Vehicle to Grid Communication Development

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Project Overview

Timeline
- Start – Oct. 2010 (Project Start)
- Finish – Sept. 2015
- 50% Complete

Barriers
- Lack of codes and standards for communication between PHEV and Grid
- Communication technology must be developed, tested, and interoperability verified

Budget
- Total project funding
  - DOE share - $750K
  - Contractor share - $60K
  - Leveraging – PNNL Lab Homes and Pacific Northwest Smart Grid Demo (PNWSGD)
- Funding for FY13
  - DOE share - $200K
- Funding for FY11 / FY12
  - DOE share - $375K / $125K

Collaborators
- Society of Automobile Engineers (SAE)
- Smart Grid Interoperability Panel (SGIP)
- ANL
- Panasonic (K-Micro) & CODICO - PLC Modules
Objectives

MYPP Relevance:

- Address codes and standards needed to enable wide-spread adoption of electric-drive transportation technologies.

- Provide technical support for the development of SAE Standards for vehicle to grid communications (J2847/1, J2847/2, J2847/3, J2836/5)

- Perform communication technologies testing in support of the SAE Standards Committee

- Validate end-to-end communication using Smart Energy Profile Version 2.0 (SEP 2.0) requirements in SAE Standard J2847/1 to support vehicle charging based on utility programs
Objective: Provide technical support for the development of SAE standards for vehicle to grid communications (J2847/1, /2, /3, and J2836/5)

Approach:

- Actively participate in working group meetings and contribute to document development
- Review and recommend changes to harmonize documents with related US and European Standards
- Test communication technologies in support of the SAE Standards Committee
- Develop and test end-to-end communications using Smart Energy Profile Version 2.0 requirements and SAE Standard J2847/1 to support utility program based vehicle charging.
- Provide leadership to the Smart Grid Interoperability Panel (SGIP). SGIP coordinates the NIST Smart Grid Standards development.

Addresses barriers:
- Lack of codes and standards for communication between PHEV and Grid
- Communication technology must be developed, tested, and interoperability verified
PNNL FY12 Scope

PNNL FY12 Testing
- Pilot Signal Impairment – PLC modules do not affect Control Pilot signal.
- Throughput - MAC/PHY throughput and Application Data (payload) rates.
- Latency - round trip message times.

System Level View
- FY12 Scope within Red Circle
- PNNL FY13 Scope outside red circle for AC messages.

(Ref: SAE J2931 PLC Communication Test Plan – S316a, Jan 2012 Hybrid Committee working document)
PNNL FY13 Testing Scope

PNNL System Leverages:
- PNWSGD – utility communications
- Lab Homes Facilities
- PNNL Load Control Demonstration

Infrastructure Enables Future Efforts:
- Renewables Integration
- Grid Reliability
- Communications Integration

Comm Options:
- OpenADR
- SPC201c
- IEC61850
- IEC6184-25
- SEP2.0
- SAE J2847
Field Testing Infrastructure

Utility Control Center
A full capability utility control room at PNNL enables pre-deployment research of advanced operation, management, and communication grid technologies.
http://eioc.pnnl.gov/about.stm

Home Power Meter
Lab Home ITRON Power Meter enables home power consumption data to be communicated and combined with vehicle charging data.

Standardized Communications Messaging
- ISO/IEC 15118 – Vehicle to Grid Communications Interface
- OpenV2G - open source reference implementation
  - Built to evaluate the ISO/IEC 15118 communication specification
  - Verifies specified messages between electric vehicles and the Electric Vehicle Supply Equipment
  - Follows DIN 70121 standard
  - Provides XML to EXI interface
  - Message Serialization / Deserialization
    - http://openv2g.sourceforge.net
- SEP2.0 messages built upon this implementation when standard available

PNNL Lab Homes
- Lab Homes – two identical 1500 square foot manufactured homes for PNNL and its research partners who aim to achieve highly energy-efficient homes.
- Capabilities:
  - Internal ZigBee network and controllable Smart Appliances
  - Three electric vehicle charging stations
  - PNNL Load Management Technology
  - EVSE to EV communications
    - http://labhomes.pnnl.gov
Field Testing – Utility Communications
Pacific Northwest Demonstration Project

- $178M / 50% ARRA
- 60,000 metered customers in 5 states
- 5-year demonstration – operational 9/2012
- Purpose:
  - Renewables Integration
  - Peak demand / supply management
  - Cost / benefit quantification
  - Utility communications protocol development
  - Standards development
- 11 utilities / 2 universities / 5 vendors
Communications – Maximize EV Impact & Adoption

PNNL projects that 73% of light-duty vehicles can be supplied with existing grid infrastructure IF the load is managed.


PNNL estimates that electric vehicles could provide all the Pacific Northwest’s projected renewables integration needs (14GW) using 16% of light-duty fleet.


PNNL study shows that adequate penetration of electric vehicles could help mitigate high voltage conditions from PV arrays.


Mobile User Interface
- Charge Complete
- 6:00AM
- Customer Info
  - Carbon emissions
  - Mileage
  - Cost

More Faster
Savings Service

Faster Service
More Savings

Mobile User Interface
- Charge Complete
- 6:00AM
- Customer Info
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  - Cost
Accomplishments - FY13 Field Testing

- Open Standard based communications implemented
  - ISO/IEC15118 communications architecture
  - J2847/1 Messages
  - SEP2.0 protocol ready

- ESI Interface developed
  - PNNL internal funds used to develop a multi-input Home ESI / HEMS for evaluation and testing with J2847/1 & SEP2.0 charging station / PEV communications.
  - Utility – PNWSGD project provides incentive signal to bias Lab Home loads being supplied.
  - Lab Home – dryer, thermostat, and hot water heater.
  - Electric Meter signal is used to limit loads based on transformer limits.
  - 3 EVSEs – AV, EATON, and SPX enabled to provide access to Control Pilot signal and act as communication servers to EV.
  - K-Micro evaluation board provides PLC communication path to EV
  - Web Server enables customer feedback and charge complete time

- Vehicle – PNNL’s 2009 Toyota Prius with Hymotion battery pack
  - PNNL controller acts as client on EVSE network.
  - PNNL controller receives Control Pilot communications and interfaces with EV.
  - PNNL controller enables access to odometer and SOC values.
SAE Standard J2836/3 and J2847/3: PEV Communicating as a Distributed Energy Resource
- J2836/3 completed SAE review and approval process
- Standard committee is integrating SEP2.0 and J1772 requirements with the J2836/3 Use Cases.

SAE Standard J2847/1: Communication between Plug-In Vehicles and the Utility Grid
- Support integrating SEP2.0 & J1772 with J2836/1 Use Cases into format similar to J2847/2.
- Compiled J2836/1 use cases to enable a messaging requirements overview of all use cases.
- Identify gaps while integrating and testing the J2847/1 standard communications with the PNNL Prius and Lab Homes / utility communications.

SAE Standard J2836/5: Use Cases for Communication between Plug-in Vehicles and their Customers
- Recent discussions have pushed the J2836/5 effort to restart and work together with the J2931/5 – telematics committees
- Develop J2836/5 Customer interaction uses cases between PEV and HAN

SAE Standard J2953/1 and J2953/2: Interoperability Testing
- Collaborate with ANL while testing J2847/1 and SEP2.0 communications
- Identify gaps in communication standards and provide feedback

SGIP V2G DEWG and ANSI EV Standards Panel
- Participated in working group meetings and contributed to the roadmap development
Accomplishments Since FY12 AMR Review

- **Outreach / Publications:**
  - Krishnan Gowri presented a technical seminar at EVS26 titled: “Testing and Validation of Electric Vehicle Communication Standards”
  - Chair the SGIP V2G DEWG and subgroups

- **Technology development / deployment**
  - Tech Transfer of OE-funded grid-friendly electric vehicle charging technology to AeroVironment
  - Field testing of SAE J2847/1 messages using PLC on Control Pilot in progress
On-going Activities

FY13

- Review and contribute to SAE J2847/1, J2847/3, and J2836/5 standard documents development
- Implement application layer communication between utility, EVSE, and EV. Develop field test plan for end-to-end communication using smart meters
- Identify EVSE and vehicle OEM partners for field testing and demonstration of charge management to validate J2847/1
- Provide industry support to evaluate commercial power line communication modules for control pilot communication.

Future Work

- Actively contribute to SAE standard documents development.
- Integrate and test vehicle charging with renewable and stationary storage systems. Evaluate and test communication and control strategies.
- Identify and partner with utility, EVSE and vehicle OEMs for field testing.
- Develop a reference design linking communication design to PNNL’s Future Power Grid initiative for EVSE to Grid Operator.
- Demonstrate compelling demand-limiting events using home automation / vehicle charging control scenarios that prevent damage to home transformers.
- Develop a set of recommendations for interoperability between the vehicle telematics network, EVSE network and the utility network.
Collaborators

- **SAE** - North American Standards development organization developing the electrical connection and communication standards for vehicle-grid communication (J1772, J2836, J2847, J2931)

- **SGIP** - Smart Grid Interoperability Panel coordinating standards development for grid modernization including electric vehicles

- **ANL** - EVSE / PEV Communication firmware implemented using common OpenV2G and ISO/IEC 15118 architecture.

Industry participants:

- **K-Micro** - Power line communication technology manufacturer
- **CODICO** - Power line communication technology manufacturer
Assumptions and Outcomes

Assumptions
- PLC Technology manufacturers are developing and providing evaluation boards and APIs needed for testing
- SEP 2.0 Application layer standard approved for implementation and testing

Outcome
- PNNL will work with EVSE manufacturers and vehicle manufacturers to incorporate the PLC technology to implement end-to-end communication
- PNNL will begin field testing in the Lab Homes to evaluate the deployment of PLC technologies and validate the J2847/1 requirements for charge management
Project Summary

- SAE Standards J2847/1 and J2847/2 are presently being revised
- SAE Standards J2836/5 and J2847/3 are in progress
- Commercial PLC vendor product provided needed platform to perform field test and evaluations of end-to-end communications.
  - Anticipate providing PLC vendor with feedback to resolve issues in developing communication modules
- This PNNL project addresses critical issues in communications standards development by:
  - Providing technical assistance for standards harmonization, use case development and document reviews to accelerate the development process
  - Assembling a field test setup using Utility Control Center, PNNL Lab Homes and charging stations to evaluate field performance of end-to-end communication between the vehicle and grid