


SPIDERS-II Industry Day
22 Apr 2014

Non-Tactical & Tactical Fleet Electrification and Vehicle to Grid Power Services

SPIDERS-II V2G Demonstration

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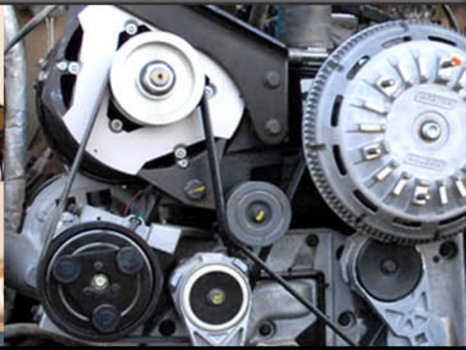


AGENDA

1. Non-Tactical V2G Projects

- Smart Power Infrastructure Demonstration for Energy Reliability and Security Phase-II (SPIDERS-II)
  - Vehicle to Grid (V2G) Demonstrations:
    - ✓ VAR Export/power Factor Correction
    - ✓ Peak Power shaving
    - ✓ Frequency regulation
- Plug in Electric Vehicle (PEV) and Vehicle to Grid service (V2G)

2. Tactical/Combat V2G Projects

- Tactical & Combat Fleet Roll-up/Roll-away Microgrid
- Advanced Propulsion With Onboard Power

3. Transition Products

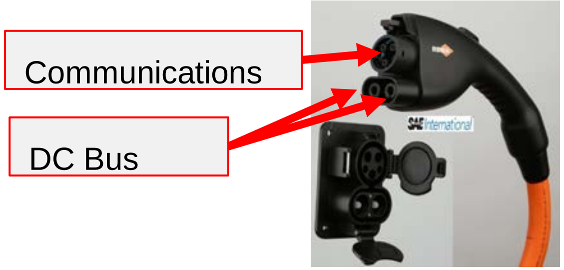
4. Summary

TARDEC is focused on the Warfighter – so why do V2G?

- Vehicle electrification enables improved capabilities:
  - Weapons systems, communications, e-armor
  - Mobile, on board, and quieter power generation system
- V2G will save fuel and improve FOB microgrid power efficiency
- V2G leads to V2V power and communications
- V2G enables powering advanced vehicle systems from base power
- Advanced Propulsion with On-board Power (APOP) builds on this capability

TARDEC V2G Activities

- **SAE L2 J1772 Combo connector**
  TARDEC co-funded auto OEMs for tooling and development

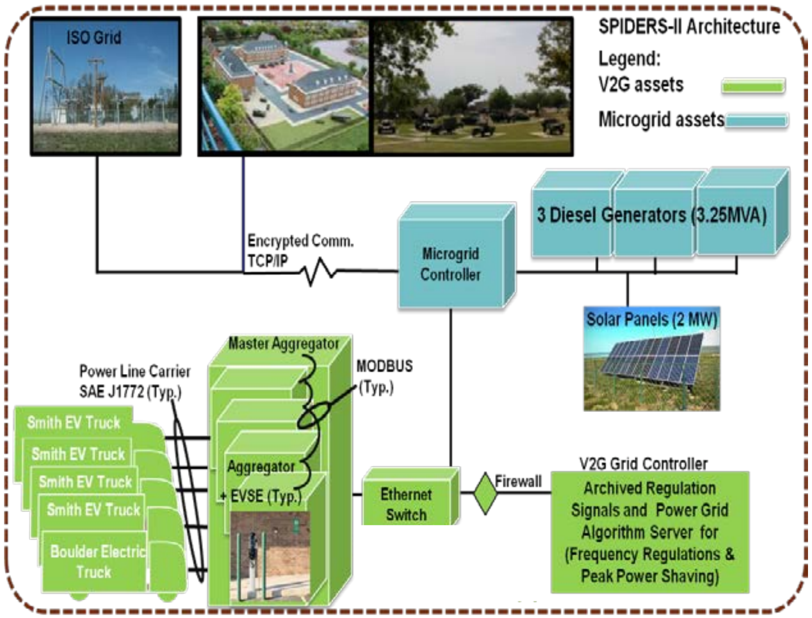


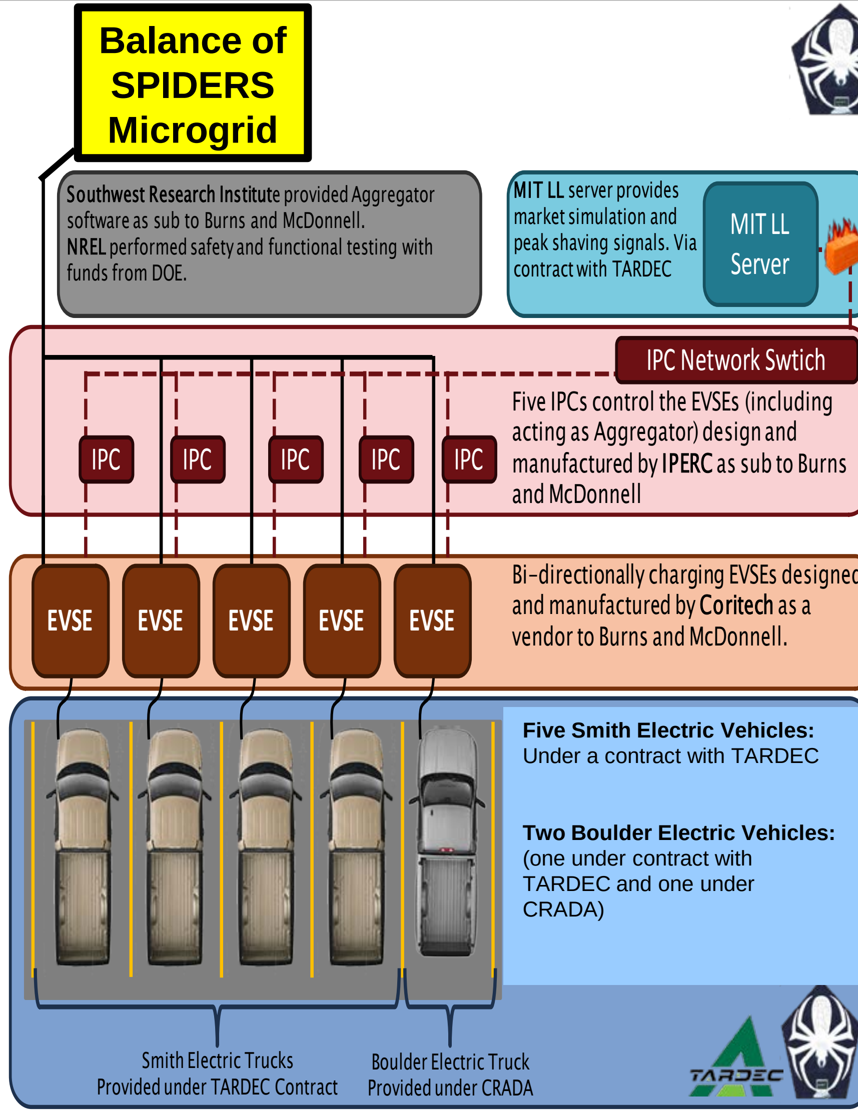
- **Leveraged SAE Standards J2836, J2847, J2931, J2953 in development of ICD for bi-directional power management, specification for the Plug in Electric Vehicle (PEV), and Electric Vehicle Supply Equipment (EVSE)**
- **MIT-LL Phase-I: Peak Shaving Algorithm Development**
- **MIT-LL Phase-II: Installation of Peak Shaving Server (Command, receive, and record real time data)**
  - ➢ **Development of "Draft UL 9741" Standard for the Bi-Directional Electric Vehicle Charging Equipment – Completed and released to UL on 28 Mar 2014**
- **NREL - ISO Regulation Signal Management (PJM signal)**
- **Five EVSEs from Coritech, seven Electric vehicles (five purchased from Smith Electric and two from Boulder Electric – one purchased and one provided under CRADA agreement)**
- **SPIDERS-II Microgrid 72 hours Cyber Secure Operational Demonstration Completed Oct 2013**
- **SPIDERS-II V2G Grid Services Demonstration – Completed: Mar 2014**

Smart Power Infrastructure Demonstration for Energy Reliability and Security Phase-II (SPIDERS-II), Ft. Carson, Co.

SPIDERS –II Microgrid Features:

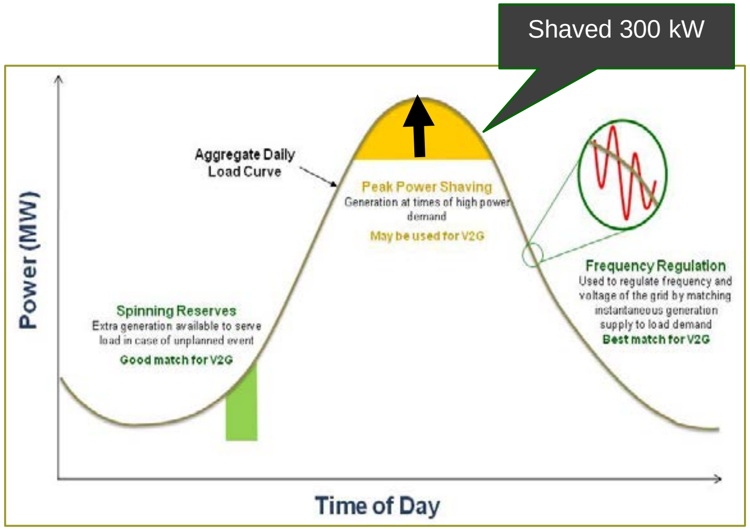
- 1.1 MW Critical Load, 1 MW Priority Load
- 3.25 MVA Diesel Generation (three existing assets)
- 2 MW Solar Array (existing asset)
- 6 Electric Vehicles with Vehicle to Grid Capability
- Comprehensive Cyber Security Solution
- 72 Hour Operational Demonstration
- V2G Demonstration Mar 14

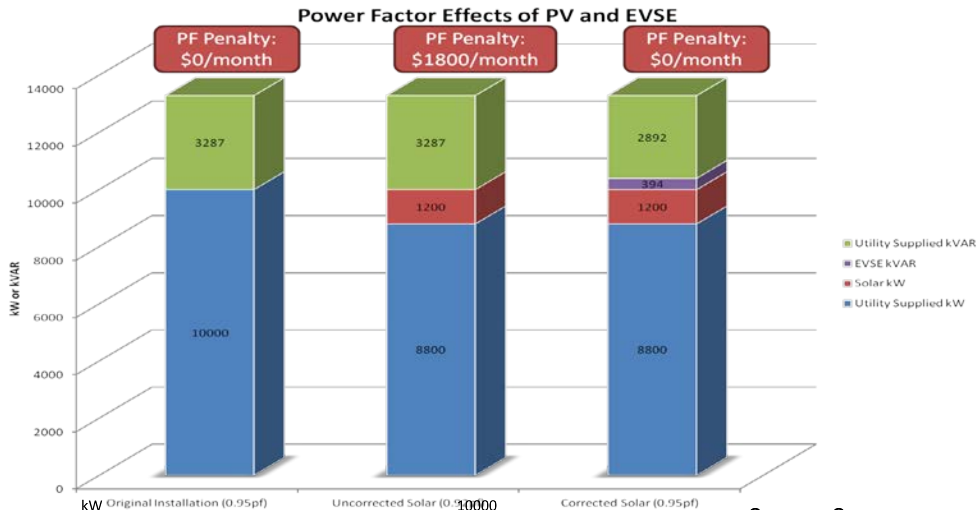




ERDC–CERL, JCTD SPIDERS Phase 2

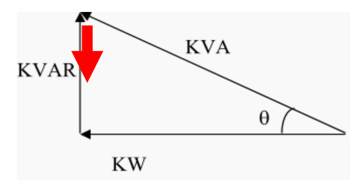
Grid Services Enabling Fiscal Viability





kW		10000
kVAR		3286.841052
kVA		10526.31579
Power Factor		0.95
Solar kW	1200	
Utility Supplied kW		8800
Utility Supplied kVA		9393.791785
Uncorrected Power Factor		0.936788914
Desired Power Factor		0.95
kVAR for Desired Power Factor		2892.420126
EVSE kVAR		394.4209262
Corrected Utility kVA		9263.157895

$$KVAR = Sqrt(KVA^2 – KW^2)$$



Fort Carson Demonstrate V2G Capabilities:

- Five operational PEVs and Five DC EVSEs
- Demonstrated power factor correction: exported and absorbed a combined 394kVAR without vehicles connected
- Potential savings of:
  - $360/month/EVSE by reducing power factor penalties through VAR export
  - Peak Shaving: 60kW/vehicle x $10/kW = $600/mo
  - Power Regulation (Followed simulated ISO/PJM signal (2/2014): $400/mo – per vehicle

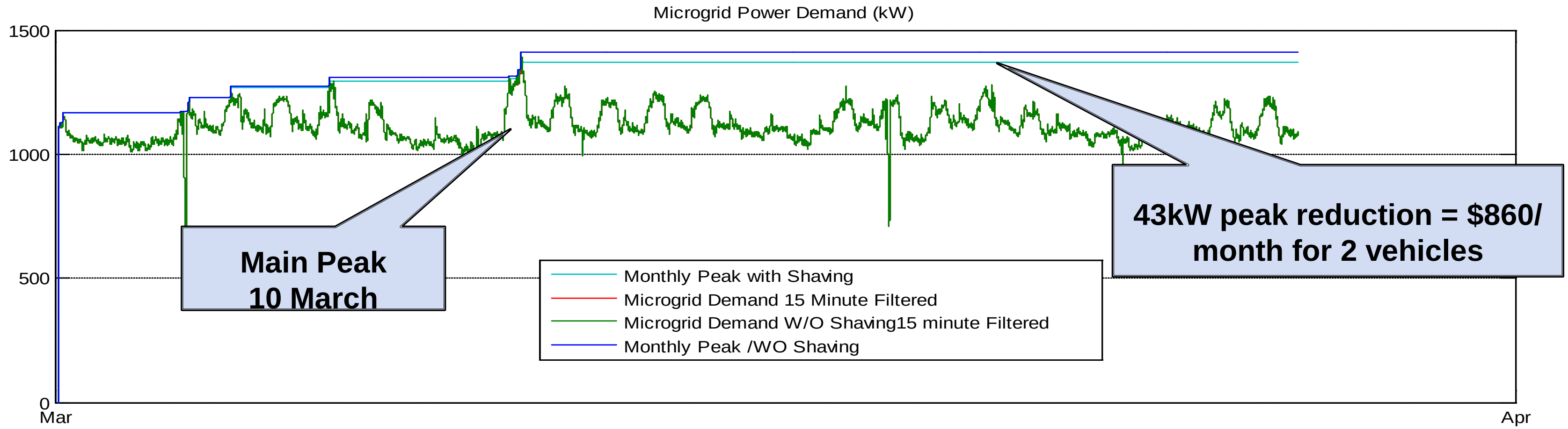
Note: Cost of infrastructure, PEV, and EVSE is not included in above figures.

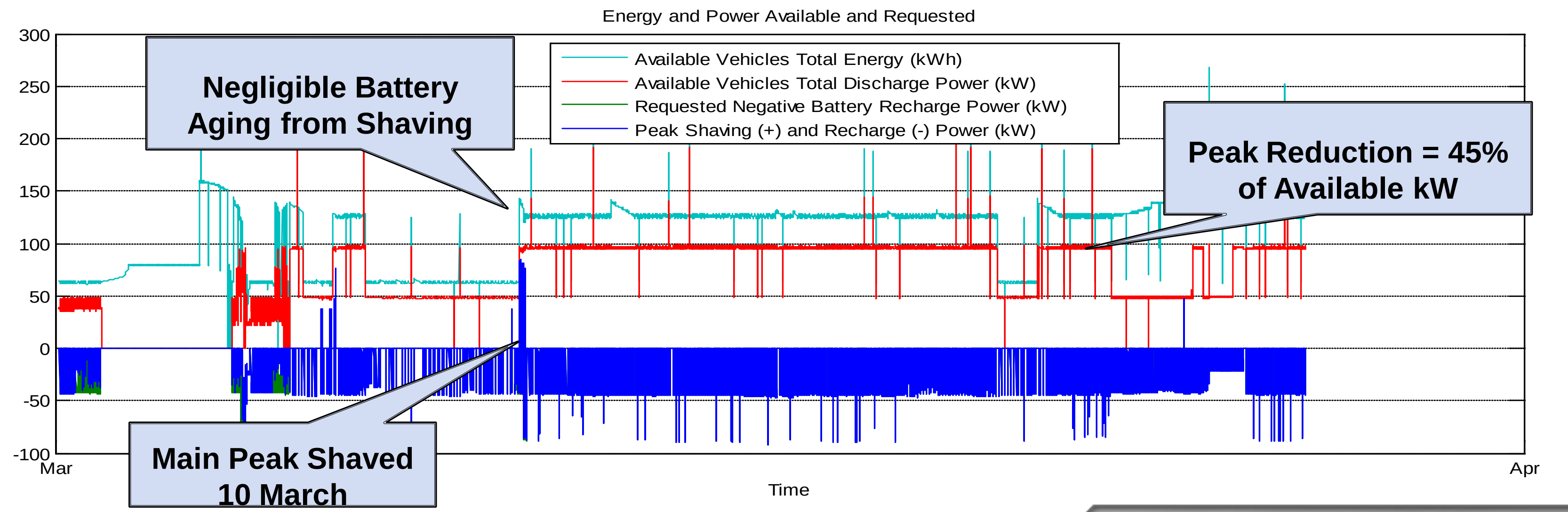
	Utility Supplied kW	Solar kW	Utility Supplied kVAR	EVSE kVAR
Original Installation (0.95pf)	10000		3287	
Uncorrected Solar (0.92pf)	8800	1200	3287	
Corrected Solar (0.95pf)	8800	1200	2892	394

	Original Installation (0.95pf)	With Solar (0.92pf)	With Solar & EVSE (0.95pf)
Utility kW	10000	8800	8800
Solar kW	0	1200	1200
Utility kVAR	3286.841052	3286.841052	2892.42013
EVSE kVAR	0	0	394.420926

Peak Shaving at Ft Carson, March 2014 Additional system optimization could yield improvements

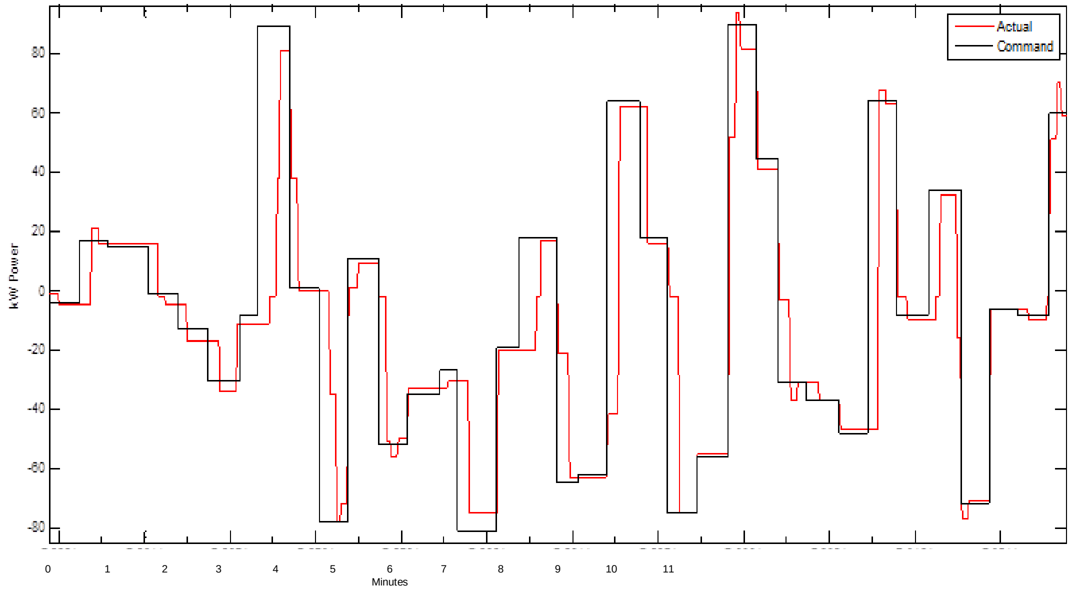
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY



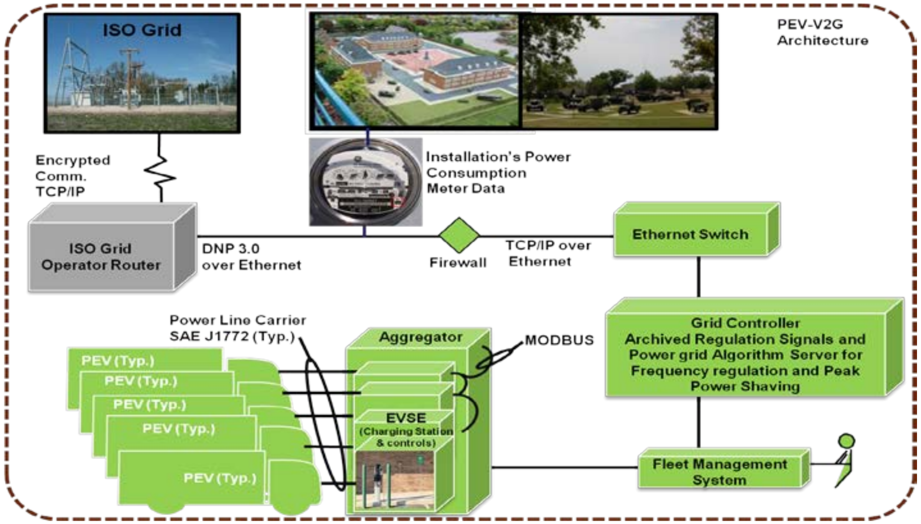


Frequency Regulation Test

- **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 Vehicle to Grid Services (V2G)



Schedule & Cost

Milestones	*FY12*	*FY13*	*FY14*	*FY15*
Vehicle to Grid For Cyber (V2G) Secured Power Grid Services				
Requirement Development				
SOW and Contract Award				
PEV & Component Development and Integration				
Field Testing and Grid connectionV2G				
V2G Demo and Training				
Project Completion				

Purpose:

- Reduce dependence on petroleum for non-tactical vehicle mobility and help secure the nation's electrical grid
- Validate cost justified non-tactical vehicle electrification path
- Develop transition-able bi-directional power systems capability that enables stable net-zero contingency bases

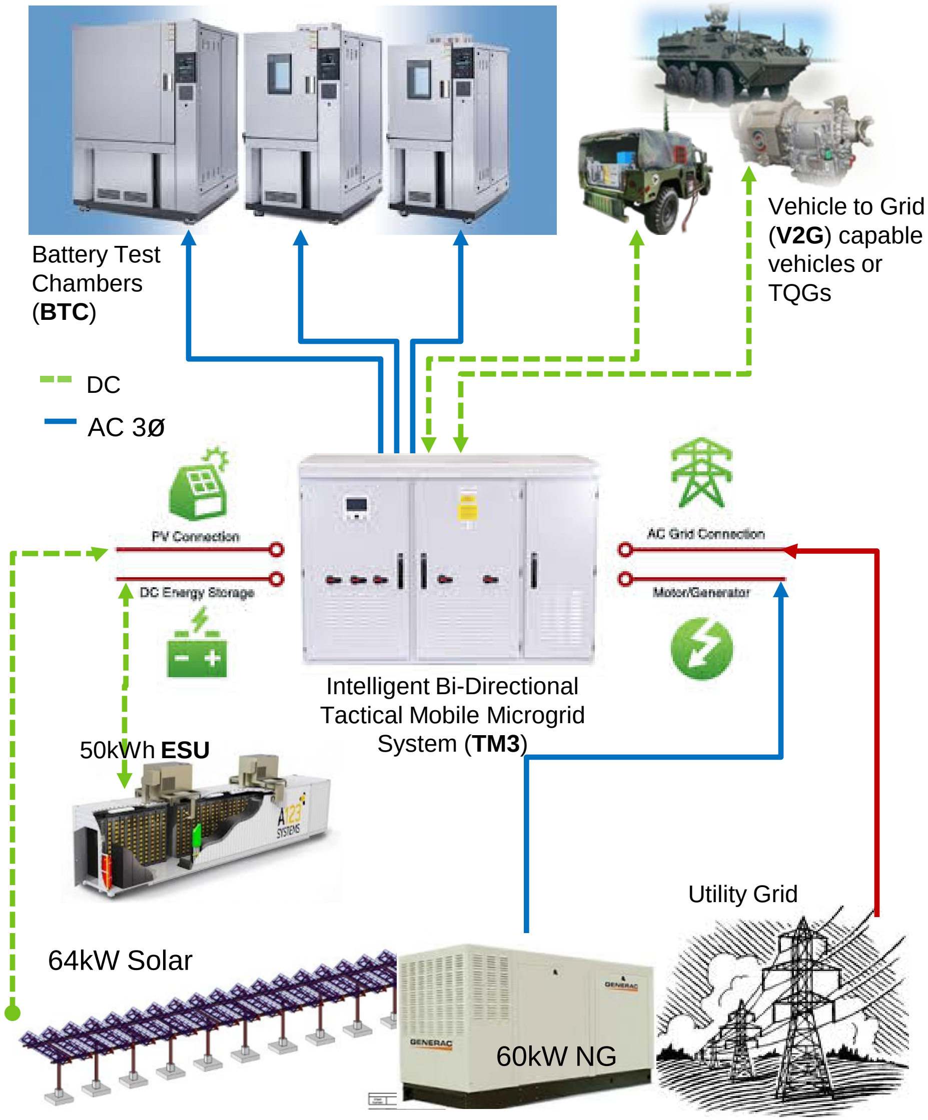
Products:

- PEVs (78 vehicles), converters, and aggregation hardware for cyber-secure and bi-directional power management (peak power shaving, power regulation, volt-VAR management, and energy storage) at 4 DOD installations
- Validated fiscally responsible electrification plan

Payoff:

- Stable, cyber secure V2G power grid services
- Assets provide cost benefit when vehicle not in use (mobile)
- Support Forward Base Operations (FOB) and improve microgrid power efficiency

TARDEC Microgrid



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) capable fleet power system to support advanced vehicle systems such as e-armor, e-weapons, and advanced C4

Results/Products:

- Laboratory environment for V2G systems development for tactical and combat vehicles utilizing mixed power generation system
- Contingency Basing grid services from tactical and combat vehicles

Payoff:

- Verified decrease in fuel consumption of base camp generators by 20% with use V2G capable vehicles - requiring fewer generators at bases and better utilization of the generator assets
- Provide capability to use base power for vehicle functions
- Increased energy security for bases and installations.

Advanced Propulsion with Onboard Power

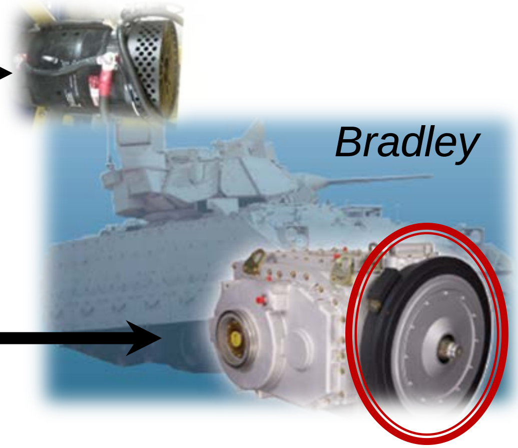
Traditional Alternator

Stryker High Voltage Onboard Generator

Vehicle power needs are continuously growing. Alternator technology

This effort will meet soldiers' future power needs using high voltage inline generators to significantly increase available electrical power to approx 10 times

Traditional Alternator



Develop, Integrate, and Test High Voltage Onboard Generators

Components
Bench Test

High Voltage Onboard Generator w/ Transmission

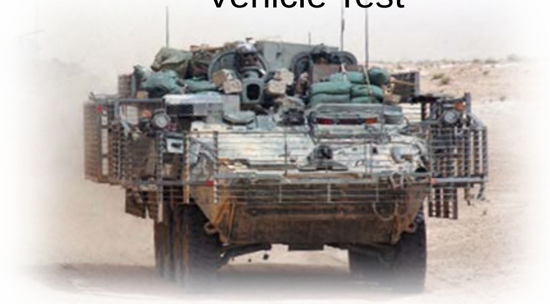
High Voltage Cooling

Power Electronics

System integration
SIL Test

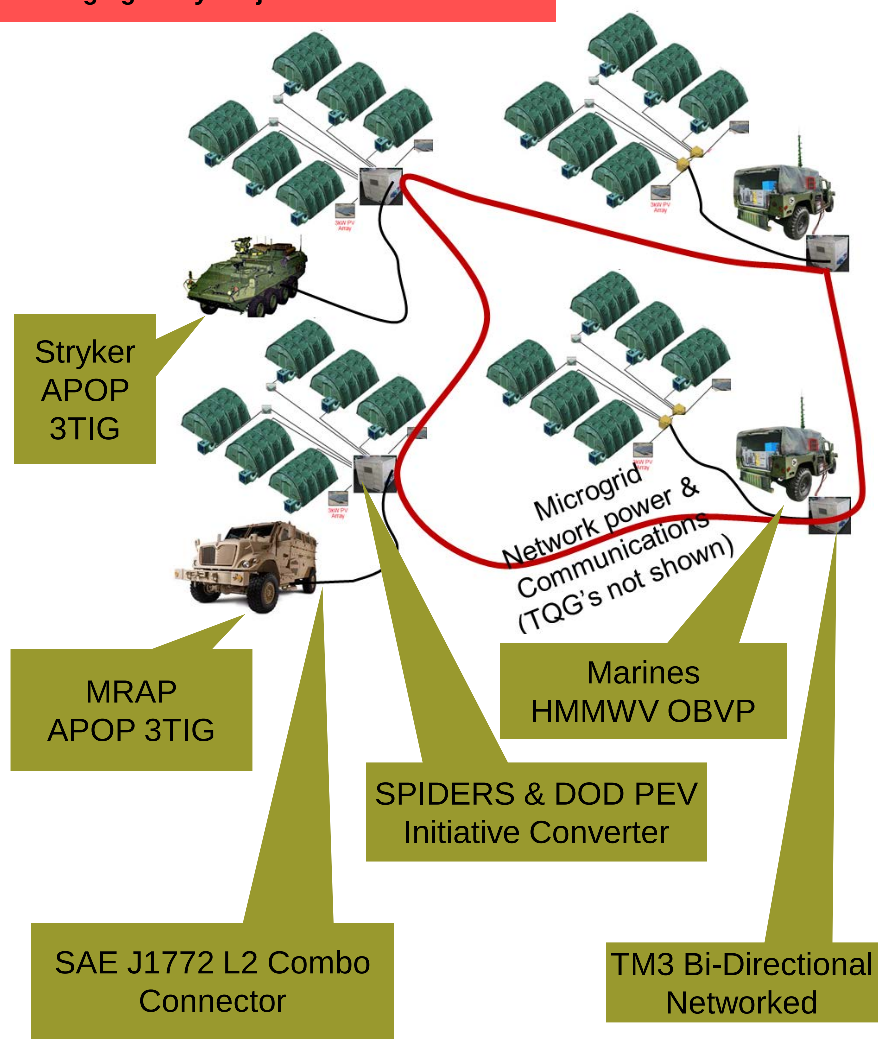
Engine w/ Generator

Vehicle Integration
Vehicle Test



Tactical & Combat Fleet Roll-up / Roll-away Microgrid

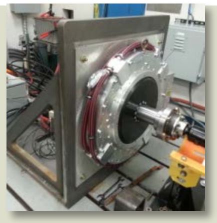
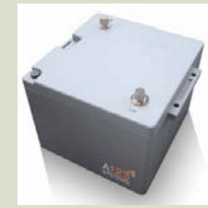
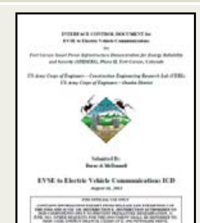
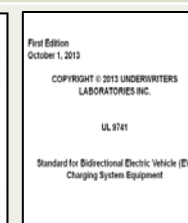
Leveraging Many Projects



Leveraging the following projects:

- Militarized and leveraging V2G Technologies from the SPIDERS-II and the PEV Initiative:
  - V2G Bi-directional EVSEs
  - V2G communications: Grid Services (power/energy management, stabilizing power grids, mobile power, peak power shaving, and frequency regulation)
  - Remote Vehicle Systems Operation
  - V2V power and communications
  - SAE J1772 Combo Connector
- Stryker Advanced Propulsion On-board Power (APOP) systems use of the Allison 3000 Series Transmission Integrated Generator (3TIG
- Bi-directional Tactical Mobile Microgrid Module (TM3) Bi-directional V2G to be demonstrated at the AEWE Spiral H (Feb 2013)
- On-Board Vehicle Power (OBVP) HMMWV: The vehicle is part of the AEWE Spiral H V2G demonstration

Transition Products

Device		Device	
ISG		LiON Battery 6T – 24V & ~350 VDC	
Bi-Directional DC-DC Converter 10kW 600V-28V		Inverters – 105C 175 kW 75 kW 10 kW	
Electric Pumps & Fans	 	Add-hoc system forming/ aggregation	
Export Power SAE-J1772 Combo Connector		PEV/EVSE Spec, Interface Control Document (ICD) for V2G/V2V and Draft UL 9741	 EVSE to Electric Vehicle Communications ICD  First Edition October 1, 2013 COPYRIGHT © 2013 UNDERWRITERS LABORATORIES INC. UL 9741 Standard for Bidirectional Electric Vehicle (EV) Charging System Equipment

Summary

PEVs and their associated DC EVSEs can generate revenue by performing power grid service such as power factor correction/stabilizing power grid, frequency regulation, and peak power shaving.

- **Vehicle to grid demonstration at Ft. Carson demonstrated that power factor improvement, peak shaving and frequency regulation services can offset the high cost of batteries for plug in vehicles.**
  - Can be beneficial to the larger system with negligible harm to the vehicle batteries by not discharging them every day.
  - Power factor improvement can yield an additional monetary benefit.
  - Peak shaving during day combined with frequency regulation at night roughly doubles the rate of return.

- **V2G system improvements will increase the economic return on these systems**
  - More robust vehicle and EVSE software will increase the availability of the energy resources.
  - Better energy management in vehicle batteries will prepare them for each type of grid service use and return them to mobility service.

- **Improved Warfighter capabilities resulting from increased on-board power and improved FOB power/energy from vehicle based microgrid services**

Questions?