Grid Connectivity Research, Development & Demonstration Projects

2013 DOE Hydrogen Program and Vehicle Technologies Annual Merit Review

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Sponsored by Lee Slezak

Project ID #VSS095

Overview

Timeline

- Grid Interaction Tech Team (GITT) initiated in summer 2009; Projects initiated in March 2010
- Hardware/software development continued; demonstration of DC/wireless charging methods in 2012
- EUMD-2 Jan. 2011, EUMD-3 July 2011
- EUMD rev 4 sensor hardware June 2012
- Multi-port communication controller in late 2012 (DC charging, AC messages)

Budget

- FY2010 $930k
- FY2011- $650k
- FY2012- $300k
- FY2013- $650k

Barriers

- **EV-Grid Connectivity and Communication**
  Development and verification of EV-grid connectivity technology, communication protocols and standards with adequate lead time to support OEM/supplier production schedules
- **EV-Grid Interoperability**
  Ability to charge any vehicle with any charger and any service provider … smart grid or not

Partners

- Utilities (DTE Energy, Southern Cal. Edison, Commonwealth Edison, Northeast Utilities, TVA, communications technology vendors)
- EVSE suppliers (BTCP, Chargepoint, Clipper Creek, Bosch, Leviton, ECOtality, G.E.)
- Vehicle OEMS (Ford, GM, Chrysler, BMW)
- National Labs (INL, PNNL, ORNL, NREL)
- NRTL Certification Labs (UL, ETL, TUV SUD)

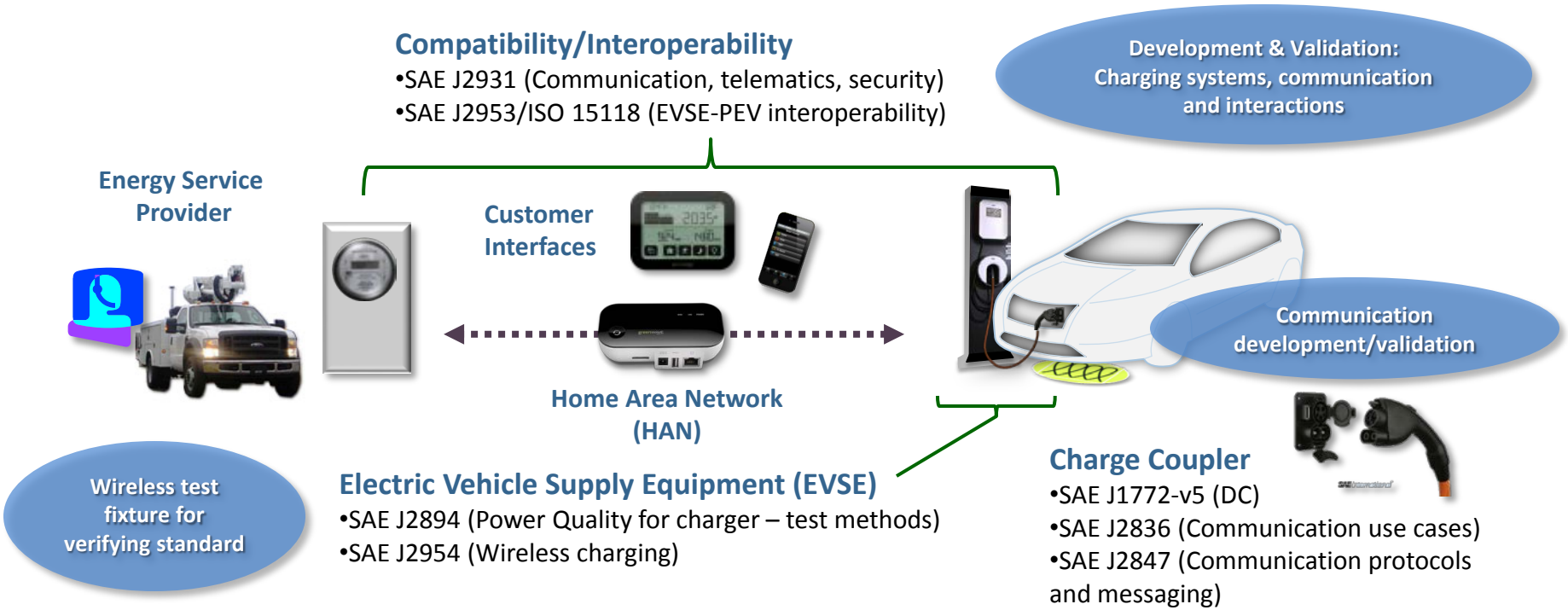
Objectives (Grid Interaction Tech Team)

Support a transition scenario to large scale grid-connected vehicle charging with transformational technology, proof of concept and information dissemination

Focus on connectivity between light-duty plug-in vehicles, the charging infrastructure and the electric power grid, including the following:

- Reduced Cost of Electric Charging Infrastructure
- Harmonization of Global Connectivity Standards
- Enabling Technology Development
- Enhanced Viability of Fast/Consumer-Friendly Charging
- Managed Vehicle Charging Loads Consistent with Smart Grid

Approach – Identify Hardware Technology Gaps and Work with RD&D Partners to Fill Gap



- Argonne's RD&D lab environment complemented by field demonstration with collaborators
- Continuously assess SOA in grid connectivity and communication technology
- Engage demonstration partners to validate NIST smart grid standards for utility network and sub-meter requirements (includes ANSI, NEMA and CPUC to address gap identified by EPRI)
- Evaluate and validate hardware and communication protocols proposed in standards

Milestones

Constructed and demonstrated proof of concept charging system related hardware and software in a grid connected environment

- **AC conductive charging** (coupler evolution, communication, interoperability)
- **DC conductive/combo charging** (power line communication, protocols, validation)
- **Wireless non-contact charging** (safety, freq. allocation, definitions, test procedures)
- **Smart Grid Related Interactions** (between utility programs and vehicles on charge)

Specifically:

Charge coupler (SAE J1772v5)

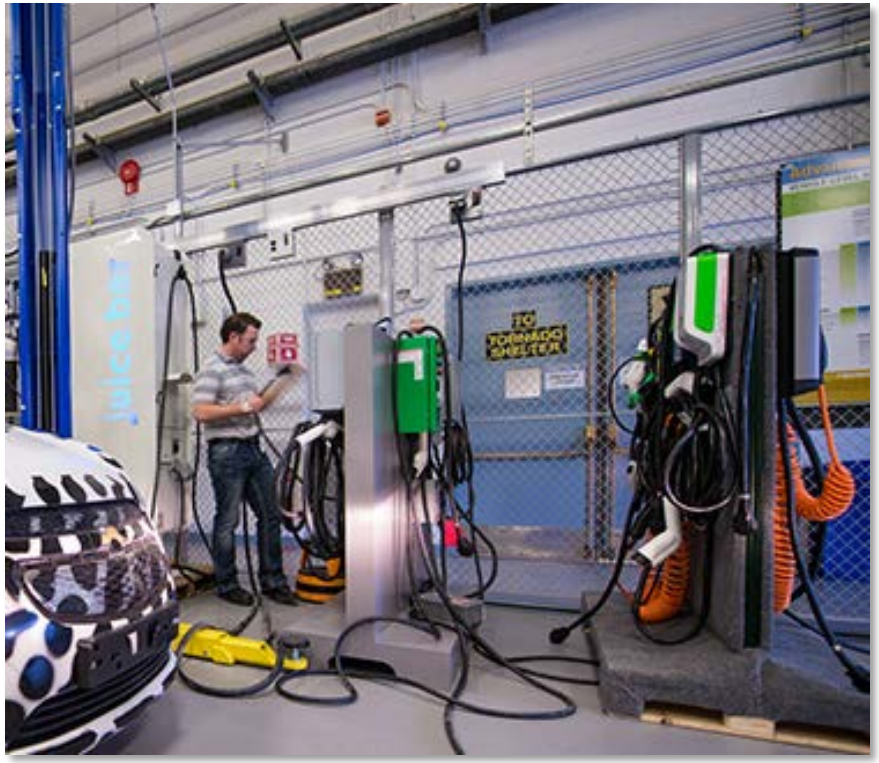
- ANL input to UL cert. (FY 2012, Q3) DC Level 1 and DC Level 2 safety/interlock hardware – demonstration on low speed electric vehicles at ANL

AC/DC Charging Communication; Interoperability

- Designed, fabricated and created open source Labview software for AC charging interoperability between PEV-EVSE along with numerous EVSE test articles for J2953
- Designed, fabricated and created open source software for DC charging communication between PEV-EVSE, collected data in support next draft of J2847/2

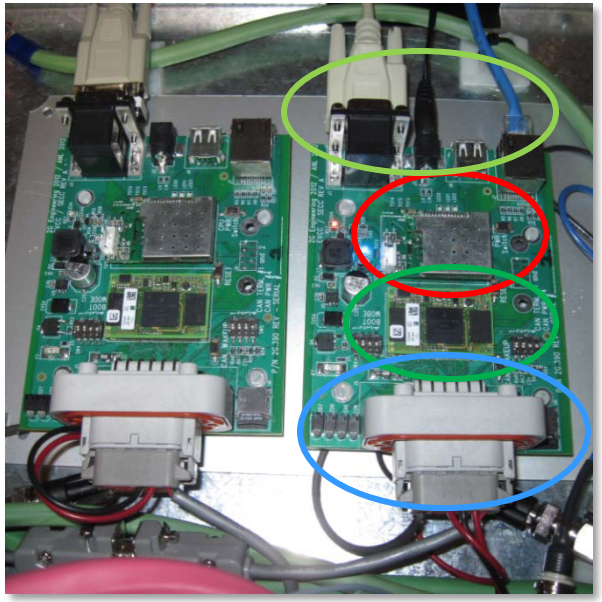
AC Charging EVSE Interoperability/Benchmarking

- Validation of PEV-EVSE interactions/issues (~40 EVSEs, mounted on skids as testing assets)
- Iteration of testing tools- Gridtest EVE-100L now upgraded to EVE-100S to match J2953
- Created National Instruments cRIO test hardware, Labview V.I.s software tools



Labview based test rack; AC, DC loads and sources; J1772 signal pass through monitoring with fault injection

In Process - DC Communication Controller Implementation- Evaluating Interoperability for DC Charging Systems



Supply equipment (charger) side of SECC- Ethernet, serial, USD, power, etc.

Homeplug GreenPhy power line communication over pilot sub module (Qualcomm)

Single board computer iMX28)

Vehicle side sealed CAN, pilot, prox, latch motor leads, 12v

Supply Equipment & Electric Vehicle Communication Controllers {SECC & EVCC} fabricated to implement the SAE J2847/2 DC charging communication protocol

Power Line Communication (PLC) over 1 kHz pilot wire requires a broad range of coexistence, crosstalk and compatibility … yet vendor independent.

Industry collaborator evaluating production DC EVSE with ANL Communication Controllers (SECC & EVCC)

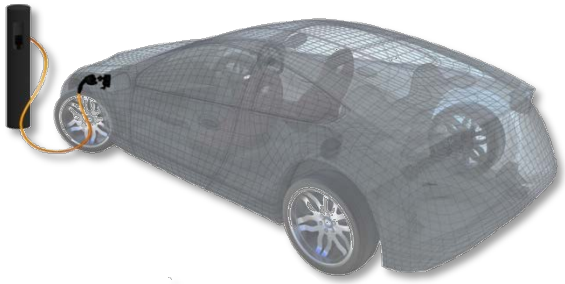
[Dual output EVSE- Level 1, Level 2 DC or SAE, CHAdeMO outputs]

Multi-Phase Approach to Interoperability Test Tools for DC Charging Communication: Emulated, Pack Level, Vehicle Loads

ABC-170 as EVSE/PEV Emulator via CAN communication

Telecom 5kWhr ESS CAN communication

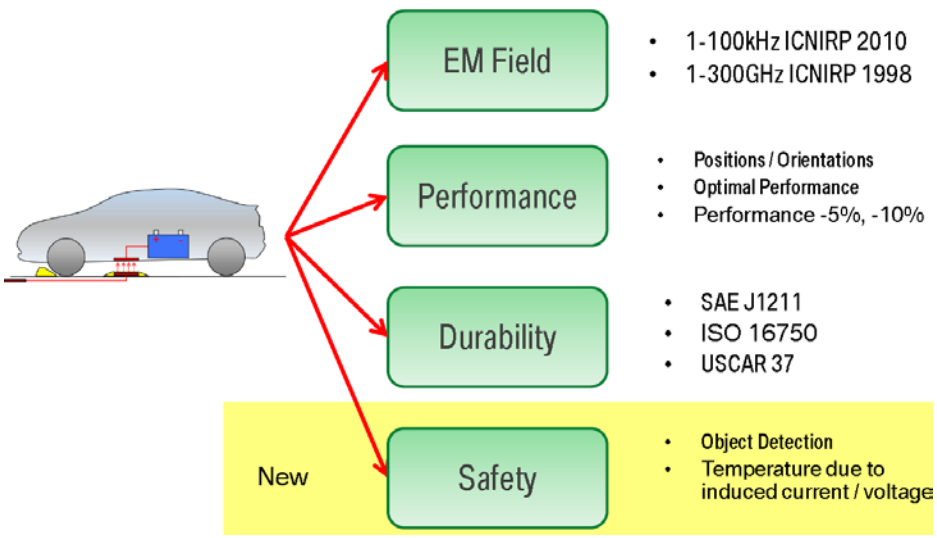
Production PEVs
Level 1, Level 2 DC Couplers
EVCC to vehicle CAN

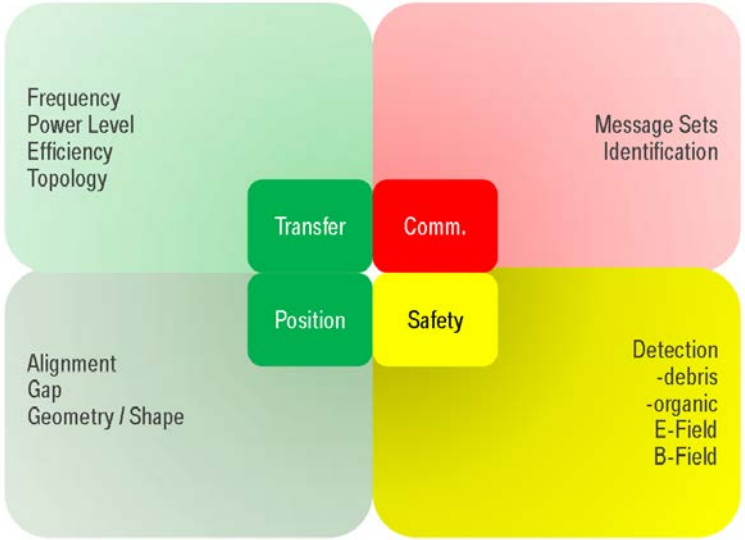


Ongoing dialog between ANL and IEC/SAE DC combo charging station vendors regarding interoperability collaboration, e.g., ABB, Aker-Wade, BTCP, Delta, Eaton, Efacec, IES, Siemens

In Process: SAE J2954 Wireless Charging Evaluation and Testing Protocol/Fixtures

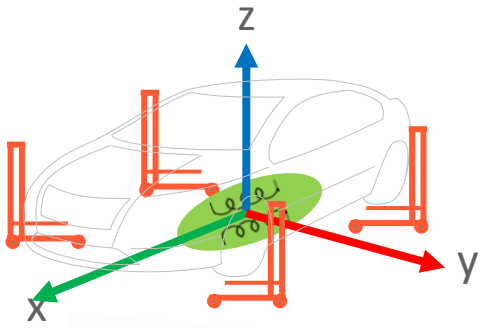
- Working with certification parties (UL/TUV SUD-America), wireless charging system vendors and automotive OEMs on a consensus based testing requirements document and protocol leading to a certification criteria.
- Designing, fabricating and evaluating a test fixture to clarify the significance of variability in the test criteria (e.g., mounting surface, ground plane of vehicle, etc.) to refine the wireless charging system performance, safety and communication requirements

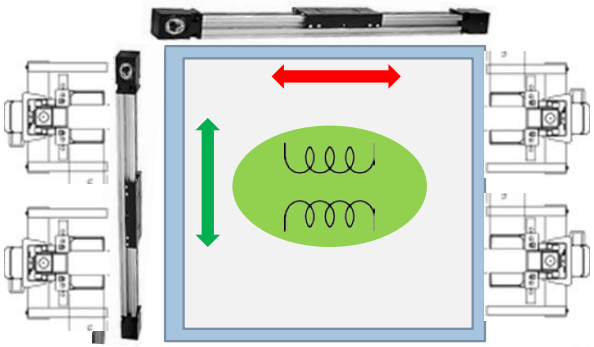


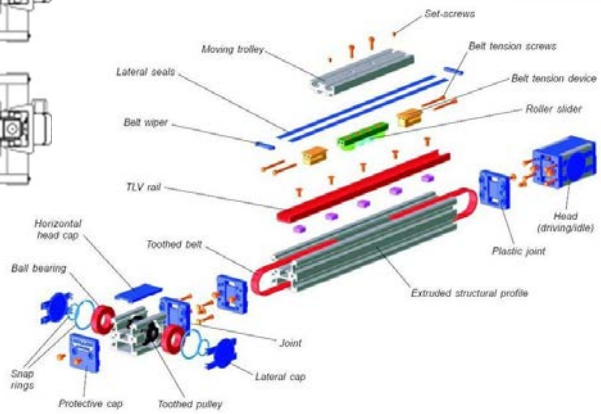


In Process: SAE J2954 Wireless Charging Evaluation and Testing Protocol/Fixtures

- Design is a 3-axis vehicle/device-under-test manipulation fixture and data collection system that can adjust relative position of primary and secondary wireless charging coils in a controlled environment (RF chamber) with 1000mm travel, 1mm accuracy





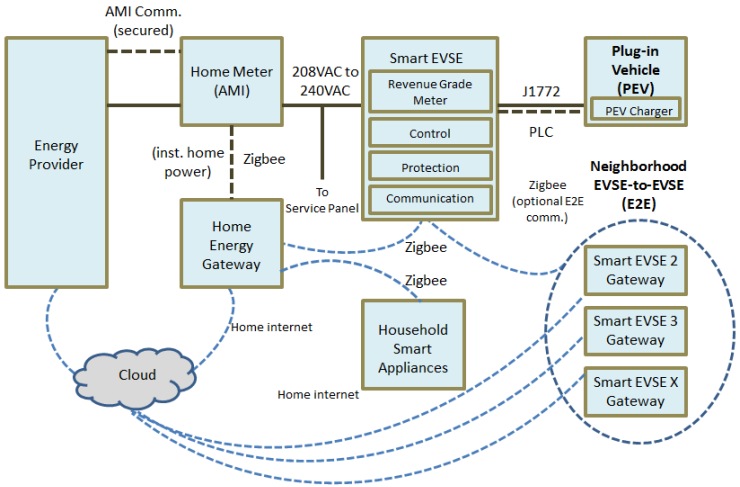


- Capable of evaluating components, systems or vehicles

AC Charging: EVSE-Grid Communication

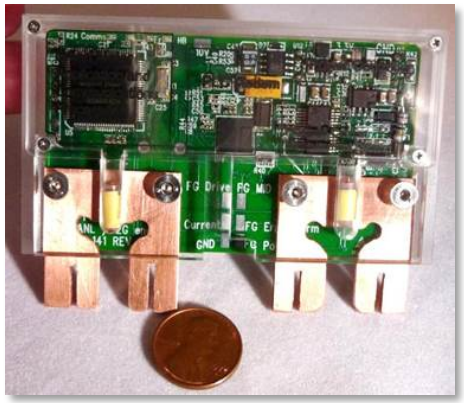
Smart EVSE Responds to Utility Messages Directly via SEP1.x

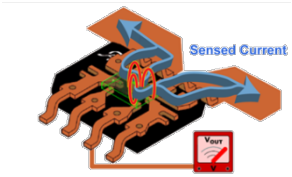
- Demand response, critical pricing, and usage tracking messages directly from utility meter to EVSE … *adjusting charge rate directly*
- Implementing EUMD meters next

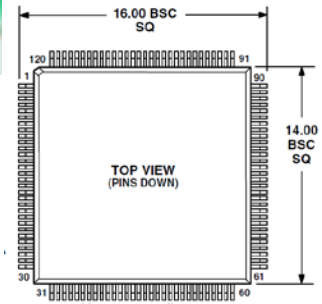


Test Case	Summary
TC.KE.PCT.1	Join the meter through the standard key establishment process, using an install code
TC.KE.PCT.8	Power off the EVSE and power it back on, ensure that it stays joined to the meter or initiates the rejoin process
TC.DR.PCT.2	Ensure that the EVSE does not receive Demand Response (DR) messages intended for other device classes
TC .DR.PCT.3	Send a DR event then cancel the event before the end time, ensure that the event is removed from the device.
TC.DR.PCT.6	Send a DR event to the device, during the DR event send another DR event, make sure the 2nd DR event supersedes the 1st
TC.DR.PCT.9	Send a DR event. Then send a Cancel All command to make sure that DR event is canceled
TC.DR.PCT.20	Send a DR event with a duty cycle of 200% (0xC8), ensure that the EVSE maintains normal operation
TC.DR.PCT.21	Send a DR event with a duty cycle of 50% (0x32), ensure that the EVSE goes to 50% then returns to 100% upon completion
TC.DR.PCT.22	Send a DR event with a duty cycle of 0% (0x00), ensure that the EVSE goes to 0% then returns to 100% upon completion
TC.DR.PCT.23	Send a DR event with a duty cycle of 100% (0x64), ensure that the EVSE mantains normal operation
TC.SM.IHD.6	Ensure the device provides both Instantaneous Demand and Current Summation Delivered.

Enabling Technology: Sub-Metering
Regulation/Interpretation for Electricity as a Fuel

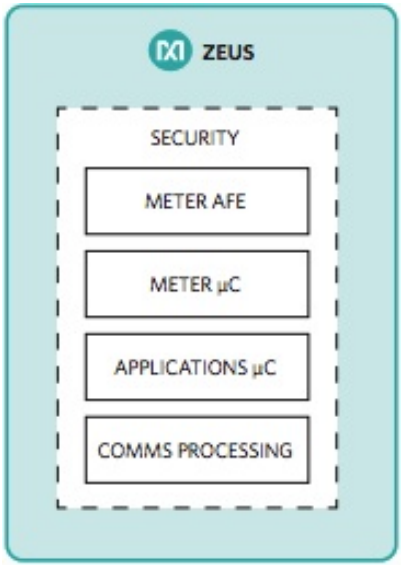






- **NIST Handbook 44-Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices**
- No existing direct specifications for PEV sub-metering (ANSI C12 for premise meters)
- Next generation meter system on chip (SOC) coupled to compact metrology sub meter POC.

3mm current sensor and 16mm Zeus SOC fit under 19mm penny



Collaboration

- **DC Charging Digital Communication- PLC over Pilot wire; Interoperability**
  - Vehicle OEMs: GM, Ford, Chrysler, BMW, VW, Audi
  - DC Charger manufacturers: Eaton, ABB, BTCP, Efacec, Siemens, Qualcomm, Mitsumi
- **Wireless EV Charging/Safety/Performance/Communication**
  - UL, TUV SUD-America, ORNL
  - Vehicle OEMs: GM, Toyota, Nissan, BMW, Daimler, Ford, VW, Audi
  - W-EVSE manufacturers: Evatran, Witricity, Qualcomm-Halo IPT, Momentum Dynamic
- **PEV-EVSE Interoperability**
  - UL, TUV SUD-America, ETL
  - Vehicle OEMs: GM, Toyota, Nissan, Honda, Mitsubishi, BMW, Daimler, Ford, VW, Audi
  - EVSE manufacturers: ClipperCreek, ChargePoint, Ecotality, Delta Products, DBT, BTCP, etc
- **Sub-metering**
  - Metrology IC, Current Sensor Manufacturers: Maxim/Teridian, Allegro, Mag Sys, 2G Engineering,
  - Utilities: PGE, SCE, Northeast Utilities, Duke
  - EVSE manufacturers: BTCP, Bosch/SPX, ClipperCreek, Delta Products, EVSE LLC, EvoReel

Future Plans

Maintain focus on near-term needs with long-term impact, identify technology and software gaps, work with partners to fill gaps, demonstrate grid connectivity technologies and concepts.

(Remaining) FY 2013 Activities

- **DC Charging communication interoperability evaluation**
  - Continue dialog and technical interactions with Vehicle OEMs, DC Charging equipment vendors and communication hardware/software suppliers to identify DC charging communication interoperability gaps. Investigate root cause of non-interoperability.
- **SAE standards committee support**
  - Continue to leverage developed technologies and demonstration-based data in support of SAE PEV charging standards. These include SAE J2953 standard for PEV-EVSE Interoperability, SAE J2954 Wireless Charging (safety issues in particular) and J2931/6 Communication for wireless charging systems
- **Sub-metering/communication modules**
  - Continue to leverage advances from the Grid Connectivity RD&D activities at ANL assist in validating assumptions used to create definitions of sub-meters (EUMD) in electric vehicle refueling
  - Proof-of-concept next generation system on chip sub-meter and related communication software implementation to further support of CPUC and similar protocol investigations; Delivery timing depends on chip vendor

Activities for Next Fiscal Year

- **Investigate limitations and propose solutions for harmonized vehicle-grid communications technologies with emphasis on interoperability**
  - Guide standards development for technology-neutral outcome
  - Expand on SAE J2XXX/6 (wireless charging communication, use case, protocols, etc.)
  - Expand on SAE J2XXX/3 (bi-directional power flow, including micro-grid implementation of DC and AC charged vehicles, with utility messages)

- **Validate performance targets in a systems context**
  - Wireless charging throughput and safety
  - Grid integration with other EERE technologies, including community storage linked to PEV charging systems for robust neighborhood level electrical distribution systems

Summary

- **Relevance** – Responds to the urgent technical needs of the EV-EVSE and EVSE-grid interfaces, and directly supports the connectivity and communications committees of SAE as well as NIST, IEEE, ISO/IEC and other standards organizations.
- **Approach** – Provides technical support in the form of proof of concept systems and demonstrations to collect reference data enabling sound vehicle electrification standards. Provides transformative developments that lead to validation of proposed approaches.
- **Technical Accomplishments and Progress** – Provides leadership, expertise, hardware/software development and laboratory facilities to directly support SAE and other organizations to develop and adopt key EV-grid connectivity standard. Supports DOE FOA556 technical requirements and guidance for awardees.
- **Collaborations and Coordination** – Grid Connectivity RD&D activities are well-connected with industry and government agencies (domestic and international).
- **Future Work** – Maintains focus on near-term needs with long-term impact.