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Vehicle Communications and Charging Control

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U.S. DEPARTMENT OF ENERGY

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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 and distributed controller software
  - 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
  - Lack of codes and standards for communication between PHEV and Grid
  - 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
  - Prof. Steve Letendre - Uni. of Vermont

Objectives and Relevance

- The barriers can be addressed by using prototype charging controllers installed in PNNL Lab Homes using the existing charging stations and employee-owned electric vehicles
  - Demonstrate Hardware In the Loop testing of vehicle charging systems and determine their response to external control.
  - Advanced control strategies needed to optimize performance and efficiency of electric vehicle charging can be developed using data from this system.
  - Existing codes and standards for communication between PHEV and Grid can be tested and recommendations forwarded to SGIP and SAE.
  - Communication technology options can be exercised for automotive application to enable lessons learned to be shared.
  - 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?

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- Coordinated charging[1] would reduce congestion, distribution transformer peak loading, and delay electric system upgrades.
- Demand Charges are expensive, but typically limited to Level 3 EVSEs or fleet charging
- 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 vehicle charging rate.
- One EVSE vendor has an integrated variable charging rate product, most have implemented a fixed charge rate control.
- Some utilities incentivize customers to shift charging times to off-peak using Time-Of-Use rate structures.
- Demand response infrastructure is being developed to delay or stop charging.
- 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: How are the owner's charging preferences implemented?

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Digital Communications

EVSE ⇔ EV → EV ⇔ Battery Management System

J1772

EVSE adjusts Control Pilot → EV battery management system interprets Control Pilot signal to limit charge rate

Telematics / Vehicle Control Panel

CAN Bus → CAN bus communication to battery management system

- The maximum charging power is limited by the J1772 Control Pilot signal
- The battery management system charges the battery within the battery's safe operating envelope limited by the Control Pilot signal.

Approach: What does the Control Pilot signal look like?

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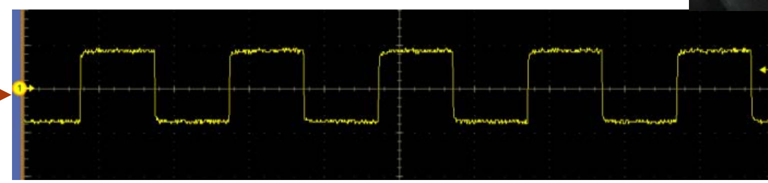
Control Pilot states

J1772 Connector

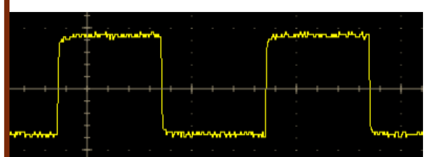
Vehicle Disconnected → **+12VDC signal**

Vehicle Connected and Contactor Open →

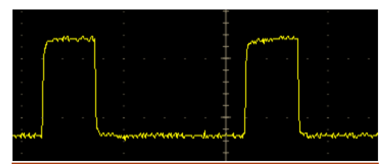


1 kHz square wave

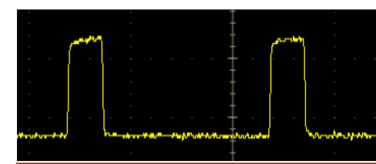
Vehicle Charging (Contactor Closed)



30 amp charge rate



15 amp charge rate

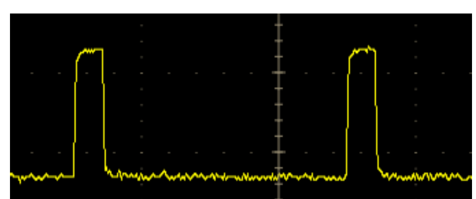


10 amp charge rate

Fault

0V ⇔ -12VDC signal

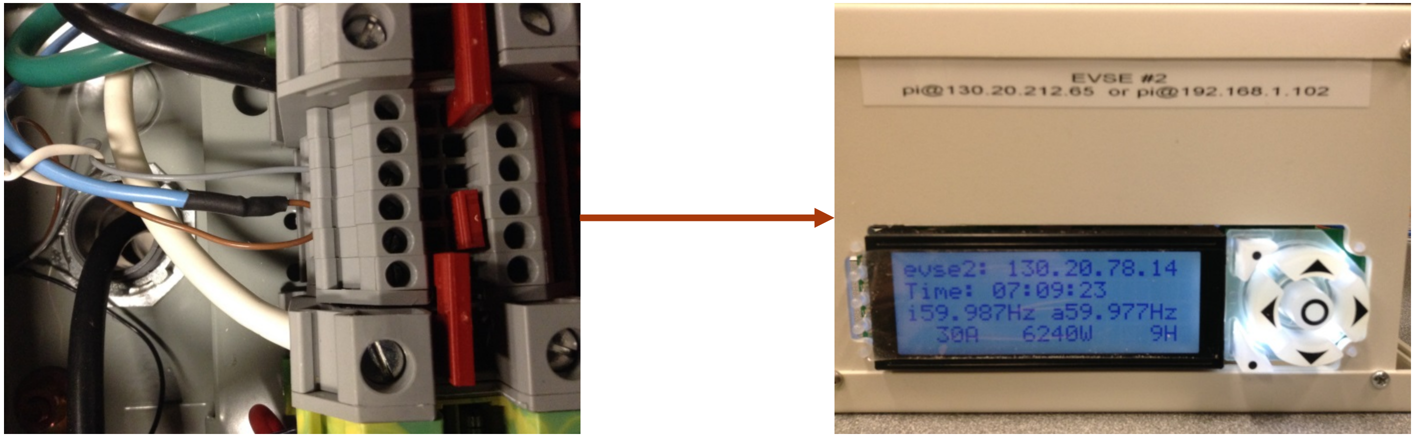
Digital Communications controlling



1 kHz and 5% pulse width

Approach: How can Control Pilot control be implemented?

Control Pilot connectivity



Using the Control Pilot signal

- Measure Control Pilot pulse width to determine maximum power EVSE can deliver.
- Create an identical Control Pilot signal to command the vehicle to reduce maximum charging power.
- The battery management system adjusts the charge rate in response to the Control Pilot signal.

Approach: Coordinated communications charging requirements

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- Advanced control strategies need the following information to optimize performance and efficiency of electric vehicle charging.
  - Grid condition awareness needs networked communications
    - Historical demand
    - Current regional conditions – renewables generation (wind or solar), temperature, time-of-day, etc.
    - Current local conditions – voltage, frequency, loads
  - Customer preferences via ZigBee / Wi-Fi / PLC / Telematics / EV Control Panel
    - Energy required
    - Charge completion time
  - Charging rate control via ZigBee / Wi-Fi / PLC / SEP2 / J1772
    - Home power delivery capability - EVSE
    - Vehicle ratings – maximum and minimum
    - Other electric vehicles
    - Other home loads
    - Local grid conditions – voltage / frequency

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
  - Other home loads – A/C, Water Heater, TV, etc.
- Implement one maximum power goal – 25% peak reduction

Technical Accomplishments: Coordinated control

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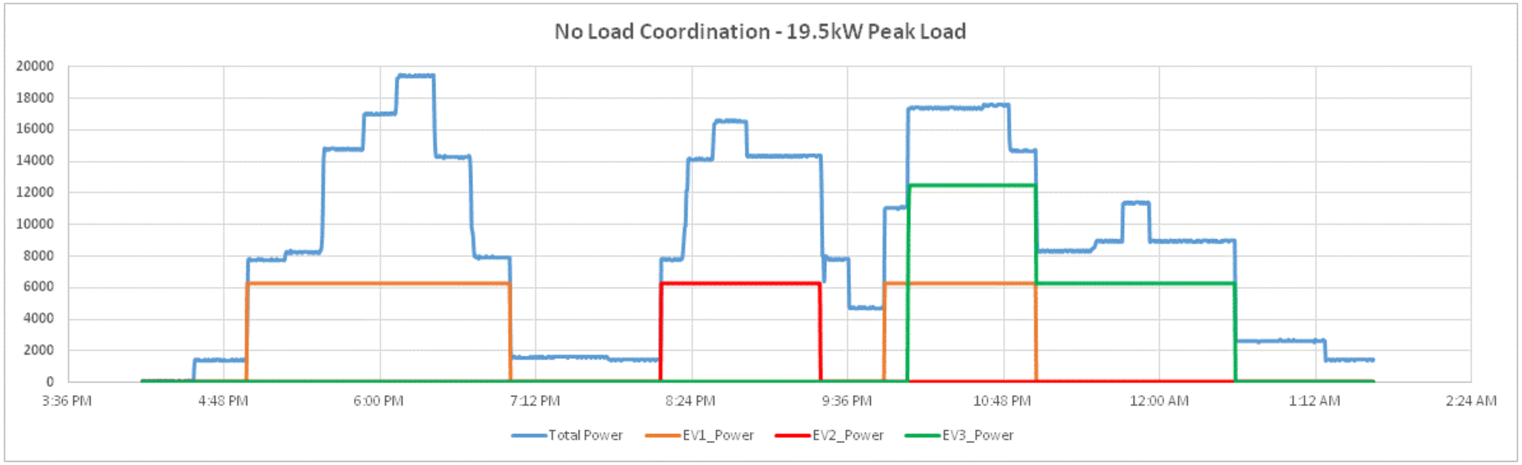
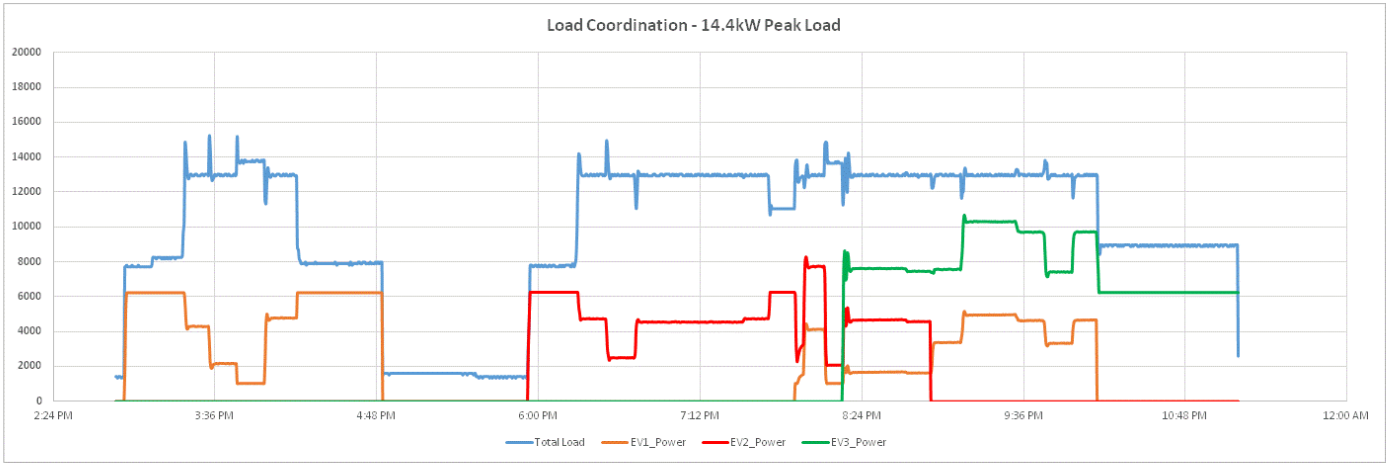
EV charging typically starts when a vehicle returns from a trip and can coincide with energy consuming activities in the home



Intelligent Vehicle Charging (IVC)

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

25% Peak Load reduction



Technical Accomplishments

- Three identical prototype charging rate control modules developed and tested on EVSEs from three different manufacturers.
- Hardware in the Loop system demonstrated 26% peak load reduction while monitoring only Lab Homes power meter output and receiving the customer preferences of energy required and charge completion time.

Standards Support Accomplishments

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- SAE J2847/1, J2847/3, and J2836/5 – updated and reapproved
- J2836/5 Use Cases for Customer / EV has been completed.
- PNNL provided technical review of SAE standards J2831/1, J2836/2, and J2847/2 for inclusion in the SGIP Catalog of Standards for smart grid interoperability.
- Leadership was provided to the Smart Grid Interoperability Panel (SGIP) through Apr 2014 to accelerate the development and harmonization of V2G codes and standards.
- Technical Report - S. Letendre, K. Gowri, M. Kintner-Meyer, “Intelligent Vehicle Charging Benefits Assessment Using EV Project Data”, PNNL-23031, Dec. 2013.

Gaps: Coordinated communications charging requirements

- J2847/5 will define standards needed to obtain customer preferences and charging control communications
- Utility incentives for coordinated charging are beginning to appear in several regions. Utility engagement in charging control vision is needed
- Energy storage will need many of the same control, policy and business models as coordinated charging.
- Develop a document identifying requirements needed for implementing coordinated electric vehicle charging.
- EV / EVSE association and authentication is currently limited to physical (personal garages) or payment mechanisms.
- Distributed charging applications and required communications needs to be evaluated and developed.

Reponses to Previous Year Reviewer Comments

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- Approach to performing the work – the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.
  - "The project team had an excellent approach and were very tuned in to what the industry needs for grid communication evaluations."
  - "Participating with the SAE in working groups and document development is a very good approach to developing useful codes and standards. The project continues to address the barriers of the lack of codes and standards for communication between PHEV and the grid. The reviewer added that the project is in communication and collaboration with ANL to make sure that there is not a duplication of effort on codes and standard development."
  - "The approach will benefit from defining technical interaction products (e.g., operational requirements, use cases) based on technical interactions with utilities and academic partners involved in the Northwest Smart Grid Project. The reviewer said these requirements may help to increase the impact of the work as an input to codes and standards organizations."
  - "Some sort of gap analysis should be used to identify where codes and standards are lacking and to present a similar ANSI vehicle standards Roadmap format assessment (e.g., VSS118). The reviewer added that the project does appear to put a limited set of grid communication hardware for development, testing and interoperability assessments."
  - "Not enough focus on how the data formats are being considered. The reviewer added that though this may be technical, it is a crucial aspect to meeting project objectives."
  - **RESPONSE:**
    - **I also feel strongly that having connectivity and an active role in the standards development process provides invaluable insight into the technical requirements.**
    - **I was working closely with Krishnan Gowri, chairman of the SGIP standard review committee throughout the year to perform standard's gap analysis.**
    - **Data formats are a critical element of interoperability and system integration. Following the requirements contained in the standards provides insights into areas of standards that need additional refinement or initial development.**

Reponses to Previous Year Reviewer Comments

- Technical accomplishments and progress toward overall project and DOE goals and demonstrated progress toward DOE goals.
  - "The project team reviewed and completed the development of several SAE standards. The reviewer added that progress has been made during 2013 on field testing including implementing open standard based communication. The reviewer indicated that the project team was leveraging other activities at PNNL, such as the PNNL laboratory homes project, which allows for good use of government funds."
  - "The presenter indicated that tangible progress has been made for establishing a working prototype to investigate key concepts."
  - "The project had multiple location sites, and a variety of vehicles, vendors, and utilities involved with field testing, that put a real world spin on project outcome. The reviewer added that the standards and codes gap analysis needs improved clarity of status similar to ANSI roadmap on electrical vehicle Standards."
  - **RESPONSE:**
    - Although not mentioned, the standard's development results were direct inputs to the SGIP standards gap analysis work. Good idea to provide status similar to the ANSI roadmap.
- Collaboration and coordination with other institutions.
  - "The project team had an excellent approach and was very tuned in to what the industry needs for grid communication evaluations."
  - "The investigator has a potentially rich collaboration and coordination context for performing the research. The reviewer added that the investigator should work to increase the level of interaction and feedback from the Northwest smart grid project partners. The reviewer indicated that the increased level of interaction has the potential to increase the impact of this project."
  - "The establishment of significant industry partnership is not yet demonstrated."
  - **RESPONSE:**
    - Gaining significant industry partnership is challenging and it is good to be reminded of its importance. Research needs to go into the field.

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 can be developed using data from this system energy sharing algorithms between home loads, electric vehicles, electric bus and a PNNL building.
- 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
- University of Vermont – Prof. Steve Letendre - "Intelligent Vehicle Charging Benefits Assessment Using EV Project Data," PNNL-23031, Dec. 2013.
- Industry partners:
  - **AeroVironment - integrated PNNL's autonomous variable charge rate technology into product line**

Project Summary

- SAE J2847/1 (AC Charging) and J2847/3 (Reverse Power Flow) standards have been issued.
- SAE J2847/2 (DC Charging) is being revised.
- SAE J2836/5 (Customer Preference communication Use Cases) has been issued.
- Three identical prototype charging rate control modules developed and tested on EVSEs from three different manufacturers.
- Hardware in the Loop system demonstrated 26% peak load reduction while only monitoring Lab Homes power meter output and receiving the customer preferences of energy required and charge completion time. This significantly reduces residential transformer maximum temperature from multiple vehicles simultaneously charging.

Questions ?

Contact:

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Backup slides

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Relevance: What communications are available to support charging control?

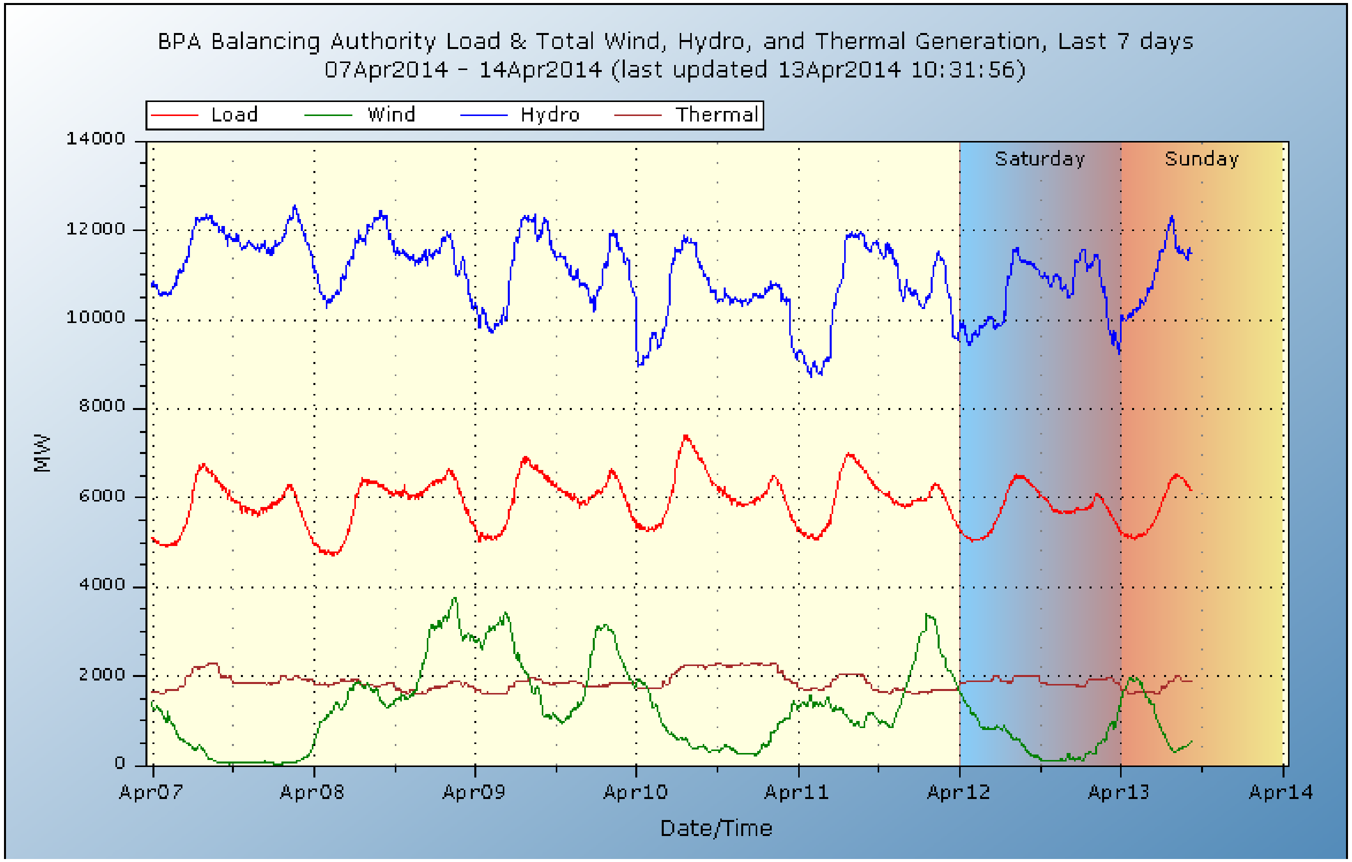
Vehicle Communications Modes

- Vehicle control panel when leaving car
- EV ⇔ Telematics (J2847/5) – remote connectivity
- EV ⇔ EVSE digital communications (J2831-4)
- HAN / LAN ⇔ EVSE ⇔ EV digital communications
- EV ⇔ EVSE communications (J1772 Control Pilot)
- EV ⇔ Owner (J2847/5) – mobile devices
- Plug-in the car at a particular time to start charging

Vehicle Charging Control

- EV ⇔ Battery Management System
- EV ⇔ EVSE – J1772 Control Pilot
- EV ⇔ EVSE – J2847 Digital Communications

Next phase: broad area communications



BPA Load & Total Wind, Hydro, and Thermal Generation

http://transmission.bpa.gov/Business/Operations/Wind/baltwg.aspx