Smart Charging 101

The Basics of Managed Electric Vehicle Charging

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Technical Update, December 2018

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ABSTRACT

As the population of plug-in electric vehicles grows, it is anticipated that smart charging implementations, the controlled and managed charging of electric vehicles, will proliferate. Utility personnel need to be up to speed on the various approaches and communications paths that are used to enable smart charging. This report provides a high-level overview of smart charging including describing the actors involved, the communications links and their structure, typical protocols used, and the technical and business requirements needed to implement and support the communications links.

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EXECUTIVE SUMMARY

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PRIMARY AUDIENCE: Utility personnel involved in transportation electrification seeking to better understand smart charging of electric vehicles.

SECONDARY AUDIENCE: Utility planners that would like to better understand how electric vehicles can be managed.

KEY RESEARCH QUESTION

What is the purpose of smart charging and how is it implemented at a high level?

RESEARCH OVERVIEW

This document provides a high-level overview of electric vehicle smart charging – its definition and implementation.

KEY FINDINGS

- A complex set of players are involved in electric vehicle charging.
- Assessing the benefits of smart charging is complex.
- Smart charging is primarily about using geographically dispersed information to manage charging of individual electric vehicles.
- The goals of a smart charging implementation greatly influence the structure of information flow.
- There are many approaches to smart charging with implementations tightly tied to the process goals.

WHY THIS MATTERS

As populations of electric vehicles grow, it is anticipated that the need for smart charging will increase. For utility personnel, understanding the implications of smart charging ecosystems will be crucial to maintaining system reliability, safety and costs.

HOW TO APPLY RESULTS

This report should provide the reader a basic understanding of smart charging and the various methods used to implement smart charging systems. This should be useful as utilities consider electrification of their own fleets and as they act as a trusted energy advisor for their customers.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- This report contains a bibliography of EPRI reports related to smart charging for individuals that want to develop a deeper understanding of smart charging technologies and implementations.
- This document lays the ground work for understanding smart charging and should have better prepare utility personnel to be knowledgeable and informed as they engage with various stakeholders in the electric vehicle space.

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PROGRAM: Electric Transportation, P18

ACRONYMS AND ABBREVIATIONS

BACNET – communication protocol developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) - A data communication protocol for building automation and control networks.

DER – distributed energy resource

DERMS – distributed energy resource management system

DRMS – demand response management system

EMS – energy management system

EVSE – electric vehicle supply equipment – common industry term for a charge station

IEEE – Institute of Electrical and Electronic Engineers

IEC – International Electrotechnical Committee

ISO – International Standards Organization

MODBUS – communications protocol for hardware control; The Modbus Organization

OCPP – communications protocol developed by the Open Charge Alliance - the Open Charge Point Protocol

OpenADR – communications protocol for demand response and distributed energy resource management; OpenADR2.0b is prevalent; Open ADR Alliance

PEV – plug-in electric vehicle

SAE – Society of Automotive Engineers

WiFi – wireless communications standard; IEEE 802.11

XFMR - Transformer

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1
SMART CHARGING BASICS

The basic function of an electric vehicle charging system is to immediately charge at plug-in at the highest available power level that the battery prefers. For many applications, this default behavior is sufficient and ensures that the vehicle is fully charged in the shortest possible time frame. While this represents the most convenient situation for electric vehicle drivers, there may be other factors that make this behavior undesirable. Smart charging focuses on altering this default behavior based on information that is likely to be external to the vehicle.

Prior to defining smart charging, it is worth noting that all electric vehicle charging is managed at the vehicle level. The vehicle has an on-board system, referred to as the battery management system, that oversees charging and discharging of the vehicle's battery. The battery management system is focused on preserving the health of the battery and ensuring safe charging and discharging. Based on this, while an external system can request that a vehicle charge, it cannot force a vehicle to accept charge. Similarly, while an external system can request that a vehicle-to-grid capable vehicle discharge to the grid, it cannot force the vehicle to do so.

Smart Charging Defined

For the purposes of this report, it is important to carefully define Smart Charging[1]:

> ***Smart Charging*** *is - the* ***managed charging*** *of an electric vehicle from a* ***point of control*** *using* ***information*** *that resides within and/or is external to the vehicle used to achieve some desired* ***control result****.*

It is essentially, the aggregation and processing of information from multiple sources to achieve managed charging of a plug-in electric vehicle. Smart charging can vary from simple use of on-board vehicle programming tools, to complex control functions implemented external to the vehicle and using information from a broad range of sources.

Key terms that were highlighted in smart charging definition above:

> ***Managed Charging*** *– is charging of an electric vehicle based on control of or response to external and internal vehicle conditions, such as grid status, service transformer loading and vehicle energy needs. Managed charging implies consideration of conditions beyond those of the on-board vehicle systems.*
>
> ***Point of Control*** *– is where information is aggregated to make control decisions. It could reside on-board the vehicle, or at some external location such as the electric vehicle supply equipment, a building energy management system, a utility's control center, or on a third-party server ("in the cloud"). Modern communications have abstracted the need for a single physical location for the point of control.*

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[1] *PEV Charging Infrastructure Technology Update.* EPRI, Palo Alto, CA: 2015. 3002005977.

__Information__ - is the knowledge unique to some element of the charging system. Examples are: The utility has information on the state of the electric grid; the electric vehicle has information on the amount of energy it needs to complete a charging session; electric vehicle supply equipment knows what time a vehicle was connected; an electric vehicle service provider has consumer charging preference information.

__Control Result__ – is the smart charging implementation functional result. Examples are: Having the vehicle curtail charging in response to a utility demand response load control event; limiting the total power consumption at a facility to mitigate demand charges; managing the total power consumed at a residential transformer. Smart charging mainly points to modulating charging demand without necessarily impacting the energy sent to the vehicle battery

The ultimate outcome of smart charging is a control result which would be designed to bring a benefit, or a set of benefits to one or more actors in the electric vehicle charging ecosystem. How this benefit is manifested and how it is distributed to the various stakeholders can be very complex. Potential beneficiaries of smart charging are the utility, the vehicle owner, the charge station host, a building owner, a third-party aggregator, a fleet manager, or an electric vehicle service provider.

Any smart charging activity must be backstopped by preserving the primary function of the electric vehicle – transportation.

Information is the Key to Smart Charging

As noted in the definition of smart charging, information is the critical element for any smart charging scenario. The various actors that make up a charging ecosystem will each have unique information that might be needed or useful to implementing a control algorithm. Figure 1-1 illustrates a set of actors that includes: the utility, energy management systems (EMS), third party aggregators, distributed energy resources (DER), the local transformer (XFMR), the plug-in electric vehicle (PEV), and the electric vehicle supply equipment (EVSE). A key challenge is that this information is likely to be held by the actors on custom systems and in custom formats.

Communications enables information flow between the various actors. Access to added information allows for more complex control algorithms to be developed. Note that any system that relies on remote communications of information must consider loss of communication and the information that communications provides as control algorithms are developed. It should also be noted that, just because information exists, that does not mean the party that holds the information is willing to share it.

Smart charging applications are generally developed for specific scenarios such that, only a limited subset of the information "bubbles" shown in Figure 1-1 would be used. Obtaining and moving information represents cost – for software and hardware interface development; and for communications channels and the hardware that must store and retrieve the data. This must be considered when developing a cost/benefit analysis for a smart charging implementation.

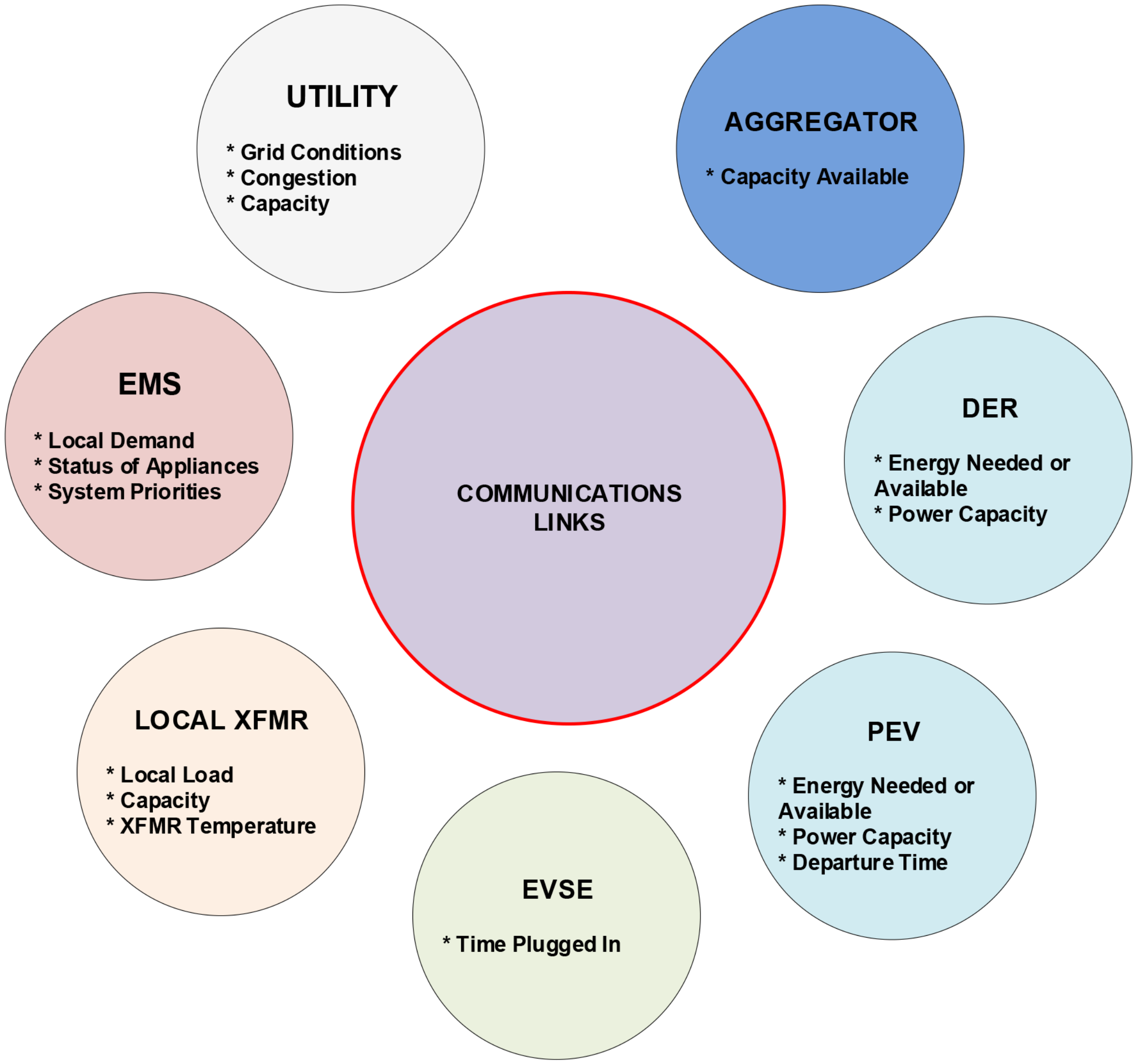

Figure 1-1
Information Resides at Many Discrete Locations

Methods of Charge Control and Data Flow

There are two primary methods to control an electric vehicle's charging: a) control via the electric vehicle supply equipment; b) control direct to vehicle. Method a) is the most commonly used today – the charge station is stationary, has a known location on the grid, and can manage the electric vehicle's charging using the standard charging interface described in the Society of Automotive Engineers charging standard. Method b) requires a communications path to the vehicle, either through the charging interface or through the vehicle's telematics system. A telematics system is a communications link direct to a vehicle that is proprietary to each auto manufacturer and is generally provided via a cellular telephone data link.

It should be noted that most electric vehicles provide the driving consumer tools that allow simple management of vehicle charging, such as in-vehicle charging timer screens and phone app-based vehicle programming tools. Electric vehicle supply equipment is also available that offers charging timers and remote management tools.

Figure 1-2 shows a high level logical view of some the potential communications paths in the smart charging ecosystem. As this is a simplified diagram, there may be intermediate layers or players in an actual smart charging implementation. Note that where smart charging is implemented by a utility, electric vehicles are likely to be one part of a larger controlled device space.

While the utility is shown as a single block in the diagram, the various communications links may connect to a variety of utility owned systems, such a demand response management system (DRMS) or distributed energy resource management system (DERMS).

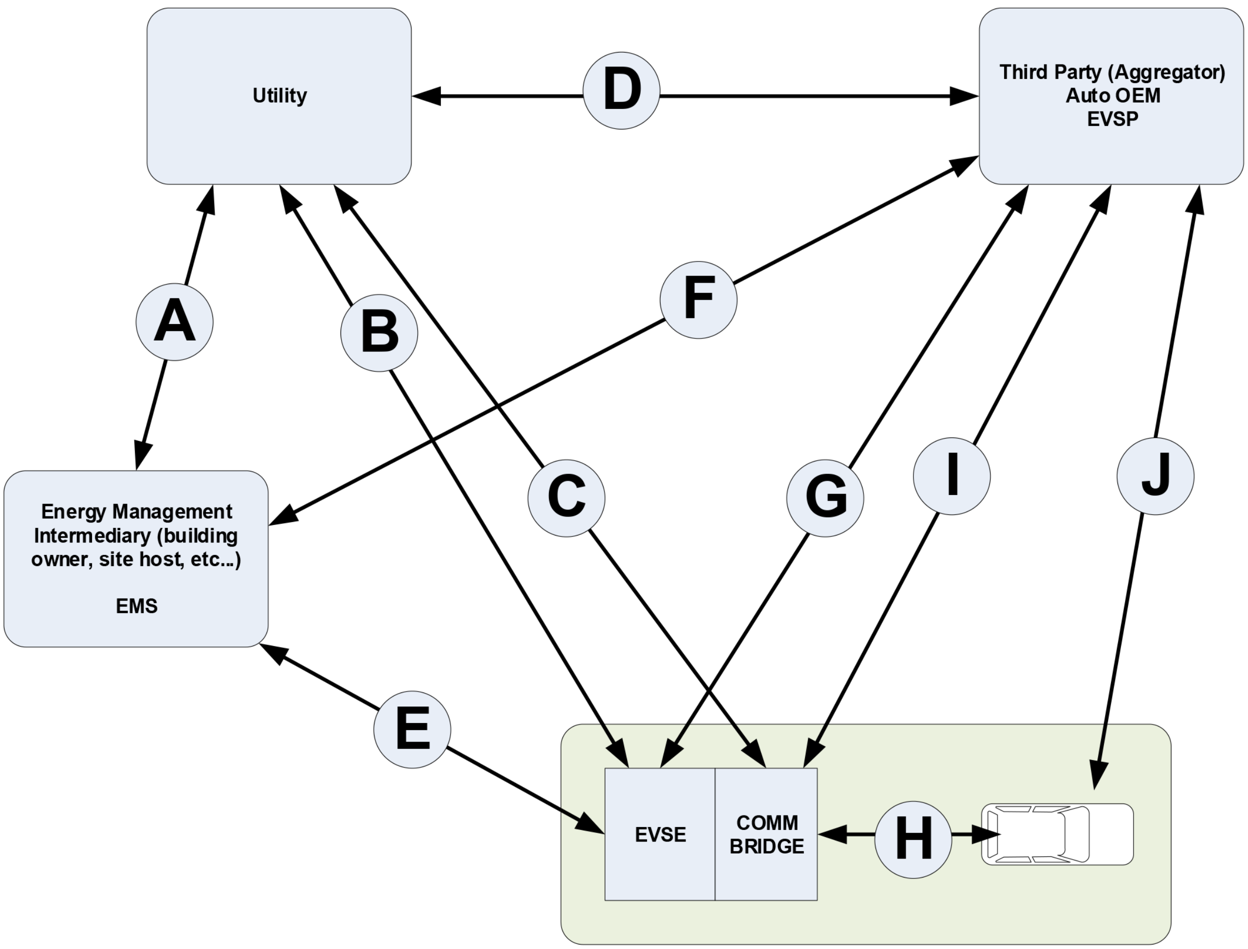

Figure 1-2
Diagram of Logical Data Flows for Smart Charging Control

Details for each of the communications paths (letters correspond to the bubbles in Figure 1-1):

A) This represents a utility connection to a local energy management system. Generally, the utility provides only information and the energy management system makes control decisions. The energy management system may provide compliance or energy information back to utility. This would typically be a connection made through an AMI system or an internet-based connection. This link will typically carry encrypted traffic, organized as "tunnels" to other links, such as to a cellular carrier or to 3rd party service providers. Common protocols include IEEE 2030.5 and OpenADR2.0b. Smart charging control via this path would require that the EMS manage the electric vehicle supply equipment or the vehicle directly, relying on links E and possibly H.

B) This path represents a utility connection direct to the electric vehicle supply equipment. This would require that the electric vehicle supply equipment support remote control operation with a function set compatible with the utility's needs. This would typically be an internet-based connection. Common protocols would include IEEE 2030.5, OpenADR2.0b, OCPP and proprietary.

C) This path represents a utility connection direct to the electric vehicle via a communication bridge in the electric vehicle supply equipment. This would require that the electric vehicle support remote control operation based on *SAE J2847/1 Communication between Plug-in Vehicles and the Utility Grid*. This link from the utility would typically be an internet-based connection. The bridge device would bridge the internet data from the utility to a power line carrier-based communications link to the electric vehicle without decoding the message traffic. The protocol would be IEEE 2030.5. It should be noted that there are no production vehicles in the market today that support J2847/1.

D) This path represents a utility connection to a third-party system that is providing aggregation of loads. This would usually involve a contractual commitment from the third party to provide a guaranteed level of service to the utility with utility providing compensation or a penalty depending on level of service provided. Note that the third party could be an auto OEM. This path is primarily a means of information flow and not necessarily control. The typical communications link would be internet based using IEEE 2030.5 or OpenADR2.0b protocols. This is the data path that would be used for EPRI's Open Vehicle Grid Integration Platform.

E) This path represents a local energy control system's connection to the electric vehicle supply equipment. This may be a facility level controller (such as at an industrial plant) or a home owners energy management system. This device's goal could be to minimize cost or energy use or to manage the timing of energy consumption with decisions based on input from local and external conditions. Information from the utility, such as current and future energy pricing may be used in the control process as represented by logical path A. The energy management system could stop or curtail electric vehicle charging as needed to meet control goals. The end user of the charging equipment may not have "opt-out" control in this situation. This is typically an ethernet, digital subscriber line over phone, cable system, embedded wireless modem to a cellular network or wi-fi based connection using IEEE 2030.5 or a proprietary protocol.

F) This path represents a third party to energy management system connection. If utility communications were involved, it would come via path D to the third party. The third party would have a contractual agreement with energy management system owner as to control functionality, compensation and penalties for access to the electric vehicle supply equipment.

G) This path represents a third party to electric vehicle supply equipment connection. If utility communications were involved, it would come via path D to the third party. The third party would have a contractual agreement with electric vehicle supply equipment owner as to control functionality, compensation and penalties for access to the electric vehicle supply equipment.

H) This represents the communications path from the electric vehicle supply equipment to the electric vehicle. Two competing, thought mostly aligned, protocols address this link – SAE J2847/1 and ISO 15118. Both protocols use a HomePlug Green PHY power line carrier communications signal passed over a wire in the charging interface to the vehicle. While the SAE protocol does address communications back to a utility or other party, the ISO 15118 protocol addresses only electric vehicle supply equipment to electric vehicle communications. ISO 15118 is also working to include "plug and charge" capability where the vehicle can identify itself to a charge station without user intervention. It is not clear if SAE will also include this capability in future versions of J2847/1.

J) This path represents a direct link from an auto manufacture to the electric vehicle. These types of systems are currently deployed by most auto manufacturers and allow for control and information flow to a consumer's vehicle and are referred to as telematics systems. Most of these systems do not address vehicle charging control and require that the vehicle owner pay an annual fee to maintain the communications link. Note that these systems are shared with conventional vehicles in an auto maker's fleet.

I) This path represents a proxy path proposed by auto manufacturers to allow for control of the vehicle without the need for a telematics communications path to the vehicle. The path allows the auto maker to maintain control of information flow and electric vehicle behavior and can provide for data processing and decision making off-board the vehicle. This would likely be an internet based link using OCPP, OpenADR2.0b or a proprietary protocol.

Table 1-1 provides an overview of each of the paths described in Figure 1-2.

Table 1-1
Summary Logical Communication Paths

Path	Communications Protocol	Communications	From-To	Standards Body or Industry Alliance
A	IEEE 2030.5; OpenADR; Proprietary	Cellular; Internet; Wireless Mesh; AMI; Fiber to Home; proprietary	Utility to EMS	IEEE, OpenADR Alliance
B	IEEE 2030.5; OpenADR; Proprietary	Cellular; Internet; Wireless Mesh; AMI; Fiber to Home; proprietary	Utility to EVSE	IEEE, OpenADR Alliance, Open Charge Alliance
C	IEEE 2030.5; Proprietary	Cellular; Internet; Wireless Mesh; AMI; Fiber to Home; proprietary	Utility Direct to Vehicle	IEEE, proprietary
D	IEEE 2030.5; OpenADR; Proprietary	Cellular; Internet	Utility to 3rd Party	IEEE, OpenADR Alliance
E	MODBUS; IEEE 2030.5; BACNET; Proprietary	Local Network; WI-Fi; Wireless Mesh	EMS to EVSE	IEEE,
F	IEEE 2030.5; OpenADR; Proprietary	Cellular; Internet; proprietary	3rd Party to EMS	IEEE, OpenADR Alliance
G	IEEE 2030.5; OpenADR; OCPP; Proprietary	Cellular; Internet; proprietary	3rd Party to EVSE	OpenADR Alliance; Open Charge Alliance
H	SAE 2847/1; ISO 15118	Power line carrier - HomePlug Green PHY	EVSE to Vehicle	SAE; ISO/IEC
I	IEEE 2030.5; Proprietary	Cellular; Public Internet; proprietary	3rd Party Direct to Vehicle	IEEE; None
J	Proprietary	Telematics (Cellular)	Auto maker to vehicle	SAE

What's in a Communications Path?

As noted previously, each communications path highlighted in Figure 1-1 represents a complex list of parameters that define that link. These include not only the technical parameters but also business and contractual agreements between the connected actors. This section looks at some of the elements that go into defining a communications path.

A key best practice in developing a smart charging ecosystem is to limit the data transferred over any given communications link to only that which is needed to accomplish the smart charging task. This limits potential unwanted data exposure, either accidental or through the nefarious activities of hackers.

Technical Requirements and Parameters

The arrowheads in Figure 1-1 represent interfaces where an external communications path terminates to an actor's system. These may be hardware interfaces, web-based application programming interfaces (APIs), or other forms of connectivity. These interfaces must be compatible with the communications link and be sufficiently documented to enable the actors to properly interface to the them.

Note that an API is a structured, documented connection point where data and communications from another cloud service are coupled between clouds. Note that "clouds" are physical collections of computers (servers) located in a data center. These generally involve a Service Level Agreement and require tightly controlled security to complete the connection.

For each of the communications paths identified in Figure 1-1, technical requirements will be needed for:

- The communications medium (radio, wired, fiber optic)
- The communication method (transmission method, modulation)
- The communications technology (ethernet, Zigbee, z-wave, wi-fi, Bluetooth)
- The communications protocol (OCPP, OpenADR2.0b, IEEE 2030.5)
- Security requirements (key exchange, certificates, encryption)

Business and Contractual Requirements and Parameters

The information that moves across the communications links may include proprietary data, business sensitive data, personally identifiable information, and the like. In addition, data required to complete a link may include security related certificates and other sensitive data that the actors may wish to tightly control. While utilities in general will have very precise requirements and rules for how data is to be used and protected, particularly personally identifiable information, companies focused on technology development may take more of an ad hoc approach to data protection.

Since the smart charging ecosystem is likely to have multiple players interacting over multiple communications links, the business/contractual agreement should also cover coordination of software upgrades and security patching such that an unplanned upgrade to one system doesn't disable a communications link.

In general, business/contractual agreements, sometimes referred to as Service Level Agreements will be needed for the communications links to address:

- Data ownership
- Rules regarding data retention
- Data security requirements
- Sharing of data with third parties

- Limitations on data usage
- Protection of personally identifiable information
- Documentation of APIs
- Physical security of servers and systems
- Link reliability requirements
- Procedures for link maintenance including software and security patching and upgrades
- Required documentation

Example Smart Charging Configurations

Following are four example cases of smart charging configurations. The first case, shown in Figure 1-3, represents vehicle smart charging based on direct control of the vehicle by a third party.

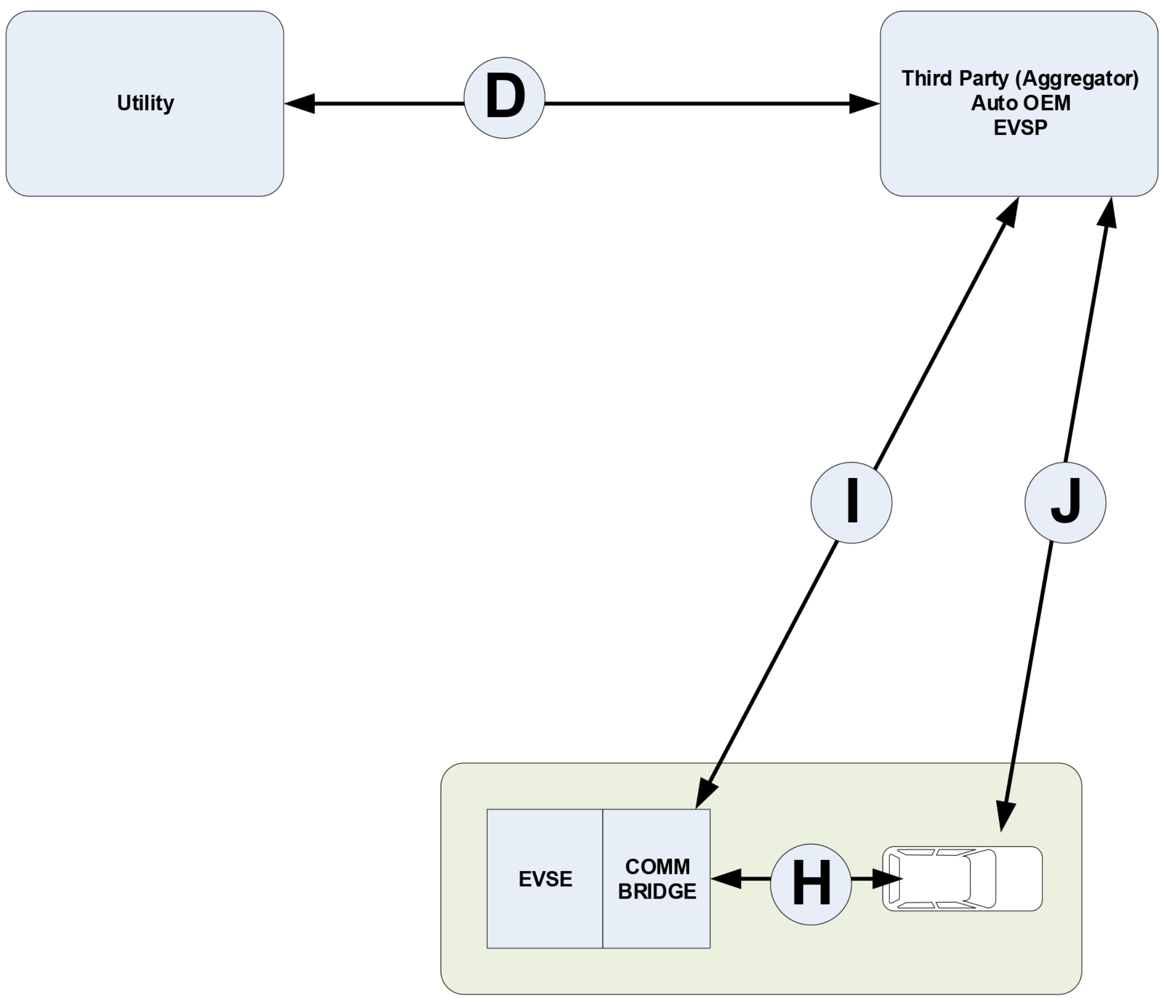

Figure 1-3
Third Party/Auto Maker to Electric Vehicle Data Flow for Smart Charging Control

In Figure 1-3, the utility communicates information about the status of the grid to a third-party server. This information is used by the third party to decide on a course of action for vehicle charging which is communicated direct to the vehicle through either path I and H or J or a hybrid of the two paths. The actual control response is decided by the third party.

The second case, shown in Figure 1-4, shows how the EPRI Open Vehicle Grid Integration Platform[2] approach to smart charging would be implemented.

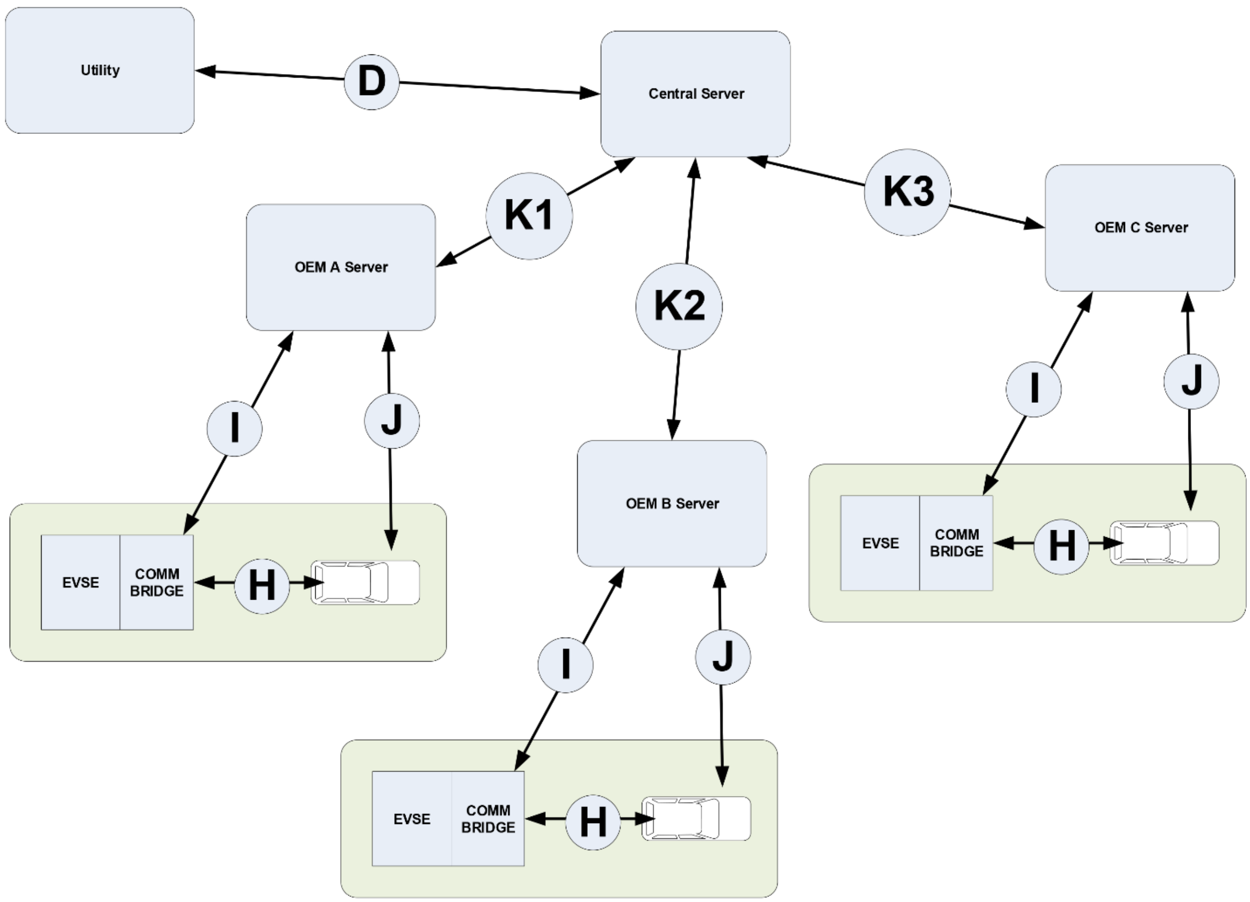

Figure 1-4
EPRI Open Vehicle Grid Integration Platform Approach for Smart Charging Control

In Figure 1-4, the utility communicates with a Central Server, a clearing house cloud service which in turn connects to each auto maker's cloud service to provide connectivity to the electric vehicles. This allows the utility to communicate to a single entity while having access to multiple brands of auto maker vehicles. The added communications links, K1 – Kn are

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[2] *Open Vehicle-Grid Integration Platform – Unified Approach to Grid/Vehicle Integration: Definition of Use Case Requirements*. EPRI, Palo Alto, CA: 2015. 3002005994.

Open Vehicle-Grid Integration Platform: Systems Approach to Standards and Interoperability. EPRI, Palo Alto, CA: 2016. 3002008866.

Open Vehicle-Grid Integration Platform: General Overview. EPRI, Palo Alto, CA: 2016. 3002008705.

Unified Plug-in Electric Vehicle (PEV) to Smart Grid Integration Approach within Automotive and Utility Industries. EPRI, Palo Alto, CA: 2013. 3002000665.

proprietary APIs provided by each auto maker under a contractual agreement with the provider of the Central Server. Auto makers prefer this arrangement as it allows them to remain “in the loop” with their customer and to provide the service in a branded fashion.

The third example, shown in Figure 1-5, represents a case where a utility works with a third-party Electric Vehicle Service Provider[3] to implement smart charging.

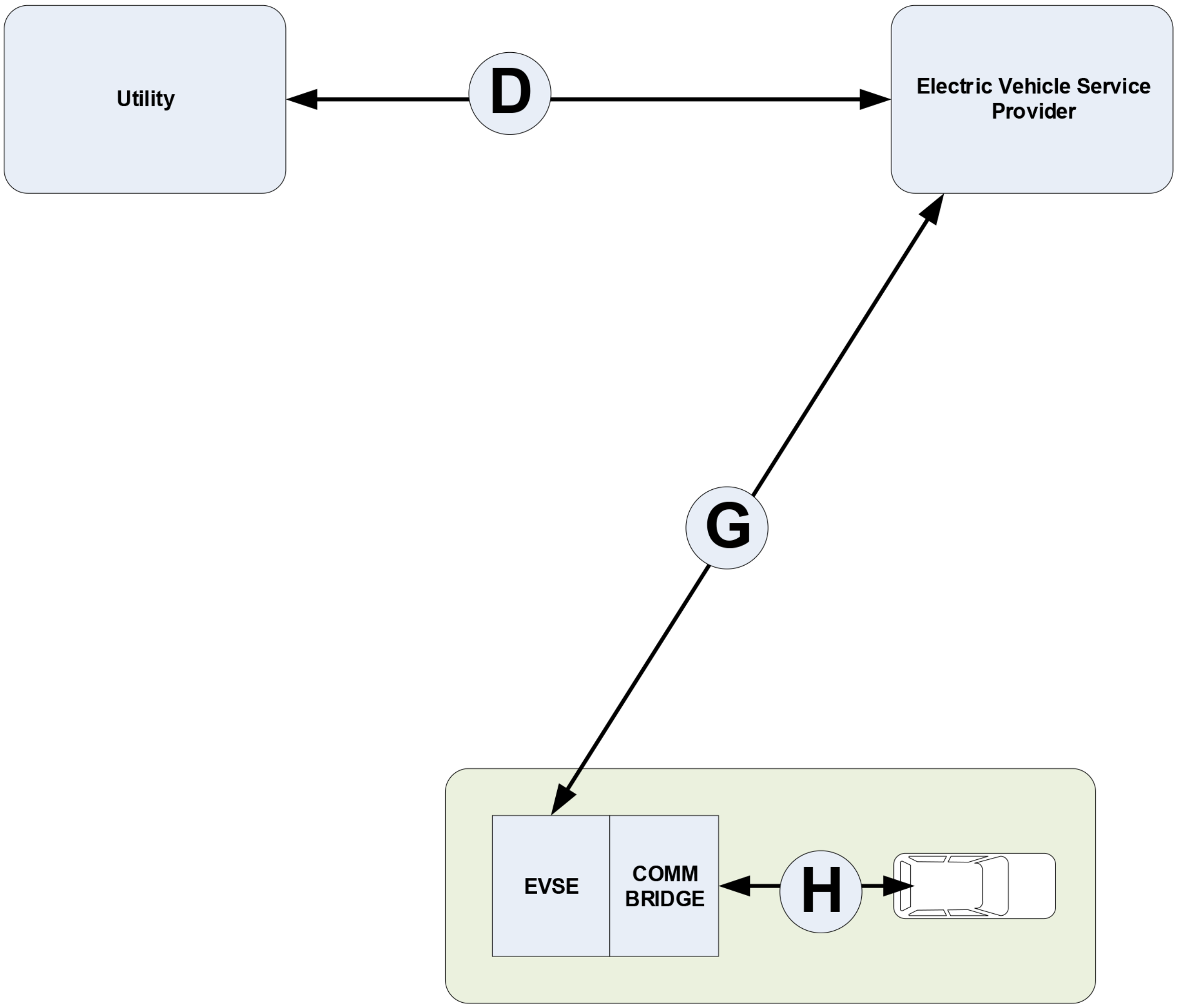

Figure 1-5
Electric Vehicle Service Provider as an Aggregator for Smart Charging Control

In Figure 1-5, the utility communicates information about the state of the electric grid to the Electric Vehicle Service Provider. The Electric Vehicle Service Provider then provides smart charging functionality through link G by controlling the electric vehicle supply equipment.

[3] Chapter 4 of this report provides a comprehensive discussion of how networked charging stations would be operated by an EVSP: *Plug-in Electric Vehicle Charging Infrastructure Technology Update*. EPRI, Palo Alto, CA: 2014. 3002003007.

The fourth and final example, shown in Figure 1-6, represents a case where a building owner is managing electric vehicle charging to manage peak power demand at the charging site.

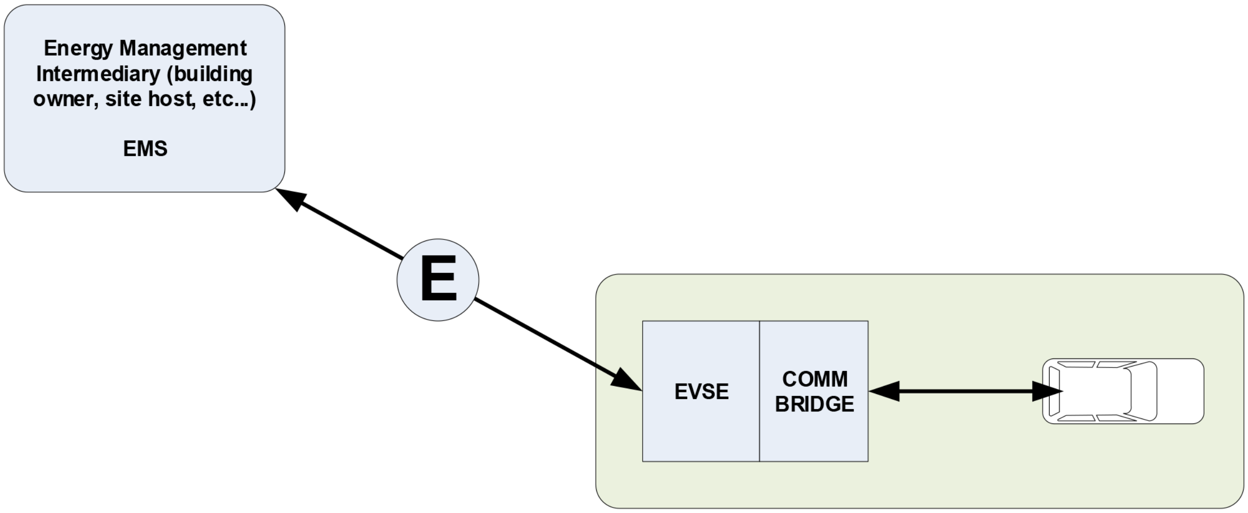

Figure 1-6
Building Energy Management System Performing Smart Charging Control

In Figure 1-6, the building energy management system controls vehicle charging via the electric vehicle supply equipment. There are many vendors that make and offer systems dedicated to electric vehicle supply equipment management[4].

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[4] Example companies in the dedicated EVSE management space: Cyber Switching, Liberty Plug-ins, MOEV, PowerFlex.

2
REFERENCE LIST – EPRI SMART CHARGING RELATED REPORTS

NOTE: Reports are listed from newest at top to oldest at bottom.

Plug-in Electric Vehicle Charging Infrastructure Technology Update

Product ID:3002011592

Date Published:20-Dec-2017; Pages:58

With a fleet of over 700,000 plug-in electric vehicles on the road in the United States, and more than 150,000 of those added from January to October of 2017, charging infrastructure continues to proliferate. For a utility, understanding this infrastructure and its operation is important on several fronts: it's what gets tied to the utility system; it is a touchpoint for utility customers; and it has the potential to be a managed grid resource. This report provides an update on the status of electric vehicle infrastructure deployments, a review of fees being charged for charging, and an overview of power management for electric vehicle charging.

Plug-in Electric Vehicle Charging Infrastructure Technology Update

Product ID:3002009499

Date Published:06-Apr-2017; Pages:40

With a fleet of nearly 580,000 plug-in electric vehicles on the road in the U.S. and nearly 160,000 of those added in 2016, charging infrastructure continues to proliferate. For a utility, understanding this infrastructure and its operation is important on several fronts: it is what gets tied to the utility system, it is a touchpoint for utility customers, and it has the potential to be a managed grid resource. This report provides an update on the status of electric vehicle infrastructure, including station populations, hardware technology, and standards for infrastructure.

Open Vehicle-Grid Integration Platform: General Overview

Product ID:3002008705

Date Published:08-Jul-2016; Pages:26

This public release document provides an overview of the Open Vehicle-Grid Integration Platform (OVGIP), which is a software application that connects various nodes involved in providing and managing energy to Plug-in Electric Vehicles (PEVs). It enables PEV and charging infrastructure management in a grid-friendly manner, and also provides benefits to PEV owners by allowing them to take advantage 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 that has been led by the Electric Power Research Institute (EPRI) since its inception in late 2012, and is in its second phase of *implementation. The document provides a brief description of the OVGIP deployment roadmap, its scope, cost considerations to develop and deliver it, current State of the technology, and the anticipated benefits from its implementation at scale.*

Open Vehicle-Grid Integration Platform: Systems Approach to Standards and Interoperability

Product ID:3002008866

Date Published:15-Jun-2016; Pages:28

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.

Pepco Demand Management Pilot for Plug-In Vehicle Charging in Maryland: Final Report — Results, Insights, and Customer Metrics

Product ID:3002008798

Date Published:05-May-2016; Pages:108

With over 390,000 Electric Vehicles (EVs) in the US light-duty vehicle market, more and more consumers are charging EVs at their homes. As many utilities have excess capacity at night, an off-peak time-of-use electric vehicle rate may offer EV drivers access to low cost fuel while minimizing impacts on the grid. This report provides an overview of the 22-month long Potomac Electric Power Company Demand Management Pilot for Electric Vehicle Charging in Maryland. 101 of Pepco's EV customers in Maryland enrolled in the program. Within this Pilot Program, Pepco offered two types of rates: 1) R-PIV Rate: a Whole House Time-of-Use (TOU) rate that applies to the entire house demand including the PEV and 2) PIV Rate: a PEV-only rate. For any customer who signed up for a PIV rate in the Pilot and didn't already have a separate PEV meter, Pepco installed a second advanced meter infrastructure (AMI) meter on the customer's premise. Using EV projection models, the effects of increased EV adoption on the grid were estimated both from a loading and cost perspective.

Results show that EV owners charge mostly during off-peak times and that demand response events can be an effective way to curb peak load events. Transformer loading analysis shows that infrastructure investment is needed to support the EV fleet; however, as the EV fleet grows the cost cumulative upgrade costs/vehicle decreases.

Vehicle-to-Grid: State of the Technology, Markets, and Related Implementation

Product ID:3002008935

Date Published:22-Jun-2016; Pages:54

This public release document provides an overview of vehicle-to-grid (V2G) as a technology, recent V2G studies, and an investigation of the applicability of V2G-related approaches in the United States—including potential customer interest, interconnection requirements, market rules, market pricing, value of competing resources, and possible alternatives.

This project will focus on outlining the V2G, definitions, a literature review, a project review, and related concepts.

Network Implementation Options for Plug-in Electric Vehicle Charging Infrastructure—A Utility Perspective

Product ID:3002005085

Date Published:20-Feb-2015; Pages:64

A number of approaches are being pursued for management of public and private electric vehicle charging installations. These vary from simple non-communicating installations at a single location to nationwide networks of charging stations. Many of the systems are being installed by private, for-profit companies, generally referred to as electric vehicle service providers (EVSPs). There remains uncertainty in viable business models for such deployments. For utilities, there is an interest in what role they might play in the electric vehicle space. Particularly, there is an interest in utility options for deployment of charging infrastructure. This report looks at the current landscape of plug-in electric vehicle (PEV) charging infrastructure and network implementations, and how they might interface with existing and future utility systems.

Plug-in Electric Vehicle Infrastructure Technology Update

Product ID:3002005977

Date Published:07-Dec-2015; Pages:38

With a fleet of nearly 400,000 plug-in electric vehicles on the road in the United States, charging infrastructure continues to proliferate. For a utility, understanding this infrastructure and its operation is important on several fronts: it's what gets tied to the utility system; it's a touchpoint for utility customers; and it has the potential to be a managed grid resource. This report provides an update on the status of electric vehicle infrastructure, hardware, and standards for infrastructure. Also included is a high level discussion of smart charging implementations, outlining communications, topologies, and information flows.

Plug-In Electric Vehicles as Distributed Energy Resources - Technology Update

Product ID:3002005989

Date Published:09-Dec-2015; Pages:68

There continues to be a great deal of interest in the use of plug-in electric vehicles (PEVs) as energy resources beyond the vehicle's transportation function, particularly for light duty vehicles. Whether grid-connected or for the operation of local loads, PEVs offer unique opportunities as energy resources. For grid-connected applications, pilot studies and demonstrations have indicated that the use of PEVs as grid resources is technically feasible, but there remain many barriers to widespread adoption. This report provides an update on the state of technology for vehicles as distributed energy resources, particularly when functioning as energy sources, sometimes referred to as "reverse energy flow." It also details some of the barriers to commercialization of vehicle to grid technology.

Open Vehicle-Grid Integration Platform – Unified Approach to Grid / Vehicle Integration: Definition of Use Case Requirements

Product ID:3002005994

Date Published:21-Dec-2015; Pages:54

This technical report provides an update on the multi-year automotive / utility industry collaborative effort to develop and implement the Open Vehicle-Grid Integration Platform (OVGIP), a platform that would allow the utility industry to address the entire electric vehicle ecosystem through a single, unified, and open interface. The focus of the past year's work was on developing use cases and security considerations to define the essential interface and functional requirements for the OVGIP Phase 2 development effort. The utility and automotive participants in this project qualified the use cases to provide value-added grid services to utility companies, Independent Service Operators (ISO), electric vehicle stakeholders, and 3rd party infrastructure and energy management service providers. This report further qualifies the attributes of the OVGIP to the utility industry and details its benefits for providing a centralized, sustainable, and progressive Vehicle Grid Integration (VGI) implementation system.

Plug-in Electric Vehicles as Distributed Energy Resources - Technology Update

Product ID:3002003008

Date Published:13-Dec-2014; Pages:44

With the steady growth of plug-in electric vehicles (PEVs) in the light-duty vehicle market, more and more consumers are parking PEVs at their homes and offices. These vehicles are equipped with onboard storage and power electronics to manage the storage system. It is a natural extension of their operation to consider their use as distributed energy resources (DER). DER are small-sized generation sources that can be aggregated in order to meet a larger power demand. In comparison to other DER, PEVs are unique in two key ways: They are mobile, and their primary function is not energy-related. Outside of these unique aspects, the PEV is very similar in function to a battery-storage system while it is connected to a load—thus offering the potential to be both a power consumer and a power generator. As the PEV market matures, it is anticipated that auto makers will begin to offer equipment that enables PEVs to act as energy sources.

This report provides an update on the current state of PEV technology and infrastructure related to the use of the vehicles as DER. It includes a review and categorization of potential-use cases and the potential methods of power extraction that can be used to meet those cases. Some use *cases are based solely on using the PEV as an energy resource. There are also applications and opportunities in which PEVs can act as energy/time shifting devices—charging when there is an excess of generation in the utility grid and acting as a generator when energy resources are in short supply. Power-extraction methods are categorized by which onboard vehicle system is used to provide power and the location and means of power conversion. Some methods of power extraction are limited to use of the vehicle as a generator and not as a load.*

There are currently no production vehicles in the United States that have onboard capability to export power beyond use of the vehicle's 12V system or at a low-power 120-V convenience outlet. Only a small number of companies have developed hardware to export power from a PEV, and none of the systems are yet commercially available in the United States. US hardware deployments remain demonstration projects. EPRI now has a working power-export system at its Knoxville, Tennessee lab. This system became operational in late 2014 and will be evaluated during 2015.

Plug-in Electric Vehicle Charging Infrastructure Technology Update

Product ID:3002003007

Date Published:23-Dec-2014; Pages:64

With the steady growth of plug-in electric vehicles (PEVs) as a consumer and commercial transportation option and with nearly 300,000 PEVs on the road in the United States, infrastructure for those vehicles has become a topic of interest for utilities. The implementation of charging infrastructure can be complex, with a broad variety of use cases to be supported, from residential charging at a single-family home, to large-scale charging installations supporting a fleet of employee-driven vehicles, to geographically dispersed public charging networks. Installations may be completed by a single consumer at a residence, by a utility in a territory-wide deployment, or by an electric vehicle service provider on a national scale. In each case, the features required at charging stations and the complexity of access control, communications, functionality, and the use of point-of-sale hardware must be appropriate for the application. This report provides a qualitative overview of the PEV infrastructure landscape, including hardware specification, implementation options, and the state of the industry.

Unified Plug-in Electric Vehicle (PEV) to Smart Grid Integration Approach within Automotive and Utility Industries

Product ID:3002000665

Date Published:30-Dec-2013; Pages:50

This technical update is a status report on the OEM (Original Equipment Manufacturer) Central Server Phase 1 project through 2013. The OEM Central Server is a server-based application that enables utilities to manage charging for the entire installed base of Plug-in Electric Vehicles (PEVs) as controllable loads. The application uses a set of open, interoperable standards-based interfaces – either via aggregated, indirect Demand Response (DR) programs using Open Automated Demand Response (OpenADR) profile 2.0b or via 'direct-to-customer' pricing and DR signals delivered through Automated Metering Infrastructure (AMI) or public internet-connected Home Area Networks (HAN) using Smart Energy Profile 2.0 (SEP2) connectivity. This server-based application also allows the DR signals to be routed through OEM servers such as

Telematics servers to reach the vehicle. The unique feature of this concept is that it enables a continuum of technologies to be incorporated into the DR framework that utilities are already implementing. It provides utilities with a single, common interface to address a wide variety of globally manufactured PEV products – a much more powerful proposition compared to interfacing with several different proprietary OEM server interfaces.

Evaluation of Power Line Carrier Technologies for Plug-In Electric Vehicle Communications

Product ID:1024105

Date Published:12-Dec-2012; Pages:96

In support of the Society of Automotive Engineers (SAE) efforts to develop standard means of communication with plug-in electric vehicles (PEVs), EPRI conducted an evaluation of several power line carrier (PLC) technologies. Evaluation of the technologies was based on a test plan developed in the SAE Hybrid Task Force. Direct PEV communication enables signaling of grid conditions to the PEV allowing for remote, intelligent management of vehicle charging. The interface can also support the use of off-board AC to DC power conversion (DC charging) by providing a means of controlling external power electronics from the vehicle.

Smart Electric Vehicle Supply Equipment Demand Response Pilot

Product ID:1023675

Date Published:31-Dec-2012; Pages:62

This report discusses a unique pilot project to evaluate electric vehicle supply equipment (EVSE) capable of demand response (DR) and its integration into the utility smart metering infrastructure.

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Emerging Technology and Architecture Approaches for Plug-in Electric Vehicles to Smart Grid Connectivity

Product ID:1021847

Date Published:21-Dec-2011; Pages:42

This report provides an overview of the latest advances in technologies evolving to facilitate plug-in electric vehicles (PEVs) to Smart Grid integration. It reiterates applicable requirements based on fundamental principles as well as provides a status on the evolving relevant standards space. Multiple technological approaches are presented, compared, and contrasted; and an *update on the status of each is provided. The document concludes with early recommendations for utility and automotive industry practitioners as well as electrical equipment makers.*

The focus of this research is to extract core technology learnings, best practices, and some hands-on "know how" for utility industry practitioner thinking of trying several technical approaches to connect their version of the Smart Grid to the PEVs using open-standards-based technologies. This report summarizes the result of EPRI research over several years, a few original equipment manufacturer (OEM) PEV to Smart Grid integration programs, and many millions of dollars worth of development on both utility and automotive industry sides. The results can, therefore, be applied by an industry professional either to train themselves or to guide themselves along decision making regarding technology choices as they navigate rapidly emerging and often chaotic space of Smart Grid to PEV integration.

BMW MINI E Smart Charging Analysis for FirstEnergy

Product ID:1023571

Date Published:30-Nov-2011; Pages:46

Without any utility controls, plug-in electric vehicles (PEVs) will be plugging in during typical coincident peak periods, and therefore, large-scale PEV deployment may create issues for the utility distribution system grid. The objectives of this Electric Power Research Institute (EPRI) study were to learn about electric vehicle (EV) charging patterns in residential and workplace settings and to assess possible grid impacts based on charging data and a forecast of PEV penetration. In the study, four BMW MINI E vehicles were provided to Jersey Central Power & Light employees. The vehicles were used for everyday workplace driving needs, and charging data was collected over a 2-year period from four charging stations—three workplace and one residential. Significantly different load patterns were observed based on charging station application. In addition, a software tool was used to estimate future PEV penetration and resulting aggregate charging load. The results suggest that in managing PEVs as a future load, some form of control would be desirable, to mitigate impacts on grid operation.

Vehicle Infrastructure Connectivity and Communications -- Requirements and Testing

Product ID:1021742

Date Published:30-Dec-2011; Pages:58

It is expected that consumers will charge electric vehicles in a variety of locations under varying weather conditions. In order to ensure that charging can be safely carried out in conditions that may include moisture, rain, and snow, the National Electric Code (NEC) requires that certain safety features be provided for as part of plug-in electric vehicle (PEV) charging equipment. While the NEC defines electric vehicle supply equipment (EVSE) more broadly, the term EVSE is commonly used to refer only to the primary enclosure provided as part of the charging equipment that houses the main contactor and safety controls.

This technical update provides a detailed overview of topics related to EVSE, including hardware specification, evaluation, and the status of communications standards related to support of electric vehicle charging infrastructure. The update describes supply equipment *features, construction, function, and hardware. In addition, it outlines EPRI testing related to the Society of Automotive Engineers communication standards work.*

Smart Charging Development for Plug-In Hybrid and Electric Vehicles - Preliminary Use-Case Development for SAE Recommended Practice J2836

Product ID:1015886

Date Published:22-Dec-2008; Pages:170

This technical update covers the complete set of functional requirements for integrating plug-in electric vehicles (PEVs) into the smart grid, along with the utility programs they will be able to participate in and a vision for getting these requirements into standardized implementations. The document will help utility and OEM staff gain a complete understanding of how they should go about developing PEV-utility requirements that will support programs for demand response and energy efficiency through their automated metering infrastructure.

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Product ID:1021847

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Evaluation of Power Line Carrier Technologies for Automotive Smart Charging Applications

Product ID:1019931

Date Published:14-Dec-2010; Pages:108

In support of the Society of Automotive Engineers (SAE) Hybrid J2836™&J2847&J2931 Committee, EPRI has undertaken evaluation of a set of power line carrier (PLC) technologies. This report documents Phase I activity, where vendor hardware evaluation kits were operated *and tested in the EPRI lab. This initial activity lays the groundwork for in-depth PLC testing to occur in the near future. The primary focus of this report is to provide an overview of the vendor evaluation hardware and software and to report results of simple tests that were conducted to vet the function of the link performance reporting software.*

Plug-in Electric Vehicle to Grid Interface Requirements

Product ID:1017674

Date Published:08-Dec-2009; Pages:48

This document provides technical requirements to ensure that plug-in electric vehicles (PEVs) will be designed for electric grid compatibility. It organizes the applicable current and future standards in an overview format, as well as providing a context as to the importance and usefulness of these standards to the utility industry.

On-Board Smart Charging Requirements for Plug-in Electric Vehicles

Product ID:1015877

Date Published:30-Sep-2008; Pages:34

The first plug-in electric vehicles (PEVs) are expected to start production in late 2010. Both vehicle owners and utility companies would benefit if PEVs could draw power during off peak periods but implementing a demand response program will require grid-to-PEV bidirectional communications to allow the utility system to influence the timing and amount of energy the PEV draws from the grid. This report defines the technology needed for such "Smart Charging" and reviews the current status of the initiatives underway to accomplish it.

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