Comprehensive Assessment of On-and Off-Board V2G Technology Performance on Battery and the Grid

Project ID #GI187

Principle Investigator: **Sunil M. Chhaya, Ph. D.**
Technical Executive
Electric Power Research Institute (EPRI)

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Overview

Timeline

- Start – November 2016
- Finish – November 2019

Percent complete: 5%

Barriers

- Lack of Data on DER Applications
  - Value of V2G integration as DER asset
- On and Off-Vehicle Hardware
  - Cost, performance, communications, monitoring, and control
- Standards verification for V2G application
  - Interoperability and Certification

Budget

- Govt Share: *$1,547,678.00*
- Cost Share : *$1,238,600.00*
- Total Program: *$2,786,278.00*

Funding for FY 2016:
Funding for FY 2017:

Partners

- Lead: Electric Power Research Institute (EPRI)
- Partners: Flex Power Control, FCA, Kitu Systems, LG Chem
- Collaborations: NREL and ORNL

Relevance

Objective

- Demonstrate and Evaluate grid DER management use cases using V2G bidirectional power flow (charging and discharging) integrated with solar and stationary energy distributed resources in the AC (on-vehicle) and DC (off-vehicle) domains.

Key Enabler: The Smart Power Integrated Node (SPIN) – single multi-functional modular unit combining solar, stationary energy storage, and V2G into an integrated localized Distributive Energy Resource System

Goals

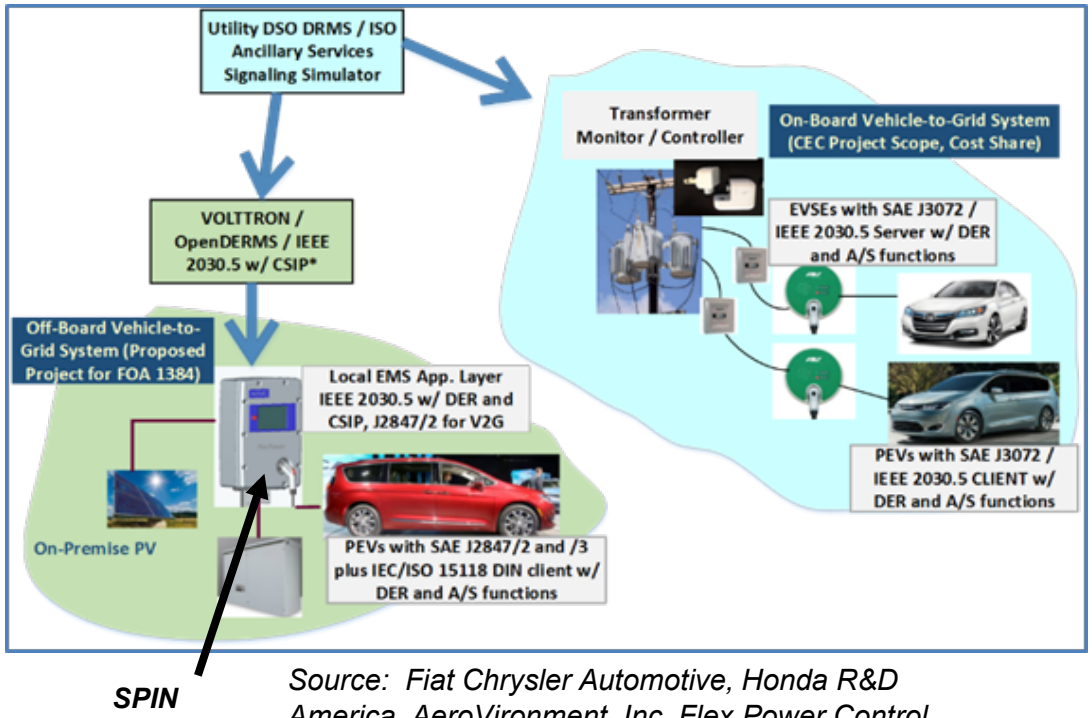
- Provide integrated hardware/software V2G/DER energy management solution (SPIN)
- Enhance utilization, efficiency, and reliability of bidirectional converter electronics
- Development of infrastructure side for AC and DC Charging enabled V2G capabilities
- Prove viability of V2G capabilities as integrated dispatchable DER
- Accelerate deployment of V2G as part of integrated DER ecosystem.
- Enable increased use and value of renewable generation and battery energy storage
- Verify application/interoperability of Standards Based Communication Protocols – SAE J1772, IEEE 2030.5, J2847/2, J2847/3, J3072, J2931/1, J2931/4, VOLTTRON
- Address automaker concerns for battery durability impacts

Milestones – Go/No Go Decision Points

Task Title	Milestone Type	Month/Year	Status
Use Case Evaluation and Determination	Milestone	January 2017	Complete
Design Review (SPIN Bidirectional Converter)	Milestone	April 2017	Complete
Release Drawings/Order Parts	Milestone	October 2017	
Critical Design Review	Go/No-Go Decision	November 2017	
System Lab Test Plan and Set Up	Milestone	January 2018	
Start of OEM Vehicle V2G Communications Integration	Milestone	April 2018	
Completion of V2G Communications Integration – Start of Verification Testing	Milestone	May 2018	
SPIN Qualification Testing for UL	Go/No-Go Decision	September 2018	
Demonstration Site Logistics Planning and Installation	Milestone	November 2018	

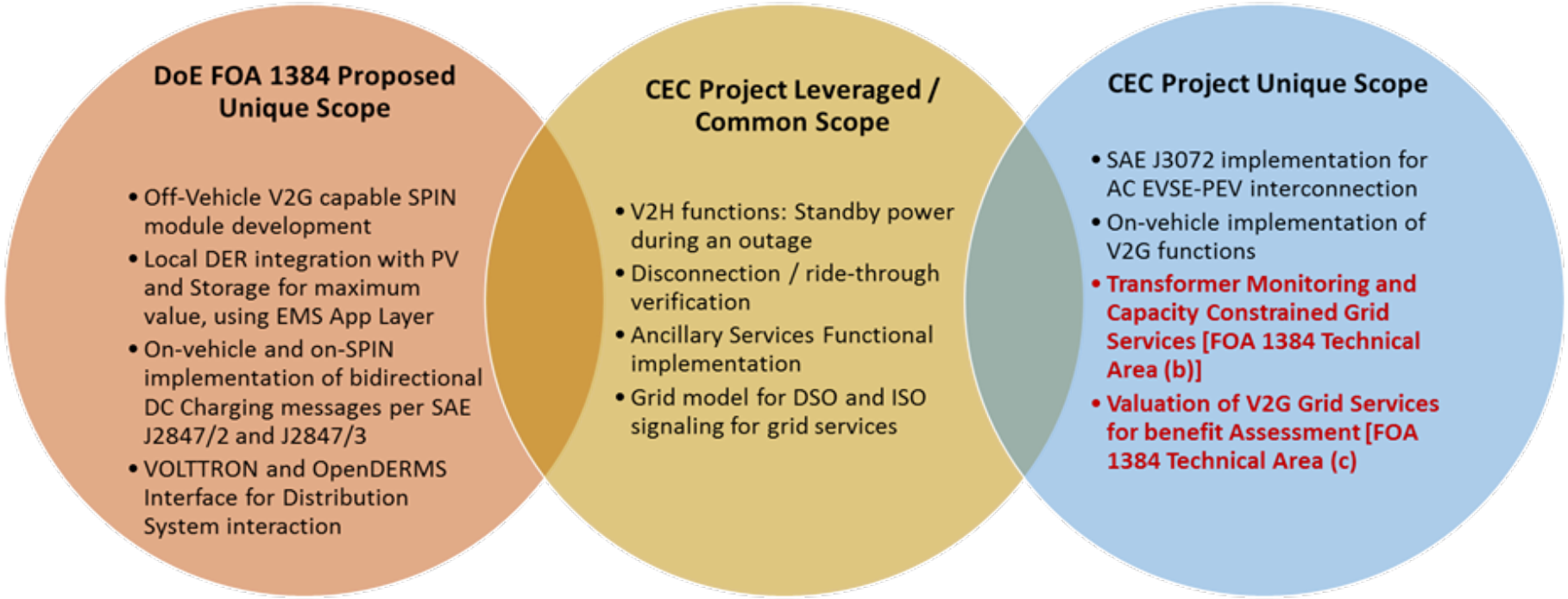
Approach

- Parallel V2G (Off-Vehicle/On-Vehicle) technology implementation projects
  - Off-Vehicle (DC) utilizes SPIN integrated DER management system with solar/energy storage
  - On-Vehicle (AC) utilizes Transformer Management and Control System
- End to End V2G/DER communications and controls technology implementations
  - Utility DSO and ISO grid services simulations
- SPIN incorporates Smart Inverter functions and communications per IEEE 1547 and CPUC Rule 21
- Evaluate battery life and durability impact through use case cycle testing / analyses
- Assess V2G technology value and grid services benefits



Source: Fiat Chrysler Automotive, Honda R&D America, AeroVironment, Inc, Flex Power Control and Creative Commons (PV and Storage images)

Approach


DoE FOA 1384 Proposed Unique Scope
• Off-Vehicle V2G capable SPIN module development
• Local DER integration with PV and Storage for maximum value, using EMS App Layer
• On-vehicle and on-SPIN implementation of bidirectional DC Charging messages per SAE J2847/2 and J2847/3
• VOLTTRON and OpenDERMS Interface for Distribution System interaction
CEC Project Leveraged / Common Scope
• V2H functions: Standby power during an outage
• Disconnection / ride-through verification
• Ancillary Services Functional implementation
• Grid model for DSO and ISO signaling for grid services
CEC Project Unique Scope
• SAE J3072 implementation for AC EVSE-PEV interconnection
• On-vehicle implementation of V2G functions
• Transformer Monitoring and Capacity Constrained Grid Services [FOA 1384 Technical Area (b)]
• Valuation of V2G Grid Services for benefit Assessment [FOA 1384 Technical Area (c)

Accomplishments

On-Vehicle V2G Technology Development

- Completed EVSE V2G com board development and integration
- Completed Transformer Management System (TMS) hardware/software integration
- Conducting simulation of use case scenarios and test requirements
- Data modeling coordination between EPRI/E3 ongoing
  - Circuit impact analysis
  - Cost benefit modeling framework and data input parameters
  - Measurement & Verification plan and definition of metrics
- Initiated alternatives for V2G on-vehicle com PLC module development and integration with FCA (Chrysler)

EVSE w/Com Board

TMS

Off-Vehicle V2G Technology Development

- Evaluation/Determination of Use Cases (Milestone)
- Conducted SPIN Design Review (Milestone)
  - Component Technical Specification Document
  - Communication, Monitoring, and Control Sub System Specification Document
- SPIN Master Controller Software Implementation
  - Implementing IEEE 2030.5 and CSIP (Calif) Guideline for Smart Inverter functionality
  - Power Electronics Controller interface/integration development/testing
- Analytics/algorithms development on-going
- LG CHEM EV Battery Pack #1 available for delivery

Source: EVSE Images – AeroVironment, Inc, Transformer Monitoring System (TMS): EPRI Technology

Responses to Previous Year Reviewers' Comments

- New Program - not reviewed previously
- No Reviewer Comments to be addressed

Collaboration and Coordination

Prime	EPRI ELECTRIC POWER RESEARCH INSTITUTE
Smart Power Integrated Node (SPIN)	FLEXPOWER CONTROL Power Your Way
IT Communications	KITU SYSTEMS
Power Electronics & Test	OAK RIDGE National Laboratory
Field Test	NREL NATIONAL RENEWABLE ENERGY LABORATORY
On-Vehicle Integration	FCA FIAT CHRYSLER AUTOMOBILES
EV Battery – Durability Assessment	LG Life's Good; NREL NATIONAL RENEWABLE ENERGY LABORATORY

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Remaining Challenges and Barriers

Standards Based End to End V2G/DER integrated system communications/controls

- Standards not fully vetted or certified for V2G application
- CA Rule 21 Smart Inverter DER functions (i.e. High/Low Voltage and Frequency Ride Through, Dynamic Var Support, Fixed Power Factors, etc.) and communications requirements implementation undergoing test and evaluation
- No established certification process for grid interconnected on-vehicle inverters – OEMs self certify…SAEJ3072 not yet adopted by utilities

Understanding of impact to vehicle battery durability and cycle life

- Validation of affects on battery life (capacity fade, impedance rise etc.) based on use case applied variables for discharge durations/cycles

Use Case value and cost effectiveness assessments

- Determination of use case value basis and cost trade off benefits
- Assessment of optimization strategies for dispatching V2G as integrated DER
  - Implementation into SPIN integrated DER energy management and control strategy

Determinations and validation of value use cases for V2G/DER application for

- Aggregation, Building Energy Management, and MicroGrid operational modes

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Proposed Future Research

FY17 – Technology Development/Implementation

- Implementation of Standards protocols and interoperability verification
  - Implement SPIN controls, monitoring, and communications specification requirements
    - Development and testing of SPIN V2G/DER control algorithms for optimizing electricity cost, energy efficiency, max renewables utilization, and zero net energy operation
    - Simulation for utility DSO and ISO signaling commands – performance response
    - Validate Smart Inverter functionality/communications

FY18 – System Integration and Use Case Testing

- Validation of SPIN analytics/algorithms to maximize local V2G/DER usage efficiency
- V2G/DER Control response to utility signals to mitigate distribution circuit impacts
- Evaluate aggregation scenarios/capability
- Determination of optimized V2G duty cycles to mitigate negative affects – run V2G optimization scenarios against use cases

FY19 – Demonstration and Validation

- Value/Cost benefit assessment of V2G attributes as integrated DER source
- Validation of optimization scenarios to maximize utilization of PV and battery storage, and minimize impact to EV battery pack

Any proposed future work is subject to change based on funding levels

Summary

Off-Vehicle (DC) V2G/DER integration - in start up mode

- SPIN design and communications specifications completed
- FY17 focus on SPIN power electronics/software/controller integration
  - Development of control algorithms for optimized V2G/DER management
  - SPIN V2G/DER lab integration testing with LG Chem EV configured Battery Packs
- Baseline characterization of EV Battery Packs for durability evaluation/assessments

On-Vehicle (AC) V2G technology development progressing

- Formalizing final use case scenarios and input parameters for on-going TMS simulation testing.
  - DSO/ISO Emulation and EV Emulation
  - Transformer load /Solar generation data profile inputs
- Formulating data models and data collection parameters
  - EPRI Distribution System GIS and Circuit Analysis data model – Distribution Circuit Hotspot impact analysis
  - Provision of data inputs for the V2G cost estimation and benefit modeling.

Emphasis on addressing V2G/DER Open Standards

- Protocol implementation and interoperability requirements and technology integration

Technical Back-Up Slides

V2G (AC) Communications Functional EVSE

Dual L2 AV EVSE

5V Power Supply

EVSE RS Control Board

IoTecha/Expansion Board

IoTecha Board contains the J3072 and IEEE 2030.5 software and connects to EVSE RS Control Board through UART (serial port). Pilot signal is generated by the EVSE RS Control Board. PLC signal is injected onto the pilot wire on the Expansion Board. The Pilot to the output cable to the EV Is connected to the Expansion Board.

Source: AeroVironment, Inc (EVSE)
IoTecha, Inc – Expansion Board (with permissions)

Transformer Management System (TMS)

Transformer Power Measurement Unit (TPMU)

- Measures Voltage, Current and Phase
- RS485 Communications Interface to the TC

Transformer Controller (TC)

- Linux based open Router Platform
- RS485 Communications Interface to the TPMU
- Communications to each EVSE(s) and PEV (s) via HomePlug AV Adaptor
- Performs Energy Management Algorithm

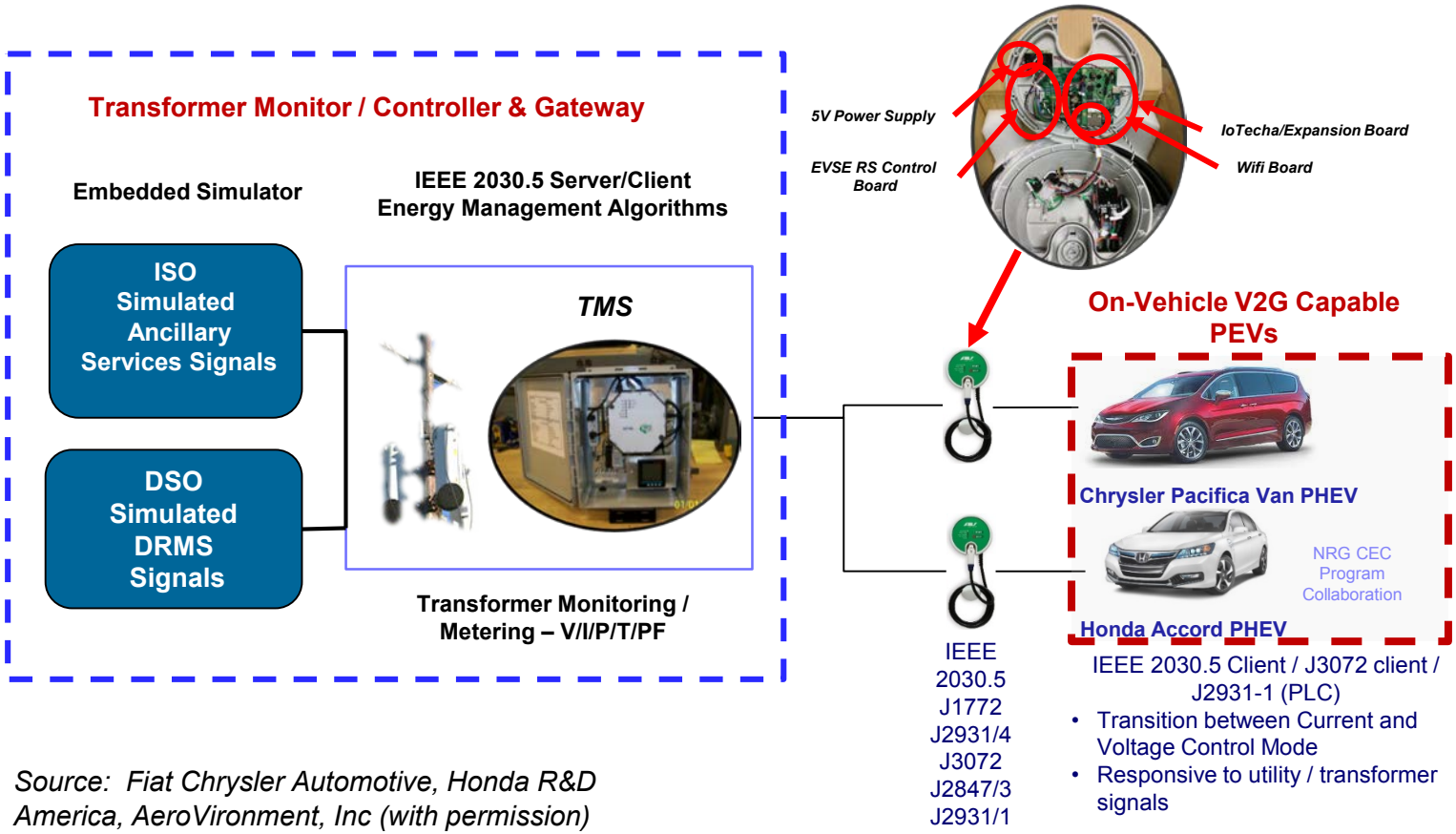
HomePlug AV Ethernet Adaptor

- Ethernet connected to the Transformer Controller
- Communicates to all connected Gateways via the premise drop

TMS Enclosure NEMA 3R Outdoor Mounted to L2 Charging Island 30KVA Transformer

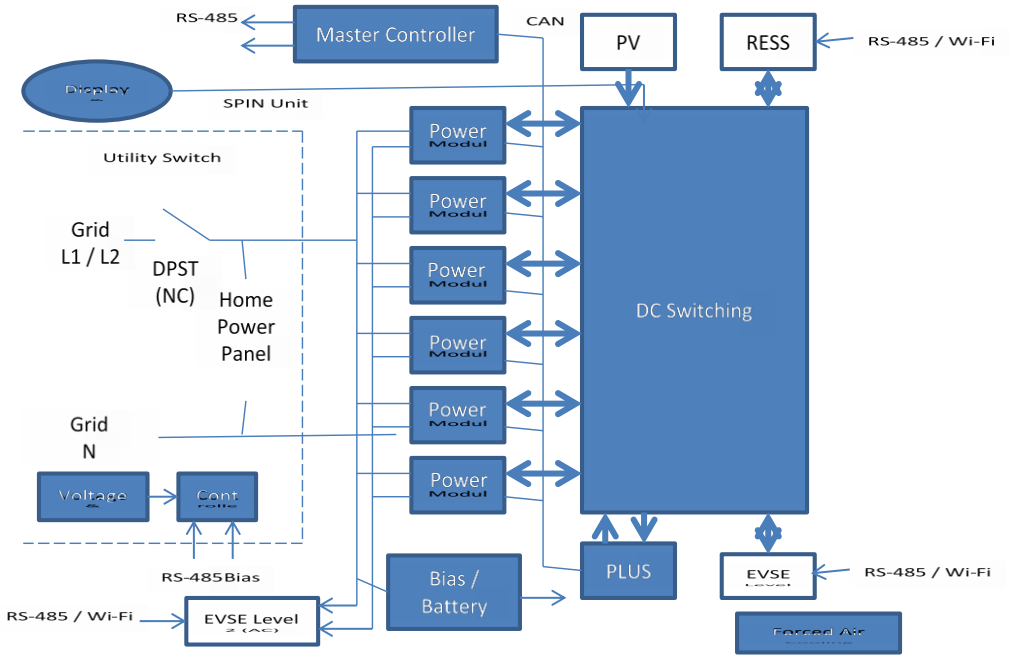
Source: EPRI

On-Vehicle V2G System Architecture



Source: Fiat Chrysler Automotive, Honda R&D America, AeroVironment, Inc (with permission)

SPIN System Functional Block Diagram



Source: Flex Power Control (with permission)

Critical Assumptions and Issues

- Implementation of Wide Band Gap technology into SPIN power electronics
  - Leverage advantage for improved efficiencies, thermal performance, and reliability
  - Assessment of cost impact for commercialization
  - Understanding of implications to controls development
- SPIN optimization V2G/DER energy management strategy/requirements
  - Customer control/preference inputs – priorities versus utility grid needs
  - Simultaneous compliance to customer and utility needs
    - Local energy management options to respond to utility signals
- Standards V2G application/interoperability verification
  - Determine and inform standards organizations on gaps for functionality and interoperability