PEV Grid Integration Research

Vehicles, Buildings, and Renewables Working Together

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Electric Vehicle Grid Integration

National Renewable Energy Laboratory

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National Energy Imperatives

Security
Ensuring resilient and reliable energy systems

Economy
Stimulating clean-energy manufacturing

Environment
Protecting resources and environmental quality
Reducing Investment Risk

- Integrating technology at scale
- Enabling basic and applied clean energy technology innovation
- Accelerating technology market introduction and adoption
- Encouraging collaboration in unique research and testing partnering facilities
- Providing analysis and expertise to inform decisions and catalyze market adoption
Grid Modernization Initiative

• This new crosscutting effort will build on past successes and current activities to help the nation achieve at least three key outcomes within the next ten years:
  > 10% reduction in the societal costs of power outages
  > 33% decrease in cost of reserve margins while maintaining reliability
  > 50% cut in the costs of wind and solar and other DG integration

• If achieved, these three key outcomes would yield more than $7 billion in annual benefit to the U.S. economy

• Grid Modernization Lab Consortium
  – Mitigate adverse impacts of EV deployment
  – Leverage existing synergies between EVs and the grid, building energy management systems, distributed renewables, and other smart grid assets.
Electric Vehicle Grid Integration at NREL
*Vehicles, Renewable Energy, and Buildings Working Together*

**Managed Charging**
Evaluate functionality and value of load management to reduce charging costs and contribute to standards development.

**Local Power Quality**
Leverage charge system power electronics to monitor and enhance local power quality and grid stability in scenarios with high penetration of renewables.

**Emergency Backup Power**
Explore strategies for enabling the export of vehicle power to assist in grid outages and disaster-recovery efforts.

**Bi-Directional Power Flow**
Develop and evaluate integrated V2G systems, which can reduce local peak-power demands and access grid service value potential.

**Vehicle-to-Grid Challenges**

**Life Impacts**
Can functionality be added with little or no impact on battery and vehicle performance?

**Information Flow and Control**
How is information shared and protected within the systems architecture?

**Holistic Markets and Opportunities**
What role will vehicles play and what value can be created?
The State of the PEV Market

2014 – Silverado

2014 – Prius

Cumulative Sales

Cumulative PHEV
Cumulative BEV
Monthly PEV

Source: AFDC NREL; USA Today (1/6/2015)
Planning for PEVs on a Highly Renewable Campus

The graph illustrates the NREL Campus Power Demand (kW) over the course of a day. The demand peaks typically around midday, with a notable drop due to on-site solar production. The graph also shows different scenarios for PEV adoption:

- "Campus Net Load with PV": Baseline demand with integrated solar.
- "Bldgs + PEVs (20%, Immediate Charging)" and "Bldgs + PEVs (20%, Staggered Charging)" show the impact of PEV adoption under two different charging strategies.

Key observations:
- **Unmanaged** cost: $11.50/veh/mo
- **Staggered** cost: $4.50/veh/mo
Expanding Charging Data Streams and Interaction to Automate PEV Charge Management with Renewable Sources

Provide simple interface with least information necessary to create managed individual and aggregate scenarios with status display.

RSF = Research Support Facility
Laboratory Resources Applied to Tech Introduction

5x 60-kW Bi-directional Stations Integrated with Microgrid Operations

Scenario Simulation

VTIF
- Communications development and testing

ESIF
- Grid integration component verification
Relevance – Additional Value to Enhance Marketability

Can PEV Grid Services Provide Similar Value to Purchase Incentives?

@ $5/day/vehicle

State PEV Incentives

Year 1

Year 2

Year 3
E-roadway Loads Reduce RE Curtailment
A Pathway to Inverter Enhanced Utilization

- Driving patterns, road usage, system sizing, and mechanical layout
  - Leads to E-roadway power profiles
  - Likely to be peaks and valleys

- Grid modernization
  - Driving toward renewables integration
  - Grid services from devices

- Leverage multiport inverters for maximum value from infrastructure investment

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Time of Day

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<thead>
<tr>
<th>Power</th>
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<tbody>
<tr>
<td>E-roadway P</td>
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<td>Solar P</td>
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<td>ESS Peak Demand</td>
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<td>ESS Grid Services</td>
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Grid components:
- INV (Inverter)
- PV (Photovoltaic)
- ESS (Energy Storage System)
- primary
- secondary
• More than 15 EVSEs accessible in lab spaces
• DC load bank to act as a programmable storage device
• Oscilloscopes for detail electrical system impacts analysis

ESIF=Energy Systems Integration Facility
EVSE=electric vehicle supply equipment
Thoughts on EV Integration Opportunities

• **EV charge management should first be focused on minimizing or eliminating the capacity costs and optimize around energy cost**
  - Adjust charge pattern such that no additional power capacity is needed at generation and distribution levels

• **The provision of ancillary services from EV charging has the potential to provide some additional value,**
  - Revenue opportunities are small relative to the benefits of reduced costs associated with controlled charging

• **The unknown path forward on Distributed Energy Resource participation in markets makes assessment challenging**
Campus Mobility of the Future

1. Employee uses smartphone to schedule automated valet vehicle delivery

2. Vehicle leaves parking pod in driverless mode

3. Vehicle arrives at pickup location and driver programs in destination

4. Vehicle self-drives, giving the passenger hands-free time to work or decompress

5. Vehicle drops passenger at destination and automatically makes next pickup or returns to parking pod

6. Vehicle’s collision avoidance system automatically averts pedestrians, cyclists and other vehicles

7. Vehicle self-parks and recharges
Acknowledgements

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