



SURFACE VEHICLE RECOMMENDED PRACTICE

J2847™/3

NOV2023

Issued 2013-12
Revised 2023-11

Superseding J2847/3 MAR2021

Communication for Plug-in Vehicles as a Distributed Energy Source

RATIONALE

This update adds Sections 5, 6, and 7 to include the additional messages and stages for AC vehicle-to-grid (V2G) and AC vehicle-to-home (V2H). Updates to UL standards for these functions is also included.

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1. SCOPE

This SAE Recommended Practice applies to a plug-in electric vehicle (PEV) which is equipped with an onboard inverter and communicates using IEEE 2030.5-2018. It is a supplement to the SEP2 standard, which supports the use cases defined by SAE J2836/3. It provides guidance for the use of the SEP2 distributed energy resource function set with a PEV. It also provides guidance for the use of the SEP2 flow reservation function set, when used for discharging. It is not intended to be a comprehensive guide to the use of SEP2 in a PEV.

Note that in this document, SEP2 is used interchangeably with IEEE 2030.5-2018.

1.1 Purpose

SAE J2836/3 defines two system architectures in which a PEV and the connected electric vehicle supply equipment (EVSE) together serve as a distributed energy resource (DER). The inverter could be located in the PEV in which case AC power would flow from the PEV through the EVSE to the electric power system. Alternatively, the inverter could be located in the EVSE, in which case DC power would flow between the PEV battery and the EVSE as needed by the inverter to perform the selected DER function.

The entity that contains the inverter should be the focus of any communication with the system that is controlling the DER devices for the DER application. This communication should be with the PEV in the case of an onboard inverter or with the EVSE in the case of an external inverter. While this recommended practice only applies to a PEV with an onboard inverter, it could optionally be followed by an EVSE manufacturer to guide SEP2 implementation for the case where the inverter is located in the EVSE. SAE J2836/3 provides guidance for updates required to SAE J2847/2 to provide a DER DC mode that will allow the inverter in an EVSE to use the PEV battery when operating together as a DER. This DER DC mode will be an inner loop control mode modeled on the internal PEV communication between the inverter and the battery management system for an onboard inverter.

This document has five specific objectives:

- Provide guidance for **WHAT** information needs be exchanged with the PEV using SEP2.
- Provide guidance for **HOW** to manage the actual exchange of information with the PEV using SEP2.
- Define **RULES** of engagement for the creation and use of information, the timing of information exchanges, and the resolution of conflicts by the PEV. The behavior of the PEV is governed by its own controls, displays, and embedded software. The purpose of SEP2 is only to move information to and from the PEV in support of the PEV functions. While SEP2 provides some recommended behavioral guidance, this document should be followed for the implementation of PEV functionality if there is a conflict.
- Identify **CHANGES** for the next version of SEP2 and IEC 61850 to better support the requirements of SAE J2836/3. In some cases, SEP2 supports SAE J2836/3 requirements, but IEC 61850 does not. In other cases, the reverse is true.
- Provide **EXAMPLES** of the use of SEP2 to perform selected V2G applications. There are too many possible V2G applications to create an exhaustive set of examples. However, a few examples can help guide the development of the embedded PEV software required to implement the protocol for the inverter functions.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2836/3 Use Cases for Plug-in Vehicle Communication as a Distributed Energy Resource

2.1.2 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

IEEE 1547:2003	Standard for Interconnecting Distributed Resources with Electric Power Systems
IEEE 1547:2018	Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
IEEE 1547.1:2020	Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces
IEEE 1547.9	Draft Guide for Using IEEE Std 1547™ for Interconnection of Energy Storage Distributed Energy Resources with Electric Power Systems
IEEE 2030.5-2018	IEEE Standard for Smart Energy Profile Application Protocol
IEEE 2030.7-2017	Standard for the Specification of Microgrid Controllers
IEEE 2030.8-2018	Standard for the Testing of Microgrid Controllers
IEEE 2030.9-2019	Recommended Practice for the Planning and Design of the Microgrid

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1772	SAE Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler
SAE J2836/1	Use Cases for Communication Between Plug-in Vehicles and the Utility Grid
SAE J2836/2	Use Cases for Communication Between Plug-in Vehicles and Off-Board DC Charger
SAE J2836/3	Use Cases for Plug-in Vehicle Communication as a Distributed Energy Resource

SAE J2847/1 Communication for Smart Charging of Plug-in Electric Vehicles Using Smart Energy Profile 2.0

SAE J2847/2 Communication Between Plug-in Vehicles and Off-Board DC Chargers

SAE J2931/1 Digital Communications for Plug-in Electric Vehicles

SAE J2931/4 Broadband PLC Communication for Plug-in Electric Vehicles

SAE J3072 Interconnection Requirements for Onboard, Grid Support Inverter Systems

2.2.2 Electric Power Research Institute (EPRI) Publications

Available from EPRI, 3420 Hillview Avenue, Palo Alto, California 94304, www.epri.com.

EPRI 1026809 Common Functions for Smart Inverters IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 61850 Communication Networks and Systems for Power Utility Automation - Part 7-420, Basic Communication Structure - Distributed Energy Resources Logical Nodes

IEC 61850 Communication Networks and Systems for Power Utility Automation - Part 90-7, IEC 61850 Object Models for Photovoltaic, Storage, and Other DER Inverters
(Note that data models are now in IEC 61850-7-420 and are being deprecated in this technical report)

2.2.3 National Fire Protection Agency Publications

Available from NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471, Tel: 617-770-3000, www.nfpa.org.

NFPA 70® National Electrical Code® (NEC®)

NEC® Article 625.27 Interactive Systems

NEC® Article 702 Optional Standby Systems

NEC® Article 705 Interconnected Electric Power Production Sources

2.2.4 UCA® International Users Group Publications

Available from UCA® International Users Group, 10604 Candler Falls Court, Raleigh, NC 27614, www.ucaiug.org.

UCAlug HAN SRS v2.0 UCAlug Home Area Network System Requirements Specification

2.2.5 UL Publications

Available from UL, 333 Pfingsten Road, Northbrook, IL 60062-2096, Tel: 847-272-8800, www.ul.com.

UL 1741 Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources

2.2.6 ZigBee Alliance Publications

Available from ZigBee Alliance, 2400 Camino Ramon, Suite 375, San Ramon, CA 94583, www.zigbee.org.

ZB 09-5162 Smart Energy Profile 2.0 Marketing Requirements Document

ZB 09-5449 Smart Energy Profile 2.0 Technical Requirements Document

2.2.7 SunSpec Publications

Available from SunSpec Alliance, <https://sunspec.org/ieee-2030-5-sae-j3072-ev-charging-profile-work-group/>.

IEEE 2030.5 V2G-AC Profile IEEE 2030.5 V2G-AC Profile: Implementation Guide for SAE J3072, Version 1.0

3. DEFINITIONS

3.1 ADVANCED METERING INFRASTRUCTURE (AMI)

Advanced metering infrastructure (AMI) typically refers to the full measurement and collection system that includes meters at the customer site, communication networks between the customer and a service provider, such as an electric, gas, or water utility, and data reception and management systems that make the information available to the service provider.

3.2 AGGREGATOR

An individual PEV may not produce or consume enough power to be able to participate by itself in an application such as frequency regulation. An aggregator is an entity (which may not be a utility) that coordinates the power flow for a group of PEVs to allow them to meet the minimum power capacity required to participate in an application. The aggregator functions to, among other things, (a) schedule aggregated V2G services with a grid operator, utility, and other entities; (b) dispatch individual vehicles according to various factors including available V2G services and driver requirements; (c) aggregate response telemetry and relay to utility or grid operator; and (d) maintain a registry of vehicle identities and characteristics.

3.3 BEVSE

A bidirectional EVSE that can convert from AC to DC in one direction to serve as a battery charger, and then be capable of being reversed and convert from DC to AC in the other direction to serve as an inverter. This term is generally not used if the inverter is also capable of injecting or absorbing reactive power while charging or discharging.

3.4 BIDIRECTIONAL CONVERTER

See inverter definition (3.25).

3.5 CLIENT

In the standard client-server model, a client is the device or host that interacts with a server to obtain information related to a resource hosted by the server.

3.6 CONSISTENT OVERHEAD BYTE STUFFING (COBS)

Consistent overhead byte stuffing (COBS) is an algorithm for encoding data bytes that results in efficient, reliable, unambiguous packet framing regardless of packet content, thus making it easy for receiving applications to recover from malformed packets.

3.7 CONTROL SIGNAL

The UCAlug HAN SRS defines this as a structured message sent from an authorized party requesting operational state change of a device. Devices are expected to respond within the operation of their control systems and algorithms. This includes messages to DER devices for the purpose of controlling both active and reactive power.

3.8 COORDINATED UNIVERSAL TIME (UTC)

Coordinated Universal Time (UTC), once known as Greenwich Mean Time (GMT), is the reference time at the Greenwich meridian (London, UK). Time in SEP2 is defined as a signed 64-bit integer value representing the number of seconds from midnight January 1, 1970, in UTC, not counting leap second corrections to UTC (35 seconds through 2012).

3.9 DEMAND RESPONSE

A temporary change in electricity consumption by a demand resource (e.g., smart appliance, pool pump, PEV, etc.) in response to a control signal which is issued.

3.10 DISTRIBUTED ENERGY RESOURCE (DER)

Distributed energy resources (DERs) are small, modular distributed generation (DG) and storage technologies that provide electric capacity or energy where it is needed on the distribution grid. DG, which includes gensets, solar panels, and small wind turbines, only serve as a source of energy. Storage is a unique form of DER because, unlike pure DG, the unit can provide either energy or variable demand. Plug-in vehicles are DER storage systems.

3.11 EFFICIENT XML INTERCHANGE (EXI)

Efficient XML interchange (EXI) is a very compact, binary representation of the Extensible Markup Language (XML) information set. EXI format increases the processing speed of XML-based data, as well as reduces the memory usage.

3.12 ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE)

Electric vehicle supply equipment (EVSE) is the generic term used to describe the device that is physically connected and provides energy to the vehicle. EVSEs may take several physical forms, and their logical function may likewise differ substantially. Physical forms include a mobile cordset used for 120 VAC charging, a fixed or wall-mounted 240 VAC charging station, or an off-board DC charger. In terms of logical function, any EVSE may or may not include one or more of the following: a “gateway” or physical layer bridge function to bridge PEV communications to the HAN, a device that communicates directly with the HAN itself, etc.

3.13 END DEVICE (EDEV)

If a device is not capable of hosting its own resources, it must place them on a host server where they can be discovered by other devices that need access to these resources. In SEP2, this set of client resources on a host server is considered to be its end device resources. These resources are uniquely associated with a specific client device.

3.14 END USE MEASUREMENT DEVICE (EUMD)

The end use measurement device (EUMD) is a revenue-grade meter responsible for directly measuring energy delivered to a specific end-device (e.g., PEV). This could be a dedicated utility meter if an EVSE is on a separate service. It could also be a sub-meter in the EVSE or PEV. The physical form, location and ownership of the EUMD may be unique for different applications. Revenue-grade means that the meter meets the requirements of the state entity that is responsible for ensuring the accuracy of the measurements, which will not necessarily be the public utility commission for a sub-meter that is not owned by a public utility.

3.15 ENERGY MANAGEMENT SYSTEM (EMS)

The term energy management system (EMS) is used in this document to describe a computer system that can communicate with a PEV or EVSE for the purpose of controlling the charging or discharging of the PEV battery. An EMS can exist at several tiers: customer premises, distribution level, or system level. These computer systems may go by other names, but the term EMS will be used generically in this document.

3.16 ENERGY SERVICES INTERFACE (ESI)

An energy services interface (ESI) is a device on a HAN which enables secure communications between authorized parties (e.g., utility, service provider, aggregator, home EMS) and all commissioned HAN devices that are registered to it. HAN architecture allows for more than one ESI in a consumer premises. Each ESI creates an independent logical power distribution network within the premises, each with its own security.

3.17 ENROLLMENT

The process by which a consumer enrolls a HAN device in a service provider's program (e.g., demand response, energy management, pre-pay, PEV programs, distributed generation programs, pricing, messaging, etc.) and gives certain rights to the service provider to communicate with their HAN device.

3.18 EXTENSIBLE MARKUP LANGUAGE (XML)

Extensible Markup Language (XML) is a markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable. The design goals of XML emphasize simplicity, generality, and usability over the internet. It is a textual data format with strong support via Unicode. Although the design of XML focuses on documents, it is widely used for the representation of arbitrary data structures; for example, in IEEE 2030.5-2018.

3.19 FORWARD POWER FLOW (FPF)

Forward power flow (FPF) means the direction of energy for charging a vehicle. In SEP2, a setpoint command for forward (charging) power flow for a DER device has a negative value.

3.20 FUNCTION SET

A function set is a logical grouping of resources in the SEP2 object model (e.g., metering, demand response and load control, flow reservation, DER). All function sets do not have to be implemented in every device and the requirements associated with a given function set may be mandatory or optional.

3.21 HOME AREA NETWORK (HAN)

In this document, a home area network (HAN) is an energy related network, contained within a premises used for communicating with devices within the premises. HANs do not necessarily require connectivity outside the premises, but may be connected to one or more external communication networks using gateways, bridges and interfaces.

3.22 HOST

This is the representation of a device in its application context, typically represented by an IP address or domain name.

3.23 HYPERTEXT TRANSFER PROTOCOL (HTTP)

Hypertext transfer protocol (HTTP) is an application layer protocol designed within the framework of the Internet Protocol Suite. Its definition presumes an underlying and reliable transport layer protocol. HTTP resources are identified and located on the network by Uniform Resource Identifiers (URI). HTTP is the foundation of data communication for the World Wide Web. HTTP functions as a request-response protocol in the client-server computing model. The client submits an HTTP request message to the server which returns a response message to the client. The response contains completion status information about the request and may also contain requested content in its message body.

3.24 INADVERTENT EXPORT

Under certain operating conditions, the customer may choose to completely offset their facility load by using the EV as a generation system which are optimally sized to meet their peak demand with load following functionality on the Generator controls to ensure conditional export of electrical power from the generating facility to distribution provider's distribution or transmission system. In situations where the loading changes rapidly and/or the generator cannot ramp down quickly enough, the generating system may need to export small amounts of power for limited duration. The event of exporting uncompensated power for a short time is referred to as inadvertent export.

3.25 INVERTER

AC power is generated from a DC source, such as a traction battery, using a device called an inverter. A pure inverter cannot convert AC to DC for charging a battery; this is done by a charger or a forward converter. Bidirectional converter is the term used for a device that can convert from AC to DC in one direction to serve as a battery charger and also be capable of being reversed and convert from DC to AC in the other direction to serve as an inverter. A grid-tied power converter can be designed to either lead or lag its sourced current relative to the grid voltage during either charging or inverter operation. This is called a four quadrant converter. It is common practice to refer to the power convertor of a storage DER device as “inverter,” even though this is not precisely correct. An onboard inverter is included within the vehicle and an offboard inverter is located off the vehicle, in the EVSE.

3.26 PLUG-IN ELECTRIC VEHICLE (PEV)

This is the generic term used to describe any vehicle that plugs in to receive electrical energy. This includes many different classifications of vehicles, such as BEVs (battery electric), PHEVs (plug-in hybrid electric), E-REVs (extended-range electric), and so on.

3.27 POWERLINE COMMUNICATIONS (PLC)

Powerline (carrier) communications (PLC) refers broadly to the group of communications technologies in which a modulated carrier is transmitted over AC power circuits. The same communications technologies and designs may sometimes also be applied to circuits that do not carry AC current.

3.28 REPRESENTATIONAL STATE TRANSFER (REST)

Representational state transfer (REST) is a style of software architecture for distributed systems such as the World Wide Web. SEP2 uses REST architecture. REST architectures consist of clients and servers. Clients initiate requests to servers; servers process requests and return appropriate responses. Requests and responses are built around the transfer of representations of resources. A representation of a resource is typically a document that captures the current or intended state of a resource.

3.29 RESOURCE

URI addressable object that is manipulated via the REST uniform interface

3.30 RESOURCE DISCOVERY

This is a process whereby clients identify resources being served on the network. Clients issue a request to all devices on the network requesting resource(s) of interest. Servers hosting the requested resource(s) respond with information necessary to access the server and its resource(s).

3.31 REVERSE POWER FLOW (RPF)

Reverse power flow (RPF) means the direction of energy for discharging a vehicle. In SEP2, a setpoint command for reverse (discharging) power flow for a DER device has a positive value.

3.32 SCHEMA

A data structure definition for XML data used to describe the structure, content, and to some extent, the semantics of XML documents. The IEEE 2030.5-2018 schema is described by a collection of XML schema definitions (XSDs), which are written in XML.

3.33 SELF DEVICE (SDEV)

If a device is a server and hosts its own resources it is considered to be a self device (SDEV) in SEP2. A complex device, such as a stationary storage DER unit, might provide its own discoverable server to host its resources. Because the connection of a PEV to the network is intermittent a PEV would most likely only act as a client and host its end device resources on an ESI or another server.

3.34 SERVER

In the standard client-server model, a server is the device or host that holds a resource and exposes representations of that resource.

3.35 SMART ENERGY PROFILE 2.0 (SEP2)

The ZigBee Alliance and HomePlug Powerline Alliance created the Smart Energy Profile 2.0 (SEP2), which defines a common information model, a common set of services, an application protocol implementation, and a set of behaviors for enabling smart energy applications while placing requirements on the underlying network stack, link layer, and security. When implemented correctly, the Smart Energy Profile will allow interoperability between different smart energy devices.

In 2014, IEEE took over governance of the standard from the ZigBee Alliance. Smart Energy Profile 2.0 is now known as IEEE 2030.5. The current version is IEEE 2030.5-2018.

3.36 UNIVERSAL ASYNCHRONOUS RECEIVER-TRANSMITTER (UART)

Universal asynchronous receiver-transmitter (UART) is a hardware communication protocol that uses asynchronous serial communication with configurable speed. Asynchronous means there is no clock signal to synchronize the output bits from the transmitting device going to the receiving end

3.37 UNIFORM RESOURCE IDENTIFIER (URI)

Uniform resource identifier (URI) is a string of characters used to identify a name or a resource. Such identification enables interaction with representations of the resource over a network (typically the World Wide Web) using specific protocols. URIs can be classified as locators (URLs), as names (URNs), or as both. A uniform resource name (URN) defines an item's identity and a uniform resource locator (URL) provides a method for finding it.

3.38 VEHICLE-TO-GRID (V2G)

When vehicle power is fed into the bulk electric grid or a microgrid, we refer to it as “vehicle-to-grid” power, or V2G. V2G is the only mode that allows a vehicle to return power to a home, business, or charge station which is actively connected to the grid. This could be at home or remote locations and initiated for contract driven ancillary services (regulation, peak shaving, reserves, etc.). A PEV in V2G operation is considered by utilities to be a DER.

3.39 WEB-APPLICATION DESCRIPTION LANGUAGE (WADL)

Web-application description language (WADL) is a machine-readable XML description of HTTP-based web applications (typically REST web services). It models the resources provided by a service and the relationships between them. It is intended to simplify the reuse of web services that are based on the existing HTTP architecture of the Web. It is platform and language independent and aims to promote reuse of applications beyond the basic use in a web browser.

4. TECHNICAL REQUIREMENTS

This major section provides recommended practices for the use of IEEE 2030.5-2018 for communication by a PEV that is equipped with an onboard inverter capable of interconnecting with an electric power system as a DER. This document does not require a PEV to be equipped with an onboard inverter, nor does it require that SEP2 be used for communication; in either case, this document is not applicable to such a PEV.

In this document, the term “inverter” is used two ways, depending on context. The requirements for interconnecting a DER to the grid only apply to the production of power (i.e., discharging a storage DER) and in this context the relevant power conversion functionality in the PEV is that of a pure inverter device. But a storage DER, such as a PEV, can also absorb power from the grid and the power conversion electronics would properly be called a battery charger or a forward converter. It is possible that a PEV could have separate inverter and charger devices, although an integrated bidirectional or four-quadrant power converter would more likely be more cost effective. For storage DER, the direct control of active power from maximum production to maximum consumption is considered to be an inverter function even though this is not precisely correct. In this document, the term inverter is used in the context of DER functions being inverter functions.

This document assumes that a PEV meets the following requirements:

- The PEV has an onboard, utility-interactive inverter. The PEV and EVSE to which it is connected using the SAE J1772 coupler shall meet the requirements of NEC® Article 625.27 for an electric power production source. This article calls out NEC® Article 705, which defines requirements for a “utility-interactive inverter.”
- The inverter shall provide the functionality to fully support SAE J2836/3 use case U6 (Basic Distributed Energy Resource). The inverter shall be capable of seamless transition between forward and reverse active power flow in response to a control signal. The inverter is not required to be capable of producing or absorbing reactive power to support U6.
- The inverter may optionally provide the functionality to support one or more of the modes defined by SAE J2836/3 use case U7 (Advanced Distributed Energy Resource). Some of these modes require an inverter to be capable of producing or absorbing reactive power. Other modes require autonomous operation, some of which may also require reactive power control. It is possible that a specific utility could require a DER to be capable of supporting one or more of these advanced modes as a condition of their interconnection agreement.
- The inverter shall provide the functionality to fully support SAE J2836/1 use case U5 (Optimized Energy Transfer). The inverter shall be capable of varying the discharge rate in response to a control signal when the PEV is engaged in discharging. Seamless transition between charging and discharging is not required.
- The PEV communication system shall comply with the SEP2 standard, except as may be constrained by this document. This includes all of the supporting protocols defined by the SEP2 standard. The communication system shall also comply with SAE J2931/1; if there is a conflict with SEP2 requirements, SEP2 shall govern.
- The PEV shall implement all mandatory resources of the SEP2 model for the power status, flow reservation, and distributed energy resource function sets and all of those optional resources that are needed to support the PEV inverter functional capability.
- SEP2 is data link agnostic. Examples in this document are based on Powerline Communications (PLC) on the SAE J1772 control pilot using HomePlug Green PHY as defined by SAE J2931/4. A PEV could use another data link and this document would still apply.

This document is a supplement to the SEP2 standard. It provides guidance for the use of the SEP2 distributed energy resource function set with a PEV. It also provides guidance for the use of the SEP2 flow reservation function set, when used for discharging. It is not intended to be a comprehensive guide to the use of SEP2 in a PEV. There are many SEP2 function sets that could be implemented in a PEV, some of which are required to support a PEV operating as a DER. For example, an application that wishes to read the current flow from the inverter might need to use the metering function set to be able to retrieve that information from a PEV. This document does not describe the use of the metering function set. A DER controller for a specific V2G application may need to engage with a PEV using other SEP2 function sets beyond the DER function set. The SEP2 standard describes the full communication capability.

The SEP2 standard focuses on the communication of information, but it does not define the creation of information by a PEV or the use of control signals or other information by a PEV. A primary focus of this document is to provide guidance for the creation and use of information which is done by the embedded operational software of the PEV. Some information may require data entry or other out of band processing during initial set up for a newly enrolled V2G application or for a specific session. This is beyond the scope of SEP2, but directly relevant to the ability to perform the DER function.

A brief overview of each subsection is provided below:

- | | |
|-----------------------------|---|
| Section 4.1 | Provides a brief overview of the basic system architecture for a PEV engaging as a DER device with a DER controller. |
| Section 4.2 | Provides a brief overview of the communication stack associated with SEP2 and the relationship of each layer to SAE documents SAE J2836/3, SAE J2847/3, SAE J2931/1, and SAE J2931/4. |
| Section 4.3 | Defines the key documents of SEP2 and the SEP2 function sets that are required to support SAE J2836/1 use case U5 (Optimized Energy Transfer) and SAE J2836/3 use cases U6 (Basic DER) and U7 (Advanced DER). |

- Section [4.4](#) Provides a very brief layman's overview of some of the concepts that will be needed to appreciate the guidance provided in this document for how to apply SEP2.
- Section [4.5](#) Reviews two approaches for an EVSE to handle the PLC communication with the PEV. In one approach, the EVSE only “bridges” the PEV to a SEP2 HAN by converting, for example, PLC to ethernet. In the other approach, the EVSE serves as a gateway and performs protocol translation for the PEV.
- Section [4.6](#) Presents some gaps between SEP2 and the IEC 61850-7-420 object model. The SEP2 model conforms to SAE J2836/3 U6 requirements and EPRI and IEC are working to include the additional information required by U6.
- Section [4.7](#) Provides guidance for the use of the SEP2 flow reservation function set for discharging as defined by the SAE J2836/1 use case U5.
- Section [4.8](#) Provides guidance for creating the PEV resource information required by the DER function set and the power status function set to support SAE J2836/3 use cases U6 and U7.
- Section [4.9](#) Describes the SEP2 concept of a DER Program which is a resource created by a DER controller that could apply to may DER devices. A DER Program could apply to only one PEV or a group of PEVs could be enrolled in a program.
- Section [4.10](#) Defines the structure of a DER Control object. This is a structured control signal that a DER controller uses to manage the PEV inverter as required by the V2G application.
- Section [4.11](#) Defines rules and guidelines for event conflicts. A DER control signal is defined as an event in SEP2, but there are other events, such as a demand response event.
- Section [4.12](#) Provides guidance for using the autonomous curve functions of the DER function set.
- Section [4.13](#) Provides guidance for using the ride through function of the DER function set.
- Section [4.14](#) Provides a brief overview of two V2G application examples. The details for each example are provided in a separate appendix.

4.1 Communication System Architecture

The basic system architecture in which a PEV can participate as a DER is shown in [Figure 1](#). The PEV has an onboard inverter and uses IEEE 2030.5-2018 for communication. The purpose of the communication system is to allow a DER controller to receive state information from the PEV and to allow the DER controller to provide timely control signals to the PEV. This end-to-end information exchange is illustrated by the dotted lines connecting the PEV with the DER controller.

If the DER controller does not use SEP2, protocol translation will be required by some network device located between the DER controller and the PEV. This translation will be easier if the DER controller conforms to the IEC 61850 object model for a DER inverter. The DER function set of SEP2 is based on IEC 61850-7-420. SEP2 supports the use cases defined by SAE J2836/3 which was also based on the IEC 61850 DER model. The figure shows the PEV communicating with the DER controller by way of the EVSE using powerline communications (PLC) on the SAE J1772 control pilot. The specific PLC implementation would be HomePlug Green PHY as governed by SAE J2931/4. This path to the network will be used for examples in this document, although SEP2 can operate using other physical layers. For example, it could be possible for a PEV that is equipped with a wireless link to bypass the EVSE and directly engage with a premises network that is based on SEP2.

Any device which can discharge power into an electric power system that is connected to the utility grid must be approved by the local utility to interconnect to the electric power system. This is true even if no net energy is delivered from the premises. The interconnection agreement with the utility will be based on a defined point of common coupling (PCC), which will generally be the utility meter at the premises. A PEV should not be permitted to discharge unless it is authorized to do so by the interconnection agreement that applies to the specific premises. Because the EVSE can be associated with the specific PCC covered by the interconnection agreement, it is essential to associate the PEV with the EVSE to which it is connected. This association with the EVSE can be less complex if the PEV only communicates with or through the EVSE. It is a more complex problem if the PEV uses an alternate communication path around the EVSE. This is only part of the problem because even though the connection path through the EVSE is confirmed, discharging can only be authorized by the PEV if the specific PEV model is approved by the interconnection agreement. For a residential application, this could be a manual confirmation by the driver using vehicle controls and displays. The authorization to discharge process is much more complex for a public charging location.

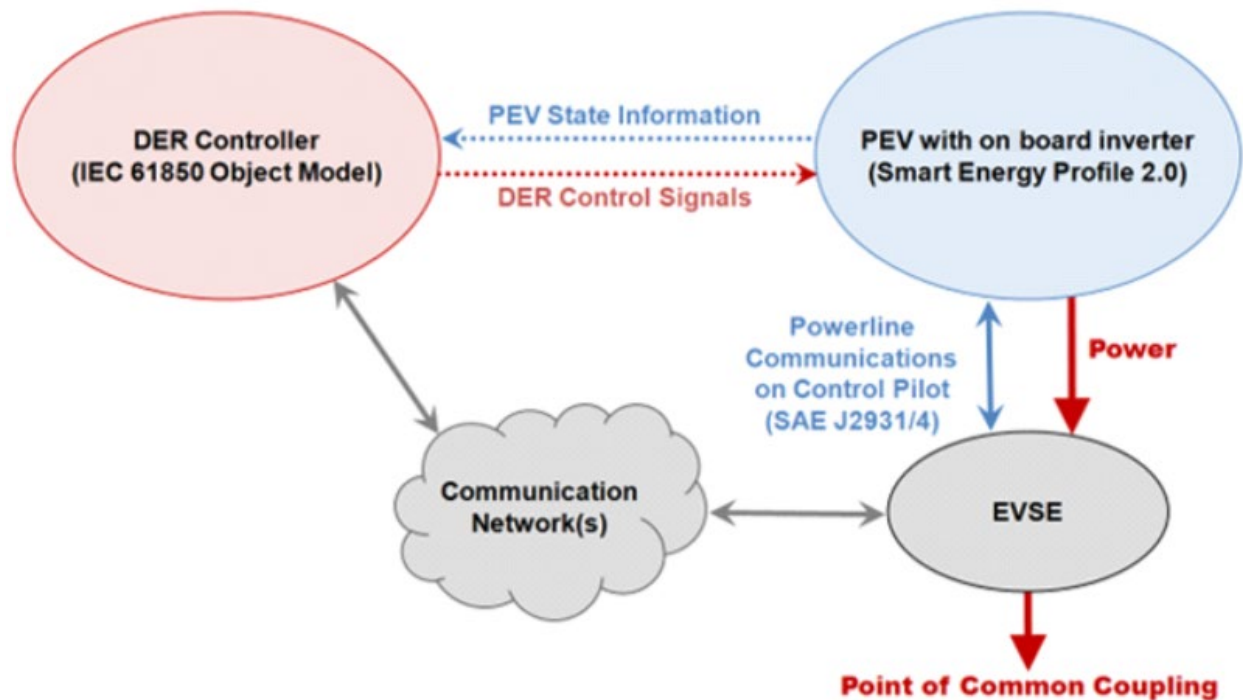


Figure 1 - Basic system architecture

4.2 Communication Stack

IEEE 2030.5-2018 is based on the Internet Protocol Suite which is the set of communications protocols used for the internet and similar networks, and is generally the most popular protocol stack for wide area networks. It is commonly known as TCP/IP, because of its most important protocols: Transmission Control Protocol (TCP) and Internet Protocol (IP). An alternative model is the open systems interconnection (OSI) model which characterizes and standardizes the functions of a communications system in terms of seven abstraction layers. [Figure 2](#) shows the seven OSI layers as grey bars and overlays the four TCP/IP layers as blue rectangles. The white rectangles show some of the protocols or standards used at each layer with SEP2.

The application layer of both the TCP/IP and OSI models is closest to the embedded DER software which is indicated by the light blue bar. The application software of the HAN device is outside the scope of the OSI and TCP/IP models. The green bar represents the data and functional model for the inverter that guides the development of the embedded PEV software.

The red rectangles show the relationship of SAE documents to the different layers. SAE J2931/4 governs the use of high bandwidth powerline communication between the PEV and EVSE on the SAE J1772 control pilot. SAE J2931/1 deals with the protocols used for the internet and transport layers and some of the protocols used in the application layers. There is overlap with SAE J2847/3 for the application layer. For example, the need to have HTTP as one of the application layer protocols used by the PEV is governed by SAE J2931/1. The specific HTTP message structures needed to send and receive DER control signals are covered by SAE J2847/3. SAE J2836/3 extends to the application level because it establishes requirements for the DER model which in turn establishes requirements for the XML schema definition (XSD).

SAE J2931/7 establishes the security requirements for digital communication between the PEV, the EVSE, and other entities in the overall system. Consequently, security will not be addressed in this document.

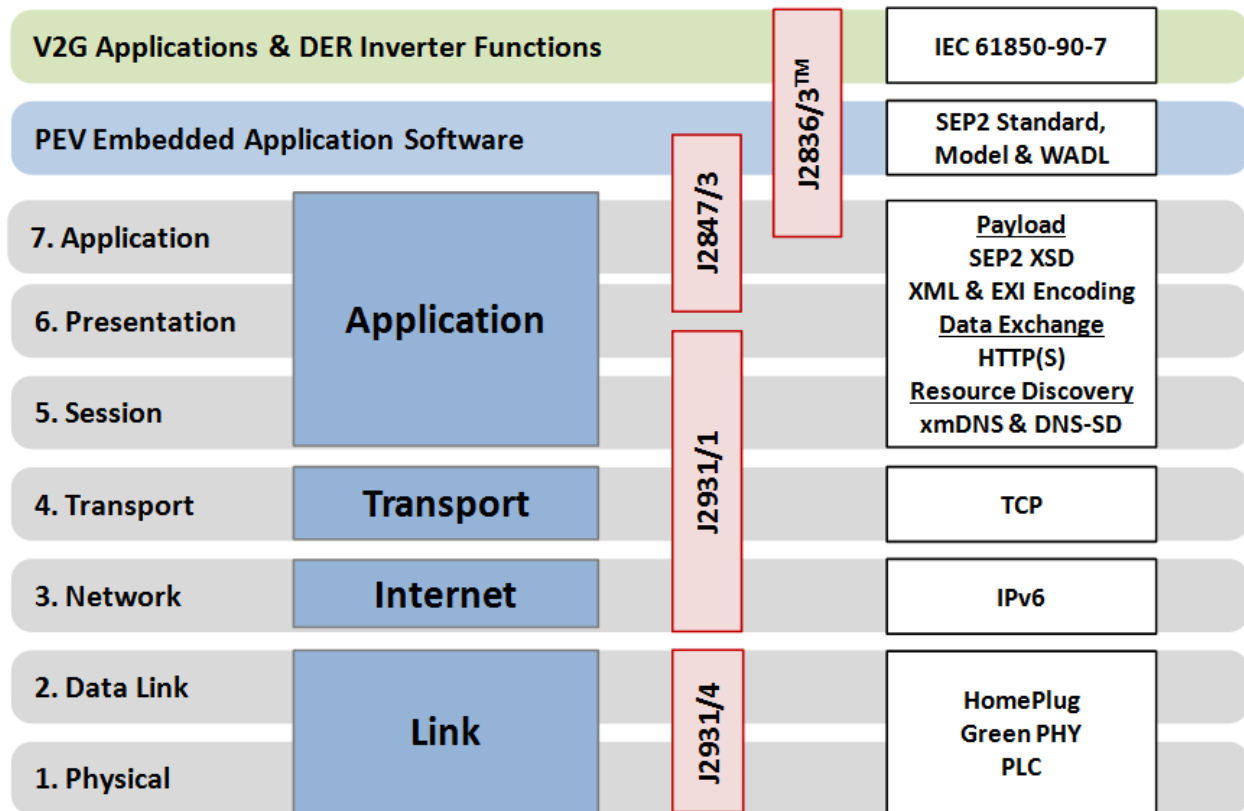


Figure 2 - PEV communication stack

4.3 IEEE 2030.5-2018 - Standard for Smart Energy Profile Application

IEEE 2030.5-2018 is designed to meet the requirements defined by the SEP2 Marketing Requirements Document and the SEP2 Technical Requirements Document. These two documents are based on the UCAlug Home Area Network System Requirements Specification.

The SEP2 Application Protocol is at the application layer of a TCP/IP stack with HTTP(S)/1.1 serving as the application data exchange protocol. Internet Protocol version IPv4 or IPv6 can be used. SEP2 is intended to enable communications that are link layer agnostic.

SEP2 is based on Representational State Transfer (REST). An important concept in REST is the existence of resources (sources of specific information), each of which is referenced with a global identifier (e.g., URI in HTTP). A server is a device that hosts a resource, and a client is a device that obtains, extends, updates, or deletes representations of that resource. A representation of a resource is typically an XML document that captures the current or intended state of a resource. Clients initiate requests to servers via a standardized interface (e.g., HTTP) and servers process requests and return appropriate responses.

In SEP2, the HTTP documents can be encoded using either Extensible Markup Language (XML) or Efficient XML Interchange (EXI). EXI is a compact alternative encoding of XML documents. A server must be able to send and receive messages either encoded as a plain XML string or encoded as an EXI stream. A client can implement both, but is only required to implement one. The rich variety of interactions on a HAN can make it difficult to define “client” and “server.” A specific HAN device could serve as a client and as a server for different functions. Devices that can act as both a client and a server would need to support both encoding methods.

The following documents comprise the definition of the SEP2 Application Protocol and all SEP2 devices will be required to maintain compliance to these documents:

- IEEE 2030.5-2018: Standard for Smart Energy Profile Application Protocol
- IEEE 2030.5-2018: Web-Application Description Language (WADL)
- IEEE 2030.5-2018: XML Schema Definition (XSD)

SEP2 uses a Web-Application Description Language (WADL) to define the recommended URI structures and the use of the HTTP methods of GET, PUT, POST, and DELETE. The default mechanism for obtaining a resource representation is a pull mechanism, implemented with GET. The use of a subscription mechanism for retrieving a resource representation is also optionally supported in many instances, where convenient and appropriate. SEP2 devices must conform to the resource specifications contained in the WADL. An Informative textual extract of the SEP2 WADL is contained in the Application Protocol Standard for convenience.

The object model of the SEP2 Application Profile is based on the IEC 61968 common information model (CIM), mapping directly where possible, and using subsets and extensions where needed. For example, the object model of the SEP2 DER function is based on IEC 61850-7-420 and not the CIM. The object model is described by a collection of XML schema definitions (XSDs) which are written in XML. The SEP2 XSD contains the definitions of the resources, attributes, and elements as well as their textual descriptions. An informative textual extract of the SEP2 XSD is contained in the Application Protocol Standard for convenience.

The Application Protocol contains three collections of function sets: support, common, and smart energy. The support function sets provide operational information to the end devices of an SEP2 network or provide those end devices with services to manage and support their operation. Common function sets provide general purpose, non-domain-specific functionality. Smart energy function sets are specific to the domain of smart energy. Each function set is fully described in the Application Protocol Standard. The WADL and the XSD follow a similar organization by function set.

A function set is the set of behaviors necessary to support a given business requirement, such as the ability of a PEV to serve as a DER device. All function sets do not have to be implemented in every device and the requirements associated with a given function set may be mandatory or optional. Devices implementing a particular function set are required to implement all mandatory requirements for that function set corresponding to the device's role. The expression [0..1] is used in the data model (XSD) to indicate that a particular object or attribute is optional for that function set.

[Table 1](#) shows which function sets are used by the Basic DER (U6) and Advanced DER (U7) use cases from SAE J2836/3. The Optimized Energy Transfer (U5) use case from SAE J2836/1 is also shown because it can be used for reverse power flow in some V2G applications. BASIS designates the core function(s) for the use case. RQD designates a function that is required to support the core DER or flow reservation functions. OPT designates a function which could be optionally used specifically for the purpose of supporting a core function. For example, subscription could be used with the DER function as an optional way of getting control signals. A blank space does not indicate functions that would not be used in PEVs. Many are used in PEVs but they are not primarily needed to support these use cases. For example, metering could be used to support payment for participating as a DER in an application, but it is not essential to the basic operation of the DER function. This document will primarily focus on providing guidance for the BASIS function sets.

Table 1 - Resources and function sets

Use Cases	SAE J2836/1 U5	SAE J2836/3 U6/U7
Support Resources		
Device Capabilities Function Set	RQD	RQD
Self Device Resource		OPT
End Device Resource	RQD	RQD
Function Set Assignments	RQD	RQD
Subscription/Notification Mechanism		OPT
Response	RQD	RQD
Common Resources		
Time Function Set	RQD	RQD
Device Information Function Set	RQD	RQD
Power Status	OPT	BASIS
Network Status		
Log Event List		
Configuration Resource		
File Download Function Set		
Smart Energy Resources		
Common Functionality	RQD	RQD
Demand Response and Load Control		
Metering Function Set		
Pricing Function Set		
Messaging Function Set		
Billing Function Set		
Prepayment Function Set		
Energy Flow Reservation Function Set	BASIS	
Distributed Energy Resources Function Set		BASIS
Metering Mirror		

4.4 Some Basics about SEP2 for the Non-Expert

The purpose of this section and its subsections is to provide a very brief layman's overview of some of the concepts that will be needed to appreciate the guidance provided in this document for how to apply the SEP2 protocol to a PEV engaging as a DER in a V2G application. Please use the actual SEP2 standard as the authoritative reference. This section is not intended for those people that are highly skilled with SEP2 and its associated processes and protocols.

4.4.1 Clients, Servers, and Resources

SEP2 is based on REST, in which a client polls a server using the HTTP GET method to obtain a representation of the current state of a resource. A device must be capable of acting as an SEP2 server for it to directly share its resources with other SEP2 network devices. Otherwise it must place (PUT) copies of the resources that it wishes to share on an end-device server that can host them and make them available to GET requests from other authorized network devices. In SEP2, the distinction between a server and a client arises dependent on whether a device exposes a resource (server) or interacts with the resource (client). A device which is a server for its own resources would be a client when requesting resources hosted by another server. A device which is not capable of hosting resources can only act as a client.

Figure 3 shows an example where one DER device is a server (DER-A) and another is only a client (DER-B). Blue designates a client behavior and red designates a server behavior. In this example, each DER device creates a resource “ABC” and the DER controller creates a resource “EFG.” For DER-A, the controller, as a client, uses an HTTP GET method to request resource “ABC” from DER-A. The DER-A server responds by providing an XML or EXI message containing a representation of resource “ABC.” In a similar manner, DER-A can GET “EFG” from the controller. It is more complex for the case of DER-B which is not directly visible to the controller. The controller interacts with an end device representation of DER-B resources on an authorized end device server (ESI). The controller uses the GET method with the end device server to request “ABC” and the server responds with the XML for “ABC.” This requires DER-B to place a copy of “ABC” on the host server so it can be discovered and retrieved by the controller. It uses the PUT method to maintain the “ABC” resource on the host server. DER-B can directly discover the “EFG” resource on the controller server just as with DER-A. If the controller could host DER-B resources, DER-B could PUT “ABC” directly into the controller and the local ESI server may not be needed.

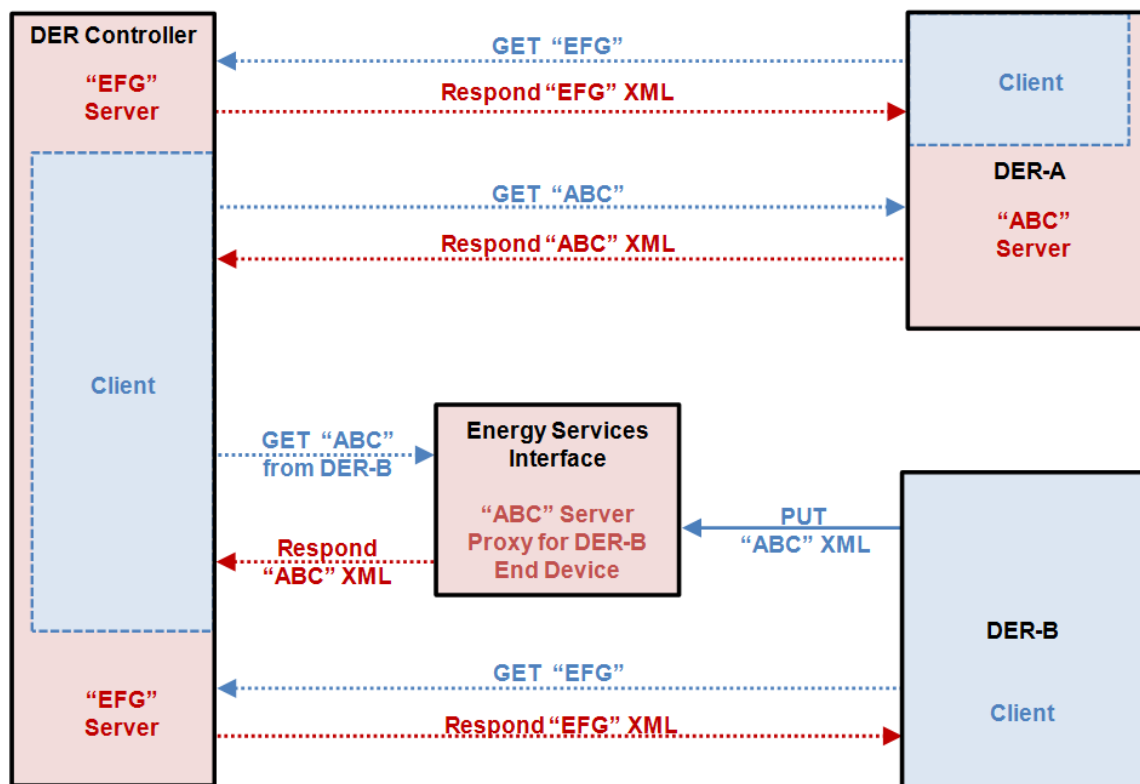


Figure 3 - DER device as client or server

4.4.2 Extensible Markup Language (XML)

The information payload in SEP2 messages can be encoded using either XML or EXI. XML is a markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable. EXI is a compact alternative encoding of XML documents which allows XML-based messages to be used and processed on a binary level. Thus, the EXI format increases the processing speed of XML-based data as well as reduces the memory usage. A server must be able to send and receive messages either encoded as a plain XML string or encoded as an EXI stream. A client can implement both, but is only required to implement one. Because of its human-readable structure, only XML will be discussed in this document. It is hard to describe anything at the binary level.

The characters making up an XML document are divided into markup and content. A markup construct that begins with “<” and ends with “>” is called a tag. There are three types of tags: start-tag (e.g., <xyz>), end-tag (e.g., </xyz>), and empty-element tag (e.g., <xyz/>).

An element is a logical document component which either begins with a start-tag and ends with a matching end-tag or only consists of an empty-element tag. The characters between the start-tag and end-tag, if any, are the element's content (e.g., <xyz>content</xyz>). The content may consist of other elements, which are called child elements. In SEP2, there can be several levels of child elements. This is often shown in an example of an XML document as a nested hierarchy to improve readability. The actual transmission is a tightly packed string of characters without spaces.

Attribute is the term used for a markup construct consisting of a name/value pair that exists within a start-tag or empty-element tag. This is the source of some confusion because the SEP2 model uses the term attribute as a property of a defined object and this named attribute then appears as an XML element. The SEP2 model uses the expression <<XSDataAttribute>> to define information that is intended to appear as an actual XML attribute. This will be discussed in more detail later.

A simple example of an XML document is shown below:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length:{contentLength}

<DERSettings href="/edev/1/der/1/derg" xmlns="urn:ieee:std:2030.5:ns">
  ...
  <setMinPFOverExcited>
    <!-- PF = 0.995 -->
    <displacement>995</displacement>
    <multiplier>-3</multiplier>
  </setMinPFOverExcited>
  ...
</DERSettings>
```

This is part of an XML payload that would come if a client requested a resource from a server using the HTTP/1.1 GET method. The server returns the response “HTTP/1.1 200 OK” followed by the XML message. The Content-Type and Content-Length are considered the “XML declaration” and tell the client device that the information is encoded in SEP2 and XML and the length.

DERSettings is the name of a DER resource object in SEP2. The start-tag has the element name DERSettings and includes two attributes within the tag. The “href” attribute provides the URI for this resource on the server. This was used in the GET. The “xmlns” attribute provides the link to the most recent XML namespace.

One of the attributes of the DERSettings object is called setMinPFOverExcited and it defines the minimum power factor for the DER device when injecting reactive power (over-excited). This is only one of several device settings returned in this XML message. This object attribute name appears as an XML element name. The minimum over-excited power factor is 0.995 for this device. SEP2 does not support floating point data types (although they are supported by generic XML schema definitions). This requires an integer value of 995 to be provided along with a power of ten multiplier value of -3. Comments start with “<!--” and end with “-->” and an example is also shown. It is not likely that comments would be embedded in machine to machine exchanges, but they are sometimes added in XML examples.

4.4.3 Hypertext Transport Protocol (HTTP) Methods

SEP2 is based on REST. An important concept in REST is the existence of resources (sources of specific information), each of which is referenced with a global identifier (e.g., URI in HTTP). Requests and responses are built around the transfer of representations of resources. A representation of a resource is typically a XML document that captures the current or intended state of a resource.

The communication of information using SEP2 is much like the process that a web browser uses to request and then display a web page. The browser requests the content of the webpage from the host server by using the HTTP GET method with the URI address of the specific page that is desired. The “resource” is located by its URI address. The server responds to the request by providing a “payload” which would consist of an HTML document. The browser uses the HTML document to create the display of the web page. The document could contain “links” to other resources. The links are just URI addresses to other pages (resources). A SEP2 payload is an XML (or EXI) document rather than an HTML document, but the fundamental process is the same.

Clients use the HTTP/1.1 methods of GET, POST, PUT, and DELETE to engage with servers. A server is a device that hosts a resource, and a client is a device that obtains, extends, updates, or deletes representations of that resource. A server device that requests a resource from another server is acting as a client for that resource.

A resource is requested from a server by using the GET method with a URI providing the address of the resource as shown below:

```
GET /edev/1/der/1/derg HTTP/1.1
Host: {hostname}
```

The end device server hosting the DER resources responds with:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml

<DERSettings href="/edev/1/der/1/derg" xmlns="urn:ieee:std:2030.5:ns">

    (More included XML tags and content)

</DERSettings>
```

The URI of “/edev/1/der/1/derg” is based on the structure presented in the WADL. The example URI relates the resource to a specific end device (number 1) which is a DER (/edev/1/der). An integrated DER system could consist of a solar PV array and a storage unit presented as a single end device but with individual DER resources. The resources for the specific DER must be located (/edev/1/der/1). Then the identifier “derg” locates the specific resource (i.e., DERSettings). These locator names could be used by the server and are used for SEP2 examples, but the entire construct is just a unique URI and the server could use its own convention.

If a HAN device is not a server which is capable of hosting its own resources (a self-device), it must place a copy of each of its resources on a host server. This makes the resources available to that client device and to other authorized client devices on the network. A client device uses the GET method to access resources on a host server and this requires a unique URI, as shown in the previous example to retrieve the DERSettings for a specific DER device. The host server assigns a unique URI to each resource of each client (end-device) that it hosts. Client devices use a resource discovery process to find the URIs on the host server for specific resources of interest.

The process of defining which network server will host the resources of a specific client device is all part of setting up the network and there are many possible system architectures. This is not necessarily a plug and play process, at least for the initial configuration. This is not unlike setting up a home entertainment network. For this discussion, it must be assumed that the client device “knows” which server will host its end-device resources. A SEP2 host server will even setup the URIs for empty resources for a specific end-device. Even though DERSettings for a specific DER may not be placed on the host server for this DER, the server will have an established a URI for the DERSettings of this specific DER. The client DER device will discover the URI where it must place its DERSettings resource.

The HTTP PUT method is used to place a basic resource on the host server and also to update it. An example of a client DER placing its DERSettings resource on the host server is shown below:

```
PUT /edev/1/der/1/derg HTTP/1.1
Host: {hostname}

Content-Type: application/sep+xml

<DERSettings xmlns="urn:ieee:std:2030.5:ns">

    (More included XML tags and content)

</DERSettings>
```

The end device server hosting the DER resources responds with:

```
HTTP/1.1 204 No Content
```

This confirms that the server accepted the placement of the resource.

A list is a special type of resource. It is a container for individual resources. Some resources of a client are basic and only one copy can exist on the server for a specific end device. DERSettings is such a resource. A client device can also create resources, such as a flow reservation request, where several different ones may need to be placed on the host server and more than one maintained. Because there are multiple instances of a resource on the server, these are placed on a list. The POST method is used to place a resource on a list as shown in the example below:

```
POST /edev/1/frq HTTP/1.1
Host: {hostname}

<FlowReservationRequest xmlns="urn:ieee:std:2030.5:ns">

    (More included XML tags and content)

</FlowReservationRequest>
```

The end device server hosting the DER resources responds with:

```
HTTP/1.1 201 Created
Location: /edev/1/frq/3
```

In this case the URI for the specific flow reservation request is returned. This is shown as the third on the list (although the URI would not necessarily follow this convention; it only needs to be a unique URI). If the posted flow reservation request needed to be updated, an HTTP PUT would be used to the URI of the specific resource—not the URI of the list.

4.4.4 SEP2 Class Diagrams

The SEP2 model is based on Unified Modeling Language (UML) principles of classes and objects and their attributes. There are many UML class diagrams in the SEP2 standard and these are handy guides to the structure of the model. They are consistent with the guidelines for UML class diagram and therefore only some of the features will be discussed here and not all of the options. These diagrams collectively define all of the information content in the model and show two types of relationships between the various classes in the model. The diagrams show how one class inherits properties from another class. It uses three different methods for showing inheritance in these diagrams to make it more interesting for the layman to try to follow. This concept of inheritance is critical to understanding how XML packages are constructed. The diagrams also show associations between classes for other than inheritance of properties. This also relates to the construction of XML packages, but in a different way.

A portion of the class diagram for DER Control is shown in [Figure 4](#). Each class is defined by a box. The name of the class is placed in the top center of the box. If the class has attributes, these are placed in the lower portion of the box and separated from the name by a line. The focus of this diagram is on the DERControl class. SEP2 shows the class diagrams, but in the text refers to DERControl as an object rather than using the term class, which is actually more precise. For consistency, the term object will be used here. The intention here is to describe the features of the class diagrams and not deal with the purpose of the specific objects and their attributes.

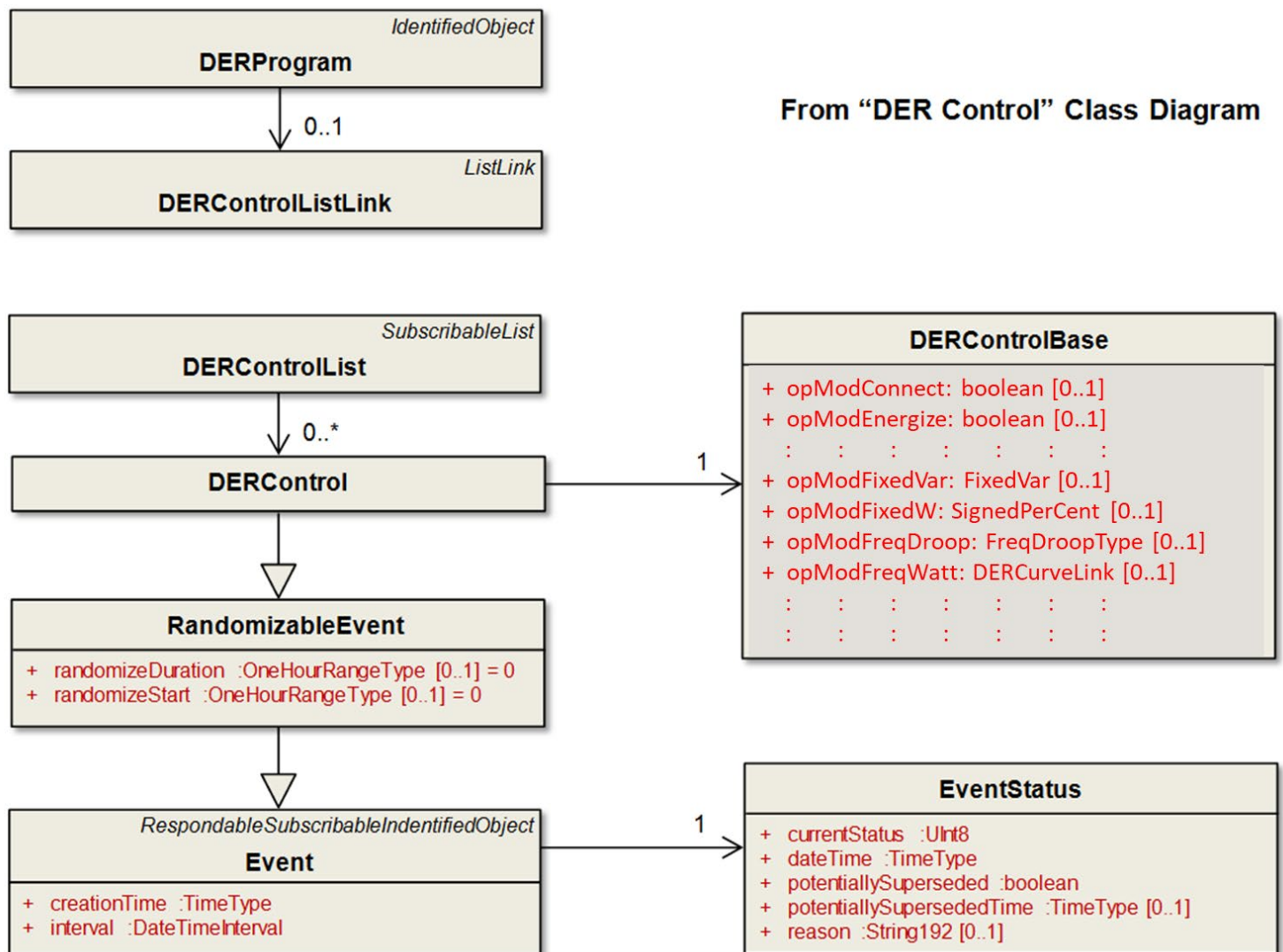


Figure 4 - Sample class diagram for DER control

If a copy of a DERControl object is requested by a client from a server that hosts this resource, the diagram helps show what comes from the server. The DERControl box only shows the name of the object. An arrow with an open head points from the DERControl object to a DERControlBase object. The line with open arrow head is called an association which can be thought of as a “belongs to” or “comes with” relationship. This means that the DERControlBase object and its included attributes are provided with the DERControl object, which itself has no attributes.

There is a “1” next to the arrow and this means that a DERControlBase object must be included, but only one instance. The open arrow with a “0..1” extending from the DERProgram object means exactly zero or one. This effectively means that a DERProgram does not need to have any DERControls, but if it does it can only have one list of DERControls per DERProgram. The open arrow with a “0..*” extending from the DERControlList means zero to whatever (or the list limit defined by SEP2 for this list object). No DERControls are required. If you ask a server for a specific DERControl by its URI you get that specific content. If you ask a server for the DERControlList you get content for from one to many DERControls depending on how the DERControlList resource is requested. There are other relationships that are described in UML books.

The attributes of the DERControlBase object are defined in the lower portion of the box below the object name. Each line describes one attribute. The “+” symbol means it is a “visible” attribute (which is the most common in SEP2) and can be accessed by an outside relating class. There are other symbols which can be found in a UML book. Next the name of the attribute appears. The attribute name may be followed by another name separated by a colon. This name defines the data type or an object that further expands on the data type (which will also be shown later). The “[0..1]” symbol means that the attribute is optional. Otherwise it is mandatory if the object is used. The “randomizeDuration” attribute in the RandomizableEvent Object shows a “=0” at the end. This defines a default value of zero for this attribute if it is not explicitly defined.

The diagram shows a closed arrow extending from the DERControl Object to the RandomizableEvent Object. This means that the DERControl Object inherits all of the attributes from the RandomizableEvent Object. The XML payload for a DERControl resource will include all of the attributes of the RandomizableEvent Object and the Event Object as XML elements. The EventStatus object and its attributes will also be included as elements in the XML document because of the association with Event.

In the upper right corner of the Event Object box, *ResponsibleSubscribableIdentifiedObject* appears in italics. This is another way of showing inheritance instead of adding boxes and connecting them with closed arrows. This is shown on left side of [Figure 5](#). In a diagram for the Identification Class, the ResponsibleSubscribableIdentifiedObject Object can be found. And it inherits from the ResponsibleResource Object which in turn inherits from the Resource Object. This means the attributes from all of these objects are also packaged with XML payload for the DERControl resource. Each of these objects shows a symbol “<<XSDataAttribute>>” which means that any attributes listed below are not object attributes which become XML elements but are actual XML attributes. As discussed earlier the XML attributes appear in the start-tag of the DERControl element.

In the DERControlBase Object there is an attribute named opModFixedW. This is considered to be a SignedPerCent. The SignedPerCent is defined in the Types class diagram as shown in the upper right corner of [Figure 5](#). SignedPerCent is defined as an <<XSDataSimpleType>> attribute of Int16 which is a defined XML class of “short.” The DERControlBase Object also shows an opModFixedVar attribute which uses the FixedVar Object to define it. This object is defined as part of the diagram for DER Control Types and is shown in the lower right corner of [Figure 5](#). Here the single attribute connects with two supporting attributes: one for value which is a SignedPerCent and another for a refType which is of the DERUnitRefType class (an uint8 data type).

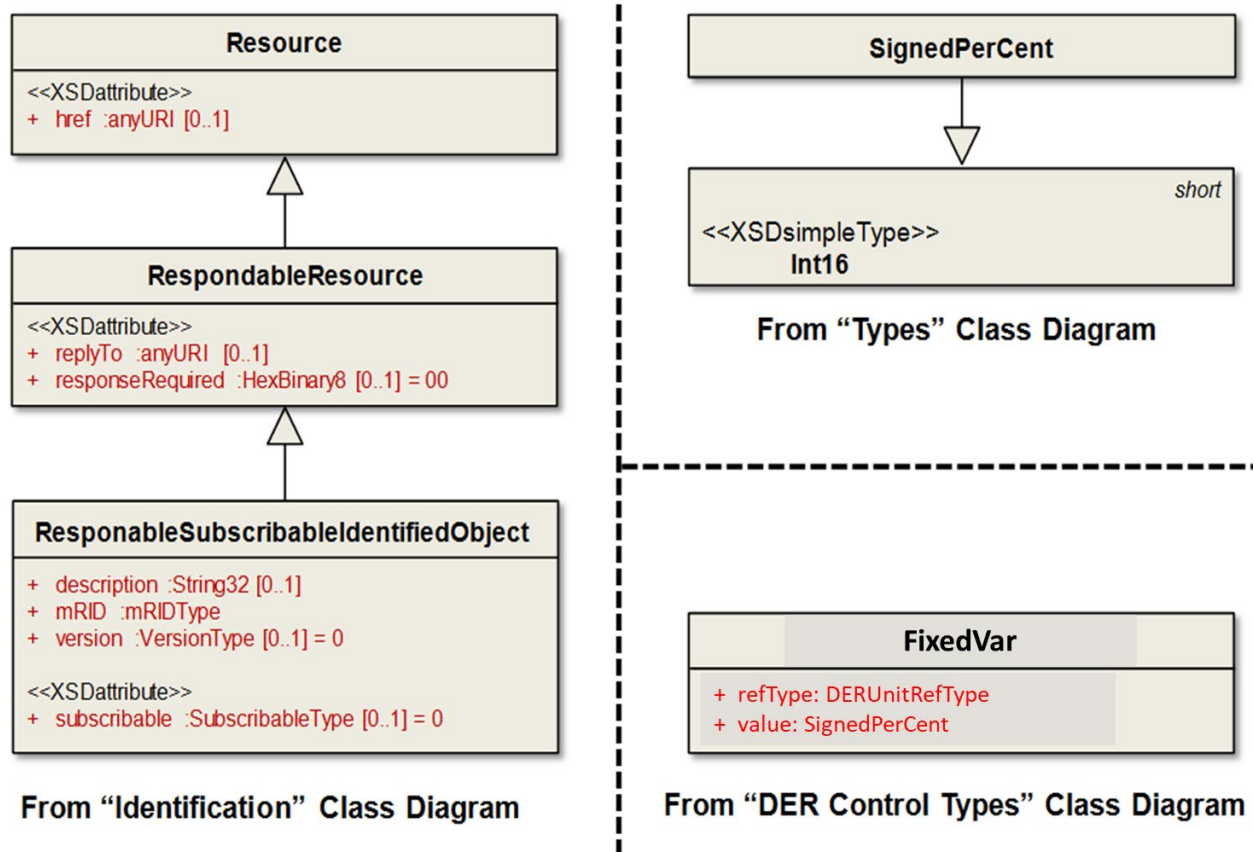


Figure 5 - Class diagrams connected to DER control

The class diagrams have a third method for showing inheritance. An example is shown in [Figure 6](#), which is a portion of the class diagram for flow reservation. The FlowReservationResponse object box actually shows the attribute expansion for the inheritance hierarchy. The double colon ahead of the italicized object name (*::Event*) shows the actual object attributes associated with the object. The XML attributes are shown in the lower portion. This is a compact way to show inheritance, but it is not entirely correct in that it did not bring across the attributes from the associated EventStatus object.

[Figure 6](#) also shows an example of a note which is connected to the RequestStatus object with a dotted line. This defines that the FlowReservationRequest could be an actual request (0) or a cancellation of a request (1) that has already been posted. The model text will define this in detail, but sometimes the class diagram includes some additional information about an object or attribute.

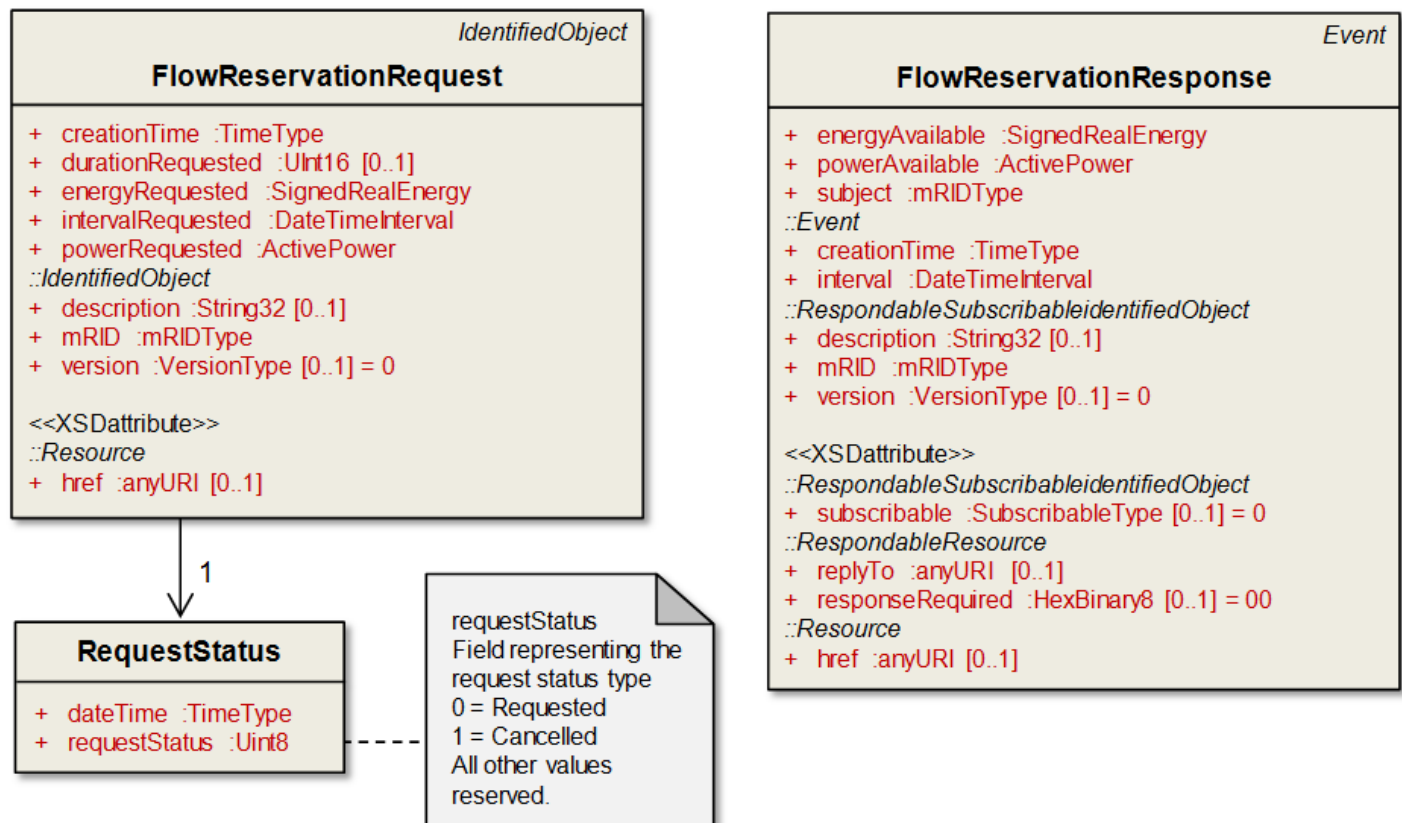


Figure 6 - Excerpts from flow reservation class diagram

4.4.5 SEP2 Informative Model

The SEP2 standard provides an “informative” model in an appendix which can also be found as a separate document. The “normative” (authoritative, real thing) model is constructed using XML and is contained in the SEP2 XSD which is more friendly for computer reading than human reading. There is also an available UML model which was used to create the SEP2 XSD which can be viewed using special software tools. Even though the UML is the source for everything, it is considered to be informative and the XSD is normative. The XSD is actually used as part of the process for encoding and decoding the SEP2 XML messages and therefore needs to be the authoritative source rather than the UML model which created it. This section will provide some guidance to the structure and organization of the text of the informative model. The UML class diagrams provided in this model have already been discussed.

The model begins by defining objects that are widely used by many, if not all, SEP2 function sets. This is where the basic Resource Object, Event Object, List Object, and Link Object are defined. This is also where type objects which are used in more than one function set are defined, such as the PerCent and RealEnergy objects. Every user needs to be familiar with this front portion. The remaining sections of the document are organized by function set which are called “packages” in the model. There is a DER Package, a FlowReservation Package, and a PowerStatus Package which are the primary focus herein. The model ends with a description of the Links Package which also supports all of the function sets. The associated class diagrams are placed near the start of each package.

An excerpt from the informative model is shown below for a portion of the DERControlBase Object which was shown in the class diagram in [Figure 4](#).

DERControlBase Object ()

Distributed Energy Resource (DER) control values

opModFixedW attribute (SignedPerCent) [0..1]

The opModFixedW function specifies a requested charge or discharge mode setpoint, in %setMaxChargeRateW if negative value or %setMaxW or %setMaxDischargeRateW if positive value (in hundredths)

opModFixedPFIjectW attribute (PowerFactorWithExcitation) [0..1]

The opModFixedPFIjectW function specifies a requested fixed Power Factor (PF) setting for when active power is being injected. The actual displacement SHALL be within the limits established by setMinPFOverExcited and setMinPFUnderExcited. If used simultaneously with other reactive power controls (e.g. opModFixedVar) the control resulting in least var magnitude SHOULD take precedence.

This excerpt only shows the opModFixedW and opModFixedPFIjectW attributes. The only new information beyond what is shown by the class diagram is the definition of the object and the attributes.

The ResponsibleResource Object, which is shown in the class diagram in [Figure 5](#), is shown below:

ResponsibleResource Object (Resource)

A Resource to which a Response can be requested

replyTo attribute (anyURI) [0..1] «XSDattribute»

A reference to the response resource address (URI). Required on a response to a GET if responseRequired is "true."

responseRequired attribute (HexBinary8) [0..1] «XSDattribute»

Indicates whether or not a response is required upon receipt, creation or update of this resource. Responses shall be posted to the collection specified in "replyTo."

This resource only has XSDattributes. It also shows that it inherits from the Resource Object which is shown in parenthesis in the first line.

4.4.6 Web-Application Description Language

The SEP2 Web-Application Description Language (WADL) defines the recommended URI structures to be used to interact with specific resources in the model. Not all SEP2 resources can be directly accessed and the WADL defines which resources can be accessed. The WADL is organized by function set.

An example from the WADL is shown below for the DERSettings resource:

DERSettings Resource

The DER settings of the associated EndDevice or SelfDevice

Sample URI: /edev/{id1}/der/{id2}/derg

Request Representation: DERSettings

Response Representation: DERSettings

Methods: GET/HEAD: Mandatory, PUT: Mandatory, POST: Error, DELETE: Error

The first line is the title of the resource as used in the model (e.g., DERSettings). This is followed by a brief description, which in this case notes that this resource contains the DER settings for the associated end device or self device.

A sample URI is provided in the next line. The WADL uses descriptive abbreviations to define the unique URI and these could be used by a server, but a server could have its own convention. This resource belongs to an end device (edev). The host server could contain resources for many end devices on the HAN. The symbol {id1} signifies that some identification is needed for each end device (which could just be as simple as a number 1, 2, 3, etc.). This resource is related to a specific DER of an end device which may have more than one DER integrated into it. The “/der/{id2}” is used to designate a specific DER. Examples in this document will use “der/1” because a PEV is a single DER. The “/derg” identifies the specific DERSettings resource. Again, this makes it easier to follow the model, but the server could just create a unique URI for this resource for a specific DER entity for a specific end device.

When a GET is used with the URI, the Response Representation designates which resource will be returned with the XML payload. The Request Representation shows which object is associated with the PUT, POST, and DELETE methods. In this example, both are the same. This is typical for a basic resource. When list resources are used these will generally be different. The request will be the named object and the response will be a list object that acts as a container for the named object.

The last line shows the compliance (MODE) definitions for each of the HTTP methods: Mandatory (“M”) must implement and conform; Optional (“O”) may implement, and if implemented, must conform; Discouraged (“D”) should not implement, but if implemented, must conform; and Error (“E”) must return one of the specified response status codes (400 - Bad request or 405 - Method Not Allowed).

A summary of WADL entries for resources associated with the DER, flow reservation, and power status function sets is provided in [Table 2](#). The table is organized in the order of function set. Within the DER function, DER Program resources (derp) are placed ahead of end device resources (edev). The WADL resources shown in red are not actual resources in the SEP2 model. These act like a specialized search of a more basic resource, such as the DERControlList response for the ActiveDERControlList resource. The provided list would only be for those DER Controls with an active status. The resources with a sample URI of “edev” are associated with a specific HAN device. The resources with a “derp” URI do not belong to the end device. These belong to the DER controller and are placed and maintained on its server using embedded software and not SEP2 messages.

Table 2 - WADL summary for selected resources

Resource	Sample URI	HTTP Method				GET Response
		GET	PUT	POST	DEL	
ActiveDERControlList	/derp/{id1}/actderc	M	E	E	E	DERControlList
DefaultDERControl	/derp/{id1}/dderc	M	O	E	E	DefaultDERControl
DERControl	/derp/{id1}/derc/{id2}	M	E	E	O	DERControl
DERControlList	/derp/{id1}/derc	M	E	O	E	DERControlList
DERCurve	/derp/{id1}/dc/{id2}	M	E	E	O	DERCurve
DERCurveList	/derp/{id1}/dc	M	E	O	E	DERCurveList
DERProgram	/derp/{id1}	M	E	E	O	DERProgram
DERProgramList	/derp	M	E	O	E	DERProgramList
AssociatedDERProgramList	/edev/{id1}/der/{id2}/derp	M	E	O	E	DERProgramList
CurrentDERProgram	/edev/{id1}/der/{id2}/cdp	M	E	E	O	DERProgram
DER	/edev/{id1}/der/{id2}	M	O	E	O	DER
DERAvailability	/edev/{id1}/der/{id2}/dera	M	M	E	E	DERAvailability
DERCapability	/edev/{id1}/der/{id2}/dercap	M	M	E	E	DERCapability
DERList	/edev/{id1}/der	M	E	O	E	DERList
DERSettings	/edev/{id1}/der/{id2}/derg	M	M	E	E	DERSettings
DERStatus	/edev/{id1}/der/{id2}/ders	M	M	E	E	DERStatus
FlowReservationRequest	/edev/{id1}/frq/{id2}	M	M	E	O	FlowReservationRequest
FlowReservationRequestList	/edev/{id1}/frq	M	E	M	E	FlowReservationRequestList
FlowReservationResponse	/edev/{id1}/frp/{id2}	M	M	E	D	FlowReservationResponse
FlowReservationResponseList	/edev/{id1}/frp	M	E	D	E	FlowReservationResponseList
PowerStatus	/edev/{id1}/ps	M	M	E	E	PowerStatus

4.4.7 Resources, Links, and Lists

[Figure 7](#) shows a small portion of the inheritance hierarchy for objects in SEP2. The left side shows resources and the right side shows links. The focus is on those objects which are of interest for flow reservation and DER applications. The objects shown in red are associated with the DER function, those shown in blue are associated with the flow reservation function, and those in green are associated with power status. Those objects shown in bold will be discussed in much more detail later in this document.

There are two fundamental types of objects in the model: Resource objects and Link objects. A resource is an addressable unit of information—actual content. Links only provide a reference, via URI, to another resource.



Figure 7 - Object hierarchy

After the name of each resource object is a designation of whether it is an end device (edev) resource or a DER program (derp) resource. The end device resources belong to a specific device. The DER program resources belong to the DER controller and could be retrieved and used by many devices. It could be that a DER program only applies to a single DER, but a program could be set up to apply to many. The grouping is flexible because a DER controller may want to organize DER devices by groups and provide a common control signal to each group.

A list object can be thought of as a container to hold a collection of resource object instances. An example is shown in [Figure 8](#) for the DERControlList resource. The example shows four individual DERControl instances which all belong to the DERControlList, but only in the sense of a relational database. These are the only DERControl objects in the server. Each of the four DERControl objects has a unique URI. Rather than use a simple numerical sequence for successive DERControl URIs, which is dangerous to assume, this example uses a code for frequency-watt curve, volt-var curve, and fixed-flow commands. Otherwise one might think that if the active control is URI/2 that the next one could be URI/3 and this could be wrong. Each list object has a defined sort order of primary, secondary, and tertiary attributes of the basic object. These are all defined in the SEP2 standard. Each DERControl object is an Event which has a designated start time, which is expressed as the integer number of seconds since midnight on January 1, 1970, GMT (class TimeType). For simplicity in this example only the last three digits are shown. For the DERControlList, the DERControl objects are sorted by ascending order event start time, and then descending order of creation time, and then by descending order of mRID.

List Query

```
GET /derp/1/derc?s=x&a=y&l=z HTTP/1.1
```

```
<DERControlList ... all="4" result="value" ... >
```

	GET	result=	XML Payload(s)
1	URI	1	A
2	URI?	1	A
3	URI?s=0&l=1	1	A
4	URI?s=1	1	B
5	URI?l=2	2	A,B
6	URI?s=2&l=2	2	C,D
7	URI?a=xx200	1	C
8	URI?a=xx200&l=2	2	C,D
9	URI?s=1&a=200&l=2	1	D

Direct Access

```
GET /derp/1/derc/ff2163
```

```
<DERControl ... >
```

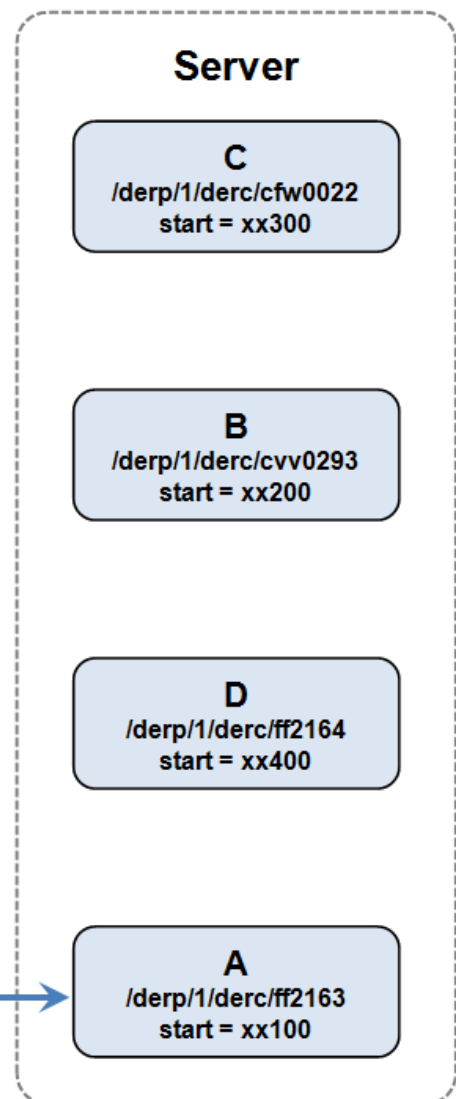


Figure 8 - List query example

There are two ways to request a DERControl. One is to directly request the exact DER Control using its full URI, if it is known by the client. In this example DERControl “A” could be retrieved from the server using:

```
GET /derp/1/derc/ff2163 HTTP/1.1
Host: {hostname}
```

The server would respond with the XML payload for this exact DERControl.

The other method is to retrieve the content of the DERControlList by using a GET query of the list. The XML payload would return content for potentially several DERControl instances. It is more likely that the exact URI of a specific DERControl would not be known and a list query would be used to retrieve the one(s) of interest from the server. An example of a list query is shown below:

```
GET /derp/1/derc?s=0&a=xx200&l=2 HTTP/1.1
Host: {hostname}
```

The server would respond with the XML payload for the DERControlList which would include, in this case, the XML payload for DERControls “C” and “D.”

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: {contentLength}

<DERControlList all="4" results="2" href="/derp/0/derc" subscribable="1"
  xmlns="urn:ieee:std:2030.5:ns" >
  <DERControl>
    (XML content for DERControl C)
  </DERControl>
  <DERControl>
    (XML content for DERControl D)
  </DERControl>
</DERControlList>
```

The query string parameters (s,a,l) are described in detail in the SEP2 standard. The DERControlList figure shows several examples. Query string parameters are parameters added to a URI to provide filtering of list items returned in query results. The “s” (start) indicates the first ordinal position in the list to be returned in the query result list as determined by the list's ordering with zero being first. Zero is also the default if this parameter is not provided. The “l” (for limit, not one) is used to set the maximum number of list items (up to 255) to be included in the query result list. If this query string parameter is not specified, the default limit is one. The “a” (after this time) is used to indicate that only items whose primary key occurs after the given date time parameter should be included in the query result list. This query string parameter is only applied to list resources that are ordered using a time-based primary key. If both a “start” and “after” query string parameter are used simultaneously, the “after” query string parameter has precedence, and the “start” position zero is relative to the position specified by the “after” parameter. Null queries are possible.

One important question is how a client device can first locate the URI of the DERControlList on the server of a DER controller. A related question is how the DER controller (as a client) can find the DERSettings resource on the end device server for the PEV. This is all done by a discovery process during which the respective client device first locates the URI of the DeviceCapability resource on the server. SEP2 makes this the “master” discoverable resource. Once the URI of this resource is located, SEP2 provides a structure of link resources and listlink resources to map the URI structure of the end device or DER program. An example of this is shown in [Figure 9](#) for the DERSettings (edev) resource and the DERControl (derp) resource.

The WADL shows a meaningful sample URI structure for all resources. DERSettings, for example, has a sample URI of “/edev/1/der/1/derg.” However, the actual URI could be “/d43x97yz3”—not great, but SEP2 requires that all resources should be capable of being found without relying on a URI naming convention. The WADL samples are great and a SEP2 server could follow the sample structure, but a client should not rely on this convention. A client device should discover and use the links, listlinks, list resources, and pure resources to identify the actual URI structure for use in its GET, PUT, and POST methods. This way, a GET /d43x97yz3 will return the DERSettings XML payload and it is exactly equivalent to the sample GET /edev/1/der/1/derg request, but with the actual URI for this resource.

The class diagrams in the SEP2 model show all of these connections. [Figure 9](#) just shows the path to DERControl and to DERSettings. It may take multiple GET requests to pure resources to find links or listlinks. Lists will need to be searched, such as the DERList to find a specific DER. In some cases, the inheritance of objects will bring information into the XML payload of objects—such as the AbstractDevice XML being returned to a client from a GET of a specific EndDevice object URI. When a PEV connects to the host server and application server there is some housekeeping work to be done to locate all of the resources needed for a session. This process is beyond the scope of this document.

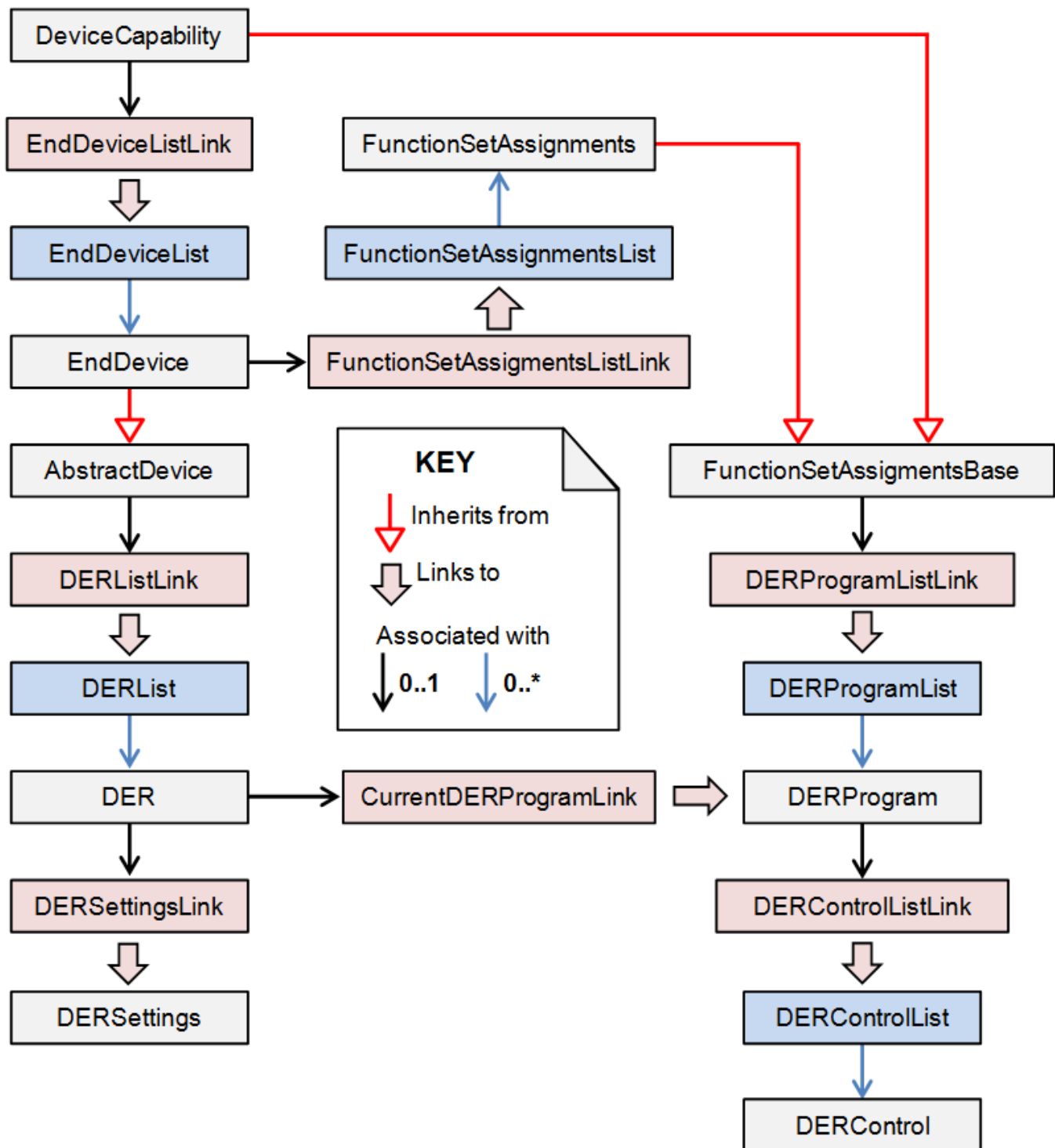


Figure 9 - Connecting resources

4.5 EVSE and PEV Network Options

Smart Energy Profile 1.0 was created to deal with home energy networks consisting of primarily simple devices such as thermostats and on/off power switches. These are low cost client devices. The object model has now been extended in SEP2 to include the information requirements for complex devices, such as a storage DER system. A stationary DER system would most likely host its own resources as a self-device. However, it is more likely that a mobile DER (PEV) would only be a client device and maintain its resources on an associated end-device server.

Most client devices are part of a fixed network. The decisions for hosting client device resources can be made when the HAN is first setup and when the homeowner enrolls in different applications. This is sometimes called an “out of band” process and it is not generally an automatic “plug and play” action. It may involve data entry on the device and in associated servers either in the home or at the service provider. It could use other communication protocols than SEP2. For a PEV at home, this would be no more difficult than setting up any other fixed complex device, such as a solar PV system. This gets much more complex if the PEV is not at home. Reverse power flow is also subject to utility approval at the point of connection and this may preclude any simple drive up and discharge operation even if a client PEV had the capability to directly communicate with an aggregator and host its resources on the aggregator server.

No matter how it is accomplished between an EVSE and a PEV, a PEV with an onboard inverter must be able to access SEP2 XML messages for DER Controls. The EVSE could serve as a simple bridge to the HAN, in which case the PEV could retrieve DER Controls from a compatible DER controller on the HAN or beyond. The EVSE could also act as a SEP2 gateway for the PEV and be the server for the PEV end device resources and the host for the DER Program of the DER controller. There are many possible SEP2 networks, but only two will be considered for examples in this document: one based on an EVSE bridge and another based on an EVSE gateway.

The system shown in [Figure 10](#) uses an EVSE that provides a bridge for the PEV to directly connect to the HAN. In this example, it translates the PLC messages to a HAN protocol, such as Ethernet, but the EVSE does not interact with the message payload. Both the EVSE and the PEV are client devices and therefore must host their resources on a discoverable server. The Energy Services Interface (ESI) performs this function for this network and acts as the end device server for the PEV and EVSE. The PEV must place copies of its resources on the ESI server using the HTTP PUT method. It is assumed that the PEV can directly discover the resources on the EMS and DER Controls (DERC) can be retrieved by the PEV using the GET Method or by subscription.

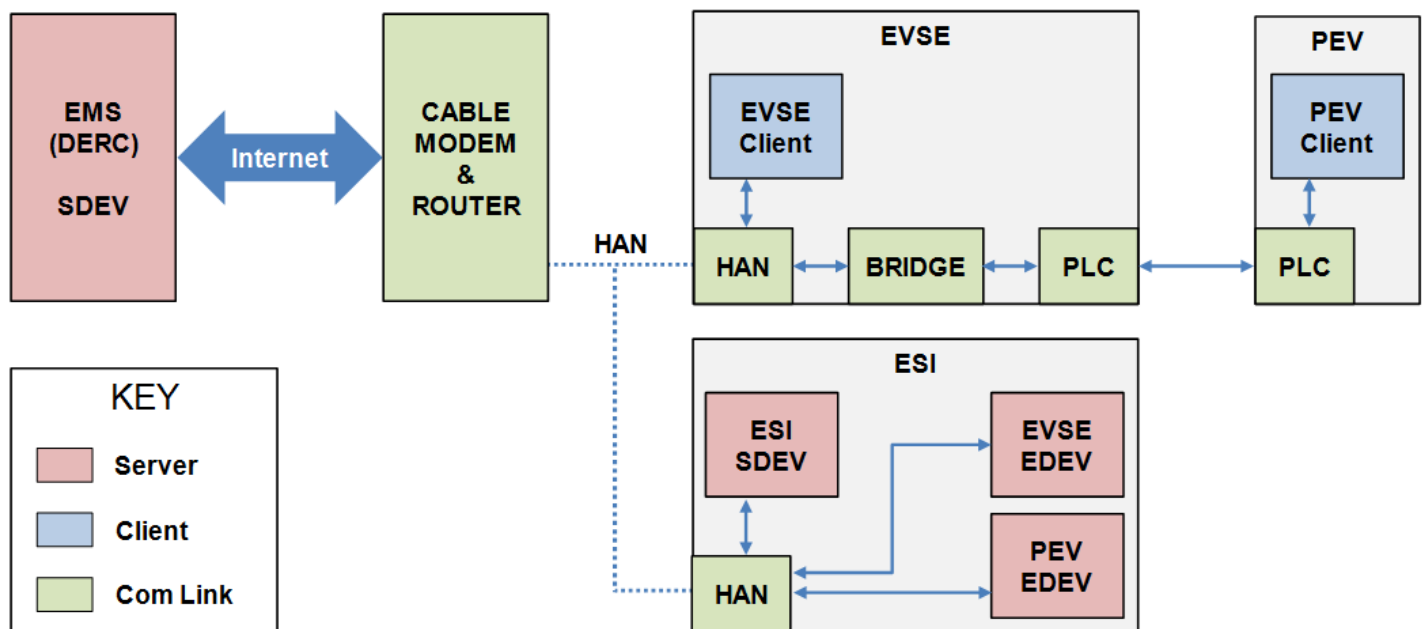


Figure 10 - EVSE as bridge

The system shown in [Figure 11](#) does not provide direct access to the HAN by the PEV. The PEV can only communicate directly with the EVSE using the SEP2 protocol. This is a private point-to-point network. In this system, the EVSE acts as an end-device server for the client PEV to host its resources. The PEV would discover the EVSE server and engage with it just as it would have engaged with the ESI in the bridge system. The DER controller will be based on the IEC 61850 DER Model, but it may or may not use SEP2. If the EVSE engages with the DER controller using the DER controller protocol, the EVSE will act as a SEP2 gateway between the DER controller and the PEV. If the DER controller and EVSE both use the SEP2 protocol, the gateway functionality is much less complex. This is all beyond the scope of this document.

If the gateway is well designed, the PEV would appear to be connected using the virtual architecture shown in the lower right of the figure. This would look like a point-to-point exchange between the DER controller and the PEV using SEP2. The gateway must ensure that resources placed in the PEV end-device representation are immediately made available to the DER controller. It must also ensure that DER Controls from the DER controller are retrieved and presented to the PEV with minimal transport delay and at the update rate of the DER application.

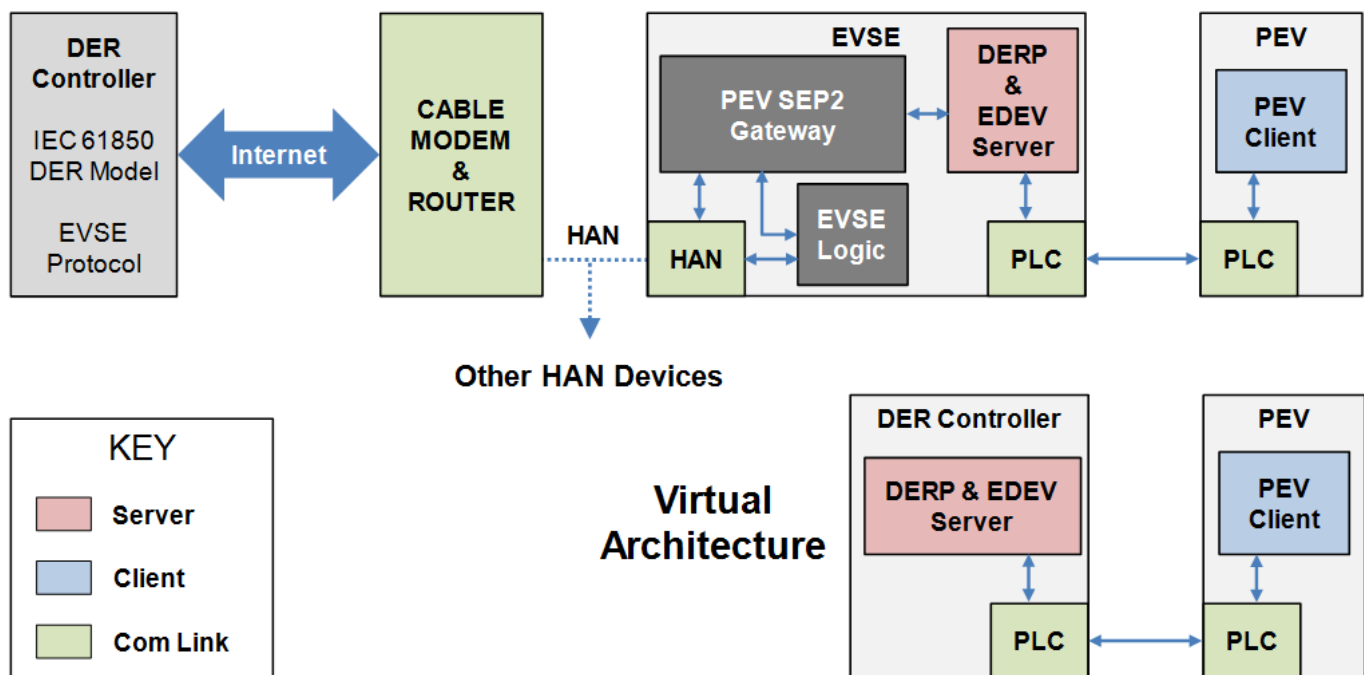


Figure 11 - EVSE as gateway

One key factor in setting up the network is getting approval to interconnect a DER device. A homeowner that wishes to connect a DER device in parallel with the grid must apply to the distribution utility for authorization, follow the utility procedures to secure their approval, and enter into an interconnection agreement with the utility. The application will be for a specific inverter (or PEV) model that has been tested and listed by a listing organization that is acceptable to the local utility to a standard (such as UL 1741) that is also acceptable to the local utility. There is currently no process for third-party-authenticated electronic verification that the inverter model is listed and approved by the governing interconnect agreement for the EVSE. Until such a process exists, it will be prudent for the EVSE owner to ensure that any vehicles that plan to discharge do so in compliance with their utility interconnection agreement. One way to achieve this is to provide controls and displays onboard the vehicle to authorize discharging at that EVSE.

Discharging at work or at public locations becomes much more complex for PEVs with onboard inverters. The interconnection procedures all assume fixed DER devices, not mobile devices. Even if individual model PEVs are all listed, there is no established method to approve a random mix of listed inverter models at a site. Significant work will need to be done with state regulators to establish procedures to allow for public sites to allow interconnection of a random mix of listed PEVs. It may be required that each PEV provide its model number to the site ESI or EMS to check against a list of approved models. SEP2 provides an object that can be used for this purpose.

4.6 Harmonization of DER Information Models

The SEP2 information object model is described by an XSD that contains the definitions of the resources, attributes, and elements as well as their textual descriptions. This XML schema is to be used for encoding and decoding XML messages to and from the PEV. An informative textual extract of the XSD is provided as an appendix in the Application Protocol Standard.

The international standard IEC 61850-7-420 describes the power control functions for inverter-based DER systems, including photovoltaic (PV) systems, battery storage systems, PEVs, and any other DER systems with controllable inverters. It defines the IEC 61850 information models to be used in the exchange of information between these inverter based DER systems and the utilities or other entities which are tasked with managing the active and reactive power capabilities of these inverter-based systems.

SAE J2836/3 incorporated most, but not all, of the inverter functions defined in IEC 61850-7-420. It included only those functions that were also included in the SEP2 DER function model. The SEP2 inverter model was based on the SunSpec Alliance Inverter Control Model which was also derived from IEC 61850-7-420. Because the IEC, SAE, SunSpec Alliance, and SEP2 information models were under development at the same time, some differences exist between the information models.

SAE J2836/3 defines information requirements for two utility use cases: U6 (Basic Distributed Energy Resource) and U7 (Advanced Distributed Energy Resource). [Table 3](#) shows these use cases. Utility use case U5 (Optimized Energy Transfer), which is defined by SAE J2836/1, is also shown. The use case and associated inverter modes (functions) are listed in the first column. U5 and U6 are single functions. U7 consists of several modes. The second column lists the type of function: fixed command, autonomous curve, or specification curve function. The third column (SEP2) designates the SEP2 function set that supports the use case mode: either DER or flow reservation (FR). The VAR column lists whether the inverter must be capable of sourcing or absorbing reactive power to perform the function.

Table 3 - SAE use cases and modes

Use Case and Mode		Type	SEP2	Var
U5	Flow Reservation	Fixed	FR	
U6	Fixed W	Fixed	DER	
U7	Fixed Power Factor	Fixed	DER	Y
U7	Fixed Var	Fixed	DER	Y
U7	Frequency-Watt	Auto	DER	
U7	Volt-Watt	Auto	DER	
U7	Volt-Var	Auto	DER	Y
U7	Watt-Power Factor	Auto	DER	Y
U7	Low Voltage Ride Through	Spec	DER	
U7	High Voltage Ride Through	Spec	DER	

There is no requirement for a PEV to have an onboard inverter. And even if it does have an inverter, there is no requirement to implement any or all of the inverter functions and associated communication to allow external control. The PEV inverter could be manually engaged to provide basic reverse flow into a live grid. However, if a PEV does implement communication to serve as a DER device, it must at least implement U6. This provides the basic capability to directly control the rate of charging or discharging of the PEV. Whether any of the U7 functions are implemented in a PEV inverter will depend on the economic case for the PEV manufacturer and the PEV customer. Some functions represent new capabilities that have no established market today.

IEC 61850-7-420 was initiated primarily to allow solar PV systems and stationary battery storage systems to assist the distribution utility with managing power quality and loads on feeders as the penetration of renewable sources increase. The autonomous volt-var capability is a key capability for providing voltage support. Unlike PEVs, solar PV systems and stationary battery storage systems are capable of sustained energy production and they have generally much larger power output than a PEV. The low and high voltage ride through functions may be essential for keeping PV solar and stationary storage systems on-line during voltage disturbances to allow the inverter to help correct the voltages using autonomous volt-var curves. While utilities have great interest in this capability for solar PV systems, they may prefer to have a PEV that is sourcing power to just drop offline during a voltage disturbance. There may not be a viable economic model to justify some of the U7 DER functions at the current time for either the PEV or the utility, but this will probably change in the future. SEP2 must provide for solar PV inverters and therefore includes most of the IEC functions. SAE J2836/3 U7 also allowed for the advanced functions, but the PEV manufacturer will need to decide which functions to implement in the inverter.

SAE J2836/3 includes information that precisely defines the PEV charging requirements which can be used by a DER controller to both use the PEV as a DER and also ensure that the PEV achieves its charging objectives. It is not required that a controller always uses this information, but there are applications where this cooperation is desired. Some of this has been added to the SEP2 model but needs to be incorporated in IEC 61850. Others are in both the IEC and SEP2 models but the use by a PEV may be different. This information is shown in [Table 4](#). They are explained in Appendix E of SAE J2836/3 and in the SEP2 model. The SEP2 items are attribute names of the objects listed in parentheses.

Table 4 - Required PEV state information

SAE J2836/3 Information	SEP2 Model	IEC 61850
PEV Charging Requirements		
Time Charge Is Needed	timeChargelsNeeded (PowerStatus)	Yes, Needed
Energy Request	energyRequestNow (PowerStatus)	Y Needed
Minimum Charging Duration	minimumChargingDuration (PowerStatus)	Y Needed
Maximum Forward Power	maxForwardPower (PowerStatus) - ALTERNATE	Y
Time of Reference	timeChargingStatusPEV (PowerStatus)	Y
Maximum Ratings of DER		
Maximum Forward Power	setMaxChargeRate (DERSettings)	Y
Maximum Reverse Power	setMaxDischargeRate (DERSettings)	Y
Minimum Power Factor	setMinPF (DERSettings)	Y
Maximum Reactive Power	setMaxVar (DERSettings)	Y
Availability of DER Capability		
Duration Maximum Forward Power	maxChargeDuration (DERAvailability)	Y Needed
Duration Maximum Reverse Power	availabilityDuration (DERAvailability)	Y Needed
Available Reactive Power	statVarAvail (DERAvailability)	Y

To ensure interoperability of the PEV serving as a DER device with a utility DER management system, a customer energy management systems (EMS), or another entity's DER controller, it is essential that the SEP2 model align as closely as practicable with the IEC 61850-7-420 model. While the content of the IEC and SEP2 model may be similar, the model structure may be different. While a DER controller may not use the SEP2 protocol, it will most likely use a protocol that follows the IEC object model. Some device between the DER controller and the PEV will need to serve as a bidirectional protocol translator and this task becomes much easier if the IEC and SEP2 models are aligned.