EV-Grid Project Update

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EXECUTIVE SUMMARY
Name of the Project CEC EPC 14-086 - Distribution System Aware Vehicle to Grid Services for Improved Grid Stability and Reliability
Issue driving the need for the Project The California Public Utility Commission's Electric Program Investment Charge (EPIC) program supports this goal and Decision (D.) 11-12-035 provides the funding for public interest investments in applied research and development, technology demonstration and deployment, market support, and market facilitation, of clean energy technologies and approaches for the benefit of electricity ratepayers. This project supports the applies research and development, S9: Advance Technologies and Strategies That Optimize the Benefits of Plug in Electric Vehicles to the Electricity System. Plug-in electric vehicles (PEVs) are poised to become viable distributed energy resources. PEVs with integrated vehicle to grid (V2G) systems have the potential to simultaneously improve air quality, reduce vehicle operational costs and to reduce grid stress and increase grid reliability and stability. Since the ESS on board an electric vehicle allows for two- way power flow, it seems likely that the EES can be used as a mechanism to take power from or supply power to a connected grid. The Vehicle-to-Grid (V2G) concept stands on this principle. [i] Monitoring at the transformer level with control of V2G provides enhanced local situational awareness and real-time responsiveness to distribution grid conditions. The developed management and monitoring system will have awareness of load, power, temperature, current, voltage, frequency, and PEV customer constraints – information to be utilized to determine need for V2G resource. This approach provides a potentially significant solution for integration of a viable energy efficient energy storage technology into a decentralized grid structure, and with the ability to operate as a unified distributed energy resource aggregation system. Several barriers must be overcome for plug-in electric vehicles (PEVs) to become viable distributed energy resources, including: • Inconsistent data communication approaches among PEVs, • A lack of situational awareness of the PEVs relative to grid state, • Fragmented technology and standards preventing interoperability and inclusion of vehicle-to-grid (V2G) resources into applicable distribution and independent system operator grid services related programs. • In addition, there is limited availability of on- or off-vehicle V2G systems on scale from original equipment manufacturers (OEMs) because OEMs do not see their value to end customers.
Description of the technology(s) and the potential it holds for solving the issue

A Transformer Management System is being developed to ensure a consistent and reliable data communication approach between PEVs and the grid. Technologies being developed and tested thru this project include:

- Transformer Power Measurement Unit (TPMU) – measures voltage, current and phase
- Transformer Controller (TC) – a Linux based open router platform that communicates to each EVSE and PEV through a HomePlug AV adaptor, performing an energy management algorithm
- Secure Neighborhood Network through HomePlug AV (IEEE1901) – utilizes an existing network to connect to the Transformer Controller, and provides a secure IPv6 to all Gateways via the premise drop

Research Question
Can

Timeline for the Project
8/1/2015 to 6/30/2018

Project details

Overview of the Project – what is it and who is leading it?
The project develops an integrated vehicle-to-grid (V2G) system that can be tested and demonstrated to be distribution-aware, self-regulating, interoperable, secure and open as well as scalable and flexible. These real-world tests and demonstrations will provide confidence in the V2G systems that provide grid support functions and possibly influence investor owned utilities (IOUs) to add them to their Assembly Bill 2514 Storage Mandate compliance plans. The data gathered will also enable validation of cost effectiveness models through direct engagement with the IOUs' existing infrastructure and distribution networks, combined with simulated independent system operator interaction.

Led by EPRI, additional contributors include Kitu Systems, AeroVironment, FCA, E3 and Clean Fuel Connection. Additional PEV partners include Fiat-Chrysler Automotive, and Honda R&D America.

Goals for the project – what do we hope to learn/develop/solve?

- Develop and implement an end to end V2G communications system using applied open standards
- Implement dynamic V2G management use cases
- Implement data collection and performance analysis
- Assess the cost/benefit for the customer, the utility and CA at a whole

Approach – what methodology is being used?

A randomized driving pattern was created for 5 EVs (based on data from National Travel Survey)
- Chevrolet Bolt used for EV parameters
- Charging is available at work and home but no public charging

Objective function is to minimize:
- Customer bill (if run in customer control mode)
- Utility costs (Utility control mode)

Key assumptions
–For V2G cases both work and home are V2G compatible
–Assumed when at work or home, all EVs plugged in for the full duration
–No restrictions on SOC or number of battery cycles per year

Project Participants – who is involved in the development and testing of this solution?
Kitu Systems, AeroVironment, FCA, E3 and Clean Fuel Connection. Additional PEV partners include Fiat-Chrysler Automotive, and Honda R&D America.

Phases of the Project (Tasks)

Task1: General Products (PM and Planning)

Task 2: Requirements, Architecture and Design
The goal of this task is to create a set of balanced requirements, system architecture, use cases and design that enables development of end-to-end open-standards-based V2G system communications and control to synthesize DSO and local transformer-aware grid services

Task 3: Technology Development
The goal for this task is to create an end-to-end system with open standards communications and interfaces comprising an ISO simulator, DSO interface with a detailed distribution system model, aggregator, transformer monitor-integrated local controller utilizing an EVSE from AeroVironment and a V2G capable PHEV from Via Motors. The EVSE will be retrofitted with control hardware and software required to communicate with on-vehicle inverter (Subtask 3.4 below). The PHEV from Via Motors with on-board inverter will be leveraged from an ongoing EPRI-managed DoE PHEV program, and will be added with software (Subtask 3.3 below) that enables it to communicate with the EVSE.

Task 4: Deployment, Test and Data Collection
The goals of this task are to commission the complete system at two test sites, test in stages the different algorithms and features developed in the development phase for each test sites, and collect data from the performance evaluation of distribution grid and ISO-aware V2G system that is safe, interoperable and outage-immune.

Task 5: Assessment of Incremental Value from V2G Services
The goals of this task are to enhance existing valuation models for storage to include V2G functions, determine distribution avoided cost model using detailed circuit analysis, and assess value of distribution services provided by V2G type system.

Task 6: Evaluate Project Benefits
The goal of this task is to report the benefits resulting from this project. This will include two tasks - one that is mandatory (Project Benefits) and another that informs the Project Benefit analysis.

Task 7: Technology/Knowledge Transfer Activities
The goal of this task is to develop a plan to make the knowledge gained, experimental results, and lessons learned available to the public and key decision makers.

Current Phase
Project is completed.

MARKET POTENIAL

Target Audience – who is this solution being developed for?
Ratepayers and systems operators in CA

Potential Benefits – if the technology is adopted by the target market, what is the perceived long-term benefit?

- Improved grid reliability by being able to provide ancillary services at the aggregated level by combining V2G enabled vehicles' charge and discharge profiles that are locally and Distribution System Operator (DSO) - will alleviate localized hotspots.
- Balance the "Duck Curve" through bidirectional power flow capability
- Lower costs for ratepayers due to extensible and scalable V2G systems that cost less to implement
- V2G systems will allow grid operators to reliably use energy storage capacity that has been procured by the customer instead of the utility
- Improved air quality, lower GHG emissions
- Advanced development of a grid integrated V2G aggregation control system will lead to technological breakthroughs to overcome barriers to the achievement of the State of California's statutory energy goals.

Potential Market Challenges – what market actors or factors currently exist that may affect adoption?
There are several potential market challenges that will require California stakeholders interested in bringing EV to Grid applications to market.

Commercialization Challenges:

1. Acceptance and adoption of J3072 for utilities for application to Rule 21 interconnection requirements
2. Route to commercialization requirements -
   a. An alternative route – J3072 adoption by UL
   b. Require a certification process of J3072 adoption (NEC 2017 states EVSE is to be listed and marked as bi-directional -vehicle and listed EVSE should be tested and certified as compatible. No UL mark required on the vehicle)
3. Technology Issues
   a. Capability of On-Vehicle V2G inverters to meet Rule 21 revisions to incorporate technical requirements for Phase 2 Smart Inverter Communications and Phase 3 Advanced Inverter Functions.
   b. Level incorporated into IEEE 1547
   c. Synchronization is required between different OEM vehicles due to local grid voltage and frequency

Delivery Channel – which key delivery channels have been identified? Have any been engaged to date? What known opportunities or challenges currently exist?

- Charging station manufacturers
- Electric utilities – programs that incentivize smart chargers and/or TOU rates

CURRENT PROJECT PROGRESS

What has been accomplished? What have we learned?

Objectives	Accomplishments	Learnings	Gaps to Scale Implementation
Develop and implement end to end open standards-based V2G communications system	Validated end to end interoperability and application of V2G SAE and IEEE 2030.5 standards	J3072 requirement for utility adoption – compatibility certification with UL marked bi directional AC EVSE	Defined SAE J3072 Interoperability Certification body requirements and harmonized UL/SAE labeling
Implement dynamic V2G management use cases	TMS automated energy management capability implemented – supports interaction with DSO / ISO grid service requests	Effective for residential Transformer energy monitoring for constraints due to load and stress conditions – community aggregation application	Transformer Management System software can be integrated at any edge of the grid node – transformer, DMS, DERMS or Facility EMS
Data collection and performance analysis	Simulated data verifies algorithmic functionality – Demo data collection ongoing	Local site electrical integration evaluation required to identify transients affects – further research required	Implement more powerful 'edge of the grid' computing tech
Assess cost/benefit – customer, utility, and societal perspectives	Positive value proposition for EV owners (5X V1G)	The preliminary assessment makes for a strong case for creating incentive structures for V2G	Define, verify and validate through customer participation incentive mechanisms that are viable and acceptable to customers to maximize participation, along with cost analysis for additional hardware on vehicles
Define and implement on-vehicle V2G converter and integrate with grid power and communication systems	Integrated grid-tied bidirectional charger and J3072 client control module with on-vehicle battery and controller	System integration revealed grid interaction both in terms of compatibility, interconnection requirements and a need to define clearer electrical integration standards	Define electrical grid integration and compatibility requirements for on-vehicle inverters (or align them with the smart inverter requirements), including testing and interoperability protocols.

ADDITIONAL LEARNING OR OPPORTUNITIES AS A RESULT OF THIS PROJECT?

Have any unexpected or additional opportunities been identified during this project?

POSSIBLE NEXT STEPS FOR THE ADVANCEMENT OF THIS TECHNOLOGY

Any additional comments:

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[i] *(PDF) Integration of the Vehicle-to-Grid Technology*. Available from: https://www.researchgate.net/publication/281581362_Integration_of_the_Vehicle-to-Grid_Technology [accessed Jul 26 2018].