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Vehicle to Grid Communications and Field Testing

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Project ID # VSS122

U.S. DEPARTMENT OF ENERGY

Overview

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- 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

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- 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.

[1]Z. Hu, Y. Song, and YZ. Luo, "Coordinated Charging Strategy for PEV Charging Stations", Power and Energy General Meeting, July 2012.

[2]S. Letendre, K. Gowri, M. Kintner-Meyer, "Intelligent Vehicle Charging Benefits Assessment Using EV Project Data", PNNL-23031, Dec. 2013.

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?

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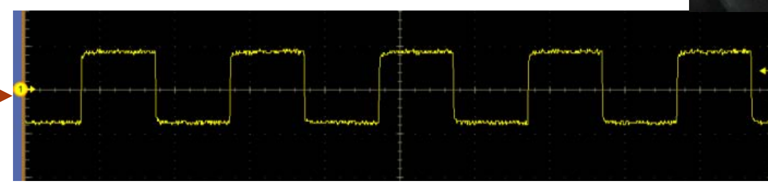
Control Pilot states

J1772 Connector

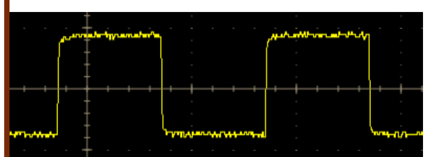
Vehicle Disconnected → **+12VDC signal**

Vehicle Connected and Contactor Open

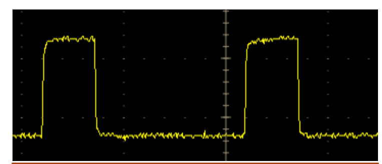


1 kHz square wave

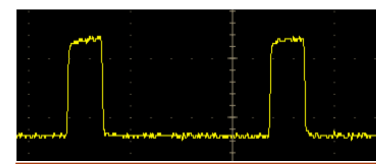
Vehicle Charging (Contactor Closed)



30 amp charge rate



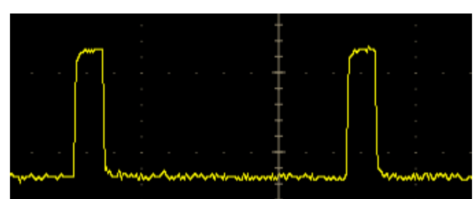
15 amp charge rate



10 amp charge rate

Fault → **0V ⇔ -12VDC signal**

Digital Communications controlling



1 kHz and 5% pulse width

Approach: How can Control Pilot control be implemented?

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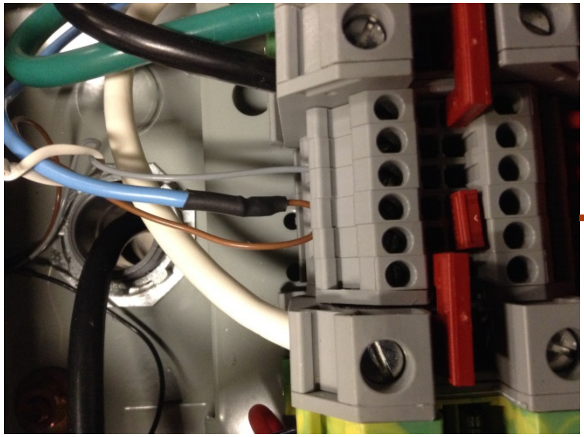
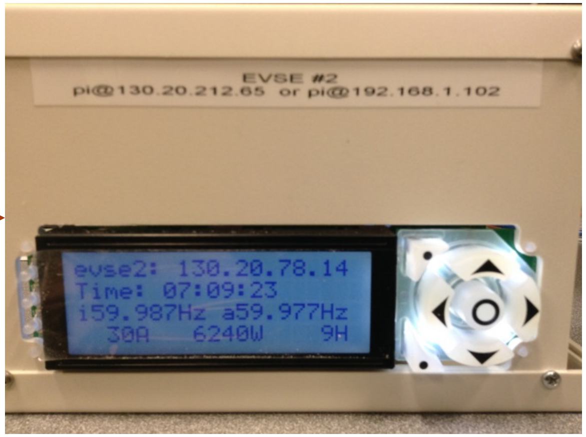
Control Pilot connectivity





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.

Current Status / Testing Approach: Coordinated charging demonstration

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- 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

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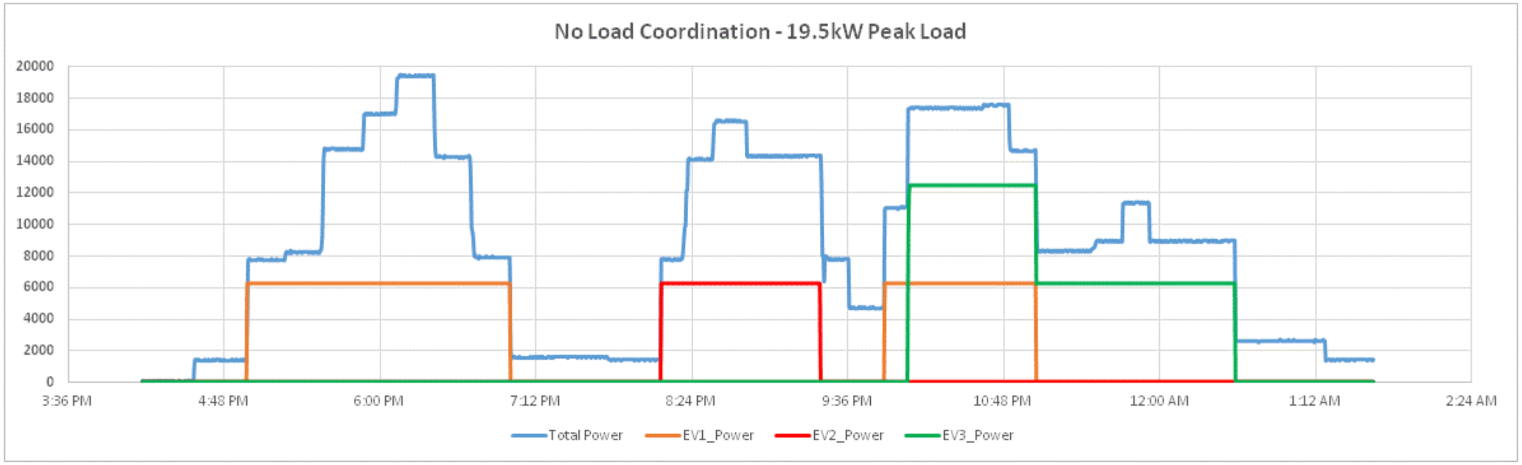
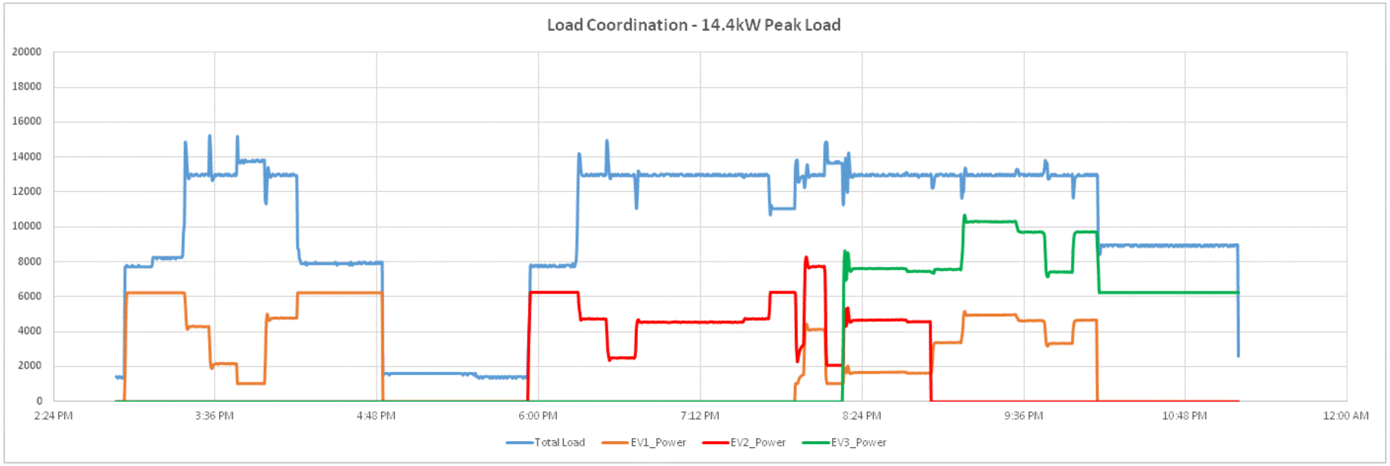
EV charging typically starts when a vehicle returns from a trip and can coincide with energy consuming activities in the home



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

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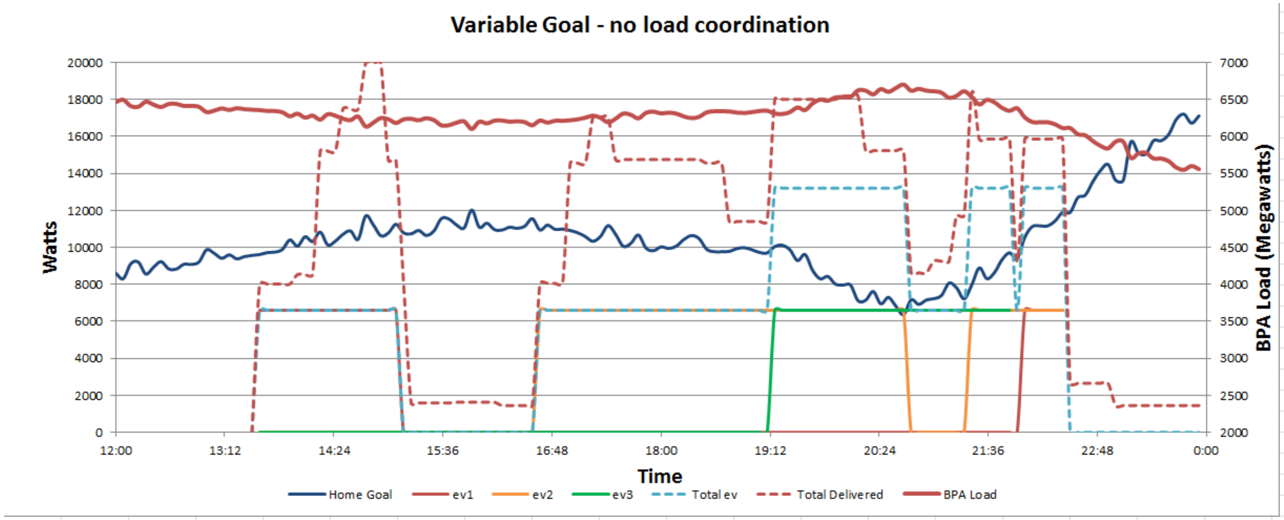
Using BPA's Forecasted Load Schedule to develop variable home goal

35.5kWh above Home Goal

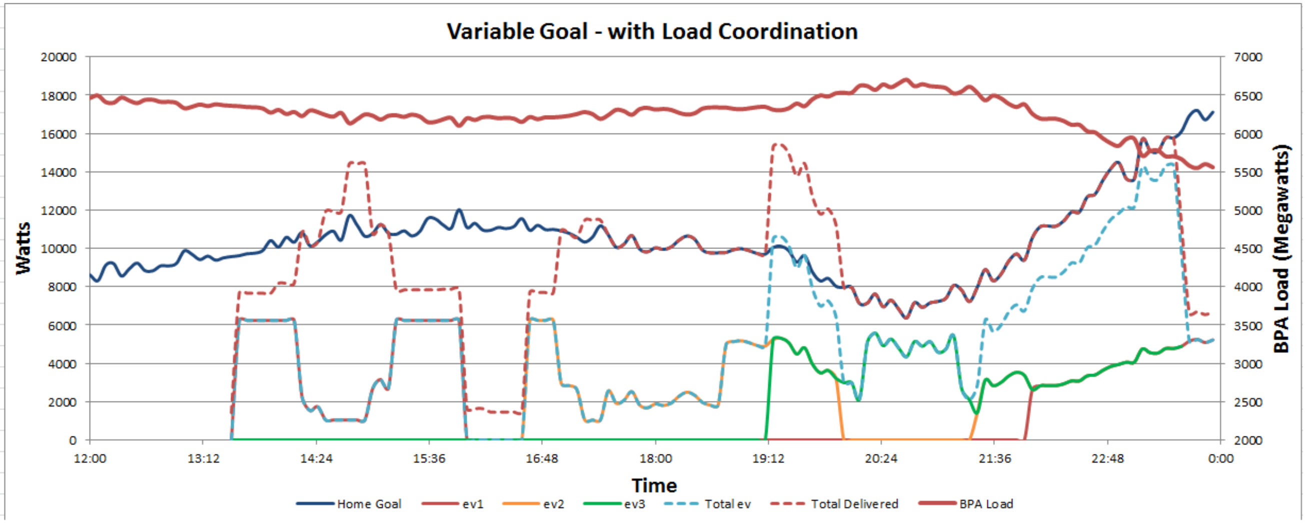


Intelligent Vehicle Charging (IVC)

EV charging rate was limited by Home Power goal

33% Peak Load reduction

4.5kWh above Home Goal



Technical Accomplishments

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- 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

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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

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- **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
- University of Vermont – Prof. Steve Letendre - “Intelligent Vehicle Charging Benefits Assessment Using EV Project Data,” PNNL-23031, Dec. 2013.
- Internal collaboration – PNNL VOLTTRON development team.
- Industry partners:
  - **AeroVironment - integrated PNNL’s autonomous variable charge rate technology into product line**

Project Summary

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- 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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