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Vehicle to Grid Communication Development

RICHARD PRATT
KRISHNAN GOWRI, PHD
Pacific Northwest National Laboratory

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Project Overview

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Timeline

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

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

Barriers

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

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

Technical Approach

Objective: *Provide technical support for the development of SAE standards for vehicle to grid communications (J2847/1, /2, /3, and J2836/5)*

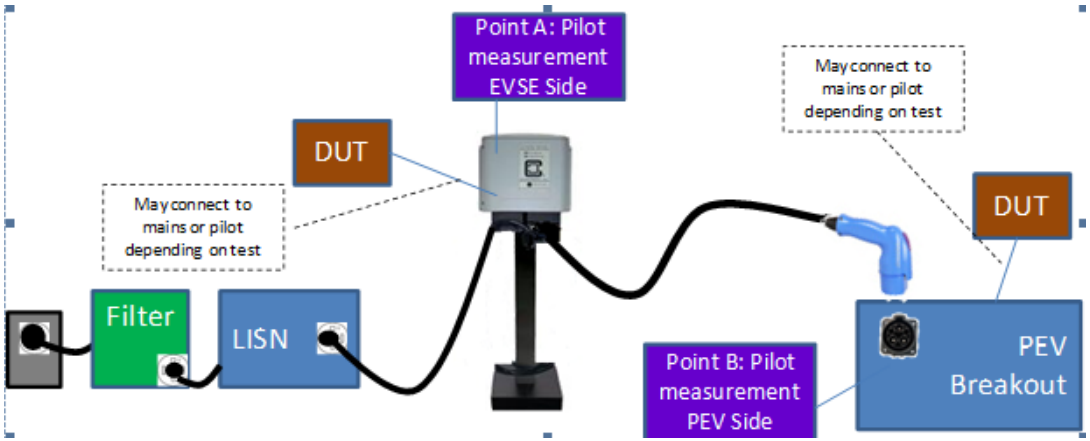
Approach:

- 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.

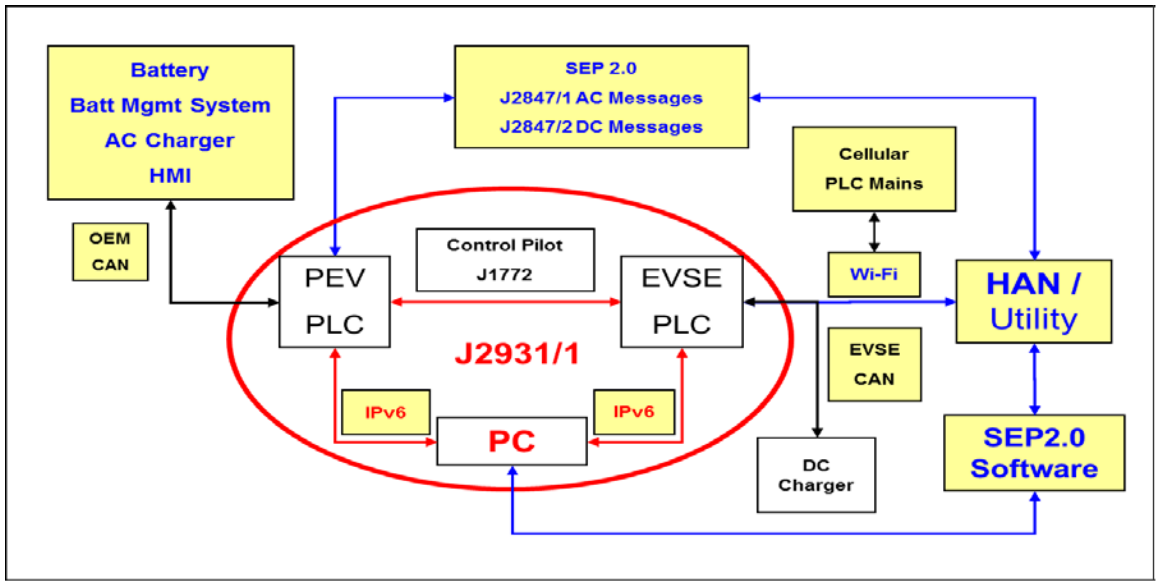
Addresses barriers:

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

PNNL FY12 Scope



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



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.

PNNL FY13 Testing Scope

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Internet Clouds

Utility Enterprise Network

Vehicle Telematics

Mobile Devices

HAN

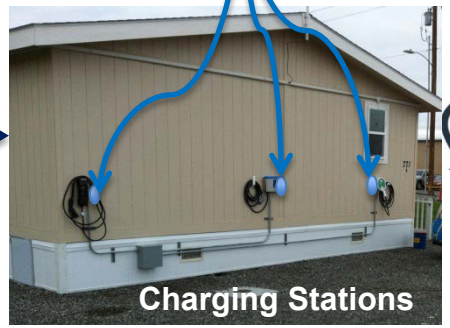
Utility AMI Network

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

Comm Options:
OpenADR
SPC201c
IEC61850
IEC6184-25
SEP2.0

Home Area Network Energy Systems Interface

Which Network Do I Listen to?



SAE J2847

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

Dashed lines outside FY13 Scope

Field Testing Infrastructure

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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

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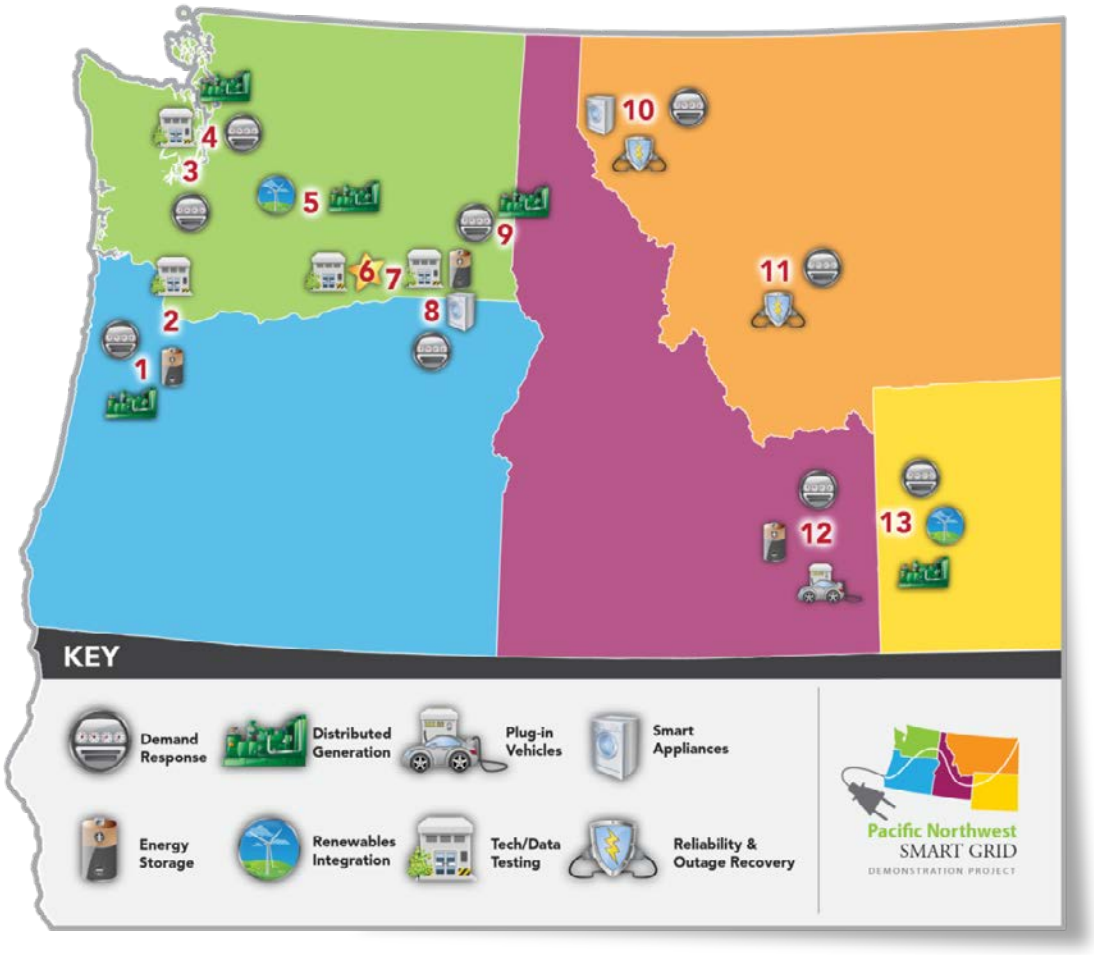

- $178M / 50% ARRA
- 60,000 metered customers in 5 states
- 5-year demonstration – operational 9/2012
- Purpose:
  - Renewables Integration
  - Peak demand / supply management
  - Cost / benefit quantification
  - Utility communications protocol development
  - Standards development
- 11 utilities /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

Communications – Maximize EV Impact & Adoption

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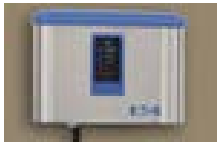
PNNL study shows that adequate penetration of electric vehicles could help mitigate high voltage conditions from PV arrays.

PNNL-22064 – Using Electric Vehicles to Assist Integration of Large Penetrations of Distributed Photovoltaic Generation, Nov. 2012.

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

PNNL-20501 – Using Electric Vehicles to Meet Balancing Requirements Associated with Wind Power, July 2011.

More	Faster
Savings	Service



Mobile User Interface

- Charge Complete

6:00AM

Customer Info

- Carbon emissions
- Mileage
- Cost

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

Kintner-Meyer, M., K. Schneider, and R. Pratt. 2007. "Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids – Part 1: Technical Analysis."

Accomplishments - FY13 Field Testing

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- 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.

Standards FY13 – Progress

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- 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”
  - PNNL Report No. PNNL-22161 – Electric Vehicle Communications Standards Testing and Validation – Phase II: SAE J2931/1, December 2012
  - PNNL Report No. PNNL-22064 – Using Electric Vehicles to Assist Integration of Large Penetrations of Photovoltaic Generation, November 2012
  - 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