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Electric Vehicle V2G AC Standard Integration by IEEE, SAE, UL

October 2021

Hawk Asgeirsson

2021 DOE OE Energy Storage Peer Review

Energy Storage Integration panel

U.S. DEPARTMENT OF ENERGY BATTELLE

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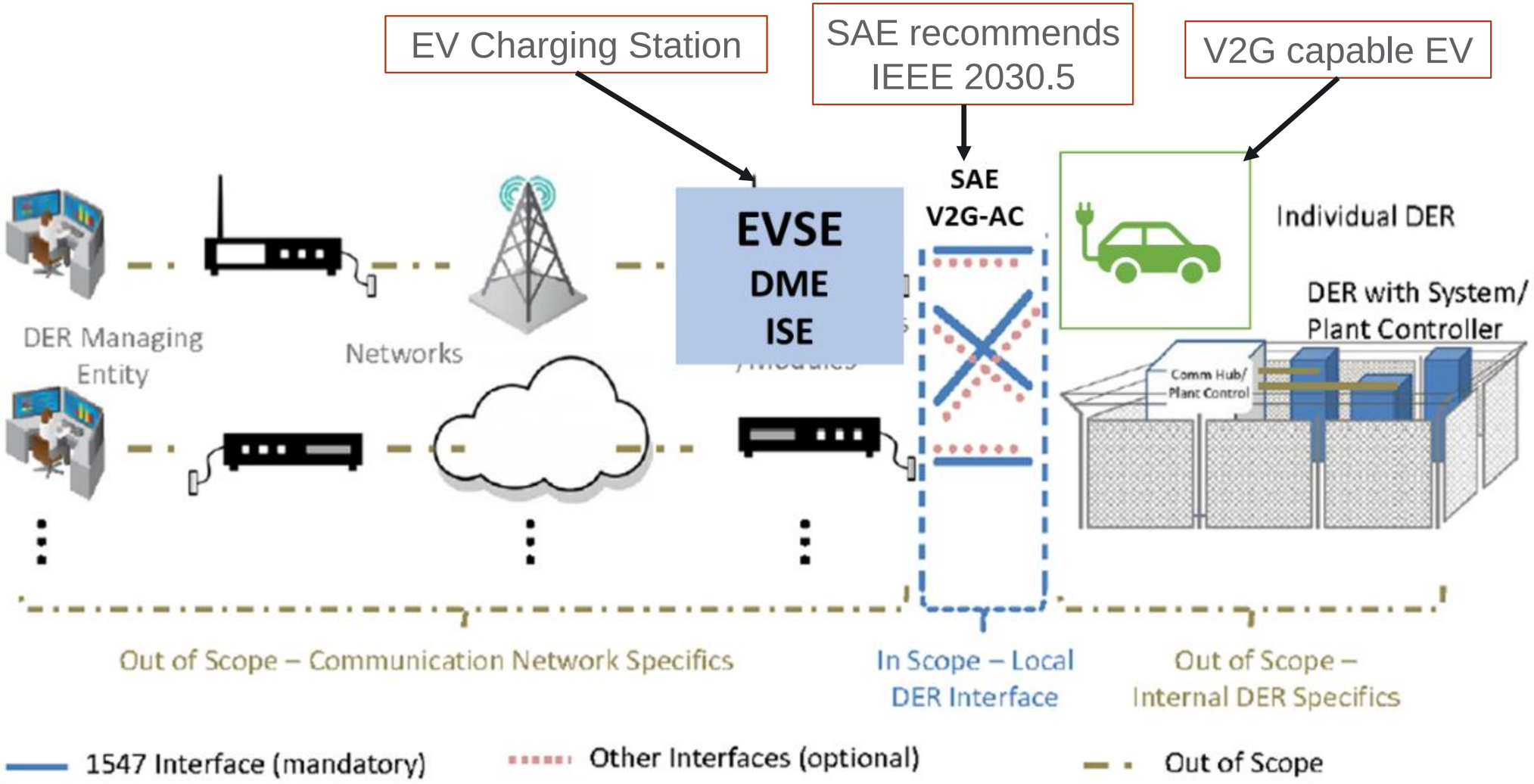
Summary

- Alignment of IEEE and SAE on V2G Energy Storage Standards
- SAE J3072 Standard on the Interconnection Requirements for Onboard, Utility-Interactive, Inverter Systems, was updated and published March 10, 2021
- Update includes on-board grid interactive inverter requirements to accomplish V2G AC
- Incorporated requirement outlined in IEEE 1547-2018, IEEE 1547.1 and IEEE 2030.5
- UL 1741 Standard is being updated to incorporate SAE J3072 requirements in V2G AC EV designed charging station
- IEEE P1547.9 includes Annex on bidirectional EV charging

IEEE 1547-2018 - IEEE Standard for Interconnection and Interoperability of DER with Associated Electric Power Systems Interfaces
IEEE 1547.1 - IEEE Standard Conformance Test Procedures for Equipment Interconnecting DER with Electric Power Systems
IEEE 2030.5 - IEEE Standard for Smart Energy Profile Application Protocol
UL 1741 - Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

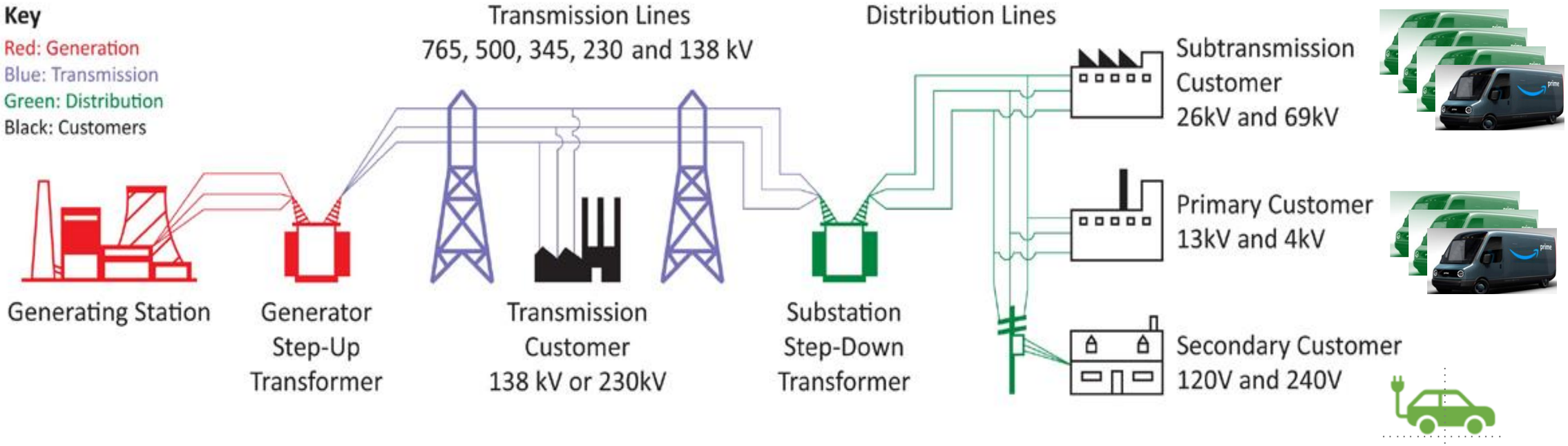
Communication and control illustration



Source: IEEE 1547-2018, 10.7 Communication protocol requirements

Future Considerations
FERC/NERC/Aggregation – Distribution/BPS

Mobile Energy Storage



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Acknowledgement

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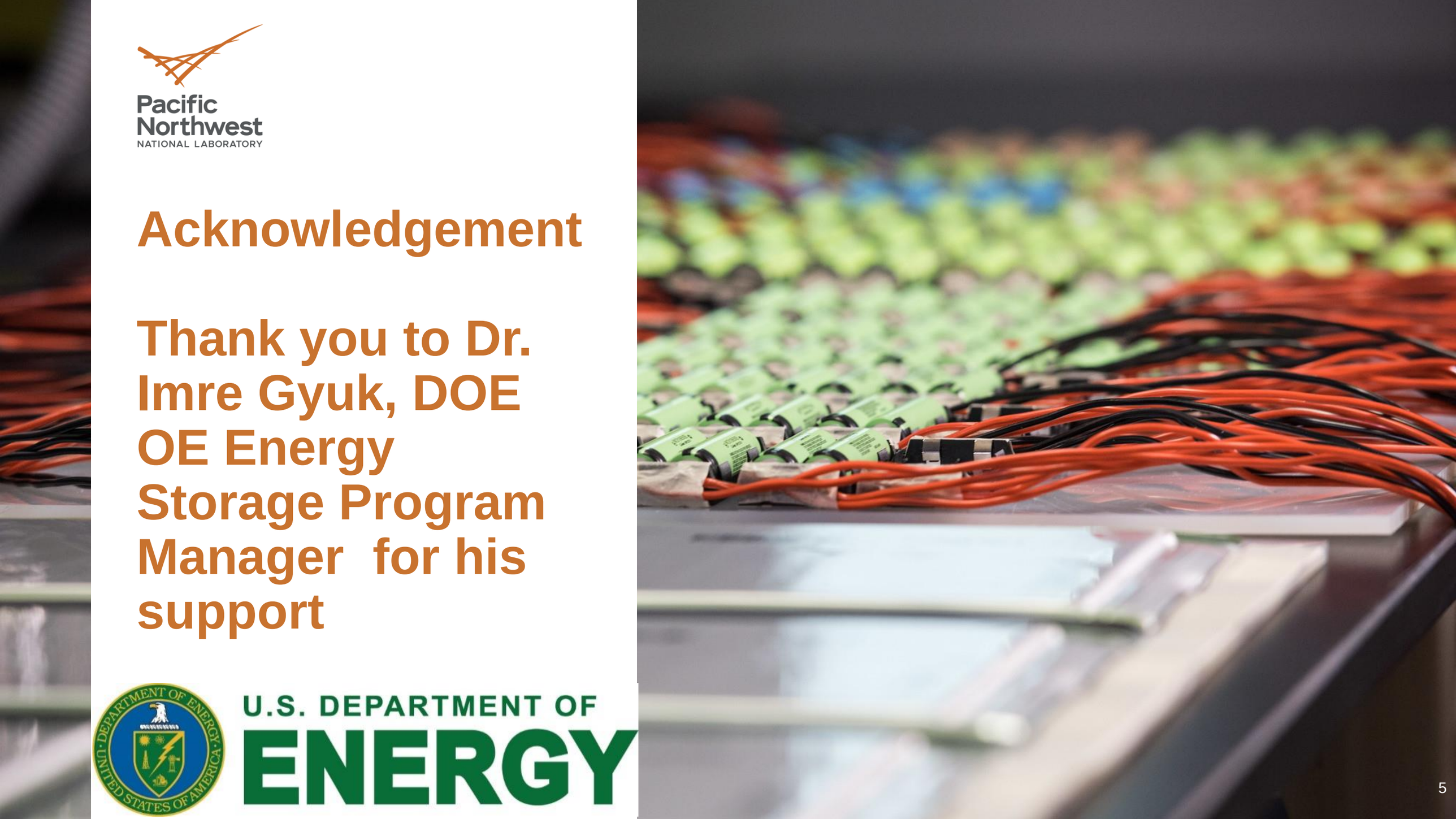

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Backup Slides

Thank you

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Electric Vehicle V2G AC Standards SAE, IEEE, UL

August 2021

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Definitions

- SAE: SAE International is a global association of engineers and related technical experts in the aerospace, automotive, and commercial-vehicle industries whose core activity is developing consensus standards
- SAE defines the interface (mechanical, electrical, and communication) standards on vehicles and between EVs and the electric power system (EPS)
- IEEE: Develops global standards for broad group of industries
- Electric Power System (EPS): Facilities that deliver electric power to a load
- EV or PEV: Plug-in electric vehicle. PEV designation is used in SAE standards
- V1G: Vehicle managed charging unidirectional energy management
- V2G: Vehicle-to-grid – Vehicle bidirectional energy flow
- EVSE: Electric Vehicle Supply Equipment – EV charging station

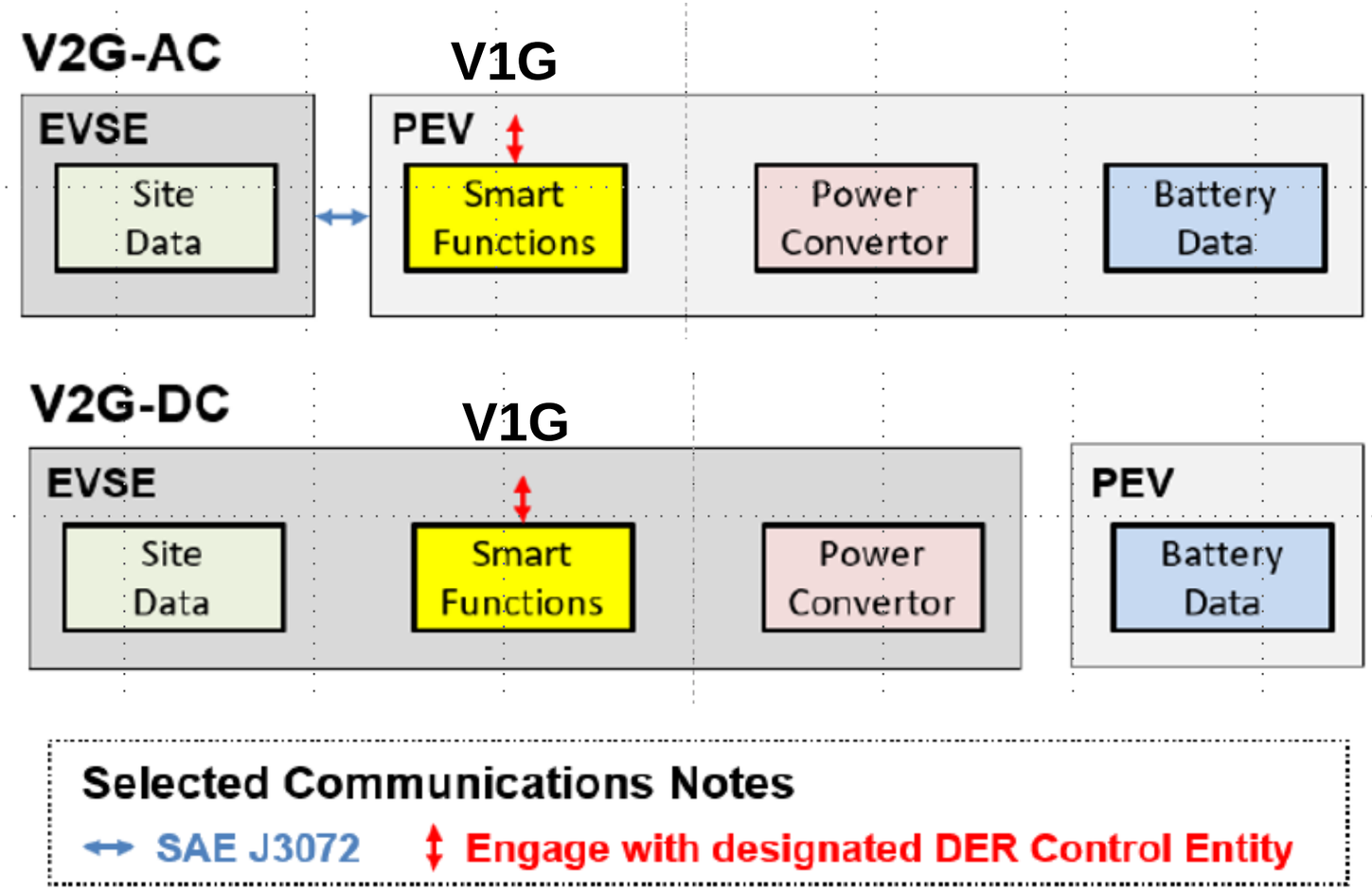
Summary

- The standard SAE J3072 Interconnection Requirements for Onboard, Utility-Interactive, Inverter Systems, was updated and published March 10, 2021
- Lates update includes on-board grid interactive inverter requirements
- It incorporated requirement outlined in IEEE 1547-2018, IEEE 1547.1 and IEEE 2030.5
- This year (2021), UL is updating their standards to incorporate SAE J3072 in V2G EV designed charging station
- The expect UL designation will be UL 1741 Supplement C (UL 1741 SC)

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

Types of V2G Inverter Systems

- V2G-AC the EVSE interacts with the on-board EV inverter and the local EPS
- V2G-DC the EVSE contains the grid interactive inverter that interacts with the EV and the local EPS



SAE J3072 Interconnection Requirements for Onboard, Utility-Interactive Inverter Systems

- SAE J3072 Standard establishes interconnection requirements for a utility-interactive inverter system which is integrated into a plug-in electric vehicle (PEV) and connects in parallel with an electric power system (EPS).
- This standard also defines the communication between the PEV and the EVSE required for the PEV onboard inverter to be configured and authorized by the EVSE for discharging at a site.
- Gap - The EVSE needs to be certified by UL 1741 to conform to SAE J3072 requirements

IEEE and DER Standards referenced by SAE

- 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 2030.5-2018 – Standard for Smart Energy Profile Application Protocol
- Previous versions of IEEE 1547 standards are also referenced – Most jurisdiction in the USA have not accepted latest IEEE 1547 standards
- Also relied on EPRI Common Functions for Smart Inverters, Version 4
- IEC 61850-90-7 Communication Networks and Systems for Power Utility Automation - Part 90-7: Object Models for Power Converters in Distributed Energy Resources (DER) Systems

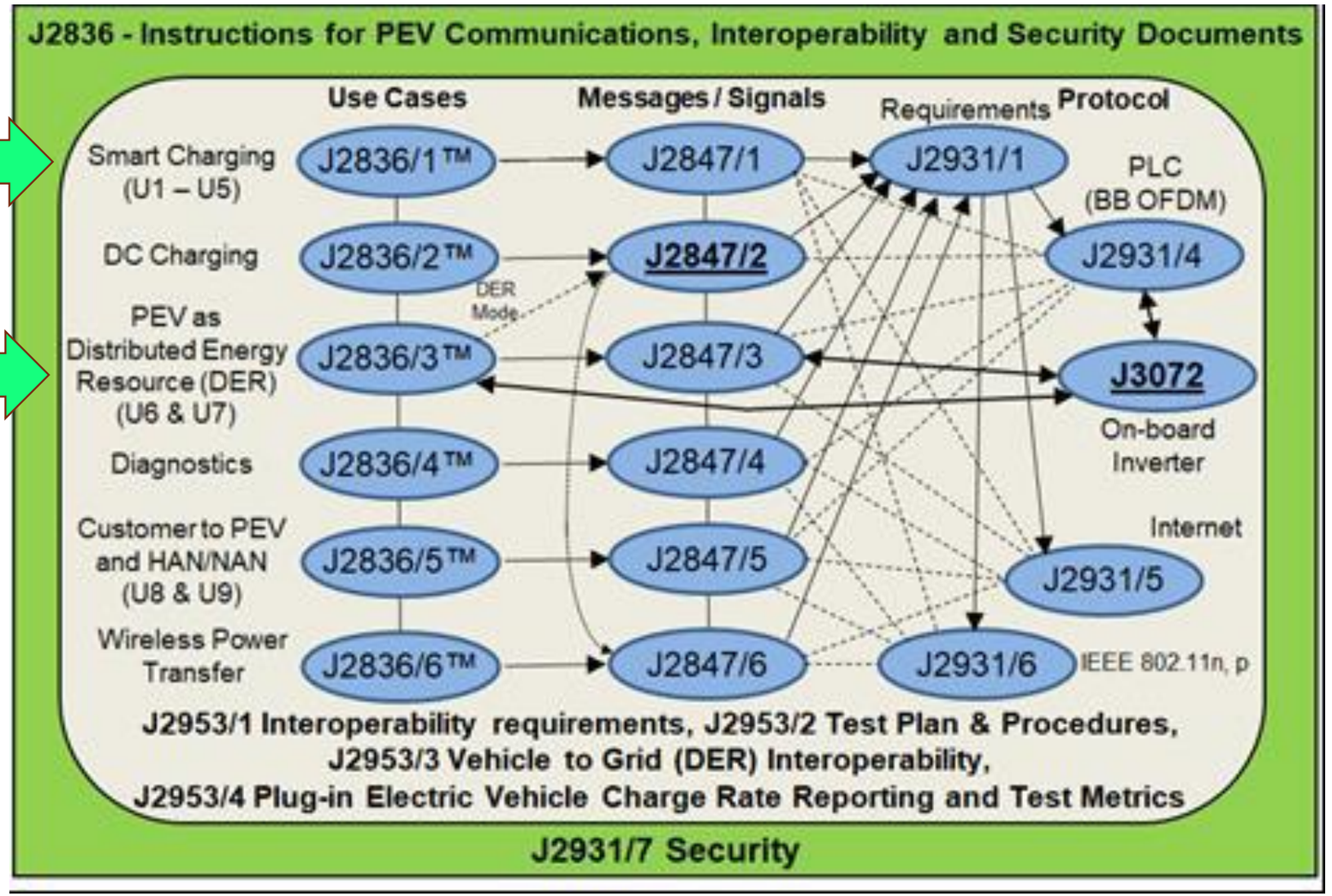
SAE Major EV Documents and Functions

- J3072 – Interconnection Requirements for Onboard, Utility-Interactive, Inverter Systems – Standard updated and published March 10, 2021
- J2836™ – Instructions and Use Cases (establishes requirements)Technical Information Report
  - An available public SAE Information Report J2836 establishes the instructions for the documents required for the variety of potential functions for PEV communications, energy transfer options, interoperability and security (J2836_201807)
- J2847 – Messages, diagrams, etc. (derived from the use case requirements)
- J2931 – Communication Requirements, Protocol & Security
- J2953 – Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)

SAE Plug-in Electric Vehicle Documents

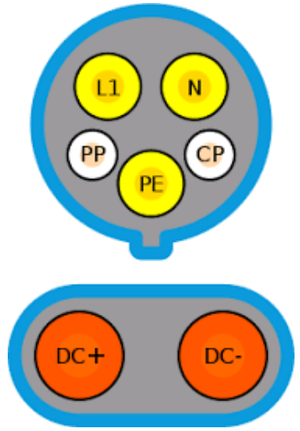
V1G

V2G



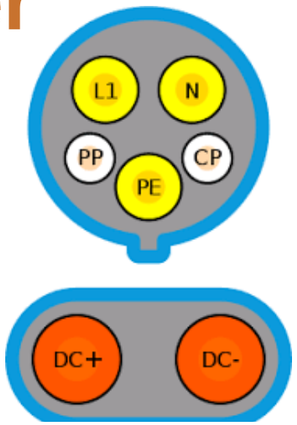
Energy transfer capability – SAE J1772

- Maximum energy transfer is a function of EVSE rating, EV capability and charge cord rating (EVSE & charge cord are rated as a system)
- Installation of EVSE is governed by National Electrical Code, state and local building codes and UL testing and listed
- Energy transfer is managed by the EV charging system
- Energy transfer rate varies over time and is a function of PEV design



SAE J 1772 Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler

SAE J1772 Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler

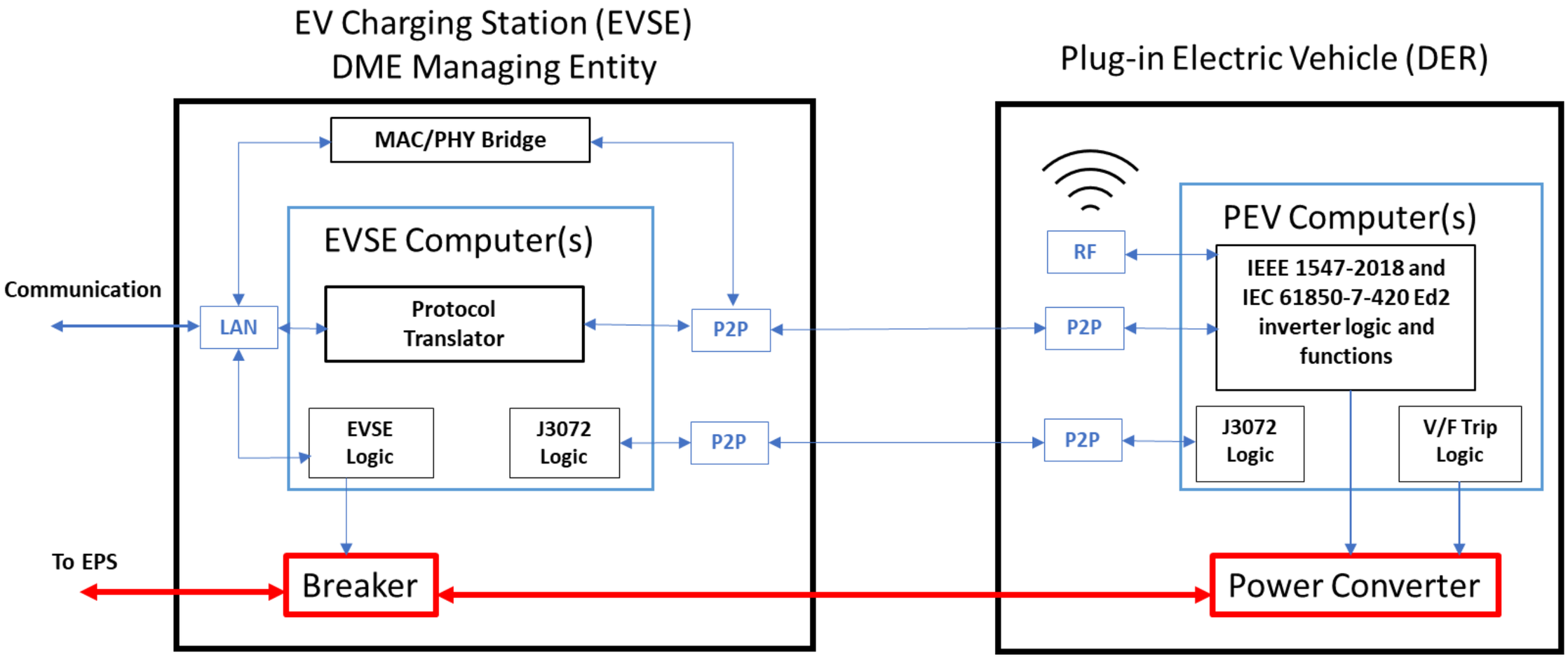


Electrical Ratings

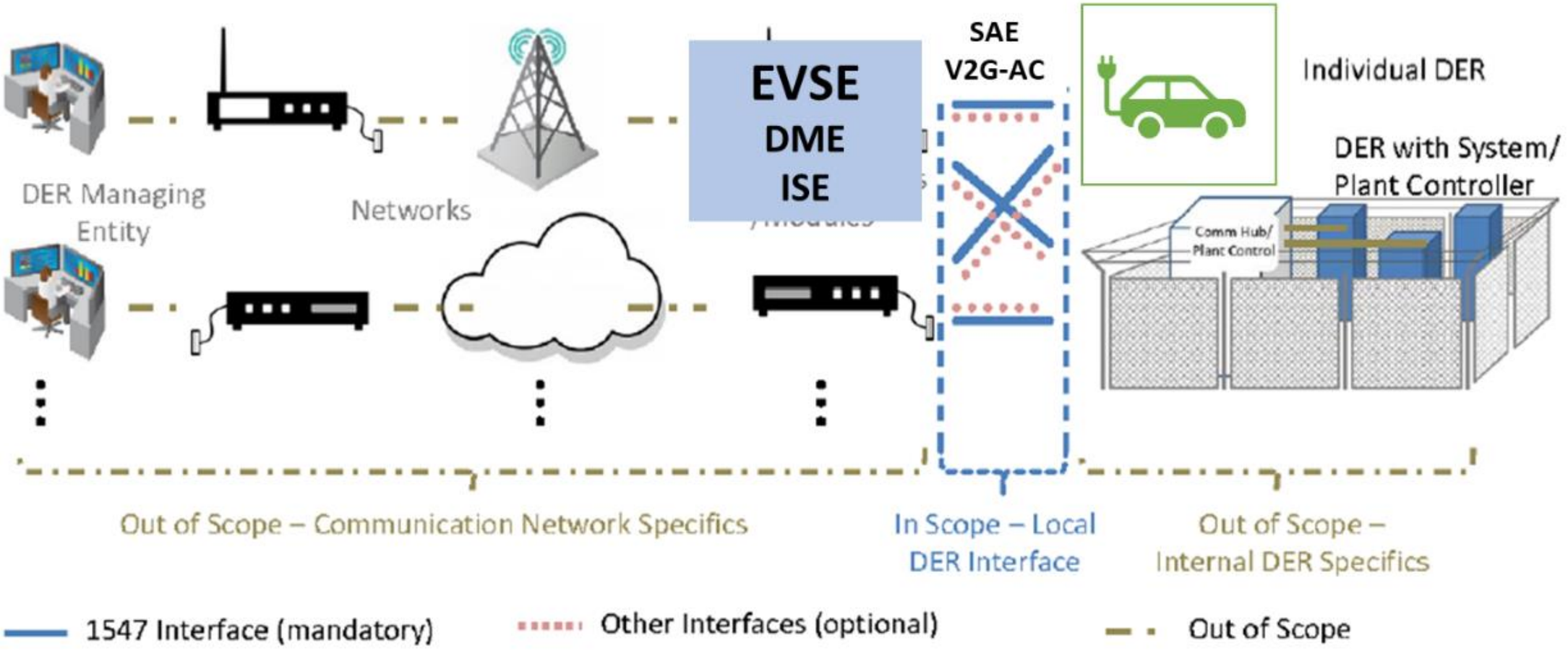
Charge Method	Voltage (AC V)	Phase	Max. Current (A, continuous)	Branch Circuit Breaker Rating (A)	Max. Power (kW)
AC Level 1	120	1-phase	12	15 (min.)	1.44
			16	20	1.92
AC Level 2	208 to 240	1-phase	≤ 80	Per NEC 625	Up to 19.2

Charge Method	EVSE DC Output Voltage (DC V)	Max. Current (A)	Max. Power (kW)
DC Level 1	50 to 1000	80	80
DC Level 2	50 to 1000	400	400

SAE J3072 Electric Vehicle V2G AC System Diagram



Communication and control illustration



Source: IEEE 1547-2018, 10.7 Communication protocol requirements

EV On-board V2G enabled inverter

SAE J3072 - Section 4 defines technical requirements System types communication protocol requirements

- 4.2.1 System Type A1 (SAE J1772 AC L2 IEEE 2030.5)
- 4.2.2 System Type B1 (SAE J3068 LIN-CP)

  SAE J3068 defines connector and control protocol for EVs, 3P & DC
- The inverter system shall meet the requirements of IEEE 1547-2018
- The inverter system shall be tested in accordance with IEEE 1547.1-2020
- The vehicle manufacturer (VM) will perform conformance testing to SAE J3072 and provide dated certificate of conformance to SAE J3072 for the specific inverter system model
- 4.6 Defines PEV Configuration and Management Information at Connection to EVSE

LIN-CP: ***L****ocal* ***I****nterconnect* ***N****etwork on the* ***C****ontrol* ***P****ilot*

Table lists the Management Information for each of the smart inverter functions defined by IEEE 1547-2018

J3072	61850 Function	IEEE 1547-2018 Function	Management Information
4.6.6.1	DFPF	Constant Power Factor	
4.6.6.2	DVVR	Voltage-Reactive Power	Volt-VAR Curve, DVVR:OplTmsMax
4.6.6.3	DWVR	Active Power-Reactive Power	Watt-VAR Curve
4.6.6.4	DVAR	Constant Reactive Power	
4.6.6.5	DVWC	Voltage-Active Power	Watt-VAR Curve, DVWC.OplTmsMax
4.6.6.6	DHVT	High Voltage Trip	OV1, OV2
4.6.6.6	DLVT	Low Voltage Trip	UV1, UV2
4.6.6.7	DHFT	High Frequency Trip	OF1, OF2
4.6.6.7	DLFT	Low Frequency Trip	UF1, UF2
4.6.6.8	DHFW	High Frequency Droop	dbOF, kOF, olrtOF
4.6.6.8	DLFW	Low Frequency Droop	dbUF, kUF, olrtUF
4.6.6.9	DCTE	Enter Service Parameters	VHiLim, VLoLim, HzHiLim, HzLoLim, RtnDlTmms, RtnDlTmms, RtnRmpTmms
4.6.6.10	DWMX	Limit Active Power	

Response to Area EPS Normal and Abnormal conditions

- IEEE 1547 Clause 5. Reactive power capability and voltage/power control requirements
  - **SAE J3072 specifies Normal Operating Performance Category B**
- IEEE 1547 Cause 6. Response to Area EPS abnormal conditions
  - **SAE J3072 specifies Abnormal Operating Performance Category III**

SAE J3072 - Section 4.6 EVSE Authorization of PEV to Discharge

- The EVSE shall be the gatekeeper for authorizing the PEV to discharge at a specific site. This section describes the information to be exchanged between the EVSE and PEV and logical decisions to be performed by both the EVSE and PEV before the EVSE can authorize the PEV to discharge during a charging session.

EVSE and PEV Interconnection Processes

Section 4.6 –Initialization

1. PEV connected to EVSE
2. Point to Point communication established
3. EVSE provides site Configuration Information to PEV
4. PEV evaluates and provides PEV Configuration Information to EVSE
5. EVSE provides static Management Information to PEV

Section 4.7 –Active Engagement

1. EVSE is sole DER Managing Entity for IEEE 1547-defined functions
2. EVSE provides PEV with Authorization to Discharge
3. PEV provides Monitoring Information
4. Require SAE U6 to be implemented with alternate DME allowed

Summary

- SAE PEV standards are updated for V2G AC and to conform to IEEE1547, IEEE 1547.1 and IEEE 2030.5
- Settings are performed through EVSE PEV J3072 exchange
- PEV inverters will be OEM certified to IEEE 1547-2018 and 1547.1
- UL is in the process of updating their **UL 1741 Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources** to incorporate updated SAE J3072 V2G AC standard. UL 9741 is being updated to accommodate J3072 V2G AC update
- The expect UL designation will be UL 1741 Supplement C (UL 1741 SC)
- Once UL 1741 SC is published, the V2G AC EVSE can be labeled and accepted by local AHJ

AHJ - authority having jurisdiction: Authority having the rights to inspection and approval of the design and construction of Local EPS premise electrical systems

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Supplemental slides

VGI Use Cases/Functions

SAE J2836/1™ (smart charging), J2836/3™ (DER)

	SAE Use Case	Type	RPF	VAR
U1	Time of Use	Price		
U2	Demand Response	Stop		
U3	Real-Time Pricing	Price		
U4	Critical Peak Pricing	Price		
U5	Flow Reservation	Fixed	Yes	
U6	Basic DER: Fixed Flow	Fixed	Yes	
U7	Advanced DER: Fixed PF	Fixed	Yes	Yes
U7	Advanced DER: Fixed VAR	Fixed	Yes	Yes
U7	Advanced DER: Freq-Watt	Auto	Yes	
U7	Advanced DER: Volt-Watt	Auto	Yes	
U7	Advanced DER: Volt-VAR	Auto	Yes	Yes
U7	Advanced DER: Watt-PF	Auto	Yes	Yes
U7	Advanced DER: H/L FRT	Limit	Yes	
U7	Advanced DER: H/L VRT	Limit	Yes	

Smart/Optimized Charging (V1G)

DER (V2G)

SAE - PEV Energy Control Classifications

RPF: Reverse Power Flow

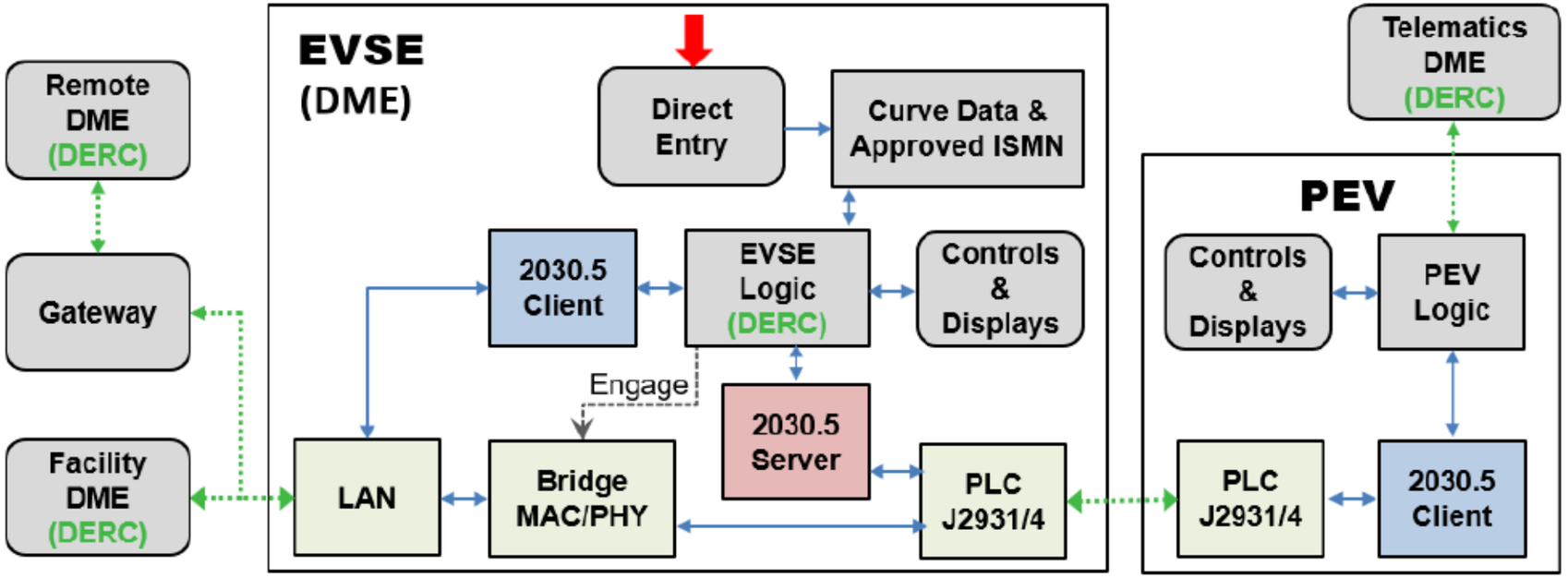
- V2L: Vehicle-to-load
- V2H: Vehicle-to-home
- V2G: Vehicle-to-grid

VGI: Vehicle-Grid Integration

- V1G: (Smart/Optimized Charging)
  - Price Based charging
    - Choose lowest price period to charge while connected
  - Demand Response Load Control
    - Delay and/or Reduce charging power
  - FlowReservation
    - Exchange Power, Energy, Time Charge Is Needed (TCIN) between vehicle and management system
  - Demand Charges
    - Stay below limits on vehicle charging power – include other site loads

FPF: Forward Power Flow

Proposed System Concept



KEY
DME: DER Managing Entity
DERC: DER Control Message
ISMN: Inverter System Model Number
MAC: Medium Access Control Layer
PHY: Physical Layer

- EVSE **sole** DME for all IEEE 1547-2018 functions
- Alternate DME allowed for SAE U6

Electric School Bus Providers

- Blue Bird Corporation (Georgia) – J1772, Level 2 @ 19.2 kW, DC @ 60 kW
- Collins Bus Corporation (Kansas) – J1772, Level 2 @ 19.2 kW, DC @ 60 kW
- Lion Electric Company (Quebec) – J1772, Level 2 @19.2 kW, DC @ 24/50 kW
- Green Power Motor Co. (Vancouver & California) – J772, Level 2 @ 22 kW, DC @ 100 kW