CALIFORNIA ENERGY COMMISSION

California Energy Commission

Clean Transportation Program

FINAL PROJECT REPORT

Install, Commission, Collect Data, and Assess Performance of Three Public Assessable DC Fast Chargers at UC San Diego

Prepared for: California Energy Commission

Prepared by: Alternative Energy Systems Consulting, Inc.

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California Energy Commission

John Clint
Joerg Lohr
Primary Author(s)

RWE Effizienz GmbH
Flamingoweg 1
44139 Dortmund, Germany

Agreement Number: ARV-12-027

Lindsee Tanimoto
Commission Agreement Manager

Mark Wenzel
Office Manager
ADVANCED VEHICLE INFRASTRUCTURE OFFICE

Hannon Rasool
Deputy Director
FUELS AND TRANSPORTATION

Drew Bohan
Executive Director

PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created the Clean Transportation Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and nonroad vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued PON-11-602 to provide funding opportunities for alternative fuels infrastructure. In response to PON-11-602, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards November 14, 2012 and the agreement was executed as ARV-12-027 on March 4, 2013.

ABSTRACT

In March 2013, the Energy Commission awarded grant funding of $145,554 to Alternative Energy Systems Consulting, Inc. to install, commission, and assess the performance of three Charge De Move Direct Current Fast Chargers for workplace operations at the University of California San Diego campus. Alternative Energy Systems Consulting, Inc. sub-contracted with RWE Effizienz, a subsidiary of the German-based utility RWE AG and an expert on the global International Organization for Standardization/ International Electrotechnical Commission 15118 Electric Vehicle charging standard, to install and assess the charging units in the University of California San Diego's micro grid environment.

The goal of the project is to demonstrate the feasibility of electric charging at the workplace level in order to achieve substantial reductions in greenhouse gas emissions through electrification of the transportation sector. A secondary goal is to assess the impact of fast charging on the electrical grid. University of California San Diego offers the perfect test bed as it provides electricity through their unique microgrid environment.

The official collection of electric vehicle charging data began on March 1, 2016 with the commissioning of the direct current fast chargers backend processes. As of date, all three chargers were installed and operational. Installation and commissioning occurred later than originally scheduled, impacting the duration of the data collection period. In addition to data collection and performance assessment, this report also includes lessons learned.

Governor Brown's Executive Orders B-16-12 and B-18-12 accelerate the integration of battery electric vehicles in state government and promote battery electric vehicle adoption by state employees and the public by making charging stations readily accessible at state buildings. This project has been responsive to these policy directives and has met its goals and objectives through the installation of three direct current fast chargers in the University of California San Diego campus. This project will accelerate the integration of electric vehicles in state fleets and make charging stations available at state buildings for fleet and workplace charging.

Keywords: California Energy Commission, fast charging, EVSE, electric vehicle charging, Charge De Move, Vehicle to grid, UCSD

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EXECUTIVE SUMMARY

Alternative Energy Systems Consulting Inc. contracted with the California Energy Commission to install, commission, collect data and assesses the performance of 16 electric vehicle chargers throughout the campus on the University of California, San Diego's micro grid environment.

This effort consisted of the installation of five level two chargers for fleet operations, eight level two chargers for workplace use, and three direct current fast chargers for general use at the University of California San Diego campus. This paper specifically covers the three direct current fast chargers.

Alternative Energy Systems Consulting Inc. subcontracted with RWE Effizienz, a 100 percent subsidiary of the German-based utility RWE AG, to install and assess these charging units in the University of California San Diego's micro grid environment. Alternative Energy Systems Consulting Inc. also subcontracted with AeroVironment, a California based electric vehicle supply equipment manufacturer, to purchase thirteen dual port level two alternating current chargers with J1772 connectors and three Charge De Move direct current fast chargers.

Alternative Energy Systems Consulting Inc., RWE Effizienz, and University of California San Diego assembled a consortium of technology leaders and experts in the field of smart energy to assess the technology on University of California San Diego's unique test bed. These participants included RWE Effizienez, San Diego Gas and Electric, University of California San Diego, Alternative Energy Systems Consulting Inc., Daimler AG, and CleanTech San Diego. The team committed to install the state-of-the-art intelligent electric vehicle charging post enabling intelligent electric vehicle charging based on the International Organization for Standardization and International Electrotechnical Commission standards.

CHAPTER 1: Objectives and Planning Phase

Project Overview

The California Energy Commission (CEC) awarded grant funding of $145,554 to Alternative Energy Systems Consulting Inc. (AESC) to install, commission, collect data, and assess the performance of three direct current (DC) fast chargers Charge De Move systems electric vehicle supply equipment (EVSE) with single port, for workplace operations at the University of California, San Diego (UCSD) campus. AESC executed this project collaboratively with two other CEC projects at the same site involving five fleet Level II chargers (ARV-12-013) and eight workplace Level II chargers (ARV-12-020). AESC subcontracted with RWE Effizienz, a wholly owned subsidiary of the German-based utility RWE AG, to install and assess these fast charging units in UCSD's micro grid environment. RWE Effizienz was responsible for the installation, construction oversight, commissioning, and EVSE expertise. Additionally, AESC subcontracted with AeroVironment, Inc., a California- based EVSE manufacturer, to purchase three 50 kilowatt DC fast chargers with Charge de Move connectors. Under a separate agreement, RWE Effizienz and AeroVironment, Inc. formed a joint venture to develop an end-to-end solution for the level II smart electric vehicle (EV) charging devices with full backend connectivity and smart-grid-functionalities according to International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) 15118. AESC also contracted with San Diego Gas & Electric (SDG&E) to perform an assessment of the effect of fast charging on the electrical grid. Although the Vehicle to Grid (V2G) aspect of overall demonstration does not directly impact the operations of the fast chargers, the interactions of the fast chargers are an important factor in the V2G analysis and the overall grid impact assessment.

The data collection phase was limited because of significant delays in subcontracting, installation, and EVSE initiation. During the installation, the fast chargers proved incompatible with RWE Effizienz backend system, and, ultimately UCSD developed a separate memorandum of understanding with NRG EVgo to operate the fast chargers. Additionally, the total number of charge sessions during the trial period was lower than anticipated because the EVSE had startup issues associated with access cards and university parking permit requirements. The final report includes the data and metrics collected in addition to lessons learned.

Intelligent EV Charging (RWE Effizienz)

In 2009, RWE Effizienz started to promote high EV penetration on existing grids and to deliver high-quality products and services for the EV industry on a global level. RWE Effizienz committed to transfer experience, expertise and technology of smart charging technology to the San Diego region, one of the early adopters in the United States of clean technology research and deployment. As part of the company's strategy to grow internationally, RWE Effizienz became part of a consortium of technology leaders and experts in the field of smart energy, which includes SDG&E, UCSD, AESC, Daimler and CleanTech San Diego. RWE Effizienz committed to develop and install the US version of its own state-of-the-art intelligent EV charging post enabling intelligent EV charging based on the ISO and IEC standards. RWE

Effizienz planned to install and operate five dual-outlet Level II EVSEs with functional above standard technology to support UCSD's goal to expand the network of electric vehicle charging infrastructure in the campus.

AESC and RWE Effizienz delivered and installed three public fast charging stations and 13 level II (ARV-12-013 and ARV-12-020) chargers on the UCSD campus. The three DC fast charger outlets are rated at 50 kilowatt per charger, with Charge de Move connector (figure 1). The objectives were to:

1. Operate/monitor the chargers and provide relevant charge detail records to UCSD for its microgrid.
2. Provide a unique back office system which allows three levels of communication and EVSE-management:
    a. Customer relations management covering authentication, registration, billing, and roaming.
    b. Asset management such as infrastructure control, status control, real-time-status-availability, and reservation.
    c. Demand management including tariff signal negotiation according to ISO/IEC 15118, peak limitation based on grid restrictions, renewable energy integration and prioritization. The unique technology would synchronize the UCSD micro grid capability with the intelligent smart-device-management software solution provided by RWE Effizienz.
3. Deliver high-quality EVSE hardware with a two-year warranty for operation at UCSD's campus
4. Allow access for research and evaluation of customer behavior, driver patterns, charging behavior, and tariff models by providing relevant data for analysis by the project partners.
5. UCSD is an ideal host for an EV charging infrastructure. As a leader in reducing reliance on conventional, gas-powered vehicles and capitalizing on new technology to build a more sustainable fleet, it was chosen as the host for this effort. More than 50 percent of its fleet of more than 800 vehicles consists of hybrid and alternative fuel vehicles. It has replaced diesel fuel with ultra-low sulfur biodiesel, and many of its buses, street sweepers, cars and trucks have been converted to run on compressed natural gas.

Figure 1 below shows a picture of one of the connectors and its specifications.

Figure 1: EV50 Specification

AeroVironment™ EV Solutions™

PUBLIC FAST CHARGING STATION, 50KW DC

SAFE, FAST, AND RELIABLE ELECTRIC VEHICLE CHARGING IN MINUTES, NOT HOURS

MODEL EV50-PS

FEATURES

- Built-in security and safety measures
- Intuitive plug-and-charge interface
- Outdoor-rated enclosure
- Robust IGBT power technology
- CHAdeMO protocol compatibility option
- Point-of-Sale (POS) options
- Data management and metering options
- Wired and wireless communication options

Prototype image shown.
Production model may vary.

SPECIFICATION	EV50
Power Rating	50kW
Power Factor	0.95
Input Power	480V, 3 Phase AC (Other inputs available)
Input Current	64A max
Frequency	50Hz / 60Hz
Efficiency Rating	>90%
Max. Output DC Current	120A
Max. Output DC Voltage	100-500V
Voltage Accuracy	1%
Current Accuracy (Lesser of the two)	.5A or 5%
Charger Shutdown Time	15 ms
Duty Cycle Rating	100%
Storage Temperature	-40°F to 140°F -40°C to 60°C
Operating Temperature	-22°F to 122°F -30°C to 50°C
Relative Humidity	95% (Non condensing)

Information and specifications subject to change.

Our EV50-PS Public Fast Charging Station delivers a fast, reliable, and safe charge to electric vehicles (EVs) when drivers are away from home and on the road. EV50-PS is designed to withstand variable weather conditions for installation in public locations including:

- Along well-traveled highways
- Federal and municipal buildings
- Charging stations in the city
- Airports
- Rest stops

How It's Used: Our Public Fast Charging Stations mirror the gas station experience by allowing drivers to pull up to a "pump" for a quick and safe charge in a matter of minutes. As battery chemistries evolve to support faster charging, a 25kWh EV battery may receive up to an 80% battery capacity charge in less than 10 minutes, depending on conditions.

Proven Architecture: Considered by many to be the most powerful and advanced EV charging technology, DC Fast Charging has been advanced by AV for more than a decade in large, fielded installations. The EV50-PS is based on the same demonstrated technology that has made AV the leading provider of industrial and commercial fast chargers to airports, warehouses, and manufacturing plants the world over.

AeroVironment™ EV Solutions™ 181 W. Huntington Dr., Suite 202, Monrovia, CA 91016
P. 888. 833.2148 F. 626.359.9628 www.evsolutions.com ev@avinc.com

Source: AeroVironment

Project Planning and Technology Adoption

In early 2012, RWE Effizienz and AeroVironment signed an agreement to jointly develop an intelligent EVSE and synchronize the new, global standard for EV charging with U.S. legal and market requirements. Based on the AeroVironment dual port with standard Level II alternating current charger and J1772 connectors, both companies created an end-to-end solution for a smart EV charging device with full backend connectivity and smart-grid functionalities complying with ISO/IEC 15118. The chargers under this contract do not operate under ISO

15118 but were an important element to test the effect of fast charging in an ISO 15118 environment. In addition to RWE Effizienz and AV, the participants are the following:

- AESC Inc.
- University of California, San Diego
- San Diego Gas & Electric
- Daimler AG

At the time of installation, the team was not able to identify any commercially available Underwriters Laboratories listed dual protocol DC fast chargers (Charge de Move and Society of Automotive Engineers Combined Charging System) for purchase in the U.S. Because Charge de Move units were specifically required under the contract, the single protocol Charge de Move Underwriters Laboratories listed units were selected and installed. The stations were wired to accommodate the installation of dual protocol units when available and if required in the future.

As part of the overall project, Daimler offered affordable leases on Smart Cars to interested faculty staff. The staff provided a test bed of consumer driving, testing and behavior. The cars are fully compatible ISO 15118. The purpose of the project is to implement the "vehicle to grid" communication interface, called V2G communication, which will help create one coherent system that better integrates EVs with the power grid, into UCSD's fleet. To enable EVs to become a significant part of the fleet on campus, the deployment of intelligent Level II EVSE was a prerequisite. V2G communication is required to identify and authenticate a vehicle, coordinate the charging and discharging process, handle the billing, and support any additional services such as remote diagnostics, navigation system updates, and entertainment.
The project team established four key competencies:

- Smart charging: Information technology solutions for smart charging and product development of an industrial production EVSE made in California.
- Information Technology: Scalable information technology backend system for EV infrastructure, leveraging RWE Effizienz information technology resources.
- Utility perspective: High safety standards and business orientation based on the needs and requirements of a large grid operator.
- Original Equipment Manufacturer perspective: Deep understanding of original equipment manufacturers' needs through joint cooperation on technology development with other original equipment manufacturers.

Upon installation, the level II Electric Vehicle Charging Station supplied by RWE Effizienz were the only charging stations in the U.S. that were certified for the ISO 15118 standards. Carlsbad-based AESC assumed the lead contracting role in the project.

The project aimed to demonstrate following use cases on campus:

Account Services

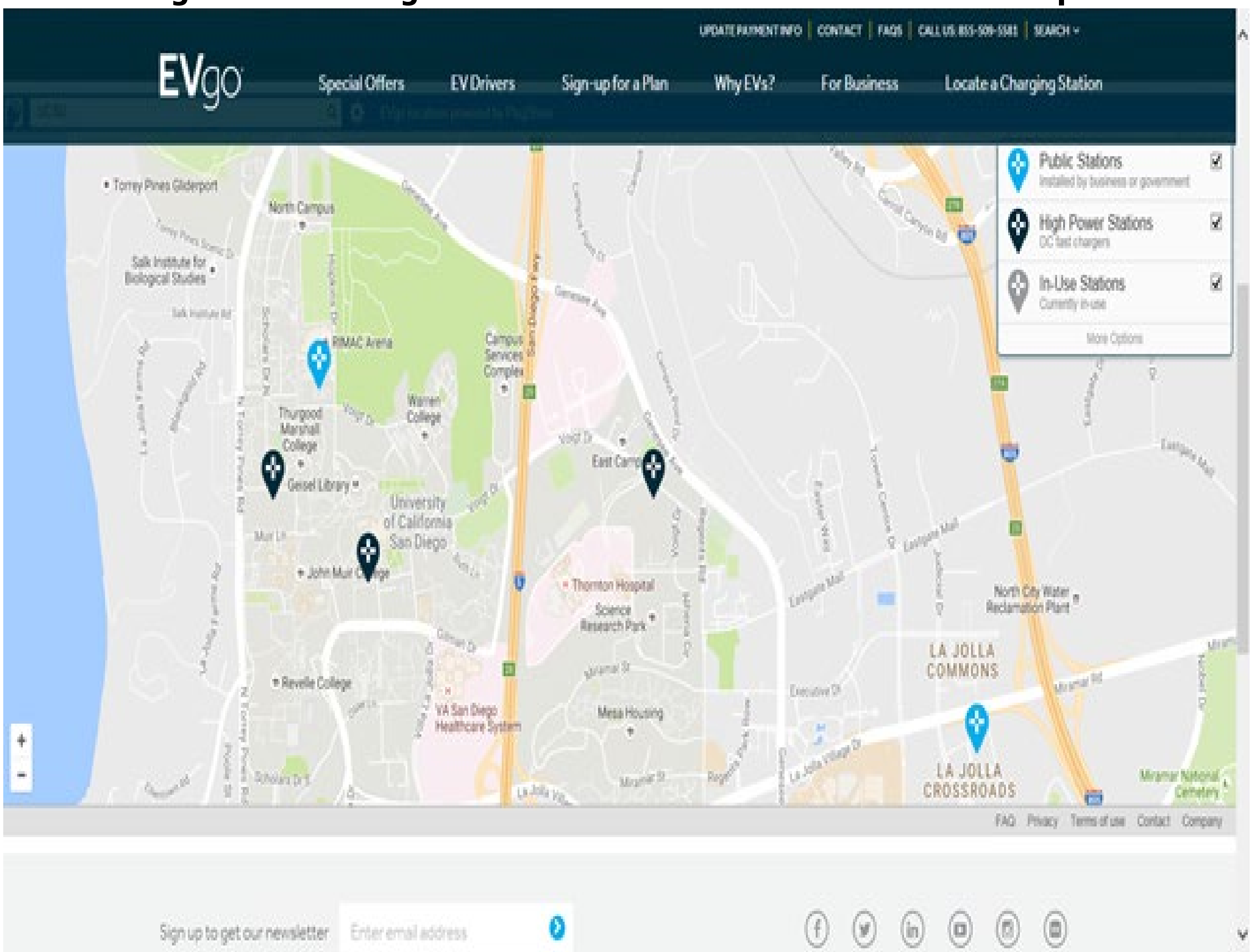
A web-based user interface provided by the NRG EVgo backend system, allowed for the following functionalities on campus:

- Account management
- Access card activation/authentication

- Site location and status
- Data capture
- Billing

A standard internet browser using a common internet connection is the only requirement for program participation (Figure 2). The web portal allows for the billing and account management of the DC Fast charger outlets. The project team grouped the charge points (DC fast chargers and Level II) into clusters to manage the data flow. The clusters represent a physical location such as UCSD East Campus Utility Plant Parking complex.

Figure 2: NRG EVgo Online Finder for EVSE On the UCSD Campus



Source: https://www.nrgevgo.com/charging-locations/

Site Selection

At the end of the planning phase, RWE Effizienz, UCSD, SDG&E, and AESC selected three locations in the UCSD campus for the fast chargers:

- Center Hall parking adjacent to the Chancellors Complex and the Student Services Center with one Charge de Move DC fast chargers.
- Nuclear Magnetic Resonance Spectroscopy ("Bubble Building") parking lot with one Charge de Move DC fast chargers.
- East Campus Utility Plant parking lot with one Charge de Move (next to five level II chargers).

Figures 3 - 5 below illustrate the three UCSD DC fast chargers' informational data from the PlugShare Charging Station Map.

Figure 3: PlugShare Real-Time Center Hall Charger Information

Source: http://www.plugshare.com/?location=9565#

Figure 4: PlugShare Real-Time Bubble Building Charger Information

Source: http://www.plugshare.com/?location=9565#

Figure 5: PlugShare Real-Time East Campus Utility Plant Parking Charger Information

Source: http://www.plugshare.com/?location=9565#

Charge Detail Records

The project team has provided charge detail records for the entire volume of three DC fast charger outlets on campus from the back end connection. Charge detail records indicate which contract identification charged at which charge point, at what time, using how much energy consumed, et cetera.

There are two kinds of charge detail records:

- Per charge point: users may analyze charging behavior and energy consumption at their infrastructure.
- Per contract identification: users may analyze their user's usage behavior and energy consumption.

CHAPTER 2:
Implementation Phase

Setup of Project Team

Phase two began in January 2013. The following contractual agreements were signed:

- AESC and RWE Effizienz: flow down agreement for the installation and commissioning of three DC fast chargers (three outlets) on UCSD campus.
- AESC and AeroVironment: pricing-model for three DC fast charger EVSE including two-year warranty.
- RWE Effizienz and Sullivan Solar/Integrated Power and Lighting: on-site pre-installation services and construction.
- UCSD and NRG EVgo: operation of three simultaneous use DC fast charger outlets.
- AESC and SDG&E: grid impact assessment (in-kind match).

Before RWE Effizienz and AESC could sign an agreement, a number of international legal issues required resolution. Since RWE Effizienz does not operate as a registered legal entity in the U.S., equipment purchased directly from RWE Effizienz would require RWE Effizienz to take possession in Germany for equipment assembled in California, resulting in additional tariffs and taxes.

An external international business-consulting firm, KPMG, was engaged to recommend a solution. It was agreed that RWE Effizienz would provide services and equipment through purchase order agreements. Under this scenario, RWE Effizienz provided a turnkey solution for its state-of-the-art charging technology and AeroVironment delivered fully functional Level II and DC fast chargers. The CEC's terms and conditions were incorporated in these agreements. RWE Effizienz then proceeded with the procurement process, after a delay of eleven months.

Testing and Installation

RWE Effizienz and AeroVironment continued to develop and test the prototypes of the new, state-of-the-art EVSE. The partners established a test laboratory at AeroVironment's site in Monrovia, California, and installed two Daimler Smart electric drives, four dual-ports and a local copy of the RWE Effizienz information technology back end system. The partners successfully completed testing in August 2013 in order to comply with the requirements for Underwriters Laboratories charging equipment. Underwriters Laboratories certified the modified EVSE in September 2013 and, after additional functional tests and use-case scenarios, AeroVironment delivered the entire lot of equipment to UCSD in December 2013. On January 14, 2014, the installation of the first fleet level II dual-port system began at UCSD's Scripps Institute of Oceanography, Keck Center, where the installation contractor had already completed pre-installation work. Installation of the chargers was successfully completed within one day.

In July 2014, installation work began on the fast chargers at the Bubble Building and Center Hall locations. After several installation issues, the chargers were fully installed and commissioned by September 2014.

In August 2014, installation began on the workplace chargers at the East Campus Utility Plant location. Significant installation issues arose at the site including siting and safety equipment (ground fault). The original electrical contractor initiated a change order process, however RWE Effizienz and the contractor were not able to come to an agreement. In January 2015, RWE Effizienz began the bid process for a new electrical contractor. In February 2015, the new electrical contractor (IPL) begins work at the site. The need for specialized switchgear caused further delay and final inspection occurred on May 9, 2015. The fast charger was commissioned on June 2, 2015.

Early in 2014, RWE Effizienz discovered that their backend system would not operate with the AeroVironment DC fast chargers. RWE Effizienz and AeroVironment worked for many months to devise a solution. UCSD then suggested to incorporate the units into another existing on-campus EVSE. In June 2015, UCSD approached NRG EVgo to operate the three DC fast chargers under their current onsite campus system. In July 2015 UCSD and NRG EVgo signed a Memorandum of Understanding, AESC requested a no cost time extension from the CEC, and the system went live in January 2016.

Going Live

On April 9, 2014, UCSD hosted a press conference and demonstration with representatives of SDG&E, Daimler, KnGrid, RWE Effizienz, AESC, and Commissioner Janea Scott of the CEC in attendance. This event marked the first official demonstration of an ISO/IEC 15118 alternating current charger in Northern America.

SDG&E's Clean Transportation group drafted and coordinated a news release and communications brief in coordination with University of California Santa Cruz for the Intelligent Charging Project at UCSD with Daimler, RWE Effizienz and SDG&E. Other partners included KnGrid, prime contractor AESC and the CEC. SDG&E coordinated closely with UCSD on the 2014 media event hosted on campus. Leading up to the event were conference calls to finalize talking points, and the review of drafts for both the news release and communications brief. Media outreach was also done to key news reporters in our territory that focus on electric vehicles as well as utility trade publications with interest in grid optimization through charging stations. SDG&E also designed and printed posters of KNGrid's graphics for the event as well as rented chairs, sound and a podium for the event. In addition, SDG&E coordinated the attendance of CEC Commissioner Janea Scott to the event.

SDG&E's Chief Development Officer Jim Avery attended meetings regarding the project with UCSD, RWE Effizienz and Daimler. The media event brief draft prepared in conjunction with UCSD and partners is attached in Appendix A – Media Event Briefing Draft.

In January 2015, the three DC fast chargers became available for general campus use and enrollment activities occurred in February 2015. Charger usage requires an NRG EVgo account/access card and a UCSD parking permit (figure 6). The first two months saw no actual charging, and the very first vehicle charged on March 10, 2015.
Figure 6 below shows a sign stating that a parking permit is required.

Figure 6: Charging Parking Requirements

Source: AESC

Figure 7 shows RWE Effizienz Project Manager Joerg Lohr with the first Daimler lease customer, Professor Veerabhadran Ramanathan of Scripps Institute of Oceanography, UCSD, in front of the newly installed EVSE for UCSD's fleet vehicles.

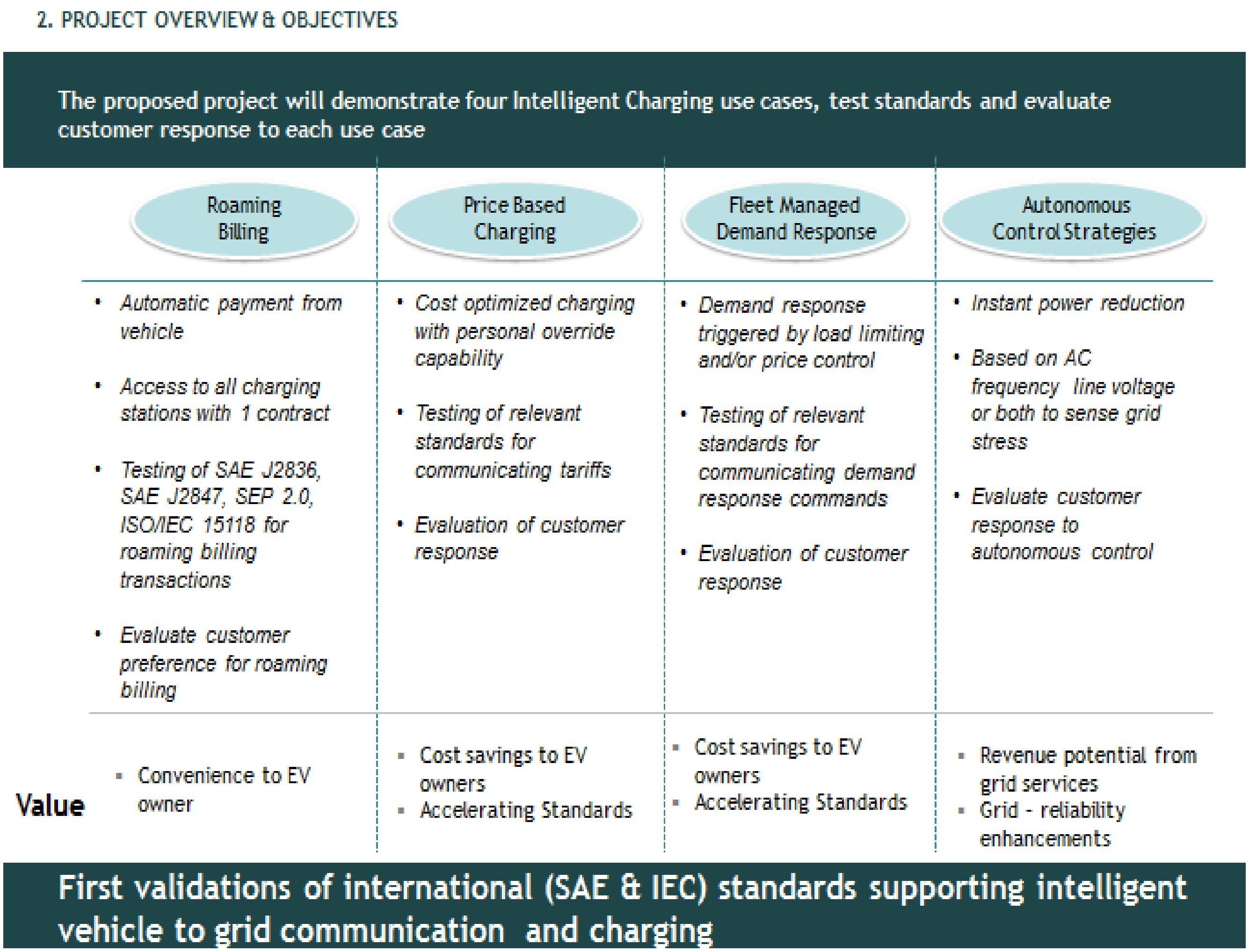
Figure 7: First EVSE Installation Media Event

Source: AESC

Follow Through and Additional Testing

RWE Effizienz and UCSD will continue with additional demonstration and testing of the EV chargers over the next three years. Figure 8 outlines the Project objectives for each of the four planned use cases.

Figure 8: Planned Use Cases



Source: RWE Effizienz

Photographs of Installations

The following photographs show the installations of the chargers at the three locations: Figure 9, Center Hall Parking Site – The first DC fast chargers installed on campus, an AeroVironment Underwriters Laboratories-listed Charge de Move coupler EV50. The charger is located adjacent to the Chancellors Complex in the University Center.

Figure 9: DC fast charger Near Chancellors Complex

Source: AESC

Figure 10 shows a picture of the Nuclear Magnetic Resonance Spectroscopy ("Bubble Building") Parking Lot Site. It is the second DC fast charger installed on campus, an AeroVironment Underwriters Laboratories-listed Charge de Move coupler EV50. The charger is located adjacent to the Bubble Building in Thurgood Marshall College.

Figure 10: Bubble Building DC fast charger

Source: AESC

Figures 11 through 13, East Campus Utility Plant Parking Lot Site – This site is near the University's demonstration utility plant and serves a large University administrative facility. It is adjacent to five pedestal mount Level II dual chargers to meet the anticipated future need. The site is close to several new University Hospitals.

Figure 11: East Campus Utility Plant DC fast charger

Source: AESC

Figure 12: East Campus Utility Plant DC fast charger and Level II Chargers

Source: AESC

Figure 13: East Campus Utility Plant EV Chargers Electrical Service Equipment

Source: AESC

CHAPTER 3: Project Results

The collection of EV charging data (Charge Detail Records) began on January 1, 2016 with the initiation of the NRG EVgo electric vehicle service provider. At present, only patrons with both an EVgo account and a UCSD parking permit are allowed to utilize the chargers. That combination along with a one hour parking limitation has proven to be severely limiting for overall DC fast charger usage. AESC reasonably concludes that typical workplace charging (students and staff) likely prefer to charge at level II stations based on costs and convenience. The benefit of fast charging is low to drivers that are likely to have longer park times. The results of the study show that a legitimate use case should be established in the future for these restricted use (e.g. parking permit) fast chargers.

Number of Fleet and Employee Vehicles Charged

Between January and June 2016, 51 charging sessions were recorded. The retail rates are approximately $0.10/minute and $14.95/month membership. After the awareness campaign, Daimler offered the lease program to 40 students, faculty, and staff to participate in a forthcoming research project. These vehicles cannot charge at the Charge de Move fast chargers, however, the increased visibility of on-campus EVs should create peripheral awareness of fast charging as an available service.

In addition, UCSD has also exchanged term sheets for a public car-sharing program on campus that will involve the exclusive use of EVs. UCSD anticipates that about 25 EVs will participate in the program. UCSD is also negotiating with NRG Energy, Inc., a Fortune 300 company, which provides charging solutions, to bring an additional 50 level II charging stations in the campus.

Number of Days Vehicles Are Charged

The following chart (Table 1) summarizes the fifty-one charging events by numbers of days that the sessions occurred (43 days).

Table 1: Charging Events by Location

Row Labels	January-2016	February-2016	March-2016	April-2016	May-2016	June-2016	Grand Total
East Campus Utility Plant	0	0	5	1	3	8	17
Center Hall	0	0	3	2	7	1	13
Bubble Building	0	0	7	2	2	2	13
Grand Total	0	0	**15**	**5**	**12**	**11**	**43**

Source: RWE Effizienz

Charging Station Days

Charging occurred across all three locations: East Campus Utility Plant, Center Hall, Bubble Building. The following chart (Table 2) summarizes monthly charging events by location.

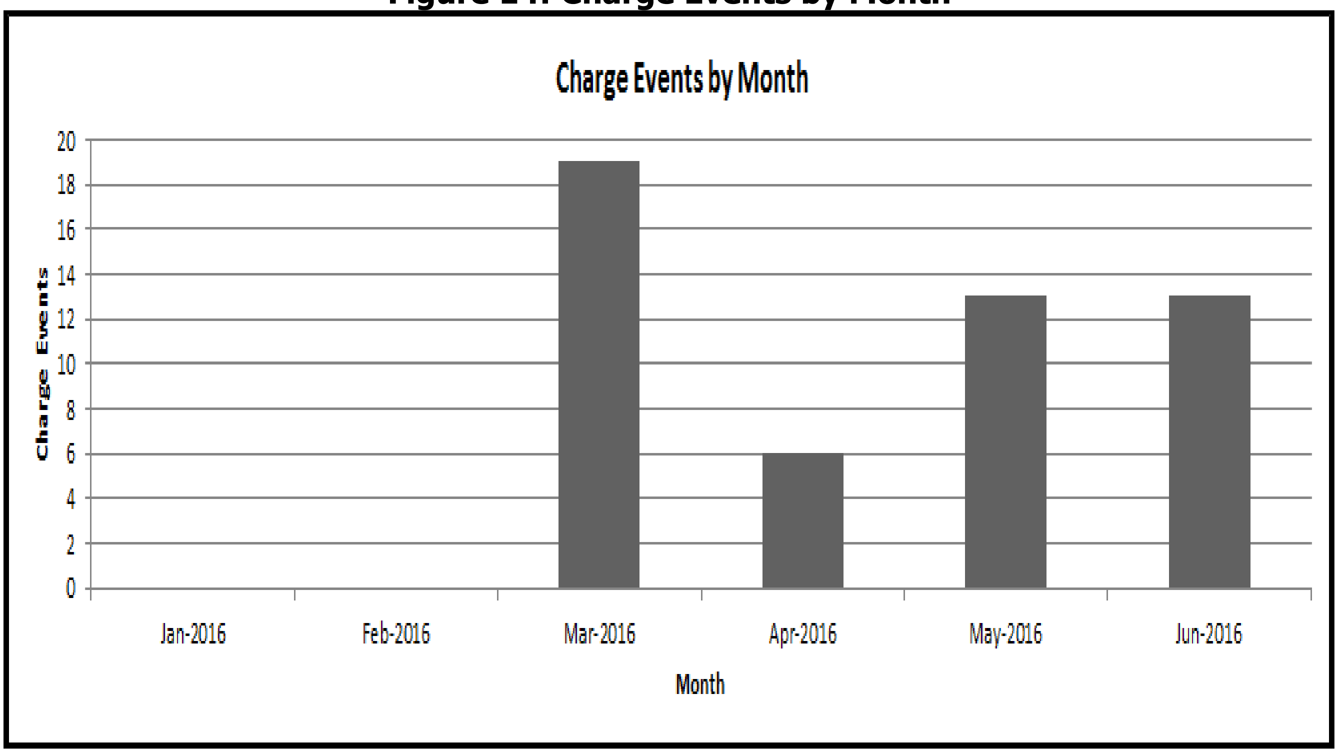
Table 2: Charging Events by Location

Row Labels	January-16	February-16	March-16	April-16	May-16	June-16	Grand Total
East Campus Utility Plant	0	0	7	2	4	8	21
Center Hall	0	0	4	2	7	2	15
Bubble Building	0	0	8	2	2	3	15
Grand Total	**0**	**0**	**19**	**6**	**13**	**13**	**51**

Source: RWE Effizienz

There was no charging during the first two months after the chargers became publicly available. Usage peaked in March 2016 and has since leveled off. Figure 14 shows a graph of the charging events.

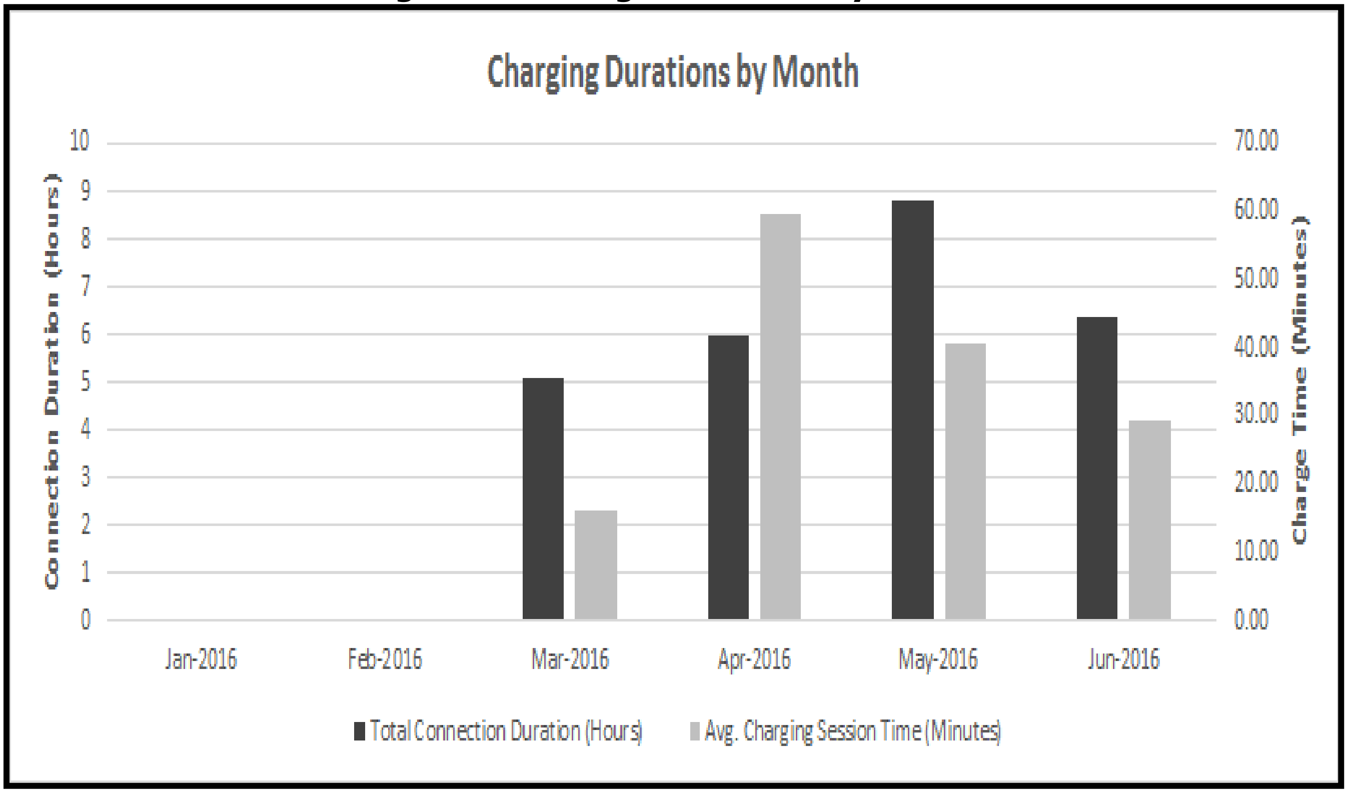
Figure 14: Charge Events by Month



Source: AESC

Charge duration was also very limited but peaked in May 2016. Total connection time over the test period was just over 26 hours and average charge duration was just over 24 minutes. Figure 15 below shows the charge durations.

Figure 15: Charge Durations by Month



Source: AESC

Maximum Capacity of the New Fueling System

In total, UCSD has installed 26 RWE Effizienz ISO Compliant Level II charging stations and three DC fast chargers. This is addition to 25 Ecotality/Blink systems installed during the American Recovery and Reinvestment Act program. The University is also working with NRG EVgo to install three Combined Charging Systems and one alternating current fast charger.

Gallons of Gasoline Displaced

Since UCSD opened the fast charging stations open for public usage, the vehicles have logged approximately 1,296 miles. According to fueleconomy.gov, this has resulted in displacing 12 gallons of regular gasoline, compared to a 2012 Chevrolet Impala using regular unleaded fuel.

Emissions Reductions

Displacing 12 gallons of regular gasoline equates to lowering greenhouse gas (GHG) emissions by 0.56 metric tons of carbon dioxide. According to fueleconomy.gov, the only GHG emissions associated with EVs are those from the production of electricity. Based on this project's location in La Jolla, California, fueleconomy.gov rates the Daimler Smart Fortwo carbon dioxide emissions from electricity production at 130 grams per mile. However, because of the unique renewable substantial weighting, UCSD's microgrid has been rated 51 grams per mile. This compares to 480 grams per mile for the average gasoline powered car of similar size. There are no tailpipe emissions associated with these EVs.

Duty Cycle of the Fleet

The UCSD EV fleet is in transition from Nissan Leaf's expiring or expired leases to an affinity lease program with Daimler for their Smart Car Generation III models, which are ISO 15118 compliant. Thus, for the first time, there will be an EV to EVSE charging that are both ISO 15188 compliant. UCSD has committed to adding at least eight new Daimlers for fleet operations and workplace charging. The Daimler affinity lease program consists of an $1100 initial payment for license/fees/first/last month payment for a 3-year lease at $86/month. In addition, there is a $2,500 state rebate that effectively reduces the monthly payment to only $17/month.

Jobs and Economic Development

Electric vehicles are transformative technologies that create a variety of benefits to the economy. EV and EVSE manufacturing creates jobs. Although it is difficult to estimate the impact of this project, the installations have provided temporary jobs and/or have contributed to increasing revenues for companies engaged in EVSE installations. Electrification of personal transportation can push job creation in a host of industries. Higher efficiency cars require sophisticated technology, which are designed and produced by adding workers to the auto industry. Many of these jobs would be in industrial sectors closely tied to auto manufacturing, advanced batteries, and research and development.

In the end, EVs are more cost efficient to operate than conventional vehicles. Drivers who switch to EVs will eventually have more disposable income to spend for housing, entertainment, and other services. This increased spending in other sectors will stimulate the economy and enhance job creation.

Quality of life of employees, students, and users of the EV infrastructure are also enhanced with the availability of EV chargers. Workplaces that offer alternative fuel infrastructure are able to attract the early adopters of green technology as employees. This project and similar projects also reduce dependence on foreign oil and studies have shown that the use of EVs can reduce utility prices.

This overall project makes use of the Vehicle to Grid (V2G) charge system, allowing vehicles to feed electricity back to the grid. Peak hours of electricity demand usually occur in the early to mid-afternoon, when most vehicles are sitting idle and can feed power back into the grid. On the other hand, EVs are generally charging late in the evening, overnight, and in the early morning, when there is excess generation capacity in the grid. Hence, large-scale deployment of EVs will allow utilities to forego the use of power plants that are only needed to satisfy peak demand. This could substantially decrease operating costs and therefore utility rates. Further, V2G makes possible the greater use of clean energy. EVs generally charge from late afternoon to early morning, a period during which a major portion of energy is generated from renewable energy sources such as wind.

Renewable Energy at the Facility

Since the late-2000's UCSD has been installing photovoltaic systems on its rooftops and parking structures and today it has produced 2.2 megawatts of electric generating capacity from the combined output of those systems.

Located at UCSD's East Campus Utility Plant is a 2.8 megawatts Fuel Cell Energy DFC3000 system that is configured to run on directed biogas from the Point Loma Waste Water Treatment Plant. While the main output of the fuel cell is electricity for use on campus, it also generates water and high temperature heat. The byproduct heat is a valuable resource that can be utilized for process or district heating or it can be used to generate cooling capacity via an absorption chiller. UCSD recently commissioned a 350-ton absorption chiller that will utilize the fuel cells' waste heat and provide baseload cooling capacity to the campus. In this new configuration (fuel cell plus absorption chiller), the project is considered a combined heat and power system and it will achieve total efficiencies in excess of 68 percent.

In January 2014, UCSD's Fleet Services changed its biodiesel feed stock source from soybeans to waste grease. It presently contracts with a local company (New Leaf Biodiesel) to pick up waste grease from numerous kitchens on campus. New Leaf refines the waste grease into biodiesel, which is sold back to the campus. This closes the loop with the use of B20 biodiesel making at least 20 percent of diesel fuel dispensed renewable.

UCSD has concluded contract negotiations to change its natural gas supplier to use 100 percent all renewable, frack free, domestic, landfill/digester methane gas to be dispensed at its compressed natural gas fueling station.

UCSD has received the following Awards and Recognition:

- Recognized as a Model Pollution Prevention Shop (2005)
- Sustainable Transportation Best Practices Award (2006)
- SANDEE Award for Special Achievement in Transportation (2006)
- United States Senate Certificate of Commendation for energy efficiency and conservation, renewable energy, and mass transportation (2007)
- Member of the EPA's National Partnership for Environmental Priorities program (2009) and recognized for successful compliance (2011)
- Green Fleet recognized UCSD Fleet Manager as a Sustainability All-Star for reducing emissions and fuel consumption (2011)
- Ranked 22nd Government Green Fleet (2010)
- Ranked 18th Government Green Fleet (2011)
- Ranked 14th Government Green Fleet (2012)
- Recognized as one of the 100 Best Fleets in the nation (2012)

Source of the Alternative Fuel

UCSD is firmly committed to provide a world class alternative fuel vehicle fleet. Approximately 60 percent of the current fleet vehicles at UC San Diego are alternatively fueled vehicles. In comparison, 10 years ago, the campus had less than 10 percent of the fleet alternative fueled. The current UCSD fleet are as follows:

- 3 each Bi-Fuel
- 100 Hybrid
- 51 Dedicated Compressed Natural Gas
- 3 Plug-In Hybrids
- 17 E85 Flex Fuel

- 49 Biodiesel
- 396 Unleaded (excludes Hybrids)
- 336 Electric (not Full Speed)
- 4 Full Speed EV (down from 7 before leases expired)

Energy Efficiency Measures

In 2013, SDG&E presented UCSD with a $7.2 million check representing energy efficiency incentives earned through implementation of 30 energy efficiency projects from 2010 to 2012. UCSD has saved more than 21 million kilowatt hours, 2.1 million therms and reduced more than 2 megawatts (MW) of demand.

"UC San Diego was recently honored as the Grand Champion in SDG&E's Energy Champion awards for implementing energy-efficiency measures to optimize energy performance across the campus. Optimizing facilities is a high priority at UC San Diego, with all new construction targeting LEED Silver certification or higher; the campus is already home to 14 buildings have met this certification. Renewable energy sources are also a critical component in the UC San Diego campus infrastructure."[1]

Lessons Learned

AESC and RWE Effizienz encountered unforeseen difficulties establishing a subcontract agreement due to legal and tariff issues. Although these were eventually resolved, this delayed the project by six months. The number of project partners also presented problems in coordination and performance monitoring. Installation planning and the permitting process also contributed to overall project delay. The project team approached this project as a traditional construction effort and did not receive the benefit that could have been obtained from utilizing an EVSE specific planning and permitting process. The installation and the connection of the DC fast chargers to the grid took only about two days per outlet, but the permitting and planning process ranged from two to six months. The entire process could have benefited from installation guidance from the expedited process contained in the Governor's Plug-in Electric Vehicles: Universal Charging Access Guidelines and Best Practices and the Plug-in Electric Vehicles Charging Infrastructure Guidelines for Multi-Unit Dwellings.

Accomplishments

The project team has fully achieved one of the project's major goals of providing made-in-California, state-of-the-art technology to the state. Twenty-six Level II EV charger ports and three DC fast chargers for the use of the UC San Diego employees, faculty, and students have been installed. Additionally, the project's goal of creating new job opportunities in California has been also been achieved. KnGrid, a California entity, will manage and operate the intelligent EVSE system on campus consisting of 10 fleet-EVSE outlets and 16 workplace outlets. AeroVironment (based in Monrovia, California) will provide the after-sales service for the term of the maintenance agreement and manage the DC fast chargers going forward

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[1] Clark, C. (2013, July 29). UC San Diego Received $7.2 Million in Energy Efficiency Incentives from SDG&E. UC San Diego News Center. Retrieved from http://ucsdnews.ucsd.edu/pressrelease/

The goal to increase EV adoption in the UCSD campus is still a work in process. The EV marketing campaign occurred in September 2015. The Daimler vehicle lease program achieved substantial adoption of EVs and usage of the EVSE in the third quarter of 2015.
The project has succeeded in increasing EV infrastructure in the UCSD campus that will eventually lead to the more widespread adoption of EVs not only for its fleet but also for the use of its employees, faculty, and students.

CHAPTER 4: Evaluation of EV Charging on Electric Distribution Circuits

Task Overview

UCSD has installed three DC fast charger on the one of their distribution circuits. This effort attempts to:

1. Determine whether the use of these three chargers can create a scenario where the circuit is adversely impacted;
2. Report on deviations from normal base profile; and
3. Evaluate circuit voltage around the time the DC chargers were in use.

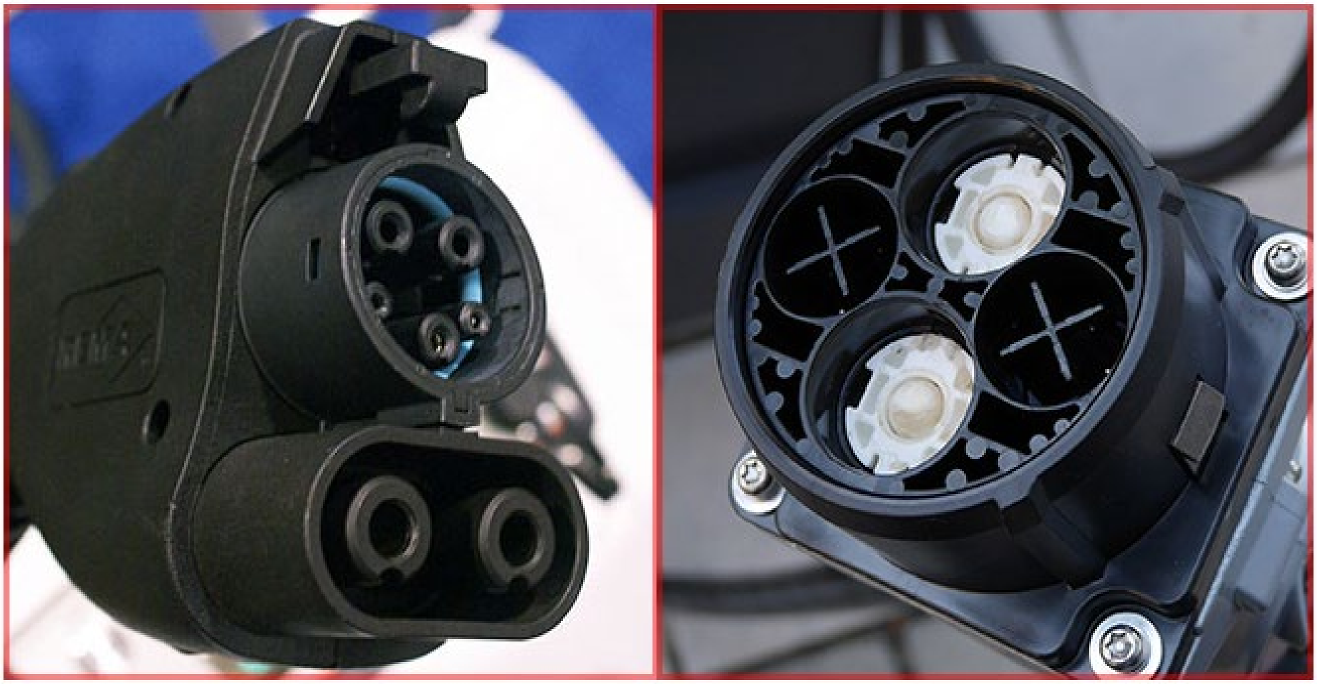
Background

Electric vehicle charging stations are generally available in 120 volt, 240 volt and 480 volt models many different models are available with different power levels to determine the speed at which they can charge EV batteries. Two lower speed chargers which are often referred to as 120 volt level 1 and 240 volt level 2. DC fast chargers are designed to charge vehicles faster than level 1 and level 2 chargers, with a maximum electric output ranging between 50 kilowatts 120 kilowatts. The three chargers installed at the UCSD campus are DC fast chargers.

The connection configuration varies depending on the DC Fast Charger manufacture. There are three dominant DC Fast Charger standards; Charge de Move, Society of Automotive Engineers Combined Charging Standard, and Tesla Supercharger. Tesla sells an add-on adapter allowing its customers to recharge at Charge de Move stations. The DC Fast chargers at UCSD have Charge de Move connectors with a maximum current draw of 64 amperes root mean square and DC output of 120 amperes.

Figure 16 shows both Combined Charger System (left) and Charge de Move (right) couplers.

Figure 16: Standard Couplers



Source: SDG&E

Figure 17 below is a picture of the Tesla Supercharger coupler.

Figure 17: Tesla Coupler

Source: SDG&E

Data Provided by SDG&E

SDG&E engineering representatives assisted with grid data collection at the direction of RWE Effizienz and UCSD. SDG&E installed 3 power quality meters at three locations where the DC fast chargers were installed. The Power Quality meters are Meggers PA-9s. The Meggers PA-9s provide 15-minute interval data for Minimum and Maximum voltage, current, RMS, and percent imbalance for current and voltage.

The Meggers PA-9s were installed in three locations, "The Dome", "Center Hall" and "P-Lot 703". Meter data recorded prior to the DC fast charger installations were retrieved approximately January 1, 2014. Meter Data recorded after the DC fast charger installations were retrieved on April 29, 2016, November 3, 2016, and November 16, 2017. The Meggers PA-9 meter located at the P-lot failed to provide data during the November 16, 2017 data collection.

Third Party Data

SDG&E was provided with installation, operation, and maintenance manuals for DC charging station model EV50-PS. The document provides installation information pertinent to installing the system itself. As well as line input information, circuit breaker rating, alternating current power factor as well as other necessary electrical parameters needed in order to properly connect and operate the system.

SDG&E was also provided with the 12 kilovolts circuits for UCSD- East Campus Utility Infrastructure Project and Medical Center switching station. This document provides electrical connections of the DC fast charge to the UCSD grid.

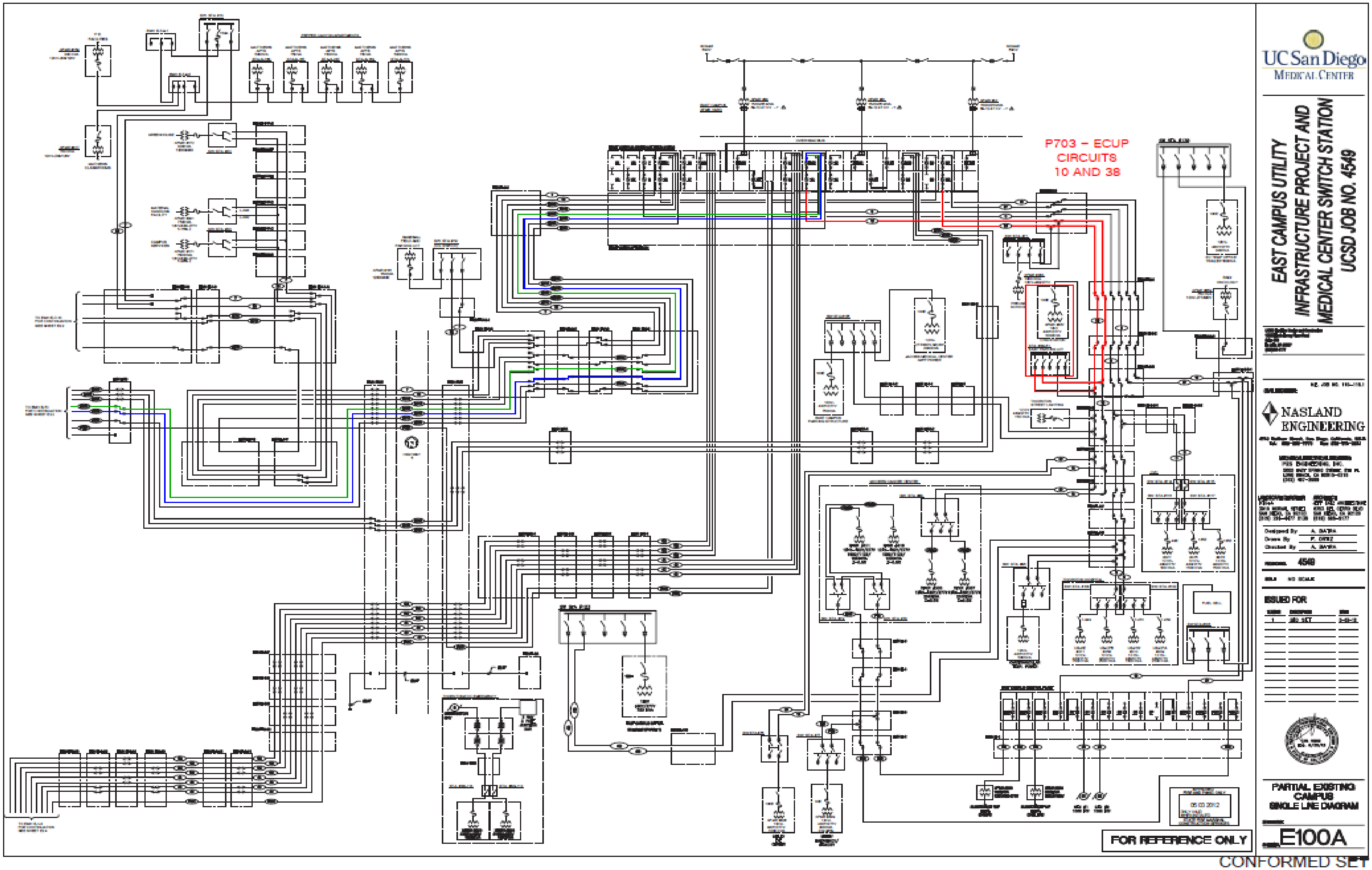
A copy of UCSD monthly kilowatt-hour report was provided for March through May of 2016. The document provided charge date and start/end time as well as energy per charge in kilowatt-hours. Loading information for the years of 2012 and 2013 was provided for the HOUSING.Dining_admin_1610, and 2013 information for SIO.Stephen_Birch_E5501. Data for SIO.Ritter_Hall_E4711 was also provided with values for Mean electric parameter. The loading information provided is one year long at 15 minutes' interval with kilovolt-amperes, amperage, kilowatt and voltage values.

Feeder-Transformer Distribution Map

The Feeder map is designed to show relationships and locations of feeders and their connected transformers. The Feeder map provides the electrical location of fast chargers. The map also has partial connected kilovolt-amperes.

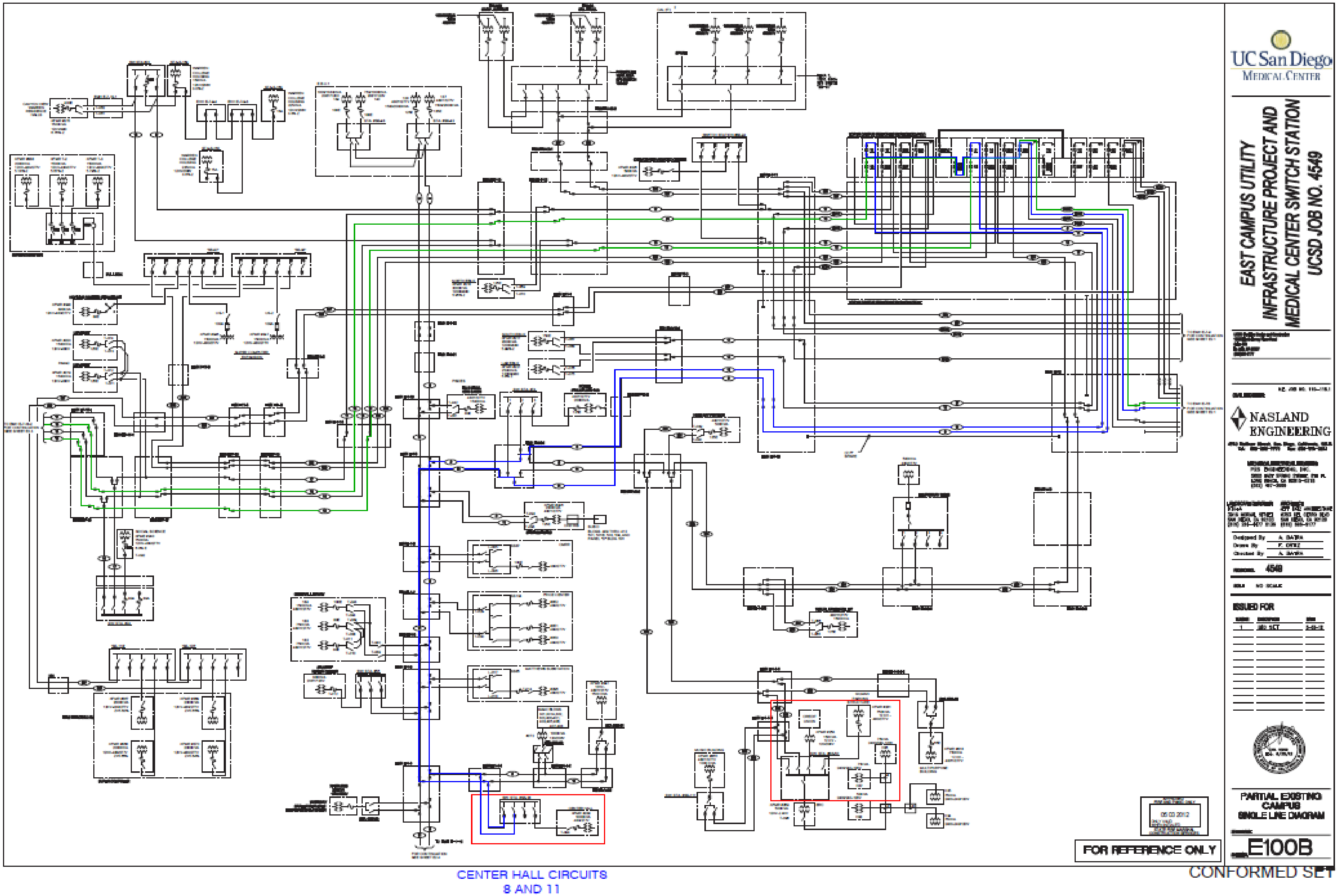
For circuit 10 and 38, the connected kilovolt-amperes was established. It is worth noting that none of chargers share a circuit. Therefore, a compounded charger effect on the singular circuit cannot take place as this scenario would not happen given the electrical configuration. Circuit on-line maps are reproduced in Figures 18 through 20 below.

Figure 18: East Campus Utility Parking (P703) Feeder Map



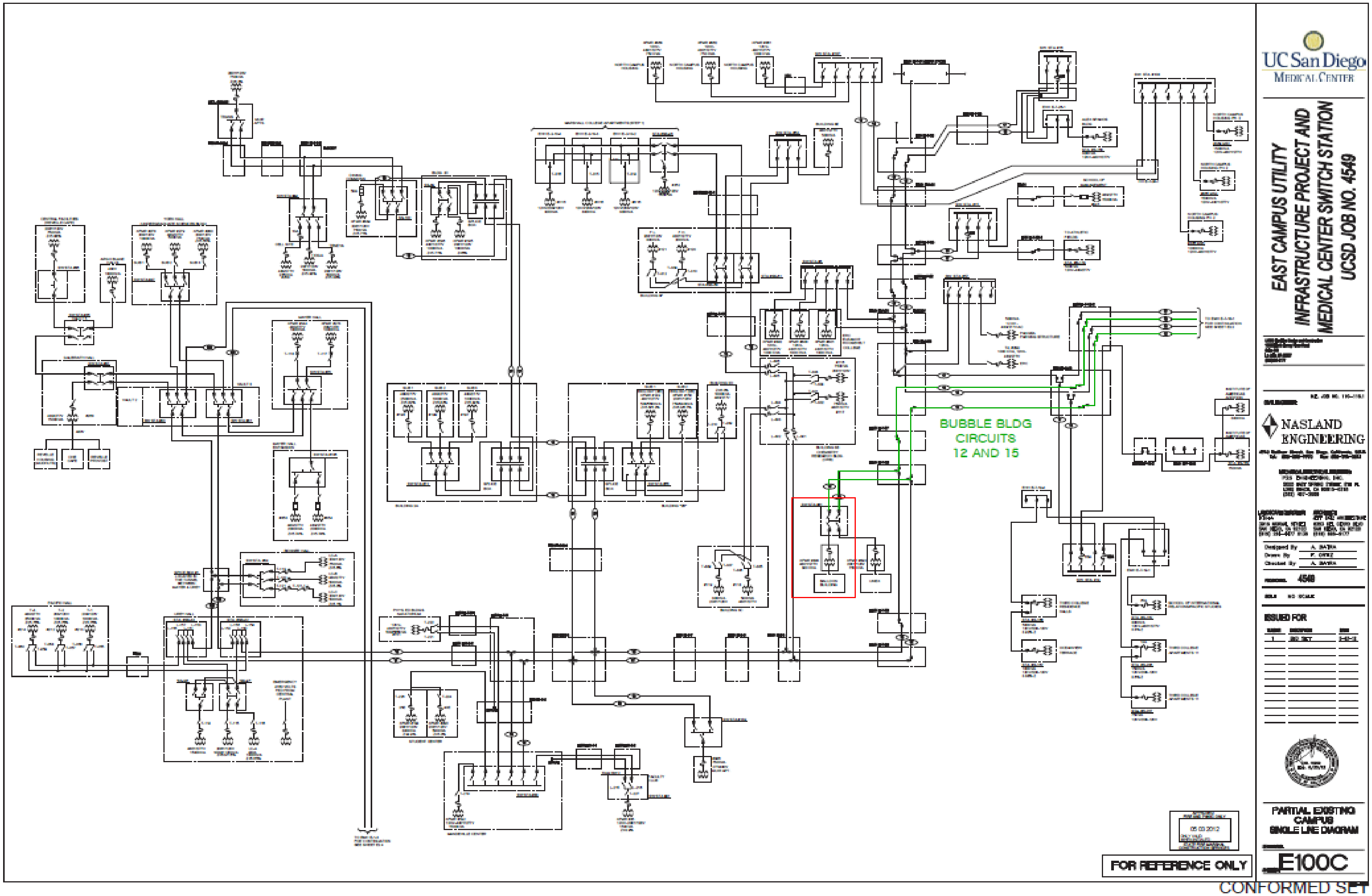
Source: UCSD

Figure 19: Center Hall Feeder Map



Source: UCSD

Figure 20: Bubble Building (Dome) Feeder Map



Source: UCSD

Satellite View of Campus

The map in Figure 21 below provides a bird's eye view of the UCSD campus. it is also meant provide orientation as to where each of the chargers are in relation to each other.

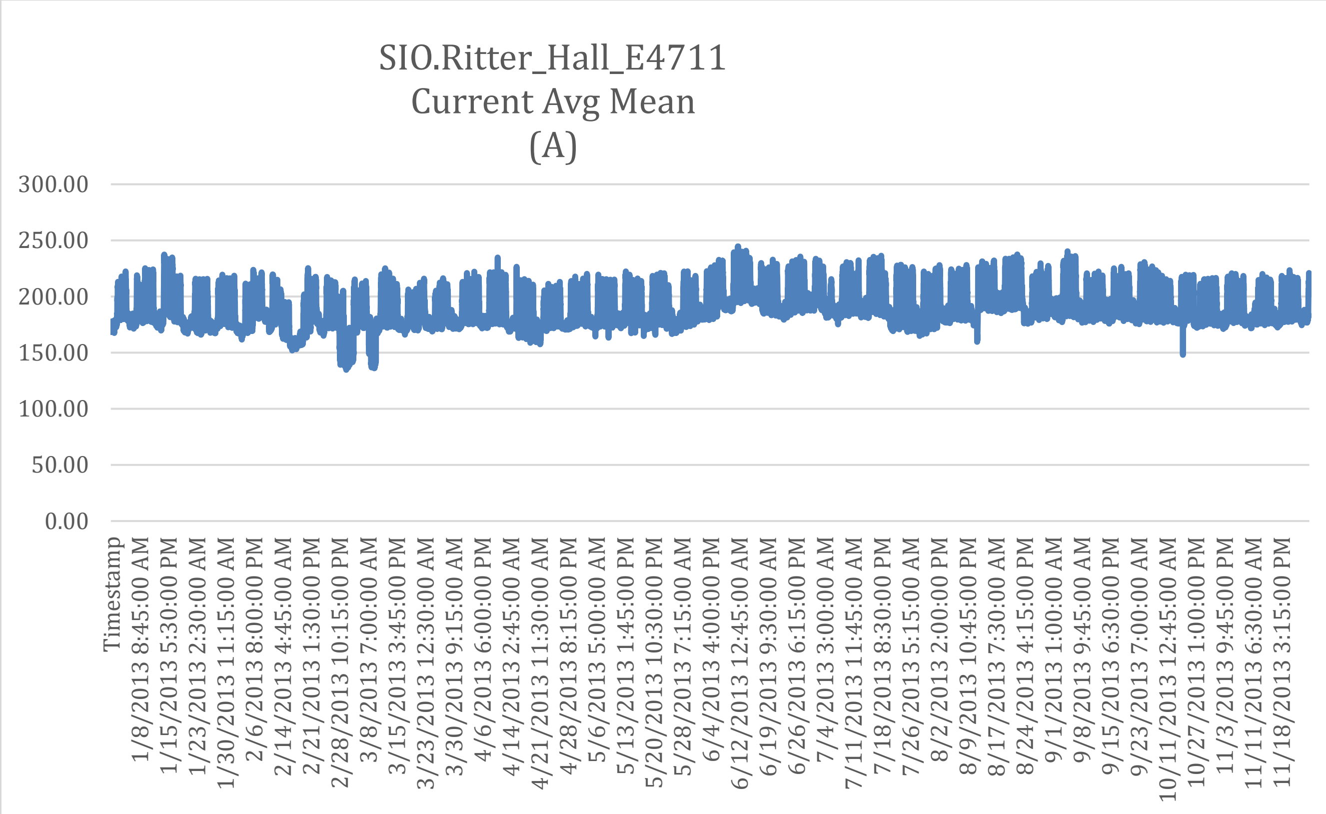
Figure 21: Satellite View of DC fast charger Locations

Source: UCSD

Baseline loading profiles

The baseline used is Ritter Hall. The highest load Ritter Hall saw was 226 amperes. Assuming that a 12 kilovolt circuit is typical to the SDG&E circuit, it is capable of being loaded to 600 amperes. This circuit will not be impacted by full draw on any one charging station. The charging station can only draw an additional 64 amperes max. Figure 22 shows a graph of the baseline current at SIO.Ritter_hall_Er711.

Figure 22: Baseline Current



Source: SDG&E

Grid Impacts for Each DC Fast Charger

Charger #1: East Campus Utility Plant Parking (P703)

Feeder Identification

P703 is being fed from a 1,000 kilovolt-amperes transformer at 480 volts, that transformer is being fed from circuits 10 and 38 at 12 kilowatts.

Connected Kilovolt-amperes

There are 6,900 kilovolt-amperes of the transformers connected to the Feeder.

Connected load (Connected kilowatts)

This information was not provided. An assumption of full kilovolt-amperes loading was made.

Conductor Impedance

This information was not provided. The system will be assumed to be lossless.

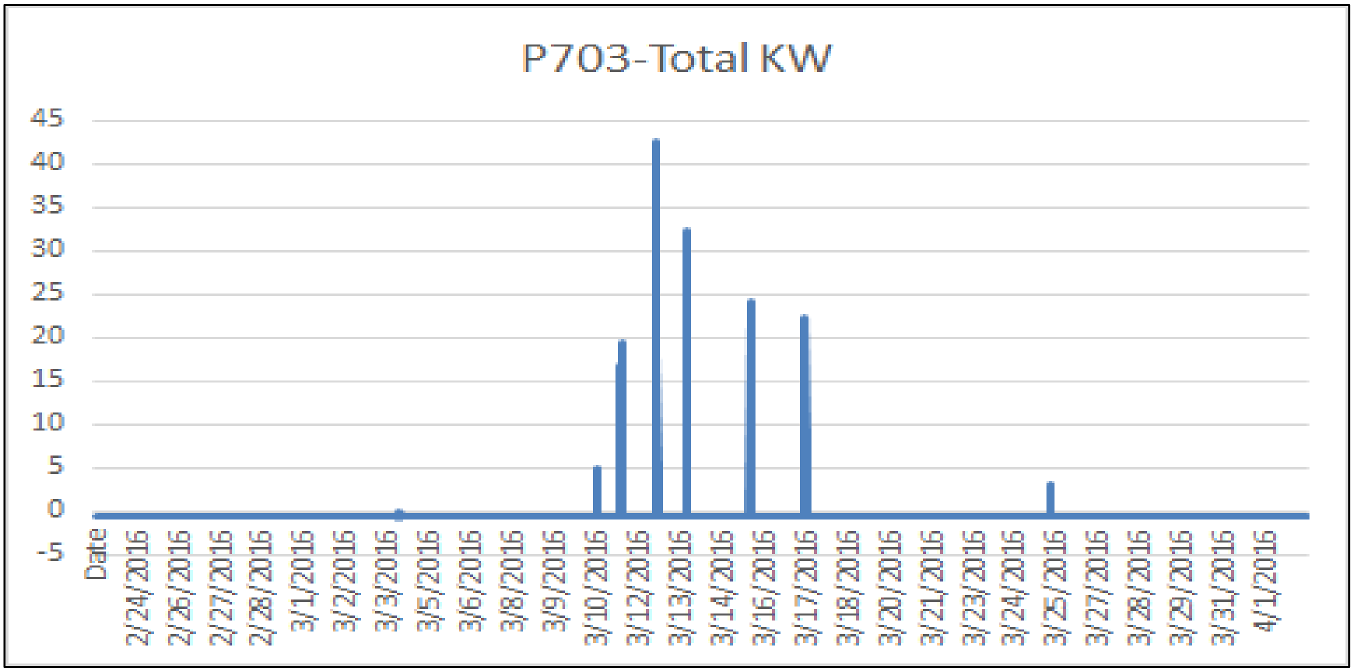
Accounts with kilowatt-hours

Account detail for other EV charging and photovoltaic systems on the same circuit was not provided, therefore no other EV or photovoltaic systems are assumed in this impact analysis.

Peak Average Demand at Connection Point

The highest kilowatt demand occurred on March 12, 2016 the demand registered 42.5 kilowatts, or 51.4 amperes. This can be seen in Figure 23 below.

Figure 23: East Campus Utility Plant Parking (P703) Peak Demand



Source: SDG&E

Voltage profile for charger connection point at P703

Figure 24 shows the voltage profile for the charger connection point at P703, which is the East Campus Utility Plant Parking.

Figure 24: East Campus Utility Plant Parking (P703) Voltage

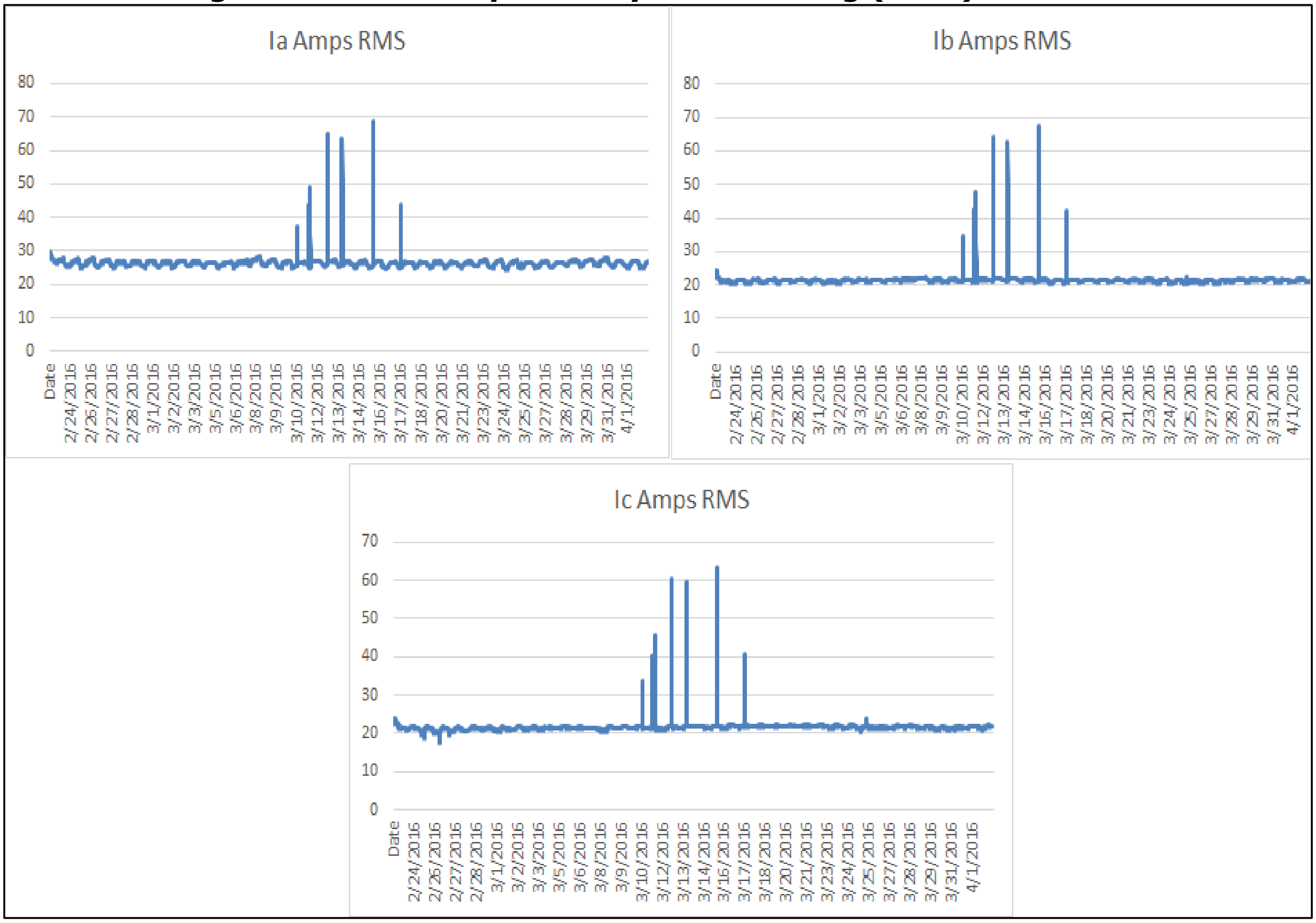
Source: SDG&E

The voltage profile for charger #1 interconnection point generally stay between 486-493 volts with a low point during the two-month time frame of 479 volts.
Considering that nominal is 480 volts with a tolerance of 24 volts over or under nominal, the circuit is within the accepted tolerance. The graph above show from March 25, 2016 to March 28, 2016 this is noticeable difference from the rest of the profile.

Figure 25 shows the current profile for charger connection point at P703:

Current profile for charger connection point at P703:

Figure 25: East Campus Utility Plant Parking (P703) Current



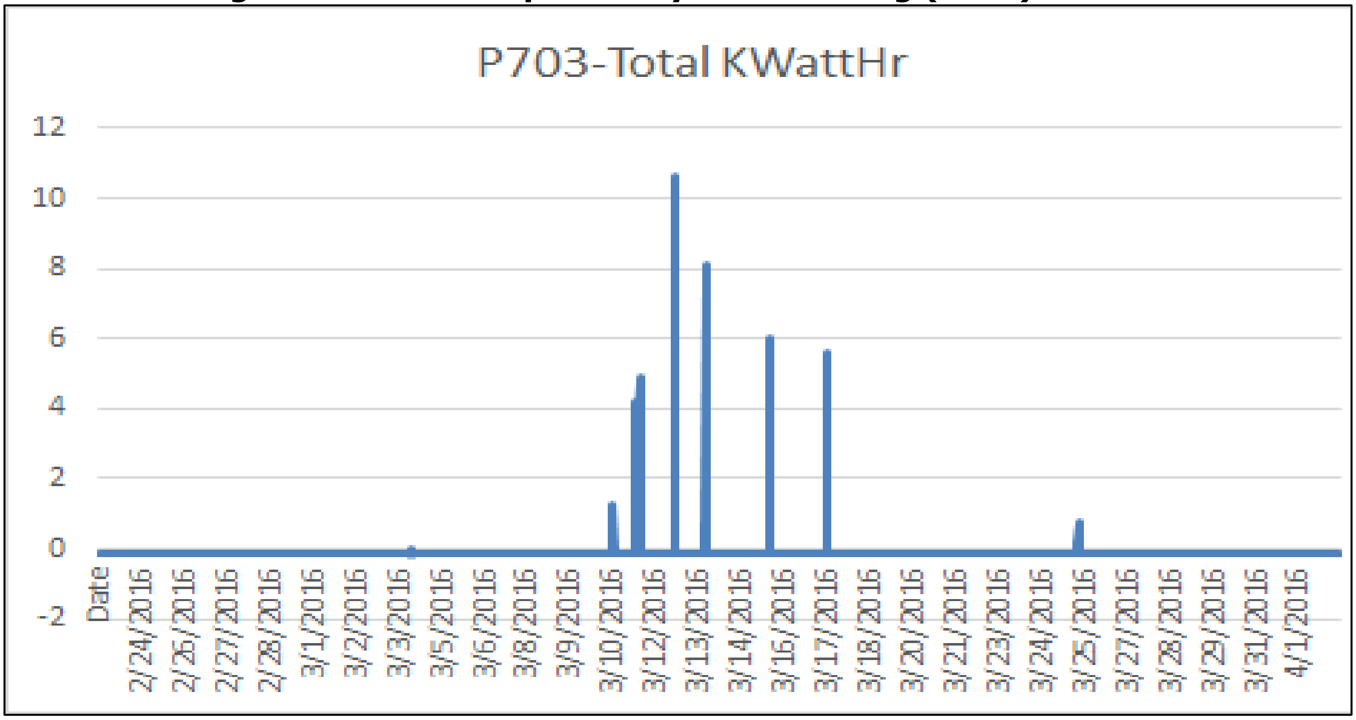
Source: SDG&E

The current profiles for all phases are consistent without a noticeable difference during the March 25 through the March 28 time frame. The absence of a voltage spike in this time frame, indicate that the voltage dip during that time period must have been due to transformer tap change, or a generation source offline.

Figure 26 shows the total amount of kilowatt hours at P703.

Total kilowatt hours at connection point:

Figure 26: East Campus Utility Plant Parking (P703) Power



Source: SDG&E

The maximum average kilowatt over the February to March time frame is 10.6 kilowatt hours. Over the two months, the most interesting day seems to be March 12th with a demand spike and the greatest kilowatt-hour draw.

Charger #2: Center Hall

Feeder ID
Center Hall is being fed from a 1000 kilovolt-amperes transformer at 480 volts, that transformer is being fed from circuits eight and 11 at 12 kilovolts.

Connected kilovolt-amperes
Connected kilovolt-amperes cannot be determined for these circuits, there is not sufficient information in order to calculate connected kilovolt-amperes.

Connected load (Connected kilowatts)
This information was not provided. No load assumption will made.

Conductor Impedance
This information was not provided. The system will be assumed to be lossless.

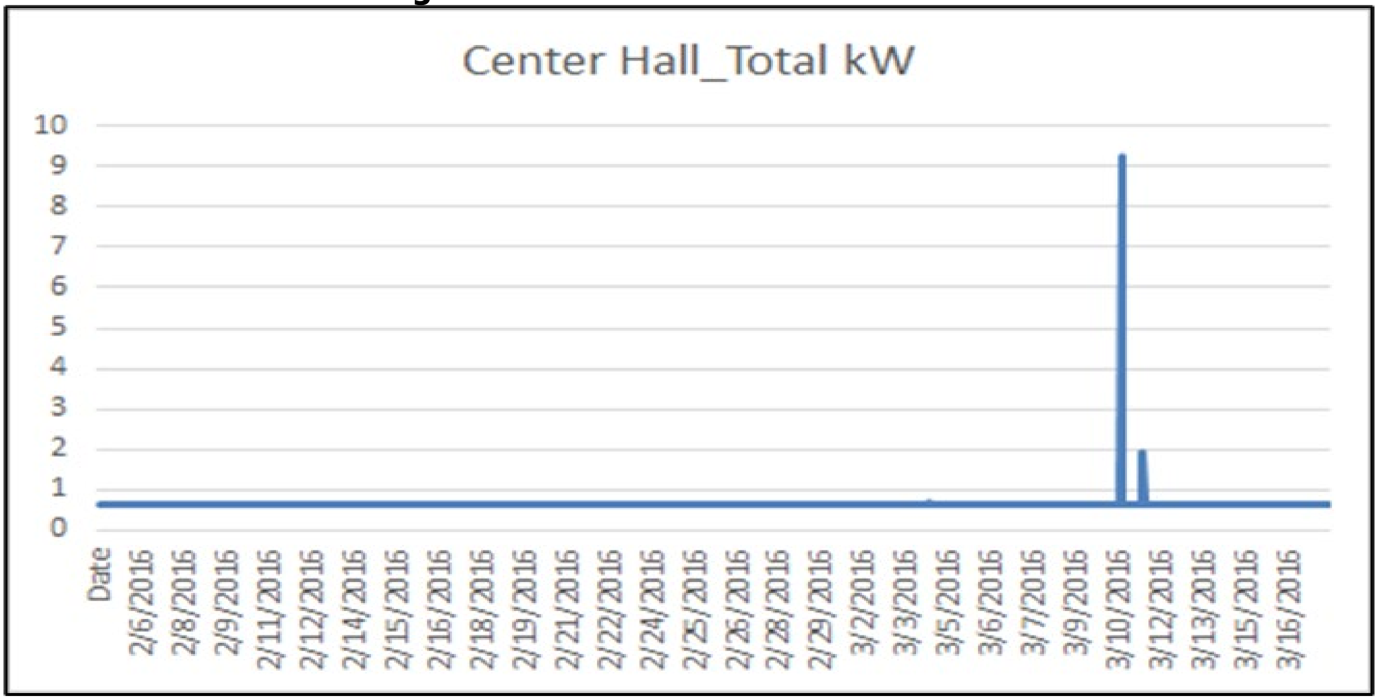
Accounts with kilowatt-hours

Account detail for other EV charging and photovoltaic systems on the same circuit was not provided, therefore no other EV or photovoltaic systems are assumed in this impact analysis.

Kilowatt Peak

Figure 27 below shows the peak demand at Center Hall.

Figure 27: Center Hall Peak Demand



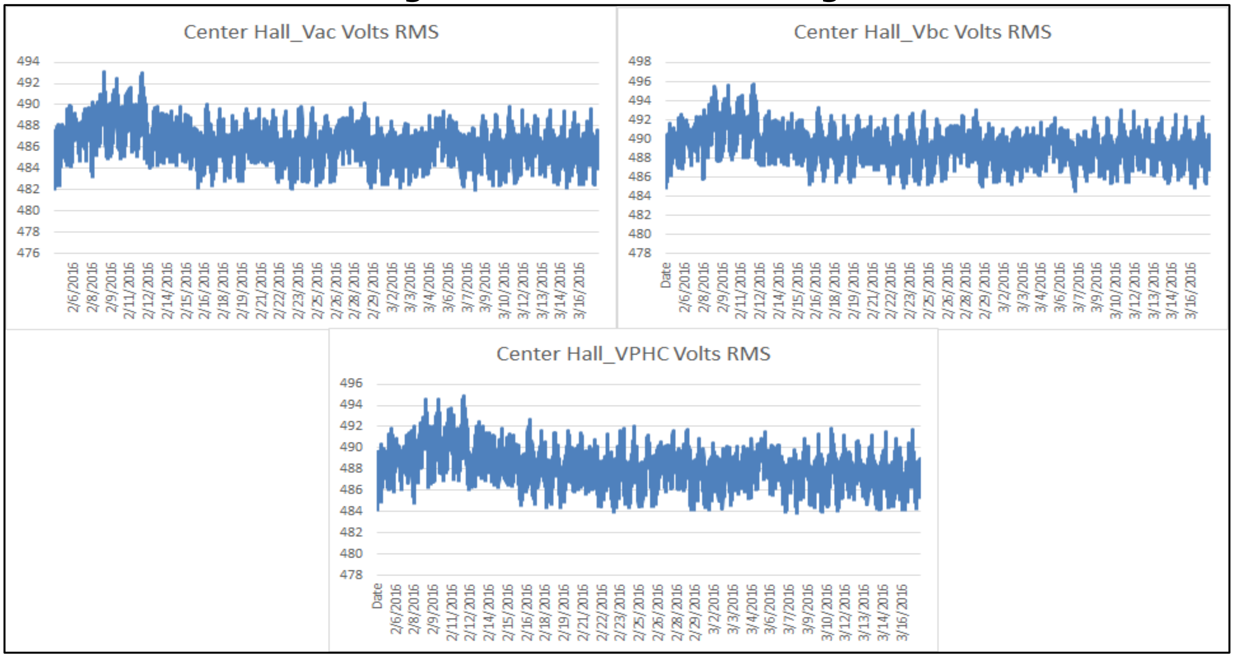
Source: SDG&E

Peak demand is slightly over nine kilowatts on March 10, 2016. The average demand at this point in Center Hall is between six and seven kilowatts. The nine-kilowatt spikes are an indicator of charging events.

Voltage Profile for Center Hall

Figure 28 shows the voltage range at Center Hall.

Figure 28: Center Hall Voltage



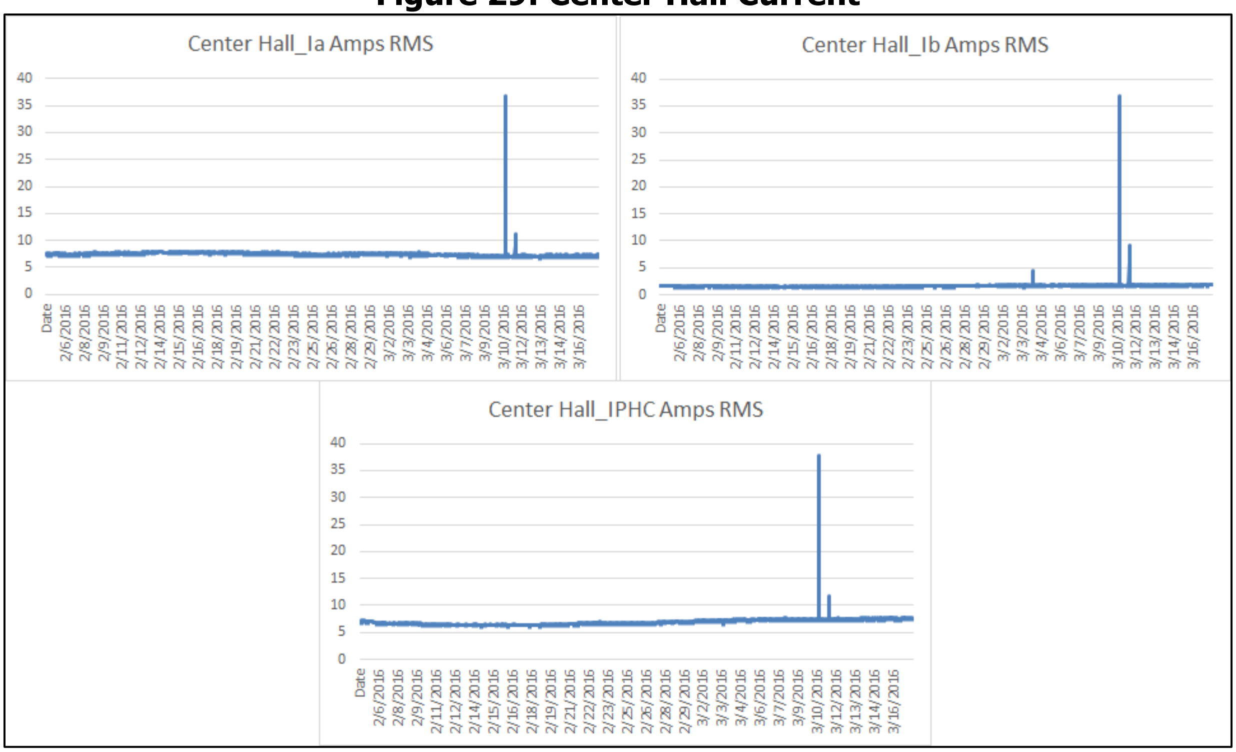
Source: SDG&E

The acceptable voltage range for a nominal 480 volt system is 454 to 504 volts. The voltage profile at Center Hall it's well within this range, and no obvious anomalies take place during the 2 months of data.

Current Profile for Center Hall

Figure 29 shows the current profile for Center Hall.

Figure 29: Center Hall Current



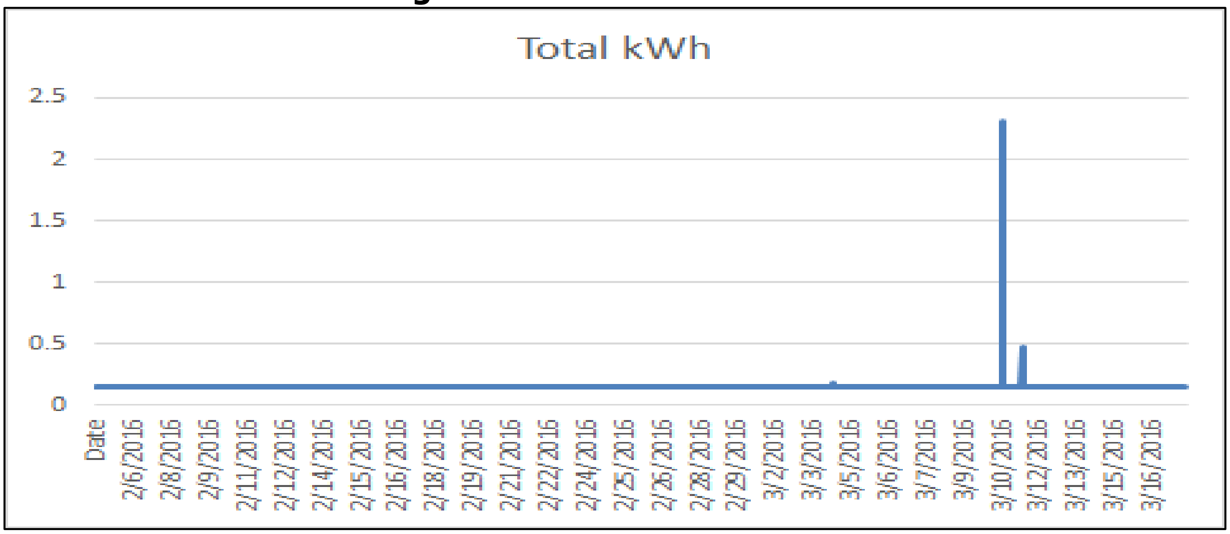
Source: SDG&E

The current profile only shows two prevalent spikes and March 10, 2016 and one on March 11, 2016. The rest of the two months of data see consistent load between five to ten amperes on each of the phases.

Kilowatt Peak

Figure 30 shows the kilowatt hour peak at Center Hall.

Figure 30: Center Hall Power



Source: SDG&E

On March 10, 2016 the total energy draw was about to 2.6 kilowatt hours. It's possible there is another charger on the same circuit that has a different connector other than a Charge de Move connector. That would explain the approximate 10-kilowatt draw, which may indicate a Toyota Prius plug-in or similar EV was charging. The Prius max draw is 11 kilowatts.

Charger #3: Dome (Bubble building)

Feeder ID

Dome is being fed from a 300 kilovolt-amperes transformer at 480 volts, that transformer is being fed from circuits 12 and 15 at 12 kilovolts.

Connected Kilovolt-amperes

Connected kilovolt-amperes cannot be determined for these circuits, there is insufficient information in order to calculate connected kilovolt-amperes.

Connected load

This information was not provided. No load assumption made.

Conductor Impedance

This information was not provided. The system will be assumed to be lossless.

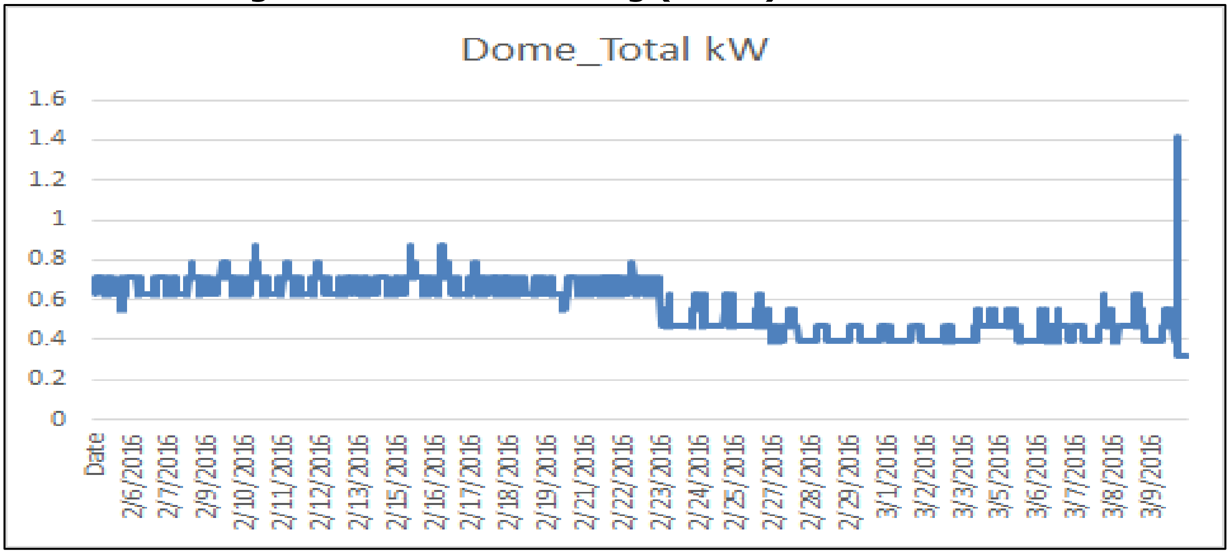
Accounts with kilowatt-hours

Account detail for EV charging and photovoltaic systems. This information was not provided and therefore no other EV or photovoltaic systems will be assumed.

Kilowatt Peak

Figure 31 below shows the kilowatt peak at the Bubble Building (Dome).

Figure 31: Bubble Building (Dome) Peak Demand



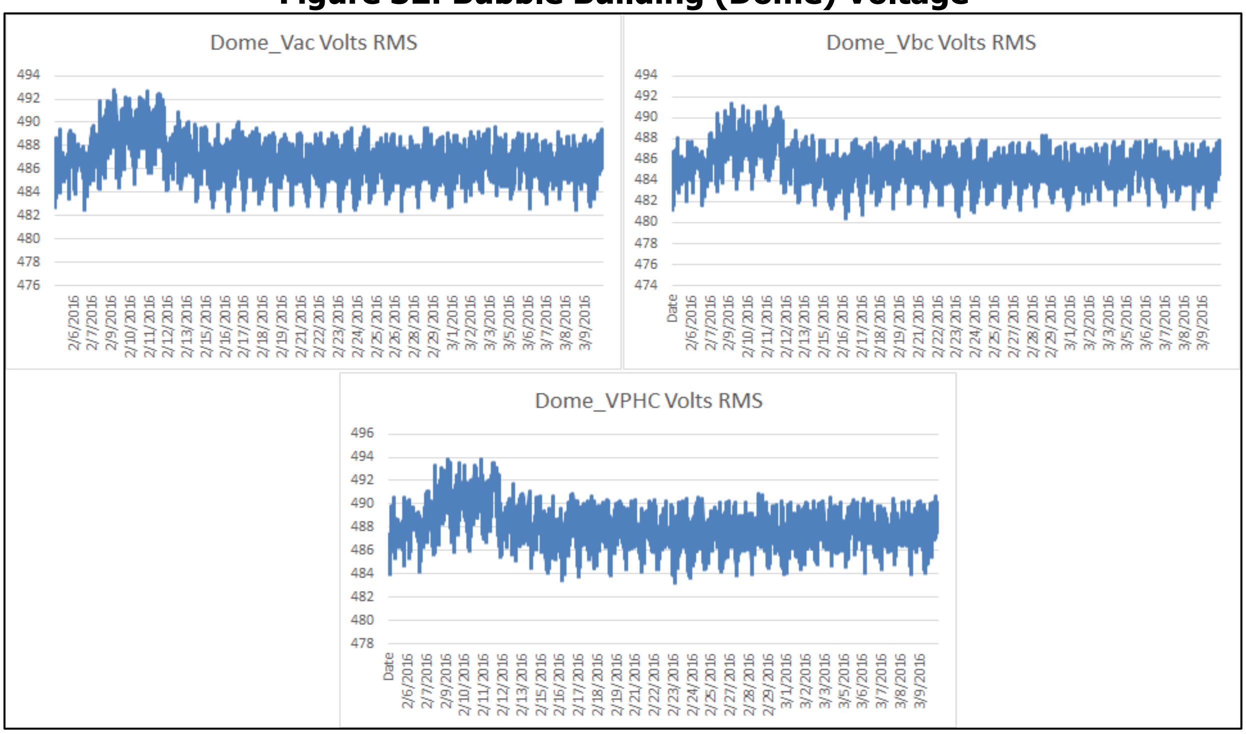
Source: SDG&E

The Dome's maximum kilowatts spiked about 1.4 kilowatts on March 10, 2016 at the end of the monitoring period.

Voltage Profile for the Dome

Figure 32 shows a graph of the voltage used at the Dome.

Figure 32: Bubble Building (Dome) Voltage



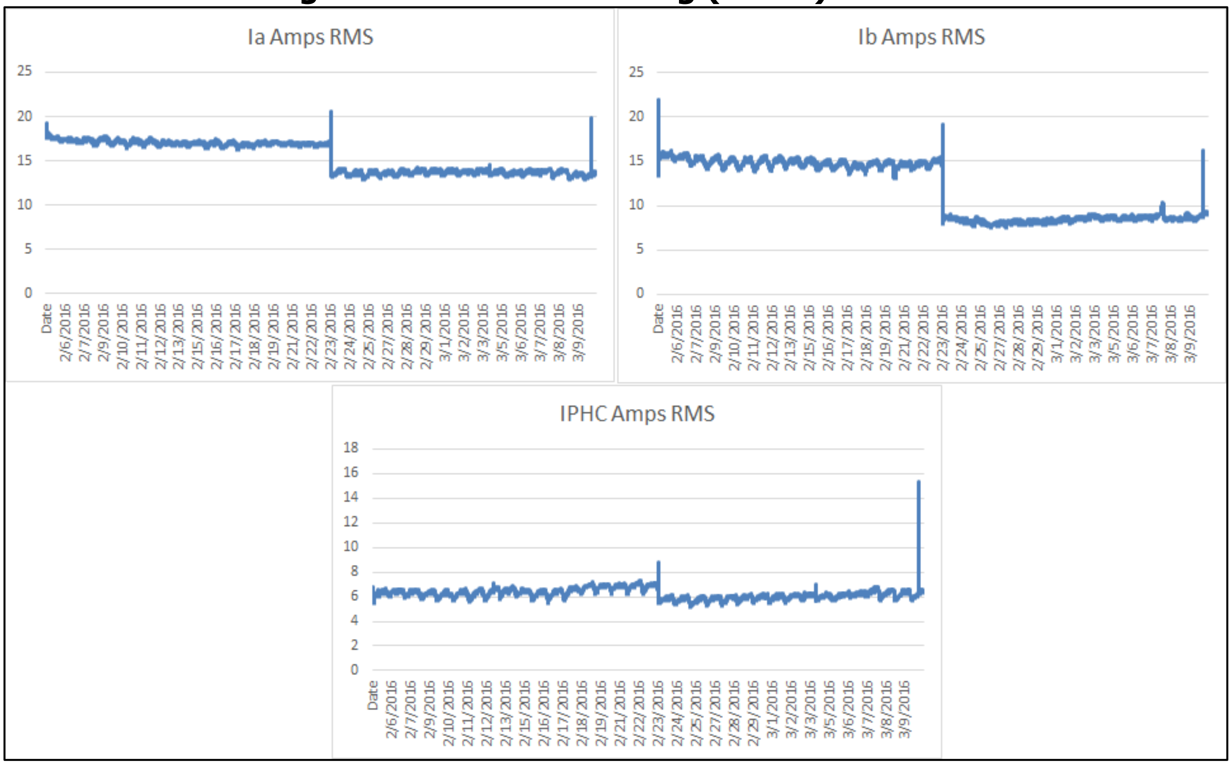
Source: SDG&E

The voltage profile for the Dome ranges between 484 volts and 494 volts.

Current Profile for the Dome

Figure 33 below shows the current profile at the Dome.

Figure 33: Bubble Building (Dome) Current



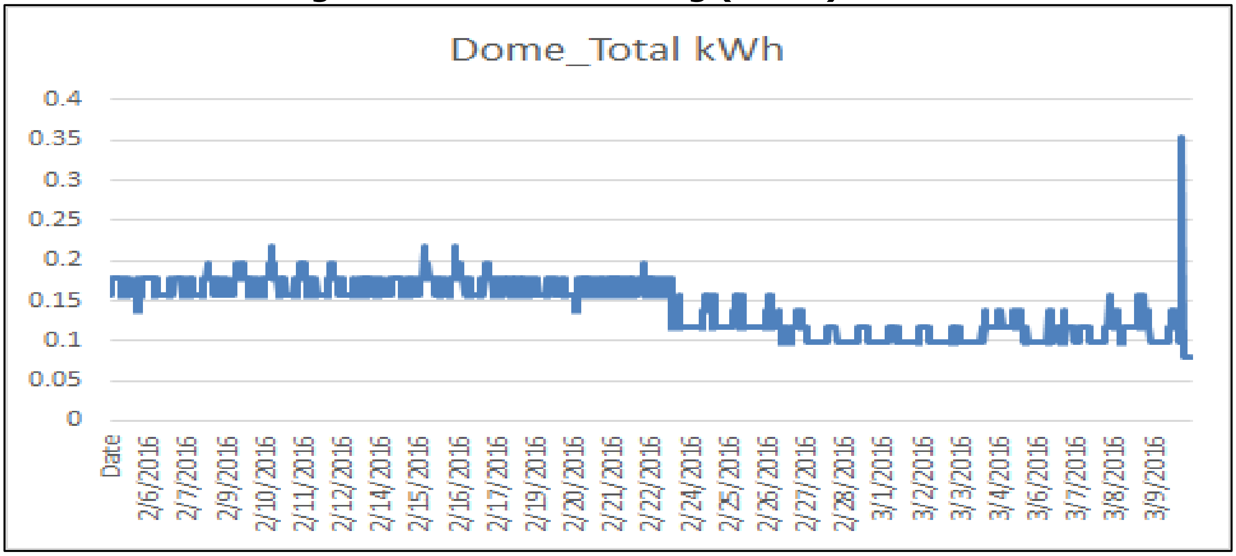
Source: SDG&E

The current profile has an interesting reduction on February 23, 2016. It's difficult to determine what causes drop in load for such a long period of time. Explanation for this phenomenon would require more information. At a glance, it looks like a three-phase constant load was dropped.

Kilowatt hour Peak

Figure 34 shows the peak kilowatt hour at the Dome.

Figure 34: Bubble Building (Dome) Power



Source: SDG&E

This charger seems to have had the least use. 0.35 kilowatt hour in a day for 30 days may represent parasitic station load.

Conclusion

From the provided one-lines we can determine that these DC Fast Chargers do not share the same circuit. Therefore, it is unlikely that the function of one will impact the function of the other or multiple vehicles charging at the same time will affect any of the circuit in a compounding way. P703 has the only charger to draw above 50 amperes, which does not cause adverse capacity impacts.

The demand on each one of these DC Fast Chargers will be dependent on the vehicle themselves. Even with fast DC charging, vehicles throttle down their charging demand below the charger’s maximum output. The power demanded will dependent on the manufacturer, battery state-of-charge, and internal resistance. Reduced power demand is part of the manufactures power management system in an effort to reduce battery capacity reduction.

The voltages for all the chargers were well within the acceptable range. In fact, the voltages seem to stay on the high end. The high voltage could be attributed to photovoltaic on campus. UCSD has several energy storage systems, electric vehicle charging systems end photovoltaic systems. This is known but the information required in order to determine what was happening on the circuits was not available.

GLOSSARY

ALTERNATIVE ENERGY SYSTEMS CONSULTING (AESC)—An energy engineering firm that works on energy efficiency, renewable energy, distributed energy resources, and custom software implementation issues.[2]

CALIFORNIA ENERGY COMMISSION (CEC)—The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy. The Energy Commission's five major areas of responsibilities are:

1. Forecasting future statewide energy needs
2. Licensing power plants sufficient to meet those needs
3. Promoting energy conservation and efficiency measures
4. Developing renewable and alternative energy resources, including providing assistance to develop clean transportation fuels
5. Planning for and directing state response to energy emergencies.

DIRECT CURRENT (DC)—A charge of electricity that flows in one direction and is the type of power that comes from a battery.

ELECTRIC VEHICLE (EV)—A broad category that includes all vehicles that are fully powered by electricity or an electric motor.

ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE)—Infrastructure designed to supply power to EVs. EVSE can charge a wide variety of EVs, including BEVs and PHEVs.

INTERNATIONAL ELECTROCHEMICAL COMMISSION (IEC)—An independent, non-governmental organization that develops voluntary international standards for electric and electronic products, systems and services.[3]

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)—An independent, non-governmental organization with members from standards organizations in 164 member countries. It is the world's largest developer of voluntary international standards and facilitates world trade by providing common standards between nations.[4]

SAN DIEGO GAS & ELECTRIC (SDG&E)—An electric and natural gas utility serving San Diego County and the southern Orange counties.[5]

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2 AESC (https://www.aesc-inc.com/)

3 International Electrochemical Commission (https://www.iec.ch/about/activities/)

4 International Organization for Standardization (https://www.iso.org/about-us.html)

5 San Diego Gas & Electric (https://www.sdge.com/more-information/our-company/about-us)

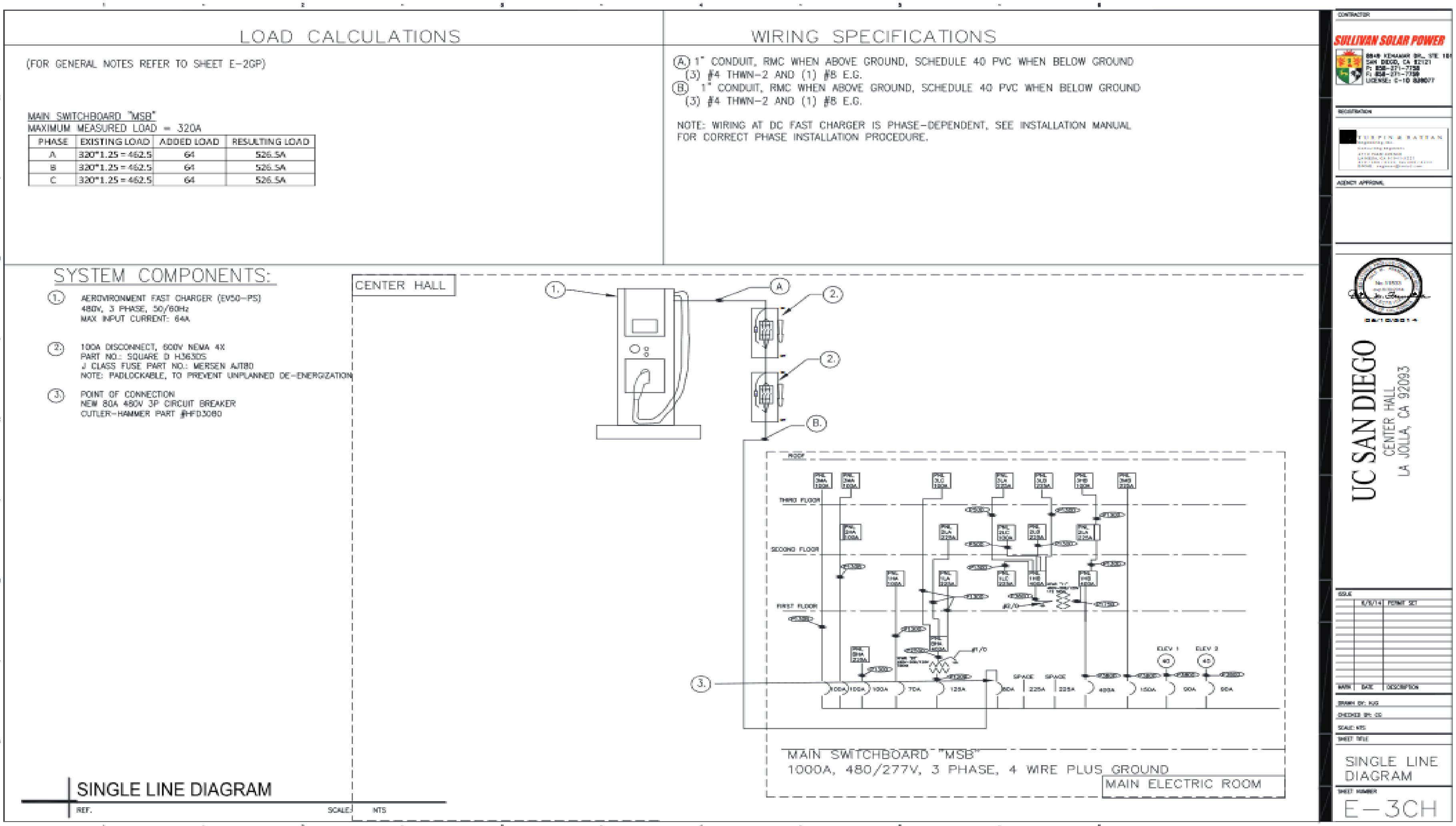
UNIVERSITY OF CALIFORNIA, SAN DIEGO (UCSD)—A public research university located in San Diego, California. It is one of the 10 campuses in the University of California (UC) system.

VEHICLE-TO-GRID (V2G)—A system in which there is a capable of controllable, bi-directional electrical energy flow between a vehicle and the electric grid. The electrical energy flows from the grid to the vehicle in order to charge the battery; it flows in the reverse direction when the grid requires energy.

APPENDIX A:
Single Line Drawings

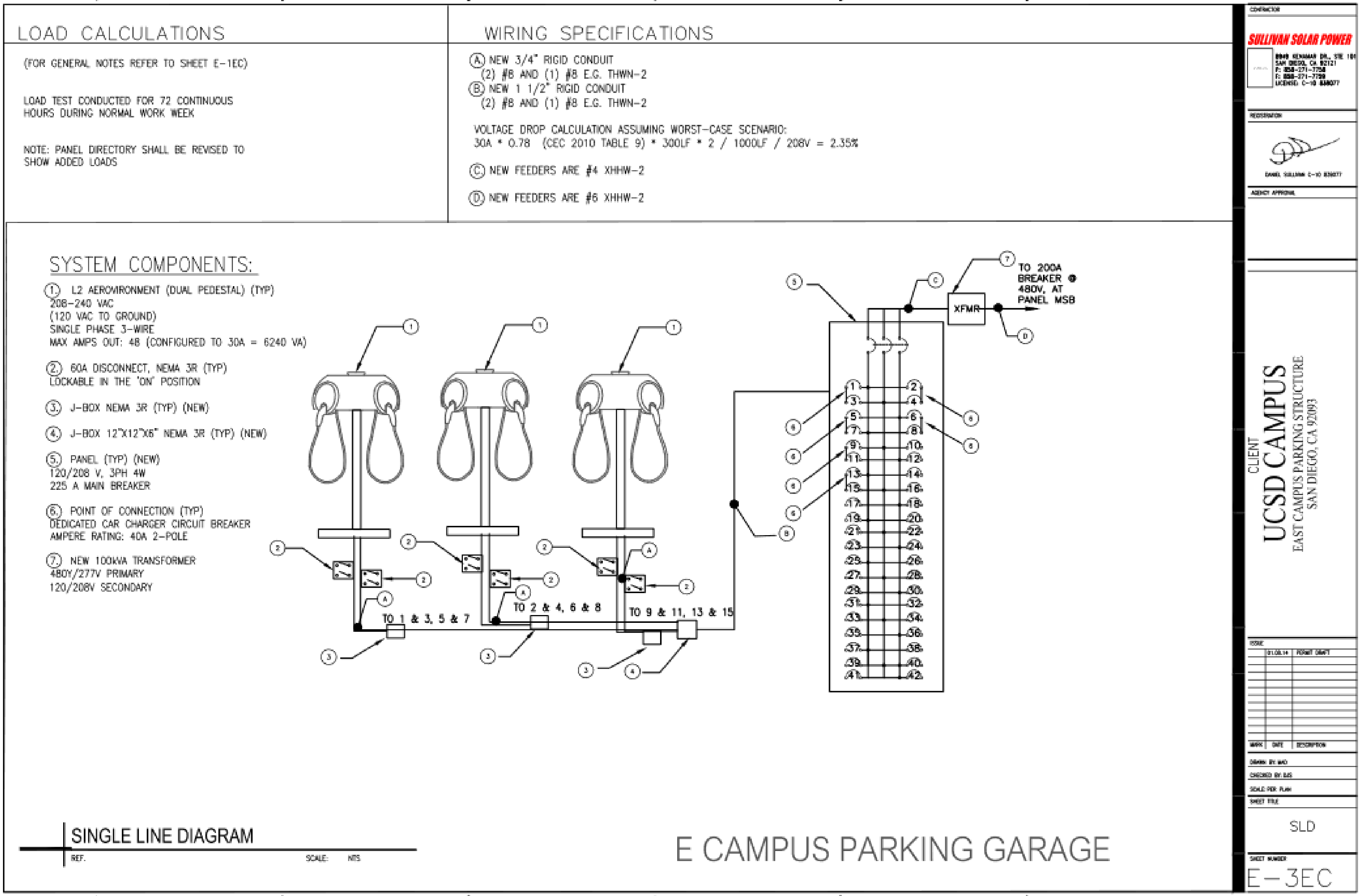
Figure A-1 to A-8 show are of single line drawings created for each of the installation locations.

Figure A-1: Center Hall Single Line Drawing



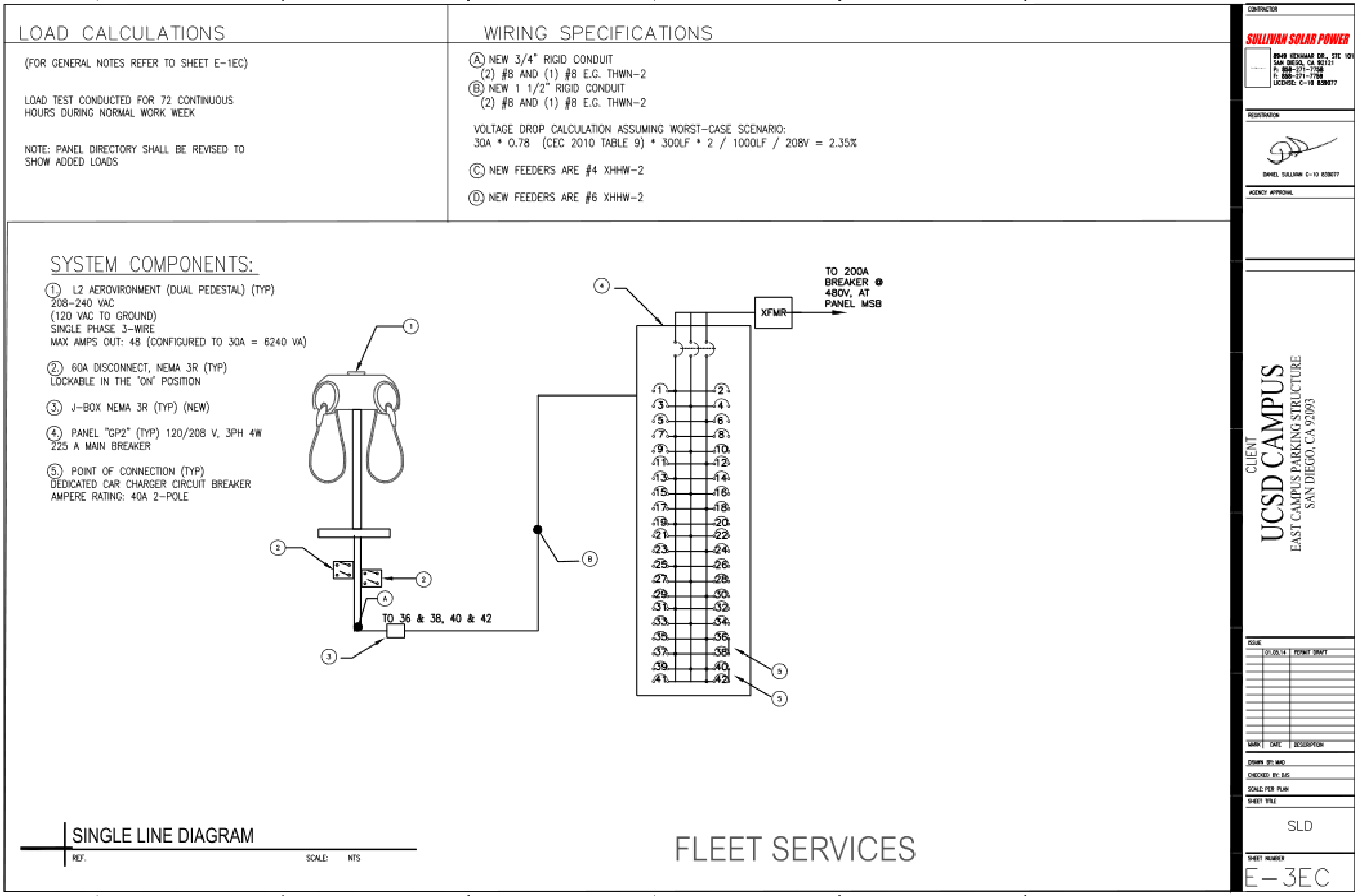
Source: UCSD

Figure A-2: East Campus Public Structure Single Line Drawing



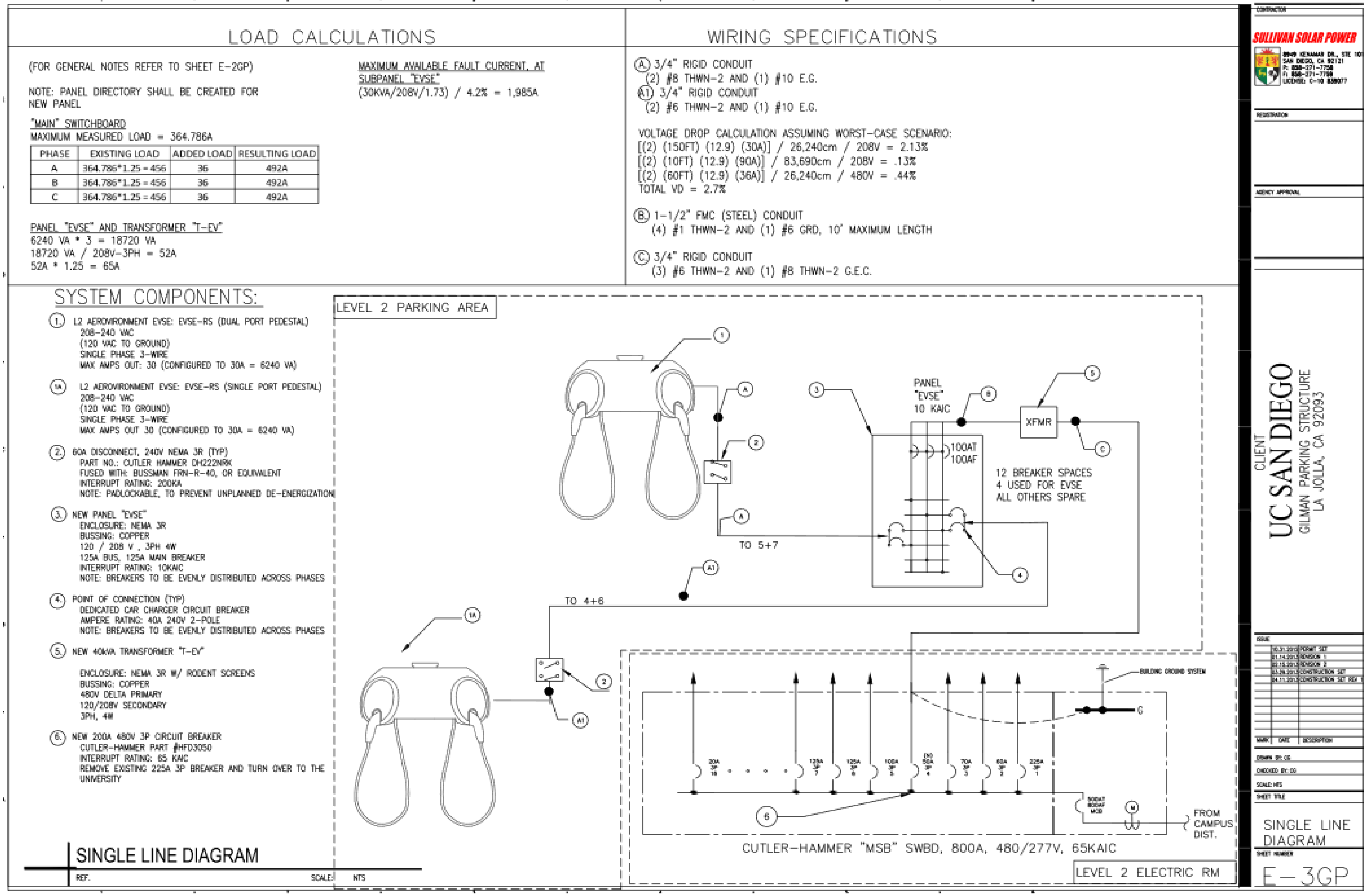
Source: UCSD

Figure A-3: Fleet Services Single Line Drawing



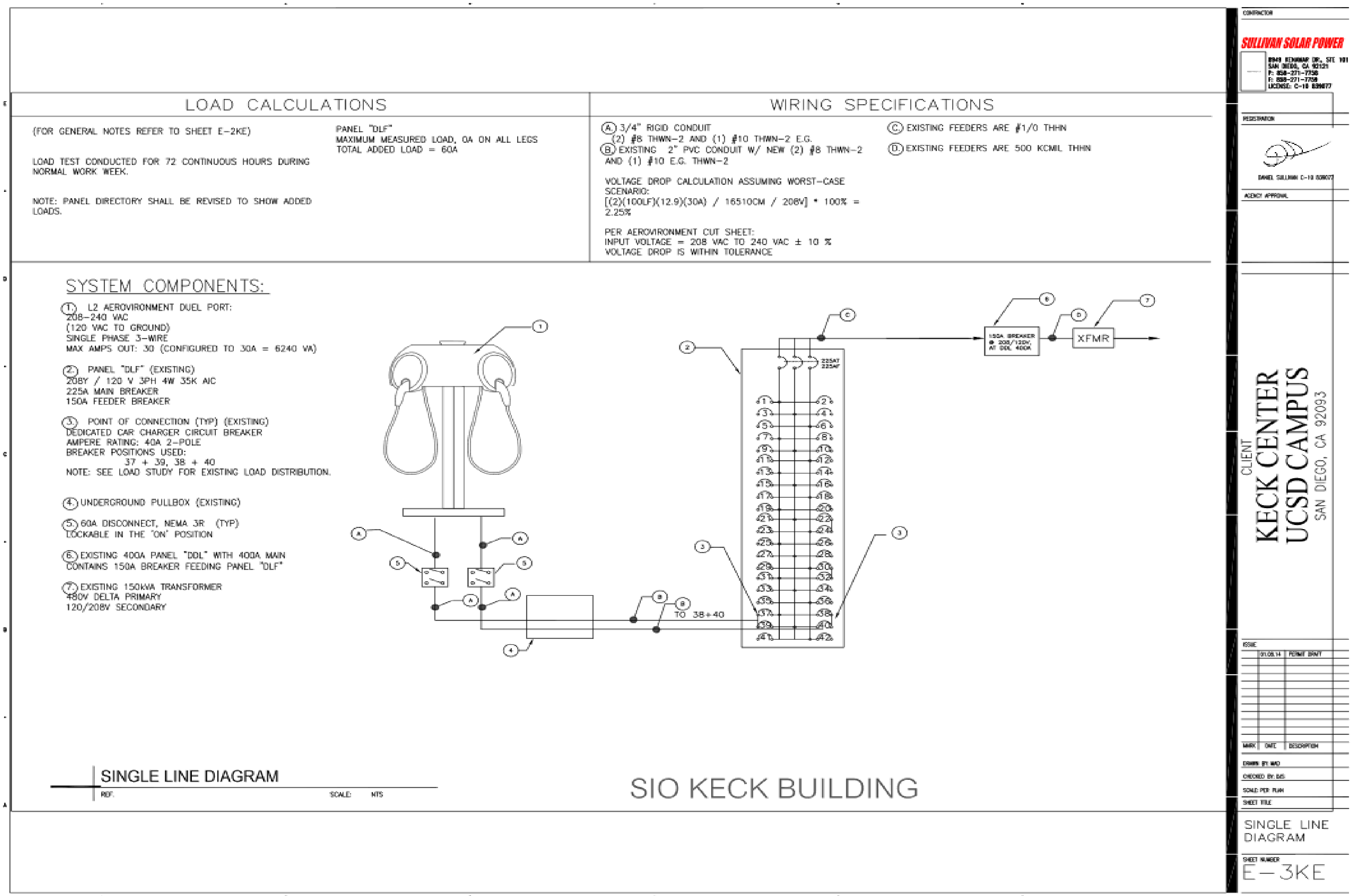
Source: UCSD

Figure A-4: Gilman Parking Structure Single Line Drawing



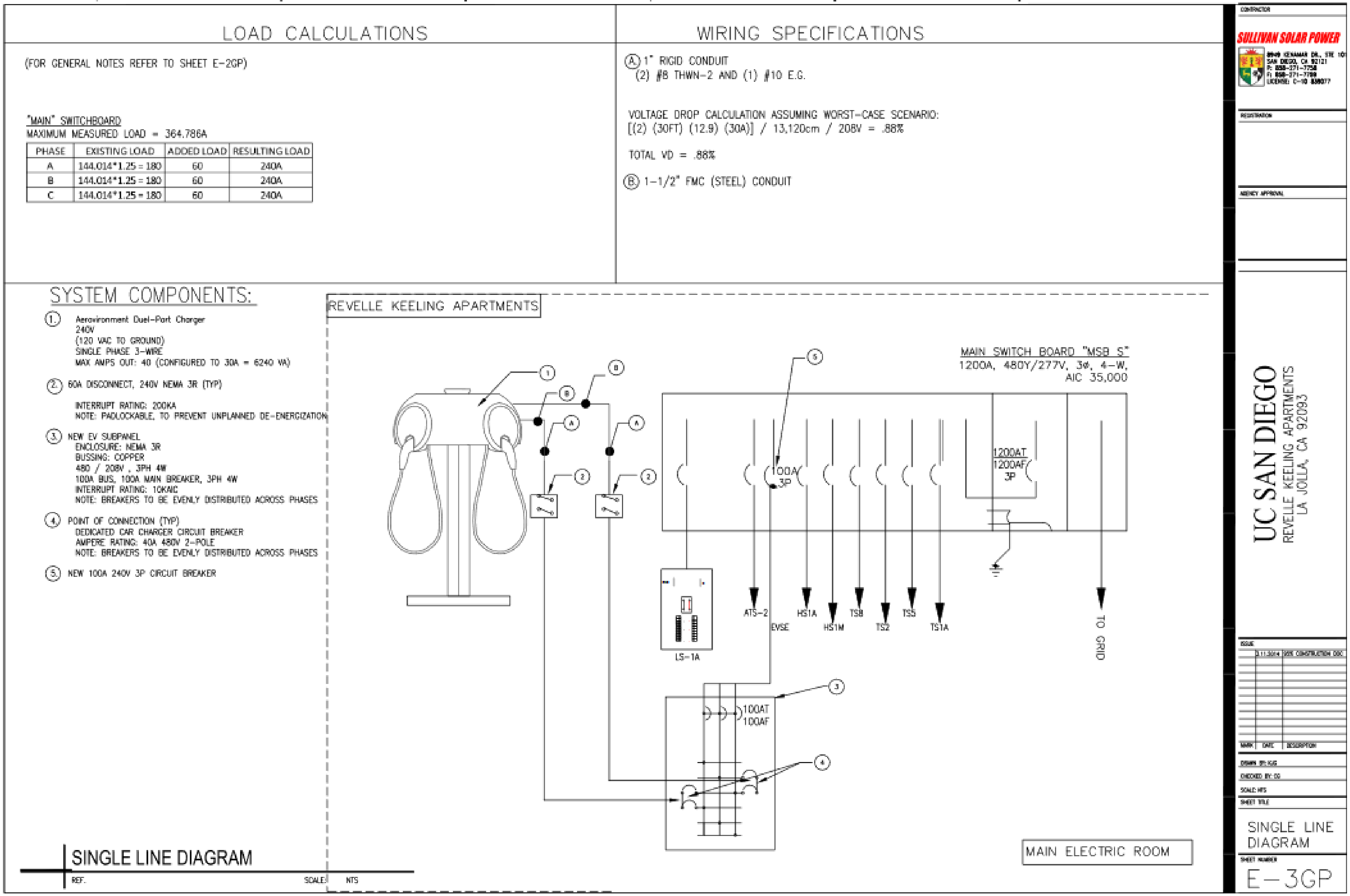
Source: UCSD

Figure A-5: Keck Center Single Line Drawing



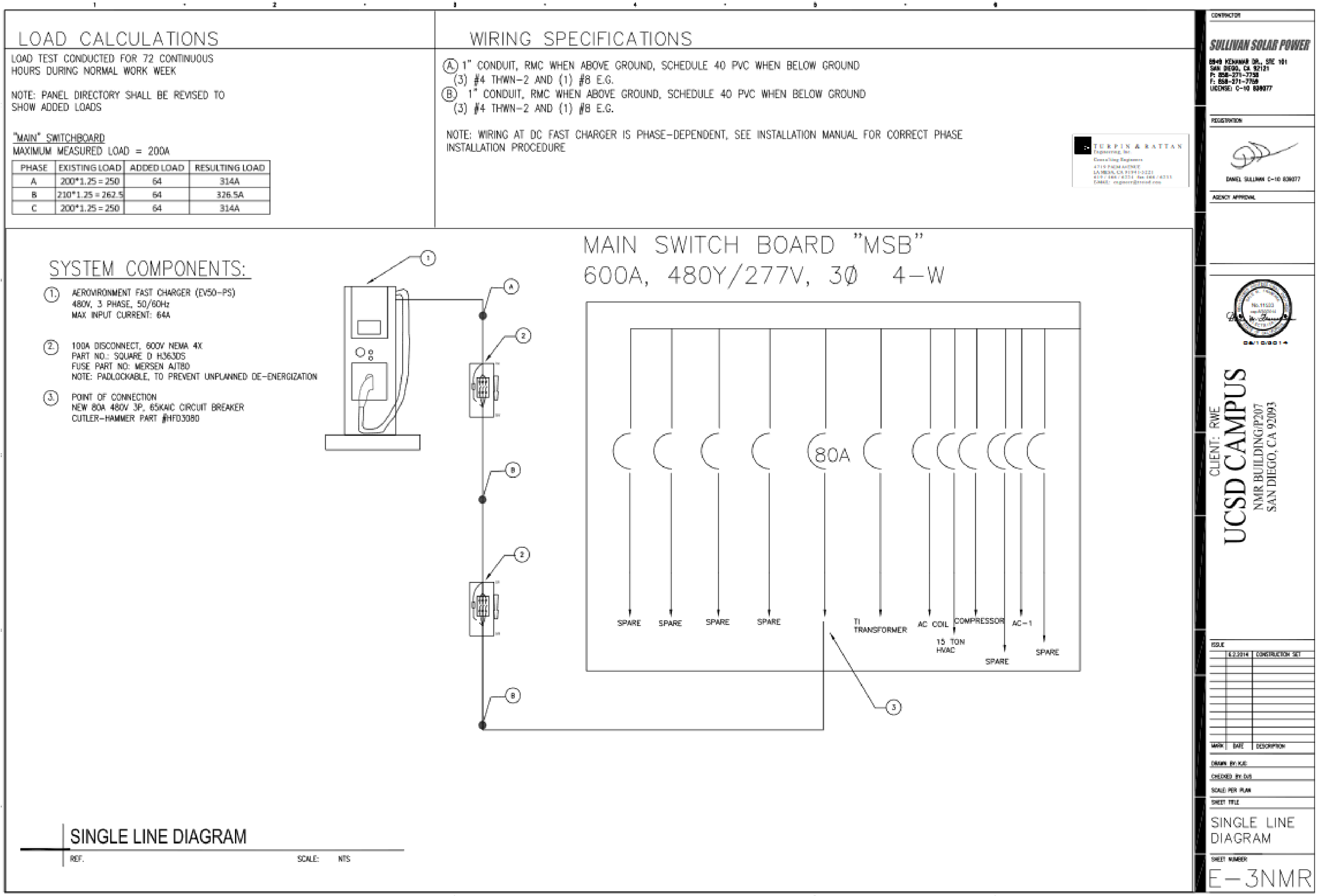
Source: UCSD

Figure A-6: Keeling Apartments Single Line Drawing



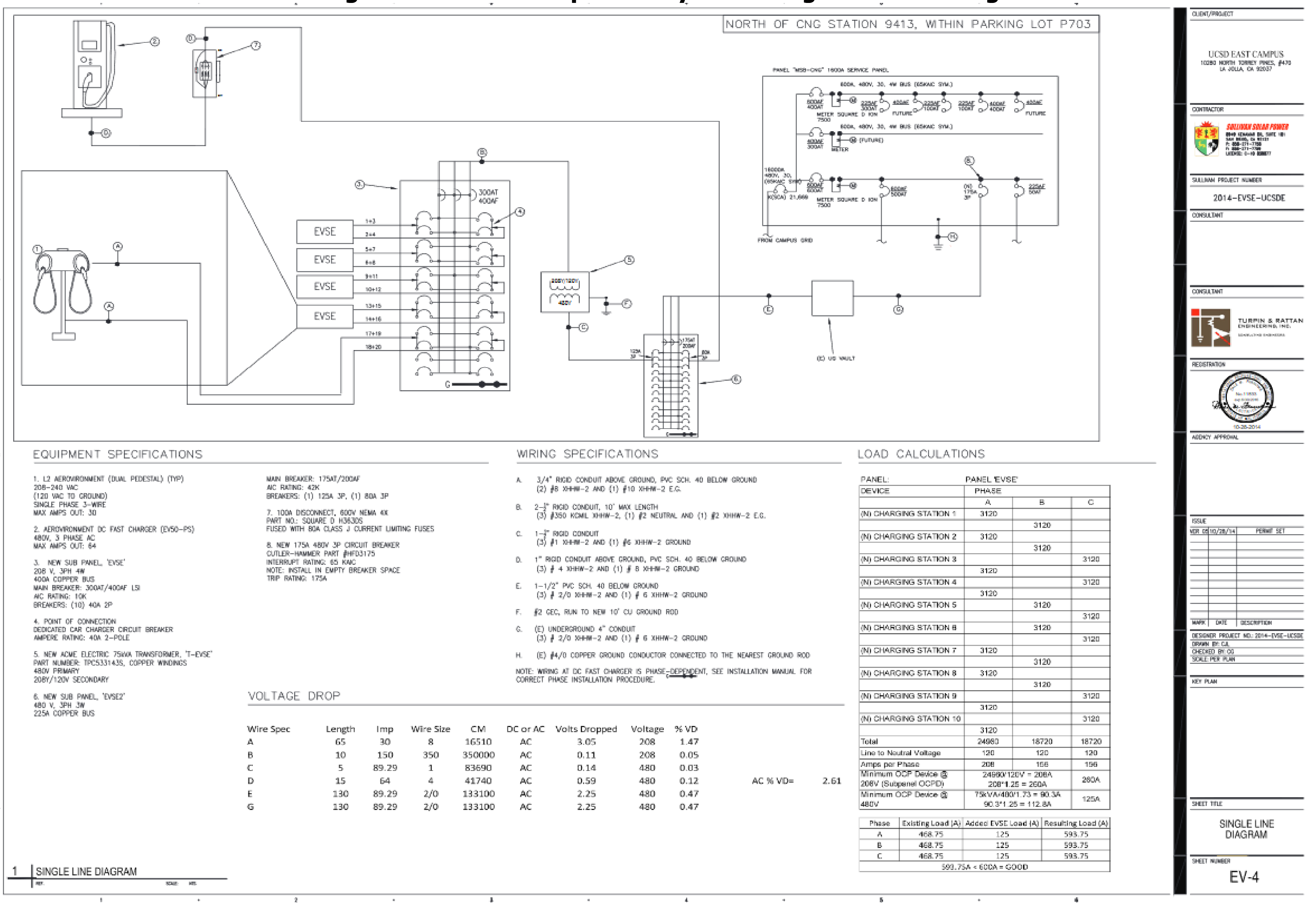
Source: UCSD

Figure A-7: Bubble Building Single Line Drawing



Source: UCSD

Figure A-8: East Campus Utility Plant Single Line Drawing



Source: UCSD