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Open Vehicle-Grid Integration Platform

Systems Approach to Standards and Interoperability

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ABSTRACT

This public release document provides a definition of the development strategy for the Open Vehicle-Grid Integration Platform (OVGIP) and the emphasis on the adoption of interoperable standards and industry application programming interfaces. These standards and interfaces will ensure accessibility and connectivity between all stakeholders involved in providing and managing energy to Plug-in Electric Vehicles (PEVs). It enables managing PEVs and charging infrastructure in a grid-friendly manner, and also provides benefits to PEV owners by allowing them to avail themselves of utility incentives, while also enabling ratepayer benefits through improved grid capacity utilization. This Platform has been a joint utility industry and automotive industry initiative led by the Electric Power Research Institute (EPRI) since its inception in late 2012, and is now in its second phase of implementation. The document describes in brief the OVGIP strategy and objectives, which are only achievable through the adoption and implementation of interoperable standards that will most effectively realize the value from PEV grid integration.

Keywords
Open vehicle-grid integration platform (OVGIP)
Interoperable standards
Application programming interface (API)
Plug-in electric vehicles (PEV)
Charging infrastructure

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1
BACKGROUND

The Electric Power Research Institute (EPRI) is a 501(c)(3) not-for-profit public interest Research, Development and Demonstration (RD&D) organization dedicated to environmentally competitive generation, delivery, and end use of electricity for the benefit of society. Since the inception of Plug-in Electric Vehicles (PEVs), EPRI has been leading engagement with numerous automakers, IT developers, equipment manufacturers, standards organizations, utilities, academia, and cognizant state agencies in the research and development of Vehicle Grid Integration (VGI) technology and value-optimal solutions. EPRI endeavors to provide an objective and neutral perspective and evaluation of technologies, and seeks to develop collaborative solutions that provide the basis for open access and engagement between a multitude of viable stakeholders to achieve the comprehensive objectives and requirements for VGI technology development, implementation, and deployment.

Over the last decade, EPRI has managed RD&D programs in the arena of PEV technology evaluation and demonstration programs worth over $130M, spanning battery, charging infrastructure standards and technology as well as multiple OEM PEV demonstration and grid integration programs with Daimler, Eaton, Ford, General Motors, Fiat Chrysler Group, Odyne, Via Motors funded by US Department of Energy, California Energy Commission, Air Quality Management District, California Air Resources Board, as well as a global base of EPRI member utility organizations. At present, EPRI is involved in several California Energy Commission (CEC) EPIC-funded programs related to developing and implementing VGI technology solutions. EPRI, under CEC PON 14-310, is developing a vehicle-to-grid V2G integrated communications / control system solution utilizing open SAE and IEEE standards, and under CEC PON 15-311 is developing an open-source Demand Side Resource Integration Platform that encompasses integration of PEV smart charging and load management systems. EPRI is also involved, from its inception, in managing the development of the Open Vehicle Grid Integration Platform (OVGIP) with the OVGIP Collaboration Team consisting of multiple automakers (Ford, GM, Daimler, BMW, Toyota, Honda - with two others in the process of consideration to join) and multiple utilities, including all three California IOUs. EPRI has developed several technical reports[1],[2],[3],[4] on the attributes and progress of the OVGIP development strategy and accomplishments.

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[1] Open Vehicle-Grid Integration Platform – Unified Approach to Grid / Vehicle Integration Definition of Use Case Requirements, EPRI, 3002005994, 2015

[2] Open Vehicle-Grid Integration Platform Phase 1 Development Update, 3002004037, EPRI, 2014

[3] Unified PEV to Smart Grid Integration Approach within Automotive and Utility Industries, 3002000665, EPRI, 2013

[4] Open Vehicle-Grid Integration Platform General Overview, 3002008705, EPRI, 2016

The purpose of this brief report is to address rationale for Open Vehicle-Grid Integration Platform emphasis on uniformity on the utility side implementation through interoperability among a diversity of standard and non-standard application programming interfaces (APIs) over selecting any particular single standard for VGI system implementation. The report also clarifies the OVGIP development rationale, strategy and its attributes for enabling engagement among the key technology and market actors: the automakers, the utilities, the ISOs, and the multitude of energy management service and EVSE network providers in VGI technology development and deployment.

2
OPEN VEHICLE-GRID INTEGRATION PLATFORM DEVELOPMENT STRATEGY

The OVGIP development strategy is to address the characteristics of the framework and key regulatory issues specified in the CPUC Energy Division VGI document released March 2014. Additionally, the OVGIP is embracing the intentional development of the four categories of VGI use cases which, as stated in the document, should be implemented sequentially, starting with the relatively simple and building in complexity, and that each additional category of use cases shall build upon the regulatory framework established for prior use cases.

EPRI is supportive of the efforts and vision put forth by the California Public Utilities Commission (CPUC) to advance the development of Vehicle Grid Integration (VGI). The CPUC, in their document, proposes a framework to characterize VGI and to assist in understanding the regulatory issues affecting the use of PEVs as a grid resource. The characteristics for the framework are:

1. The capability of the resource to provide power to the grid in addition to managing its power draw;
2. The alignment of the objectives of the various actors (a vehicle owner, an electric charging station operator, and the facility at which they are located) involved with provision of power to or from the resource; and
3. The provision of grid services from an individual or an aggregation of resources.

Based on these characteristics, the CPUC defines four categories of use cases that are to allow customer vehicles to be compensated for VGI benefits from a variety of charging arrangements. The Use Case Categories are:

- Use Case Category 1: Unidirectional Power Flow (V1G) with One Resource and Unified Actor Objectives
- Use Case Category 2: V1G with Aggregated Resources
- Use Case Category 3: V1G with Fragmented Actor Objectives
- Use Case Category 4: Bidirectional Power Flow

The OVGIP Phase 2 development has identified 11 Use Case scenarios[5] that fit within the CPUC Use Case 1.2. and 3 categories. These are being coordinated with the utility participants in the OVGIP Collaboration for definition of requirements and applications to their desired VGI strategies and program initiatives.

[5] Open Vehicle-Grid Integration Platform – Unified Approach to Grid / Vehicle Integration Definition of Use Case Requirements ,EPRI 3002005994, 2015

The key issues that are impacted by regulatory considerations in the OVGIP development are

- For the appropriate regulatory authorities to define the primacy rules among different grid benefits; and
- For the utilities need to develop methods to capture and return to customers the value that VGI provides to their distribution infrastructure.

A primary issue for development is the definition of VGI wherein the description per the CPUC VGI document dated March 2014 addresses PEVs as a viable opportunity for being an individual and aggregated grid resource. The reality is PEVs are being categorized as a potential Distributed Energy Resource (DER) requiring interface with a diversity of residential and commercial building energy management systems, and energy service providers to serve as an integrated controllable mobile distributed energy storage resource. The solutions need to address the prioritization of the varied objectives between the PEV customers, the controlling infrastructure entities, the aggregators, and the energy service providers based on value for the grid and the customer. Need to define the rules of primacy for the different grid benefits, as stated by the CPUC, which are to address alignment of the fragmented objectives between the different actors involved in any particular charging arrangement. Need to achieve a clear definition of the grid service use cases, the primacy rules, and the customer and utility value based requirements to provide a path to qualify the standards, and to verify their capabilities to execute the necessary interactions between the relevant actors. Additionally, the standards have been determined based on use case scenarios that may not reflect all the requirements for a PEV customer and rate payer valued VGI structure going forward.

The key objectives for the development of the OVGIP are[6]:

- Provide an accessible common platform that will seamlessly interconnect all actors in the charging ecosystem by providing flexibility in technology choices and business applications.
- Provide uniformity of utility VGI communications utilizing utility standard interfaces/protocols.
- Prioritize PEV customer charging preferences and transportation needs for charging decisions.
- Integrate existing diverse communications technologies and protocols to ensure backward and forward compatibility that will preemptively avoid stranded investment and costly retrofits.
- Leverage individual automaker's developments in car connectivity technologies ensuring compatibility with existing and future PEVs.
- Provide evaluation and certification of interoperability among standards for VGI, including ISO/IEC15118, IEEE2030.5, OpenADR2.0b, OCPP, and yet to be defined standards

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[6] Open Vehicle-Grid Integration Platform – Frequently Asked Questions, Chhaya. S., EPRI Infrastructure Working Council Meeting, March 2016, http://www.epri.com/Documents/Infrastructure%20Working%20Council%20Meeting/Day%20Two-%20Infrastructure%20Working%20Council%20(IWC)%20Meeting%20Presentations.pdf

- Develop U.S. wide utility geographic-specific VGI application solutions.
- Provide flexibility and adaptability to be extensible and scalable for integration with Distributed Energy Resource management systems and implementation of future V2G technologies.

The design intent is to provide an adaptable and extensible platform that will enable the development of dynamically evolving PEV grid integrated energy services, programs, and technologies. The ultimate goal being to integrate PEVs as an economically viable Distributed Energy Resource (DER) that supports gird reliability, and is beneficial to both ratepayers and PEV customers.

3
DEFINITION OF THE OPEN VEHICLE-GRID INTEGRATION PLATFORM—LEADING TO STANDARDS ADOPTION

The OVGIP is defined as a network communications system solution enabling access to all VGI actors to interface and interact in the development of VGI operational and business applications. This is to be accomplished using prevailing standards based protocols and specific or common APIs that will interoperate, and are compatible with existing and evolving communications technologies. This is necessary to provide flexibility in technology choices and business applications development on the automotive manufacturers, utility and third-party provider sides. More importantly this will ensure backward and forward compatibility that will avoid stranded investment and/or costly retrofits to the existing and near term deployment of PEVs and infrastructure equipment.

The current development and implementation of VGI applicable standards is fragmented among various industry and standards groups endeavoring to address presumptive use cases and technology agendas. Two recent EPRI reports[7],[8] provide a comprehensive update on the state of the PEV infrastructure standards. There are various alliances and associations within the EVSE industry trying to achieve consensus on standard protocols for interoperability between EVSE network providers to achieve uniform EVSE customer access and interface. Standard organizations such as SAE, IEEE and IEC/ISO[9] are still in the process of developing and enhancing communication protocols, especially for wireless charging and AC as well as DC Vehicle to Grid (V2G) technologies. Standards are generally released as either Technology Information Report (TIR) or Recommended Practice (RP), and as such not systemically vetted nor universally adopted or implemented on any large scale. PEV infrastructure requirements, standards, and communications technologies are all still evolving. These considerations dictate the need for system flexibility and adaptability to address the progressive evolution of VGI value, requirements, technology, and standards.

Prevailing VGI applicable standards are OpenADR2.0b, IEEE 2030.5 (SEP2), ISO/IEC15118, and OCPP (v1.6) which individually address segments of a holistic VGI ecosystem. OpenADR2.0b and IEEE 2030.5, with DR and DER functional communications features, are the only potential end to end (end device to utility or 3rd party provider back-end) open VGI system solutions. ISO/IEC 15118 specifically provides communications between the EVSE and the

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[7] Plug-in Electric Vehicle Infrastructure Technology Update, EPRI 3002005977, 2015

[8] National Electric Transportation Infrastructure Working Council (IWC): 2015 Annual Report, EPRI 3002005970, 2015

[9] Day 2 Proceedings (See Niemninski and Halliwell segments) from EPRI Infrastructure Working Council Meeting, March 2016, http://www.epri.com/Documents/Infrastructure%20Working%20Council%20Meeting/Day%20Two-%20Infrastructure%20Working%20Council%20(IWC)%20Meeting%20Presentations.pdf

PEV, with the behind-the-PEV communications left to third-party providers (mostly proprietary, as in the case of KnGrid/RWE Mobility Demand ClearingHouse). In the case of IEC/ISO 15118, therefore, the EVSE becomes the translation point between a proprietary and open protocol and is vulnerable to 'man in the middle' type hacker attacks. It is in fact because of this reason that NIST Smart Grid Interoperability Panel could not include IEC/ISO 15118 into its Catalog of Standards (Both IEEE 2030.5 and OpenADR 2.0b are included in the catalog of standards). In addition, as currently written, IEC/ISO 15118-1 (AC charging) and 15118-2 (DC charging) are not designed to support reverse power flow (as in V2G) applications (IEEE2030.5, SAE J2847/1 and J3072 which both rely on IEEE 2030.5 currently do support V2G applications) at present. There is currently an effort underway to enhance IEC/ISO 15118-1 and 15118-2 to include reverse power flow applications, but standards-making is a multi-year development, validation and technology adoption / proliferation process to achieve scale. OVGIP is designed to be flexible and adaptable so that as and when the newer standards become available and are mature enough, they will be able to be included in the Open VGI Platform supported standards. There is the expectation these standards will evolve and new standards will be required to adapt to innovative new VGI technologies and business models. At this stage, interoperability of these standards is critical to link these important elements of the complete VGI ecosystem. There is also the need for interoperability with non-standard Application Programming Interfaces established by specific industries and companies to ensure they still provide a uniform behavior through a common interface to their operational back end systems. Interoperability is an absolute must for enabling an all-inclusive sustainable VGI system.

The OVGIP, in its current form, intends to implement and evaluate the technical merits of each grid/vehicle connectivity approach. This will enable simultaneous implementation and side-by-side comparison of existing and emerging standards in terms of their technical performance, measurement and verification capabilities, and ability to create value streams for the utilities. The expectation from all of the key participants is that the sooner the integrated ecosystem is operational in a meaningful way that allows utilities and OEMs (as well as third-party providers) to simultaneously learn the technology and business merits of a diversity of approaches (as well as identify more value-added applications), the sooner they can include these technology choices into their future product designs. Furthermore, real-world evaluation results will allow the standards community to fine-tune the standards and revise them to better address real-world technology and business considerations. It is therefore imperative that flexibility, adaptability and speed of execution are emphasized (as is the case with OVGIP) versus rigid adherence to a single protocol, unchangeable compliance and then waiting for this 'perfect' standard to appear, when its in-field application alone can ascertain its validity.

The OVGIP purpose is to collect experiential data derived from actual pilots of the grid service use cases within a variety of utility jurisdictions that will provide a basis for determining the commercial benefits of VGI to utilities, manufacturers, and customers, as well as ratepayers. The data can be used to further inform implementable technical, commercial and regulatory approaches and decisions. Data analytics will assist Distribution System Operators (DSO) and Independent System Operators (ISO) in creating grid service programs that will maximize the value from using PEVs as a grid resource.

The results from the OVGIP VGI use case implementation and evaluation will provide empirical data to influence the adoption of standards that most effectively support the commercial deployment of VGI initiatives. Additionally, the results may identify gaps in specific standards

that will need to be addressed, inclusive of business and regulatory implications that will influence technical requirements.

It is noted that each industry is endeavoring to address the development of standards for interactive grid integration of their VGI related products and services. Determination of appropriate standards requires implementation and verification of the individual industry applied protocols against the requirements of the VGI use cases and qualification to execute each actor's responsibilities. It is evident that due to the dynamic nature of a unified communications network system and the complexity for integrating and synchronizing multiple stakeholder objectives and priorities, there is no single standard that will suffice. The determination needs to be about what are the most effective set of interoperable standards.

4
END TO END VGI COMMUNICATIONS STANDARDS

As mentioned earlier, Only IEEE 2030.5 and OpenADR2.0b are standard protocols that define end to end communications between the utility or aggregator and the PEV, and in some cases between utility or third party to the EVSE depending on the infrastructure owner's energy management requirements. It should also be noted the CPUC Smart Inverter Working Group selected IEEE 2030.5 as the recommended standard protocol for communications between the utilities and manufacturer's grid tied smart inverters for managing distributed energy resources. The reasoning being that IEEE 2030.5 has established certifiable DER functional feature sets that can provide direct integration between utilities and DER inverter systems (including PEVs). Also these protocols are easily leveraged through the use of the existing PEV communications data transfer technologies.

In the case of ISO/IEC 15118, it is not an end to end protocol or standard. The standard document for ISO/IEC 15118-1 states "All connections beyond the SECC (Supply Equipment Communications Controller in the EVSE) and method of message exchanging are considered to be out of scope..." (Draft 2012 Version, Part 1, Section 1). This means that the ISO/IEC 15118 protocol only applies to communications between the EVSE and the PEV. All methods of communications beyond the EVSE, with and between secondary actors (Utility, Demand Clearing House, eMobility Operator, EVSE Operator, Fleet Operator, etc.) are not part of defined standard and presently implemented using proprietary protocols. It would therefore be a misrepresentation of fact to state or imply that ISO/IEC 15118 is a VGI system communications standards solution.

However, it is acknowledged that ISO/IEC 15118 has merit as a method for communicating between the EVSE and PEV, and is therefore included in the development of the OVGIP and evaluated as one of the options to support VGI communications system requirements, with the Open (and not proprietary) VGI Platform taking the role of providing the utility to EVSE interface, along with interfaces with all the other market and technology actors.

5
ASSOCIATION

Association predominantly means pairing a specific PEV charging event from the grid with a specific utility billing/metering account. This is presently being required for some but not all utility Demand Response programs and is not intended to be required for PEV aggregated DR programs.

The capability for association is presently achieved through a PLC (HomePlug GreenPHY or IEEE1901.2 or SAE J2931/4) link between the conductive EVSE and PEV. This is an enabling technology that is used by multiple standards – both IEC/ISO 15118 and IEEE2030.5 (as well as SAE J2847 series of standards and J3072). It must be emphasized that association is not dependent on any data messaging protocol or software such as ISO/IEC 15118 standard protocol. IEEE 2030.5 uses the exact same method for association which was implemented and verified in the DOE sponsored Chrysler RAM PHEV commercial demonstration program as well as DoE Commercial PHEV program. Every DC charging equipped EV has PLC on-board for EVSE communications. SAE J2931-4 specifies the use of HomePlug GPHY PLC and includes the requirements and methodology for association, but is protocol agnostic. ISO/IEC 15118-2 also stipulates the use of HomePlug GPHY PLC which is the result of a harmonization effort for DC Fast Charge communications control between ISO/IEC and SAE

It has been stated the OVGIP is primarily only using telematics and cannot provide association. Firstly, it is a mis-statement that OVGIP is primarily a telematics based communications platform, and this was demonstrated live during the October 16, 2014 Phase 1 demonstration of the platform at SMUD. The OVGIP is a system platform that will adapt and implement the ability to communicate over multiple physical transfer mediums such as PLC, Wi-Fi, cellular, 4G wireless, and communicate via a number of open and proprietary protocols as the EV and charging infrastructure technologies evolve. Logic and understanding of communications networks prescribes that the communications path will involve multiple data transfer mediums. Secondly, there are three issues that should be acknowledged in regards to association:

1. The specific requirements and needs for PEV to meter association are not well defined nor yet determined by the utilities; and
2. Alternatives to PLC for association will need to be innovated with the onset of wireless charging which does not provide any physical connection between the EVSE and the PEV.
3. The association via PLC implies a physical, conductive electrical connection between the EVSE and the EV. As the industry continues to introduce wireless charging, new means of association will need to be devised if required to incorporate wireless charging technologies. Wireless charging is governed by SAE J2954 which has just been released as a TIR.

In regards to requirements and need for association, indications are that utilities are taking the approach to measure and verify DR at the premise (residential and commercial building) primary meter level without any requirement to identify the PEV or to measure it independently from the premise meter. Utilities are also indicating the establishment of incentive based pay for

performance DR programs based on compliance to notifications to not charge during specified periods of the day. Verification will be provided by the vehicle telemetry verifying compliance.

The CAISO is developing guidelines and rules to establish Distributed Energy Resource Providers for aggregating DER (including PEVs) as a biddable energy resource for ancillary and regulation services. The aggregator or DERP is responsible to determine the M&V requirements for each sub-resource. The measurement and verification requirements are still being evaluated and may consider using on-vehicle telemetry for verifying PEV aggregated capacity.

PG&E is developing a distribution level aggregated energy capacity control program. PG&E intends to contract with OEM to provide access to prescribed aggregated energy capacity within specified sub lap areas for DR and other load management programs as part of their resource adequacy requirements. The OEM is responsible for direct control of the energy resources utilized to guarantee the capacity threshold is met, which can include PEV V1G and/or V2G capability. Driver participation is measured based on the vehicle telemetry.

The OVGIP development program includes the objective for determining each use case's related association requirements, and further acknowledges the need to conduct investigation of wireless alternatives for association.

6
SUMMARY

VGI requires a communications/control network that interconnects PEVs with predominantly four levels of energy resource management: residential, commercial/workplace, utility/distribution, and ISOs/aggregators. The network needs to integrate the contractual relationships and interfaces between the primary actors involved in executing the PEV grid service use cases, and to incorporate the business rules that apply to each level of energy resource management. This is to enable the ability to identify and prioritize which program and resource control entity has precedence.

Unification of the communications networks is a necessity. Unification consists of ensuring interoperability between applied industry standards, development of common business rules, and uniformity of the PEV Driver interface - seamless automation is the objective

The cost benefit and revenue value of each VGI use case/scenario needs to be determined and appropriate business rules applied to ensure commercial sustainability. This may involve determination of regulations to ensure enforcement of the business rules and each actor's compliance requirements. The business case for VGI is still an unknown for many of the stakeholders.

The OVGIP is to unify VGI communications by providing a common bridge from the PEVs to all stakeholders. It will adapt present and future technical and business requirements through interoperability among standard and non-standard interface and communications protocols. It is to provide flexibility to address the diversity of data and functional requirements from multiple utilities, energy service providers, wholesale energy market aggregators, and energy management system owners. Most importantly, is the OVGIP focus on prioritizing customer preferences and needs, and implementation of a constant customer interaction which is seamless, transparent, and automated.

No single standard will be able to address the complexity of all the diverse technical and business requirements that are evolving from the various levels of stakeholders. OVGIP is providing an open non-discriminatory systems approach to engage the implementation of the prevalent standards, and to provide a method to assess the suitability of which standards best enable VGI functionality and benefits.

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