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

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

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AGENDA

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**

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

TARDEC V2G Related Projects and the SPIDERS-II Program

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Novi, MI, 15-17 Sep 2015

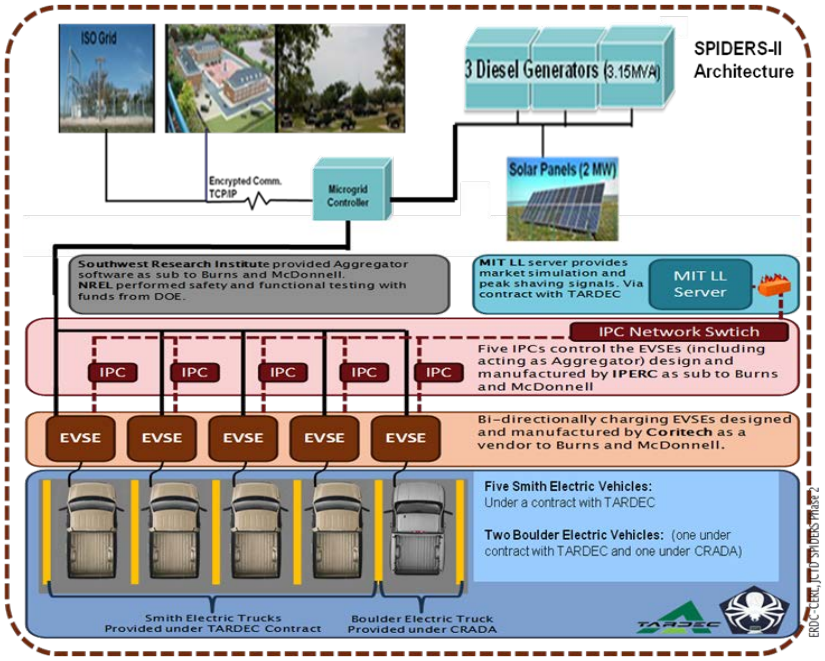
2010:

- 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

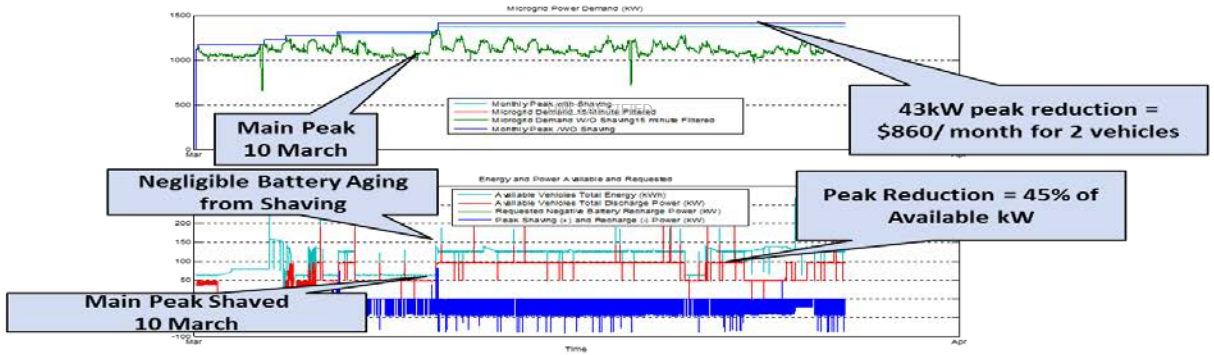


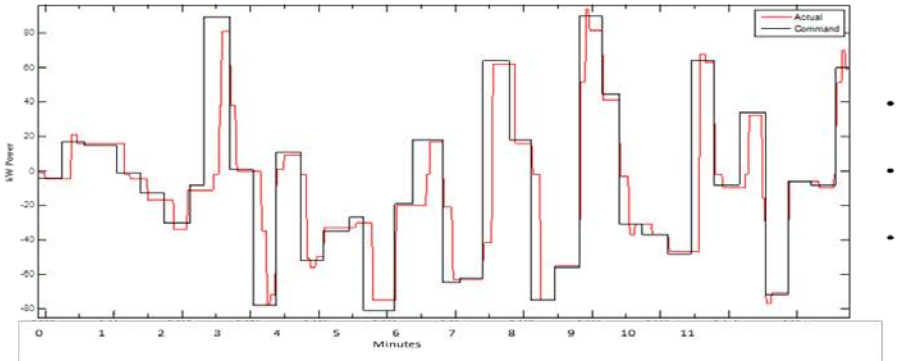
- Successfully survived a 72 Hour Microgrid Cyber Attack
- Demonstrated microgrid support and V2G power grid services

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

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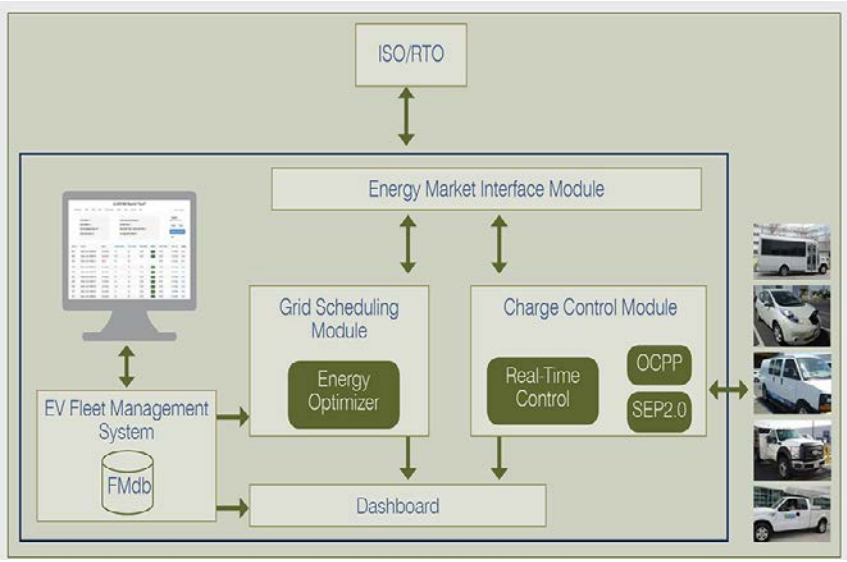
PEV-V2G Objectives/Products:

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



EV Fleet Management System
- Support for base vehicle fleet
- Vehicle management to accomplish operational mission
- Assigns available vehicles to energy market participation

Energy Market Interface Module
- Supporting CAISO, PJM, ERCOT
- Bid-Award in Ancillary Services Energy Market
- Demand Response Market to Frequency Regulation Market Support

Charge Control Module
- Calculate optimal charging and discharging trajectories for both operational requirements and market participation
- Manage the aggregated state of charge across the entire fleet (Virtual Battery)
- Controls the EV Charging Station (EVSE) through industry standard protocols

Grid Scheduling Module
- Day ahead and real-time bidding into energy markets
- Continuous monitoring and re-optimization based on actual vehicle status
- Complies with FERC-ISO rules in each energy market

Dashboard
- Tracks revenue generation in the energy markets
- Management tool for system monitoring and control
- Detailed views of vehicle usage, energy trading history, forthcoming schedules, audits, alerts, and dispatches

DOD Plug in Electric Vehicle Initiative

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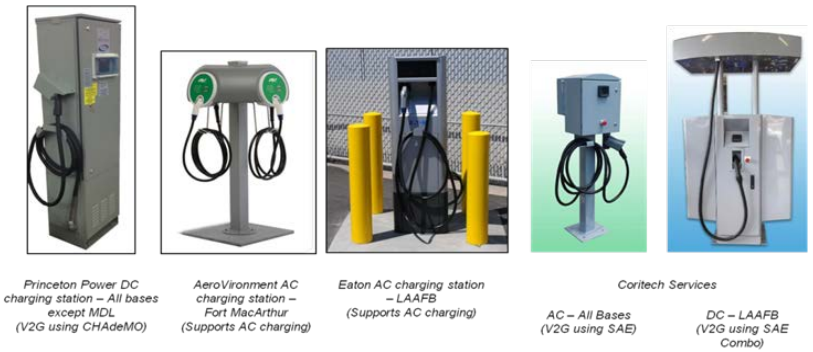
Selected PEVs:
EVAOS, VIA, EVI, Nissan Leaf, and Phoenix

Selected Charging Stations:
Coritech, Princeton Power, Eaton, and Aerovironment



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

PEVs and Ancillary Services Market Requirements

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

U.S. ARMY / U.S. AIR FORCE	 Nissan LEAF Sedan	 Ford F-Series Trucks with EVAOS PHEV kits	 VIA Motors VTRUX Van	 Electric Vehicle International (EVI) Range Extended Electric Vehicle (REEV)	 Phoenix Motorcars Electric Shuttle
Range Description 	(29) PEV electric range: 75 miles fuel efficiency: 99 MPGe	(32) PHEV electric range: N/A fuel efficiency: 45 MPG**	(11) PHEV* electric range: 31 miles fuel efficiency: 38 MPG**	(4) PHEV* electric range: 40 miles fuel efficiency: 43 MPG**	(1) PEV electric range: 100 miles fuel efficiency: 32 MPGe
General Purpose Fleet Role 	23.6 cubic feet cargo capacity	1500 to 2800 lbs payload	2650 lbs payload (cargo van only)	5300 lbs payload	116 cubic feet cargo capacity
	5 seats	3 seat standard cab 6 seats crew cab	2 seat cargo 12 seat passenger	2 seats	visitor transport: 12 passengers + driver
Battery Capacity 	24 kWh	27 kWh	21 kWh	54 kWh	102 kWh
# at Locations 					
LAAFB	13	5	11	4	1
Fort Hood	8	14	---	---	---
JB Andrews	8	5	---	---	---
JB MDL	---	8	---	---	---

How is V2G Infrastructure Controlled?

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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

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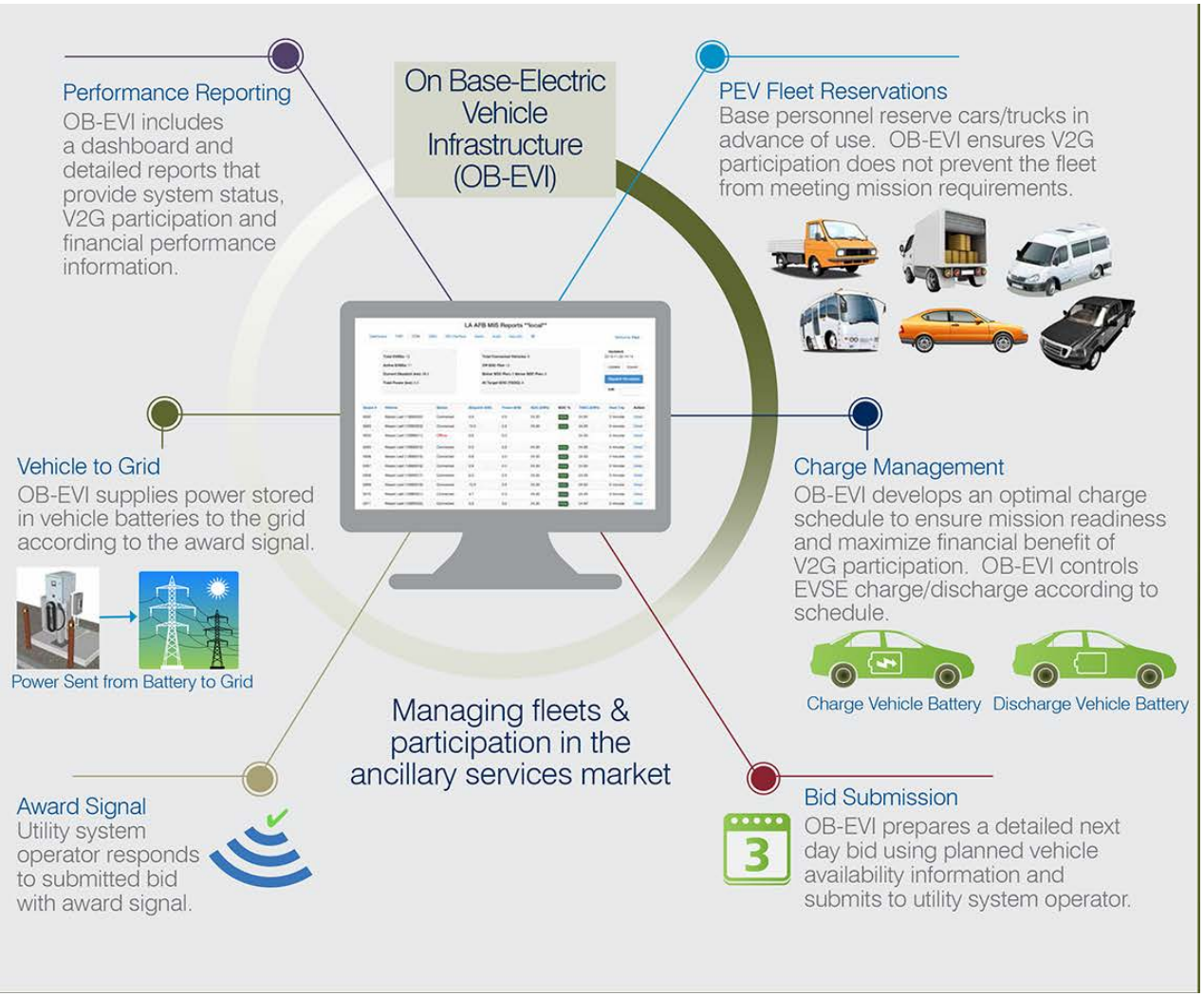

TARDEC Microgrid

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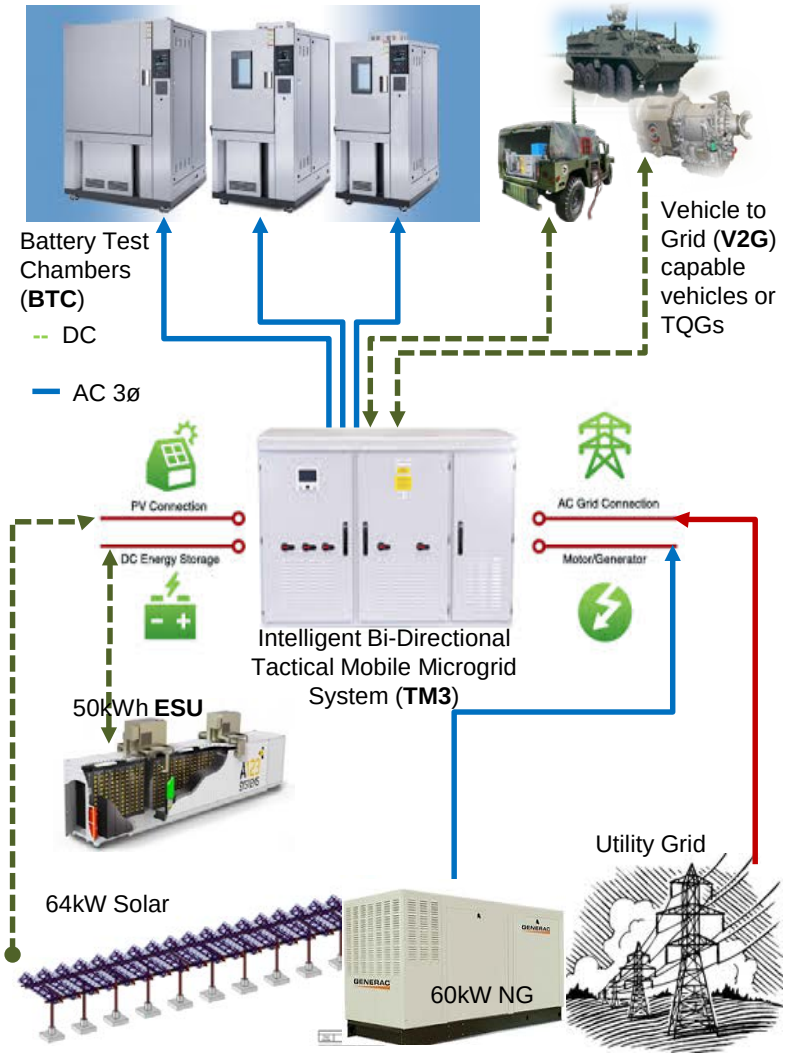

Purpose:

- 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

Advanced Propulsion with Onboard Power

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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)**

Traditional Alternator

Stryker

Stryker High Voltage Onboard Generator

Traditional Alternator

Bradley

Bradley High Voltage Onboard Generator

<u>Develop, Integrate, and Test High Voltage Onboard Generators</u>

Components
Bench Test → **System integration**
SIL Test → **Vehicle Integration**
Vehicle Test

High Voltage Onboard Generator w/ Transmission

Export Power

6T LiON Energy Storage

Power Electronics

High Voltage Cooling

Tactical Vehicle to Grid & Vehicle to Vehicle Demo

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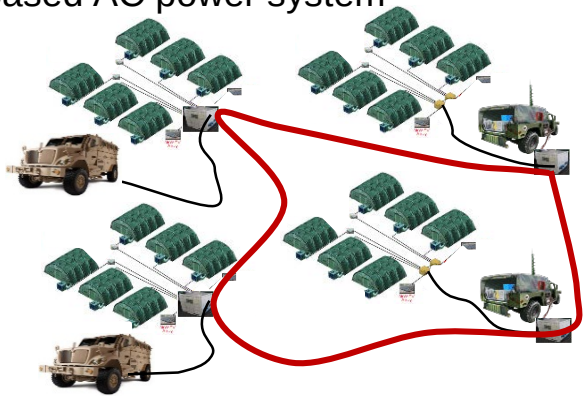
Tactical Vehicle to Grid (V2G) and Vehicle to Vehicle (V2V) Sustainability Logistics Basing Science & Technology Objective Demonstration (SLB-STO/D):

Purpose:

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



J1772 Combo

Fast Unloading

Off-board Converter

120 kW MRAP

30 kW HMMWV

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

PEV Potential Benefits and Impacts

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
  - Sequence of operations is frequently not defined by the standard
  - Detailed ICD required
- Perform periodic monitoring of selected standards to discover published updates
  - Relatively immature Standards set (evolving) – lessons learned driving changes
  - Assess updates and determine if implementation revisions are either required to maintain compliance or desired to remediate prior inadequacies or add relevant functionality

…What we intend to learn/show

Future Verification/Findings

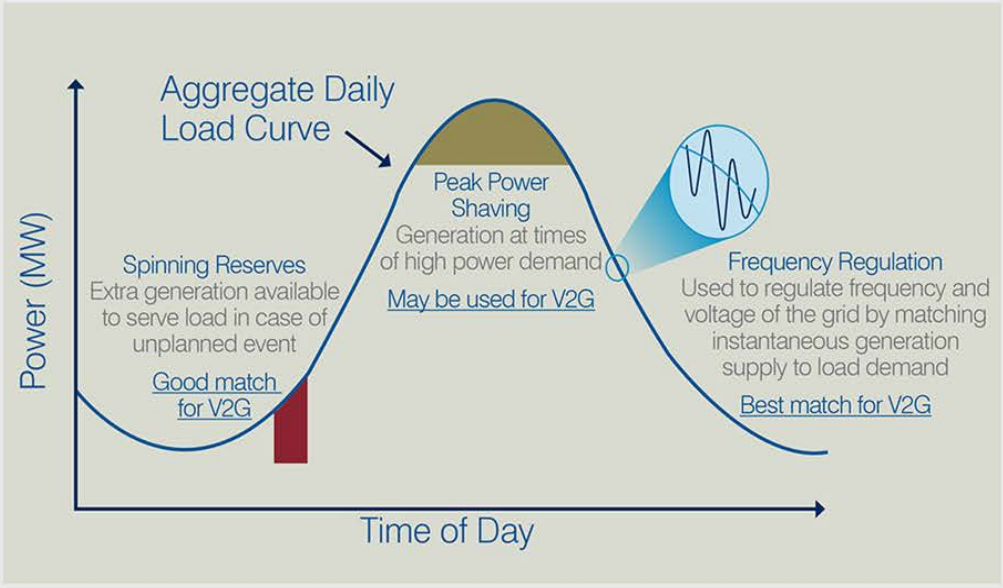
- Aggregated V2G capable fleets provide a fiscal ROI justifying electrification
- User feedback (drivers/fleet managers) regarding fleet management system
- Data collection from vehicle usage
- Data collection from V2G/ISO participation
- Data regarding effect on battery life from V2G/Grid participation
- Validation of fast forming, ad-hoc vehicle based grids

PEV V2G Applicable Standards

- **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 (OCPP) 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 J2464 Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing.
  - 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- J2847/3
  - 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?



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.

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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

Questions?