49	123.37	5.87	59.98	667.43	724.18	0.92	14.803
12	2014-11-24 15:50	123.61	6.59	59.98	757.99	814.59	0.93	14.813
13	2014-11-24 15:53	123.25	5.76	59.98	608.27	622.33	0.98	14.847
14	2014-11-24 15:56	123.11	5.11	59.98	599.46	731.29	0.82	14.88
15	2014-11-24 15:59	123.62	6.64	60.1	700.61	820.84	0.85	14.912
16	2014-11-24 16:02	123.86	5.39	60.1	620.22	667.61	0.93	14.945
17	2014-11-24 16:05	124.53	6.48	60.1	717.1	717.1	1	14.98
18	2014 11 24 16:08	123.79	5.27	59.98	652.37	652.37	1	15.014

Source: UCLA

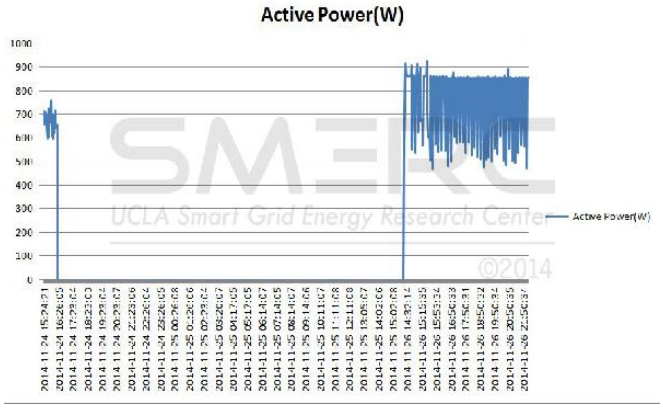
Figure 19 and Figure 20 show the measured power quality information over two days.

Figure 19: Measured Voltage



Source: UCLA

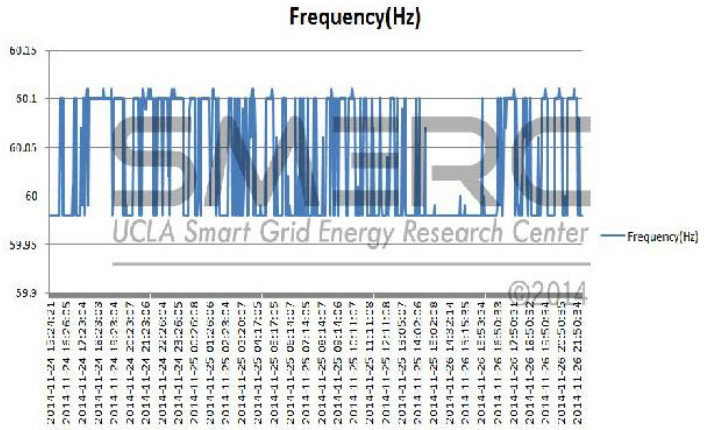
Figure 20: Measured Power Flow



Source: UCLA

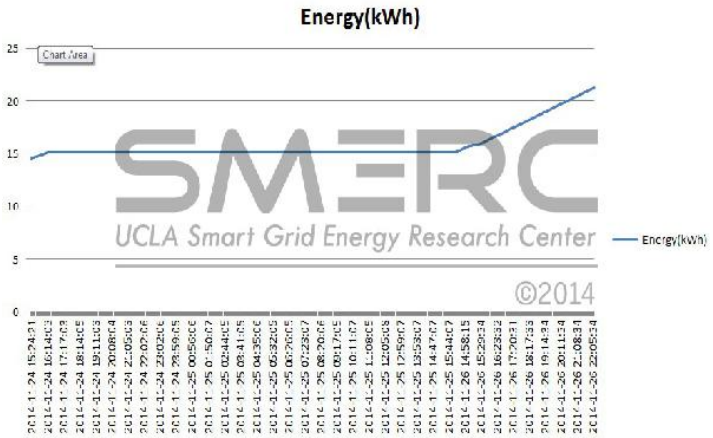
From the figures, it can be observed that voltage magnitude fluctuates with the discharge of EV. It can be clearly seen that with the support of V2G, the voltage rises from 121V to 124V. Figure 21 and Figure 22 further show frequency variation and accumulated energy.

Figure 21: Measured Frequency Variation



Source: UCLA

Figure 22: Energy Accumulation



Source: UCLA

It can be observed that V2G at an individual level cannot affect the frequency of the power grid. The frequency variation still comes from the generation and load side. However, if V2G is performed in a large scale - for example, 1000 EVs perform V2G at the same time - there is a possibility that observable frequency change can occur on the grid side.

2.2.4 Recommendations / Future Work

The Mitsubishi i-MiEV power box built by the company is limited to functionality that is only for V2G - to be used in a standalone power outage situation to supply power to a residential home only. Therefore, additional components with systems added and implemented by UCLA SMERC enable the V2G function in this demonstration to monitor and control power flow. When UCLA SMERC started this research, this customized configuration was necessary to collect data and to have full control of the V2G operations due to lack of support from EV manufacturer and unavailability of V2G communication protocols.

2.3 Fully Functional Microgrid

2.3.1 Methodology

This demonstration area will be responsible for inductive charging, the ability to charge various vehicles, a study on distribution effects and a demonstration of the local grid balancing management. Other demonstrations that have been performed in the EV Project will be included in this fully integrated demonstration. A key outcome will be the demonstrated ability of the Microgrid to operate either off-grid or on-grid and the viability of the fully automated wireless sensing, monitoring and control to move between these two states depending on system conditions. Table 5, shows the fully functional Microgrid equipment list.

To demonstrate the use cases and meet the success criteria for this demonstration area, the EV Project team will retrofit selected electric vehicles to support inductive charging. Additionally, the EV team will install inductive charging stations to monitor power consumption and usage patterns. The EV team will also purchase various electric vehicles to compare the performance of various battery types and sizes. The EV team will study various positive and negative effects of electric vehicles on the microgrid to demonstrate how customers can lower their demand chargers and/or limit daily electric loads with EV chargers and battery storage.

Table 5: Fully Functional Microgrid Equipment List

Equipment Overview	Total	Installed/ Acquired
Capacitor Bank Controllers w/cellular Modems	6	6
34.5KV Motorized Switch Operator (MSO)	1	1
MSO Single Phase Current Transformers	3	3
MSO Single Phase Potential Transformers	3	3
MSO Single Phase Faulted Circuit Indicators	3	3
MSO Controller/ Cabinet with Cellular Modem	1	1
Distribution Transformer Monitors (DTM)	74	74

2.3.2 Success Criteria

The success criteria for the Fully Functional Microgrid include the successful completion of all use cases. Additionally, a report on EV charger integration and its impact on the grid will also be generated as a part of the success criteria for the demonstration area.

The report on EV charger integration and its impact on the grid will be generated at the end of the project in 2016.

2.3.3 Observations and Results

The EV Project team installed six capacitor bank controllers at Distribution Station (DS) 88 in the LADWP grid. Each controller is equipped with a Remote Terminal Unit (RTU) and a cellular modem. These controllers are connected to the LADWP OSI SCADA network and are

observable and controllable. A sample screenshot depicting the performance of two controllers at DS-88 and the corresponding KVAR flow is shown in Figure 23..

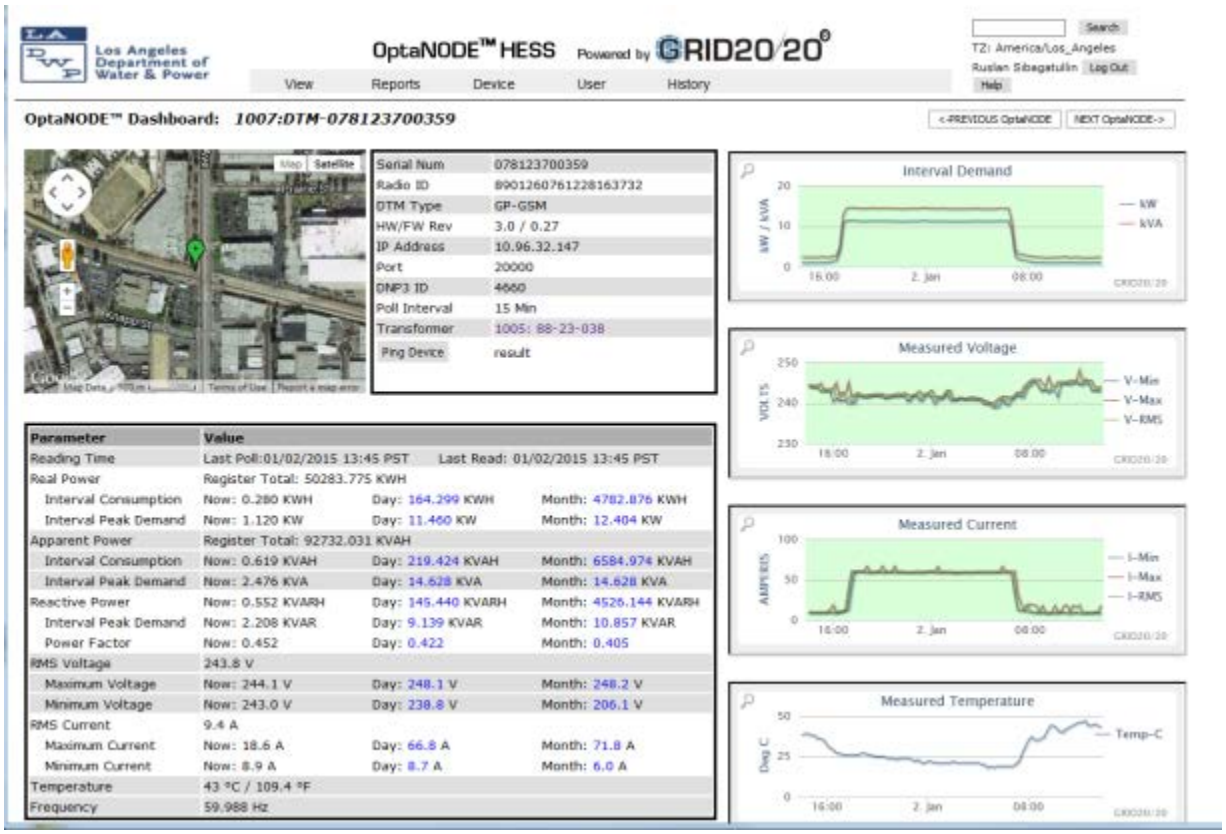
Figure 23: KVAR flow on a Capacitor Controller at DS-88

Additionally, the EV Project team deployed 65 overhead transformer monitors in circuits fed by DS-88. These devices log the following 11 characteristics with corresponding timestamps:

- DTMID – Distribution Transformer Monitor Identification
- KWH – Total Accumulated KWH for the device
- KVAH – Total accumulated KVAH for the device
- VRMS, VMAX, VMIN – The RMS voltage at time of reading and the max and min voltage recorded since last reading
- IRMS, IMAX, IMIN – The RMS current at time of reading and the max and min current recorded since last reading
- TEMPC, TEMPF – Recorded temperature in ^{o}C and ^{o}F

Figure24 is a screenshot of a sample data on a transformer monitor that the EV Project team delivers to USC on a monthly basis for analytical purposes.

Figure 24: Transformer Monitoring Data Screenshot



Source: GridSense

2.3.4 Recommendations / Future Work

2.3.4.1 Switch (34.5 kV)

As of February 19, 2015, the switch is only partially deployed. Remote switching is activated but the fault indicators are not integrated yet. LADWP is expecting the arrival of the replacement RTU from the vendor to complete the commissioning.

The switch hardware and control electronics has been working with a reasonable stability. Only one outage was discovered and it was caused by user error. Analog sensors were difficult to configure but during the last reading session, the data was validated by the Energy Control Center. Conclusive recommendation requires a finished commissioning and a reasonable operation timeframe in order to ascertain the feasibility of the hardware.

2.3.4.2 Capacitor Bank Controllers

Based on the deployment of the six remote capacitor bank controllers, LADWP recommends a system wide deployment with the following adjustments:

1. Deploy capacitor bank controllers capable of leveraging the AMI communication network

2. Deploy capacitor bank controllers with neutral current sensing capability to detect failing/failed capacitor banks

The reasons behind the recommendation are as follows:

1. Capacitor bank controller deployment showed stable operation for the six months since commissioning. Only one outage was registered and it was caused by user error
2. Remote capacitor bank controller allows for fast deployment of 450 KVA on a per bank basis
3. Meter socket mounted controllers allow for relatively safe, fast, and low cost installation
4. Economical deployment due to a low average number of banks per feeder (approximately three)

2.3.4.3 Transformer Monitors

Based on the deployment of the Grid 20/20 transformer monitors and the associated cost, LADWP does not recommend a system wide deployment of these transformer monitors. The reasons behind this are as follows:

1. Hardware expenses with the data plan fees significantly exceeds the overhead transformer cost vs. benefits
2. Devices are incapable of monitoring banked transformers
3. Hot spot detection is unavailable
4. Electrical parameters measured by the transformer monitors can be derived from the deployment of AMI meters

2.4 Renewables and Battery Integration

2.4.1 Methodology

This demonstration area will be responsible for the use of community storage on Electric Vehicle batteries and external storage, the Garage of the Future, the cycling of batteries, the aggregation of batteries, and integrating Electric Vehicles and solar. This will demonstrate the viability of using charged EV batteries as an integrated set of storage devices to use for maintaining grid integrity.

To demonstrate the use cases and meet the success criteria for this demonstration area, the EV Project team will install lithium-ion battery modules in a parking structure to store/release energy. The EV team will also build a Garage of the Future to demonstrate EV charging through various renewable resources. Additionally, the EV team will replicate normal electric vehicle driving conditions by charging and discharging an EV battery in a lab environment. Lastly, various scenarios to explore the feasibility of load-shedding using a group of EV chargers will be performed in order to find the optimal aggregation, control methods, and potential benefits.

2.4.2 Success Criteria

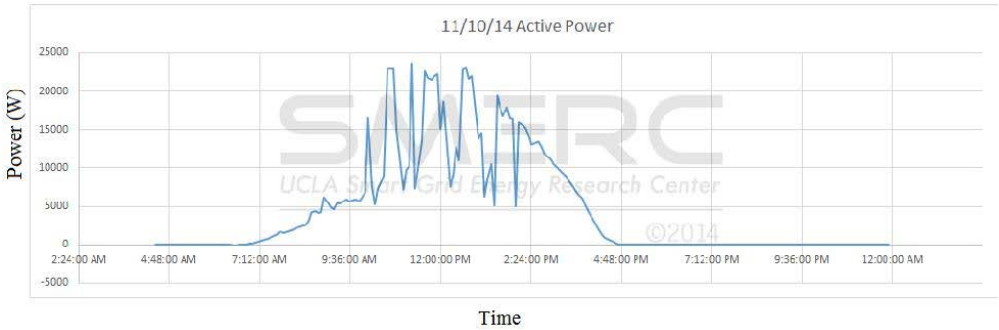
The success criteria for Renewables and Battery Integration include the successful completion of all use cases. Additionally, a report on the usage of EVs as renewables will also be generated as a part of the success criteria for the demonstration area.

The report on the usage of EVs as renewables will be generated at the end of the project in 2016.

2.4.3 Observations and Results

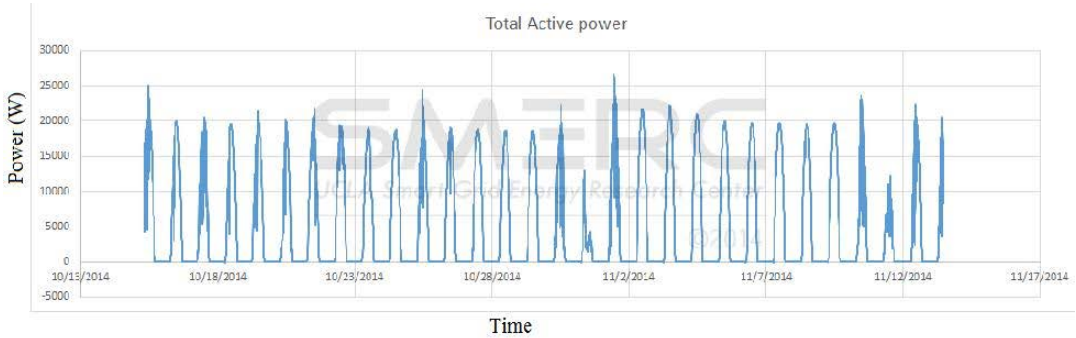
UCLA SMERC is running practical experiments using the integrated battery storage system in the lab to research how to best decrease the power fluctuations of solar generation. These experiments will provide a solution for the fluctuation of photovoltaic (PV) output, which can negatively affect the performance of the greater electric network, especially where there are high levels of PV penetration. These fluctuations also complicate the prediction of the PV's output power, which makes PV generation difficult to consider for scheduling on the power network. Figure 25 and Figure 26 show the fluctuations of the solar panels on Ackerman Union.

Figure 25: PV Power Fluctuation over One Day



Source: UCLA

Figure 26: PV Power Fluctuation over One Month

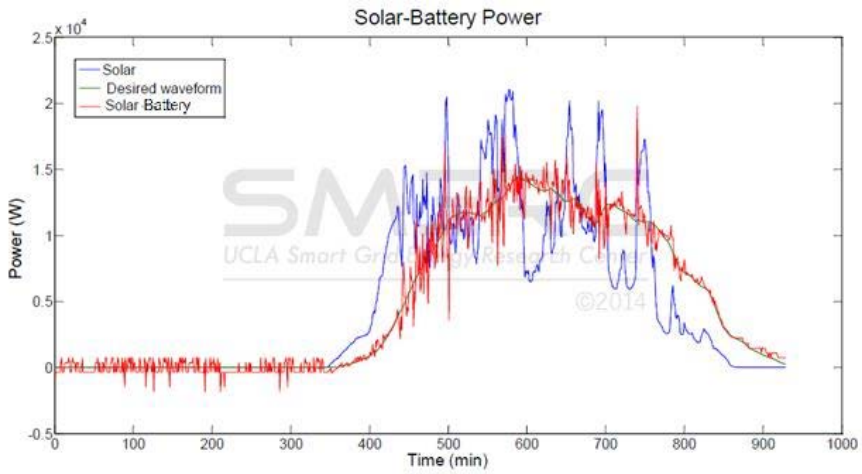


Source: UCLA

For the experiments, a real-time control algorithm was developed for the control center that processes data from solar power to generate an appropriate compensation command. The control center sends the generated command to the local controller via Ethernet and http, and the local controller communicates with the BMS and grid-tie inverter through the Modbus

TCP/IP and serial port to execute the command. Figure 27 shows the battery storage system's energy compensation for solar power fluctuations on a typical day, using data obtained from the solar panels on Ackerman Union.

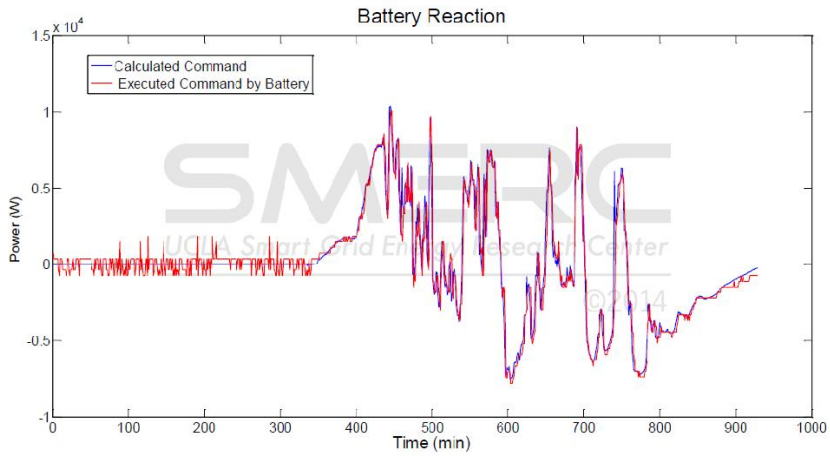
Figure 27: Output Power of Solar and Battery



Source: UCLA

From the chart, some fluctuations in the output power is still seen, due to the computational and execution delays of the controller and devices, but the root-mean-square deviation (RMSD) or root-mean-square error (RMSE) show a 70% improvement in damping the fluctuation by employing the battery storage system. Moreover, the remaining fluctuations fall in a higher frequency range that can be ignored, as utilities are more concerned about results that last for several minutes. Despite these results, we continue research on how to decrease solar power fluctuations. It should be noted that, theoretically, the researchers do not expect to dampen completely these fluctuations due to the existing delay in the control center; a 100% success rate in a future physical system cannot be expected. Figure 28 shows the battery storage system's execution time for a command signal sent by the control center. Although the battery system follows the command perfectly, a delay still exists between the sent command and its execution by the battery system.

Figure 28: Battery Reaction to Command Sent by Control Center



Source: UCLA

Additionally, UCLA SMERC team successfully integrated the data collection for the existing Solar panel at Ackerman roof top – a 38 kW solar panel system.

Figure 29: Ackerman Roof Top Solar Panels

Source: UCLA

Another Solar Panel system (50 kW) is being installed in UCLA and will be used for the demonstration's 2nd phase data collection and demonstration with EV charger and ESS during the operation phase of the project.

Systematic data collection started on 10/15/2014. The following figure shows current data captures.

Figure 30: Solar Panel Data of 10/15/2014

Source: UCLA

2.4.4 Recommendations / Future Work

Based on the current results, LADWP recommends renewables and battery integration when the following two issues are addressed:

- Add the uncertainty of energy generation from EVs to the voltage regulation problem and develop an algorithm to optimize a battery storage system by improving its voltage profile
- Improve the algorithm for damping PV power fluctuations

Additionally, the following are three recommendations for the renewables and battery integration:

- Use a battery storage system for load leveling a level 3 EVSE
- Implement and commission a microgrid that consists of solar, battery, and EV chargers
- Expand the monitoring framework to include other power monitoring applications found in Level 3 DC EVSEs and battery systems

2.5 Car Sharing Programs

2.5.1 Methodology

This demonstration area will be responsible for the monitoring of charges, power usage and car usage, and the distribution effects of the car/ride sharing programs. This will provide the opportunity to use two distinct test-beds that include different user demographics, grid specifications, and driving patterns. UCLA and USC are in different areas of Los Angeles that result in different average distances traveled per car trip, a key factor in planning the rate and

capacity of charge provided to a fleet of EVs. This information can be used for full scale Smart Grid implementation planning.

To demonstrate the use cases and meet the success criteria for this demonstration area, the EV Project team will collect data from 67 electric vehicles to perform statistical analysis and driving characterization. Additionally, the EV team will study customer charging habits and will create models to study the impacts of large-scale deployment of EV chargers.

2.5.2 Success Criteria

The success criteria for the Car Sharing Programs include the successful completion of all use cases. Additionally, a report on EV usage, consumption, and charging will also be generated as a part of the success criteria for the demonstration area.

2.5.3 Observations and Results

The EV Project team has been using LADWP's fleet to collect data for this demonstration. Table 6 is a sample of the data collected. Additionally, the EV team is submitting this data to USC for further analysis.

Table 6: Electric Vehicle Usage Sample Data

Electric Vehicle Usage														
Required Basic Information			Trip Start						Trip Stop					
EV ID	Driver Name	Extension	Date	Time	EV Charger ID	Odometer Mileage	Battery Mileage	Battery Percent	Date	Time	EV Charger ID	Odometer Mileage	Battery Mileage	Battery Percent
P44658	Aram Chavdarian	x75292	6/19/2014	2:00 PM	PL3EV3	1785	63		6/19/2014	2:30 PM	PL3EV3	1790	57	
P44658	Aram Chavdarian	x75292	6/20/2014	10:45 AM	PL3EV3	1790	63		6/20/2014		PL3EV3	1796	57	
P44658	Emil Abdelshehid	x74841	6/23/2014	7:52 AM		1795.8	64		6/23/2014	8:15 AM				
P44658	Emil Abdelshehid	x74841	6/23/2014	8:49 AM					6/23/2014	9:06 AM		1808.7	53	
P44658	Aram Chavdarian	x75292	6/25/2014	2:30 PM	PL3EV3	1808	63		6/25/2014		PL3EV3	1814	57	
P44658	Emil Abdelshehid	x74841	6/26/2014	11:53 AM		1814.2	68		6/26/2014	1:15 PM		1823	58	
P44658	Aram Chavdarian	x75292	6/27/2014	8:15 AM	PL3EV3	1823	63		6/27/2014	9:45 AM	PL3EV3	1831	57	
P44658	Aram Chavdarian	x75292	6/30/2014	1:30 PM	PL3EV3	1836	63		6/30/2014		PL3EV3	1842	57	
P44658	Surendra Vohra	x74705	7/9/2014	7:30 AM		1847.3	70		7/9/2014	9:30 AM		1851.7	60	
P44658	Aram Chavdarian	x75292	7/9/2014	2:15 PM	PL3EV3	1850	67		7/9/2014	2:50 PM	PL3EV3	1856	63	
P44658	Aram Chavdarian	x75292	7/10/2014	1:38 PM	PL3EV3	1856	65		7/10/2014	2:10 PM	PL3EV3	1862	59	
P44658	Aram Chavdarian	x75292	7/11/2014	7:20 AM	PL3EV3	1862	66		7/11/2014	8:55 AM	PL3EV3	1867	65	
P44658	Aram Chavdarian	x75292	7/14/2014	2:22 PM	PL3EV3	1867	63		7/14/2014	3:05 AM	PL3EV3	1873	58	
P44658	Aram Chavdarian	x75292	7/15/2014	9:48 AM	PL3EV3	1871	63		7/15/2014	11:07 AM	PL3EV3	1877	56	
P44658	Emil Abdelshehid	x74841	7/17/2014	8:00 AM		1877.7	65		7/17/2014	8:40 AM		1879.4	59	
P44658	Aram Chavdarian	x75292	7/17/2014	2:10 PM	PL3EV3	1879	62		7/17/2014	3:01 PM	PL3EV3	1884	57	
P44658	Aram Chavdarian	x75292	7/18/2014	9:35 AM	EV3PL3	1884	63		7/18/2014	12:04 PM	EV3PL3	1891	61	
P44658	Aram Chavdarian	x75292	7/22/2014	10:10 AM	PL3EV3	1891	63		7/22/2014	11:47 AM	PL3EV3	1897	61	
P44658	Emil Abdelshehid	x74841	7/24/2014	7:37 AM		1901.3	69		7/24/2014	7:44 AM		1902.3	67	
P44658	Emil Abdelshehid	x74841	7/24/2014	8:07 AM		1902.3	67		7/24/2014	8:12 AM		1903	63	

2.5.4 Recommendations

As this demonstration is underway, no recommendations can be made at this time.

2.6 Grid Impact Stability / Power Study

2.6.1 Methodology

This demonstration area will be responsible for the generation, transmission, and distribution effects and various loading scenarios of the Electric Vehicle on the Grid. This will demonstrate the impact of EVs on the Electrical Grid.

To demonstrate the use cases and meet the success criteria for this demonstration area, the EV Project team will collect data from the chargers to study the impacts to generation, transmission, and distribution and perform various loading scenarios. The EV team will create computer models to analyze existing LADWP infrastructure and will gather information from various substations, distribution automation equipment, and various AMI meters.

2.6.2 Success Criteria

The success criteria for the Grid Impact Stability and Power Study include the successful completion of all use cases. Additionally, a report demonstrating the impact of EVs to the grid will also be generated as a part of the success criteria for the demonstration area.

The report demonstrating the impact of EVs to the grid will be generated at the end of the project in 2016.

2.6.3 Observations and Results

This demonstration area is underway with the data collection occurring with the other demonstration areas. A final report will be delivered at the end of the project at 2016.

2.6.4 Recommendations / Future Work

Because this demonstration is still in process, no recommendations can be made at this time.

CHAPTER 3:
Metrics and Benefits

3.1 Benefits

The Smart Grid Regional Demonstration Program has numerous benefits, including are reduced emissions, lower costs, increased reliability, and greater security and flexibility to accommodate new energy technologies, including renewable, intermittent, and distributed sources. Table 7 shows these benefits in detail.

Table 7: Electric Vehicle Benefits

Benefit Type	Categories	2.1	2.2	2.3	2.4	2.5	2.6
Energy and Cost Savings	Utility Bill Savings	X			X	X	
	Peak Demand Reductions	X	X	X	X	X	
	Energy Savings	X	X	X	X		
	Reduced Utility Capital Expenditures	X	X	X	X		
	Reduced Utility Maintenance Expenditures						
	Avoided Procurement Costs					X	
Greater Reliability	Reduced Frequency of Service Interruptions		X	X	X		
	Reduced Duration of Service Interruptions		X	X	X		
	Improvement in Power Quality	X	X	X	X		
Addressing Barriers	Grid Integration	X	X	X	X	X	
Information Dissemination	Journal Articles Published						X
	Web-based surveys of people viewing materials or participating in program reviews						
Adoption of technology, strategy, and research data/results by others	Availability of a new technology for sale in the marketplace	X	X	X	X	X	
	Customers using outcome						
Economic Development	Job Creation	X	X	X	X	X	
	Economic Growth	X	X	X	X	X	
Environmental Benefits	GHG Emission Reduction	X	X	X	X	X	

3.2 Job Creation

Throughout the duration of the project, the Smart Grid Regional Demonstration Program created numerous jobs. These jobs include scientific/technical professionals, staff positions, and non-scientific support staff positions that include researchers (post-doctoral and graduate student), project managers, statisticians, analysts, assistants, and clerks. In the Electric Vehicle portion of the program, SGRDP has generated over 75 jobs in California.

CHAPTER 4: Conclusion

The support and funding by the California Energy Commission and the United States Department of Energy has been instrumental in the progress that has been achieved during the project. With the funding, the Los Angeles Department of Water and Power and its partners were able to implement smart charging and install necessary equipment to collect data for the battery aggregation and backfill, the fully functional microgrid, the renewables and battery integration, and the car sharing program. The Los Angeles Department of Water and Power has gained valuable experience throughout the program and plans to garner more experience until the completion of the program. While the project is beginning the first year of a two year data collection effort, enough research was done to make preliminary recommendations for California. Additionally, the Los Angeles Department of Water and Power plans to make final recommendations that will benefit all of California's ratepayers and globally at the completion of the program.

GLOSSARY

Term	Definition
Advanced Metering Infrastructure	A project part of the SGRDP that focuses on smart meters
Application Programming Interface	A set of routines, protocols, and tools for building software applications
Battery Aggregation	A group of batteries connected with another to create a larger battery
Battery Management System	A device in an electric vehicle containing a system which controls the battery
Capacitor Bank Controllers	A device used to control capacitor banks
Charging Algorithm	A set of rules used to charge multiple electric vehicles
Charging Station	A location where electric vehicle users can charge their electric vehicle
Customer Behavior	A project part of the SGRDP that focuses on the behaviors of customers when introduced to the smart grid
Cyber Security	A project part of the SGRDP that focuses on the network security of the smart grid
DC Fast Charger	An electric vehicle charger that is capable of higher current and is able to charge an electric vehicle faster than other electric vehicle chargers
Demand Response	A project part of the SGRDP that focuses on the smart grid's ability to respond to the power grid's demand
Distribution System	The "last mile" of the power grid, where electricity flows to a customer
Electric Vehicle	A project part of the SGRDp that focuses on electric vehicles and its effects in the smart grid
Garage of the Future	A building built by LADWP to perform various demonstrations in the SGRDP
http	Hypertext Transfer Protocol, an application protocol for distributed collaborative, hypermedia information systems
Inductive Charging	A charging method in which an electric vehicle is charged wirelessly
Inverters	A piece of equipment used to change direct current to alternating current
Load Leveling	A smart grid demand response technique used to adjust for peak loads
Load Shedding	A smart grid demand response technique used to purposefully curtail power

Local Grid Balancing	A smart grid demand response technique used to normalize power in an area
Microgrid	A scalable grid where demonstrations are performed on a smaller scale
Peak Load	A point in a day with the highest usage of power
Photovoltaic	A method of converting solar energy into electricity
Remote Terminal Unit	A device that allows the remote control of a piece of equipment through SCADA
Renewables	A method of generating electricity using
Root-Mean-Square Deviation	Or Root-Mean-Square Error, a used measure of the differences between value predicted by a model or an estimator and the values actually observed
Smart Charging	A method of charging where a charging algorithm is used to efficiently charge an electric vehicle
Supervisory Control and Data Acquisition (SCADA)	A system used to remotely control equipment over communication channels
Transformer Monitor	A device that is installed on a transformer and monitors various information including but not limited to voltage, current, power, etc.
Transmission System	A system of high voltage lines to transfer electricity over long distances
Vehicle-to-Grid/Grid-to-Vehicle	The direction of electricity flow
WINSmartEV	A UCLA Proprietary EV charging network used to implement charging algorithms