Integrating PEVs with Renewables and the Grid

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NREL/PR-5400-66638
Vehicle Testing and Integration Facility (VTIF)

VTIF provides interior and exterior areas for systems EVGI communications and power exchange

18 kW solar PEV parking lot with 50 kW fast charger
NREL parking garage with 36 EVSEs that charge research and visiting vehicles
Energy Systems Integration Facility (ESIF)

- 182,500 sq. ft.
- 1-MVA bi-directional grid simulator
- Low voltage distribution bus
- Medium Voltage Outdoor Test Area
- Full Power Hardware in the Loop (PHIL) testing
- Petascale High Performance Computing (HPC)

**Research Electrical Distribution Bus (REDB)**

**AC** (600 V)  **DC** (±500 V)
- 250 A  • 250 A
- 1600 A  • 1600 A
Residential Transformer (25KVA)

Leviton EVSE
Leviton EVSE

250kW Load Bank

Utility grid power

AV EVSE
AV EVSE
AV EVSE
AV EVSE
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AV EVSE

MVOTA

NREL Internet

X2 Home Circuit
Lighting
Appliances
HVAC Systems
Electronics
EV Charging

ESL: Energy Storage Laboratory
MVOTA: Medium Voltage Outdoor Testing Area
REDB: Research Electrical Distribution Bus
SPL: Smart Power Laboratory
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

- GE Wattstation in NREL Parking Garage
- Grid2Home EVSE and Gateway with SEP2.0
- Leviton with Modbus
- AV EVSE via Wifi

### 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

- Toyota collaboration leverages vehicles and ESIF
- Light- and heavy-duty wireless charging systems
- Bi-directional fast charge

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

- Via Motors van with export to loads
- Nissan Leaf with V2H unit for backup

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

- Mini-E with Univ of Del and NRG PGE utility truck characterization in ESIF
- Smith EV truck from Ft. Carson microgrid project
- Via Motors van with grid SEP2.0

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

- Using BLAST-V for scenario assessment

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

- Developed data entry and campus connections

### Holistic Markets and Opportunities
What role will vehicles play and what value can be created?

- SEAC collaboration on market opportunities report
Managed Charging and Local Power Quality
Provide simple interface with least information necessary to create managed individual and aggregate scenarios with status display.
On-board Charging Characterization

- Unidirectional control of EVSEs over Modbus using market vehicles
- 5- to 10-A step-up/down tests to validate dynamic performance
Unidirectional Charging Characterization

- ~0.56 s communication delay using Modbus protocol
- Different vehicles respond with different transfer functions
- SAE J1772 specifies a 5 s maximum response time (from CP change)
Unidirectional Charging Characterization

- Different vehicles respond with different transfer functions
  - iQ ramp response in this example is ~5.3 A/s
  - Mini-E ramp response in this example is ~ 1.5 A/s
Wireless Power Transfer Grid Integration Testing

- Power quality testing for different grid voltage/frequency, receiver alignment, and battery charging power conditions
  - Current harmonics
  - Battery ripple current
  - Power factor
- Management with renewable and L2 EVSEs
- Three-phase implementation in a microgrid study

DC Electronic Load

Source NREL, Andrew Meintz
Bi-directional Power Flow and Emergency Power Back-up
Bi-directional System Component Characterization

- Sharp Energy Storage System: 43 kWh, 30 kW IPC interface
- Via Motors Van - Coritech EVSE: 23 kWh, 14.4 kW V2G-V2H
- Nissan Leaf - Nichicon EV Power Station: 6 kW V2H
- Smith EV Truck - Coritech EVSE: 80 kWh, 60 kW
- Transpower School Bus - Milbank EVSE: 90 kWh, 22.6 kW
- Mini-E – Milbank EVSE: 30 kWh, 14.4 kW
- PV System (emulated: 22 kW and real: 18 kW)
- Residential and commercial loads (125 kW AC)
- 30 kW grid simulator and RTDS system
Export Power Using PEVs

- **Via Motors Van with Coritech EVSE**
  - 14.4-kW on-board bidirectional charger
  - Series hybrid PHEV with 23-kWh battery
  - V2H and V2G capable, SEP 2.0 grid link, Homeplug GREEN PHY
  - Single phase 120V/240V up to 60 A off-grid power generation

- **Nichicon EV Power Station**
  - 6-kW off-board charging capability
  - 120 V / 240 V, total 50 A@120 V V2H power capability
  - Runs with Chademo-compatible PEVs (Leaf, Mitsubishi i-MiEV)
  - Switching from grid-connected to grid-isolated operation

**Research scope**
- Analysis of powering real home loads with Nissan Leaf and Via Van w/o grid.
- Evaluating the emergency power capability of EV (Leaf) and PHEV (Via-Van).
- Integrating emulated/real solar PV systems with V2H to extend the emergency power duration.
- Investigating microgrid operation of vehicles to power several houses.

Source NREL, Mithat Kisacikoglu
Emergency Power Backup

PV Array Power

| Time of Day | 0000 | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 | 8000 | 9000 | 10000

Power (W)

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000 9500 10000

<table>
<thead>
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<th>On Time (Min)</th>
<th>HVAC</th>
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<td>56.6</td>
<td>37.17</td>
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<td>1.12</td>
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## Emergency Power Backup

### PV Generation

![Image of PV panels](NRELPIX32681)

### Home Loads

![Image of home appliances](NRELPIX32465)

### Table: Home Load Consumption

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Emergency Power Backup

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Dryer

### On Time (Min)
- HVAC: 56.6
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- Dryer: 65.52
- Stove: 1.12
- Refrigerator: 122.12
- Washer: 45.50
- Dishwasher: 55.50
- Lights: 24.35
- Television: 20.58

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Nissan Leaf

EVPS AC/DC

Relay Box

Grid

PV Generation

Home Loads
Modeling and Testing of Microgrid

Power hardware-in-the-loop testing

Source NREL, Andrew Meintz
Grid Modernization Efforts
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.
Funding for research at National Labs to define and develop integrated systems supporting Grid Modernization Initiative objectives

EERE Solar, Wind, Buildings, Vehicles, Fuel Cells program supporting along with Office of Electricity

Proposals are intended to be multi-year and include collaboration across multiple labs

Category 1 – Foundational efforts; cross-cutting

Category 2 – Program-specific technologies with interfaces to Category 1 activities
Vehicle to Building Integration Pathway

Description

- Enable workplace charging and promote broader PEV adoption through the development and demonstration of an interoperable communication pathway and control system architecture that connects:
  1. Plug-in Electric Vehicles (PEVs)
  2. PEV drivers
  3. Electric Vehicle Support Equipment (EVSE)
  4. Building Energy Management System (BEMS)
in order to create value for all parties.

- Demonstrate scalable communications and control system will enable managed energy use between dissimilar grid-connected devices that will mitigate demand charges.

- Establish a physical platform to develop and test the technical requirements needed for standards development and interoperability.

Participating labs (lead lab first): PNNL, ANL, INL, LBNL, NREL
Partners: AeroVironment, Bonneville Power Administration, University of Delaware, DTE Energy, California Energy Commission
Funding: $3.4M over three years

Multi-Lab EV Smart Grid Working Group
DOE Vehicle Technologies Office
Description

- **Develop a distributed vehicle/grid integration platform** to determine the feasibility of PEVs providing grid services and renewable energy integration without negatively impacting the PEV customer experience.

- Perform **distribution-level hardware-in-the-loop demonstrations** involving a variety of vehicles and other distributed energy resources at numerous facilities.

- Trial multiple communications pathways to **accelerate standards development** and understand how to prioritize the needs of the PEV customer, facility, third-party aggregator, and grid operator in multiple use cases.

Participating labs (lead lab first): INL, ANL, LBNL, NREL, ORNL, PNNL

Partners: Bonneville Power Administration, DTE Energy, Eversource, University of Delaware, Siemens, California Energy Commission, USDRIVE Grid Interaction Technical Team

Funding: $3.6M over three years
Modeling and Control Software to Support V2G Integration

Description:

Develop advanced *modeling and simulation tools* to:

1. **Understand how much renewables integration is enabled by vehicles**, and developing operational frameworks so clean vehicles enable a clean grid.
2. **Understand the value available for vehicles** to serve as a grid resource under different VGI approaches.
3. Provide tools and understanding to **guide effective decision-making on VGI pathways** for all stakeholders.

Participating labs (lead lab first): LBNL, ANL, INL, NREL, ORNL, PNNL

Partners: Bonneville Power Administration, California Energy Commission

Funding: $2.8M over three years
Questions:
Andrew Meintz,
andrew.meintz@nrel.gov