Hawaiian Electric Companies

Electric Vehicle Pilot Rates Report

Annual Report on the Progress and Status of the Commercial Public Electric Vehicle Charging Service Pilot Rates

Transmittal No. 13-07

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Executive Summary

Due to the relatively higher costs to install high-demand electric vehicle charging, Schedule EV-F has experienced limited growth on O`ahu and Hawai`i Island. On the other hand, the JUMPSmart Maui program, a separate program in collaboration with the Hitachi Corporation that provides high-demand electric vehicle charging at a fixed monthly price, has influenced the utilization of Schedule EV-F on Maui. The Companies' own high-demand electric vehicle charging program leveraged under Schedule EV-U, has experienced continued growth in aggregate as the number of installations increase. In 2015, the Companies installed four DC Fast Chargers on O`ahu, at Dole Plantation, Ko`olau Center, Kapolei Commons and Hawai`i Kai 7-Eleven. The Companies saw increasing sales under Schedule EV-U during 2015 and anticipate continued growth into 2016. In 2016, the Companies are planning to install up to seven additional DC Fast Chargers between O`ahu and Hawai`i Island and will begin demonstration of demand response capabilities on O`ahu.

Background

In accordance with Ordering Paragraph 1.C. in the Hawai`i Public Utilities Commission's ("Commission") Decision and Order No. 31338 filed July 1, 2013 in Transmittal Nos. 13-07 and 13-08 (consolidated), the instant 2015 report provides year ending December 31, 2015 information on the status of implementing Commercial Public Electric Vehicle Charging Service Pilot Rates Schedules EV-F and EV-U.

I. Schedule EV-F Tariff

On July 3, 2013, in accordance with Decision and Order No. 31338, the Hawaiian Electric Companies[1] ("Companies") filed their commercial rate Schedule EV-F to be effective July 4, 2013 pursuant to certain terms, including:

1. The rate is applicable only to separately metered commercial public EV charging facilities providing charging services with demand no greater than 100 kW. The facility is limited to no more than 5 kW for ancillary load, such as area lighting.

2. Time-of-use ("TOU") rate periods include Priority-Peak, Mid-Peak, and Off-Peak periods.

Priority-Peak	5:00 p.m. – 9:00 p.m., Monday-Friday
Mid-Peak	7:00 a.m. – 5:00 p.m., Monday-Friday

[1]The Hawaiian Electric Companies are: Hawaiian Electric Company, Inc., Hawai'i Electric Light Company, Inc., and Maui Electric Company, Limited.

	7:00 a.m. – 9:00 p.m., Saturday-Sunday
Off-Peak	9:00 p.m. – 7:00 a.m., Daily

3. The maximum number of accounts is limited to: (A) 100 meters within Hawaiian Electric's service territory; (B) 40 meters within Hawai‘i Electric Light's service territory; and (C) 40 meters within Maui Electric's service territory, consisting of its Lana‘i, Maui, and Moloka‘i Divisions.

4. The five year pilot is effective through June 30, 2018.

Schedule EV-F supports clean energy goals by encouraging "the development of public EV charging facilities by pricing electricity at levels that are lower than Schedule EV-C and Schedule J at lower energy consumption levels for start-up EV public charging operators."[2]

By Decision and Order No. 33165 issued on September 25, 2015, the Commission approved "the Companies' request to terminate Schedule EV-C, as of October 1, 2015" and "suspend[ed] the Companies' request to establish their proposed Schedules TOU EVD, EV-RD, and EV-CD"[3]. Therefore, as of October 1, 2015 Schedule EV-F is the only commercial EV rate available for EV charging services.

[2] Transmittal No. 13-07 at 22.

[3] Docket No. 2015-0342, Decision and Order No. 33165, issued on September 25, 2015, at 36. The Commission subsequently closed Docket No. 2015-0342 with Order No. 33279, filed October 23, 2015, stating "the commission's review and adjudication of the Companies' proposed electric vehicle time-of-use tariff schedules will be undertaken in Docket No. 2014-0192, as part of the commission's consideration of all of the Companies' proposed time-of-use tariff proposal as a whole."

A. Adoption and Status of Schedule EV-F

Tables 1a and 1b, below, provide a breakdown of the number of customer accounts and kilowatt hour (kWh) consumption billed each month on the Schedule EV-F pilot rate for the three Companies. In 2015, there was one additional EV-F account on Hawai`i Island, with no change on other islands.

Table 1a
Schedule EV-F Customers Billed
January – December 2015

Month	O‘ahu	Hawai‘i	Maui
Jan	3	0	2
Feb	3	0	2
Mar	3	1	2
Apr	2	1	2
May	3	1	2
Jun	3	1	2
Jul	3	1	2
Aug	3	1	2
Sep	3	1	2
Oct	3	1	2
Nov	3	1	2
Dec	3	1	2

As reflected in Table 1b, below, a total of 122,391 kWh were billed in the year 2015, supporting electric vehicle charging under Schedule EV-F. The larger average kWh consumption on Maui is attributed to the JUMPSmart Maui program which provides program participants access to the program's DC fast charging stations. Use of their DC fast chargers was free for their participants until 2015. Starting in January 2015, program participants are charged $15 per month while non-participants are charged $30 per month for access to JUMPSmart Maui fast charging stations.[4] The drop in Maui Schedule EV-F consumption after February 2015 may partially be attributed to the introduction of the program's monthly fee.

[4] http://www.jumpsmartmaui.com/electric-vehicles/

Table 1b
Schedule EV-F kWh Billed
January – December 2015

Month	O'ahu	Hawai'i	Maui	Total
Jan	345	0	11,454	11,799
Feb	630	0	12,829	13,459
Mar	1,320	107	5,537	6,964
Apr	1,621	93	8,150	9,864
May	1,262	90	8,002	9,354
Jun	1,117	97	9,077	10,291
Jul	1,000	124	8,435	9,559
Aug	723	60	9,893	10,676
Sep	1,300	166	9,021	10,487
Oct	1,391	190	9,174	10,755
Nov	1,251	112	8,150	9,513
Dec	1,218	152	8,300	9,670
TOTAL	13,178	1,191	108,022	122,391

The average billed kWh per customer account is provided in Table 1c, below. The larger average kWh consumption on Maui is attributed to the JUMPSmart Maui program, which provides users unlimited access to the program's DC fast charging stations for either $15 or $30 per month, depending on program participation. Assuming an EV owner travels the average annual vehicle miles on Maui and obtains all of their charging needs from the JUMPSmart Maui program, this equates to an effective electricity rate of either $0.07 or $0.14 per kilowatt hour [5] which is extremely cost-competitive when compared to similar fast charging options under the Schedule EV-U rate, or other charging options at the driver's residence.

[5] This calculation assumes an electric fuel economy of a 2016 Nissan Leaf S (3.5 miles per kilowatt hour) and utilizes the 2014 average vehicles miles for Maui Count (8,919 miles) from the State of Hawai`i Department of Business, Economic Development and Tourism "Data Book", Table 18.17. http://dbedt.hawaii.gov/economic/databook/data_book_time_series/

Table 1c
Schedule EV-F Average kWh Billed per Account
January – December 2015

Month	O'ahu	Hawai'i	Maui	Combined
Jan	115	0	5,727	2,360
Feb	210	0	6,415	2,692
Mar	440	107	2,769	1,161
Apr	811	93	4,075	1,973
May	421	90	4,001	1,559
Jun	372	97	4,539	1,715
Jul	333	124	4,218	1,593
Aug	241	60	4,947	1,779
Sep	433	166	4,511	1,748
Oct	464	190	4,587	1,793
Nov	417	112	4,075	1,586
Dec	406	152	4,150	1,612
ANNUAL	377	119	4,501	1,774

Table 1d below provides a breakdown of Schedule EV-F consumption in each time-of-use ("TOU") period for each territory in 2015. Throughout the Companies' territories, 17% of the energy was consumed during the Priority-Peak, 68% in the Mid-Peak, and 15% in the Off-Peak. Currently, the Companies are not aware of any of the Schedule EV-F customers extending a TOU fee to their customers.

Table 1d
Schedule EV-F Billed kWh Consumption by TOU Period
January – December 2015

Territory	Priority	Mid	Off
O'ahu	2,127	8,342	2,709
Hawai'i	206	741	244
Maui	18,660	74,358	15,004
TOTAL	20,993	83,441	17,957
PERCENTAGE	17%	68%	15%

B. Summary of Cost and Revenue

Table 2 presents a breakdown of the revenue generated each month from Schedule EV-F for the three Companies. In 2015, $44,036.97 in revenue was generated from customers under the Schedule EV-F Pilot rate.

Table 2
Schedule EV-F Revenues
January – December 2015

Month	O‘ahu	Hawai‘i	Maui	Total
Jan	$ 140.47	$ -	$ 4,725.18	$ 4,865.65
Feb	$ 236.03	$ -	$ 4,952.88	$ 5,188.91
Mar	$ 462.24	$ 47.69	$ 1,914.52	$ 2,424.45
Apr	$ 548.74	$ 40.92	$ 2,780.35	$ 3,370.01
May	$ 436.57	$ 38.99	$ 2,800.72	$ 3,276.28
Jun	$ 379.62	$ 41.49	$ 3,239.58	$ 3,660.69
Jul	$ 349.83	$ 53.27	$ 3,091.01	$ 3,494.11
Aug	$ 257.20	$ 28.29	$ 3,653.85	$ 3,939.34
Sep	$ 446.45	$ 69.39	$ 3,263.85	$ 3,779.69
Oct	$ 473.89	$ 76.59	$ 3,173.13	$ 3,723.61
Nov	$ 412.34	$ 46.36	$ 2,697.36	$ 3,156.06
Dec	$ 399.24	$ 60.25	$ 2,698.68	$ 3,158.17
TOTAL	$ 4,542.62	$ 503.24	$ 38,991.11	$ 44,036.97

Incremental costs to support Schedule EV-F, including cost to enroll and bill customers, are de minimis.

C. Subsidization by non-participating ratepayers

The Companies defined rate Schedule EV-F such that "[w]hen monthly consumption exceeds around 5,000 kWh on a regular basis, the public EV charging facility may be considered large enough such that it no longer needs rate tariff support."[6] This is because EV-F is structured in such a way that energy usage beyond 5,000 kWh on a regular basis no longer is cost competitive with other rate schedules, such as Schedule J. As provided in Table 1c above, the monthly average billed kWh for most accounts remains below 5,000 kWh per month; thus the Companies believe Schedule EV-F is still needed to further support the adoption of electric transportation.

Table 3 below summarizes the total monthly revenue generated from Schedule EV-F at all Companies compared to the potential revenue generated if the charging facility were billed under each Companies' respective Schedule J, General Service Demand rate. The potential Schedule J[7] revenue provided in Table 3 is calculated based on an assumed monthly billing demand of 47.5 kW[8]. The total potential Schedule J revenue in excess of Schedule EV-F revenue for the year 2015 was $30,047.80.

Table 3
Schedule EV-F to Schedule J Revenue Comparison
January – December 2015

Month	Total Schedule EV-F	Potential Schedule J	Difference
Jan	$ 4,865.65	$ 6,865.34	$ 1,999.69
Feb	$ 5,188.91	$ 6,404.67	$ 1,215.76
Mar	$ 2,424.45	$ 5,700.87	$ 3,276.42
Apr	$ 3,370.01	$ 5,140.35	$ 1,770.34
May	$ 3,276.28	$ 6,012.75	$ 2,736.47
Jun	$ 3,660.69	$ 6,205.32	$ 2,544.63
Jul	$ 3,494.11	$ 6,309.67	$ 2,815.56
Aug	$ 3,939.34	$ 6,506.05	$ 2,566.71
Sep	$ 3,779.69	$ 6,622.81	$ 2,843.12
Oct	$ 3,723.61	$ 6,429.86	$ 2,706.25
Nov	$ 3,156.06	$ 5,923.25	$ 2,767.19
Dec	$ 3,158.17	$ 5,963.83	$ 2,805.66
TOTAL	$ 44,036.97	$ 74,084.77	$ 30,047.80

[6] Transmittal No. 12-05, filed October 26, 2012, at 22.
[7] Schedule J, General Service Demand, is applicable to services which exceed 5,000 kWh per month or exceed 25 kW three times within a twelve month period but are less than 300 kW per month, and supplied through a single meter. The demand charge for Schedule J is $11.69 per kW billing demand.
[8] A typical DC fast charging station is capable of up to 50 kW output. The duration of this maximum output is variable and based upon the battery state of charge.

Despite this difference in revenue from Schedule J, the implementation of Schedule EV-F is meant to support the development of EV charging infrastructure, which may otherwise be uneconomical for customers to install under a pre-existing tariff. Per Transmittal No. 13-07, "[r]evenues from Schedule EV-F are expected to be generated from incremental or new kWh sales. All of the kWh sales under this schedule are expected to generate a positive contribution toward fixed costs, including any sales during off-peak charging hours. ... In this manner, all customers will benefit from any kWh sales under these rates."[9]

[9] Transmittal No. 13-07, filed June 3, 2013, at 19.

D. Recommendation of revisions to rate structures

The Hawaiian Electric Companies continue to see a need to support high demand charging. Other than the DC fast charging stations installed by the Company under Schedule EV-U and JUMPSmart Maui, there has been limited growth of high demand charging facilities. Notwithstanding this limited growth, there are clear industry indicators of customer need and interest. Indeed, a recent study found that fast charging was key to EV adoption "fast chargers, which can charge car batteries in as little as 30 minutes, make up about 3 percent of the more than 12,000 public chargers now available in the U.S. Though fast chargers represent only a fraction of available chargers, nearly half of all drivers with long-range battery electric vehicles reported having used a quick charger in the past 30 days, as well as about one-third of mid-range EV drivers."[10] This is supported by an EV network operator's survey finding, "[w]hen comparing the number of DC fast-charging session to Level 2 session, it found drivers preferred fast charging 12 to 1."[11] [12]

The Companies continue to view Schedule EV-F as an appropriate mechanism to encourage development of public charging facilities. As the Companies stated when proposing pilot Schedule EV-F, "[t]ogether, the absence of a demand charge and the inclusion of time-of-use rates serve to encourage the development of public EV charging facilities by keeping electricity costs low for new, start-up public EV charging facilities."[13] In absence of any other EV commercial rate, Schedule EV-F is still needed to support the growth of high demand charging facilities by removing the billing demand charge for electric service for EV charging.

Notably, a report prepared by Idaho National Laboratory ("INL") concluded that "Demand charges associated with 50 to 60-kW high power charging of a direct current (DC) fast charger (DCFC) can have a significant impact on a business' monthly electric utility bill."[14] Table 1c above shows the average Schedule EV-F monthly energy consumption is typically lower than 5,000 kWh. These customers were provided an incentive to provide fast charging facilities through relief of potential demand charges which would have otherwise been assessed by Schedule J.

The Companies will continue to evaluate the effectiveness of Schedule EV-F and consider the alignment of TOU rates as rate changes are approved.

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[10] "Fast Charging Key to Electric Vehicle Adoption, Study Finds", http://www.greentechmedia.com/articles/read/fast-charging-key-to-electric-vehicle-adoption-study-finds, November 17, 2013

[11] "Electric-Car Drivers Will Pay For DC Fast-Charging 12-to-1 Over Level 2", http://www.greencarreports.com/news/1100804_electric-car-drivers-will-pay-for-dc-fast, November 9, 2015

[12] DC fast charging can charge a depleted EV battery to about 80% capacity (about 65 miles) in 30 minutes. Level 2 charging can provide between 12-25 miles for every hour charged. DC fast charging can provide up to 50 kW during a charging session. Level 2 chargers are typically single phase, 240 Volts (AC) and can range from 3.3 kW to 6.6 kW.

[13] Transmittal No. 12-05, filed October 26, 2012, at 23.

[14] "What is the Impact of Utility Demand Charges on a DCFC Host?", https://avt.inl.gov/sites/default/files/pdf/EVProj/EffectOfDemandChargesOnDCFCHosts.pdf, June 2015

Decision and Order No. 31338 requires that the Companies "determine and recommend any revisions to the applicable rate structures that are necessary to: (A) meet the objectives of sufficiently addressing "range anxiety" among EV end-users and conducting the Companies' research, development, and demonstration activities related to EV charging technologies and load control; and (B) minimize the level or extent of subsidization by non-participating ratepayers."[15]

1. Addressing range anxiety

   As provided above, the EV industry believes high demand charging is essential to support the EV adoption and meet driver's needs. Even if public Level 2 charging stations are available, EV drivers will often still use DC fast charging stations. Schedule EV-F supports high demand charging facilities by alleviating potential impacts of demand billing charges. Therefore, as this nascent market continues to develop, the Hawaiian Electric Companies do not recommend any revisions to Schedule EV-F at this time.

2. Conducting research, development, and demonstration activities related to EV charging technologies and load control

   The Hawaiian Electric Companies do not recommend any revisions to Schedule EV-F at this time. New technologies and load control for DC fast charging will first be demonstrated on Company-operated DC fast charging stations under Schedule EV-U.

3. Minimize the level of extent of subsidization by non-participating ratepayers

   Per Transmittal No. 13-07, "Schedule EV-F encourages the development of public EV charging facilities by pricing electricity at levels that are lower than Schedule EV-C and Schedule J at low energy consumption levels for start-up EV public charging operators. As an EV charging facility's business volume grows such that the EV public charging facility operator no longer needs rate tariff support, the EV charging facility operator can elect to change to an alternative commercial demand rate tariff."[16] To support continued development of public EV charging, and because the administration of Schedule EV-F requires minimal labor, the Hawaiian Electric Companies do not recommend any revisions to Schedule EV-F at this time.

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[15] Transmittal No. 13-07, filed July 1, 2013, at 41
[16] Transmittal No. 13-07, filed June 3, 2013, at 22.

II. Schedule EV-U Tariff

On July 3, 2013, in accordance with Decision and Order No. 31338, the Hawaiian Electric Companies filed their commercial rate Schedule EV-U to be effective July 4, 2013 pursuant to certain terms, including:

1. Company-operated public charging facilities are based upon a fee-per-charge session.

2. Per session fees during the Priority-Peak and Off-Peak periods are set no more than $0.50 above and $0.50 below the Mid-Peak fee, respectively.

3. The maximum, aggregate amount of Company facilities will be twenty-five (25).

4. The Company may curtail charging of electric vehicles under certain circumstances.

5. The five year pilot is effective through June 30, 2018.

Schedule EV-U is intended to support the EV market by allowing the Companies to install and operate public EV charging facilities in strategic locations to address range anxiety, support the rental EV market, and increase EV acceptance by residents in multi-family dwellings.

A. Adoption and Status of Schedule EV-U

Hawaiian Electric Highlights

In 2015, Hawaiian Electric opened its first DC fast charging station and installed three additional stations at strategic public sites around O'ahu. These four locations were targeted to support the Company's position that "the adoption of EVs in the State of Hawai`i may be facilitated by locating some Company-operated Schedule EV-U DC fast charging facilities in areas lacking EV charging infrastructure to help address range anxiety."[17]

- In June 2015, the first DC fast charging station was opened at Dole Plantation. This charging station is in central O'ahu providing fast charging service to EV drivers traveling to and from North O'ahu. North O'ahu currently has limited public charging infrastructure, as illustrated in the charging maps provided in Attachment A of this report.
- In October 2015, a second DC fast charging station was made available at Ko`olau Center, providing a fast charging station on a main arterial road to North O'ahu from the windward side of the island.
- In November 2015, a DC fast charging system with an integrated battery energy storage system ("BESS") was placed in service at Kapolei Commons, providing fast charging services to West O'ahu.
- In December 2015, a DC fast charging station opened at a 7-Eleven in Hawai`i Kai, along Hawai`i Kai Drive and near many multi-unit dwellings ("MUDs").

As stated in the jointly signed Transmittal No. 13-07, the "Companies will competitively bid for Schedule EV-U EV fast charging system[s]."[18] Selecting different types of equipment and network providers gives the Company the ability to better understand the market needs and the capabilities of various equipment and services. The equipment and network for the charging stations at Dole Plantation, Ko`olau Center, and Hawai`i Kai 7-Eleven are provided by OpConnect. These charging stations support both CHAdeMO[19] and SAE J1772 combo[20] connectors. The charging station at Kapolei Commons is a 50 kW CHAdeMO-only charging station with a 12 kWh integrated BESS, which was provided by VLI-EV Partners and the network provided by Greenlots. In conjunction with the Electric Power Research Institute ("EPRI"), Hawaiian Electric will be demonstrating the effectiveness of battery storage to alleviate potential grid and customer demand impacts at this location.

[17] Transmittal No. 13-07, For Approval to Establish Schedule EV-F – Commercial Public Electric Vehicle Charging Facility Service Pilot, and Schedule EV-U – Commercial Public Electric Vehicle Charging Service Pilot, Filed June 3, 2013, at 10.

[18] Transmittal No. 13-07, filed June 3, 2013, at 14

[19] CHAdeMO Compatible EV manufacturers include, but are not limited to Honda, Kia, Mitsubishi, Nissan, Tesla http://www.chademo.com

[20] SAE International's J1772 "combo connector" is currently support by, but not limited to BMW, Ford, General Motors, and Volkswagen.
http://articles.sae.org/11005/

Building off of the work done in conjunction with EPRI at Kapolei Commons in 2015, Hawaiian Electric issued a RFP for a 50 kW charging station and for development of demand response capabilities during a DC fast charging session. While the RFP defined nine use cases, the RFP only required the development and demonstration of four use cases. The RFP was awarded to Greenlots. In conjunction with Greenlots and EPRI, these four use cases will demonstrate the ability to set the maximum charging output to 25 kW without driver intervention. This project will demonstrate the feasibility to curtail up to 25 kW of charging load while still providing an EV with a charge rate exceeding J1772 Level 2. The charging station to incorporate this functionality will be opened in March, 2016 at Hawaiian Electric's main office on Ward Avenue. After the initial effort, Hawaiian Electric will begin demonstration of the remaining six defined use cases, including opt-out and under frequency support as well as demand response capability on Company fleet vehicles at the Ward location.

These demonstration projects are consistent with the Companies' strategy "to test EV charging systems from various vendors and test different technologies that show promise for load control and for EV charging purposes."[21]

Hawai'i Electric Light Highlights

In 2015, Hawai'i Electric Light purchased three DC fast charging stations from Greenlots. Hawai'i Electric Light started construction of a DC fast charging stations at their offices located at 1200 Kilauea Avenue, Hilo, HI, and at 74-5519 Kaiwi Street, Kailua-Kona. These charging stations are targeted to open the first half of 2016. In 2015, negotiations started with a site host in Waimea, which is a strategic location to extend driving range between Hilo and Kailua-Kona. While installation of this charging station is dependent upon ongoing site construction, it is targeted to be completed in 2016. There is currently one other DC fast charging station, provided by another company, on Hawai'i Island at Mauna Lani. Mauna Lani is about 18 miles from Waimea and 27 miles from the Kailua-Kona site.

Maui Electric Highlights

In June 2014, Maui Electric began providing DC fast charging service to the public at their headquarters located at 210 W Kamehameha Avenue Kahului, Maui.[22] Figure 2f below (page 23) provides a summary of charging sessions during 2015. Although the usage is low, it is important to note that any discussion regarding electric vehicle charging on Maui must consider the impact of the JUMPSmart Maui project. The JUMPSmart Maui project currently provides participants unlimited monthly fast charging for between $15 and $30 per month, including

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[21] Transmittal No. 13-07, For Approval to Establish Schedule EV-F – Commercial Public Electric Vehicle Charging Facility Service Pilot, and Schedule EV-U – Commercial Public Electric Vehicle Charging Service Pilot, Filed June 3, 2013, at 11.

[22] Transmittal No. 13-07, For Approval to Establish Schedule EV-F – Commercial Public Electric Vehicle Charging Facility Service Pilot, and Schedule EV-U – Commercial Public Electric Vehicle Charging Service Pilot Hawaiian Electric Companies' Annual Report, Filed March 31, 2015, at 11.

access to DC fast charging at nine locations across the island.[23] As previously discussed, this service is very cost-competitive with charging options under Schedule EV-U.

Site Acquisition

Through 2015, Hawaiian Electric contacted or attempted to contact 57 prospective site hosts. Hawaiian Electric is currently seeking opportunities in north, west, and central O'ahu. The Companies note some property owners have expressed that they are not aware of Hawai`i Revised Statues §291-71, which mandates that "[p]laces of public accommodation with at least one hundred parking spaces available for use by the general public shall have at least one parking space exclusively for electric vehicles and equipped with an electric vehicle charging system"[24]: Additional common concerns regarding hosting a fast charging station include the following:

- Many property owners feel there is no need to install any EV charging infrastructure.
- Some property owners have stated there is no enforcement or a lack of clarity in the law (Hawai`i Revised Statues §291-71).
- Despite the Companies offering to own and operate the charging station, some property managers feel it is a penalty to relinquish valuable parking, real estate, and revenue. Due to the size of the charging station and supporting infrastructure, property managers may need to provide more than one parking stall. Some property owners have requested the Companies to lease space for the charging infrastructure and stall.
- Another common concern of property owners is the potential use of the equipment and space after the pilot period. The uncertainty of what will happen to the equipment and who may manage the equipment after the five year pilot is of concern to many property owners.

In addition to the site selection criteria, Maui Electric's ability to locate fast charging facilities has been constrained due to the prevalence of existing JUMPSmart Maui locations. To date, none of the landowners whose sites met project requirements have shown interest in completing the process to host fast charging infrastructure on their property.

Combined Adoption

Despite these challenges, four new DC fast chargers were made available for public usage in 2015 under Schedule EV-U. One station was available on Maui in 2014. The breakdown of available charging stations on each service territory is detailed in Table 4 below.

[23] http://www.jumpsmartmaui.com/dc-charger-locations/
[24] http://www.capitol.hawaii.gov/hrscurrent/Vol05_Ch0261-0319/HRS0291/HRS_0291-0071.htm

Table 4
Total DC Fast Chargers Under Schedule EV-U
January – December 2015

Month	O'ahu	Hawai'i	Maui
Jan	0	0	1
Feb	0	0	1
Mar	0	0	1
Apr	0	0	1
May	0	0	1
Jun	1	0	1
Jul	1	0	1
Aug	1	0	1
Sep	1	0	1
Oct	2	0	1
Nov	3	0	1
Dec	4	0	1

Table 5a, below, provides details of monthly charging sessions for each territory. The data in this section is provided by the EV charging network providers. All data reflect paid sessions and do not include any sessions used for testing or Company purposes. The Companies are also working with the network provider with some intermittent data issues. Initially, there had been a few isolated charging sessions with missing energy consumption data. However, the data in this section serves as very good approximations.

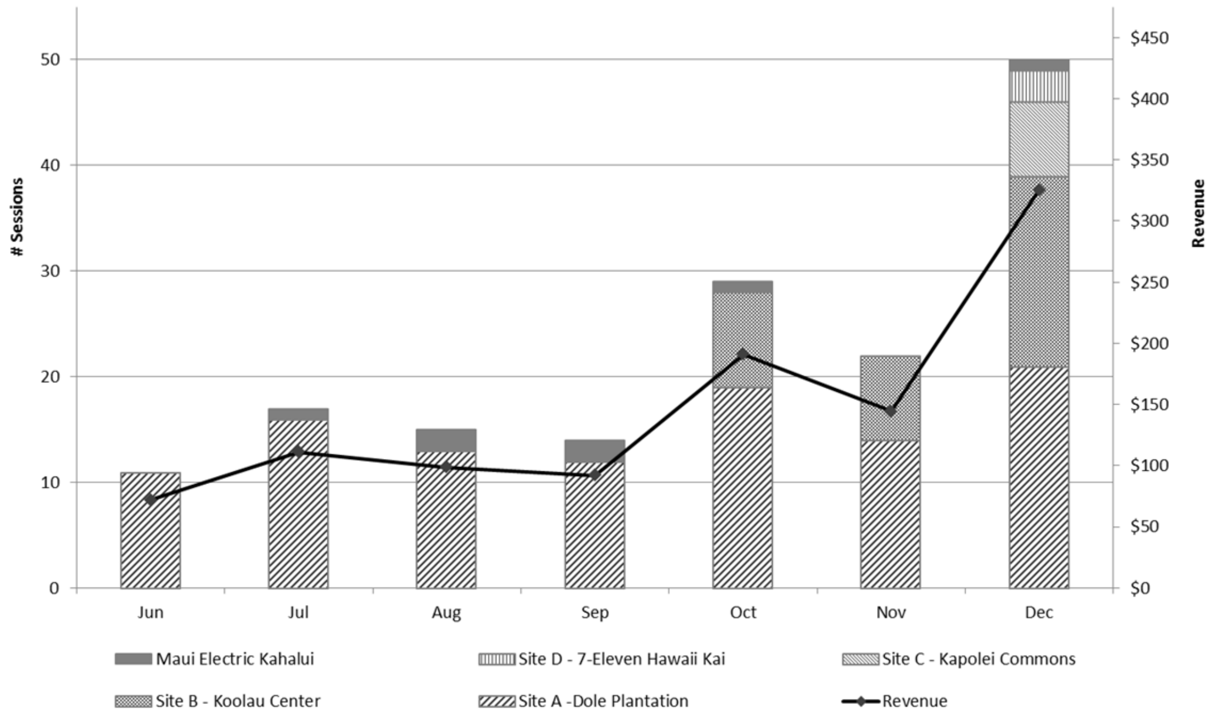
Table 5a
Schedule EV-U Charging Session Detail
January – December 2015

Month	O'ahu		Hawai'i		Maui	
	Sessions	**kWh**	**Sessions**	**kWh**	**Sessions**	**kWh**
Jan	0	0.0	0	0.0	0	0.0
Feb	0	0.0	0	0.0	0	0.0
Mar	0	0.0	0	0.0	0	0.0
Apr	0	0.0	0	0.0	0	0.0
May	0	0.0	0	0.0	0	0.0
Jun	11	90.1	0	0.0	0	0.0
Jul	16	162.1	0	0.0	1	6.3
Aug	13	65.8	0	0.0	2	42.0
Sep	12	120.6	0	0.0	2	6.7
Oct	28	245.4	0	0.0	1	35.0
Nov	22	277.0	0	0.0	0	0.0
Dec	49	631.4	0	0.0	1	12.7
TOTAL	151	1,592.4	0	0	7	102.8

There were no paid sessions between January and May 2015 and these months are omitted from the following charts.

Figure 1 illustrates the combined usage of the five charging stations.

Figure 1
Monthly Charge Sessions and Gross Revenue
All Sites, January – December 2015



The tables, below, provide the breakdown of charging sessions by TOU period for each territory. Table 5b provides kWh consumption for each TOU period and Table 5c provides sessions per TOU period. Note, the TOU period of a charge session is based upon its start time.

Table 5b
Schedule EV-U kWh Consumption by TOU Period[25]
January – December 2015

Territory	Priority	Mid	Off
O’ahu	90.7	1,474.0	27.8
Hawai’i	0.0	0.0	0.0
Maui	0.0	102.8	0.0
TOTAL	90.7	1,576.8	27.8
% TOTAL	5.3%	93.0%	1.6%

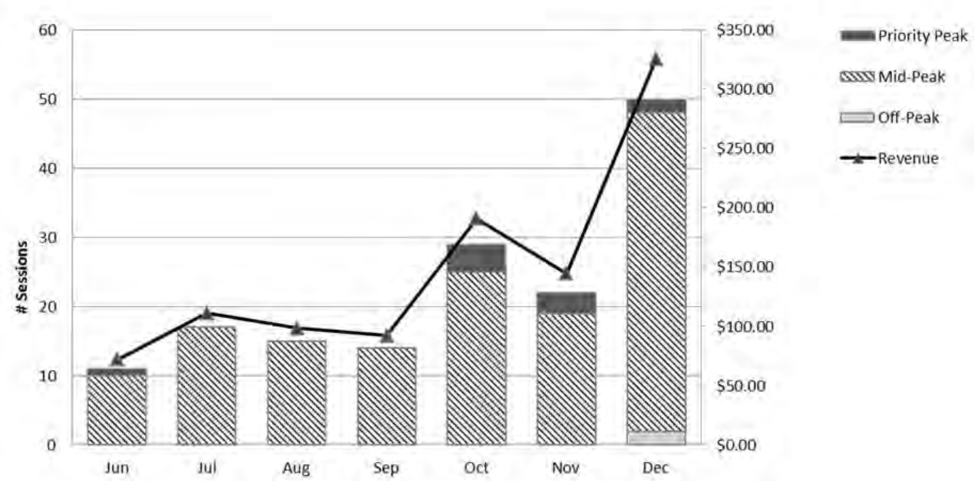
[25] Schedule EV-U TOU periods are: Priority-Peak (5:00 p.m. – 9:00 p.m., Monday – Friday); Mid-Peak (7:00 a.m. – 5:00 p.m., Monday – Friday, 7:00 a.m. – 9:00 p.m., Saturday-Sunday); Off-Peak (9:00 p.m. – 7:00 a.m., daily).

Table 5c
Schedule EV-U Charge Sessions by TOU Period[26]
January – December 2015

Territory	Priority	Mid	Off
O'ahu	10	139	2
Hawai'i	0.0	0.0	0.0
Maui	0.0	7	0.0
TOTAL	10	146	2
% TOTAL	6.3%	92.4%	1.3%

The figures below show the number of charging sessions in each TOU period by month. The aggregate usage has increased as new sites have become available and as EV drivers discover their availability.

Figure 2a
Monthly Charge Sessions, TOU Periods, and Gross Revenue
All Sites, January – December 2015



Hawaiian Electric Adoption

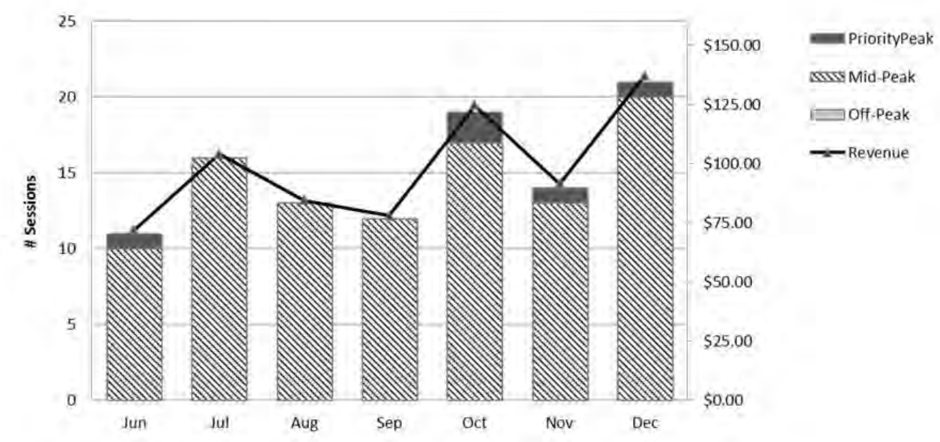
The charging station at Dole Plantation was opened to the public in June 2015. A media release (see Attachment A) and opening ceremony was provided on June 25, 2015. While there were six charging sessions that day, four charging sessions may be attributed to attendance at the opening ceremony. Figure 2b, below, shows an increasing usage trend. In 2015, 43% of all charging sessions at Dole Plantation occurred during the weekend, compared with 21% weekend charging at all other charging stations in this pilot. This contrast in weekend usage illustrates the different

[26] Schedule EV-U TOU periods are: Priority-Peak (5:00 p.m. – 9:00 p.m., Monday – Friday); Mid-Peak (7:00 a.m. – 5:00 p.m., Monday – Friday, 7:00 a.m. – 9:00 p.m., Saturday-Sunday); Off-Peak (9:00 p.m. – 7:00 a.m., daily).

needs for EV charging at different locations. Unlike other charging stations on O'ahu, this site provides charging services along a main arterial, but is not near residential dwellings.

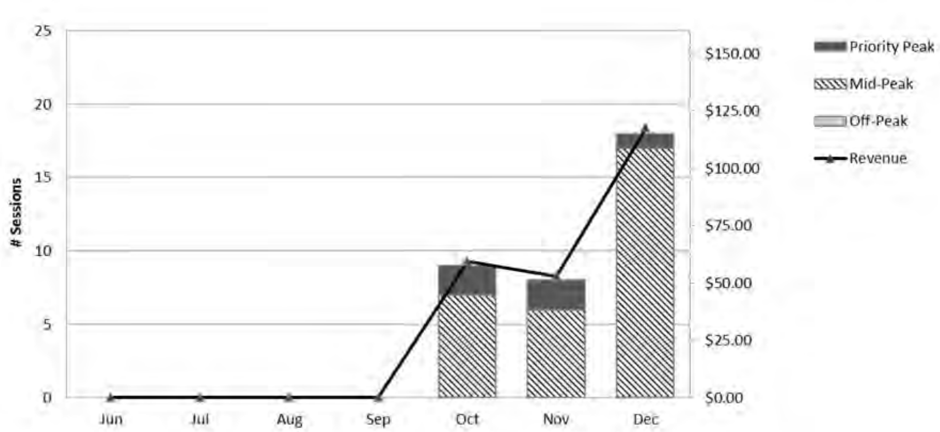
This charging station is only available during Dole Plantation's business hours of 10:00 a.m. to 5:00 p.m. daily.

Figure 2b
Monthly Charge Sessions, TOU Periods, and Gross Revenue
Dole Plantation, January – December 2015



The charging station at Ko`olau Center was opened to the public in October 2015, and quickly began to see increased usage. Approximately, 14% of all charging sessions at Ko`olau Center occur during the Priority-Peak. In contrast, approximately 4% of the combined charging sessions at the other four locations occur during the Priority-Peak. This difference may be attributed to longer commutes for residents along the windward coast and again illustrates different usage patterns and needs at different locations.

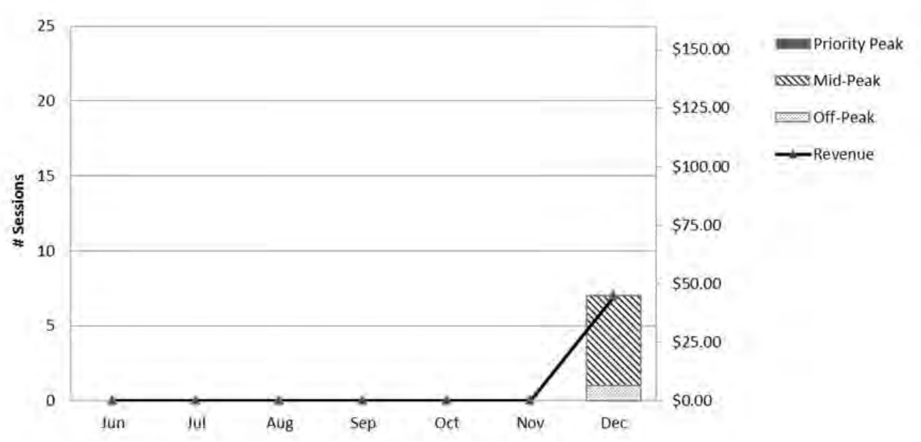
Figure 2c
Monthly Charge Sessions, TOU Periods, and Gross Revenue
Ko`olau Center, January – December 2015



The charging station at Kapolei Commons opened during the last week of November 2015, incorporating an internal BESS.

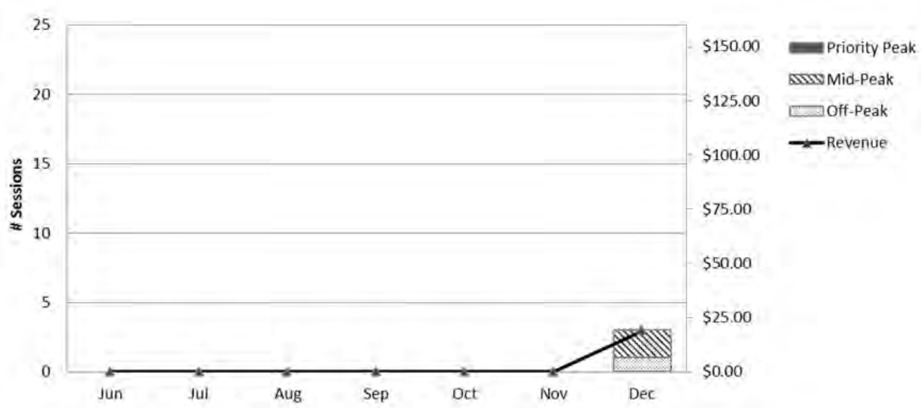
Currently, other businesses in Kapolei Commons provide two fee-based Level 2 charging ports and two free (for the first two hours) Level 2 charging ports. Despite the availability of nearby free Level 2 charging, the DC fast charging station was used six times during its first month of service in December. The fact that the DC fast charging station continues to be used in spite of its proximity to free level 2 charging stations support the position that fast charging infrastructure is a vital and needed component of electric transportation.

Figure 2d
Monthly Charge Sessions, TOU Periods, and Gross Revenue
Kapolei Commons, January – December 2015



The charging station at Hawai`i Kai 7-Eleven opened during the last week of December.

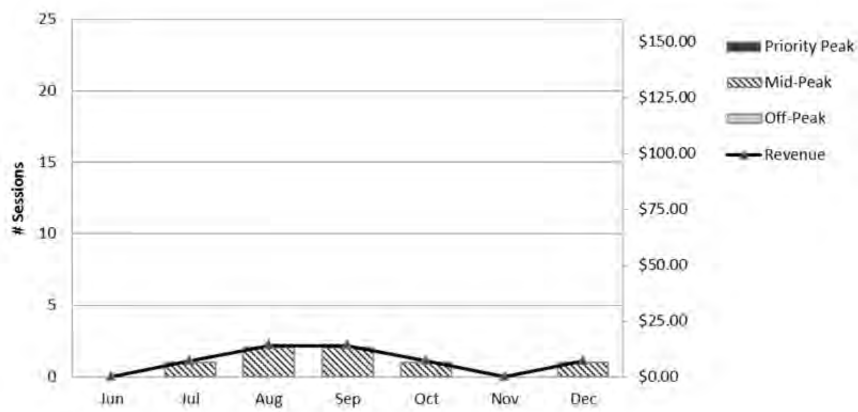
Figure 2e
Monthly Charge Sessions, TOU Periods, and Gross Revenue
Hawai`i Kai 7-Eleven, January – December 2015



Maui Electric Adoption

The charging station at Maui Electric is approximately one-half miles from a Maui JUMPSmart charging location, and continues to experience low usage. JUMPSmart Maui is funded by the New Energy and Industry Technology Development Organization ("NEDO") and provides project participants access to its DC fast charging stations for either $15 or $30 a month. The current Maui Electric EV charging fee of between $6.50 and $7.50 per session is not cost-competitive with JUMPSmart Maui program which has an estimated effective electricity rate of either $0.07 or $0.14 per kilowatt hour.[27] Despite requiring a higher price than other nearby charging stations, the Maui fast charging station was used seven times in 2015 and suggests that there is additional demand for EV fast charging solutions beyond the current nine JUMPSmart locations.[28] The Companies will continue to evaluate its DC fast charger program as EV penetration increases and adopt best practices to offer competitive charging options on Maui.

Figure 2f
Monthly Charge Sessions, TOU Periods, and Gross Revenue
Maui Electric Kahului Office, January – December 2015



Utilization Details

DC fast charging is more complicated than Level 2 charging. For a level 2 charging session, the kW charge rate is generally constant throughout the entire charging session. On the other hand, due to the power capacity of a DC fast charging station, the EV charge controller manages battery conditions by decreasing the power output as the battery recharges. For example, a DC fast charging session will start at 50 kW. Depending upon the state of the battery and the algorithm of the EV charge controller, the charge rate will decrease during a charging session to maintain the life of the battery. Some EVs may terminate a charging session after a predetermined duration or amount of energy transferred. Due to variability of the EV make and

[27] See page 7 for details on this rate estimate
[28] http://www.jumpsmartmaui.com/dc-charger-locations/

model, the state of charge of the battery, and the temperature, there is variability in the power and energy transferred during DC fast charge sessions.

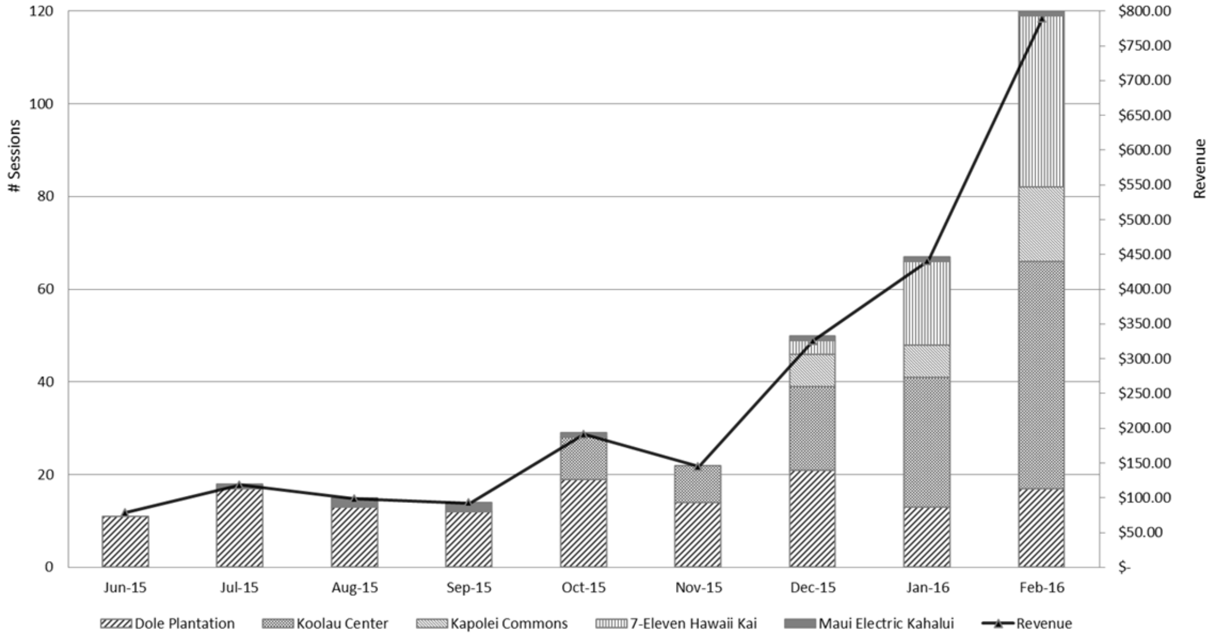
Fast charging stations provide the length of time an EV is connected to the charging station. The average connection time of all charging sessions in 2015 was 27 minutes. Approximately 67% (a standard deviation) of all connection times are within 10 minutes of the average connection time. Upon further examination, this variability was partly due to the difference of long-range EVs (such as the Tesla Model S). Segregating long-range EVs[29] from all other EVs, the average connection time of long-range EVs was 56 minutes while other EVs were connected for an average of 25 minutes. These findings reveal most EVs are not connected to the charging station longer than the time needed to charge. Since a typical Nissan Leaf fast charging session is up to 30 minutes, these findings further reveal many EV drivers do not wait for their batteries to fully charge. Furthermore, this usage pattern suggests that some EV drivers are willing to pay for the convenience of faster charging service, even in the presence of free Level 2 charging.

During 2015, the average DC fast charging session consumed 11.6 kWh. However, similar to connection time, there was some variability of energy consumed, depending on the type of EV. Segregating consumption between long-range and all other EVs, long range EVs consumed on average 36.6 kWh per session while other EVs consumed on average 9.4 kWh per session. Assuming the Hawaiian Electric Mid-Peak session fee of $6.50, this entails that the average long-range EV driver paid an equivalent $0.18 per kWh while the average “other” EV driver paid an equivalent $0.69 per kWh. While it is still very early in the pilot and limited data is available, the Companies will continue to monitor the impact of long range EVs and may propose alternative fee structures for Schedule EV-U to accommodate a diverse range of customer charging needs and behaviors.

In 2016, the Companies plan to install up to three DC fast charging stations on Hawai`i Island and up to four additional stations on O`ahu. Through February, total sales under EV-U continue to increase as drivers discover new charging stations. This will provide more data to understand customers’ needs and help inform the pilot. Figure 3 includes preliminary usage data for all charging stations for the first two months of 2016.

[29] In this comparison, long-range EVs were defined as EVs exceeding 20 kWh per charge session.

Figure 3
Monthly Charge Sessions and Gross Revenue
Preliminary Data for 2016

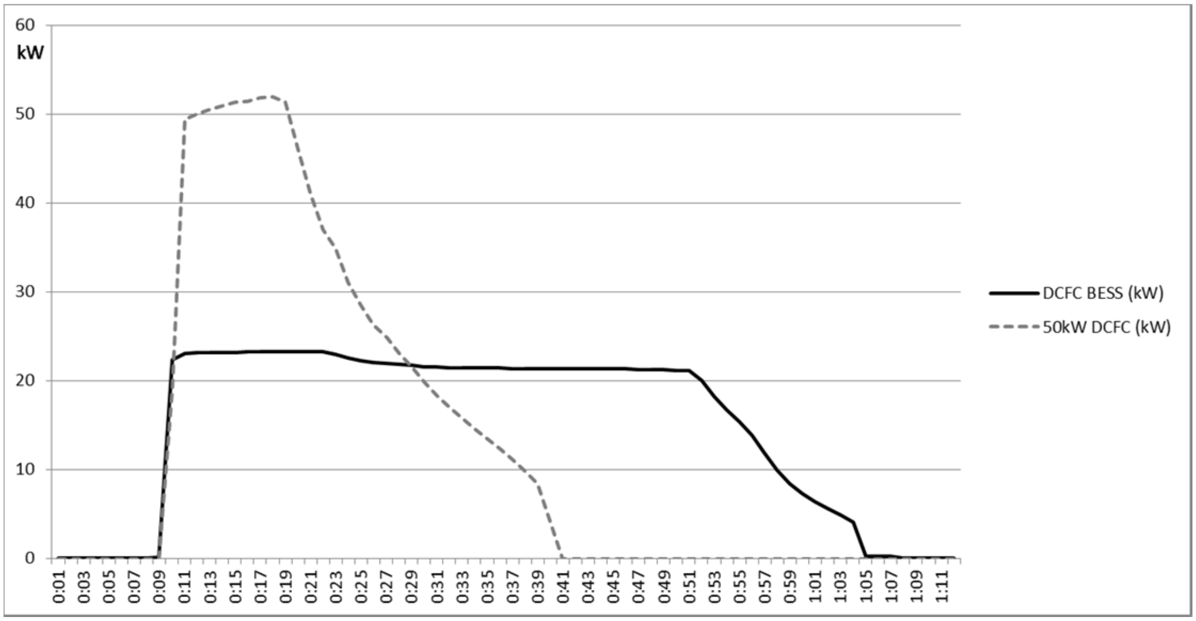


Hawaiian Electric Company's Data Analytics and On-Site Power Monitoring

The DC fast charging station at Kapolei Commons is integrated with an internal 12 kWh BESS. This BESS DC fast charging station is configured to not exceed 23 kW input from the grid while providing up to 50 kW to the EV. The remaining power is provided by the BESS. The BESS recharges when the charging output drops below 23 kW. This project will demonstrate the system's ability to reduce potential impacts to the grid, cost for infrastructure upgrades, and customer billing demand charges.

Figure 4, below, provides load profiles for two charging sessions, each consuming approximately 16 kWh. The solid line represents the kW power from the BESS DC fast charging system. The dashed line represents the kW power from a non-BESS 50 kW DC fast charging system. Note, due to the variability of DC fast charging, these charge sessions are not meant to represent exact equivalents. However, this example illustrates that the peak demand of a non-BESS charging station exceeded 50 kW for nine minutes and the BESS charging station never exceeded 23 kW.

Figure 4
BESS DC Fast Charging Load Profile
16 kWh charging session



The comparative load profiles in Figure 3 demonstrate how an integrated BESS may lower peak demand of a charging station while maintaining the total energy delivered to charge an EV. Hawaiian Electric will be working with EPRI, VLI-EV Partners[30], and Greenlots to further demonstrate the capabilities of the BESS DC fast charging system and assess the ability of a BESS to relieve the potential impact to the grid and customer billing demand charges.

As described in the Commission's Order, one of the Companies' objectives of the Schedule EV-U pilot is to conduct "research, development, and demonstration activities related to EV charging technologies and load control"[31]. Hawaiian Electric applied its Power Quality ("PQ") program expertise and resources to deploy power quality monitors at each site where its DC fast chargers were installed and in operation in 2015. A complete report of t of the data collection and analysis at Dole Plantation, Ko`olau Center and Kapolei Commons, "In Situ Power Monitoring of Hawaiian Electric Company EV Fast Charging Operations" is included as Attachment B.

The key results of the report are:

- The data monitoring and collection equipment, communications, and software deployed and utilized by Hawaiian Electric Company are well-suited for the EV fast charging pilot and provide the data granularity required for the data analytics of this report.
- Data suggests that once EV drivers know the whereabouts of the fast chargers, they will use them regularly.

[30] VLI-EV Partners was awarded the bid for this site, providing the integrated solution of the BESS DC fast charging system with the Greenlots network.
[31] Transmittal No. 13-07 and 13-08 (Consolidated), Decision and Order No. 31338, issued on July 1, 2013, at 41.

- EV battery fast charging profiles for non-BESS fast chargers can be characterized with data monitoring equipment and analysis techniques.
- Most EV drivers will fast charge during the mid-peak.
- Data collected for this report confirms that fast charger users are paying the same flat, per-session fee to fill their EV battery which could vary in size and state of charge. Moving forward, the Hawaiian Electric companies may propose alternative fee structures to accommodate a diverse range of customer charging needs and behaviors.
- The demand limiting capability of the integrated buffer battery-EV fast charging system deployed at Kapolei Commons has been confirmed to limit demand below 25 kWh, which is the threshold for Hawaiian Electric's commercial rates at which demand charges are assessed.
- Limiting the output of non-BESS fast chargers may be a viable demand response strategy to utilize EV fast chargers as a DR resource.
- EV fast charger power electronics technology is robust and can withstand non-optimal electrical operational environments and furthermore, can ride through certain power quality disturbances.

B. Summary of Costs and Revenue

Tables 6a and 6b reflect costs and revenues booked in the Companies' accounting systems.

Table 6a, below, provides program expenses from January to December 31, 2015, for Capital Cost (for purchase of capital equipment and labor for design and installation of the project site), O&M Labor (for project management and research) Non-Labor (for operations and maintenance), and Other Costs (for revenues from charging stations, EPRI reimbursements, and other adjustments). Project reimbursements through research partnerships with EPRI are reflected as negative costs in Other Costs for the Kapolei site on O'ahu.

Table 6a
Program Costs
January – December 2015

Service Territory	Cost Element	Cost
O‘ahu	Capital Costs	$ 662,461.85
	O&M Labor Costs	$ 46,749.59
	O&M Non-Labor Costs	$ 9,675.04
	Other Costs	$ (164,530.88)
	Total Costs	$ 554,355.60
Hawai‘i	Capital Costs	$ 322,707.30
	O&M Labor Costs	$ -
	O&M Non-Labor Costs	$ -
	Other Costs	$ -
	Total Costs	$ 322,707.30
Maui	Capital Costs	$ 8,220.05
	O&M Labor Expense	$ 17,386.38
	O&M Non-Labor Expense	$ 6.32
	Other Costs	$ -
	Total Costs	$ 25,612.75
ALL	CAPITAL COSTS	$ 993,389.20
	O&M LABOR COSTS	$ 64,135.97
	O&M NON-LABOR COSTS	$ 9,681.36
	OTHER COSTS	$ (164,530.88)
	TOTAL COSTS	$ 902,675.65

Table 6b, below, provides cumulative total program expenses through December 31, 2015.

Table 6b
Program Costs
Pilot Inception Through December 2015

Service Territory	Cost Element	Cost
O‘ahu	Capital Costs	$ 800,008.63
	O&M Labor Costs	$ 70,366.32
	O&M Non-Labor Costs	$ 9,688.82
	Other Costs	$ (164,530.88)
	Total Costs	$ 715,532.89
Hawai‘i	Capital Costs	$ 344,055.08
	O&M Labor Costs	$ -
	O&M Non-Labor Costs	$ -
	Other Costs	$ -
	Total Costs	$ 344,055.08
Maui	Capital Costs	$ 86,775.92
	O&M Labor Expense	$ 29,818.55
	O&M Non-Labor Expense	$ 7.11
	Other Costs	$ (63.00)
	Total Costs	$ 116,538.58
ALL	CAPITAL COSTS	$ 1,230,839.63
	O&M LABOR COSTS	$ 100,184.87
	O&M NON-LABOR COSTS	$ 9,695.93
	OTHER COSTS	$ (164,593.88)
	TOTAL COSTS	$ 1,176,126.55

Table 6c, below, provides expenses (labor and non-labor) for each site in service as of December 31, 2015. The capital cost of the Kapolei site was offset by funds through the joint EPRI project. “Other” cost elements also includes site revenues. “Other” sites include costs for sites not yet in service, project administration, and overall research.

Table 6c
Costs Per Available Site
Pilot Through December 2015

Territory	Site	Cost Element	Cost
O'ahu	Kapolei	Capital	$ 211,185.43
		O&M	$ 244.12
		Other	$ (163,531.38)
		TOTAL	$ 47,898.17
	Dole Plantation	Capital	$ 128,093.96
		O&M	$ 2,997.28
		Other	$ (750.50)
		TOTAL	$ 130,340.74
	Ko`olau Center	Capital	$ 177,329.19
		O&M	$ 975.19
		Other	$ (230.00)
		TOTAL	$ 178,074.38
	Hawaii Kai	Capital	$ 156,623.22
		O&M	$ 2.49
		Other	$ (19.00)
		TOTAL	$ 156,606.71
	Other	Capital	$ 126,776.83
		O&M	$ 75,836.06
		Other	$ -
		TOTAL	$ 202,612.89
Hawai’i	Other	Capital	$ 344,055.08
		O&M	$ -
		Other	$ -
		TOTAL	$ 344,055.08
Maui	Maui Electric Company	Capital	$ 86,775.92
		O&M	$ 9,851.98
		Other	$ (63.00)
		TOTAL	$ 96,564.90
	Other	Capital	$ -
		O&M	$ 19,973.68
		Other	$ -
		TOTAL	$ 19,973.68

Table 6d, below, provides gross revenues reported by the charging network for Schedule EV-U between January 1 and December 31, 2015. Due to lags in processing transactions, some of these revenues are reported by the charging network, but may not yet be remitted to the Companies.

Table 6d
Schedule EV-U Revenue
January – December 2015

Month	O'ahu	Hawai'i	Maui
Jan	$ -	$ -	$ -
Feb	$ -	$ -	$ -
Mar	$ -	$ -	$ -
Apr	$ -	$ -	$ -
May	$ -	$ -	$ -
Jun	$ 72.00	$ -	$ -
Jul	$ 104.00	$ -	$ 7.00
Aug	$ 84.50	$ -	$ 14.00
Sep	$ 78.00	$ -	$ 14.00
Oct	$ 184.00	$ -	$ 7.00
Nov	$ 144.50	$ -	-
Dec	$ 318.50	$ -	$ 7.00
TOTAL	$ 985.50	$ -	$ 49.00

All DC fast charging stations under Schedule EV-U, except Kapolei Commons, were equipped with a credit card reader in 2015. In that year, 68% of all transactions were collected by credit card at the charging station. The remaining 32% are collected through an application, subscription card, or by requesting activation by phone. To date, a credit card reader appears to be most commonly used. The Companies will continue to evaluate customer payment preferences.

C. Subsidization by non-participating ratepayers

Table 7 provides the subsidization when compared to revenues which may have been generated if similar fast charging services were provided by another company under Schedule J. The potential Schedule J revenues were based upon the reported monthly kWh energy provided to charge EVs under Schedule EV-U and 47.5 kW billing demand. Months in which existing charging station had no usage we reflected with the minimum charge for Schedule J.

Table 7
Schedule EV-U to Potential Schedule J Revenue Comparison
January – December 2015

Month	Total EV-U Revenues	Potential Schedule J Revenue	Difference
Jan	$ -	$ 347.99	$ 347.99
Feb	$ -	$ 347.99	$ 347.99
Mar	$ -	$ 347.99	$ 347.99
Apr	$ -	$ 347.99	$ 347.99
May	$ -	$ 347.99	$ 347.99
Jun	$ 72.00	$ 1,026.42	$ 954.42
Jul	$ 111.00	$ 1,276.36	$ 1,165.36
Aug	$ 98.50	$ 1,265.44	$ 1,166.94
Sep	$ 92.00	$ 1,267.15	$ 1,175.15
Oct	$ 191.00	$ 1,959.89	$ 1,768.89
Nov	$ 144.50	$ 1,731.30	$ 1,586.80
Dec	$ 325.50	$ 3,352.54	$ 3,027.04
TOTAL	$ 1,034.50	$ 13,619.05	$ 12,584.55

A key criterion in developing EV rates and programs is to encourage the adoption of electric vehicles by our customers. Because the EV market is still nascent in Hawai`i and EV proliferation is regarded as a State policy goal, it is prudent to provide rate support for the development of public EV charging infrastructure. Furthermore, as expressed in Transmittal 13-07, a key objective of Schedule EV-U is to strategically locate Company-owned public fast charging stations to address "range anxiety" that supports the adoption of EVs.[32] Therefore, incremental load from electric vehicles should not be considered to benefit from subsidization in the same way as pre-existing load that is now subject to Schedule EV-U. Unfortunately, it is difficult to quantify how the availability of the DC fast charging stations under Schedule EV-U may have encouraged anyone to purchase a new electric vehicle.

D. Recommendation of revisions to rate structures

Decision and Order No. 31338 requires that the Companies "determine and recommend any revisions to the applicable rate structures that are necessary to: (A) meet the objectives of sufficiently addressing 'range anxiety' among EV end-users and conducting the Companies' research, development, and demonstration activities related to EV charging technologies and load control; and (B) minimize the level or extent of subsidization by non-participating ratepayers."

[32] Transmittal No. 13-07, filed June 3, 2013, at 22.

1. Addressing range anxiety

   The usage data provided in this report supports the need for DC fast charging. Of the four charging stations placed into service in 2015, two were placed into service during the last two months of 2015. Preliminary data suggests there has been a significant increase in usage into the first two months of 2016. Usage data also suggests that EV drivers are willing to pay for the convenience of DC fast charging even when cheaper or nearly free Level 2 charging is available nearby. This is further supported the national finding provided in Section I.D. of this report, as well as by a recent anonymous post on an internet charge station mapping website, “I wish Hawaiian [E]lectric would put more fast chargers around the island like the one at the Dole Plantation. I feel like every 15 miles there should be a fast charger because the [O]ahu hills eat up our power fast. EVs won’t really catch on until then.”[33]

   Furthermore, the data in this report reveals different usage patterns at different locations, as some sites are utilized more on weekends and others have more utilization during the Priority-Peak. This finding supports the need for charging stations at varying strategic locations around the state. Therefore, to continue support of the developing EV market in Hawaii, the Hawaiian Electric Companies do not recommend any revisions to Schedule EV-U at this time. As additional data is collected, the Companies will continue to evaluate the pilot and consider recommendations for revisions to the existing rate structures.

2. Conducting research, development, and demonstration activities related to EV charging technologies and load control

   In November 2015, Hawaiian Electric installed a DC fast charging station with integrated BESS. In 2016, Hawaiian Electric installed a DC fast charging station and will partner with EPRI to develop and demonstrate demand response on a DC fast charger. The Companies will evaluate these technologies and potential changes in rate structures to determine how fast charging may better serve the needs of the grid.

3. Minimize the level of extent of subsidization by non-participating ratepayers

   To support continued development of public EV charging options and address “range anxiety,” the Hawaiian Electric Companies do not recommend any revisions to Schedule EV-U at this time.

[33] http://www.plugshare.com

Electric Vehicle Pilot Rates Report

Attachment A

Informational Material on
Commercial Public Electric Vehicle Charging Service Pilot Rates
and Locations

Electric Vehicle Event, January 17, 2015
Maui Electric Company

HawaiiDealer

Sign of the times

Look for a new Electric Vehicle fast charger early in 2015 at Dole Plantation on Kamehameha Highway in Wahiawa. Strategically set between Waikiki and the North Shore, it will calm "range anxiety" for residents and visitors. Fast charging fills a flat battery 80% within 30 minutes.

Maui Electric has another utility-owned fast charger at its Kamehameha Avenue office in Kahului and Hawaii Electric Light is adding another at the entrance to the Kailua-Kona Baseyard on Kaiwi Street. These are more "signs" that the Hawaiian Electric Companies are encouraging more transportation alternatives.

Building on our new Power Supply Improvement Plans, we'll "recharge" our drive to electrify transportation in 2015. Coming soon are plans to:

- Support more EVs through partnerships and collaboration
- Lead in developing better EV infrastructure
- Develop EV rates and program to create value for customers and our grid
- Manage EVs potential impact on the electric system

Look for more "signs of the times" in the year ahead and visit **www.hawaiianelectric.com/goev**.

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

Why are these people smiling?

Chris Lowvorn, Castle & Cooke vice president for commercial development; Senator Loraine Inouye, chair of the Senate Energy and Transportation Committee; Kahu Kelekona Bishaw of Kamehameha Schools; Randy Iwase, chair of the Hawai'i Public Utilities Commission; Alan Oshima, Hawaiian Electric Company president & CEO; Susan Harada, Dole Plantation manager; Mike Moon, Dole Plantation operations manager; Jim Alberts, Hawaiian Electric senior vice president for customer service.

Hawaiian Electric officially opened its first utility-owned and operated Fast Charger on O‘ahu at Dole Plantation in Wahiawa.

The Hawaiian Electric Companies believe a major contribution to accelerating the use of electric vehicles is providing public charging infrastructure to help eliminate “range anxiety.”

Dole Plantation is an ideal charge spot for residents and visitors driving EVs to or from the North Shore. Drivers can safely operate the charger and pay a small fee by credit card or smartphone app. Learn more at www.hawaiianelectric.com/goev.

The DC Fast Charger at Dole Plantation has a CHAdeMO connection (used mostly by Japanese and Korean EVs) and a CCS connection (used by American and European EVs.) This is the first charger on O‘ahu supporting both types of fast charging.

Maui Electric also has a DC Fast Charger at its Kahului headquarters. Hawai‘i Electric Light is installing one in Hilo. The Hawai‘i Public Utilities Commission authorized our utilities to install, own and operate up to 25 fast chargers in our service territory. Additional sites are being scouted on O‘ahu and other islands. Hawaiian Electric will own, operate and maintain the units so host locations get the benefits for employees and customers with minimal responsibility. If interested, reach us at goev@hawaiianelectric.com or 543-goev.

View a short video at www.youtube.com/hawaiianelectric.

Hawaiian Electric
Maui Electric
Hawai‘i Electric Light

GOEV

Press Release for Hawaiian Electric Company

Hawaiian Electric

NEWS RELEASE

FOR IMMEDIATE RELEASE

Hawaiian Electric opens O'ahu's first utility-owned DC Fast Charger for electric vehicles at Dole Plantation in Wahiawa

HONOLULU, June 25, 2015 – Hawaiian Electric Company, in partnership with host Castle & Cooke Properties, Inc., has opened the first utility-owned and operated DC Fast Charger for electric vehicles on O'ahu at Dole Plantation in Wahiawa.

The fast charger will help eliminate "range anxiety" for residents and visitors driving EVs to or from the North Shore. Using a fast charger, a near-depleted battery can be recharged to 80 percent capacity in 30 minutes, less for smaller recharges. Drivers will be able to safely operate the charger and pay by credit card or by smartphone app with an OpConnect subscription.

A fast charging session will cost $6.50 during most of the day; slightly more during times of peak electric use. Session prices may change based on the changing cost of electricity. Information on charging, including the current price, will be available at www.hawaiianelectric.com/goev.

"At the Hawaiian Electric Companies, we believe we can make a major contribution to accelerating the use of electric vehicles by providing public charging infrastructure so drivers always have the peace of mind knowing they can quickly top off," said Jim Alberts, Hawaiian Electric senior vice president for customer service. "O'ahu has over 200 publicly accessible Level Two charging ports, but recharging there takes longer and it may be hard to find an open unit. This will help."

The DC Fast Charger at Dole Plantation has both a CHAdeMO connection (used mostly by Japanese and Korean EVs like the Nissan Leaf, Mitsubishi i-MiEV, and Kia Soul EV) and a CCS connection (used by American and European EVs like the BMW i3.) This is the first charger on O'ahu supporting both types of fast charging.

"As one of the state's most popular attractions, Dole Plantation draws more than one million people each year. Whether local residents or island visitors, they are increasingly likely to be driving electric vehicles," said Christopher M. Lovvorn, Castle & Cooke vice president for commercial development. "Given our location in the midst of Central O'ahu's pineapple fields, we at Dole Plantation were committed to helping Hawaiian Electric provide this needed service for Hawai'i's drivers."

Maui Electric also has a DC Fast Charger accessible at its Kahului headquarters. The Hawai'i Public Utilities Commission authorized a five-year demonstration for the utilities to install, own and operate up to 25 fast chargers in their service territory. Additional sites are now being scouted on O'ahu and other islands.

Although some fast chargers may be on utility property, most will be located on host sites like Dole Plantation. Hawaiian Electric will operate the equipment at no cost to the host for

-more-

Hawaiian Electric

NEWS RELEASE

FOR IMMEDIATE RELEASE

Hawaiian Electric dedicates first utility-owned EV Fast Charger for Windward drivers at Ko'olau Center

HONOLULU, October 22, 2015 – Electric vehicle drivers on O'ahu's Windward side have a new charging option that offers relief from "range anxiety." Hawaiian Electric Company, in partnership with the J.H. Schnack Estate, Inc., has opened a utility-owned and operated DC Fast Charger at Ko'olau Center in Kaneohe.

The shopping center, just off Kahekili Highway across Valley of the Temples at 47-388 Hui Iwa St., is home to popular shopping, dining, entertainment and service businesses.

Using a fast charger, a near-depleted EV battery can be recharged to 80 percent capacity in 30 minutes, less for smaller recharges. Drivers will be able to safely operate the charger and pay by credit card or by smartphone app with an OpConnect subscription.

A fast charging session will cost $6.50 during most of the day; slightly more during peak electric use times. Session prices may change based on the changing cost of electricity. Information on charging, including the current price, is always available at www.hawaiianelectric.com/goev.

"At the Hawaiian Electric Companies, we continue to help accelerate use of electric vehicles by providing public charging stations so drivers always know where they can top off quickly across the islands," said Jim Alberts, Hawaiian Electric senior vice president for customer service. "O'ahu alone has over 200 publicly accessible Level Two charging ports, but these fast chargers will make it easier and faster for all EV drivers."

The DC Fast Charger at Ko'olau Center, like the one at Dole Plantation in Wahiawa, has both a CHAdeMO connection (used mostly by Japanese and Korean EVs like the Nissan Leaf, Mitsubishi i-MiEV, and Kia Soul EV) and a CCS connection (used by American and European EVs like the BMW i3).

"Ko'olau Center is a convenient stop for Windward residents and visitors, one of the largest shopping centers with the most offerings from Kaneohe to Kahuku. Our customers are environmentally aware and cost conscious so we are happy to make it easier for them to own and drive electric vehicles," said David Yamada, Ko'olau Center manager. "We are glad to provide one more reason to stop here."

The Hawai'i Public Utilities Commission authorized a five-year demonstration for the utilities to install, own and operate up to 25 fast chargers in their service territory. Additional sites are now being scouted on O'ahu and other islands.

Although some fast chargers may be on utility property, most will be located on privately owned host sites. Hawaiian Electric will operate the equipment at no cost to the host for installation,

-more-

Charging Station Locations

Information regarding the location and fees for the charging stations are provided on the Companies' and third-party websites.

The follow information is provided on the Company website[34].

Share

EV Charging Locations

Hawaiian Electric Companies Fast Chargers

In an effort to support clean transportation, the Hawaiian Electric Companies requested and received approval to operate publicly accessible DC Fast Chargers across Oahu, Maui County, and Hawaii Island. These facilities will allow drivers to quickly recharge their vehicles for a per-session fee. Below are the prices and some sites where Electric Vehicle owners can quickly charge their vehicles.

Oahu - Prices & Locations

Price per sessions based upon start of session:		
$7.00	5 p.m. - 9 p.m.	Monday - Friday
$6.50	7 a.m. - 5 p.m. 7 a.m. - 9 p.m.	Monday - Friday Saturday - Sunday
$6.00	9 p.m. - 7 a.m.	Daily

Dole Plantation

64-1550 Kamehameha Hwy
Wahiawa, Hawaii 96786

Located: Near parking lot entrance by Bus Stop (21.5258, -158.0387)
Hours of Operation: About 10:00 a.m. - 5:00 p.m., 7 days a week
Charging Standard: CHAdeMO, SAE - CCS
Payment Option: Major Credit Cards or OpConnect Network

Koolau Center

47-388 Hui Iwa Street
Kaneohe, Hawaii 96744

Located: Near main shopping center entrance (across from McDonalds) (21.4360,-157.8258)
Hours of Operation: 24/7
Charging Standard: CHAdeMO, SAE - CCS
Payment Option: Major Credit Cards or OpConnect Network

Kapolei Commons

4470 Kapolei Parkway
Kapolei, Hawaii 96707

Located: Next to Ruby Tuesday near Kapolei Parkway (21.3290,-158.0916)
Hours of Operation: 24/7
Charging Standard: CHAdeMO
Payment Option: Major Credit Cards or Greenlots Network

[34] https://www.hawaiianelectric.com/products-and-services/electric-vehicles/fast-charging-locations

7-Eleven

515 Pepeekeo St
Honolulu, Hawaii 96925

Located: Near Hawaii Kai Drive entrance (21.2940,-157.7102)
Hours of Operation: 24/7
Charging Standard: CHAdeMO, SAE - CCS
Payment Option: Major Credit Cards or OpConnect Network

Maui - Prices & Locations

Price per sessions based upon start of session:		
$7.50	5 p.m. - 9 p.m.	Monday - Friday
$7.00	7 a.m. - 5 p.m. 7 a.m. - 9 p.m.	Monday - Friday Saturday - Sunday
$6.50	9 p.m. - 7 a.m.	Daily

Maui Electric Company Ltd.

Kahului Office
210 W Kamehameha Avenue
Kahului, Hawaii 96733

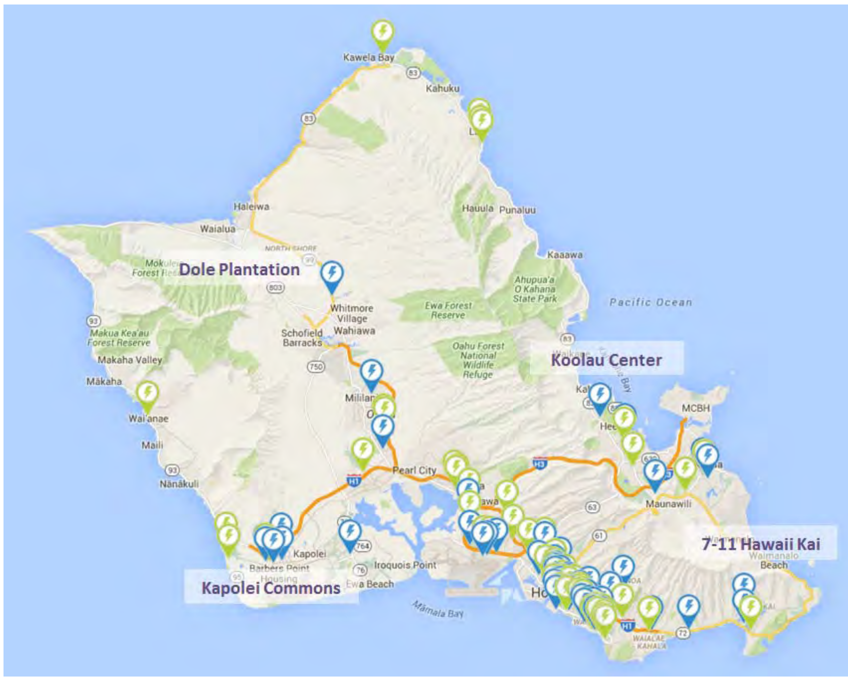
Located: (21.3290,-158.0916)
Hours of Operation: 24/7
Charging Standard: CHAdeMO
Payment Option: Major Credit Cards or Greenlots Network

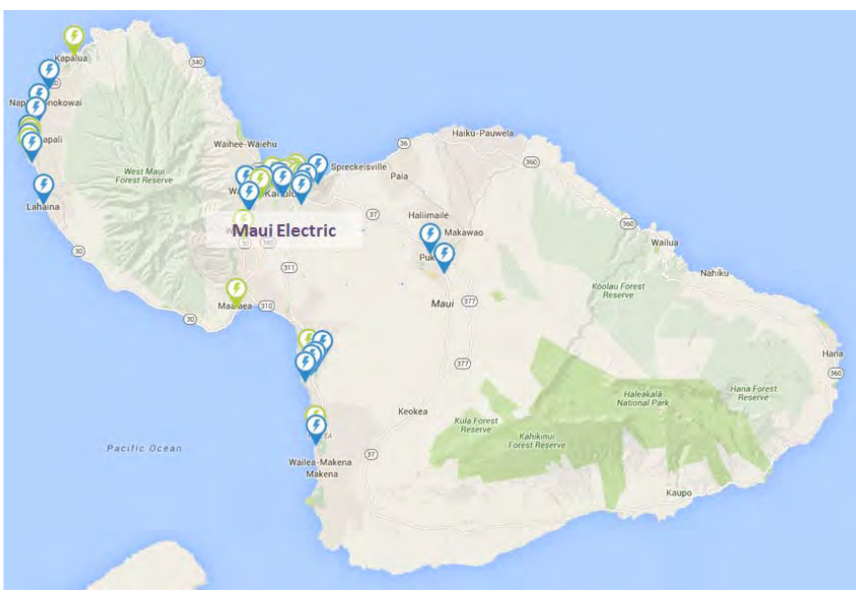
Additional Public Charging Resources

Many public places are installing Level 2 chargers and DC Fast chargers to support the EV Community. Below is a list of a few external websites which track the location of public charging stations around the State.

- Plugshare
- State of Hawaii Charging Stations

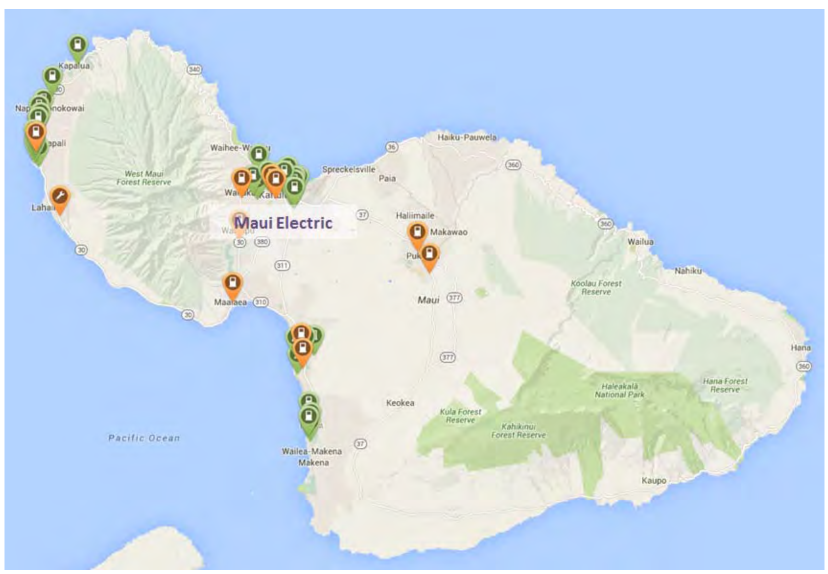
The following information is provided on both the “EV Stations Hawaii” online and app maps provided by the Department of Business Economic Development and Tourism[35]. In these maps below, the blue map tacks denote fee-based charging stations and the green map tacks denote free charging stations. The Company locations have been overlaid.





35 http://energy.hawaii.gov/testbeds-initiatives/ev-ready-program/electric-vehicle-ev-charging-stations-in-hawaii

The following information is provided on www.plugshare.com. In these maps below, the green map tacks denote Level 2 charging stations and the orange map tacks denote DC fast charging stations. The Company locations have been overlaid.



Attachment B

In Situ Power Monitoring of Hawaiian Electric Company EV Fast Charging Operations

In Situ Power Monitoring of Hawaiian Electric Company EV Fast Charging Operations

Presented By
Hawaiian Electric Company, Inc.
Customer Solutions Engineering Division

2015 Report

Executive Summary

This report provides a summary of the electric power monitoring activities and results of the Hawaiian Electric Company at its Electric Vehicle (EV) fast charger sites located on the island of O`ahu. The data provided herein has been collected from the Dole Plantation, Ko`olau Center and Kapolei Commons EV fast charger sites placed into operation in 2015. Key results of data analysis and observations of the outcomes resulted in the following key results:

- The data monitoring and collection equipment, communications, and software deployed and utilized by Hawaiian Electric Company are well-suited for the EV fast charging pilot and provide the data granularity required for the data analytics of this report.
- The data suggests that once EV drivers know the whereabouts of the fast chargers, they will use them regularly.
- EV battery fast charging profiles for fast chargers can be characterized with data monitoring equipment and analysis techniques.
- Most EV drivers will fast charge during the mid-peak (the hours of 7 AM – 5 PM).
- Data collected for this report confirms that fast charger users are paying the same per-session flat fee to fill their EV battery which could vary in size and state of charge. Hawaiian Electric Company may want to explore options to improve the pricing mechanism for EV fast charge services.
- The demand limiting capability of the integrated buffer battery-EV fast charging system deployed at Kapolei Commons has been confirmed to limit demand below 25 kWh, which is the threshold for Hawaiian Electric's commercial rates at which demand charges are assessed.
- Limiting the output of non-BESS fast chargers may be a viable demand response (DR) strategy to utilize EV fast chargers as a DR resource.
- EV fast charger power electronics technology is robust and can withstand non-optimal electrical operational environments and furthermore, can ride through certain power quality disturbances.

1. Introduction

As described in the Hawai`i State Public Utilities Commission's Order, one of the Companies' objectives of the Sch. EV-U pilot is to conduct "research, development, and demonstration (RD&D) activities related to EV charging technologies and load control."[36]

Pursuant to the Order, this report provides a summary of the electric power monitoring activities and results of the Hawaiian Electric Company at its Electric Vehicle (EV) fast charger sites located on the island of O`ahu. The data provided herein has been collected from three EV fast charger sites placed into operation in 2015. The sites include Dole Plantation, Ko`olau Center, and Kapolei Commons. A fourth site, 7-Eleven Hawai`i Kai was placed into operation on December 29, 2015 and its data and analysis was therefore omitted from this report.

This report has the following goals:

- Characterize unique EV fast charging profiles
- Validate EV charge sessions for each fast charger site with power quality (PQ) monitoring data
- Characterize and quantify in situ electrical environments and PQ events, and cross-reference events to system events, where applicable
- Assess EV DC fast charger (DCFC) technology in terms of immunity and sensitivity to its electrical environment
- Quantify EV fast charger electrical demand and validate RD&D solutions as improvement measures
- Validate or identify varying EV battery state of charge and energy consumption for EV fast charging based on charge session data

[36] Transmittal No. 13-08 (Consolidated), Decision and Order No. 31338, issued on July 1, 2013.

2. **Background Information**

2.1. Power Quality Monitoring Equipment, Software and Data Gathering Background

At each fast charger site, power monitoring data was collected through the deployment of PQ monitoring equipment. Data collected is granular and encompasses a full range of trended electrical characteristics, as well as PQ events.

The equipment deployed is the PQube™, manufactured by Power Standards Lab (PSL). The PQube provides date-time stamped data sampled at 256 samples per cycle at 1 minute intervals. It can also provide PQ event data based on pre-set thresholds. For the purposes of this report, the following tables 2.1 and 2.2 provide the specifications for date-time stamped data that has been collected and archived:

Data Parameter	Engineering Unit	Resolution	Trend Interval	Interval Amplitude Capture
Frequency	Hz	1 cycle	1 minute	Min, Max, Avg
L-N Voltage	V	1 cycle	1 minute	Min, Max, Avg
L-L Voltage	V	1 cycle	1 minute	Min, Max, Avg
Line Current	A	1 cycle	1 minute	Min, Max, Avg
Neutral Current	A	1 cycle	1 minute	Min, Max, Avg
Apparent Power	kVA	12 cycle	1 minute	Min, Max, Avg
Reactive Power	kVAR	12 cycle	1 minute	Min, Max, Avg
Real Power	kW	12 cycle	1 minute	Min, Max, Avg
True Power Factor	%	12 cycle	1 minute	Min, Max, Avg
Energy	kWh	12 cycle	1 minute	Min, Max, Avg
Vthd	%	DFT of sample rate	1 minute	Min, Max, Avg
Dthd	%	DFT of sample rate	1 minute	Min, Max, Avg

Table 2.1 Trended Data Specifications

Event	Trigger Threshold	Reported Paramenters
Under-Frequency	99.5% of Nominal	Location, Nominal Value, Trigger Channel, Magnitude, Duration, Date, Day of Week, Trigger Time, Min-Max Values
Over-Frequency	100.5% of Nominal	Location, Nominal Value, Trigger Channel, Magnitude, Duration, Date, Day of Week, Trigger Time, Min-Max Values
Voltage Sag	95.0% of Nominal	Location, Nominal Value, Trigger Channel, Magnitude, Duration, Date, Day of Week, Trigger Time, Min-Max Values
Voltage Swell	105.0% of Nominal	Location, Nominal Value, Trigger Channel, Magnitude, Duration, Date, Day of Week, Trigger Time, Min-Max Values
Interruption	10.0% of Nominal	Location, Nominal Value, Trigger Channel, Magnitude, Duration, Date, Day of Week, Trigger Time, Min-Max Values
Waveshape Change	HF Imppulse Detection	Location, Trigger Channel, Date, Day of Week, Trigger Time

Table 2.2 PQ Event Data Specifications

Remote communications to each PQube is via a secure 3G cellular broadband connection through a virtual private network. Daily trends are pushed to Hawaiian Electric's server and emails are also sent to various recipients in the Customer Solutions Engineering Division for redundancy. These emails include .csv (comma separated value) date-time stamped data files as well as pqdif (power quality data interchange format), xml, text, and .gif files of trended data and statistical histograms. Events are emailed and text-messaged to recipients in near-real time when they are triggered. These event emails also contain attached data and .gif files for both rms and waveforms of the event. A typical PQ event email page is shown below in Fig 2.1:

Subject: PQube - 2015/08/24 14:17:17 - Voltage Sag - Dole Plantation EV Charging Station
Attachments: 2015-08-24 (T 14-17-17-110)Voltage Sag Waveform.gif; 2015-08-24 (T 14-17-17-110)Voltage Sag RMS.gif; 2015-08-24 (T 14-17-17-110)Voltage Sag Waveform.csv; 2015-08-24 (T 14-17-17-110)Voltage Sag RMS.csv; Event.xml; Event.txt; Event.htm; EventSummary.txt; 2015-08-24 (T 14-17-17.110) Voltage Sag PQDIF.pqd

Voltage Sag - Dole Plantation EV Charging Station

PQube Information

Location:	Dole Plantation EV Charging Station
PQube ID:	Dole EV PQube
Note 1:	64-1550 Kamehameha Hwy
Note 2:	
PQube Serial Number:	P007194
Model Number:	PQube 02-0000
Firmware Version:	2.1.7 #2930
IP Address:	192.168.119.203

Configuration

Power Configuration:	Wye/Star
Nominal Line-to-Neutral Voltage:	277V
Nominal Line-to-Line Voltage:	480V
Nominal Frequency:	60Hz
CT Ratio:	100:0.333

Event

Event Type:	Voltage Sag
Event Magnitude:	88.18%
Event Duration in Seconds:	0.025
Trigger Date:	2015/08/24
Trigger Day of Week:	Monday
Trigger Time:	T 14:17:17.110
Trigger Channel:	L1-N
Trigger Threshold:	95.0% of nominal

Channel	Min	Max	Min During Event Only	Max During Event Only
N-E	0.6V	1.1V	0.8V	1.0V
L1-N	244.2V	280.4V	244.2V	277.9V
L2-N	272.3V	279.3V	272.3V	279.3V
L3-N	277.3V	290.6V	280.3V	290.6V
L1-L2	455.7V	484.9V	455.7V	478.3V
L2-L3	479.7V	480.6V	479.8V	480.3V
L3-L1	467.1V	483.7V	467.1V	479.8V
L1 Amp	2.72A	2.93A	2.76A	2.85A
L2 Amp	2.68A	2.93A	2.72A	2.85A
L3 Amp	2.72A	2.97A	2.80A	2.80A
N Amp	0.00A	0.00A	0.00A	0.00A
E Amp	0.00A	0.00A	0.00A	0.00A
Frequency	59.955Hz	59.963Hz	59.957Hz	59.960Hz
Power	-0.05kW	0.06kW	-0.05kW	-0.03kW

Fig. 2.1 PQ Event Email Example

Complete manufacturer's specifications of the PQube are included in Appendix 1 of this report.

Data is archived and can be interrogated on Hawaiian Electric's Intranet through the PQWeb®[37] user interface, as illustrated in the screen shot below in Fig. 2.2:

[37] PQWeb® is a web-based power quality user interface provided to Hawaiian Electric Company by Electrotek Concepts as part of PQView®, its suite of power quality database and analysis tools.

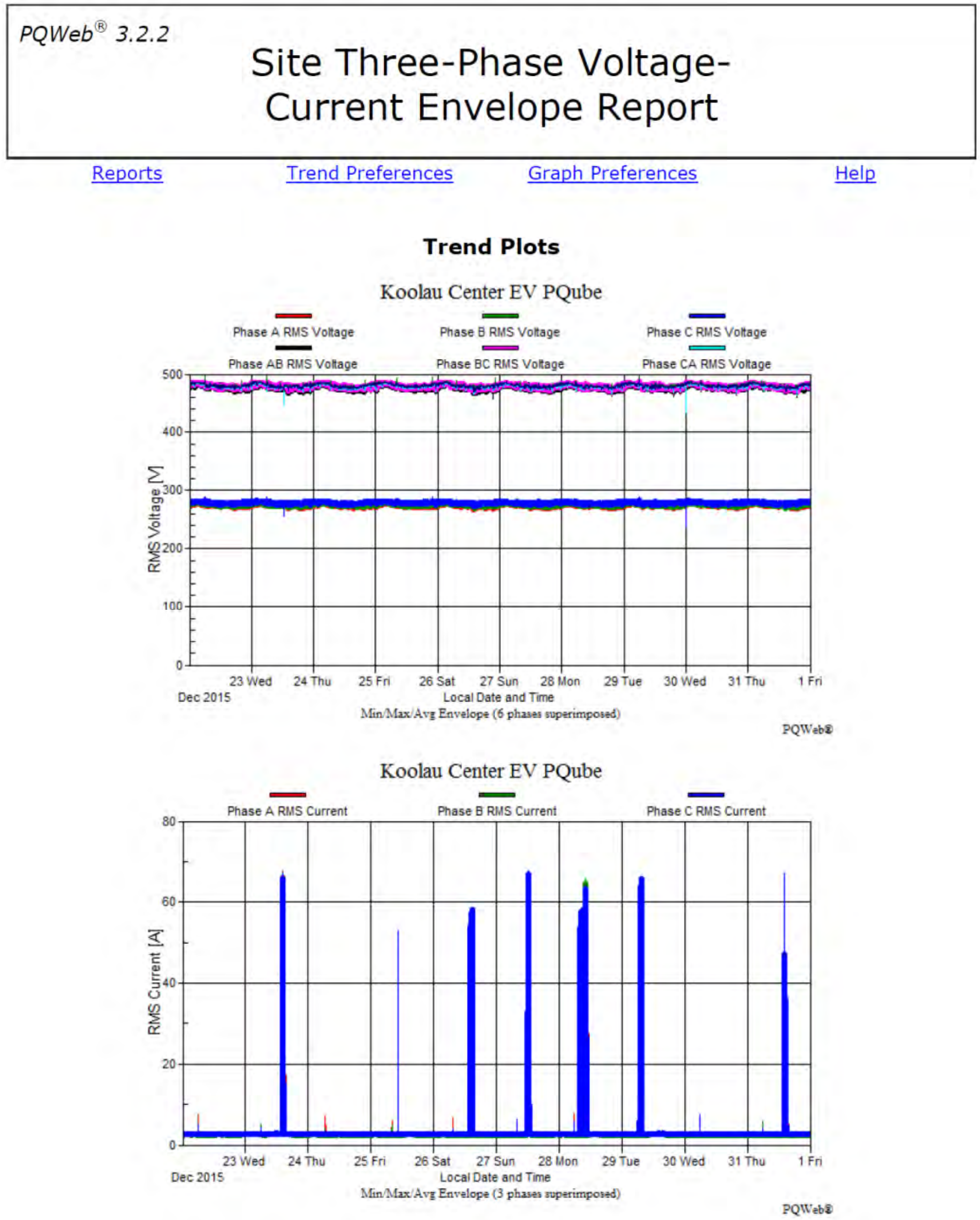


Fig. 2.2 PQWeb Screen Shot Example

Utilizing these various tools, the data used in this report has been collected, archived and subsequently analyzed and presented herein.

2.2. EV Fast Charger Host Site Information

Hosts sites selected for this report include Dole Plantation, Ko`olau Center and Kapolei Commons. Site information is tabulated below in Table 2.3:

EV Fast Charger Host Site	Address	In-Service Date	Data Collection Period	Electrical Service	EV Fast Charger
Dole Plantation	64-1550 Kamehameha Hwy., Wahiawa, HI 96786	6/25/2015	10/1/2015 - 12/31/15	480/277 V 3-phase, 4-wire wye, 60 Hz	Efacec QC50 DC Fast Charger. Input: 480/277 V, 3-phase, 4-wire, 79 A max. current, 65.5 kVA, 0.98 PF. Output: 50-500 VDC, 0-125 A, supports CHAdeMO and SAE-CSS charging protocols and plugs. Dimensions: 31.5" x 31.5" x 82.67". NEMA 3R - outdoor rated.
Koolau Center	47-338 Hui Iwa St., Kaneohe, HI 96744	9/28/2015	10/1/2015 - 12/31/15	480/277 V 3-phase, 4-wire wye, 60 Hz	Efacec QC50 DC Fast Charger. Input: 480/277 V, 3-phase, 4-wire, 79 A max. current, 65.5 kVA, 0.98 PF. Output: 50-500 VDC, 0-125 A, supports CHAdeMO and SAE-CSS charging protocols and plugs. Dimensions: 31.5" x 31.5" x 82.67". NEMA 3R - outdoor rated.
Kapolei Commons	4450 Kapolei Parkway, Kapolei, HI 96707	11/27/2015	11/18/2015 - 12/31/15	208/120 V 3-phase, 4-wire wye, 60 Hz	VLI-EV (distributor) Rapid Charger. Input: 208/120 V, 3-phase, 4-wire, 23 kW. Output: 50-500 VDC, 50 kW, supports CHAdeMO charging protocol and plug. Integrated 12 kWh BESS buffer battery system to limit input demand to 23 kW. Dimensions: 1100 mm x 1915 mm x 791 mm. Outdoor rated.

Table 2.3 EV Fast Charger Host Sites (2015)

Single-line diagrams for each EV fast charger site installations as included in this report are shown below in Figures 2.3-2.5. The "HECO PQ Meter" designation is the PQube data monitoring equipment.

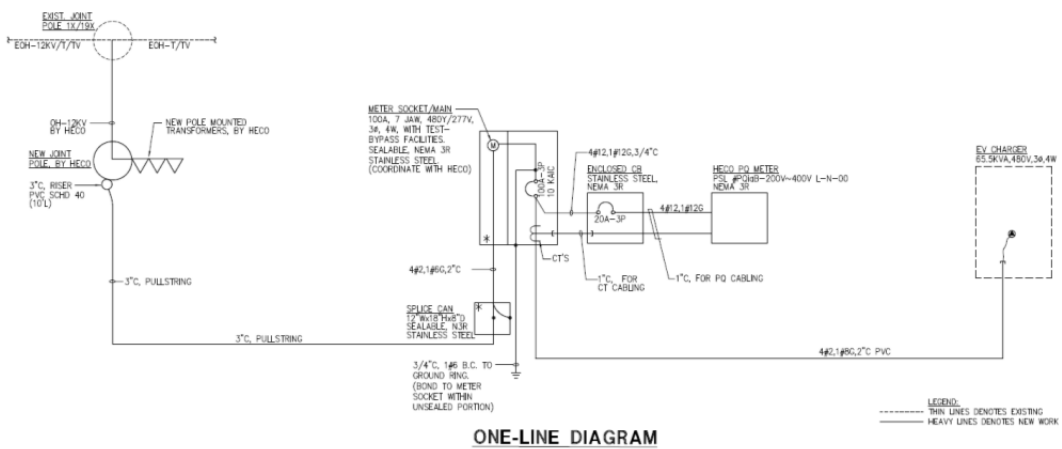


Fig. 2.3 Dole Plantation EV Fast Charger 1-Line Diagram

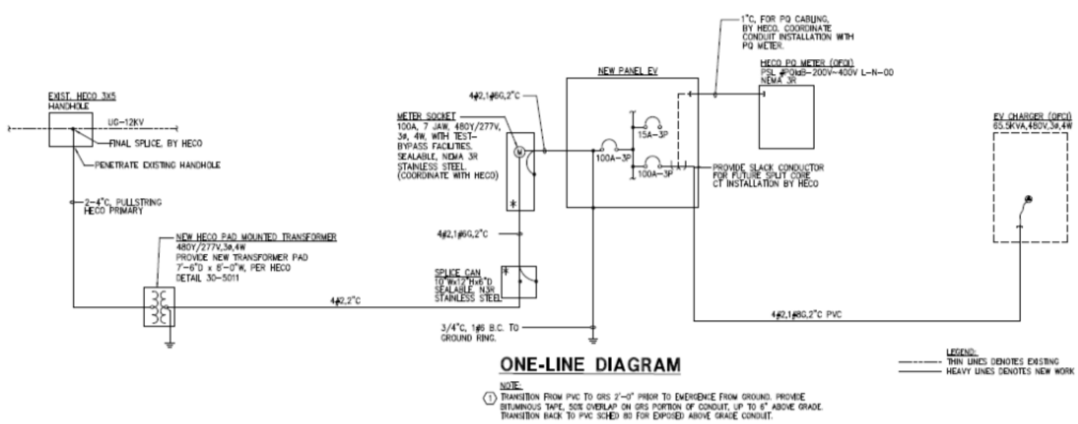


Fig. 2.4 Ko`olau Center EV Fast Charger 1-Line Diagram

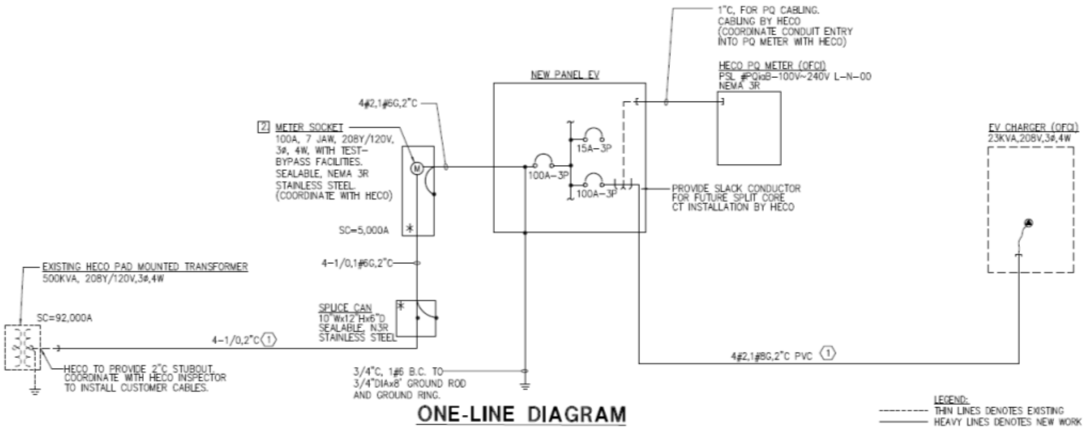


Fig. 2.5 Kapolei Commons EV Fast Charger 1-Line Diagram

The specification sheets for the EV fast chargers deployed at the three sites of interest are included in Appendix 2 of this report. The EV fast charger installed at Kapolei Commons includes an integral buffer battery system that limits the input demand to the charging system to 23 kW, while providing up to 47 kW of DC charging to the EV. This technology is part of a Hawaiian Electric Company – Electric Power Research Institute (EPRI) joint research, development and demonstration project.

2.3. Electric Vehicle Charging Profiles

One of the goals of this report is to characterize, to the extent possible, the unique charging profiles of EVs charging at Hawaiian Electric's charger fast sites. The EV fast chargers that are being deployed and placed into operation by Hawaiian Electric support both CHAdeMO and SAE CSS charging protocols and vehicle connector plugs, with the exception of the charger/battery system at Kapolei Commons, which supports CHAdeMO.

The CHAdeMo EV DC fast charging protocol has been adopted mainly by Japanese EV manufacturers. SAE CSS is being adopted by European and American EV manufacturers. Plug configurations are different for each protocol, and Hawaiian Electric made a decision to offer both plug and cord sets on each of its chargers, again with the exception of the Kapolei charger. It should be noted that the chargers currently in operation do not support simultaneous charging with both plugs.

CHAdeMo charging characteristics for the Nissan Leaf and the Mitsubishi i-MiEV are relatively well-known and documented. EPRI has conducted research and cataloging of CHAdeMO commercial EV fast charging characteristics of these two EVs. EPRI's report "Utility Direct Medium Voltage DC Fast Charger Update: DC Fast Charger Characterzation", by A. Maitra, and published in December 2012 will be referenced in this report of CHAdeMO protocol background information.

Under a near-empty state of EV battery charge conditions, CHAdeMO fast charging for a Leaf and i-MiEV have similar characteristics and profiles. Initially, a very quick ramp in power is supplied to the onboard EV battery charger within a few seconds, followed by a slow ramp to maximum supplied power, known as the Constant Current (CC) portion of the fast charge session. This is followed by an exponential decay in supplied power to a minimum at the end of the session. This decay is known as the Constant Voltage (CV) portion of the profile, as illustrated in Fig. 2.6 below:[38]

[38] *Utility Direct Medium Voltage DC Fast Charger Update: DC Fast Charger Characterzation.* EPRI, Palo Alto, CA: 2012. 1024106. Pp. 1-7 – 1-10

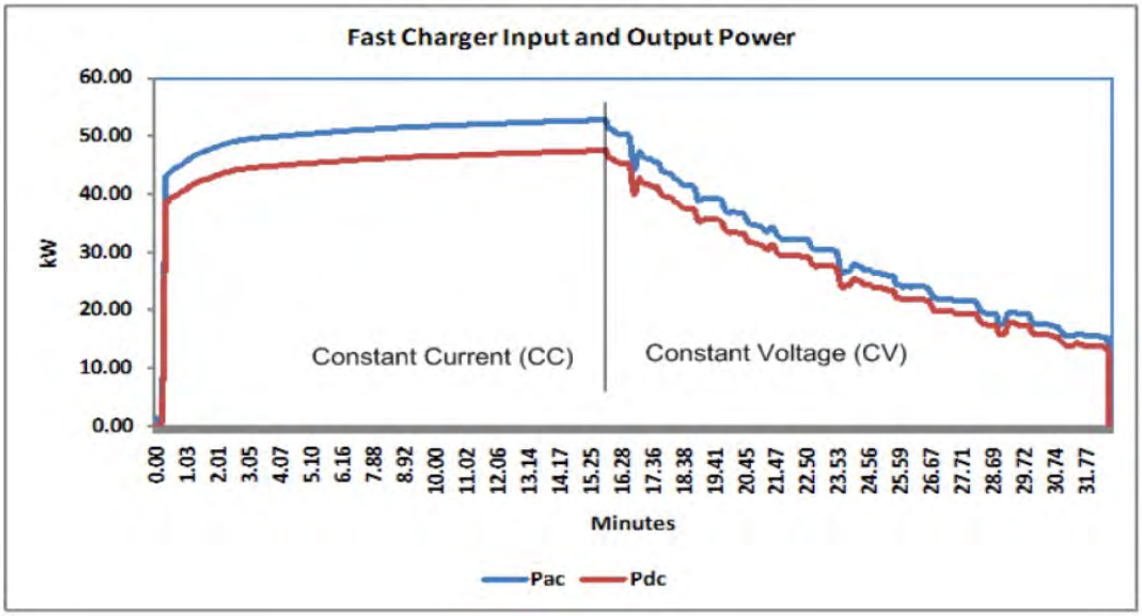


Fig. 2.6 Nissan Leaf Charge Profile During Full Charge Cycle (EPRI)

The Mitsubihi i-MiEV has a very similar charging profile as illustrated in Fig. 2-7:[39]

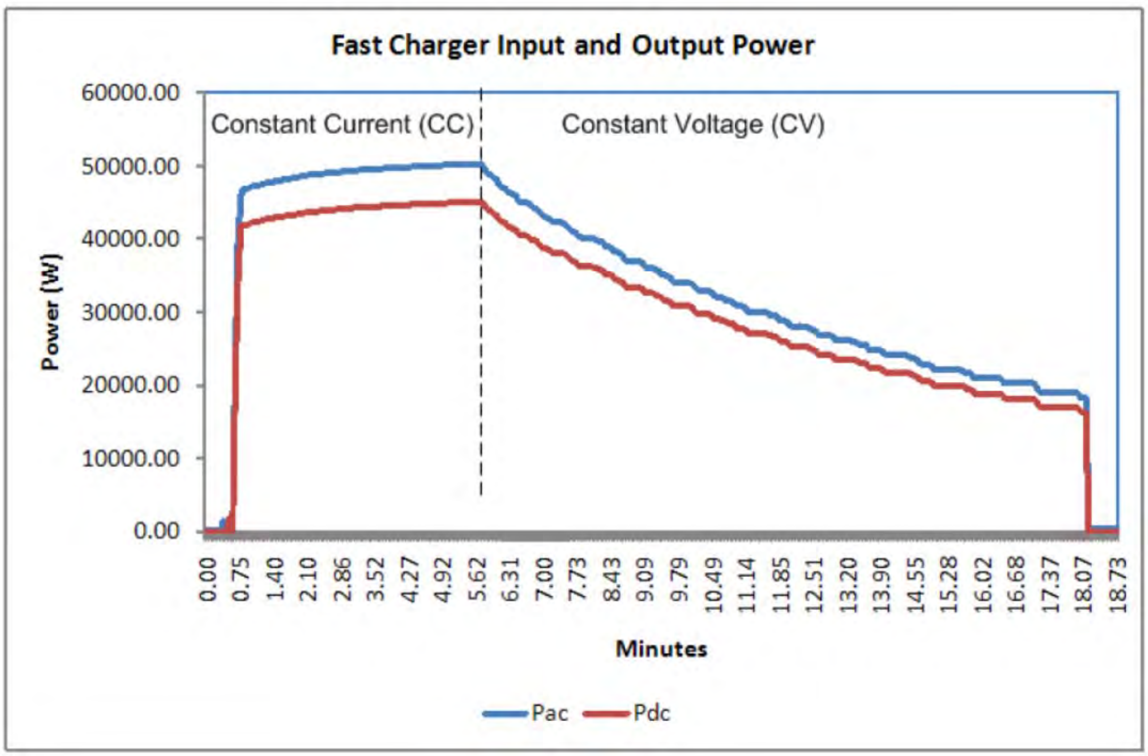


Fig. 2.7 Mitsubihi i-MiEV Charge Profile During Full Charge Cycle (EPRI)

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39 Ibid. p. 1-10 – 1-11.

Referencing EPRI's results, we can verify in situ EV fast charging activity to a certain degree. Results for EPRI's Nissan Leaf fast charging test and evaluation results are tabulated below in Table 2.4:[40]

Starting Battery Capacity (kWh)	Input AC Energy (kWh)	Output DC Energy (kWh)	Ending Battery Capacity (kWh)	Charge Time (min.)
0.7	21.3	19.2	18.0	32
13.6	8.6	7.5	20.6	39
16.4	6.0	5.1	20.8	25
17.2	4.4	3.7	20.8	34

Table 2.4 Energy Consumption for Nissan Leaf Under Various Starting Battery Capacities

As advertised by Nissan in various publications, the Nissan Leaf battery (through 2015) has a capacity of 24 kWh and fast charging can restore up to 80% of capacity (19.2 kWh) in approximately 30 minutes. EPRI's test and evaluation results confirm this.

The Tesla Model S is capable of fast charging through its proprietary Supercharging protocol. An adapter is offered by Tesla such that the Model S can be fast charged at at CHAdeMO-compliant fast chargers. Little is known about the CHAdeMO charging characteristics of Tesla EVs. The Tesla Model S can have battery configurations of 40, 60, 70, 85, and 90 kWh and is the only known EV available in the Hawai`i market through 2015 to have battery capacities of 40 kWh or more.

From what Hawaiian Electric knows about the local EV market, there are a few BMW i3 and other European EVs that can charge at SAE CSS-compliant fast chargers. The i3 has a 23 kWh Lithium-Ion battery with a range (81 miles) comparable to the Nissan Leaf. At the time of this report, Hawaiian Electric could not obtain fast charge characteristic information on SAE CSS.

2.4. Applicable Power Quality Standards and Hawaiian Electric Company Tariff Information

Background information for the in situ electrical environment and PQ event analysis and characterization is provided in this section.

Steady State Voltage Regulation and Unbalance

Sections B.2 and B.3 in Rule 2 of HECO's tariff stipulate:

[40] Ibid. pp. 1-12 – 1-13.

2. Primary and Transmission Voltages

The nominal primary line-to-line voltages are 4.16, 11.5, 12.47 and 24.94 KV. If service is rendered at any of these voltages by transformation from another primary voltage, then such service will be considered secondary for determining the charges in the rate schedules. Nominal transmission voltages are 44 and 132 KV.

Service will be supplied at primary or transmission voltage only under conditions specifically provided in the rate schedules. Where three-phase service is supplied, the load shall be balanced on the three phases in accordance with good engineering practice.

3. Voltage Limits

Voltage variations will normally be within the range specified in paragraphs a, b, and c below.

a. Secondary Voltages

For all service, except power service, the voltage variation will normally be no more than ***5 percent*** *above or below the nominal voltage. For power service, the voltage variation will normally be no more than* ***7-1/2 percent*** *above or below the nominal voltage. Where 3-phase service is provided the Company shall exercise reasonable care to assure that the phase voltages are in balance.*

b. Primary Voltages

For service rendered at a primary voltage the voltage variation will normally be no more than ***5 percent*** *above or below the nominal voltage.*

Several publications discuss the topic of 3-phase voltage unbalance. Percent voltage unbalance is defined as the maximum voltage deviation per phase from the average per phase voltage divided by the average per phase voltage multiplied by 100%.

- ANSI C84.1-1995[41] recommends: "electrical supply systems should be designed and operated to limit the maximum voltage unbalance to **3%** when measured at the electrical-utility meter under no-load conditions."
- The International Electrotechnical Commission (IEC)[42] "recommends that the maximum voltage unbalance of electrical supply systems be limited to **2%.**"

[41] ANSI Standard Publication No. ANSI C84.1-1995, for Electrical Power Systems and Equipment -- Voltage Ratings (60 Hertz), Developed by NEMA

- NEMA also recommends de-rating motors above **1%** voltage unbalance.

Harmonics

Harmonics are components of a signal present at various frequencies other than the fundamental frequency. Hawaiian Electric Company strives to transmit voltage as a nearly pure sinusoid (no harmonics present) at a fundamental frequency of 60 Hz. Harmonics may arise from non-linear loads such as solid-state electronics, adjustable speed drives, or lighting ballasts. High harmonic content in electrical power is undesirable as it may cause conductor heating and insulation failure in equipment and conductors. Total harmonic distortion is defined as the square root of the sum of the squares of harmonic voltage amplitudes divided by the voltage amplitude at the fundamental frequency multiplied by 100%. IEEE Standard 519-2014, Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems recommends that for service voltages below or equal to 69 kV, the total harmonic distortion at the point of common connection be kept below 5%.

Frequency Variations

Power frequency variations are deviations from the line fundamental frequency of 60 Hz. For Hawaiian Electric Company these variations are typically indicative of power generation loading and unloading. For example, a large generation unit tripping offline will typically cause the line frequency to fall. Alternating current motors can typically withstand frequency deviations of up to 5% of rated frequency (+ or – 3 Hz based on 60 Hz rated frequency).[43] According to IEEE Standard 446-1995 (IEEE Orange Book - Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications), the majority of end-use electronic equipment can tolerate frequency deviations of up to + or – 1% of rated frequency (+ or – 0.6 Hz based on 60 Hz rated frequency).

RMS Voltage Variations (Sags, Swells, and Interruptions)

RMS voltage variations include interruptions, undervoltage events, voltage sags, voltage swells and overvoltage events. These voltage variations are typically short duration events lasting one or more cycles to a few seconds. Voltage sags can be caused by faults in HECO's transmission and distribution system. A portion (circuit) of the transmission and distribution system is isolated by a protective device, such as a substation circuit breaker, and the voltage throughout adjoining areas of the system drops or sags until the fault is cleared. When the fault is isolated, the voltage in the adjoining areas returns to normal levels. The typical duration for a fault on a transmission system is about 6 to 13 cycles. Longer duration sags can also be caused by

[42] EPRI Power Electronics Applications Center, "Input performance of ASDs during supply voltage unbalance," Power quality testing network PQTN Brief No. 28, 1996

[43] NEMA Standards Publication, *Information Guide for General Purpose Industrial Small and Medium Squirrel-Cage Induction Motor Standards – "MG1-1998 Condensed",* 2002

distribution system faults. Within a customer site, large magnitude inrush currents due to induction motor starting can sag voltage levels. In extreme cases, adjacent sites may have their service voltage affected. Voltage swells may be caused by customer sited interruptions of large load, load shifting for operational maintenance, repairs or upgrades at substations, voltage regulator malfunction or the loss of a 3-phase line, commonly referred to as "single-phasing."

IEEE Standard 1159-2009 defines the various categories of short-duration and long-duration steady state variations. According to this standard, instantaneous sags have durations between 0.5 – 30 cycles and magnitudes between 10 – 90% of nominal voltage. Momentary sags have durations between 30 cycles and 3 seconds, and have magnitudes between 10 – 90% of nominal voltage.

IEEE Standard 1159-2009 also defines sustained interruptions as a voltage loss down to 0.0% of nominal voltage for a duration greater than 1 minute.

The following chart illustrates the various categories of short-duration and long-duration RMS voltage variations of IEEE Standard 1159-2009:

IEEE Standard 1159-2009 RMS Variation Magnitude and Duration Categories		
Category	Duration	Voltage Magnitude
Short Duration Variations		
Instantaneous		
Sag	0.5 to 30 cycles	0.1 to 0.9 PU
Swell	0.5 to 30 cycles	1.1 to 1.8 PU
Momentary		
Interruption	0.5 to 3 seconds	Less than 1 PU
Sag	30 cycles to 3 seconds	0.1 to 0.9 PU
Swell	30 cycles to 3 seconds	1.1 to 1.8 PU
Temporary		
Interruption	3 seconds to 1 minute	Less than 1 PU
Sag	3 seconds to 1 minute	0.1 to 0.9 PU
Swell	3 seconds to 1 minute	1.1 to 1.8 PU
Long Duration Variations		
Sustained Interruption	Greater than 1 minute	0.0 PU
Under-voltage	Greater than 1 minute	0.8 to 0.9 PU
Over-voltage	Greater than 1 minute	1.1 to 1.2 PU

For the purposes of this report, we have used the duration parameters in the IEEE Standard 1159-2009 category chart above, but have used 0.1 to 0.95 PU[44] and 1.05 to 1.80 PU as the magnitude parameters for all sag and swell categories, respectively. The upper limit of the sag magnitude threshold and lower limit of the swell threshold coincide with the voltage variation ranges set forth in HECO's Character of Service Rule No. 2.B.3.a.

In addition, paragraph B.3 in Rule 2 of HECO's tariff states:

d. Exceptions to Voltage Requirements

Voltage outside the limits specified above may be furnished when:

(1) The customer, by contract, agrees to accept service with unregulated voltage.

(2) The variations arise from the action of the elements.

(3) The variations are infrequent fluctuations not exceeding 5 minutes duration.

(4) The variations arise from service interruptions.

(5) The variations arise from temporary separation of parts of the system from the main system.

(6) The variations are from causes beyond the control of the Company.

(7) Such fluctuations are caused solely by the load of one particular customer that does not affect the voltage of other customers in the vicinity.

<u>Voltage Transients</u>

Transients are sudden, non-power frequency changes in the steady-state magnitude of voltage, current, or both. Transients can be characterized as either impulsive or oscillatory in nature. Impulsive transients are unidirectional in polarity (either positive or negative) and are typically attributed to lightning. Oscillatory transients are characterized by a damped high-frequency distortion of the voltage and/or current sinusoidal waveform. All transients are short-lived occurring in less than a cycle and have durations between less than 50 nanoseconds to several milliseconds. A typical cause of low-frequency (300 – 900 Hz primary frequency) oscillatory transients is the energization of utility capacitor banks on subtransmission or distribution

[44] Per Unit = percent of nominal divided by 100.

systems. Peak magnitudes of oscillatory transients can approach 200% of nominal voltage or current but is typically in the range of 130 – 150% of nominal rms magnitude.[45]

Utilities have a responsibility to maintain steady-state voltages within a specified range. A typical voltage profile for a distribution system serving commercial customers during a weekday will show voltage levels beginning to fall off during the start of the business day and rising at the end of the day. To compensate for this voltage depression during the work day, utilities will often deploy capacitor banks at substation transformers that are switched on in the morning and then switched off later in the early evening. As mentioned, capacitor bank switching may induce an oscillatory transient on the distribution system. It has been found that sensitive electronic control equipment such as adjustable speed drives may trip or malfunction due to the impressed oscillatory transient at the time of the capacitor bank energization. It has also been found that customer-installed power factor correction capacitors may have the effect of magnifying voltage transients at the resonant frequency of the transient. A cost-effective means to mitigate nuisance trips of adjustable speed drives by the end-user is to have 3 – 5% series reactors installed at the line side of the drive.[46]

3. Collected Data Summary

3.1. <u>Fast Charging Sites Charge Session Data</u>

In this section EV fast charging session data is summarized. To distinguish between apparent longer-range EV data (such as the Tesla Model S) and conventional EV data (such as the Chevy Volt or Nissan Leaf), a designation "Type 1" was given to longer-range EVs and "Type 2" given to conventional EVs. These designations were given based upon length of charge session, amount of energy consumed during the session and unique fast charging profiles that revealed the distinction.

[45] Roger C. Dugan, Mark F. McGranaghan, Surya Santoso, H. Wayne Beaty, *Electrical Power Systems Quality,* McGraw-Hill, 2nd Edition, 2002, pp. 15-17.
[46] Ibid. pp. 111-116, p. 161.

Dole Plantation EV Fast Charging Session Data

Dole Plantation EV fast charging session data collected from 10/1/15 through 12/31/15 is tabulated below in Table 3.1:

Date	Session Start	Session Duration (min.)	TOU Period	Avg. Demand (kW)	Max. Demand (kW)	Usage (kWh)	Charge Profile	Coincident PQ Events
10/1/2015	12:24 PM	30	Mid-Peak	25.7	53.2	13.3	Type 1	
10/6/2015	10:29 AM	30	Mid-Peak	29.4	53.2	15.2	Type 1	
10/6/2015	4:57 PM	31	Mid-Peak	30.5	53.2	16.3	Type 1	
10/6/2015	5:38 PM	31	Priority-Peak	21.7	53.2	11.6	Type 1	
10/7/2015	2:46 PM	30	Mid-Peak	27.8	53.2	14.4	Type 1	
10/7/2015	3:34 PM	7	Mid-Peak	5.0	18.5	0.7	Type 1	
10/7/2015	3:44 PM	30	Mid-Peak	21.1	53.3	14.4	Type 1	
10/9/2015	9:49 AM	30	Mid-Peak	23.7	53.2	12.3	Type 1	
10/10/2015	12:22 PM	30	Mid-Peak	15.6	52.8	8.0	Type 1	
10/13/2015	1:53 PM	23	Mid-Peak	30.7	53.3	12.3	Type 1	
10/17/2015	3:33 PM	29	Mid-Peak	37.5	53.3	19.7	Type 1	
10/17/2015	4:36 PM	5	Mid-Peak	33.7	52.9	3.7	Type 1	
10/18/2015	9:56 AM	31	Mid-Peak	13.5	52.6	7.2	Type 1	
10/18/2015	3:27 PM	31	Mid-Peak	32.4	53.3	17.3	Type 1	
10/21/2015	4:46 PM	18	Mid-Peak	26.5	53.3	11.5	Type 1	
10/24/2015	2:23 PM	30	Mid-Peak	19.4	53.2	10.0	Type 1	
10/30/2015	7:19 PM	30	Priority-Peak	36.3	53.2	18.7	Type 1	
10/31/2015	12:02 PM	25	Mid-Peak	23.3	53.2	10.1	Type 1	
10/31/2015	4:27 PM	21	Mid-Peak	40.0	53.3	14.7	Type 1	
11/1/2015	8:49 AM	29	Mid-Peak	14.3	52.8	14.3	Type 1	
11/1/2015	1:52 PM	30	Mid-Peak	12.5	53.2	14.3	Type 1	
11/4/2015	11:26 AM	25	Mid-Peak	21.1	53.1	9.1	Type 1	
11/5/2015	12:05 PM	9	Mid-Peak	30.4	53.1	5.1	Type 1	
11/5/2015	5:32 PM	31	Mid-Peak	23.4	53.2	12.5	Type 1	
11/6/2015	2:48 PM	23	Mid-Peak	38.8	53.3	15.5	Type 1	
11/7/2015	1:37 PM	30	Mid-Peak	24.4	53.2	12.6	Type 1	
11/9/2015	2:12 PM	22	Mid-Peak	25.1	53.2	10.5	Type 1	
11/12/2015	3:59 PM	30	Mid-Peak	25.4	53.2	13.1	Type 1	
11/22/2015	3:43 PM	31	Mid-Peak	19.9	53.1	10.6	Type 1	
11/27/2015	12:03 PM	31	Mid-Peak	22.7	53.1	12.1	Type 1	
11/27/2015	2:17 PM	22	Mid-Peak	29.5	53.1	11.3	Type 1	
11/28/2015	10:35 AM	31	Mid-Peak	22.4	53.1	11.9	Type 1	
11/29/2015	12:07 PM	24	Mid-Peak	30.3	53.1	12.6	Type 1	
12/2/2015	8:12 AM	26	Mid-Peak	25.9	53.0	11.7	Type 1	
12/2/2015	10:36 AM	11	Mid-Peak	37.7	53.1	7.5	Type 1	
12/2/2015	12:28 PM	7	Mid-Peak	16.2	53.0	2.2	Type 1	
12/4/2015	1:07 PM	27	Mid-Peak	30.2	53.1	14.1	Type 1	
12/5/2015	3:57 PM	20	Mid-Peak	21.0	53.1	7.4	Type 1	
12/6/2015	11:11 AM	30	Mid-Peak	21.3	53.1	11.0	Type 1	
12/9/2015	3:07 PM	32	Mid-Peak	16.8	52.7	9.2	Type 1	
12/11/2015	3:26 PM	28	Mid-Peak	29.3	53.2	14.2	Type 1	
12/11/2015	6:08 PM	35	Priority-Peak	18.9	52.8	11.4	Type 1	
12/12/2015	11:53 AM	30	Mid-Peak	33.3	53.1	17.2	Type 1	
12/12/2015	12:26 PM	21	Mid-Peak	4.1	20.1	1.5	Type 1	
12/13/2015	3:53 PM	17	Mid-Peak	27.2	53.1	8.1	Type 1	
12/18/2015	2:17 PM	30	Mid-Peak	26.3	53.1	13.6	Type 1	
12/19/2015	9:19 AM	30	Mid-Peak	16.4	53.0	8.5	Type 1	
12/19/2015	1:26 PM	31	Mid-Peak	31.2	53.2	16.7	Type 1	Instantaneous Voltage Sag at 1:31 PM
12/19/2015	5:54 PM	12	Mid-Peak	25.5	52.7	5.5	Type 1	
12/20/2015	2:16 PM	30	Mid-Peak	25.7	53.1	13.3	Type 1	
12/27/2015	12:30 PM	30	Mid-Peak	33.0	53.1	17.1	Type 1	
12/28/2015	9:14 AM	31	Mid-Peak	12.4	53.0	6.6	Type 1	
12/28/2015	10:46 AM	26	Mid-Peak	18.4	52.8	8.3	Type 1	

Table 3.1 Dole Plantation EV Fast Charging Data

The data from Table 3.2 is summarized below:

Number of Sessions:	53
Number of Days Monitored:	92
Number of Mid-Peak Sessions:	50
Number of Priority-Peak Sessions:	3
Days with 2 or More Sessions:	14
Average session per day:	0.58
Number EVs Type 1:	53
Number EVs Type 2:	0
Average Demand (kW):	24.6
Maximum Demand (kW):	53.3
Average Usage (kWh):	11.4
Maximum Usage (kWh):	19.7

Sample graphs of EV fast charging profiles are presented below in Figures 3.1 through 3.4:

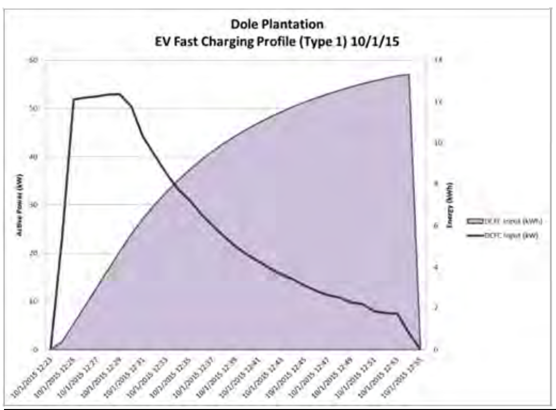

Fig. 3.1 Type 1 Fast Charging 10/1/15

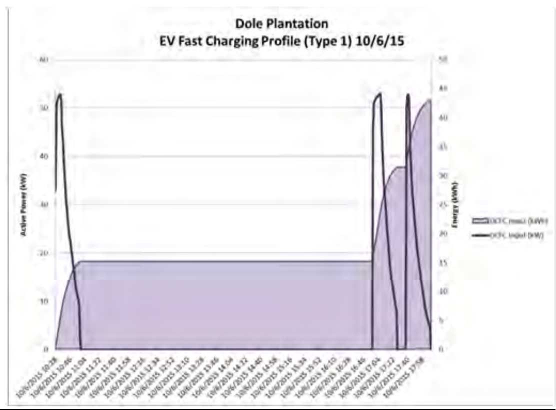

Fig. 3.2 Type 1 Fast Charging 10/6/15

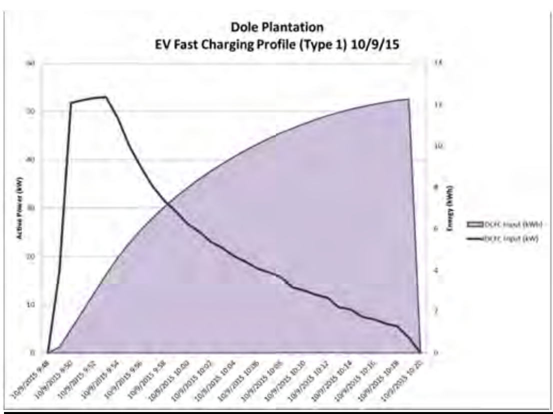

Fig. 3.3 Type 1 Fast Charging 10/9/15

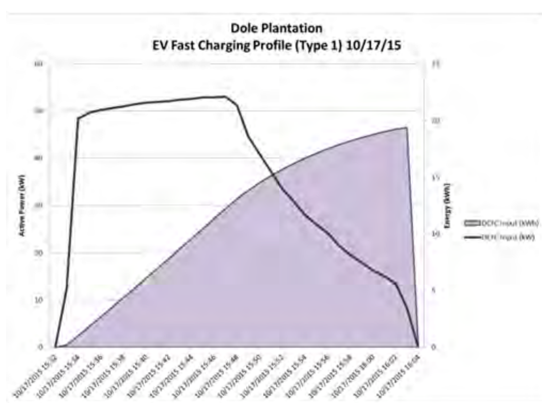

Fig. 3.4 Type 1 Fast Charging 10/17/15

Ko`olau Center EV Fast Charging Session Data

Ko`olau Center EV fast charging session data collected from 10/1/15 through 12/31/15 is tabulated below in Table 3.2:

Date	Session Start	Session Duration (min.)	TOU Period	Avg. Demand (kW)	Max. Demand (kW)	Usage (kWh)	Charge Profile	Coincident PQ Event
10/1/2015	8:00 PM	30	Priority-Peak	32.3	52.4	16.7	Type 1	
10/3/2015	2:29 PM	30	Mid-Peak	28.3	52.3	14.6	Type 1	
10/5/2015	10:32 AM	27	Mid-Peak	18.1	52.3	8.4	Type 1	
10/6/2015	8:47 PM	7	Priority-Peak	33.2	52.3	4.4	Type 1	
10/10/2015	9:40 AM	21	Mid-Peak	11.8	52.2	4.3	Type 1	
10/22/2015	11:48 AM	28	Mid-Peak	10.5	35.7	5.1	Type 1	
10/24/2015	5:03 PM	27	Priority-Peak	20.0	52.3	9.3	Type 1	
10/25/2015	12:11 PM	30	Mid-Peak	19.5	51.9	10.1	Type 1	
10/27/2015	3:20 PM	28	Mid-Peak	21.1	52.4	10.0	Type 1	Temporary Voltage Swell
10/29/2015	11:33 AM	33	Mid-Peak	23.7	52.0	13.4	Type 1	
11/3/2015	7:30 PM	17	Priority-Peak	22.6	47.9	6.8	Type 1	Temporary Voltage Sag
11/11/2015	4:50 PM	11	Mid-Peak	20.8	52.3	4.2	Type 1	
11/13/2015	11:54 AM	17	Mid-Peak	14.7	47.9	4.4	Type 1	
11/22/2015	11:25 AM	33	Mid-Peak	40.7	44.0	23.1	Type 2	
11/23/2015	8:35 AM	62	Mid-Peak	41.2	45.5	43.3	Type 2	
11/26/2015	4:23 PM	23	Mid-Peak	12.6	38.7	5.0	Type 1	
11/27/2015	8:03 PM	30	Priority-Peak	40.3	42.7	20.8	Type 2	
11/29/2015	11:50 AM	62	Mid-Peak	41.9	45.6	44.0	Type 2	
12/5/2015	6:57 PM	25	Priority-Peak	21.1	52.3	9.1	Type 1	
12/7/2015	11:04 AM	71	Mid-Peak	42.0	45.7	50.3	Type 2	
12/8/2015	8:04 PM	4	Priority-Peak	40.2	50.7	3.3	Type 2	
12/10/2015	11:16 AM	58	Mid-Peak	41.1	45.5	40.4	Type 2	
12/14/2015	8:50 AM	62	Mid-Peak	41.9	45.5	44.0	Type 2	
12/15/2015	4:44 PM	24	Mid-Peak	18.9	52.3	7.9	Type 1	
12/17/2015	8:40 AM	54	Mid-Peak	40.9	45.5	37.5	Type 2	
12/18/2015	2:06 PM	32	Mid-Peak	19.1	52.3	10.5	Type 1	
12/20/2015	4:50 PM	30	Mid-Peak	30.2	52.3	15.6	Type 1	
12/21/2015	8:42 AM	65	Mid-Peak	40.9	45.6	45.0	Type 2	
12/21/2015	4:09 PM	30	Mid-Peak	29.7	52.3	15.3	Type 1	
12/23/2015	2:04 PM	32	Mid-Peak	19.8	52.0	10.9	Type 1	
12/26/2015	1:52 PM	49	Mid-Peak	41.2	43.8	34.3	Type 2	
12/27/2015	12:01 PM	29	Mid-Peak	18.1	52.2	9.0	Type 1	
12/28/2015	7:57 AM	57	Mid-Peak	40.6	45.5	39.3	Type 2	
12/28/2015	10:03 AM	33	Mid-Peak	23.3	52.0	13.2	Type 1	
12/29/2015	7:11 AM	30	Mid-Peak	35.8	52.3	18.5	Type 1	
12/31/2015	2:20 PM	30	Mid-Peak	12.0	52.2	6.2	Type 1	

Table 3.2 Ko`olau Center EV Fast Charging Data

The data from Table 3.2 is summarized below:

Number of Sessions:	36
Number of Days Monitored:	92
Number of Mid-Peak Sessions:	29
Number of Priority-Peak Sessions:	7
Days with 2 Sessions:	2
Average session per day:	0.39
Number EVs Type 1:	24
Number EVs Type 2:	12
Average Demand (kW):	28.1
Maximum Demand (kW):	52.4
Average Usage (kWh):	18.3
Maximum Usage (kWh):	50.3

Sample graphs of EV fast charging profiles are presented below in Figures 3.5 through 3.10:

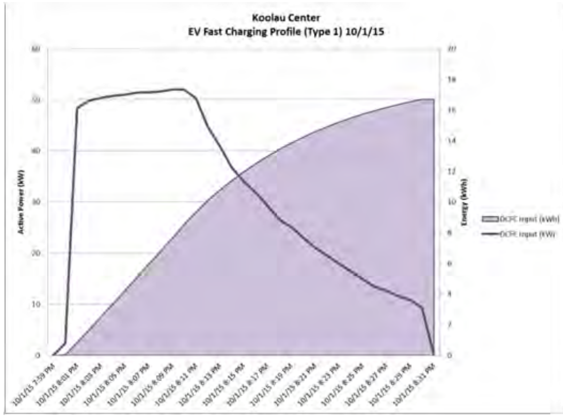

Fig. 3.5 Type 1 Fast Charging 10/1/15

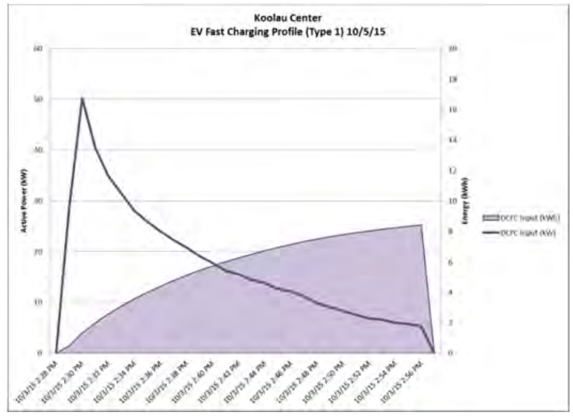

Fig. 3.6 Type 1 Fast Charging 10/5/15

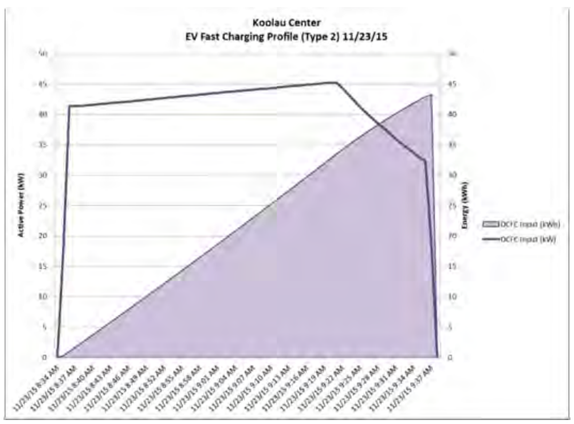

Fig. 3.7 Type 2 Fast Charging 11/23/15

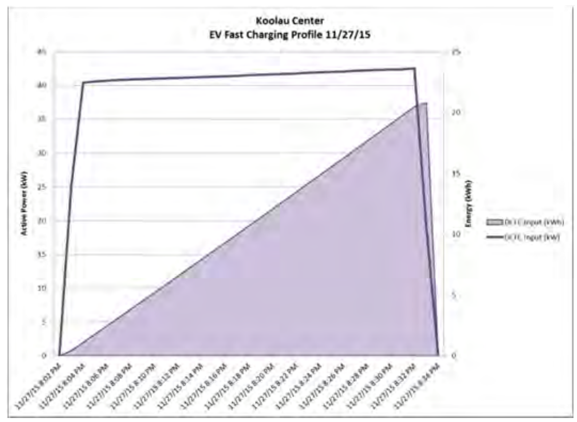

Fig. 3.8 Type 2 Fast Charging 11/27/15

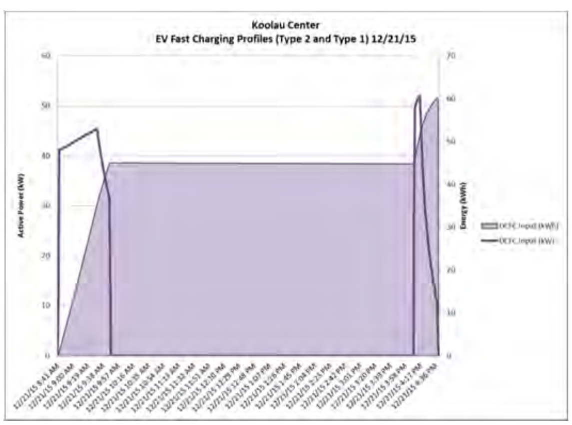

Fig. 3.9 Types 2 and 1 Fast Charging 12/21/15

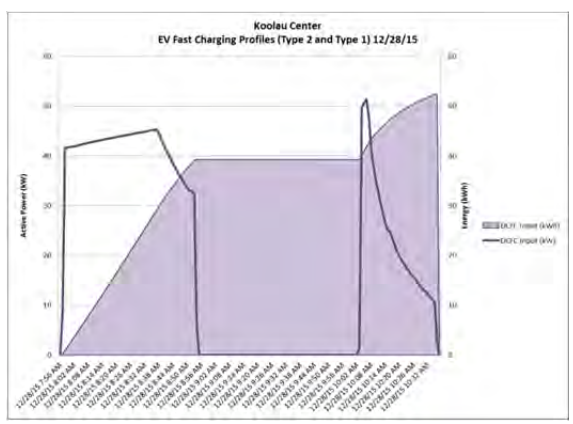

Fig. 3.10 Types 2 and 1 Fast Charging 12/28/15

Kapolei Commons EV Fast Charging Session Data

Kapolei Commons EV fast charging session data collected from 11/18/15 through 12/31/15 is tabulated below in Table 3.3:

Date	Session Start	Session Duration (min.)	TOU Period	Avg. Demand (kW)	Max. Demand (kW)	Usage (kWh)	Charge Profile	Coincident PQ Event
12/3/2015	10:44 AM	21	Mid-Peak	14.4	21.2	9.7	Type 1	
12/10/2015	10:51 AM	9	Mid-Peak	12.8	21.3	8.3	Unknown	
12/17/2015	10:42 AM	17	Mid-Peak	14.0	22.8	4.9	Type 1	
12/18/2015	1:28 PM	24	Mid-Peak	16.5	22.9	8.0	Type 1	
12/20/2015	10:55 AM	10	Mid-Peak	13.4	23.2	6.0	Type 1	
12/21/2015	9:24 PM	39	Mid-Peak	18.2	23.3	6.0	Type 1	

Table 3.3 Kapolei Commons EV Fast Charging Data

The data from Table 3.3 is summarized below:

Number of Sessions:	20
Number of Days Monitored:	45
Number of Off-Peak Sessions:	8
Number of Mid-Peak Sessions:	8
Number of Priority-Peak Sessions:	4
Average Demand (kW):	5.0
Maximum Demand (kW):	12.9
Average Usage (kWh):	0.8
Maximum Usage (kWh):	0.8

Sample graphs of EV fast charging profiles are presented below in Figures 3.11 through 3.16:

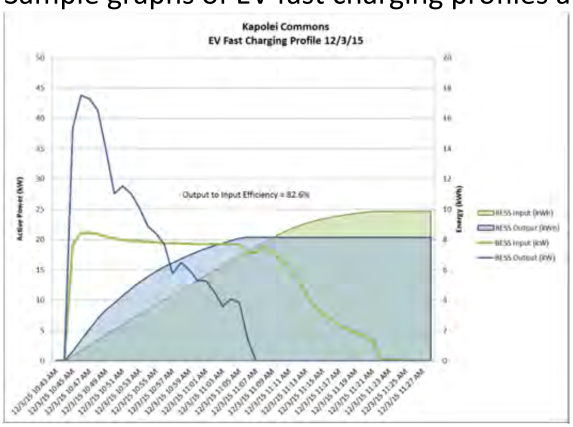

Fig. 3.11 Type 1 Fast Charging 12/3/15

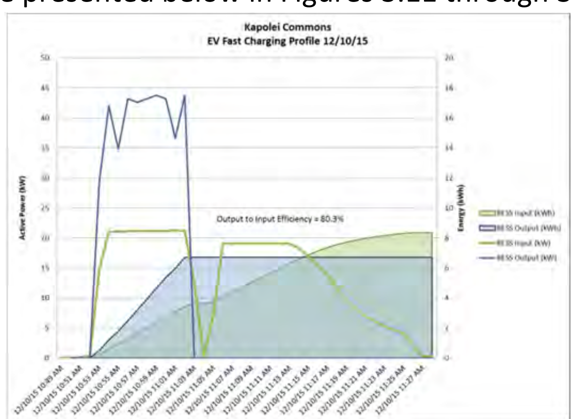

Fig. 3.12 Unknown EV Type Fast Charging 12/10/15

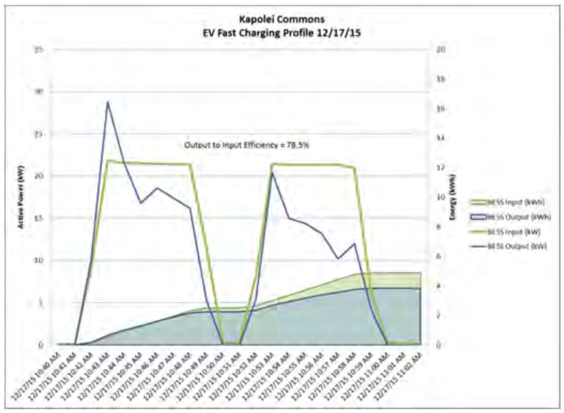

Fig. 3.13 Type 1 Fast Charging 12/17/15

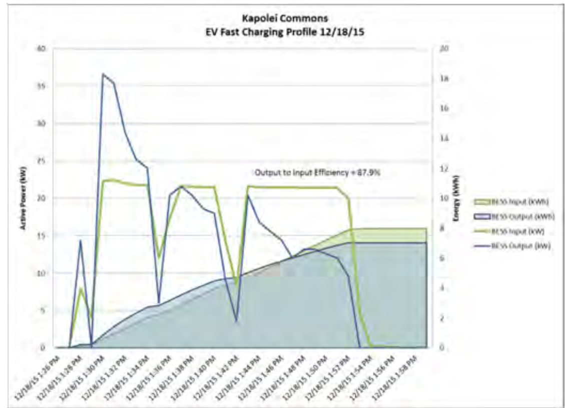

Fig. 3.14 Type 1 Fast Charging 12/18/15

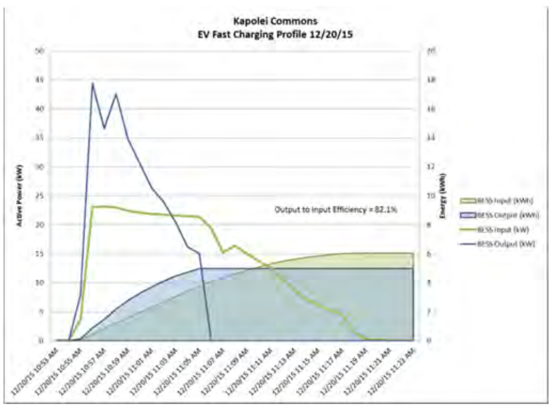

Fig. 3.15 Type 1 Fast Charging 12/20/15

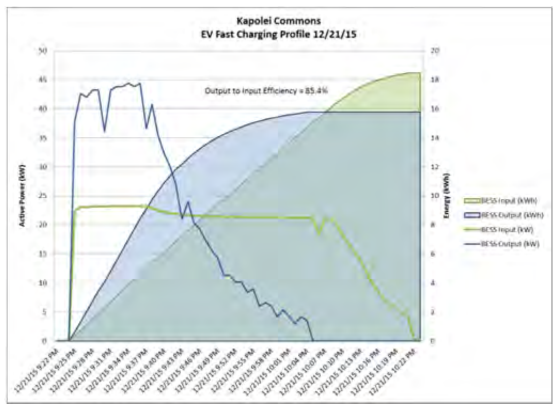

Fig. 3.16 Type 1 Fast Charging 12/21/15

Kapolei Commons buffer battery charging session data collected from 11/18/15 through 12/31/15 is tabulated below in Table 3.4:

Date	Session Start	Charging Duration (min.)	TOU Period	Avg. Demand (kW)	Max. Demand (kW)	Usage (kWh)	Coincident PQ Event
11/18/2016	10:44 AM	9	Mid-Peak	4.8	12.9	0.8	
11/20/2015	11:52 AM	7	Mid-Peak	5.3	12.9	0.8	
11/22/2015	10:02 AM	9	Mid-Peak	4.8	12.9	0.8	
11/24/2015	8:41 AM	9	Mid-Peak	4.8	12.9	0.8	
11/26/2015	7:26 AM	9	Mid-Peak	4.8	12.8	0.8	
11/28/2015	5:56 AM	10	Off-Peak	5.2	12.1	0.8	
11/30/2015	4:31 AM	9	Off-Peak	4.8	12.9	0.8	
12/2/2015	2:52 AM	8	Off-Peak	5.3	12.9	0.8	
12/5/2015	5:05 PM	8	Priority-Peak	5.3	12.9	0.8	
12/7/2015	3:35 PM	8	Mid-Peak	5.3	12.9	0.8	
12/9/2015	2:27 PM	8	Mid-Peak	5.3	12.9	0.8	
12/12/2015	9:19 PM	8	Off-Peak	5.3	12.9	0.8	
12/14/2015	7:56 PM	8	Priority-Peak	5.3	12.9	0.8	
12/16/2015	5:12 PM	5	Priority-Peak	1.2	12.1	0.1	
12/19/2015	3:37 PM	9	Mid-Peak	5.3	12.9	0.8	
12/24/2015	3:08 AM	9	Off-Peak	5.3	12.8	0.8	
12/26/2015	1:04 AM	9	Off-Peak	5.3	12.8	0.8	
12/27/2015	11:02 PM	9	Off-Peak	5.3	12.8	0.8	
12/29/2015	9:26 PM	9	Off-Peak	5.3	12.9	0.8	
12/31/2015	7:41 PM	9	Priority-Peak	5.3	12.8	0.8	

Table 3.4 Kapolei Buffer Battery Charging Data

The data from Table 3.4 is summarized below:

Number of Sessions:	20
Number of Days Monitored:	45
Number of Off-Peak Sessions:	8
Number of Mid-Peak Sessions:	8
Number of Priority-Peak Sessions:	4
Average Demand (kW):	5.0
Maximum Demand (kW):	12.9
Average Usage (kWh):	0.8
Maximum Usage (kWh):	0.8

3.2. Site Power Quality Data

In this section power quality for each fast charging site is summarized. Steady state electrical characterization, as well as power quality event data is presented.

Steady State Electrical Data Summaries

Summary data for each of the three sites of interest in this report are presented in the following Tables 3.5 through 3.7:

Dole Plantation Fast Charger Site

Nominal L-N Voltage =	277				
Voltages	L1-N (V)	L2-N (V)	L3-N (V)	Combined L-N	
Average Voltages	279.8	278.2	278.0	278.7	
	Nominal + 1.0%	Nominal + 0.4%	Nominal + 0.4%	0.6%	
Maximum Voltages	288.2	285.8	285.4	288.2	
	Nominal + 4.0%	Nominal + 3.2%	Nominal + 3.0%	4.0%	
Minimum Voltages	265.9	264.9	263.7	263.7	
	Nominal -4.0%	Nominal -4.4%	Nominal -4.8%	-4.8%	
Currents	L1 (A)	L2 (A)	L3 (A)	Combined Phases	
Average Currents	3.0	3.0	3.0	3.0	
Maximum Currents	67.8	69.2	65.6	69.2	
Minimum Currents	2.1	2.3	2.2	2.1	
	Voltage Unbalance (%)	Voltage THD (%)	Current THD (%)	Power Factor (%)	Frequency (Hz)
Average	0.41%	1.40%	0.50%	0.9%	60.0
Maximum	0.99%	1.50%	0.70%	98.0%	60.2
Minimum	0.00%	1.40%	0.00%	0.0%	59.7

Table 3.5 Dole Plantation Steady State Electrical Trending Data

Ko`olau Center Fast Charger Site

Nominal L-N Voltage =	277				
Voltages	L1-N (V)	L2-N (V)	L3-N (V)	Combined L-N	
Average Voltages	274.7	276.1	279.0	276.6	
	Nominal -0.8%	Nominal -0.3%	Nominal + 0.7%	-0.1%	
Maximum Voltages	286.9	288.8	290.8	290.8	
	Nominal + 3.6%	Nominal + 4.3%	Nominal + 5.0%	5.0%	
Minimum Voltages	263.2	263.5	266.1	263.2	
	Nominal -5.0%	Nominal -4.9%	Nominal -3.9%	-5.0%	
Currents	L1 (A)	L2 (A)	L3 (A)	Combined Phases	
Average Currents	3.0	3.0	3.1	3.0	
Maximum Currents	70.5	66.9	70.8	70.8	
Minimum Currents	2.0	2.0	2.4	2.0	
	Voltage Unbalance (%)	Voltage THD (%)	Current THD (%)	Power Factor (%)	Frequency (Hz)
Average	0.86%	3.16%	0.93%	-1.3%	60.0
Maximum	2.37%	43.80%	26.90%	98.0%	60.2
Minimum	0.00%	2.40%	0.00%	-5.0%	59.7

Table 3.6 Ko`olau Center Steady State Electrical Trending Data

Kapolei Commons Fast Charger Site

Nominal L-N Voltage =	120				
Voltages	L1-N (V)	L2-N (V)	L3-N (V)	Combined L-N	
Average Voltages	122.8	122.4	123.7	123.0	
	Nominal + 2.3%	Nominal + 2.0%	Nominal + 3.1%	2.5%	
Maximum Voltages	124.5	124.3	125.6	125.6	
	Nominal + 3.8%	Nominal + 3.6%	Nominal + 4.7%	4.7%	
Minimum Voltages	117.2	116.0	118.6	116.0	
	Nominal -2.3%	Nominal -3.3%	Nominal -1.2%	-3.3%	
Currents	L1 (A)	L2 (A)	L3 (A)	Combined Phases	
Average Currents	1.5	1.4	1.4	1.4	
Maximum Currents	64.0	64.6	63.7	64.6	
Minimum Currents	0.7	0.6	0.6	0.6	
	Voltage Unbalance (%)	Voltage THD (%)	Current THD (%)	Power Factor (%)	Frequency (Hz)
Average	0.61%	1.73%	1.12%	13.0%	60.0
Maximum	1.13%	4.20%	27.20%	100.0%	60.3
Minimum	0.41%	1.50%	0.60%	-62.0%	59.7

Table 3.7 Kapolei Commons Steady State Electrical Trending Data

Site PQ Event Data Summary

Summary data for each of the three sites of interest in this report are presented in the following Table 3.8:

Data Summary	Dole Plantation	Koolau Center	Kapolei Commons
Number of PQ Events Recorded:	33	111	17
Number of Days Monitored:	92	92	45
Number of Instantaneous Voltage Sags:	25	57	12
Number of Momentary Voltage Sags:	5	3	0
Number of Temporary Voltage Sags:	0	5	0
Number of Undervoltages:	0	0	0
Number of Instantaneous Voltage Swells:	0	1	0
Number of Momentary Voltage Swells:	0	0	0
Number of Temporary Voltage Swells:	1	1	3
Number of Overvoltages:	0	2	2
Minimum RMS Event Magnitude (Sag):	86.1%	87.4%	92.6%
Minimum RMS Event Duration (sec.):	0.026	0.0042	0.025
Maximum Event Magnitude (Swell):	105.5%	108.4%	105.6%
Maximum Event Duration (sec.):	32.5	339.8	210.2
Number of RMS Events Attributed to Localized Distribution Events:	6	21	0
Number of RMS Events Attributed to Subtransmission Events:	9	20	1
Number of RMS Events Attributed to Transmission Events:	10	11	9
Number of Events With No System Correlation or Due to Unknown Cause:	6	16	6
Number of Events Inter-related:	17	29	10
Number of Oscillatory Transients	0	38	0
Number of Underfrequency (UF) Events:	2	2	0
Minimum UF Magnitude (Hz):	59.21	59.22	NA
Maximum Duration of UF (sec.):	313.1	313.1	NA

Table 3.8 PQ Event Data Summary

4. **Analysis and Discussion of Results**

4.1. EV Fast Charging

Based on the data presented, there are several observations that can be made for each EV fast charger site.

Dole Plantation

The Dole Plantation EV fast charger is well-utilized, probably by virtue of its central location and that it was the first fast charger placed into service by Hawaiian Electric Company in late June of 2015. Customers by various means (Hawaiian Electric's webpage www.hawaiianelectric.com/goev and the online Plugshare[47] app, for example), have found its location and have grown accustomed to relying upon it. A testimony to this is evidenced by the 14 days with 2 or more sessions per day during the 3-month data collection period. Within this period, Dole Plantation averaged about 4 sessions per week. EV drivers charge mostly during mid-peak hours (between 7 AM and 5 PM) with very little charging occurring during the priority peak (between 5 PM and 9 PM).

By plotting demand and energy data with respect to date-time, charging sessions profiles can be displayed (refer to Figures 3.1 through Fig. 3.4), and these profiles are well-defined due to granular data monitoring at 1 minute intervals. These profiles exhibit the CC and CV charging characteristics typical of CHAdeMO and are consistent with EPRI results (compare sample profiles to EPRI Figures 2.7 and 2.8). Further observation and analysis reveals that the Dole Plantation fast charger was used by Type 1 CHAdeMo EVs exclusively (Leafs and i-MiEVs) during the 3-month data collection period.

Based on the data collected at the site, the average demand is 24.6 kW and maximum demand is 53.3 kW. This suggests that there is an opportunity for demand response (DR) technology application to fast chargers, perhaps to limit input demand to 25 kW through locally controlled frequency response (e.g., an under-frequency relay) or through participant opt-in and opt-out of a utility dispatched signal. Hawaiian Electric is currently working with EPRI and its DR team to implement such piloted RD&D efforts.

The data also indicates that the average and maximum charge energy is 11.4 kWh and 19.7 kWh, respectively, which is consistent with Type 1 EV fast charge characterization.

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[47] Plugshare is an online map that displays EV charge station locations. Its IP address is www.plugshare.com.

Ko`olau Center

Placed into service in October of 2015, the Ko`olau Center EV fast charger is also well-utilized. Similar to the customer adoption of the Dole Plantation fast charger, EV drivers appear to have become accustomed to relying upon the fast charging service offered at the site. There were 2 days with 2 sessions during the 3-month data collection period. Ko`olau Center averages about 3 sessions per week, and customers charge mostly during the mid-peak.

As evidenced by the graphical rendering of charge session demand and energy profiles, the fast charger at Ko`olau Center is used by drivers of both Type 1 and Type 2 EVs.

Average demand is 28.1 kW and maximum demand is 52.4 kW, which suggests an opportunity here for a demand response piloted effort. Average and maximum charge energy is 18.3 kWh and 50.3 kWh, respectively.

Type 1 EV fast charging profiling is consistent with EPRI characterization, whereas Type 2 EV characterization appears to be consistent with Tesla battery size and charging requirement. Type 2 fast charging sessions may take up to an hour and charging energy requirements are above 18.5 kWh, which is consistent with EPRI's findings for Type 1 EV fast charging characteristics.

Based on the utilization data, where all EV drivers pay a flat fee for a fast charge session, users are paying the same per-session fee to fill their EV battery which could vary in size (i.e., capacity) and state of charge. Moving forward, the Hawaiian Electric companies may propose alternative fee structures to accommodate a diverse range of customer charging needs and behaviors.

Kapolei Commons

The Kapolei Commons EV fast charger was placed into service in mid-November 2015 and did not see EV charging activity until December. As such, EV drivers were just beginning to learn of its location and make use of it during this time. The data indicates that there were no days with multiple sessions, and utilization rate was approximately one session per week during the 45-day monitoring period. All charging occurred during the mid-peak.

The EV fast charging system deployed at Kapolei Commons is a DC fast charger with an integrated buffer battery energy storage system (BESS). Greenlots, the network provider for the system monitors the DC output energy and provided EV charging session data for this report such that AC input demand and energy (as collected by the on-site PQube monitor) could be compared to the output demand and energy.

EV charging session profiles for the six sessions during the monitoring period have been graphically rendered in Figures 3.13 through 3.18, but they are somewhat inconsistent with EPRI results due to the unknown characteristics of the proprietary buffer battery technology.

Energy delivered to the EVs that charged at the site appears to be in the range of 6 to 16 kWh, with all except for the one on 12/21/15 at 16 kWH (Fig. 3.18), having 8 kWh or less delivered during the fast charge session. Based upon the charging profiles, durations of charge sessions, demand and energy data, it appears that 5 of the 6 sessions were for Type 1 EVs.

The main objectives of the integrated BESS-EV fast charger pilot deployment is to limit overall demand of the system as seen by the utility, such that apparent power capacity (kVA) of certain utility infrastructure can be reduced or re-allocated to support other customer loads and the system provides a customer option that could potentially reduce demand charges. For customers contemplating the installation of an EV fast charger, the current state of nominal 50 kW fast charger technology is such that the buffer BESS-EV charger may be a solution to consider in order to avoid the threshold where demand charges are ratcheted (25 kW for Hawaiian Electric, for example). The BESS-EV fast charger has its input demand setting limited to 23 kW. The data confirms that the demand has been kept below 25 kW during the 2015 monitoring period for both EV fast charging and the BESS charging as well. Input to output efficiency appears to be on the order of 79 to 85%.

More data collected and further analysis performed in 2016 and beyond will determine the efficacy of this integrated BESS-EV fast charger system.

Average demand during EV fast charging is 13.8 kW and maximum demand is 23.3 kW, which confirms the demand limiting capability of the buffer BESS. Average demand during BESS charging is 5.0 kW and maximum demand is 12.9 kW, which again confirms the demand limiting capability. Sufficient delivered DC energy to EV under fast charging is confirmed (for Type 1 EVs): Refer to Fig. 3.18 where approximately 16 kWh was delivered to EV within a half-hour. Average and maximum EV charging energy is 18.3 kWh and 50.3 kWh, respectively

4.2. Fast Charger Site Power Quality

Analyses and conclusions made of the electrical steady state and PQ event data are presented in the following Table 4.1:

Parameter	Dole Plantation	Koolau Center	Kapolei Commons
Steady State Voltage Regulation	Steady state voltage is within Hawaiian Electric Tariff (Rule 2 B.3.b) limits (does not exceed + or - 5% of nominal voltage).	Steady state voltage is normally within Hawaiian Electric Tariff (Rule 2 B.3.b) limits but sometimes reaches these limits. May be related to voltage phase imbalance.	Steady state voltage is within Hawaiian Electric Tariff (Rule 2 B.3.b) limits (does not exceed + or - 5% of nominal voltage).
Voltage Unbalance	Voltage unbalance is within recommended tolerances based on ANSI (3%), IEC (2%), and NEMA (1%) standards.	Voltage unbalance is within recommended tolerances based on ANSI (3%) standards. May warrant further investigation if fast charger nuisance tripping becomes an issue.	Voltage unbalance is within recommended tolerances based on ANSI (3%), and IEC (2%) standards.
Voltage Total Harmonic Distortion	Vthd within IEEE recommendations (5%) at PCC.	Vthd exceeds IEEE recommendations (5%) at PCC. Trended data shows high levels related to RMS voltage disturbances.	Vthd within IEEE recommendations (5%) at PCC.
Power Factor	>0.9 lagging while fast charger is in operation which is acceptable for the utility from an infrastructure perspective.	>0.9 lagging while fast charger is in operation which is acceptable for the utility from an infrastructure perspective. Anomolous data showing leading PF at times.	>0.9 lagging while fast charger is in operation which is acceptable for the utility from an infrastructure perspective. Some short-duration leading power factor during BESS charging cycle startup - could indicate low levels of export. Warrants further investigation.
RMS Disturbances - Voltage Sags	17 transmission or sub-transmission-related events that were also captured at Koolau Center (11 at Kapolei Commons). The balance of 13 voltage sags are due to localized distribution events or events that do not have a known cause.	17 transmission or sub-transmission-related events that were also captured at Dole Plantation (11 at Kapolei Commons). The balance of 48 voltage sags are due to localized distribution events or events that do not have a known cause. Recently, the Windward-Kaneohe area underwent a massive vegetative management effort to trim overgrown vegetation, and this should help mitigate many overhead line faults due to contact with branches.	11 transmission or sub-transmission-related events that were also captured at Dole Plantation and Koolau Center. The remaining balance of a single voltage sag did not have a known cause.
RMS Disturbances - Voltage Swells	A single voltage swell just exceeding 5% above nominal voltage was recorded.	3 voltage swells and overvoltage events exceeding 5% above nominal voltage were recorded. May be related to voltage unbalance.	5 voltage swells and overvoltage events just exceeding 5% above nominal voltage were recorded.
Voltage Transients	None	Several - all related to capacitor bank switching operations at an upstream distribution substation.	None
Events per Day	0.4	1.2	0.4
PQ Impact to EV Fast Charging Equipment	None that has been determined. Equipment appears to ride through coincident disturbances.	None that has been determined. Equipment appears to ride through coincident disturbances. Will continue to monitor PQ disturbance activity and take corrective action if necessary	None that has been determined.

Table 4.1 Site PQ Assessment

Dole Plantation

In terms of EV fast charger operations, the electrical environment at Dole Plantation appears to be optimal. Steady state electrical parameters generally fall within Hawaiian Electric Tariff and operational standards, and RMS voltage disturbances, thus far, are kept to a minimum.

The ITIC curve is used to graphically plot voltage disturbances to determine if in situ equipment can withstand such disturbances without failure within certain voltage magnitude-duration envelopes. It was developed for the computer and electronics industry for single-phase, 120 V equipment but is often used as a tool to determine if there may be compatibility issues with other equipment, operating at three-phase, 480/277 V, for example. A plot of PQ events on the ITIC curve for the Dole Plantation site is depicted below in Fig. 4.1:

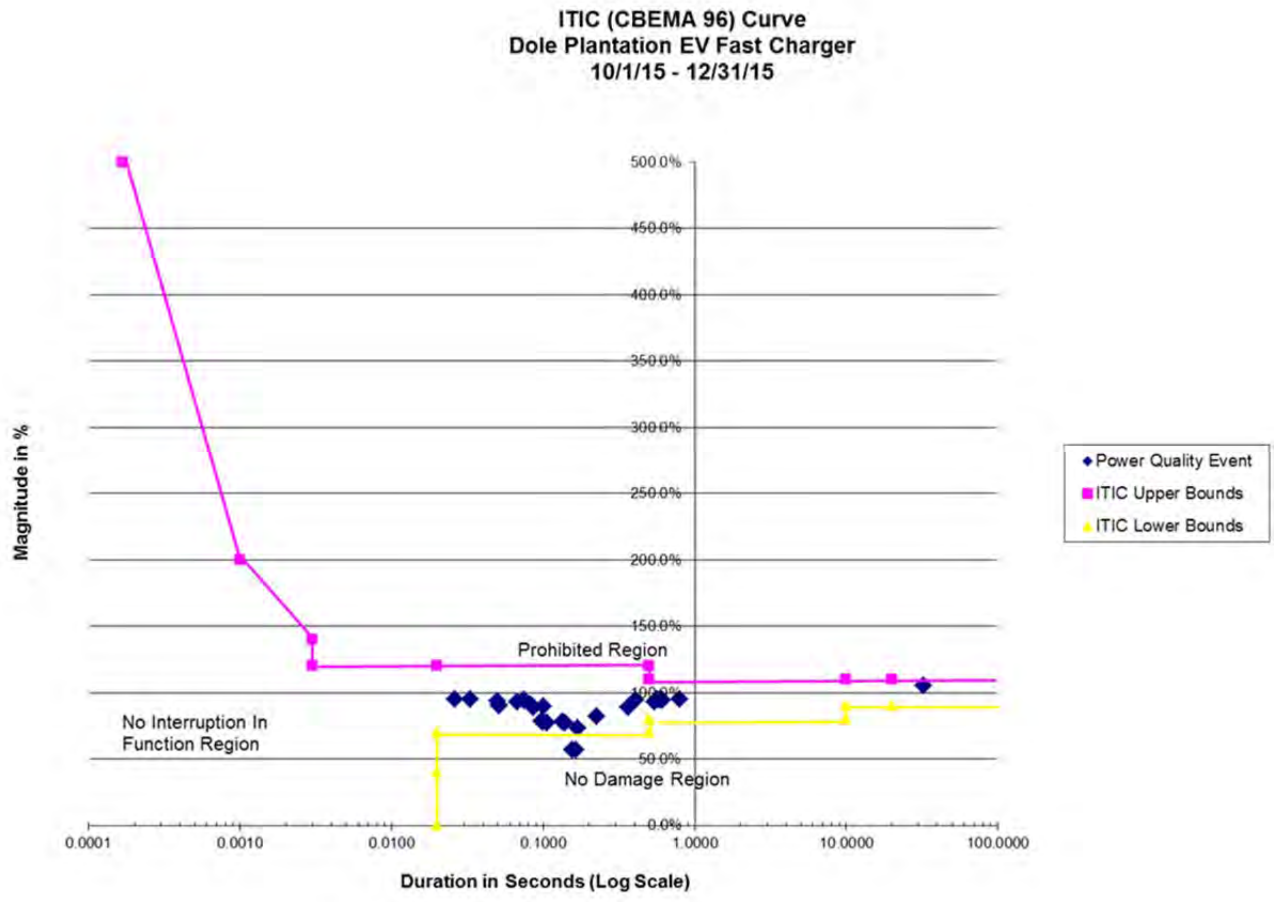

Fig 4.1 Dole Plantation ITIC Curve

Most of the recorded PQ disturbances for Dole Plantation fell within the “No Interruption of Function Region.” A couple of the events landed in the “No Damage Region” where some sensitive equipment or functions may halt and require a manual reset, or may self-reset. In such cases certain processes such as semi-conductor chip manufacturing would be negatively impacted.

There were several voltage sag disturbances that were related to transmission and sub-transmission fault and switching/clearing activity, and these recorded disturbances were common to all three sites.

Data collected for Dole Plantation uncovered an instance where a voltage sag coincided with EV fast charging. The fast charging operation rode through the event and this is graphically depicted below in Fig. 4.2:

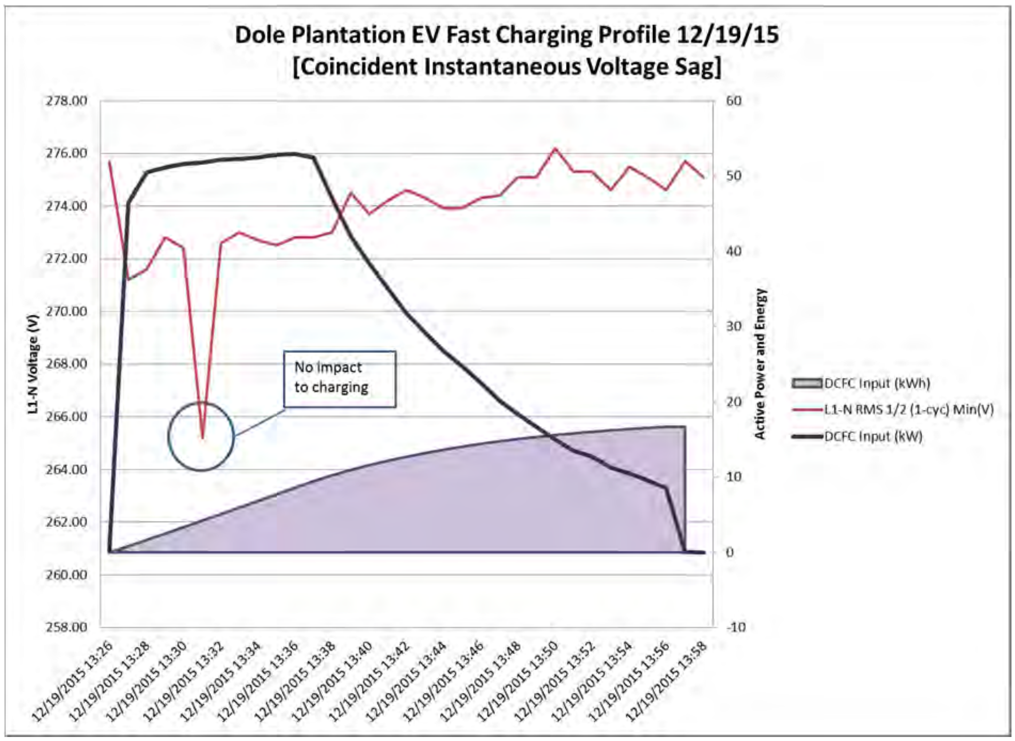

Fig 4.2 Dole Plantation EV Fast Charging and Coincident PQ Event

<u>Ko`olau Center</u>

The electrical environment at Ko`olau Center is somewhat less than optimal. Nevertheless, the fast charging equipment deployed there has not failed and has ridden through coincident PQ disturbances in two recorded EV fast charging sessions.

Data collected of the site's steady state electrical characteristics show voltage regulation and unbalance issues. As each Hawaiian Electric EV fast charger is on a dedicated service and separately metered, such issues should not propagate and affect other customer equipment. Voltage total harmonic distortion levels appear to be quite high, but they also appear to be an anomaly of the waveshape distortion that occurs during transient voltage and RMS disturbances.

Short duration voltage sags were recorded at the Ko`olau Center site. While a few can be attributed to transmission and sub-transmission faults and clearing activity, some were also due to localized distribution faults. The Windward side of O`ahu faces the prevailing trade winds and rain as transmission lines climb up and over the steep walls of the Ko`olau mountain range. The rains produce lush vegetation in the Maunawili-Kaneohe area which, in combination with the prevailing trades, can make contact with overhead lines and cause line faults. These faults often give rise to voltage sags. Recently, the area underwent a massive vegetation management effort to trim overgrown tree branches. It is hoped that this effort will help mitigate many of the overhead contact faults in the area.

The distribution substation upstream of the Ko`olau Center operates capacitor banks on a near daily basis to help boost the voltage levels as load begins to appear on the system in the early weekday morning. These capacitors impart a short duration (typically a quarter cycle) voltage transient on the circuit. Oscillatory transients of this nature were captured by the PQube monitor at the site. Comparing the time-date stamped sample waveform recorded at the site with that of a waveform recorded at the substation confirms this phenomenon as shown below in Fig. 4.3:

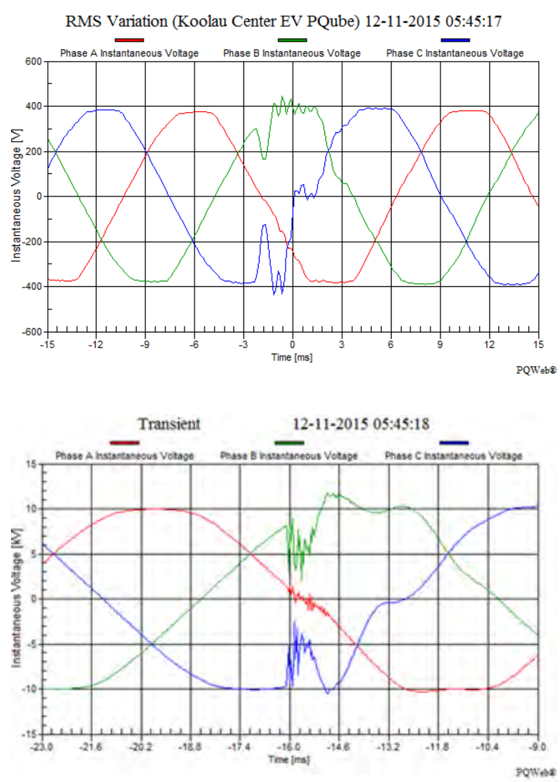

Fig 4.3 Ko`olau Center and Substation Transient Waveform

A plot of PQ events on the ITIC curve for the Ko`olau Center site is depicted below in Fig. 4.4:

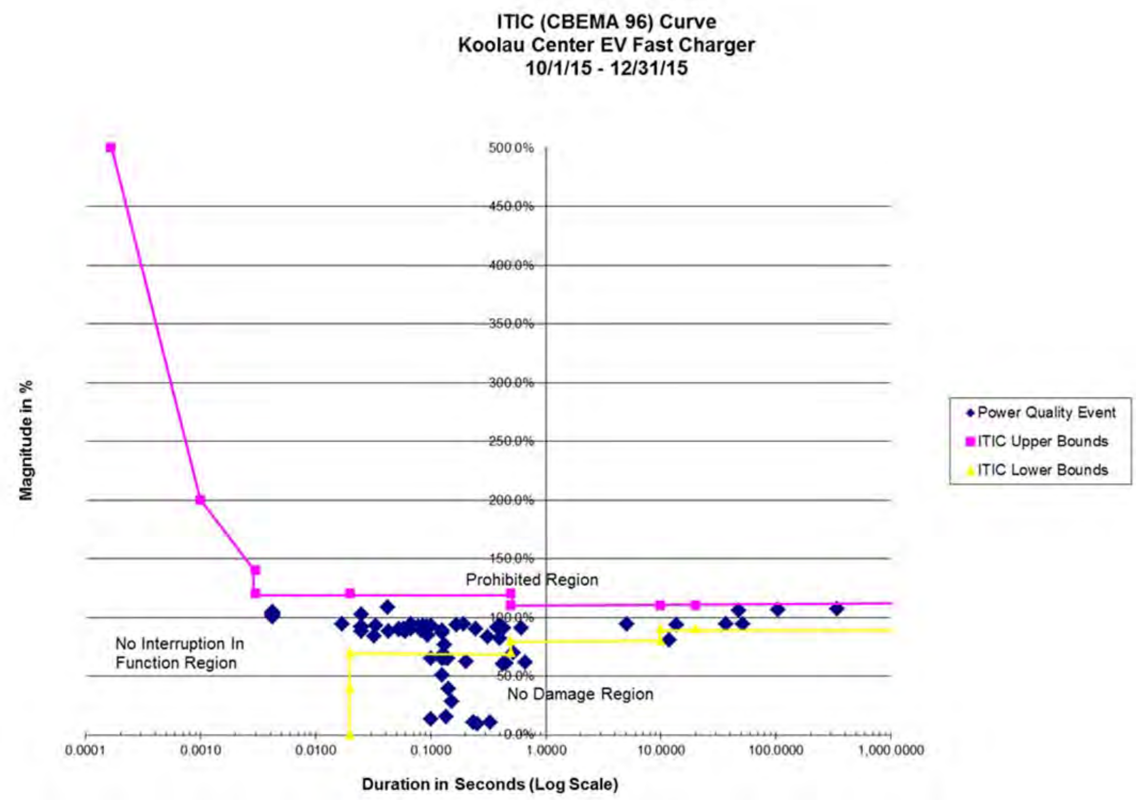

Fig 4.4 Ko`olau Center ITIC Curve

As was the case for Dole Plantation, most of the recorded PQ disturbances for Ko`olau Center fell within the "No Interruption of Function Region." A few of the events landed in the "No Damage Region."

Data collected for Ko`olau Center uncovered two instances where RMS voltage disturbances coincided with EV fast charging. The fast charging operation rode through both events and this is graphically depicted below in Figures 4.5 and 4.6.

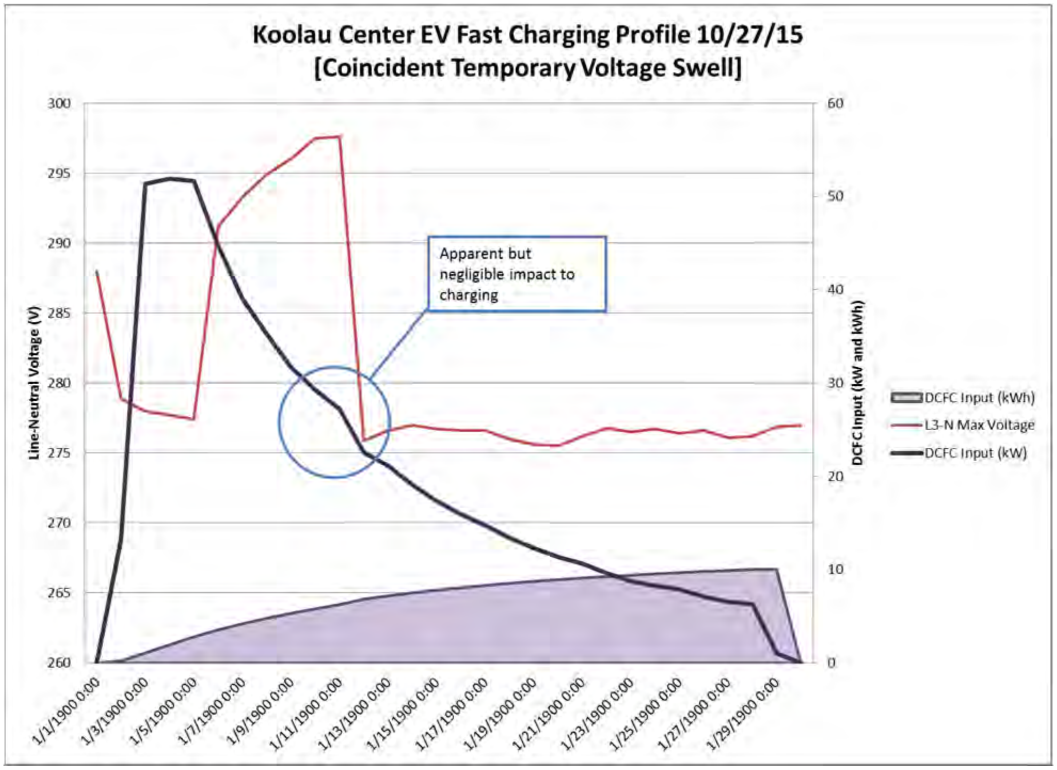

Fig 4.5 Ko`olau Center EV Fast Charging and Coincident Voltage Swell Disturbance

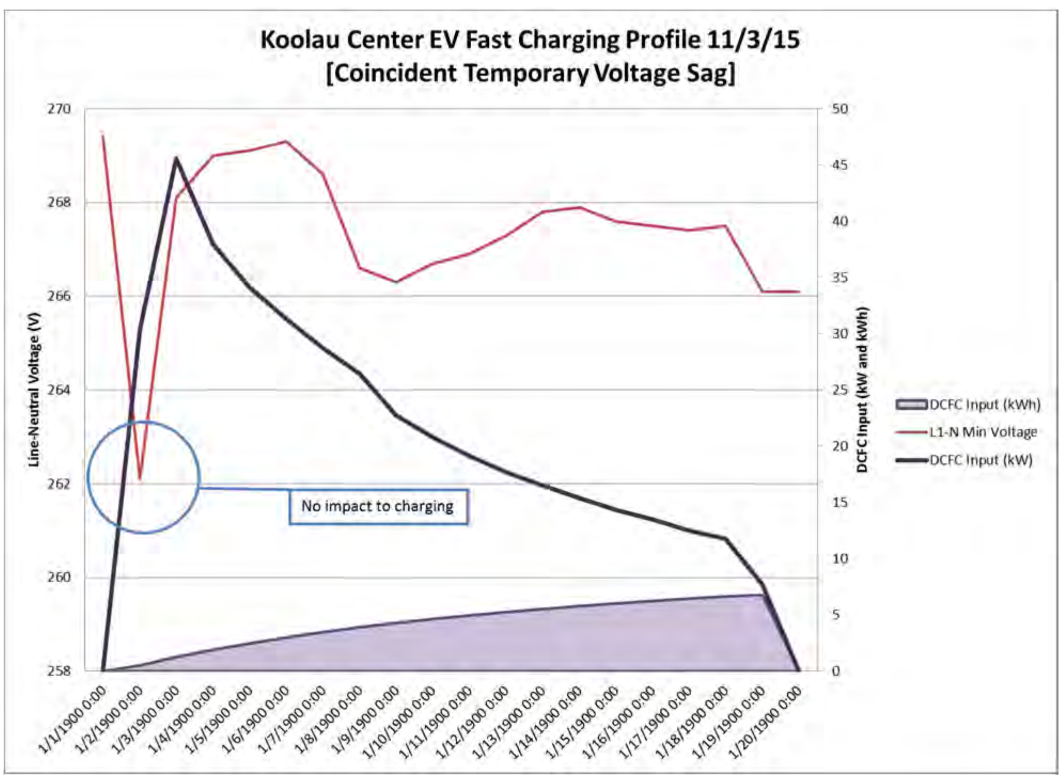

Fig 4.6 Ko`olau Center EV Fast Charging and Coincident Voltage Sag Disturbance

<u>Kapolei Commons</u>

The electrical operating environment at Kapolei Commons appears to be somewhat optimal for EV fast charging operations with the integrated BESS-fast charger. Other than apparent short-duration leading power factor occurrences during BESS charging startup, there were no steady state issues for the site.

Leading power factor suggests power exporting to the grid. This may be short in duration and low in magnitude, but it may warrant further investigation with the equipment manufacturer. A sample graphical rendition of this phenomenon is shown below in Fig. 4.7.

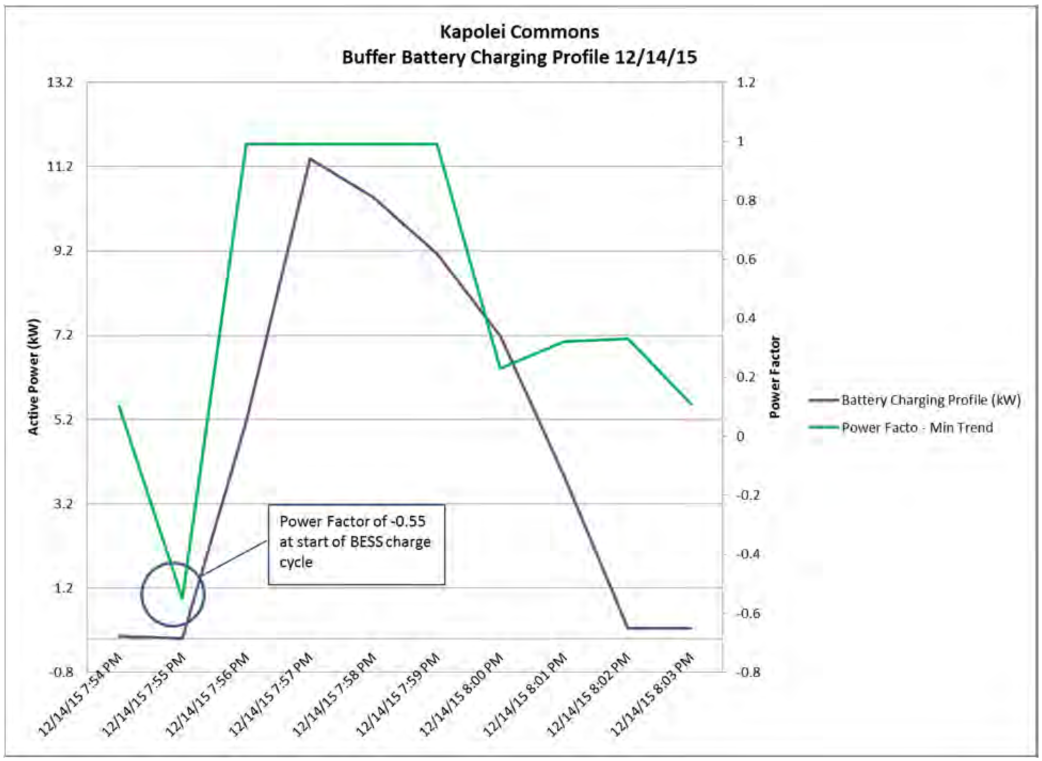

Fig 4.7 Kapolei Commons BESS Charging Demand and Power Factor

A plot of PQ events on the ITIC curve for the Kapolei Commons site is depicted below in Fig. 4.8.

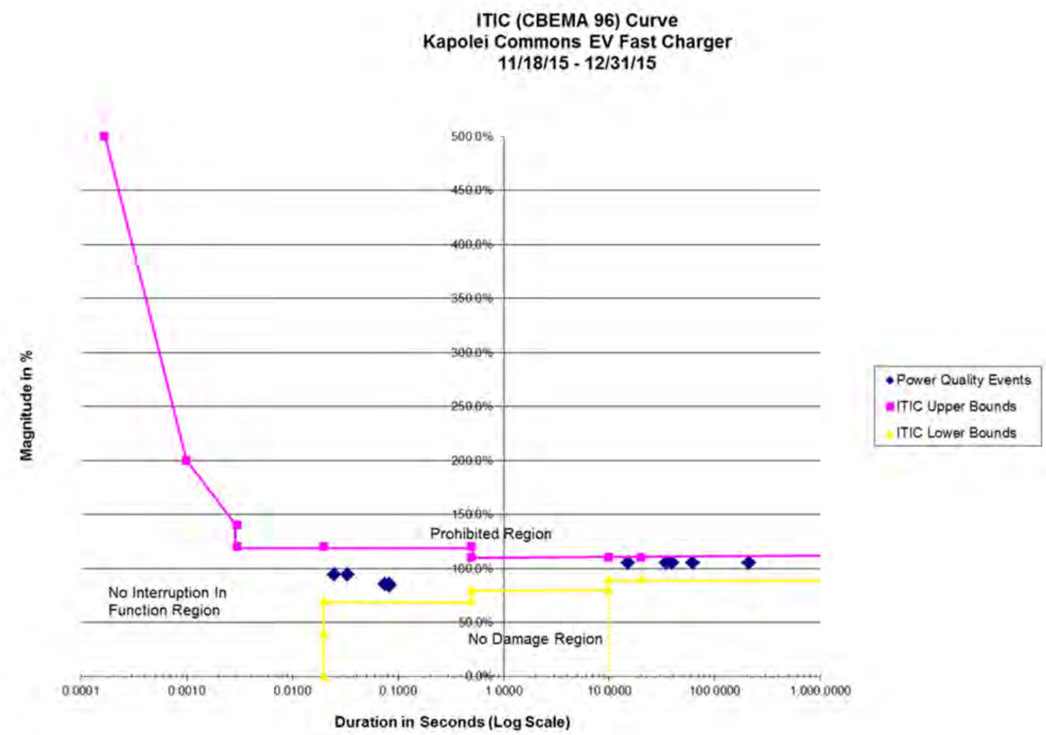

Fig 4.8 Kapolei Commons ITIC Curve

All of the PQ disturbances recorded at the Kapolei Commons site fell within the "No Interruption in Function Region" of the ITIC curve.

5. **Conclusion**

The analysis of data collected at the Dole Plantation, Ko`olau Center and Kapolei Commons EV fast charger sites, lead to the following key observations and results:

- The data monitoring and collection equipment, communications, and software deployed and utilized by Hawaiian Electric Company are well-suited for the EV fast charging pilot and provide the data granularity required for the data analytics of this report.
- Data suggests that once EV drivers know the whereabouts of the fast chargers, they will use them regularly.
- EV battery fast charging profiles for non-BESS fast chargers can be characterized with data monitoring equipment and analysis techniques.
- Most EV drivers will fast charge during the mid-peak.
- Data collected for this report confirms that fast charger users are paying the same flat, per-session fee to fill their EV battery which could vary in size and state of charge. Moving forward, the Hawaiian Electric companies may propose alternative fee structures to accommodate a diverse range of customer charging needs and behaviors.
- The demand limiting capability of the integrated buffer battery-EV fast charging system deployed at Kapolei Commons has been confirmed to limit demand below 25 kWh, which is the threshold for Hawaiian Electric's commercial rates at which demand charges are assessed.
- Limiting the output of non-BESS fast chargers may be a viable demand response strategy to utilize EV fast chargers as a DR resource.
- EV fast charger power electronics technology is robust and can withstand non-optimal electrical operational environments and furthermore, can ride through certain power quality disturbances.

Appendix 1

Power Standards Lab
PQube Specifications

PSL

PQube Specifications

PQube Specifications 2.1

Reference conditions for factory tests: 19~25°C, 15%~50% RH, steady-state 10/12 cycle signals. ±1/2 display count on all accuracies.

INPUTS	
Mains Voltage Measuring Channels	
Connection	L1, L2, L3, N PQube screw terminals [9], [11], [13], [15]
Frequency Range	40 Hz ~ 70 Hz and 320 Hz ~ 560 Hz. Nominal 50 Hz, 60 Hz, or 400 Hz auto, 320-560 Hz manually selected. Specifications below apply at 50/60 Hz.
Mains Configuration	Single-phase, split-phase, delta, wye or star. User selected or auto-selected.
Range of Nominal Input Voltage	100 VAC ~ 690 VAC L-L (69 VAC ~ 400 VAC L-N). User selected or auto-selected.
Measurement Channels	Line-to-Neutral, Line-to-Line, Neutral-to-Earth.
Sampling Rate	256 samples per cycle, phase-locked to input frequency.
Measurement Range	0 VAC ~ 900 VAC L-L (520 VAC L-N)
Accuracy	±0.05% rdg ±0.05% FS typical (10%~150% of nominal). Factory tested at better than ±0.04% rdg ±0.04% FS. Note: FS = 345 VAC or 520 VAC, selected based on nominal line-to-earth voltage.
RMS Measurement Method	True single-cycle RMS, phase-locked to each channel, updated every cycle or every 1/2 cycle. $U_{rms\frac{1}{2}}$ per IEC 61000-4-30 Class A. Also 10/12 cycle true-RMS per IEC 61000-4-30 Class A.
HF Impulse Detection	L1-E, L2-E, L3-E. ±450 Vpk nominal threshold detected through 2-pole high-pass 4.8 kHz nominal filter. Every PQube factory tested with 1-μsec 10%-to-90% impulses; trigger required at ±650 Vpk, must not trigger at ±250 Vpk.
Unbalance – Voltage	Measurement method: ANSI C84.1, IEC, and GB. Range: 0.0% ~ 100.0%. Accuracy equivalent to RMS voltage specification applied to measurement method. Supports ANSI, GB, IEC (positive and negative sequence).
THD – Voltage	Measurement method: DFT of phase-locked 256 samples-per-cycle. Range: 0.0% ~ 100.0%. Accuracy: ±0.2% at 60-Hz test waveform having typical harmonic content (5% 5th, 2.5% 7th, 1.5% 9th, and 1% 11th)
Flicker	±5% rdg at all reference points on the eye-response curve defined in IEC 61000-4-15 for $P_{st} \geq 1$.
Harmonics and Interharmonics	Range: 0% ~ 100% of fundamental, measured up to the 63rd order (harmonics displayed up to the 50th order). Harmonic accuracy: IEC 61000-4-7:2002 Class II, typical, up to the 50th order, for units manufactured after February 2010. (Preliminary specification, subject to further evaluation)
Isolation	PQube provides more than 7500 VDC isolation to Earth. UL/IEC 61010 reinforced insulation.
PT Input Ratio Range	1:1 to 10000
Installation Category	CAT IV UL/IEC 61010 for voltages up to 300 VAC L-N (equivalent to 480 VAC L-L), CAT III for higher voltages. Pollution degree 2.
Analog Input Channels	
Connection	AN1, AN2 PQube screw terminals [22], [30
Nominal Input	High range: 0 ~ 30 VAC or ±60 VDC to Earth max. Low range: 0 ~ 7VAC or ±10VDC to Earth max.
Input Impedance	800 kΩ to Earth
Full Scale	High range: 70 VAC, ±100 VDC, Low range 7 VAC, ±10 VDC.
Measurement Channels	Standard: AN1-Earth, AN2-Earth, AN1-AN2. DC Energy Mode: DC Power and DC Energy.
Accuracy	±0.2% rdg ±0.2% FS typical (10% ~ 100% FS), ANx-Earth. Every PQube factory tested at better than ±0.1% rdg ±0.1% FS AC
Digital Input	
Connection	DIG1 PQube screw terminal [24]
Rating	60 VDC to Earth
Wetting	5.4 VDC at 3 μA
Threshold	1.5 V ±0.2 V with respect to PQube's Earth terminal, with 0.3 V hysteresis typical.
Sampling Rate	12.8 kHz or 15.4 kHz (sampled at same rate as mains voltage measuring channels.
Frequency Measurement	
Range	40 Hz to 70 Hz and 320 Hz to 560 Hz.
Accuracy	±0.01 Hz, steady state.
Method	Cycle-by-cycle zero-crossing detection on L1-E or L2-E (auto-selected). Firmware phase-locked for frequency slew rate up to 5 Hz/sec. For 50/60 Hz, measured through an 9-pole low-pass analog filter, 3-dB frequency 76 Hz. For 400 Hz, measured through 7-pole low-pass filter, 3-dB frequency 1 kHz. Poles and 3 dB frequency are auto-selected based on nominal frequency.
OptionalTemperature/Humidity Probes	
Connection	2.5 mm stereo jack. Functional electrical isolation from PQube.
Location	Optional probes plug into the PQube directly or through PSL-provided extension cable.
Scan Time	5 seconds max.
Temperature Accuracy	Typical: ±0.5ºC. Max: ±2ºC (-20 ~ +80ºC).
Humidity Accuracy	Typical: ±4.5% RH (20 ~ 80% RH), max:±7.5% (0 ~ 100% RH).
Note: For optimal ambient temperature and humidity accuracy, use extension cable to avoid self-heating of probe by PQube.	
Instrument Power	
Screw Terminals	(AC or DC) PQube POWER screw terminals [23], [31]
AC Input	24VAC ± 20% 50/60 Hz
DC Input	24-48VDC ± 20% (polarity independent)
Power Required	5VA max.
Isolation	PQube provides more than 150VDC isolation to all other circuits.
Internal UPS	
Type	Lithium Polymer Battery (replacement batteries available from PSL).
Capacity	600mAH.
Backup Period	User controlled. 1 to 10 minutes, 3 minute default.
Storage & Discharge Temp.	-20ºC to +60ºC
Charge Temperature	0ºC to +45ºC
Charging Cycles	>500 full cycles.
Lifetime	Estimated 5+ years, depending on operating and environmental conditions.
Replacement Method	User-replaceable while PQube is operating (tool required).
Optional PS1 Plug-in Module	
AC Input	100~240VAC ± 10%. 50/60 Hz
Power Required	25VA max
Isolation	Module provides more than 3200VDC isolation to all other circuits

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Appendix 2

EV Fast Charger
Equipment Specifications

QC50

Product Sheet

QC50 DC Fast Charger

Efacec has extensive experience in power electronics design and industrial product manufacturing, which allows for innovative product development and engineering. Currently, the Efacec Electric Vehicle (EV) charging family in the USA features DC Fast Charging for CHAdeMO and SAE Combo compliant vehicles. Efacec has been developing solutions and products for the different EV charging market segments since 2008. Efacec is a member of CHAdeMO and has received the certification for its DC Fast Chargers. The QC 50 is also ETL listed for both CHAdeMO and SAE Combo DC Fast Charging.

Intertek

Product description

The Efacec QC50 DC Fast Charger can be used to charge all EVs with CHAdeMO and SAE J1772 Combo charging standard compliance. Depending on the EV, it takes up to 30 minutes to charge from a low battery state.

The DC Fast Charger is user-friendly and safe. After user identification, just couple the charger's DC output plug into the EV for automatic starting. The battery charging state is displayed, and the charging cycle finishes automatically or can be interrupted by the user.

Configuration customization is available. Choices include both single and dual DC outputs in a single cabinet to handle both CHAdeMo and SAE Combo vehicles. We offer a bundled solution with a remote wired charging kiosk and standard charging cabinet. The charging kiosk bundle allows for true customization of the user-facing appearance and payment interface.

The DC Fast Charger's unique power electronics design results in top specifications for conductive DC fast charging. It produces high power output while still maintaining top power factor, THD and efficiency ratings. The DC Fast Charger is highly recommended for service stations, EV service workshops and public EV Infrastructure.

Key features

- Supports up to (500 VDC @ 125 A) 62.5 KW
- CHAdeMO standard certification
- SAE J1772 Combo compliant
- Stand-alone or network-integrated charger

Customizations

- Charging kiosk design
- Communication options
- Payment solutions

Applications

- Filling stations, service stations
- EV Service Workshops
- EV Infrastructure Operators
- Car dealerships
- Parking lots
- Office buildings
- Supermarkets and convenience stores

Dual-connector design supports both SAE and CHAdeMO connectors

Choose the color of your energy!

efacec

RAPID CHARGING SYSTEM
For EV with Internal Battery System

CHAdeMO

Battery Incorporated DC Fast Charger

- ✓ **80% Charge in 30 minutes!**
- ✓ **Compliant with CHAdeMO standard**
- ✓ **Low installation cost (208V 3Ø Input)**
- ✓ **Little to no Power Demand Charges (<20kW , 25kW, 28kW input)**
- ✓ **Time shift with lower running cost**

Distributed by: VLI-EV *variable load integrator*

VLI-EV Partners
1128 Wall Street, La Jolla, CA 92037
www.vli-ev.com

Model	RAPID CHARGINS SYSTEM with INTEGRATED BATTERY STORAGE USA Version
Input	4 Wire, 3 phase 208V AC, Y Connection
Rated Input	Version 1, max. 20kW AC
	Version 2, max. 25kW AC
	Version 3, max. 28kW AC
Output Voltage	DC 50V-500V
Rated Output	Version 1, max. 45kW DC
	Version 2, max. 47kW DC
	Version 3, max. 50kW DC
Communication with Vehicle	CHAdeMO Protocol
Dimensions	W 1100 mm x H 1915.4 x D 791 mm
Product Safety	Intertek Approval est. February 2014
Operating Temperature	0° C to 40° C
Credit Card Reader	Optional
RFID Reader	Optional

Example: Version 1

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