Testing and Validation of Vehicle to Grid Communication Standards

Krishnan Gowri, Ph.D.

Pacific Northwest National Lab.

May 9, 2011

Project ID # VSS055

Pacific Northwest NATIONAL LABORATORY

Overview

Timeline

- Start– Oct. 2010 **(Project Start)**
- Finish – Sept. 2011
- 50% Complete

Budget

- Total project funding
  - DOE share - 125k
  - Contractor share - None
- Funding Received in 2010
  - DOE share – 320k
- Funding for FY11
  - DOE share -125k

Barriers

- Lack of codes and standards for communication between PHEV and Grid
- Communication technology options are unproven for automotive application

Partners

- Society of Automobile Engineers
- Echelon, MAXIM
- Hymotion

Objectives

MYPP Relevance:

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

- Develop testing and validation procedures for VGC standards and technologies based on SAE Documents J2847 and J2931
- Build “VGC Virtual Testbed” to test validation procedures for VGC
- Develop prototype communication modules to establish performance requirements for vehicle and charging station OEM adoption

Technical Approach

Objective: *Support SAE Hybrid Committee with standard development and requirements definition for vehicle to grid communication*

- Possible communication pathways for vehicle to charging station communication:
  1. Power line communication over the mains (no special communication cables)
  2. Power line communication over the pilot line (using the J1772 connector pilot wire)
  3. CAN bus communication using additional pins

- Possible communication pathways for vehicle/charging station to utility:
  1. Wireless, HAN
  2. Power line communication over mains to the AMI meter
  3. Cellular communication to the utility back haul network

  (Several architectural variations are possible with the vehicle and charging station capabilities)

  - Select communication pathways and architectures to support SAE standard development with the committee input and EPRI requirements documents

Technical Approach

Objective: *Develop test plan and performance requirements for testing and validation of VGC standards and technologies based on SAE Documents J2847 and J2931*

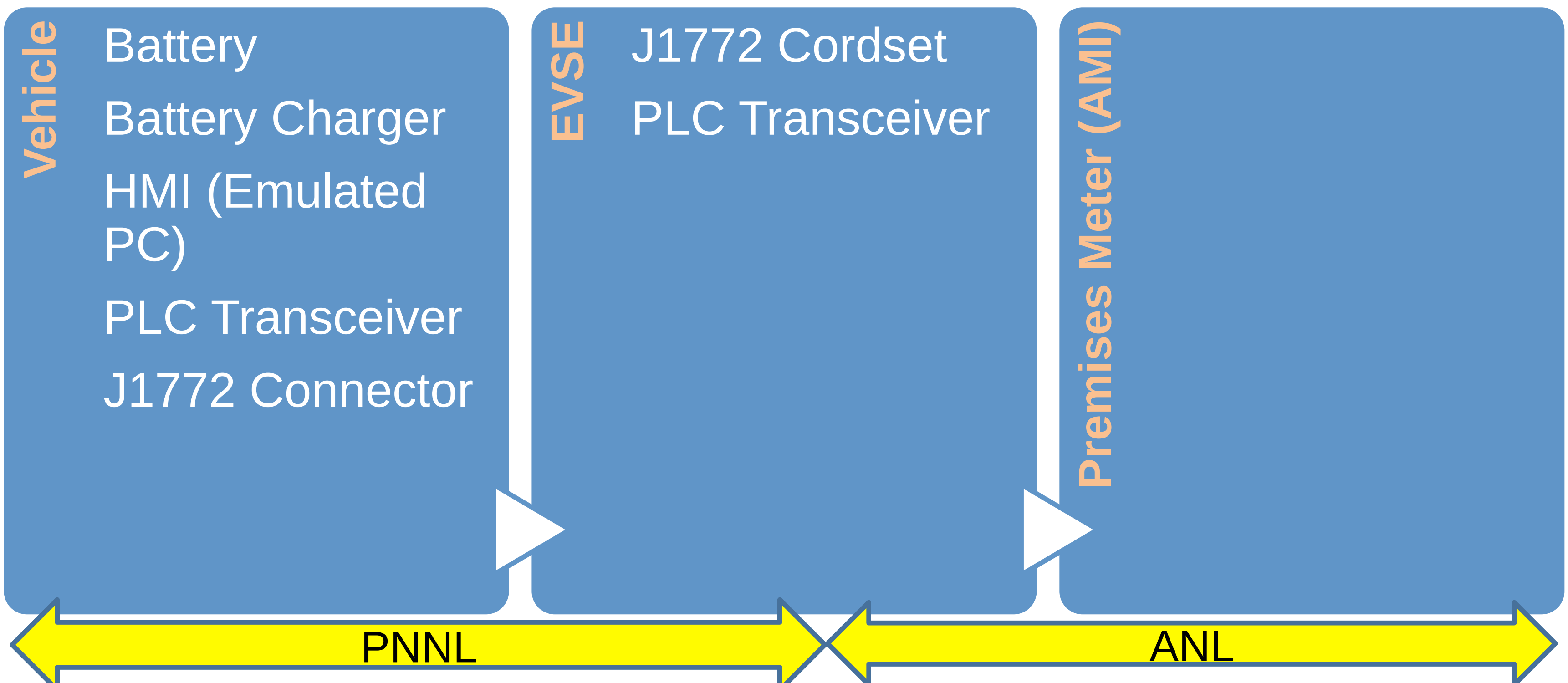
- Select Power Line Communication (PLC) technologies for testing J2847/1 messages from vehicle to electric vehicle supply equipment (EVSE)
  - Selected Echelon and MAXIM G3 lite low-frequency, narrow band PLCs

- Fabricate test bed and develop test plan
  - Identified charging station and battery module for lab test bench
  - Develop test procedures for association and authentication
  - Perform integrated laboratory testing of PLC technologies with bench set up using battery, charger, and EVSE.
  - Perform co-existence and attenuation tests for data transmission and error rates

Pacific Northwest NATIONAL LABORATORY

Technical Approach - Test Bench Schematic

Objective: *Develop "VGC Virtual Testbed" and collaborate with industry partners to develop a prototype for testing and validation of VGC in laboratory.*



Test Scenario: Send message from vehicle and receive at utility interface

* ANL integration of EVSE to Premises Meter is a separate effort and not included in the FY11 activities

Pacific Northwest
NATIONAL LABORATORY

Functional Test Architecture

Pacific Northwest
NATIONAL LABORATORY

Functional Test Plan

PLC System Configuration

1. Default settings used for filtering and signal magnitude
2. L1 to N (L2) connection.
3. MAXIM testing primarily used NORMAL mode
4. Messages were short to allow comparable testing between the MAXIM and Echelon units

Testing Performed

1. System operation verified on 120VAC line
2. 208 VAC - data and error rate test w/o charger
3. 208 VAC - data and error rate test at 100% charge rate
4. 208 VAC - data and error rate test at 75% charge rate
5. 208 VAC - data and error rate test at 50% charge rate
6. 208 VAC - data and error rate test at constantly variable charge rate
7. 208 VAC - data and error rate test w/o charger and extra 45’ AC cable length
8. 208 VAC - data and error rate test w/o charger and FSK noise injection
9. 208 VAC - data and error rate test w/o charger with both MAXIM and Echelon on the same 17’ 208 VAC cable

Functional Test Results (preliminary)

MAXIM – MAX 2991

1. 33.6 million messages / 2.9 million while charging
2. Data rate increases to ~100Kbps with long messages
3. Error rate – < 1×10^{-6} in NORMAL mode and no interference
4. **ROBO mode is required in the presence of interfering signals.**
5. Interfering signal measured Data Rate unchanged in ROBO mode.
6. Interfering signal Error Rate in ROBO mode < 1×10^{-6}

Echelon PL3170

1. 5.2 million messages / 322,000 while charging
2. Data rate ~1.9Kbps
3. Error rate – ~20×10^{-6} – errors were typically no response to transmitted message
4. **Performance not affected by interfering signals**

Notes

- Data rates reported do not include vendor incorporated overhead (CRC, protocol, etc.) necessary to support communications. The data rate values reflect only number of bits sent and received.
- Data rate measurement calculated by dividing the number of bits sent by the elapsed time between transmission and reception. A correction was made to the measured elapsed time to remove measurement equipment delays.

Pacific Northwest NATIONAL LABORATORY

FY’10 Accomplishments
(DOE/OE funded FY’10 activity, leveraged for this project)

- Human Machine Interface (HMI) development completed and integrated with the communication modules
- J2847 messages reviewed and mapped to SEP 2.0 for supporting price-based, time-based and optimized charging
- IEC and SAE use cases reviewed and comments submitted for harmonization
- Grid-friendly charging implemented in a field prototype with Toyota Prius and Coloumb Level 2 charging station

FY'11 – Progress

- Outreach:
  - Co-authored a technical paper with SAE committee members on communication standards development and test plan. This was presented by Rich Scholer at the SAE Congress in April 2011
  - Presented three technical seminars at UCLA, Smart Grid Road Show and NYSERDA conferences and workshops related to electric vehicle communication and grid-friendly charging
- Technology development
  - Laboratory test bed development completed.
  - Two PLC module prototypes developed and tested.
  - Human-Machine-Interface integrated and tested with the PLC modules.

On-going Activities for FY'11

- **May – Sept. 2010**
  - Review and contribute to J2931 document development
  - Develop power line communication module prototypes for control pilot communication (three modules will be developed based on SAE needs and EPRI requirements documents)
  - Implement SEP 2.0 application layer in the prototypes to test the latency, data rate and error rates

Collaborators

- **SAE** – Leading North American Standards development organization developing the electrical connection and communication standards for vehicle-grid communication (J1772, J2836, J2847, J2931)
- **NIST** – US National Standards coordination activity developing the Smart Grid Roadmap and framework for standards and protocols
- **EPRI** – Research and development organization representing the electric utility industry and involved in use case development and communication testing coordination with Ford for SAE and NIST.
- Industry partners:
  - **Echelon** – Power line communication technology manufacturer
  - **MAXIM** – Power line communication technology manufacturer
  - **Hymotion** – Electric vehicle battery and charger manufacturer

Pacific Northwest NATIONAL LABORATORY

Assumptions and Outcomes

- Assumptions
  - EVSE and vehicle manufacturers will be engaged in project and provide equipment for integrated testing
  - SEP 2.0 will be finalized for implementation

- Outcome
  - Contribute to SAE and NIST activities to accelerate the development and harmonization of VGC codes and standards
  - Capability development for validation and testing of communication modules
  - PNNL functional testing will assist SAE make the final choice of PLC technology selection

Project Summary

- Codes and Standards for vehicle-grid communication are not fully developed and no standard communication protocols are available yet.
- The communication technology needs to be implemented in laboratory setting and tested in demonstration vehicles before performance requirements can be provided to automobile manufacturers.
- This PNNL project addresses critical issues in communications standards development by:
  - Developing a test bench for integrated testing of communication modules
  - Developing communication module prototypes for implementing J2847/1
  - Testing and validating J2847/1 communication messages in a PLC prototype

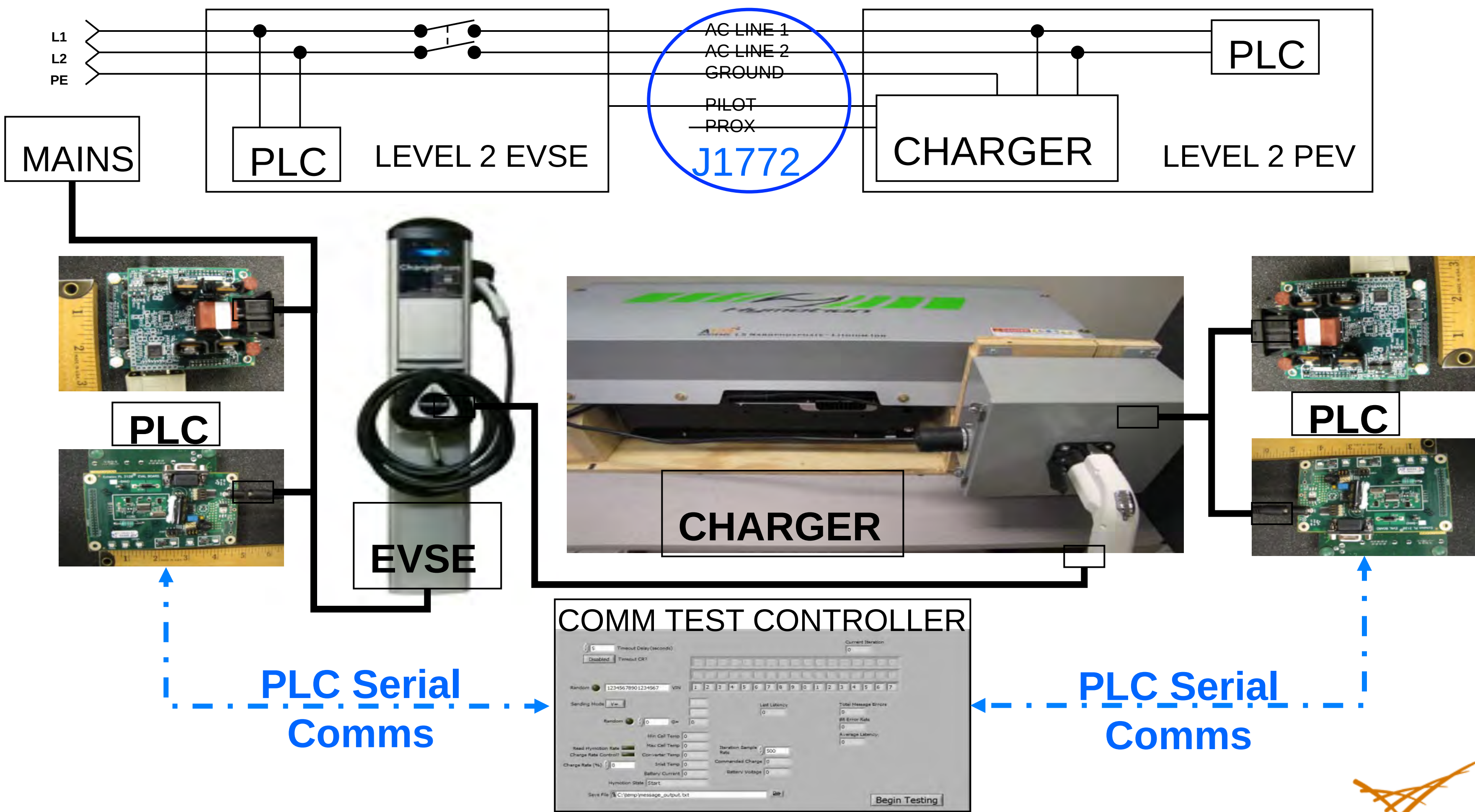
Questions ?

Contact:

- *Krishnan Gowri at (425) 273-0190*
  krishnan.gowri@pnl.gov

Backup slides

Functional Test Schematic



Pacific Northwest
NATIONAL LABORATORY