SAE INTERNATIONAL

SURFACE VEHICLE TECHNICAL INFORMATION REPORT

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Superseding J2836 JUL2018

(R) Instructions for Using Plug-In Electric Vehicle (PEV) Communications, Interoperability, and Security Documents

RATIONALE

This SAE Technical Information Report has been updated to add the summary and references to the new documents now published and updates to existing documents for V2X Charge Rate Reporting and other features.

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TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

For more information on this standard, visit
https://www.sae.org/standards/content/J2836_202412/

1. SCOPE

This SAE Technical Information Report (TIR) establishes the instructions for the documents required for the variety of potential functions for PEV communications, energy transfer options, interoperability, and security. This includes the history, current status, and future plans for migrating through these documents created in the Hybrid Communication and Interoperability Task Force, based on functional objective (e.g., [1] If I want to do V2G with an off-board inverter, what documents and items within them do I need, [2] What do we intend for V3 of SAE J2953, …).

1.1 Purpose

The purpose of SAE J2836 is to document the general information that is supported by SAE J2836, SAE J2847, SAE J2931, and SAE J2953 series and SAE J3072 for Plug-In Electric Vehicles.

1.2 Background

PEV charging and communications include several options, and the Communication and Interoperability Task Force determined how to separate these functions in their effort to keep the standards concise and targeted toward each of the objectives and generate various versions of the documents as the market matured and updated aspects could be added. Smart Charging was the initial approach, and Use Cases were generated that included interaction with the utility. These Use Cases were included in SAE J2836/1, and the messages added to SAE J2847/1. The communication protocol high-level requirements are in SAE J2931/1, and the specific median is SAE J2931/4. The task force soon followed with DC charging with the same approach and continued into six slash sheets of Use Cases and Messages. These are described in this TIR, and the objective is to identify the document path for all options that can be considered.

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 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 J1634 Battery Electric Vehicle Energy Consumption and Range Test Procedure

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 J2836/4 Use Cases for Diagnostic Communication for Plug-in Electric Vehicles

SAE J2836/5 Use Cases for Customer Communication for Plug-in Electric Vehicles

SAE J2836/6 Use Cases for Wireless Charging Communication for Plug-in Electric Vehicles

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 J2847/3 Communication for Plug-in Vehicles as a Distributed Energy Source

SAE J2847/5 Communication Between Plug-in Vehicles and Customers

SAE J2847/6 Communication for Wireless Power Transfer Between Light-Duty Plug-in Electric Vehicles and Wireless EV Charging Stations

SAE J2894/1 Power Quality Requirements for Plug-In Electric Vehicle Chargers

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

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

SAE J2931/6 Signaling Communication for Wirelessly Charged Electric Vehicles

SAE J2931/7 Security for Plug-In Electric Vehicle Communications

SAE J2953/1 Plug-in Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)

SAE J2953/2 Test Procedures for the Plug-in Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)

SAE J2953/4 Plug-In Electrical Vehicle Charge Rate Reporting and Test Procedures

SAE J2954 Wireless Power Transfer for Light-Duty Plug-in/Electric Vehicles and Alignment Methodology

SAE J2954/2 Wireless Power Transfer for Heavy-Duty Electric Vehicles

SAE J3072 Interconnection Requirements for Onboard, Grid Support Inverter Systems

SAE J3400 North American Charging System (NACS) for Electric Vehicles

2.1.2 ANSI Accredited Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ANSI C12.20 Electricity Meters - 0.2 and 0.5 Accuracy Classes

2.1.3 Code of Federal Regulations (CFR) Publications

Copies of these documents are available online at https://www.ecfr.gov.

16 CFR Part 309 Labeling Requirements for Alternative Fuels and Alternative Fueled Vehicles

2.1.4 DIN Publications

Copies of these documents are available online at https://www.din.de/en/.

DIN SPEC 70121:2014 Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging in the Combined Charging System

DIN SPEC 70122 Conformance tests for digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging in the Combined Charging System

2.1.5 EPRI Publications

Available from Electric Power Research Institute, 3420 Hillview Avenue, Palo Alto, CA 94304, Tel: 650-855-2000, www.epri.com.

Common Functions for Smart Inverters, Version 4, EPRI, Palo Alto, CA, 2016, 3002008217

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

Open Vehicle-Grid Integration Platform - Unified Approach to Grid/Vehicle Integration: Definition of Use Case Requirements, EPRI, Palo Alto, CA, 2015, 3002005994

EPRI's recently pre-published EV Charging Standards Guidebook document:

An Electric Vehicle Charging Standards Guidebook for North America: First Edition (epri.com)

2.1.6 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	Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
IEEE 1547.1-2020	Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems
IEEE 1547.3	Guide for Cybersecurity of Distributed Energy Resources Interconnected with Electric Power Systems
IEEE 2030.5-2018	Standard for Smart Energy Profile Application Protocol

2.1.7 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 15118-1	Road vehicles - Vehicle to grid communication interface - Part 1: General information and use-case definition
ISO 15118-2	Road vehicles - Vehicle to grid communication interface - Part 2: Network and application protocol requirements
ISO 15118-3	Road vehicles - Vehicle to grid communication interface - Part 3: Physical layer and data link layer requirements
ISO 15118-4	Road vehicles - Vehicle to grid communication interface - Part 4: Network and application protocol conformance test
ISO 15118-5	Road vehicles - Vehicle to grid communication interface - Part 5: Physical and data link layer conformance test
ISO 15118-6	Road vehicles - Vehicle to grid communication interface - Part 6: Physical layer and data link layer requirements for differential HomePlug Green PHY

ISO 15118-8 Road vehicles - Vehicle to grid communication interface - Part 8: Physical layer and data link layer requirements for wireless communication

ISO 15118-9 Road vehicles - Vehicle to grid communication interface - Part 9: Physical layer and data link layer conformance test for wireless communication

ISO 15118-10 Road vehicles - Vehicle to grid communication interface - Part 10: Physical layer and data link layer requirements for single-pair Ethernet

ISO 15118-20 Road vehicles - Vehicle to grid communication interface - Part 20: 2nd generation network layer and application layer requirements

ISO 15118-21 Road vehicles - Vehicle to grid communication interface - Part 21: Common 2nd generation network layer and application layer requirements conformance test plan

ISO 15118-23 Road vehicles - Vehicle to grid communication interface - Part 23: 2nd generation network layer and application layer requirements conformance test plan - DC charging

2.1.8 NFPA Publications

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

NFPA 70®, National Electrical Code® (NEC®)

2.1.9 NIST Publications

Available from NIST, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070, Tel: 301-975-6478, www.nist.gov.

NIST Handbook 130 Uniform Laws and Regulations in the Areas of Legal Metrology and Fuel Quality

NIST HB44-3.40 Measurement Requirements for Electric Vehicle Fueling Systems

NIST IR 7628 Guidelines for Smart Grid Cybersecurity

2.1.10 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

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

UL 1741 SC Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources: Supplement SC (Bidirectional Electric Vehicle Supply Equipment (BEVSE)/Interconnection Systems Equipment (ISE) for EVs with Bidirectional Onboard Inverters)

UL 2202 Standard for Safety for Electric Vehicle (EV) Charging System Equipment

UL 2941 Outline of Investigation for Cybersecurity of Distributed Energy and Inverter-Based Resources

UL 9741 Outline of Investigation for Bidirectional Electric Vehicle (EV) Charging System Equipment

UL 61010-1 Safety Requirements for Electrical Equipment For Measurement, Control, and Laboratory Use; Part 1: General Requirements

2.1.11 United States Code Publications

Copies of these documents are available online at https://uscode.house.gov/.

42 U.S.C. §17381 Statement of policy on modernization of electricity grid

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 J1715 Hybrid Electric Vehicle (HEV) and Electric Vehicle (EV) Terminology

2.2.2 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 61851-1 Electric vehicle conductive charging system - Part 1: General requirements

IEC 61851-23 Electric vehicle conductive charging system - Part 23: DC electric vehicle supply equipment

IEC 61851-24 Electric vehicle conductive charging system - Part 24: Digital communication between a DC EV charging station and an electric vehicle for control of DC charging

IEC 62196-1 Plugs, socket-outlets, vehicles connectors and vehicle inlets - Conductive charging of electric vehicles - Part 1: General requirements

IEC 62196-2 Plugs, socket-outlets, vehicles connectors and vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for AC pin and contact-tube accessories

IEC 62196-3 Plugs, socket-outlets, vehicles connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3: Dimensional compatibility and interchangeability requirements for DC and AC/DC pin and contact-tube vehicle couplers

2.2.3 Connectivity Standards Alliance Publications

Available from Connectivity Standards Alliance, 508 2nd Street, Suite 109B, Davis, CA 95616, https://csa-iot.org/.

Matter 1.3 and Later Releases - EVSE Management and Device Energy Management support - provides management of all loads and DER supplies (solar, Battery, EV) with NIST compliant ECC security. https://community.csa-iot.org/page/matter-resource-kit Global Open-source standard. Overlay protocol on EVSE to talk to other devices in the home.

3. DEFINITIONS

3.1 BIDIRECTIONAL CONVERTER

A 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 then be capable of being reversed and convert from DC to AC in the other direction to serve as an inverter.

3.2 CHARGER

The charger can either be on-board the vehicle or off-board. On-board chargers require AC energy transfer to the vehicle (either 120 V or 240 V single phase), and off-board chargers are within the EVSE and require DC energy transfer to the vehicle.

3.3 DISTRIBUTED ENERGY RESOURCES (DER)

A Distributed Energy Resource is a small generation source or energy storage system (ESS) that connects to the distribution grid. A rooftop photovoltaic (PV) system is one of the most common types of DER. The combined EVSE and PEV form an ESS type of DER.

3.4 ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE)

This 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 charger, or an off-board DC charger. An EVSE may also support reverse power flow (discharging).

3.5 ENERGY MANAGEMENT SYSTEM (EMS)

An Energy Management System is 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.

3.6 ENERGY PORTAL

Energy Portal is any charging point for a PEV. At a minimum, the Energy Portal is a 120 V, 15 A outlet but can also be a 240 V Electric Vehicle Supply Equipment (EVSE) outlet connected to the premises circuit. This needs to follow the nomenclature in SAE J1772 for L1 and L2 charging.

3.7 ENERGY TRANSFER STRATEGY

A strategy that accounts for all of the electrical energy needs of an EV and the present status of all on-board equipment, including the EV Storage Battery. It determines the rate that energy is to be transferred to the EV and how the ETS shall be operated to accomplish this.

3.8 FORWARD POWER FLOW (FPF)

Forward Power Flow means the direction of energy for Charging a Vehicle. While the term “forward” suggests a positive sign convention, care must be used with any communications because the convention for DER devices is to use a positive sign to designate energy produced (discharged) by the DER.

3.9 FOUR-QUADRANT CONVERTER

This term refers to an electronic device that can produce or absorb both active and reactive power. When a PEV is discharging, the device serves as an inverter converting DC current to AC current. It can displace the AC current waveform relative to the AC voltage waveform to generate or absorb reactive power, depending on whether it leads or lags the supplied current relative to the grid voltage. The device converts AC power to DC current to charge the PEV battery. It can also shift the consumed current relative to the grid voltage waveform to produce or absorb reactive power.

3.10 HOME AREA NETWORK (HAN)

A HAN is an energy related network, contained within a premise 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 (e.g., Utility AMI, internet, cell phone network, etc.) using gateways, bridges, and interfaces.

HomePlug powerline adapters are an alternative solution for having your house completely networked using existing power lines. The advanced HomePlug powerline adapter is capable of transmitting data at up to 200 Mbps channel data rate. The HomePlug powerline adapter delivers maximum range and speed for voice, internet, video, and music throughout your home or office.

Matter is a HAN protocol that support ethernet, Wi-Fi, and Thread via 802.15.4 using IPv6 network with encrypted security with a common application layer used to talk between all loads, all DER supplies (solar, battery, EVs) using common HMI interfaces - voice controls, cell phones, Amazon Echo/Google Look/Apple, Matter TV to common global home ecosystems.

3.11 INTEROPERABILITY

The condition where components of a system, relative to each other, are able to work together to perform the intended operation of the total system. Information interoperability is the capability of two or more networks, systems, devices, applications, or components to share and readily use information securely and effectively with little or no inconvenience for the user. As an example, a 10-mm box-end hand wrench and a 10-mm socket wrench are interoperable, relative to a 10-mm hex-head bolt. The wrench and the bolt are both parts of a fastening system. The fact that the system will perform as required with either wrench establishes the interoperability of the wrenches and the bolt.

3.12 INVERTER

AC power is generated from a DC source, such as a traction battery, using a device called an inverter. For operation as an off-grid, standalone power source, the inverter regulates the amplitude and frequency of the AC voltage, and the connected loads determine the AC current flow from the inverter. A grid-connected inverter (i.e., utility-interactive inverter) must act as a current source and synchronizes to the frequency of the grid voltage waveform. A bidirectional converter or four-quadrant converter are often just referenced as being an inverter.

Modern four-quadrant inverters can be grid forming, grid following, or both to add power factor correction and allow home to stay synchronized with grid when islanded when grid is down to allow reconnect when grid comes back up per IEEE 1547.

3.13 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 Battery Electric Vehicle (BEV), Plug-In Hybrid Electric Vehicle (PHEV), Extended-Range Electric Vehicle (E-REV), and so on.

3.14 REVERSE POWER FLOW (RPF)

Reverse Power Flow means the direction of energy for discharging a Vehicle. While the term “reverse” suggests a negative sign convention, care must be used with any communications because the convention for DER devices is to use a positive sign to designate energy produced by the DER.

3.15 TIME CHARGE IS NEEDED (TCIN)

Time Charge Is Needed is the identification of the end of the potential charge session. This is when the customer wants to use their vehicle for the next drive cycle and the expected recharging is complete.

3.16 UTILITY-INTERACTIVE INVERTER

An inverter intended for use in parallel with an electric power system to supply common loads and sometimes deliver power to the utility. This is also called a grid-connected inverter.

3.17 VEHICLE GRID INTEGRATION (VGI)

This is a very broad term that encompasses the many ways in which a vehicle can provide benefits or services to the grid, to society, the EV driver, or parking lot site host by optimizing plug-in electric vehicle (PEV) interaction with the electrical grid. VGI includes both active management of electricity (e.g., bidirectional management, such as vehicle-to-grid [also known as V2G] or unidirectional management such as managed charging [also known as V1G]) and/or active management of charging levels by ramping up or down charging. VGI also includes passive solutions such as customer response to existing rates, design of improved utility rates (e.g., time-of-use [TOU] charges, demand charges, and customer fees), design of the grid to accommodate EVs while reducing grid impacts to the degree possible, and education or incentives to encourage charging technology or charging level (e.g., rebates for lower-level charging, modifying current allowance policy).

3.18 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. A PEV in V2G operation is considered by utilities to be a Distributed Energy Resource (DER). V2G is about bidirectional flow and not just reverse flow. The term V2G includes the special case where only the rate of charging can be dynamically controlled - sometimes, this is referred to as V1G. V2G-AC designates the use of an on-board inverter feeding AC power back through the EVSE. V2G-DC designates the use of DC current from the PEV battery with an inverter located in the EVSE.

3.19 VEHICLE TO HOME (V2H)

V2H describes the capability of a vehicle to act as a backup “generator” for selected critical loads in a home isolated from the power grid, for example, after the failure of the power grid. SAE defines two types. For V2G-EPP, the inverter is on-board the PEV and power is routed to an exportable power panel on the PEV. The PEV is connected to the same home backup power port used for portable generators. For V2H-DC, the inverter is in the EVSE and can change modes from a V2G-DC to V2H-DC when the home is disconnected (islanded) from the grid.

3.20 VEHICLE TO LOAD (V2L)

V2L describes the capability of a PEV with an on-board inverter to provide power to tools or other loads which are not connected to a home or the grid. The inverter regulates the amplitude and frequency of the AC voltage, and the power is routed to NEMA receptacles on an exportable power panel.

4. ABBREVIATIONS

A	Amperes
AC	Alternating Current
ADR	Automated Demand Response
AGC	Automatic Generation Control
AMI	Advanced Metering Infrastructure
ANSI	American National Standards Institute
APP	Customer Wireless Application
BA	Balancing Authority
BESS	Battery Energy Storage System
BEV	Battery Electric Vehicle

BMS	Building Management System
BPT	Bidirectional Power Transfer
BTM	Behind-the-Meter
CAISO	California Independent System Operator
CARB	California Air Resources Board
CCS	Combined Charging System
CEC	California Energy Commission
CFR	Code of Federal Regulations
CPP	Critical Peak Pricing
CPUC	California Public Utilities Commission
CSO	Charging Station Operator
DC	Direct Current
DER	Distributed Energy Resources
DERMS	DER Management Systems
DG	Distributed Generation
DIN	German Institute for Standardization
DLC	Direct Load Control
DMS	Distribution Management System
DR	Demand Response
DRLC	Demand Response Load Control
DRP	Distribution Resources Plan
DSO	Distribution System Operator
ECP	Electrical Connection Point
EM	Electricity Meter
EMS	Energy Management System
EPP	Exportable Power Panel
EPRI	Electric Power Research Institute
EPS	Electric Power Systems
ESCO	Energy Services Company

ESI	Energy Services Interface
ESS	Energy Storage System
EUMD	End Use Measurement Device
EV	Electric Vehicle
EVBS	Electric Vehicle Battery System
EVCC	Electric Vehicle Communication Controller
EVSE	Electric Vehicle Supply Equipment
EVSP	Electric Vehicle Services Provider
FERC	Federal Energy Regulatory Commission
FPF	Forward Power Flow
FTC	Federal Trade Commission
GHG	Greenhouse Gas
GIS	Geographic Information System
GPS	Global Positioning Satellite
HAN	Home Area Network
HEMS	Home Energy Management System
HFRT	High Frequency Ride Through
HVRT	High Voltage Ride Through
Hz	Hertz
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IFOM	In-Front-of-Meter
IOT	Internet of Things
IOU	Investor-Owned Utility
IRP	Integrated Resources Plan
ISB	International Standards Body
ISO	Independent System Operator
ISO	International Organization for Standardization

kV	Kilovolt
kW	Kilowatts
LCR	Local Capacity Requirements
LDA	Local Distribution Area
LFRT	Low Frequency Ride Through
LMP	Locational Marginal Price
LSE	Load-Serving Entity
LVRT	Low Voltage Ride Through
MOS	Method of Sale
MW	Megawatt
MWh	Megawatt Hour
NAESB	North American Energy Standards Board
NCWM	National Conference on Weights and Measures
NDA	Non-Disclosure Agreement
NEC®	National Electrical Code®
NEM	Net Energy Metering
NEMA	National Electrical Manufacturers Association
NERC	North American Electric Reliability Corporation
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NMV	Net Market Value
NPV	Net Present Value
NQC	Net Qualifying Capacity
NRTL	Nationally Recognized Testing Laboratory
NSB	National Standards Body
NSP	Network Service Provider
NTEP	National Type Evaluation Program
OBW	Operational Bandwidth
OCA	Open Charge Alliance

OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturer
OVGIP	Open Vehicle Grid Integration Platform
PAP	Priority Action Plan
PCC	Point of Common Coupling
PEV	Plug-In Electric Vehicle
PFE	Power-Flow Entity
PHEV	Plug-In Hybrid Electric Vehicle
PLC	Power Line Carrier
POU	Publicly Owned Utility
PUC	Public Utilities Commission
PV	Photovoltaic (solar)
PWM	Pulse Width Modulation
RP	Recommended Practice
RPF	Reverse Power Flow
RPS	Renewables Portfolio Standard
RTD	Real-Time Dispatch
RTM	Real Time Market
RTO	Regional Transmission Organization
RTP	Real Time Pricing
SCADA	Substation Control and Data Acquisition
SDO	Standards Development Organization
SECC	Supply Equipment Communication Controller
SEP2	Smart Energy Profile 2.0
SGIP	Smart Grid Interoperability Panel
SI	International System of Units
SLAC	Signal Level Attenuation Characteristics
SOC	State of Charge

SSO	Standards Setting Organization
STD	Standard
T&D	Transmission and Distribution
TCIN	Time Charge Is Needed
TIR	Technical Information Report
TOU	Time of Use Rate
TSO	Transmission System Operator
UC	Use Case
UCAP	Usable Capacity of Battery
UF	Utilization Factor
UII	Utility Interactive Inverter
UL	Underwriters Laboratory
URN	Uniform Random Number
UTC	Universal Time, Coordinated
V	Volts
V1G	Managed or Controlled Charging
V2B	Vehicle to Building
V2G	Vehicle to Grid
V2H	Vehicle to Home
V2L	Vehicle to Load
V2V	Vehicle to Vehicle
VA	Volt-Amperes
VAR	Volt-Amperes Reactive
VGI	Vehicle-Grid Integration
VPP	Virtual Power Plant
VRef	Reference Voltage
VRefOfs	Reference Voltage Offset
VSS	Voltage Support Service

W Watts

W&M Weights and Measures

WPT Wireless Power Transfer

XFMR Transformer

ZEV Zero Emission Vehicle

5. TECHNICAL REQUIREMENTS

5.1 Document Interactions

The following list shows the intention of the standards developed within the Communication and Interoperability Task Force.

1. SAE J2836: Use Cases (establishes requirements)
    - Technical information report (TIR)
2. SAE J2847: Messages, diagrams, etc. (derived from the use case requirements)
    - SAE J2847/2 is a standard and the others are recommended practices (RPs)
3. SAE J2931: Communication Requirements and Protocol
    - TIR
4. SAE J2953: Interoperability
    - RP
5. SAE J3072: Interconnection Requirements for Onboard, Utility-Interactive, Inverter Systems
    - Standard

Figure 1 shows the interaction between the various documents, including this document at the top. These start with Use Cases in the SAE J2836 slash sheets, and direct lines to the associated SAE J2847 document.

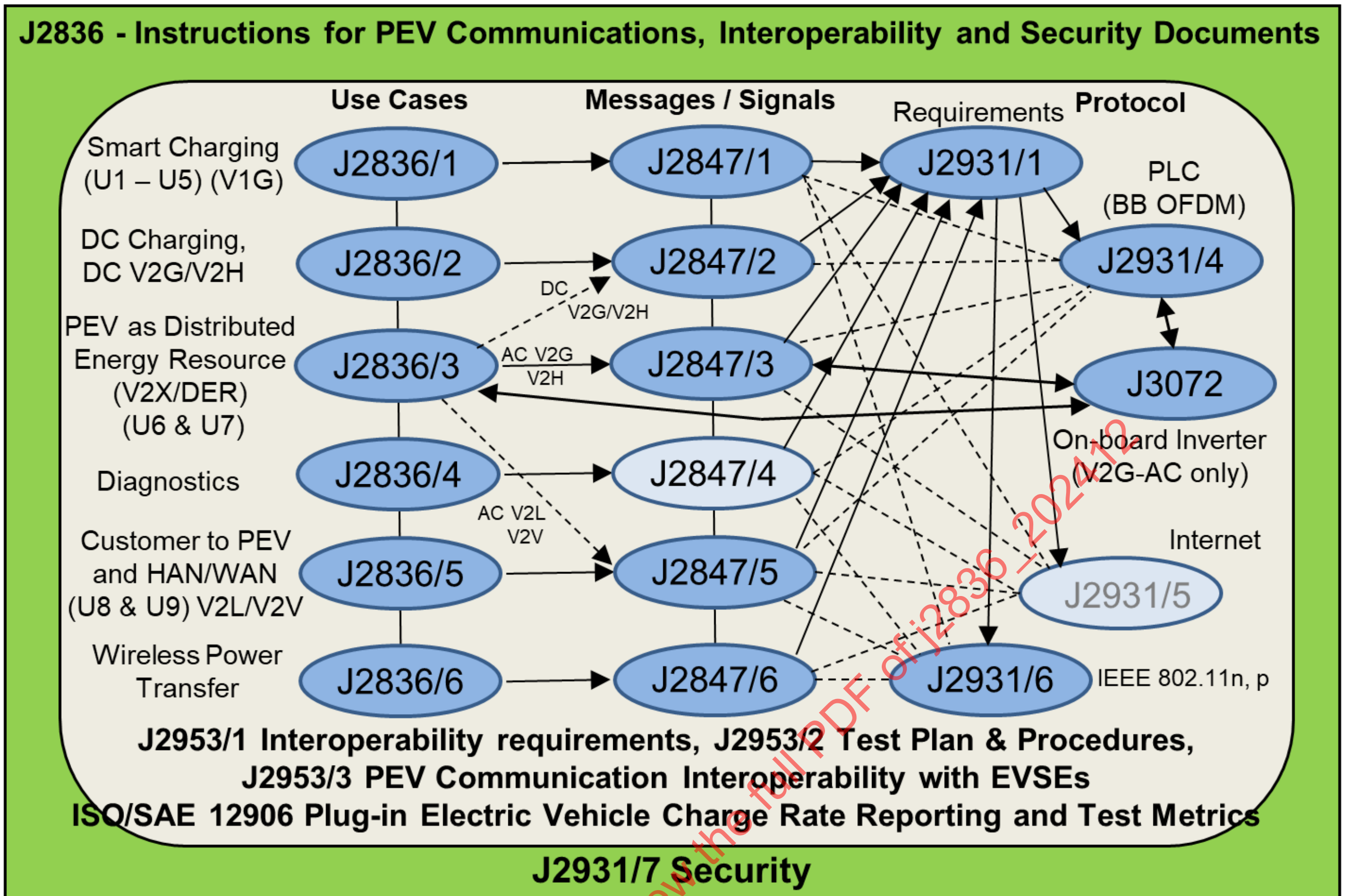

Figure 1 - Document interaction

5.2 Smart Charging

5.2.1 Standards

The communication standards required for Smart Charging using wired communications that use PowerLine Carrier (PLC) on the SAE J1772 Control Pilot are as follows:

1. SAE J2836/1: Use Cases for Communication Between Plug-in Vehicles and the Utility Grid

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

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

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

If a wireless protocol is used, such as telematics or cellular, item 4 above changes as shown below, but the rest stay the same.

1. SAE J2836/1: Use Cases for Communication Between Plug-in Vehicles and the Utility Grid

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

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

4. ISO 15118-8: Road vehicles - Vehicle to grid communication interface - Part 8: Physical layer and data link layer requirements for wireless communication

5.2.2 Description

Smart Charging is the approach from the utilities to balance the grid loads during the day. This includes varying the price of electricity based on anticipated load variations and also varies between seasons as winter and summer loads are different. When the predicted grid loads are higher, the customer is charged a higher price for energy, and this incentive is to have the customer curtail or delay loads that can be altered. Another approach is for the customer to agree to install a Demand Response Load Control (DRLC) or DR device in the circuit of loads that are capable of being curtailed or delayed. This includes Air Conditioners that can be curtailed during a period such as increasing the temperature in the home by a couple of degrees or hot water heaters that don't need full power until evening when they are used. Cooking and entertainment items are not candidates for DR.

Smart Energy Profile 2.0 was created and is available as IEEE 2030.5. This continues with Price and DR function sets but also includes FlowReservation, whereas the PEV can send a signal to the utility for the current charge session for Energy, Power, and Time Charge Is Needed (TCIN). If charging power and duration can be obtained when connected, then no delays would occur, but if there is a lower price period that could be used, and/or a DR signal is desired to be used, the PEV would simply adjust the power level over the connected time session and still accomplish charging within the overall TCIN period and optimize the price for the customer while reducing the peak load to the grid.

The Use Cases for Pricing, DR, and FlowReservation are also in SAE J2836/1 and shown in Figure 2 as U1 through U5.

- U1 is the Time of Use (TOU) that the most common price program. It is projected a year ahead of time but may adjust for seasonal variations (e.g., summer versus winter loads). This is for predictable loads.

- U4 is Critical Peak Pricing (CPP) that would replace a TOU schedule but notify the customer a day ahead of this if they participated. This may periodically change the peak price to a higher if additional loads are expected on the grid for the next day.

- U3 is Real Time Pricing (RTP) and is used when immediate load issues exist. This would be a 5 to 15 minute notification that the price could change and replace either TOU or CPP rates. The RTP is a candidate for both positive and negative pricing where negative pricing could be used when excess energy is available, and the utility desires the customer to turn on loads during these periods.

- Virtual Power Plant (VPP) pricing is used to sell energy back to grid by home/EV batteries and/or guarantee load decrease for a period of time to act as a temporary power plant. Utility VPP energy sold can be higher than DR energy decrease compensation.

These three charging price programs (U1, U3, and U4) are staged as least to most critical load requirements on the grid exist and load shedding is crucial to stabilize it. VPP pricing is for discharging.

- U2 is the DRLC use case that does not include any price component, but the utility has the opportunity to send a targeted signal to this device in the appliance circuit to curtail, delay, or both as grid stability becomes less stable. The customer has an option to “opt out” for the current DR signal, but repeated use of this may remove them from the program and higher costs would be imposed.

- U5 is the FlowReservation use case and is the preferred approach to price or DR control since the PEV is not a predictable load. It will need a different amount of energy, and the duration would vary on each connected session. In most cases, the vehicle is connected considerably longer than the actual charge time, and this would stretch out the energy to optimize this session while still completing the expected State of Charge for the next drive cycle.

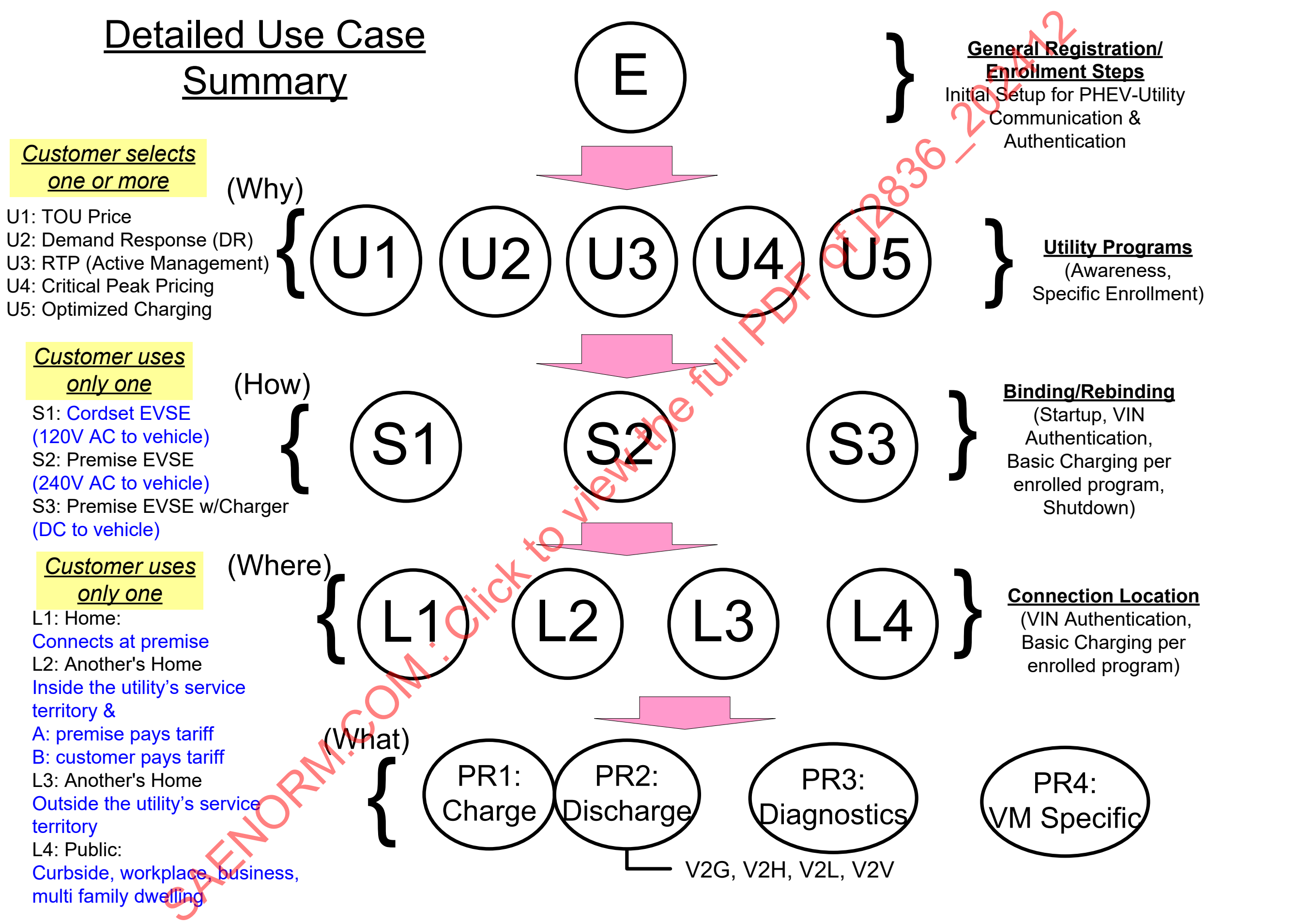

Figure 2 - Smart charging use case summary

The messages for these five use cases are in SAE J2847/1 and have corresponding Function Sets in IEEE 2030.5. High-level requirements are in SAE J2931/1 and wired communication is expected at least to associate the PEV to the utility and described in SAE J2931/4 using PowerLine Carrier (PLC). Once association from the PEV to the specific circuit is established, other protocols can also be used such as Wi-Fi, Bluetooth, or Telematics. At private locations, other means of association may be used if required, and PLC may not be used at all. Public locations may be the same since a parking attendant or central payment meter may be used to associate the vehicle with a particular space and EVSE.

The sequence of FlowReservation is shown starting in Figure 3 at the start of the charge session and identification of TCIN. The initial or Customer TCIN is shown by the right end of the "Connected Time" bar. The customer can combine this with any Price or DR signals for Optimized charging for the session for the lowest price and also schedule the power limit to stay below any known Demand Charge Limit imposed at the site. CPP is shown that overrides TOU for the day with a higher cost for the peak period in the home. The DR signal would also indicate any load curtailment or delay the utility desires the vehicle to include for this session. Dynamic acknowledgement is transferred during the session between the vehicle and utility so further adjustments can be made as long as the customer TCIN is met.

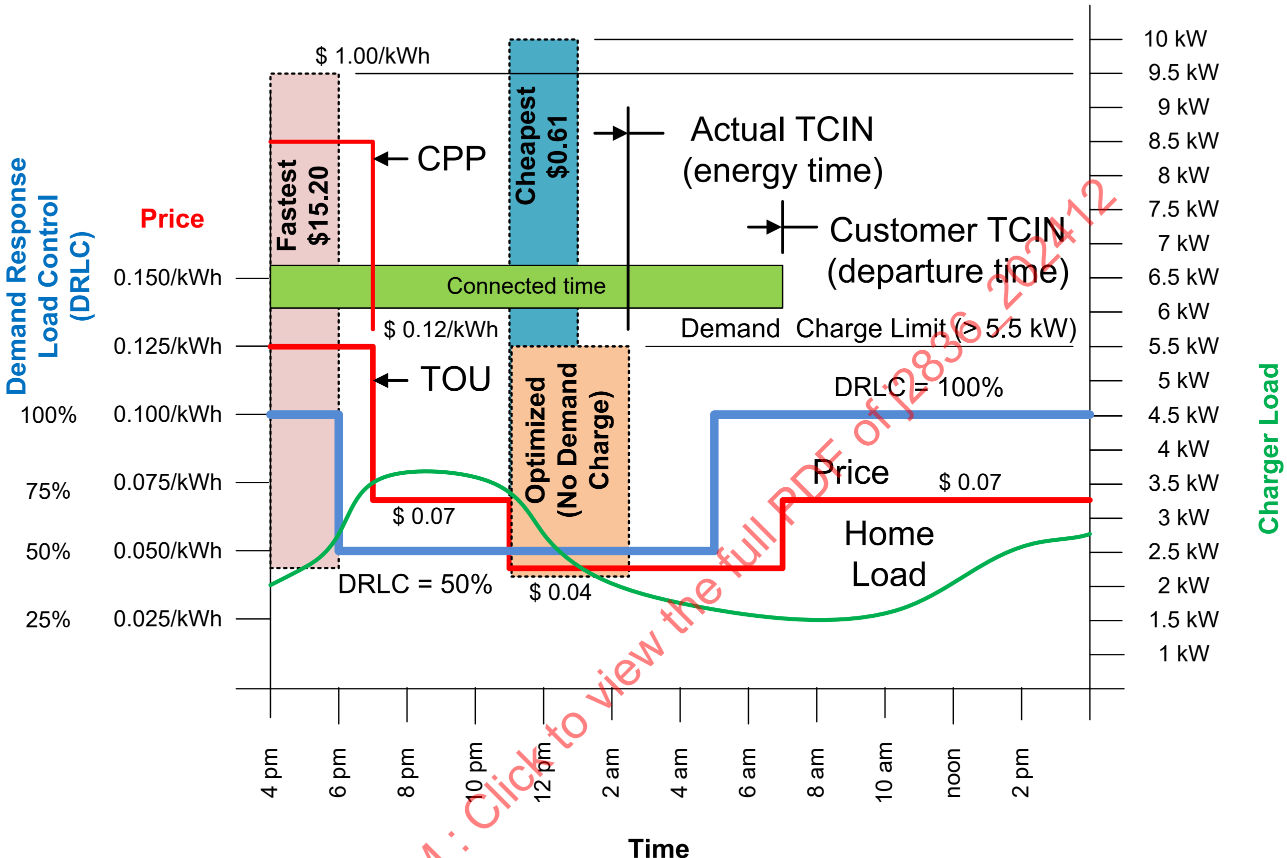

Figure 3 - Optimized charging example

Smart Charging using a wireless protocol:

1. SAE J2836/1: Use Cases for Communication Between Plug-in Vehicles and the Utility Grid

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

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

5.3 AC and DC Charging

5.3.1 Standards

The communication standards required for DC Charging are as follows:

1. SAE J2836/2: Use Cases for Communication Between Plug-in Vehicles and Off-Board DC Charger

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

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

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

SAE J2847/2 and SAE J2931/1 were harmonized with DIN SPEC 70121:2014 that is the first version of DC EVSEs in both Europe and the USA.

DIN SPEC 70122 is the conformance standard for DIN SPEC 70121.

ISO 15118-1, -2, and -3 include additional features for DC charging and also apply to AC charging.

ISO 15118-4 and -5 are the conformance standards.

ISO 15118-2 and ISO 15118-20 include both AC and DC charging requirements.

5.3.2 PKI Requirements

One of the optional features to ISO 15118-2 versus DIN SPEC 70121 is the addition of PnC (Plug and Charge) that includes public key infrastructure (PKI) requirements.

- If a protocol requires use of a Public Key Infrastructure (PKI) to enable secure EV - EVSE communication to implement Plug and Charge (PnC), value-added charging services or other functionality, the PKI policy should comply with the SAE Electric Vehicle Public Key Infrastructure - Certificate Policy (CP) available from the SAE EVPKI Consortium website: https://www.sae-itc.com/programs/evpki.

- As multiple Certificate Authorities (CAs) begin operating in the EV charging ecosystem, a Certificate Trust List (CTL) may optionally be used by EVs and EVSEs as the main source of authenticated Root certificates and digital credentials for PnC and other functionality. An integrated set of requirements applicable to all participants within the EVPKI chain of trust for CTL technology, PKI onboarding and issuance, life cycle management, and auditing has been published by the SAE EVPKI Consortium and may also be downloaded from the website above.

- Matter EVSE to home utilizes PKI and ECC certificates to encrypt all communication between EVSE supporting Matter and all other Matter devices in the home - solar panels, home batteries, loads, TV, Voice controllers - Amazon Echo/Show, Google Look, Apple, etc., thermostats, breakers, outlets, smart plugs, water heater, heat pumps, etc. Matter controller can also support HEMS via Device Energy Management cluster. All Matter devices can support electrical power and electric energy measurements as part of base functionality. Matter can be an overlay protocol on EVSE in parallel with other protocols to support the migration from silo solution protocols for one device type to a common protocol for energy management of all devices in the home or business.

5.3.3 Description

PLC was selected for the communication means using the SAE J1772 Control Pilot circuit for both AC and DC charging and was also applied to Smart Charging using SEP2. We use Signal Level Attenuation Characteristics (SLAC) to determine which PEV and EVSE is connected before sending communication messages. There is coupling between the Control Pilot and Mains circuits in the EVSE to PEV cable, but we use a dB level loss that is expected to ensure an EV is able to send messages to only the EVSE it is directly connected to, not adjacent ones. PLC is available for AC charging if High Level Communication is desired. It is required for DC charging.

The DC charging use cases are in SAE J2836/2 with the messages in SAE J2847/2. SAE J2931 includes high-level requirements, and SAE J2931/4 includes the PLC protocol.

5.4 PEV as Bidirectional Power (BPT and a Distributed Energy Resource [DER])

5.4.1 Standards

All the communication standards required for Smart Charging, as defined in 5.2.1, apply.

The following communication standards specifically apply:

1. SAE J2836/3: Use Cases for Plug-In Vehicle Communication as a Distributed Energy Resource

2. SAE J2847/3: Communication for Plug-in Vehicle as a Distributed Energy Source

3. SAE J2847/5: Communication Between Plug-in Vehicles and Customers

The following communication standard specifically applies when the inverter is on-board the PEV:

1. SAE J3072: Interconnection Requirements for Onboard, Grid Support Inverter Systems

The following communication standard applies when the inverter is in the EVSE:

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

ISO 15118-20 also include BPT for both AC and DC. The schema is divided into modules and the AC charging module includes AC BPT, the DC charging module includes DC BPT, and there is a third module for AC_BPT_DER/.

The ISO 15118 conformance standards are also divided into separate standards for the Common module and subsequent functions.

5.4.2 Description

The purpose of a PEV is transportation and its battery must be periodically recharged to be able to perform this role. As discussed in earlier sections, the charger can be located on-board the PEV or externally in the EVSE for DC charging. If the charging current could be reversed, energy from the traction battery could be used for other purposes. The device that converts DC current from a battery into AC current for a load is called an inverter. The inverter can be located on-board the PEV or externally in the EVSE. When used with an energy storage system, such as a PEV, a combined charger-inverter device (known as a bidirectional converter) would be used. If the device is designed to be capable of also absorbing or supplying reactive power, it is called a four-quadrant power converter. However, it is common practice to just to refer to each of these devices as an inverter. There are several basic types of reverse power flow (RPF) or BPT. **Vehicle to Load (V2L)** describes the case where a portable tool or other isolated load can be plugged into a vehicle-mounted receptacle which is powered by an on-board inverter. **Vehicle to Vehicle (V2V)** describes the case when one vehicle provides energy to another vehicle. Both AC V2L and AC V2V are included in SAE J2847/5 and certified to UL 9741.

SAE defines **Vehicle to Home (V2H)** to be where the PEV serves as an emergency generator for a home which has been disconnected (islanded) from the grid following a power failure. For both V2L and V2H, the inverter regulates the amplitude and frequency of the AC voltage, and the AC current flow is determined by the loads.

Vehicle to Grid (V2G) describes the case where the combined EVSE-PEV is connected to a live electric power system (EPS). For V2G, the inverter cannot possibly regulate the amplitude and frequency of the entire connected EPS. Rather, a utility-interactive inverter generates an AC current which is synchronized to the frequency of the grid voltage waveform. By controlling the amplitude and leading or lagging the supplied AC current relative to the grid AC voltage, the inverter can provide a commanded value of both real and reactive power. If the inverter is located on-board the PEV, SAE defines this type of RPF as **V2G-AC**. SAE defines it as RPF type **V2G-DC** when conversion is performed by the EVSE.

A Distributed Energy Resource (DER) is a small generation source or energy storage system (ESS) that connects to the distribution grid. A rooftop photovoltaic (PV) system is one of the most common types of DER. The combined EVSE and PEV form an ESS type of DER. There are many concepts for control of a DER because the device simultaneously operates in three EPS domains. An ESS operating behind a customer meter could be controlled by a customer energy management system (EMS) to better integrate the ESS with a site PV system. Alternatively, the customer may have assigned responsibility for managing the facility ESS to a third-party aggregator that is performing a fleet DER management service for a bulk grid system operator. It is also possible that the distribution utility serving the customer site assumes control of all DER in its service area. The utility industry is exploring how to best integrate DER into the distribution system and bulk grid and deploying new smart functions into inverter-based DER for this purpose.

Targeting DERs behind the main utility meter to utilize Matter protocol globally for HAN and business/industrial networks, where DER in the grid will utilize other protocols like IEEE 2030.5, IEEE 1812 MESA, Open ADR 2.0b (ISO Price server), etc.

SAE J2836/3 defines a new top-level use case PEV4 (PEV as a Distributed Energy Resource). Four top-level use cases were previously defined by SAE J2836/1 (PEV0 – PEV3). SAE J2836/3 also defines two new detailed use cases, U6 and U7, as shown by Figure 4. PR2 Discharge was identified in SAE J2836/1, but it was not actually defined until SAE J2836/3. U6 is identified as Basic DER because it defines the essential capability for some authorized control entity to command the PEV to charge or discharge to a rate setpoint. The controller can provide a sequence of commands to a PEV during a session. U7 is identified as Advanced DER and defines a collection of smart inverter functions to supplement U6.

All the smart inverter functions described by U6 and U7 are based on EPRI report Common Functions for Smart Inverters and are implemented by the Smart Energy Profile 2.0 (refer to IEEE 2030.5). One of the defined U7 functions is “autonomous volt-VAR” where the inverter produces or absorbs VAR (volt-amperes reactive) by measuring voltage in real time and using a utility supplied curve of VAR versus measured voltage. This dynamic function helps stabilize the voltage at the customer connection point to the distribution feeder. This function is now required by California to be implemented in all inverter-based DER installed after September 8, 2017. This is likely to be required in other states because the IEEE is including the requirements in their widely recognized DER interconnection standards (IEEE 1547 and IEEE 1547.1). Other U7 functions, such as autonomous frequency-Watt, are also gaining interest by utilities.

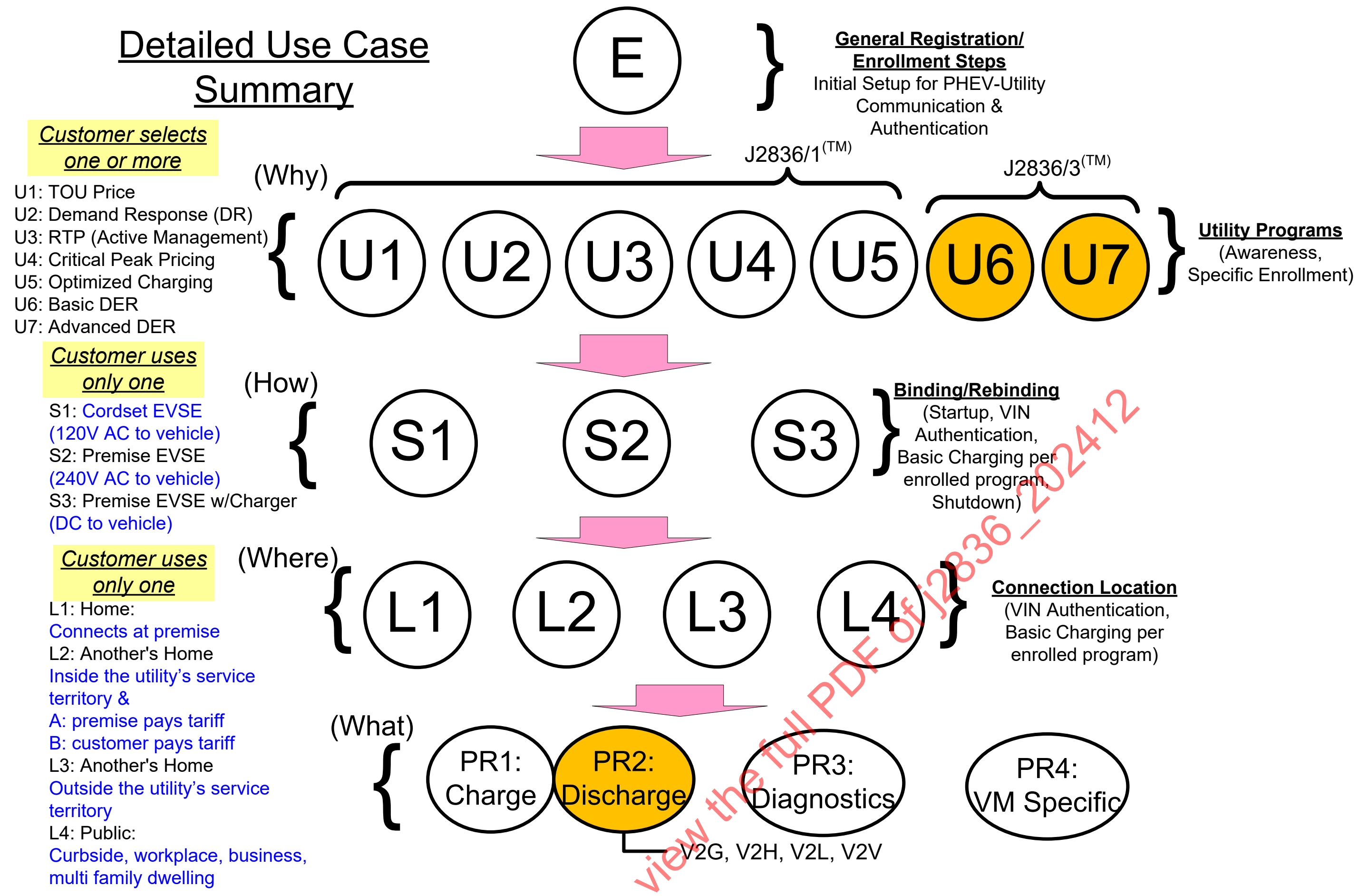

Figure 4 - DER use case summary

If a DER control entity uses IEEE 2030.5 SEP2 to engage smart inverter functions of a PEV on-board inverter (V2G-AC), SAE J2847/3 provides guidance to the PEV manufacturer for using the DER function set of SEP2. The governing document for the protocol is IEEE 2030.5, but SAE J2847/3 relates SEP2 to the use cases as described by SAE J2836/3. For V2G-DC, the EVSE manufacturer could also look to SAE J2847/3 for guidance in using the SEP2 DER function set for communication with the DER control entity. For type V2G-DC systems, communication between the EVSE and PEV for managing the DC currents is defined by SAE J2847/2 for the new DER Mode (V4), which adds different logic than used for DC fast charging. In DC fast charging, the PEV commands the DC current provided by the EVSE to the PEV battery. For an EVSE engaging upstream as a DER and performing a smart function such as autonomous frequency-Watt, the inverter generates the AC current as required to perform the smart function and DC current just flows in or out of the PEV battery as needed by the inverter. The PEV provides DC current limits to the EVSE inverter. Because a DER is only useful when connected for longer durations, the peak DC currents would be much lower than those used during fast charging.

Figure 5 shows an example where a home EMS controls the PEV during its entire connection period using the basic charge/discharge command capability (U6). The EMS is expected to charge the PEV to a designated target state of charge (SOC) by a designated Time Charge Is Needed. The EMS also plans use available PEV battery energy to offset any power demand that would exceed a demand charge target of 3.5 kW. The EMS is also trying to minimize total energy cost. This example assumes that the PEV is the only controllable load or source. The EMS commands the PEV to start charging when it first connects at 4:00 pm taking advantage of the low energy price and adjusts the rate of charge to keep the total power flow less than 3.5 kW. The EMS stops PEV charging when the energy price jumps at 6:00 pm and shortly after starts commanding the PEV to discharge to offset other home loads to hold the total demand at 3.5 kW. After the home loads drop below 3.5 kW, the EMS holds the PEV at zero flow until the energy price drops at midnight and the PEV is commanded to charge. The EMS continues to manage the charging rate to stay below the total 3.5 kW facility maximum target (home solar array output). The PEV reaches the target SOC before the target time. The Matter EMS has the information from the PEV to adjust the start time for recharge, if needed, to ensure meeting the PEV targets. Matter utilizes a common register set and commands used in IEEE 2030.5, IEEE 1547, etc., for interoperability across multiple protocols so can support existing protocols and migrate to newer protocols.

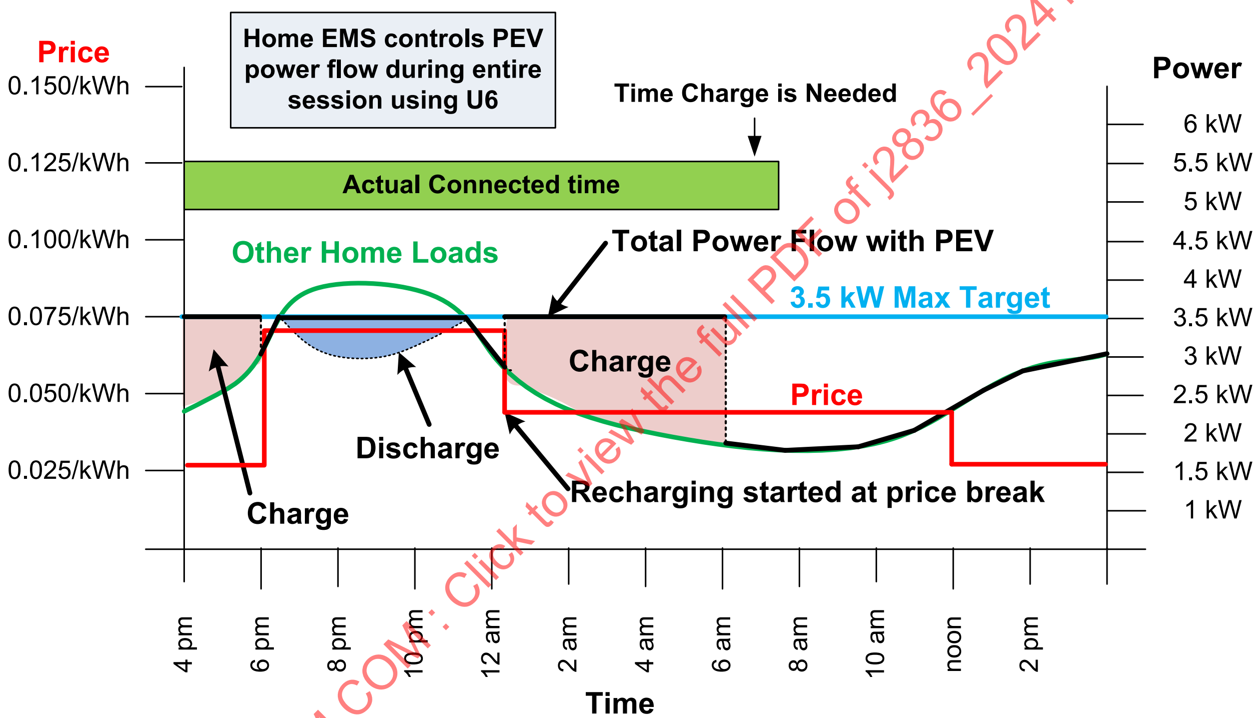

Figure 5 - Example of use of DER U6

5.4.3 DER Interconnection Requirements

A utility customer must apply to and secure approval of the utility before operating any generating device (DER) which is connected to the utility grid. Even where no net export of energy from the facility to the grid is expected but can happen, approval of the interconnection is still required because of safety and reliability concerns at the distribution feeder. In California, these procedures are harmonized across regulated utilities and documented as Rule 21: Generating Facility Interconnection. Utility commissions of other states have deployed equivalent interconnection regulations. And some utilities are not subject to the jurisdiction of utility regulators (even in California) and may develop their own procedures. However, all utility procedures include technical requirements for the DER installation to meet IEEE 1547 and IEEE 1547.1.

To facilitate the broad deployment of rooftop solar systems, the solar industry and electric power industry worked together to develop a very simple application and approval process for PV systems. The PV system installer applies to the utility using a simple form which identifies the inverter manufacturer, model number of the inverter, and that it has been listed by a Nationally Recognized Testing Laboratory (NRTL) as conforming to UL 1741. UL 1741 was created primarily to support PV inverters. This UL standard simply calls out meeting the two fundamental IEEE DER standards. UL 1741 also includes the mechanical and electrical design requirements which are typically required for the installation of electrical equipment by local electrical codes. The PV inverter manufacturers provide each new model to a NRTL to be tested and listed. Some states, such as California, maintain a database of all listed PV inverters approved for use in the state.

Utilities could easily modify the short form used for PV installations to be used for V2G-DC DER applications. The EVSE manufacturer would submit each EVSE model to a NRTL to be tested and listed to both UL 1741 and UL 2202, an EVSE standard. The specific PEV models that could connect to a V2G-DC EVSE over its service life have no direct effect beyond the EVSE and should not be relevant to the DER approval process.

It is the V2G-AC configuration that is unprecedented from the perspective of utility approval of the interconnection and for which SAE developed SAE J3072 as a possible approach to the dealing with the conundrum. Some of the V2G-AC issues include:

- The inverter is located on-board a PEV which can roam during one day between different customer sites, with different utilities, and even in different states. This means that site settings and curve function data must be loaded into the PEV at connection to the EVSE each time it connects.

- The utility customer would know the model number of the EVSE located at their site, but the EVSE does not contain the inverter. How do you approve a site for discharge without an actual inverter at the site?

- The inverter in the vehicle may not support curve functionality and power factor correction, can the vehicle use default curve without power factor correction?

- The utility customer may not know in advance which models of PEV might connect and discharge, and this is particularly true over the useful life of the EVSE installation. How is a PEV authorized to discharge at an EVSE?

- If visiting a level 2 or level 3 “gas station” not interested in discharging vehicle but only in charging vehicle as fast as possible and leaving, so do I need PEV authorization at an EVSE to discharge? The level 3 charger is fixed and has inverter in DC changer so can do power factor correction based on location. Only interested in charging/discharging as home EVSE charger location, and interested in curves/power factor correction at my location.

- Why not have a NRTL test the PEV inverter to UL 1741? The on-board inverter is a distributed system within the PEV and not a removable unit. Aside from the UL 1741 callout of the IEEE standards, most of the document contains mechanical and electrical inspection and test requirements suitable for facility electrical equipment, not vehicle equipment. The scope of the National Electrical Code specifically excludes “installations in automotive vehicles” (refer to NEC 90.2 [B] [1]). The PEV can be tested to the IEEE 1547 standards.

The purpose of SAE J3072 is to establish the PEV interconnection requirements for a utility-interactive inverter system which is integrated into a PEV and connects in parallel with an electric power system (EPS) by way of conductively coupled, electric vehicle supply equipment (EVSE). An approach to utility approval of V2G-AC interconnection is proposed but needs to be embraced by over 3000 utilities.

5.4.4 SAE J3072 V3 - Summary of Additional Changes in 2021 and 2024-02-11 Version

1. Certification to IEEE 1547-2018 or later is required.

   References to "IEEE 1547-2003" and "IEEE 1547.1-2005" have been deleted from 1. Scope, 2.1.2 IEEE References, and 4.8 Utility Interaction. Appendix F IEEE 1547-2003 CONSIDERATION has been deleted and reserved for other use.

2. Certification testing to follow UL 1741 Supplement B.

   Section 4.8 requires: "The inverter system shall be tested in accordance with IEEE 1547.1-2020 with any clarifications, exceptions, or modifications described in Appendix E." But because of known errors in the published IEEE 1547.1-2020, Appendix E provides the following:

   "NOTICE: UL 1741 SB shall be used where its requirements conflict with those of IEEE 1547.1-2020. When a revision to IEEE 1547.1 is published that corrects errors and omissions in IEEE 1547.1-2020, that new revision shall be used rather than UL 1741 SB."

3. Use of IEEE 2030.5 Protocol.

   SAE J3072 allows for the use of IEEE 2030.5 for communication between the PEV and the EVSE. And Appendix C was included as a guide to using the IEEE 2030.5 protocol standard: "IEEE Adoption of Smart Energy Profile 2.0 Application Protocol Standard." Both the 2015 and 2021 version of Appendix C stated:

   "This appendix shall be followed for those System Types that use IEEE 2030.5 Smart Energy Profile 2.0 (SEP2) to exchange the information between the EVSE and PEV which is required by this standard (i.e., the J3072 information). This appendix is not intended to be a comprehensive guide to communication protocols and the use of IEEE 2030.5. The IEEE 2030.5 documents will serve that purpose. SAE J2847/3 provides some useful guidance on the use of the DER function set of IEEE 2030.5. This appendix only defines certain aspects of the use of IEEE 2030.5 which are unique to how specific aspects of the IEEE 2030.5 model are used to exchange SAE J3072 information. The EVSE and PEV shall use the exact IEEE 2030.5 resource objects and attributes defined in this appendix for information exchange."

   This version of SAE J3072 requires the use of "IEEE 2030.5 V2G-AC Profile Implementation Guide for SAE J3072" which fully replaces Appendix C.

4. System Types.

   System types are defined in 4.2 "System Types." Each system type is assigned a unique two-character code. In the initial SAE J3072-2015 version, two system types A1 and B1 were identified. The individual characters did not designate anything. The type included the charging receptacle on the vehicle and the complete "Open System Interconnection Model" protocol stack for communication between the EVSE and the PEV. Type A1 used an SAE J1772 receptacle and IEEE 2030.5 at the application layer. Type B1 used an SAE J3068 receptacle and SunSpec Modbus at the application layer.

   This revision established a new approach for system types. The two-character code is continued but each character is now assigned a specific purpose. The first character designates a complete OSI Model stack with all layers defined and the second character designates the charging receptacle used by the PEV.

5. System Types Added for Use of SAE J3400.

   SAE J3400 (North American Connector Standard) is introduced in this version of SAE J3072 as system type [*]3.

6. System Types added for use of modified ISO 15118 Protocol.

   ISO 15118-20 does not currently provide objects to support the information to be exchanged between the EVSE and PEV described in SAE J3072, 4.6, to support IEEE 1547-2018, Section 10. Work is underway to extend the protocol object model to support SAE J3072.

   Also, IEEE 1547-2018, 10.7, does not designate ISO 15118 as a designated protocol. By a strict reading, ISO 15118 would not meet 10.7 requirements. But by strict reading, the PEV does not use Ethernet in its OSI stack. If the UL 1741 SC EVSE can use Ethernet with IEEE 2030.5 to load functions to be passed to the PEV, this may be considered by the IEEE as meeting the intent of the standard.

   But the limiting technical factor is that the protocol does not yet provide the capability to move the required information between the EVSE and PEV.

   The intent for this revision was to allow for use of a revised SAE J3072-compliant version of ISO 15118-XX, but its actual use would be determined by IEEE guidance and the authority having jurisdiction over the interconnection.

7. Certification of EVSE to SAE J3072.

   Currently, 4.5 "Certification of EVSE to SAE J3072" states:

   The EVSE shall be tested and certified to the requirements of SAE J3072 or to an EVSE standard which calls out conformance to SAE J3072, as well as other required and applicable standards such as United Laboratory (UL) or Protocol. The authorized entity shall issue a certificate of conformance to SAE J3072 or other EVSE standard for each authorized EVSE model.

   The EVSE, as an independent device, will need to meet many other requirements. Appendix G provides guidelines for a System Type A1 EVSE.

8. Certification of Vehicle Inverter System Model to SAE J3072.

   The VM is required to play a major role in managing the certification of the inverter function which is executed by the vehicle. There are functions outside the scope of IEEE 1547-2018 that are performed by the vehicle inverter system. For example, the Coordinated Charge/Discharge Function is required to be implemented by SAE J3072, but there are no tests defined in IEEE 1547.1-2020 for the function. The exact design may be proprietary for how the required information is calculated. SAE J3072 only defines that the information shall be calculated and provided to the controlling entity for active power. An OSHA NRTL could be used for IEEE 1547.1 testing, but that is only a portion of SAE J3072 requirements.

   The authority having jurisdiction over approval of the interconnection at a specific site based on local, state, and/or federal requirements established the exact requirements. But the vehicle manufacturer has ultimate accountability for the safety of its vehicle. It is likely that it will be more efficient to rely on specialized labs for IEEE 1547.1 testing.

9. Section 4.6.6 EVSE Transfers Management Information.

   This section has been updated to correct errors and clarify requirements to better align with IEEE 1547-2018. Some of these related to requiring a four-quadrant inverter. Others corrected for errors in interpretation of the IEEE 1547-2018 requirements.

10. Section 4.7 Control of Inverter Functions During Session.

    The 2021 revision assumed that all management information would be transferred from the EVSE to the PEV before authorization to discharge was received and a controlling entity could activate or deactivate specific loaded functions during a session. This is allowed by the IEEE 2030.5 protocol. It did not consider loading new functions after authorization to discharge was received - only turning loaded functions on or off or providing setpoints.

    IEEE 2030.5 allows multiple versions of a volt-VAR function to be transferred from the EVSE to the PEV and the EVSE can command the PEV to change between loaded curves while operating. SAE J3072 now only allows one reactive power function to be provided by the EVSE and the PEV transitions between the new and old function at the time a new function is provided.

    This version has been modified to allow management information to be loaded and activated after authorization to discharge has been provided by the EVSE.

5.5 Vehicle-Grid Integration (VGI) Communication Protocols

In the earlier sections, use cases U1 through U7 were introduced. These are all functions which support smart charging and vehicle-to-grid (V2G) applications. Collectively, these use cases can be called “Vehicle-Grid Integration” (VGI) functions. The “grid” in VGI is intended to refer to the “Smart Grid.” This section will explain the origin of the term VGI and the “Smart Grid.” It will also review certain protocols which are intended to support communication between a PEV and the smart grid.

5.5.1 California Defines VGI

In response to California Executive Order B-16-2012, the Governor’s Interagency Working Group on Zero-emission Vehicles published the “2013 ZEV Action Plan: A roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025.” One objective was to “plan for and integrate peak vehicle demand for electricity into the state’s energy grid.” As part of this objective, the California Public Utility Commission (CPUC) was directed to “ensure that rulemaking about smart grid enhancements include projections for ZEVs and their electricity demand and maximize potential for ancillary services provided by PEV batteries.” And the California Independent System Operator (CAISO) was tasked to “develop a roadmap to commercialize vehicle to grid (V2G) services provided by PEV batteries.” The term Vehicle-Grid Integration (VGI) emerged from the resulting efforts led by CPUC and CAISO.

Two coordinated and defining VGI documents arose based on the 2013 ZEV Action Plan. CPUC initiated Rulemaking R.13-11-007 (filed 2013-11-14) which included a CPUC Energy Division staff whitepaper titled “Vehicle-Grid Integration.” CAISO published the “California Vehicle-Grid Integration (VGI) Roadmap: Enabling vehicle-based grid services” February 2014. The CAISO roadmap builds on the VGI framework defined by the CPUC whitepaper.

The CAISO roadmap and CPUC whitepaper provide a good framework for understanding the SAE documents. In fact, the roadmap provides information about the SAE documents. V2G is used in the exact same context by SAE J2836/3 and the CAISO/CPUC documents. If a defined V2G function is operated to only allow the rate of charging to be controlled, SAE J2836/3 defines this as V1G. The CAISO/CPUC documents consider V1G to also include all the smart charging functions (see 5.2).

5.5.2 EISA-2007 Defines the Smart Grid

The first “official” definition of Smart Grid was provided by the Energy Independence and Security Act of 2007 (Public Law 110-140, Title XIII, §1301), which is codified by 42 U.S.C. §17381 as:

> It is the policy of the United States to support the modernization of the Nation’s electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following, which together characterize a **Smart Grid**:
>
> (1) Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.
>
> (2) Dynamic optimization of grid operations and resources, with full cyber-security.
>
> (3) Deployment and integration of distributed resources and generation, including renewable resources.
>
> (4) Development and incorporation of demand response, demand-side resources, and energy-efficiency resources.
>
> (5) Deployment of “smart” technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation.
>
> (6) Integration of “smart” appliances and consumer devices.
>
> (7) Deployment and integration of advanced electricity storage and peak-shaving technologies, including **plug-in electric and hybrid electric vehicles**, and thermal-storage air conditioning.
>
> (8) Provision to consumers of timely information and control options.
>
> (9) Development of **standards for communication and interoperability** of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.
>
> (10) Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services.

Today, smart grid technology is being deployed around the world and the architecture models for the smart grid are very similar. VGI clearly fits within the scope of item 7 with an objective of using smart grid communication standards of item 9.

5.5.3 The PEV in the Smart Grid - Two World Views

In one world view, the PEV is at a facility which has other smart loads and distributed generation and a building management system (BMS) controls the charging and discharging of each of the loads and sources to achieve a target power flow at the facility point of common coupling (PCC) to the distribution system. A higher tier control entity engages the many facilities in the system to achieve the desired aggregated power flow at a location on a distribution feeder or in the bulk area. This model can be thought of as aggregation by facility. This is the view taken by most distribution utilities regarding the integration of solar PV systems and stationary storage systems with their feeders. Everything is about managing the real and reactive power at the PCC.

Figure 6 shows a facility with a PV system, a stationary energy storage system, and a V2G-AC EVSE-PEV. It has several smart loads. It also has an EVSE that only supports charging. The BMS controls all the loads and sources at the facility. The facility integrates into the distribution feeder. In this model VGI is really a subset of facility-grid integration - it is how the PEV integrates with the BMS. This example shows that the Smart Energy Profile 2.0 (SEP2) is used by all devices on the facility network. The V2G EVSE shows that the internet messages with the PEV directly pass to the network with only conversion at the physical layers - the EVSE does not engage with the PEV-BMS information flow. The EVSE is an independent device on the local network. The V1G EVSE is shown as engaging the BMS using SEP2 but using ISO 15118 to engage the PEV.

Figures 6 and 7 can be simplified with smart Matter main and branch breakers that measure compliance to IEEE 1547 (grid and load side in specification to correct or disconnect) utilizing smart inverters that support grid forming, grid following, and/or both smart AC supplies/loads. In general, homes with DERs only want to disconnect from grid when grid is down to not back drive the grid for safety or when grid is in overvoltage to prevent damage to home electronics. Grid may only be down 1 hour or 2 hours per year and want to buy and sell energy to grid on a daily based to make money and create grid stability. With combination of Matter smart breakers, smart outlets, smart plug ins, smart loads, and smart supplies can turn on or off noncritical loads and turn on critical loads on per consumer Matter preferences. Matter protocol being built into devices like appliances, thermostats, water heaters, heat pumps, EVSE, etc., to add additional energy control features built into devices for global use.

In the other world view, the PEV, while always located behind some utility customer meter, is independently controlled by a PEV fleet aggregator. The PEV fleet aggregator would set the net charging rate of the fleet to stay within a target. This is the model used to demonstrate frequency regulation for a V2G fleet. The V2G aggregator bids a regulation capacity and commands each PEV in the fleet to charge or discharge at a target rate to follow the automatic generation control (AGC) signals from the system operator. In Europe, this PEV-only management concept is known as E-Mobility.

Figure 7 shows an example of a charge station site operated by a charge station fleet manager. This example shows the use of the Open Charge Point Protocol (OCCP) by the fleet operator and the EVSEs. The EVSEs communicate with the vehicles using ISO 15118. In this system, the EVSE does not just translate OCPP and ISO 15118 messages. The EVSE represents the combined PEV and EVSE as an entity.

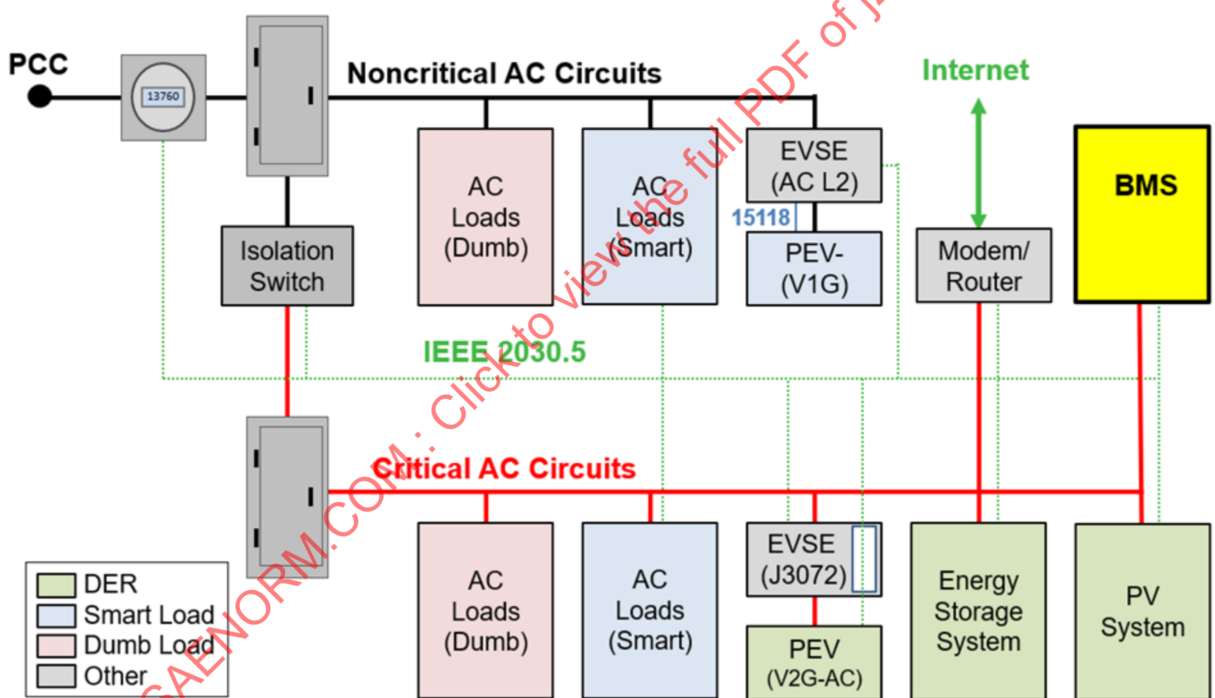

Figure 6 - VGI model - Smart building integration

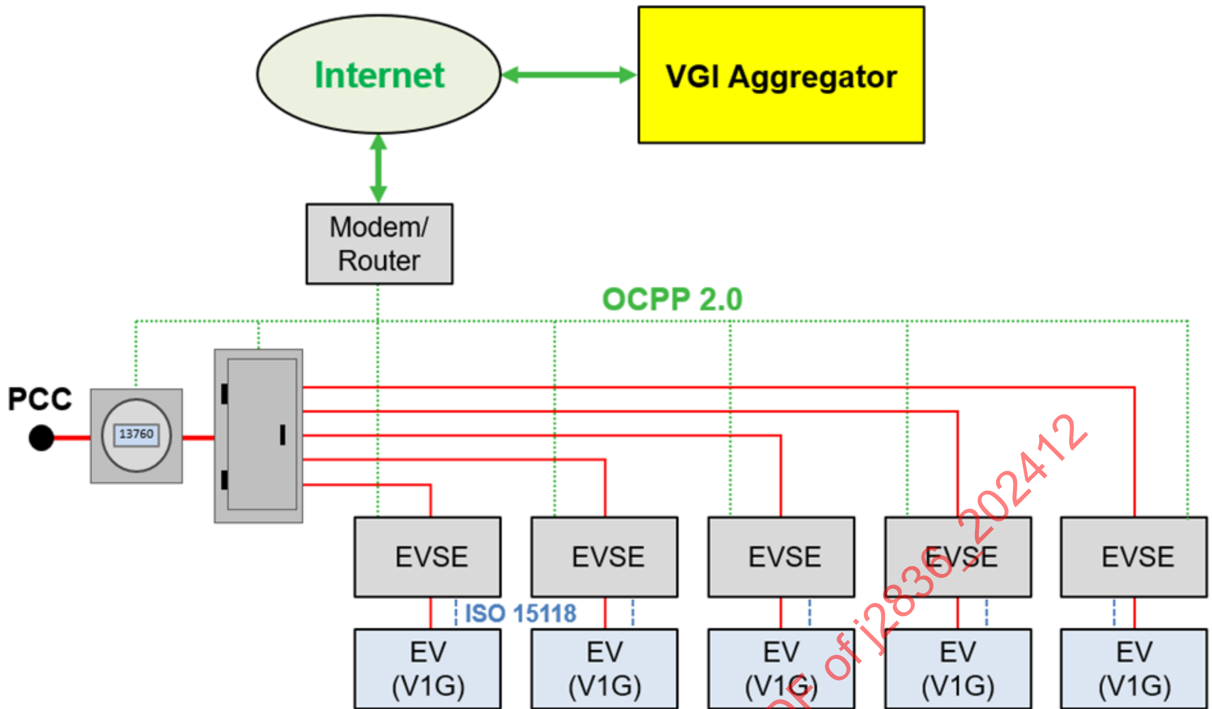

Figure 7 - VGI model - Charge station operator

5.5.4 Smart Energy Protocol 2.0

Smart Energy Profile 2.0 (SEP2) was developed specifically to support communication and interoperability of appliances and equipment connected to the Smart Grid. SEP2 has a very robust DER function set that supports the functions defined by EPRI report Common Functions for Smart Inverters. It also supports smart load and demand response functions. The SEP2 developers accounted for several unique requirements of the combined EVSE-PEV which were provided by SAE.

The "Smart Energy Profile 2 Application Protocol Standard" was first published by the ZigBee Alliance and HomePlug Powerline Alliance in April 2013. Control of future versions of SEP2 was subsequently transferred to the IEEE, and the April 2013 version of the standard was then republished in November 2013 as "IEEE 2030.5-2013 IEEE Adoption of Smart Energy Profile 2.0 Application Protocol Standard." This protocol has been revised by IEEE based on recommendations from the California Smart Inverter Working Group (SIWG) and other sources and is expected to be applied as the "IEEE 2030.5-2018 Standard for Smart Energy Profile Application Protocol."

The SIWG designated SEP2 as a protocol to be used by California utilities to communicate with DER aggregators, facility BMS, and selected individual DER devices. Many other protocols were considered by the SIWG, but SEP2 was one of the few that implemented the smart inverter functions that CPUC planned to require of all newly installed DER devices. IEEE 1547-2018 also designated SEP2 as one of three protocols to be used with DER devices (the others being IEEE 1815 DNP3 and SunSpec Modbus).

SAE J2847/1 provides guidance for a PEV using SEP2 for communicating with a control entity for use cases U1 through U5 described in SAE J2836/1, and SAE J2847/3 provides guidance for using SEP2 with use cases U6 and U7. The IEEE 2030.5 standard is the governing standard, but the SAE J2847 documents provide guidance and examples.

5.5.5 ISO 15118 Protocol

Technical Committee 69 (Electric road vehicles and electric industrial trucks) of the International Electrotechnical Commission (IEC) created a Joint Working Group (JWG1) with Subcommittee 21 (Data communications) of Technical Committee 22 (Road vehicles) of the International Standardization Organization (ISO) to create a series of standards for vehicle to grid communications interface (V2G-CI). This is known as JWG1-ISO/TC22/SC31-IEC/TC69 - or, more informally, as the ISO 15118 joint working group. The standards are collectively identified as "ISO 15118 Road vehicle - Vehicle to grid communication interface" and identified by part. Each part is developed and published separately, but the parts function collectively:

- ISO 15118-1: Road vehicles - Vehicle to grid communication interface - Part 1: General information and use-case definition
- ISO 15118-2: Road vehicles - Vehicle to grid communication interface - Part 2: Network and application protocol requirements
- ISO 15118-3: Road vehicles - Vehicle to grid communication interface - Part 3: Physical layer and data link layer requirements
- ISO 15118-4: Road vehicles - Vehicle to grid communication interface - Part 4: Network and application protocol conformance test
- ISO 15118-5: Road vehicles - Vehicle to grid communication interface - Part 5: Physical and data link layer conformance test
- ISO 15118-6: Road vehicles - Vehicle to grid communication interface - Part 6: Physical layer and data link layer requirements for differential HomePlug Green PHY
- ISO 15118-8: Road vehicles - Vehicle to grid communication interface - Part 8: Physical layer and data link layer requirements for wireless communication
- ISO 15118-9: Road vehicles - Vehicle to grid communication interface - Part 9: Physical layer and data link layer conformance test for wireless communication
- ISO 15118-10: Road vehicles - Vehicle to grid communication interface - Part 10: Physical layer and data link layer requirements for single-pair Ethernet
- ISO 15118-20: Road vehicles - Vehicle to grid communication interface - Part 20: 2nd generation network layer and application layer requirements
- ISO 15118-21: Road vehicles - Vehicle to grid communication interface - Part 21: Common 2nd generation network layer and application layer requirements conformance test plan
- ISO 15118-23: Road vehicles - Vehicle to grid communication interface - Part 23: 2nd generation network layer and application layer requirements conformance test plan - DC charging

ISO 15118 is only intended for direct communication between the PEV and EVSE. The EVSE would use a different protocol, such as SEP2, OpenADR, or OCPP, to engage with the BMS, utility, or other entity. The EVSE can interact with the control entity and just privately manage the PEV using 15118 messages. Alternatively, the EVSE could translate the messages from the upstream protocol into ISO 15118 messages and not engage in any processing of the message content from the upstream controller.

5.5.6 OEM Telematics

Vehicle manufacturers provide various telematics options, even for conventional vehicles. These systems can be extended to provide special features for electric vehicles. Information can be provided to a driver to locate available charge stations. A driver may be able to use a cell phone to check on the charging status of the PEV. Much of this can be done using proprietary equipment on-board the PEV and using cell phone applications provided by the vehicle OEM. This is discussed in 5.7.

EPRI, working with eight vehicle manufacturers and several utilities, demonstrated a concept known as Open Vehicle-Grid Integration Platform (OVGIP) in 2016. Two EPRI OVGIP reports, which are available for download, are listed in 2.1.5. One provides a general overview and the other describes use cases that guided the design and demonstration of the system. The OVGIP use case document defines how the system allows the PEV to participate in the SAE defined use cases described by SAE J2836/1 (U1-U5) and SAE J2836/3 (U6-U7). A controlling entity could be a home EMS, a BMS, a charge station fleet owner, or utility. The engagement could be as simple as providing a TOU (U1) schedule to a PEV for a utility service area or as sophisticated as engaging with a V2G aggregator for frequency regulation (U6).

The OVGIP concept is shown in Figure 8 with two PEVs each built by a different vehicle manufacturer (VM) with telematics that are not compatible. For each participating PEV, for example, the VM could have access to vehicle state information: the VIN, GPS location, EVSE control pilot setting, SOC, target SOC, time charge is needed, current rate of charging, and other data. This information would be provided to the OEM central server. The central server could create a virtual fleet as required to perform a certain service, or even to just make state information available for a PEV (VIN).

Assume that the OEM central server is engaged with a utility or E-Mobility aggregator to reduce the charging demand by a target rate for a defined duration. The central server could send a command to each of the two PEVs at the site by way of the VM telematics. For this application, the GPS location accuracy would be adequate.

The example also shows that a facility BMS could also engage the OEM central server to gain access to the state information of a vehicle and use the SAE J1772 control pilot to control rate of charging. This is more complex for the OEM central server to associate a specific PEV with the site using GPS and even more difficult with a specific EVSE. For discharging, the PEV and EVSE are certified to SAE J3072, and this provided exact association of the PEV and EVSE. Telematics could then be used for V2G commands.

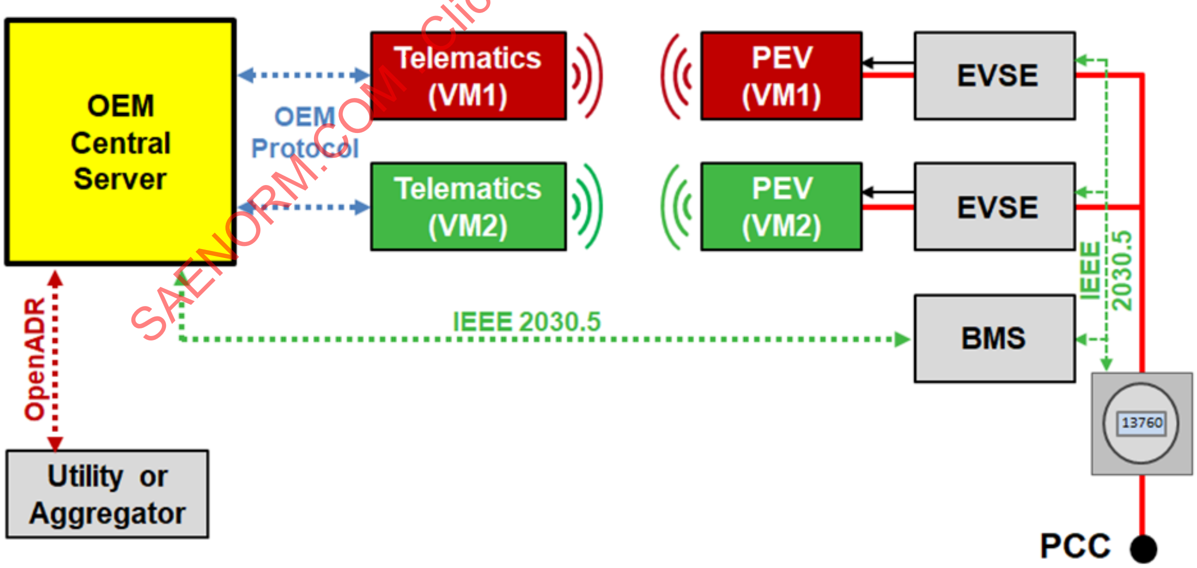

Figure 8 - OEM telematics

5.5.7 VGI Communications Protocol Working Group

At VGI workshops, some organizations promoted the exclusive use of ISO 15118 for use with electric vehicles. Others promoted the use of telematics. And others promoted the use of SEP2. This was based, in part, on the world view of whether the PEV integrates with a facility BMS or separate from the facility as part of an E-mobility distributed fleet. CPUC Energy Division staff addressed the issue of divergent communication protocols by following the E-mobility model and starting a formal process to resolve any issues with the selection.

The assigned CPUC commissioner for R.13-11-007 published a ruling on September 14, 2016, that stated in 4.10 (VGI Communication Standards) that the CPUC "Energy Division recommends that the utilities' VGI programs, including those associated with electric vehicle supply equipment deployed through utility applications, conform to the ISO/IEC 15118 Standard … For the Commission to decide whether statewide standards need to be adopted, the parties … should be prepared to provide testimony to support or oppose adopting such a standard. The Commission is to cooperate with the CEC, CARB, CAISO and other key stakeholders, in deciding whether such a standard should be adopted or not."

The VGI Communications Protocol Working Group (www.cpuc.ca.gov/vgi/) was established for this purpose and conducted substantial effort throughout 2017. The website provides access to material from all the meetings and work by various subgroups.

The premise behind designating ISO 15118 to be used for utility VGI programs was flawed because ISO 15118 is not a smart grid protocol that could be used by any utility. ISO 15118 is only used for point-to-point communication between the PEV and EVSE. A utility needs to use a recognized smart grid protocol for this purpose. This immediately raised the issue of what protocol would the utility use, even if the EVSE-PEV uses ISO 15118. The VGI project properly expanded to look at the larger VGI communications scope. SEP2, OpenADR, and OCPP were considered. The only protocol that supports V2G of the three is SEP2, and it is the only one designated by CPUC to be used with DER. OCPP would be useful for charge station fleet managers. OpenADR is used by utilities today for load management, but it does not provide the level of capability needed for DER and was bypassed by CPUC when selecting SEP2 for use with DER.

In the end, it was decided that ISO 15118 could not be mandated as an exclusive protocol and the market needs to mature. SEP2 could easily be used by a PEV with an EVSE that provided a MAC/PHY bridge. Telematics will be provided by many vehicle manufacturers and could provide a viable approach to VGI.

CPUC focus shifted to establishing technical requirements for EVSE devices which would be procured by utilities regulated by CPUC. A key requirement would be that purchased EVSE devices could support different protocols and be easy to upgrade. CPUC does not have authority over the private purchases of EVSE for homes or businesses but will certainly influence product offering in those markets.

5.6 Diagnostics

5.6.1 Standards

The communication standards required for Diagnostics are as follows:

SAE J2836/4: Use Cases for Diagnostic Communication for Plug-in Electric Vehicles

5.6.2 Description

These documents describe the analogue diagnostics for the SAE J1772 Control Pilot and Prox circuits at various points. Four locations for the control pilot and five for the prox were identified for (1) open circuits, (2) short to ground, and (3) short to power and then results were if the failure was "detectable" or not as shown in the schematic for Figure 9.

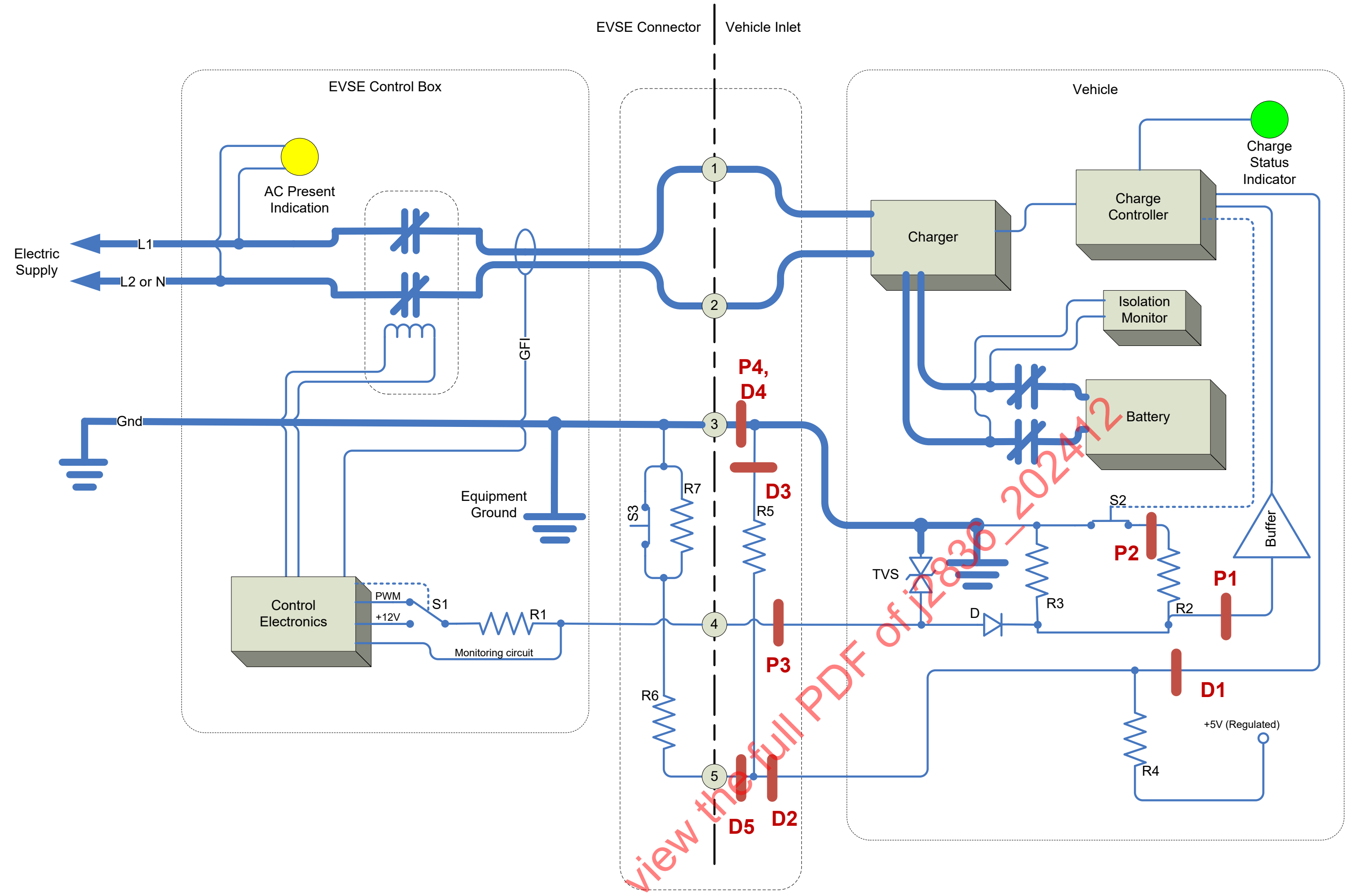

Figure 9 - Control pilot and detection circuit schematic and failure detection points

5.6.3 History and Next Steps

SAE J2836/4 was reopened to include DC charging communication diagnostics in 2018. The messages, signals, values, and timing will be included to identify what failed the session with a common approach that should be conveyed by both the vehicle and EVSE.

5.7 Customer to Vehicle Communication

5.7.1 Standards

The communication standards required for Customer to Vehicle communications are as follows:

1. SAE J2836/5: Use Cases for Customer Communication for Plug-in Electric Vehicles

2. SAE J2847/5: Communication Between Plug-in Vehicles and Customers

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

5.7.2 Description

Figure 10 adds Use Cases #8, 9, and 10 to the diagram shown in Figure 2.