EV Charging Station and Los Angeles Air Force Base V2G Pilot Technical Evaluations

Southern California Edison

An overview of the equipment test methodology and process

Jordan Smith for FUPWG, Fall 2017

Agenda

- SCE intro
- SCE Labs
- EV and Charging Infrastructure Evaluation
- Charging Infrastructure Evaluation Basics
- LAAFB Pilot overview
- LAAFB Equipment testing
- Conclusion

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Southern California Edison Overview

- 50,000 square-mile service area
- 5 million customer accounts
- 14 million residents
- Infrastructure
  - 1.4 million poles
  - 700,000 transformers
  - 103,000 miles of T&D lines
- Rate base growth driven by:
  - Safety and reliability
  - Distribution Resources Plan
  - Transmission growth, renewables
  - State environmental policy
  - Electric Vehicle charging and energy storage

SCE Pomona Labs – EV Technical Center

- Established in 1993
- Quality Management System
- Unique in utility history
- DOE QTS
- Energy storage testing in transportation and stationary fields
- Vehicle and power train testing and evaluation
- Charging infrastructure evaluation, standards
- Fleet support

Testing

- You should do it if you can
  - Claims vs reality and benchmark
  - Real world performance
  - Safety: employees, public
  - Reliability
- *SCE EV Test Procedure*
- *SCE Charger Test Procedure*
- *SCE Battery Test Procedure*
- *SCE Interconnection Rules*
  - *V2G System Testing*
- Field Test - PQ

Requirements, Specifications – Basis

Standards/Codes

- SAE J1772 AC L1 and L2
  - North American EVSE Standard
- SAE J2894
  - Power Quality Requirements for PEV Chargers
- NEMA 3R or NEMA 4 enclosure
  - Outdoor installations
- California Title 24
  - California Building Code, Electric Code
- California Title 20
  - Appliance Efficiency
- NIST (Handbook 44 and Handbook 130)
  - Specifications for measurements (kWh, t)

CR Program Specific

- 40 A maximum
  - Long duration dwell time – no need for higher power charging
- 10 W power maximum per port, not connected
  - Energy efficiency
- OpenADR 2.0b
  - Communication standard for demand-response events
  - Certification required

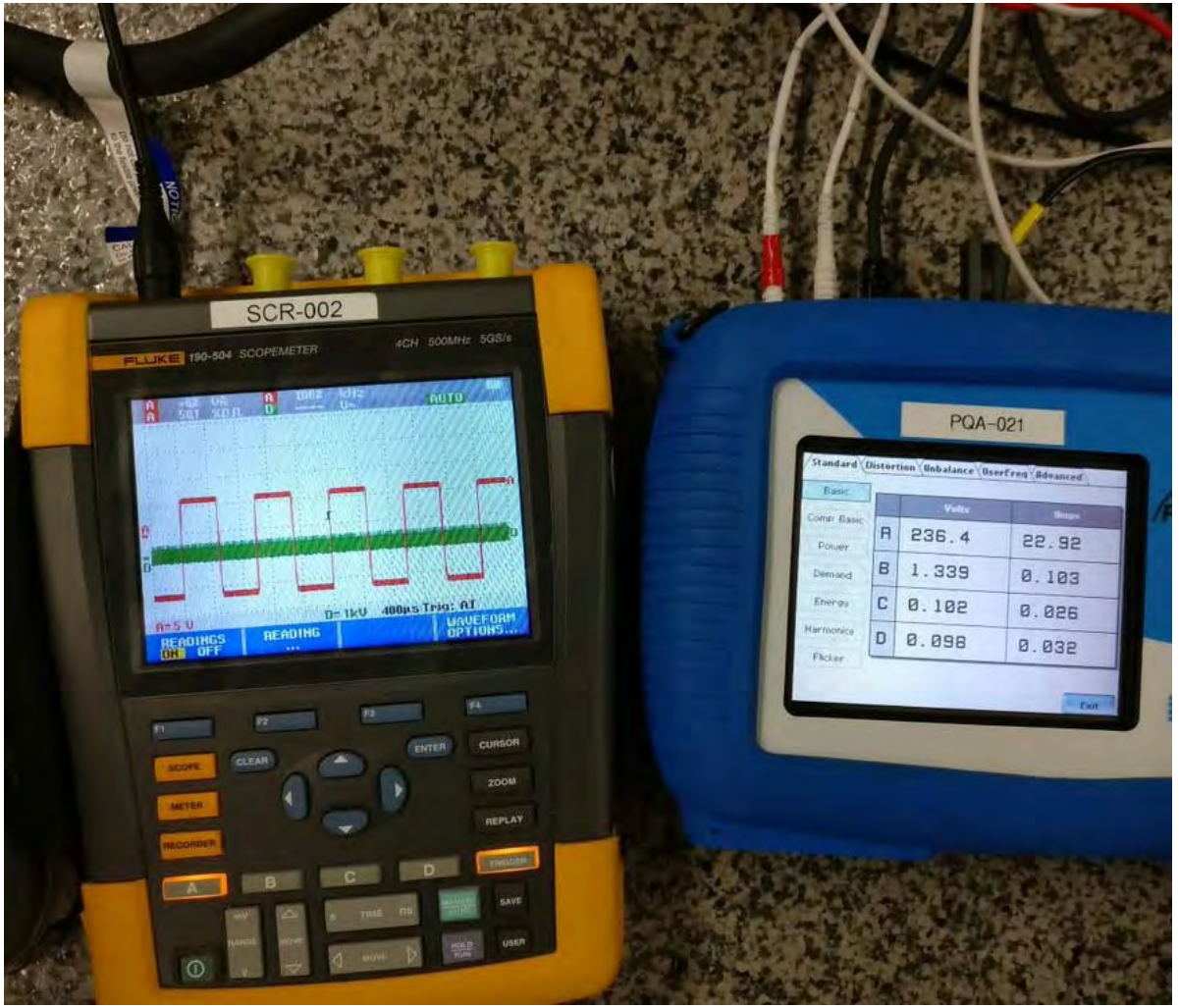
V2G

- SCE Rules
  - Rule 21
  - WDAT
- Interconnection
  - System generator
- UL 1741
  - Inverter certification
- IEEE 1547
  - Inverter performance and safety
  - Smart Inverter Requirements
- SAE J3072?

General Lab Test Scope

The following series are performed with each EVSE package for Charge Ready

1. Function and Safety
2. Power Quality – Impact on the Grid
3. Grid Impact on the System
4. Communications and Controls:
    1. DR Functionality
    2. EVSE Metering Validation
    3. DR UI Assessment



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Function and Safety

1. Unsecured wires that lead to cable melting
2. Unsecured hardware inside EVSE
3. Coupler's sparking upon removal
4. Cable management mechanisms
5. Improperly crimped wires
6. Failure to pass demand response testing
7. Failure to pass GFCI testing
8. Failure to stop charging after mains ground disconnection or initiating charge with no ground

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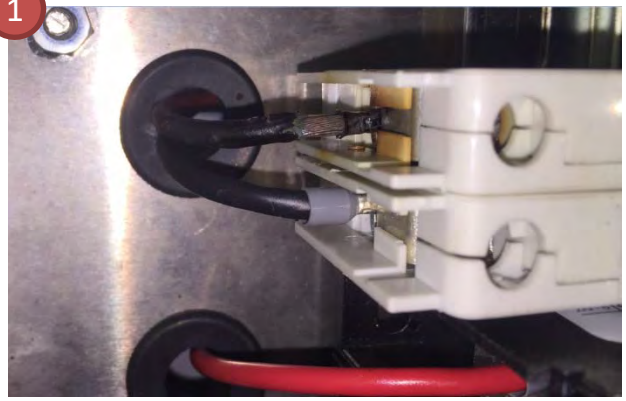

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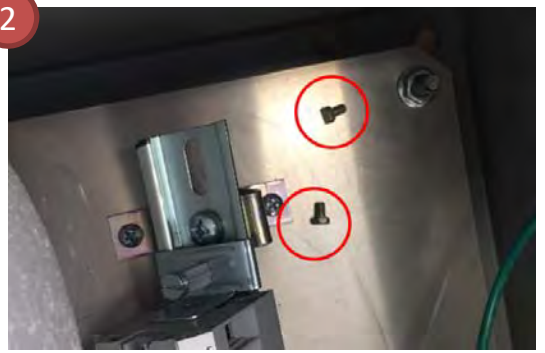

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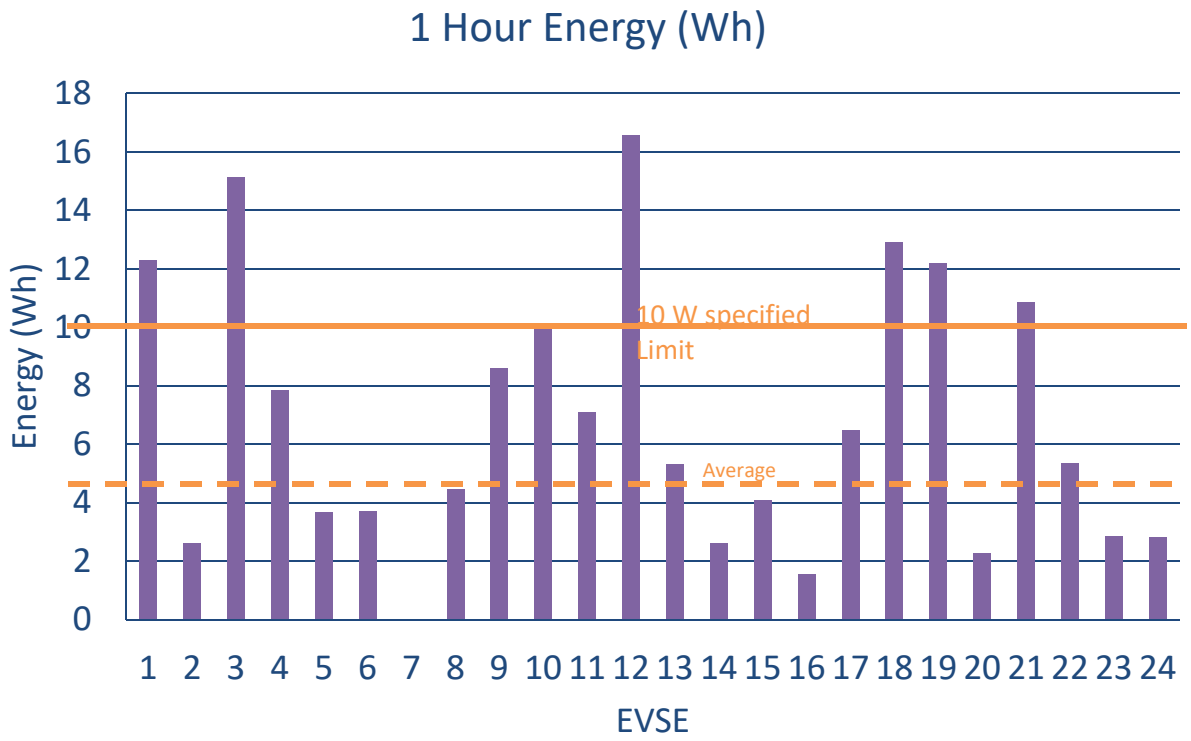
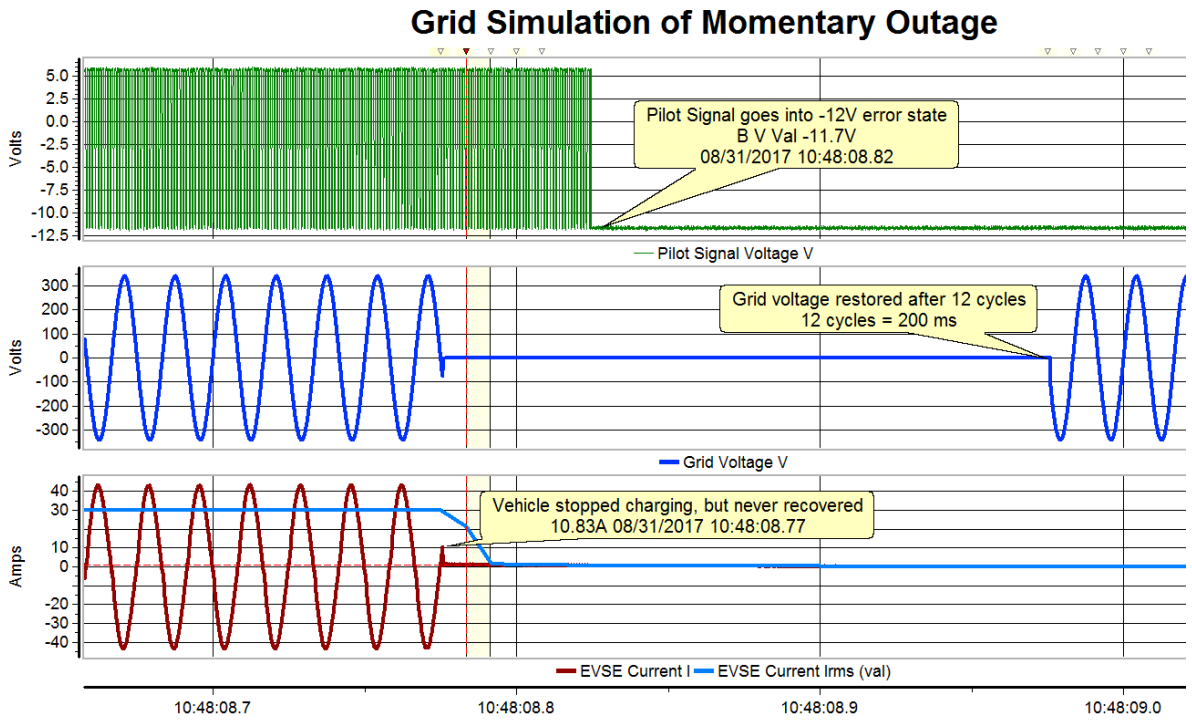
Energy Efficiency – no battery test



Grid Impact Issues Corrected

- Demonstrated ability to reliably charge a vehicle under typical grid events (SAE J2894) is required
- Failure to ride through some simulated grid events during charging was not uncommon, but was corrected by vendor updates when it occurred.
- Grid events include:
  - Momentary outages
  - Voltage sags
  - Voltage swells
  - Frequency variations
  - Voltage variations
  - Voltage harmonic distortion



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DoD LAAFB V2G Pilot Overview

DOD Objectives: *Demonstrate that battery storage of PEV fleets can provide energy and ancillary services to the CAISO markets to generate additional revenues reducing the cost difference between PEVs and conventional ICE vehicles*

34 V2G PEVs, 11 other PEVs
655 kW theoretical capacity

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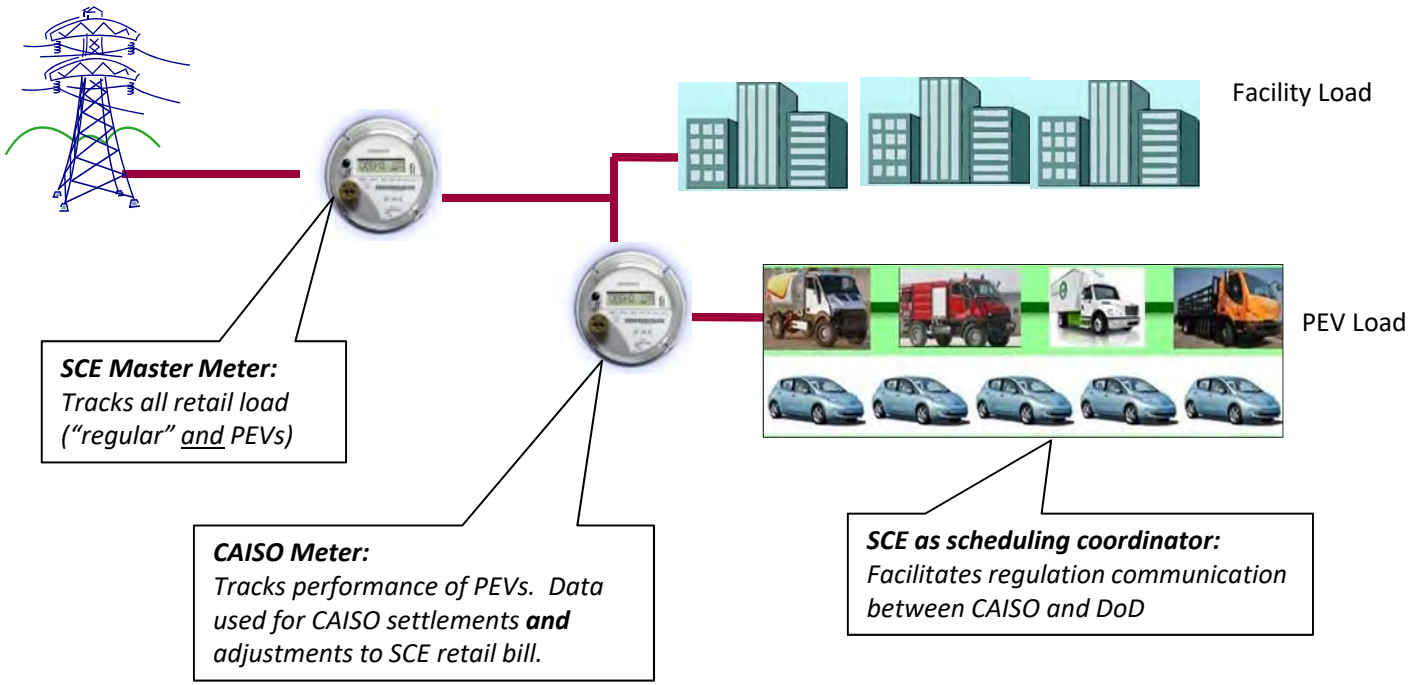
General Operational Architecture



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LAAFB Equipment Test Plan

Agreed with DOD at beginning that no commercial V2G systems exist – all equipment will be novel and developed for the pilot – All equipment to be tested at SCE lab prior to deployment

1. Baseline Vehicle Performance: Range and Acceleration, Fuel Economy
2. Charger/EVSE Inspection and Safety Test
3. Charger Functional Test and Power Quality
4. V2G System Reverse Power Test

Abbreviated tests were designed to achieve results quickly and get systems to the base for deployment.

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V2G System Reverse Power Test

- Based on SCE's Interconnection Rules, and by reference, IEEE 1547, *Standard for Interconnecting Distributed Resources with Electric Power Systems*
- Focused on specifications to test based on minimum safety expectations
- Created event profiles to test specifications

Line Voltage		Maximum Trip Time	
Voltage (Assuming 120V Base)	% of Nominal Voltage	# of Cycles (Assuming 60Hz Nominal)	Seconds
Less than 60V	Less than 50%	10 Cycles	0.16 s
Greater than or equal to 60V but less than 106V	Greater than or equal to 50% but less than 88%	120 Cycles	2 s
Greater than 132V but less than or equal to 144 V	Greater than 110% but less than or equal to 120%	60 Cycles	1 s
Greater than 144V	Greater than 120%	10 Cycles	0.16 s

Frequency Range	Maximum Trip Time (Assuming 60 Hz)
Less than 59.3 Hz	10 Cycles
Greater than 60.5 Hz	10 Cycles

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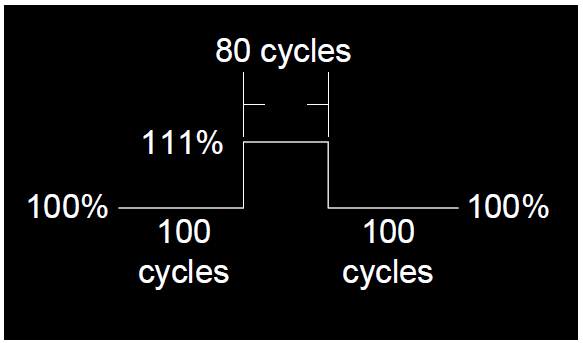
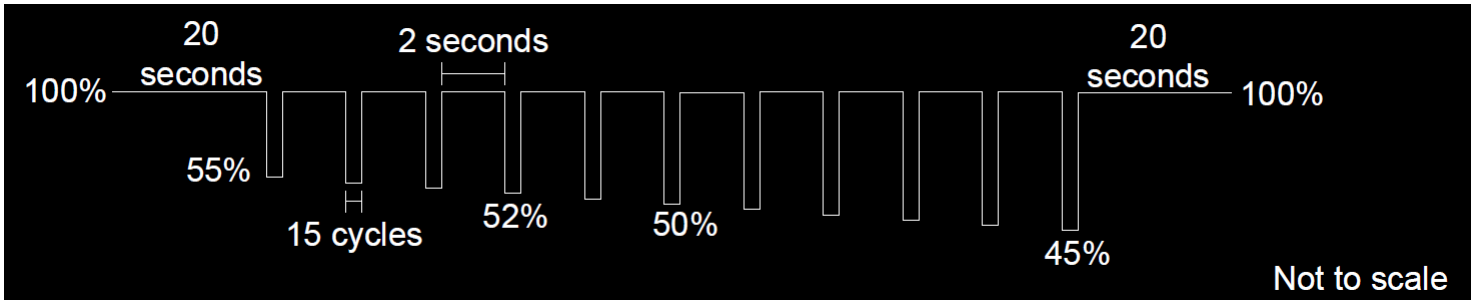
Test Profile Development

- 12 Pass / Fail Tests
- System must disconnect from grid within specified time limit
- Examples:
  - Single Over Voltage Protection Test
  - Stepped Very Under Voltage Protection Test





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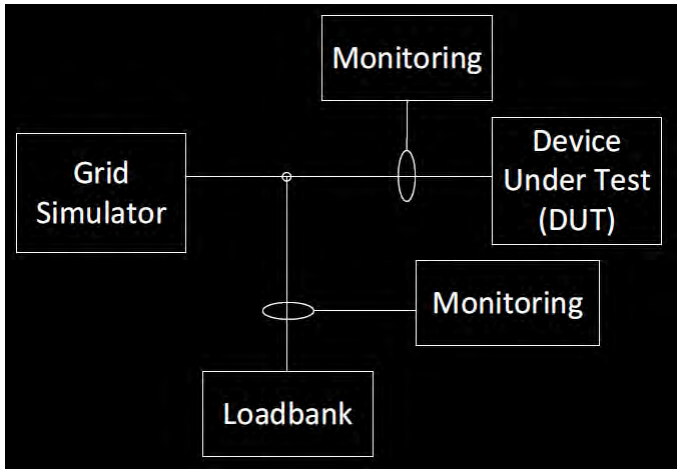
Test Bed Development



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Test List

Bi-Directional Vehicle	Bi-Directional Charger Manufacturer	Charger Type	Charger Rated Power (kW)	Vehicle & Charger Count
Nissan Leaf	Princeton Power System	DC Off-board	15	13
Phoenix Bus	Coritech	DC Off-board	50	1
EVAOS Truck	Bel Power Solutions Charger/Inverter	AC On-Board	15	5
EVI Truck	Coritech	DC Off-board	50	4
VIA Van	Bel Power Solutions Charger/Inverter	AC On-Board	15	11
			Total Systems Tested	34

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Systems Tested

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Results, Timeline

	Vehicle Functionality	Charger Functionality	IEEE 1547	SAE J2894	Test Start	Test End	Months of Testing
Nissan & Princeton Power Systems Charger					Nov, 2013	Nov, 2014	12
Phoenix bus & Coritech Charger	Not Performed				Jan, 2015	March 2015	3
EVAOS Truck & Coritech Charger					Sep, 2015	Dec, 2015	4
EVI Truck & Coritech Charger					Mar, 2015	Sept, 2015	6
VIA Van & Coritech Charger					Aug, 2015	Apr, 2016	9

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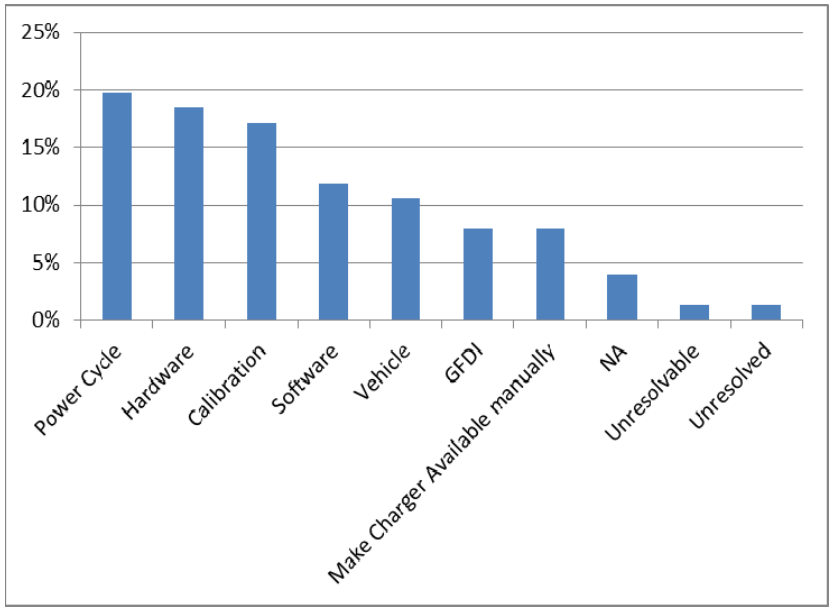
Results, Resolution - Example



- Initial systems (Leaf) planned 6 week test – actually took almost one year to complete
- Over 80 issues identified and resolved

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Questions

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Appendix

SCE Pilot Objectives

- SCE described the following pilot objectives in its Advice Letter on 4/23/13:
  - Studying the role of the utility, if any, in direct participation by retail end-use customers
  - Determining the costs involved in facilitating the proper maintenance of direct participation
  - Supporting a pioneering customer in the direct participation space, with all its technical and metering advances
  - Developing a potential solution that may be scalable (possibly with modifications) to other retail customers wishing to participate in CAISO's ancillary services market
  - Completing a "proof of concept" test demonstrating the technical viability of V2G
  - Better understanding of the settlement process for wholesale market participation on behalf of a retail customer

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Pilot Timeline

Event listed in the Resolution	Date
Base infrastructure design and permitting	September 2013
Interconnection studies	April 15, 2014
Equipment testing	October 15, 2015
Execution of Wholesale Distribution Access Tariff	August 22, 2014
Execution of Participating Load Agreement	February 12, 2014
Participating Generator Agreements	February 12, 2014
Master Service Agreement	February 12, 2014
ISO Certification of Ancillary Service Testing	October 15, 2014
Launch of Operations	December 24, 2015
CPUC approves pilot extension through September 2017	December 12, 2016 (effective October 23, 2016)
Pilot Ends	September 30, 2017

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Lessons Learned

- The DoD identified the following lessons learned:
  - Maintain and report status of all equipment to the system to ensure proper resource planning
  - Ensure suppliers are contracted and active to maintain/repair equipment
  - Equipment testing at factory or a selective environment may not emulate actual field conditions
  - Fleet management system needs to be well tailored to unique requirements of users and solicits input and constant feedback to actively refine
  - Adopt conservative expectations of equipment performance at first, and relax as confidence grows
- What is the value proposition?
  - Customer
  - Utility
  - Grid

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