Vehicle to Grid
Communications and Field Testing

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Project ID # VSS122
Overview

Timeline
- Start – Oct. 2013
- Finish – Sept. 2014
- 50% Complete

Budget
- Total project funding
  - DOE share – $200K
  - Leveraging PNNL’s Distributed Control System Initiative
- Funding Received in 2014
  - DOE share – $200K
- Funding for FY13
  - DOE share – $325K
  - Contractor share – $30K

Barriers and Targets
- Demonstrate Hardware In the Loop testing of vehicle charging systems
- Advanced control strategies needed to optimize performance and efficiency of electric vehicle charging
- Communication technology options are unproven for automotive application
- Most vehicles and EVSE’s only have J1772 communication capabilities

Partners
- Society of Automobile Engineers: J2847/1, J2847/2, J2847/3 and J2836/5 committees
Objectives and Relevance

- Prototype charging controllers installed at PNNL in a manufactured Home using the existing charging stations and employee-owned electric vehicles to perform field trials
  - Demonstrate Hardware In the Loop testing of vehicle charging systems and determine their response to external control.
  - Built and tested infrastructure needed to develop control strategies for optimizing performance and efficiency of electric vehicle charging.
  - Most vehicles and EVSE’s only have J1772 communication capabilities

The J1772 Control Pilot provides a variable charging rate control signal for production vehicles that enables vehicle charging performance testing.
Approach: Benefits of using charge rate control?

- Coordinated charging\(^1\) would reduce congestion, distribution transformer peak loading, and delay electric system upgrades.
- Feeder congestion from multiple EV’s charging is causing some local transformer upgrades.
- Coordinated EV charging times could improve renewable energy utilization.
- Energy storage sizes could be reduced with coordinated EV charging
- The economic benefits of an Intelligent Vehicle Charging Infrastructure (IVCI) are substantial. Stakeholders must evaluate these economic benefits and costs to develop the necessary communication and control standards to develop a nation-wide IVCI\(^2\).

Charging control enables growing EV adoption to accelerate by mitigating negative impacts to the grid and enabling EV’s to become a grid resource.


Approach: What are the current charging Control Options?

- Over 190K plug-in vehicles\(^1\) have been sold in the U.S.
- All production EV’s have J1772 charging rate control.
- The J1772 Control Pilot signal can be used to adjust the maximum vehicle charging rate.
- Two EVSE vendors have variable charging rate products, but many have implemented a fixed charge rate control.
- Some utilities incentivize customers to shift charging times to off-peak using Time-Of-Use rate structures.
- Start charging when plugged-in
- Delay charging start until a given time
- Delay charging until charging will be completed by given time

The J1772 Control Pilot provides a variable charging rate control signal for production vehicles.

\(^1\)http://electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952
Approach: What does the Control Pilot signal look like?

<table>
<thead>
<tr>
<th>Control Pilot states</th>
<th>J1772 Connector</th>
<th>1 kHz square wave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Disconnected</td>
<td>+12VDC signal</td>
<td></td>
</tr>
<tr>
<td>Vehicle Connected and Contactor Open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle Charging (Contactor Closed)</td>
<td>30 amp charge rate</td>
<td>1 kHz and 5% pulse width</td>
</tr>
<tr>
<td>Fault</td>
<td>15 amp charge rate</td>
<td></td>
</tr>
<tr>
<td>Digital Communications controlling</td>
<td>10 amp charge rate</td>
<td></td>
</tr>
</tbody>
</table>

0V ↔ -12VDC signal
Approach: How can Control Pilot control be implemented?

Control Pilot connectivity

Using the Control Pilot signal

- Measure the EVSE Control Pilot pulse width to determine maximum power the EVSE can deliver.
- Create a similar Control Pilot signal to command the vehicle to reduce maximum charging power.
- Key: The battery management system adjusts the maximum vehicle charging rate in response to the Control Pilot signal.
Three EVSEs from different manufacturers were configured with the prototype charging rate controller. All were successfully tested using a GridTest EV Emulator.

A prototype controller was connected to the KYZ output of the home’s power meter. The KYZ output was 1 pulse / 90W.

Prototype controllers integrated into VOLTTRON agent-based control system. This control system enables each EVSE to share available power according to customer priorities.

An employee-owned NISSAN LEAF® and the PNNL PRIUS were simultaneously charged at the Manufactured Home facility.

Relocated prototype controllers to lab facility to make enhancements to the agent-based control system.

Performed the tests shown below using simple circuits to create load changes and EV power consumption responses.
Technical Accomplishments: Coordinated charging demonstration

- Used an example American family day
- Incorporated two customer preferences into charging
  - Energy required
  - Charge completion time
- Implemented Charging rate control
  - Home delivery capability – three Level II EVSE’s
  - EV’s – Ford Focus, Nissan Leaf, and Chevy Volt charging parameters
  - Other home loads – A/C, Water Heater, TV, etc.
- Implement one maximum power goal seek to determine if 25% peak load reduction possible.
Technical Accomplishments: Coordinated control

EV charging typically starts when a vehicle returns from a trip and can coincide with energy consuming activities in the home.

Intelligent Vehicle Charging (IVC)

EV charging rate was limited by 13kW Home Power goal to 14.4kW peak load.

25% Peak Load reduction
Technical Simulation: Coordinated control with variable goal

Using BPA’s Forecasted Load Schedule to develop variable home goal

35.5 kWh above Home Goal

Intelligent Vehicle Charging (IVC)

EV charging rate was limited by Home Power goal

33% Peak Load reduction

4.5 kWh above Home Goal
Technical Accomplishments

- Three identical prototype charging rate control modules developed and tested on EVSEs from three different manufacturers.
- Hardware in the Loop system demonstrated 25% peak load reduction while monitoring only Lab Homes power meter output and receiving the customer preferences of energy required and charge completion time.
- Adding BPA forecasted load curve information to use as a variable home goal was simulated to cause a 33% peak load reduction.
On-going Activities for FY14

May – Sept. 2014

- Perform field testing of coordinated charging (Hardware In the Loop) infrastructure to include:
  - Static energy use goals
  - Variable energy use goals – using the PNWSGD project incentive signal.
  - Determine vehicle response to external control.

- Develop control strategies needed to optimize performance and efficiency of electric vehicle charging using experimental data from energy sharing algorithms between home loads, electric vehicles, and electric bus.

- Prepare a report summarizing tested and projected communication technology options that can be exercised for automotive applications.
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


- Internal collaboration – PNNL VOLTTRON development team.

- Industry partners:
  - AeroVironment - integrated PNNL’s autonomous variable charge rate technology into product line
Project Summary

- Three identical prototype charging rate control modules developed and tested on EVSEs from three different manufacturers.
- Only inputs used were power meter output and the customer preferences of energy required and charge completion time.
- Hardware in the Loop system demonstrated 25% peak load reduction while only monitoring total power. This significantly reduces residential transformer maximum temperature from multiple vehicles simultaneously charging.
- Adding BPA forecasted load curve shape as a variable home goal was simulated to cause a 33% peak load reduction.
- These load sharing functions can be used on J1772 enabled vehicles using minor changes to existing EVSE’s.
Questions?

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