Microgrid and Plug in Electric Vehicle (PEV) with Vehicle to Grid (V2G) Power Services Capability

Shukri Kazbour
PEV Lead Engineer
Shukri.b.kazbour.civ@mail.mil
Ground Vehicle Power and Mobility, Advanced Propulsion Team, Warren, MI, 48397
# Microgrid and Plug in Electric Vehicle (PEV) with Vehicle to Grid (V2G) Power Services Capability

**Author(s):** Shukri Kazbour

**Performing Organization:** US Army RDECOM-TARDEC, 6501 E. 11 Mile Road, Warren, MI 48397-5000

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**Number of Pages:** 18
1. Non-Tactical Vehicle-to-Grid (V2G) Projects
   • Smart Power Infrastructure Demonstration for Energy Reliability and Security Phase-II (SPIDERS-II)
   • Plug in Electric Vehicle (PEV) and V2G Power services

2. Tactical/Combat V2G Projects
   • TARDEC Microgrid and V2G System Integration Lab (SIL)
   • Advanced Propulsion With Onboard Power
   • Tactical Fleet Roll-up/Roll-away Microgrid

3. PEV and V2G Potential Benefits and Lessons Learned
Microgrids and with Vehicle-to-Grid (V2G)

Why DOD is interested in Microgrids and with Vehicle-to-Grid (V2G) Capabilities?

For the Nation
• Help stabilize smart grid and can generate revenue stream
  ➢ Performing Peak Power Shaving, Power Factor Correction, Frequency Regulation, and power management
• Reduce fuel consumption and dependence on foreign oil
• Support DOD/Federal Mandates to increase the use of renewable energy

For the Warfighter
• Vehicle Electrification with V2G capabilities will:
  ➢ Support e-weapon and e-armor systems, and enhance Vehicle-to-Vehicle (V2V) communications and load management
  ➢ Provide on-board, mobile, and quieter export power
  ➢ Improve power distribution efficiency of Forward operating Base (FOB)
  ➢ Reduce the logistic burden of hauling generators and fuel
2010:
• Co-funded with Auto OEMs for SAE L2 J1772 Combo connector

2011-2014:
• Leveraged SAE Standards (J2836, J2847, J2931, and J2953) to develop specifications for:
  • Plug in Electric Vehicle (PEV),
  • Electric Vehicle Supply Equipment (EVSE)
  • Interface Control Document (ICD)
• Developed:
  • Peak Shaving Algorithm
  • ISO Regulation Signal Management
  • “Draft” UL 9741 Standard for the Bi-directional EVSE
• Modified Six Electric Vehicles with V2G capability
• Built five 60 kW DC Bi-directional charging stations

• SPIDERS–II Microgrid:
  • 1.1 MW Critical Load, 1 MW Priority Load
  • 3.25 MVA Diesel Generation (three existing assets)
  • 2 MW Solar Array (existing asset)
  • 6 Electric Vehicles with Vehicle to Grid Capability
  • Comprehensive Cyber Security Solution

• Successfully survived a 72 Hour Microgrid Cyber Attack
• Demonstrated microgrid support and V2G power grid services
V2G Power Services Demonstration at Fort Carson, CO:
- Performed power factor correction, peak power shaving, and frequency regulation
  - Verified the PEV and EVSE potential savings:
    ✓ $360/month/EVSE (approximately 394KVAR) by reducing power factor penalties through VAR export (without vehicles connected)
    ✓ $430/month/vehicle from Peak Shaving: 43kW/vehicle x $10/kW
    ✓ $400/month/vehicle from frequency regulation

- Power requested signal was sent with 4 second update rate from MIT LL server.
- EVSE reacted to new command in about 15 seconds (red) with good fidelity.
- Frequency regulation capability is proven. Further optimization at system level to reduce delays and manage state of charge are necessary.
DOD Plug in Electric Vehicle (PEV) Initiative With V2G Capability

PEV-V2G Objectives/Products:
Install 77 PEV/EVSE at 4 DOD installations:
LA AFB - CA, Fort Hood - TX, JB Andrews - MD, and JB MDL - NJ

- Plug-in Electric Vehicles:
  - Bi-directional V2G capability
  - Fleet management system
  - Built to applicable SAE/IEEE standards

- Bi-directional EVSE
  - UL certified
  - Built to applicable SAE/IEEE standards
  - Supporting multi-vehicle aggregation
  - Cyber-secure grid connectivity
  - Hardware/software

- Electric grid territories (CAISO, ERCOT, PJM)

- Validated fiscally responsible fleet electrification plan and grid service power regulation

Vehicle Technology Expo and the Battery Show Conference
Novi, MI, 15-17 Sep 2015

UNCLASSIFIED – Distribution Statement A. Approved for public release
DOD Plug in Electric Vehicle Initiative

UNCLASSIFIED

Selected PEVs: EVAOS, VIA, EVI, Nissan Leaf, and Phoenix

LAAFB* (34 vehicles)
- 13 Nissan LEAFs sedans (*California Energy Commission)
- 11 VIA plug-in hybrid vans (2 from GSA; 9 PEV-V2G Program)
- 5 Ford pickups equipped with EVAOS hybrid kits (PEV-V2G Program)
- 4 EVI hybrid trucks - 2 stake beds and 2 box trucks (PEV-V2G Program)
- 1 Phoenix shuttle bus (PEV-V2G Program)

Fort Hood (22 vehicles)
- 8 Nissan LEAF sedans
- 14 Ford pickups equipped with EVAOS hybrid kits

JB Andrews (13 vehicles)
- 8 Nissan LEAF sedans
- 5 Ford pickups equipped with EVAOS hybrid kits

JB MDL (8 vehicles)
- 8 Ford pickups equipped with EVAOS hybrid kits

Selected Charging Stations:
Coritech, Princeton Power, Eaton, and Aerovironment
## PEVs and Ancillary Services Market Requirements

<table>
<thead>
<tr>
<th>Base (Market)</th>
<th>Expected Demonstration Date</th>
<th>Minimum Requirement KW Bid/Price</th>
<th>Method to Meet Minimum Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAAF (CAISO)</td>
<td>Sep 2015</td>
<td>500 KW $0.016/KWh</td>
<td>5 DC Charging Stations (50 KW each)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13 DC Charging Stations (15 KW each)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>17 AC Charging Stations (15 KW each)</td>
</tr>
<tr>
<td>Fort Hood (ERCOT)</td>
<td>Sep 2015</td>
<td>100 KW $0.01/KWh</td>
<td>5 DC Charging Stations (15 KW each)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>14 AC Charging Stations (13.4 KW each)</td>
</tr>
<tr>
<td>JB Andrews (PJM)</td>
<td>Oct 2015</td>
<td>100 KW $0.025/KWh</td>
<td>4 DC Charging Stations (15 KW each)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5 AC Charging Stations (18 KW each)</td>
</tr>
<tr>
<td>JB MDL (PJM)</td>
<td>Oct 2015</td>
<td>100 KW $0.025/KWh</td>
<td>8 AC Charging Stations (18 KW each)</td>
</tr>
</tbody>
</table>

### Range Description

<table>
<thead>
<tr>
<th>Range Description</th>
<th>(29) PEV electric range: 75 miles fuel efficiency: 99 MPG</th>
<th>(32) PHEV electric range: N/A fuel efficiency: 45 MPG**</th>
<th>(11) PHEV* electric range: 31 miles fuel efficiency: 38 MPG**</th>
<th>(4) PHEV* electric range: 40 miles fuel efficiency: 43 MPG**</th>
<th>(1) PEV electric range: 100 miles fuel efficiency: 32 MPG</th>
</tr>
</thead>
</table>

### General Purpose Fleet Role

<table>
<thead>
<tr>
<th>General Purpose Fleet Role</th>
<th>23.6 cubic feet cargo capacity</th>
<th>1500 to 2800 lbs payload</th>
<th>2650 lbs payload (cargo van only)</th>
<th>5300 lbs payload</th>
<th>116 cubic feet cargo capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 seats</td>
<td>3 seat standard cab</td>
<td>2 seat cargo</td>
<td>2 seats</td>
<td>visitor transport: 12 passengers + driver</td>
</tr>
</tbody>
</table>

### Battery Capacity

<table>
<thead>
<tr>
<th>Battery Capacity</th>
<th>24 kWh</th>
<th>27 kWh</th>
<th>21 kWh</th>
<th>54 kWh</th>
<th>102 kWh</th>
</tr>
</thead>
</table>

### # at Locations

<table>
<thead>
<tr>
<th>Location</th>
<th>LAAFB</th>
<th>Fort Hood</th>
<th>JB Andrews</th>
<th>JB MDL</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>13</td>
<td>8</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>
How is the V2G infrastructure controlled?

Introduction
A V2G system is comprised of plug-in electric vehicles (PEVs), bi-directional charging stations, and software controls that enable an installation to compete in utility ancillary services markets. Customized for each base, the OB-EVI provides the communication and software controls needed for all aspects of V2G.

Goal
Meet utility system operator’s charge and discharge requirements
- Fulfill base fleet mission requirements
- Maximize ancillary services revenues
- Minimize non-conformance penalties

Performance Reporting
OB-EVI includes a dashboard and detailed reports that provide system status, V2G participation and financial performance information.

On Base-Electric Vehicle Infrastructure (OB-EVI)

PEV Fleet Reservations
Base personnel reserve cars/trucks in advance of use. OB-EVI ensures V2G participation does not prevent the fleet from meeting mission requirements.

Vehicle to Grid
OB-EVI supplies power stored in vehicle batteries to the grid according to the award signal.

Charge Management
OB-EVI develops an optimal charge schedule to ensure mission readiness and maximize financial benefit of V2G participation. OB-EVI controls EVSE charge/discharge according to schedule.

Power Sent from Battery to Grid

Managing fleets & participation in the ancillary services market

Award Signal
Utility system operator responds to submitted bid with award signal.

Bid Submission
OB-EVI prepares a detailed next day bid using planned vehicle availability information and submits to utility system operator.

Charge Vehicle Battery Discharge Vehicle Battery
Purpose:

- Provide an on site research and development venue for the development, test, and demonstration of a smart, aggregated, ad-hoc capable, vehicle to grid (V2G) and Vehicle to Vehicle (V2V) capable fleet power system to support advanced vehicle systems such as e-armor, e-weapons, and advanced C4:
  
  ➢ Utilizing mixed power generation system such as solar arrays, Plug in electric and hybrid electric vehicles, energy storage system, base power, and various type of generators
  
  ➢ Provide capability to test, evaluate and integrate advanced power generation technologies
  
  ➢ Provide capability to test vehicle to vehicle (V2V) and V2G communication and control systems
Vehicle power needs are Continuously growing. Need to generate 10x Power to:

- Support electric weapon system, and auxiliary system electrification such as e-cooling, e-armor, and e-mobility/silent watch
- Provide on-board, mobile, and quieter export power in support of power distribution efficiency of Forward operating Base (FOB)

**Develop, Integrate, and Test High Voltage Onboard Generators**

- Traditional Alternator
- Stryker High Voltage Onboard Generator
- Bradley High Voltage Onboard Generator

**Components**
- Bench Test

**Export Power**
- High Voltage Onboard Generator w/ Transmission

**System integration**
- SIL Test

**Power Electronics**
- Energy Storage

**High Voltage Cooling**
- Vehicle Integration
- Vehicle Test
Tactical Vehicle to Grid (V2G) and Vehicle to Vehicle (V2V) Sustainability
Logistics Basing Science & Technology Objective Demonstration (SLB-STO/D):

**Purpose:**
Develop and demonstrate fast forming, ad-hoc, cyber secure 240 kW vehicle based AC power system

**Leverages the following projects:**
- SPIDERS and the DOD PEV Initiative
  - SAE J1772 Combo Connector
  - Bi-directional V2G EVSE
  - Vehicle Aggregation and Ad-hoc system forming
  - Peak shaving, VAR control, power regulation
  - Cyber Secure power generation/communications
  - Communication - Interface Control Document

**Products and payoff:**
- Validate fast forming vehicle based microgrid (20 minutes or less)
- Validate V2G & V2V power/communications sharing
- 2 MRAPs (120 kW) and 2 HMMWVs (30kW) with V2G and V2V.
- Communications standards/ICD between vehicles
- Performance & fuel data of vehicles
- Support Forward Operating Base (FOB) power distribution grid
- Better utilization of vehicle systems (Currently vehicles utilized ~5% of time)
- V2G capable PEVs saving 20% of base fuel
Potential benefits of the PEV with V2G capability:
• Stabilize smart grid
• Generate revenue streams from grid services reducing electric bill
• Base backup power in the event of a power failure
• Mobile power generation to augment/facilitate power after man-made or natural disaster
• Provides power for e-weapon, e-armor, advanced jamming and communications systems
• Reduces fuel consumption and dependence on foreign oil
• Improves base power efficiency
• Reduces the logistic burden of hauling generators and fuel
• Maximizes the utilization of advanced vehicles by providing power when they are parked

PEV Impacts and Costs:
• Requires additional up-front investment in the vehicle and base infrastructure
• Reduces electrical system operational costs (cost justifies investment)
• Negatively impacts power grid cyber security if the system has not been configured properly
• Shortens energy storage system life - depends on how the energy storage is used
• Result in modestly higher:
  - Maintenance cost as a result of the additional solid state V2G equipment
  - Disposal cost of the on-board Battery pack/energy storage
  - Training and handling costs - high voltage and complex system
    (but minimized if system plug-n-play)
V2G Lessons Learned

Following applicable PEV/V2G standards:
• Achieves consistency across the program
• Accelerates integration of charging stations and vehicles from various vendors

General findings
• Display systems and processors - must be robust to perform in outdoor environment
• Component Electro-Magnetic Interference must be managed - affects operation
• 12v batteries must be charged while in V2G mode
• Battery pack balancing - interrupts planned V2G usage
• Late reservations degrade ability to meet day ahead energy bid
• Compliance to Standards does not guarantee successful operation
  o Sequence of operations is frequently not defined by the standard
  o Detailed ICD required
• Perform periodic monitoring of selected standards to discover published updates
  o Relatively immature Standards set (evolving) – lessons learned driving changes
  o Assess updates and determine if implementation revisions are either required to maintain compliance or desired to remediate prior inadequacies or add relevant functionality
Future V2G Lessons Learned

...What we intend to learn/show

Future Verification/Findings

• Aggregated V2G capable fleets provide a fiscal ROI justifying electrification
• User feedback (drivers/fleet managers) regarding fleet management system
• Data collection from vehicle usage
• Data collection from V2G/ISO participation
• Data regarding effect on battery life from V2G/Grid participation
• Validation of fast forming, ad-hoc vehicle based grids
**Communication protocols for EVSE communications**
- Smart Energy Profile 2.0 (SEP 2.0)
  - Enables communication with a set of fully SAE standard compliant equipment
  - Home Plug Green PHY 1.1
  - Open Charge Point Protocol (OCP) v1.5
- CHAdeMO

**UL Standards**
- UL 991 Tests for Safety-Related Controls Employing Solid-State Devices
- UL 1998 Software in Programmable Components
- UL 2594 Standard for Electric Vehicle Supply Equipment
- UL 2231/1/2 Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits
- UL 1741 Standard for Inverters, Converters, Controllers and Interconnection System for Use With Distributed Energy Resources
- UL 2202 Electric Vehicle (EV) Charging System Equipment

**SAE Standards**
- SAE J2344 Guidelines for Electric Vehicle Safety
- SAE J2293 Energy Transfer System for Electric Vehicles
- SAE J2836/1 Use Cases for Communication between Plug-in Vehicles and the Utility Grid
- SAE J2836/2 Use Cases for Communication between Plug-in Vehicles and Off-Board DC Charger
- SAE J1772 Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler
- SAE J2847/1 Communication between Plug-in Vehicles and the Utility Grid
- SAE J2847/3 Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow
- SAE J2931/1 Power Line Carrier Communications for Plug-in Electric Vehicles
How is V2G Infrastructure Controlled?

What benefits will the DoD obtain from future large-scale V2G implementation?

- **Cuts Installation Electricity Costs**
  - Earns energy revenue to offset installation utility expenses
  - Increases penetration of energy storage systems
  - Encourages use of lower cost, off-peak electricity

- **Increases Resiliency & Reliability**
  - Overcomes natural disasters and intentional threats with on-site power support
  - Serves as backup power to mission critical facilities during outages

- **Aids Energy System Stabilization**
  - Reduces failure and degradation of system’s electrical devices with bi-directional power flow
  - Increases power distribution efficiency with on-demand reserve supplies
  - Supports ancillary services market that provides grid operators with real-time adjustment capabilities
  - Cuts electrical generation operational costs

- **Provides a Positive Environmental Impact**
  - Promotes use of renewable energy
  - Supports the national goal of reducing fossil fuel and energy consumption
  - Reduces dependence on foreign energy sources
  - Reduces greenhouse gas emissions

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Frequency regulation is a continuous adjustment of power generation or electrical demand to maintain the grid frequency at or near the nominal 60 hertz standard.
Questions?