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Grid Standards Challenges and Opportunities for V2G and Hybrid Systems

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Energy Storage System Safety & Reliability Forum

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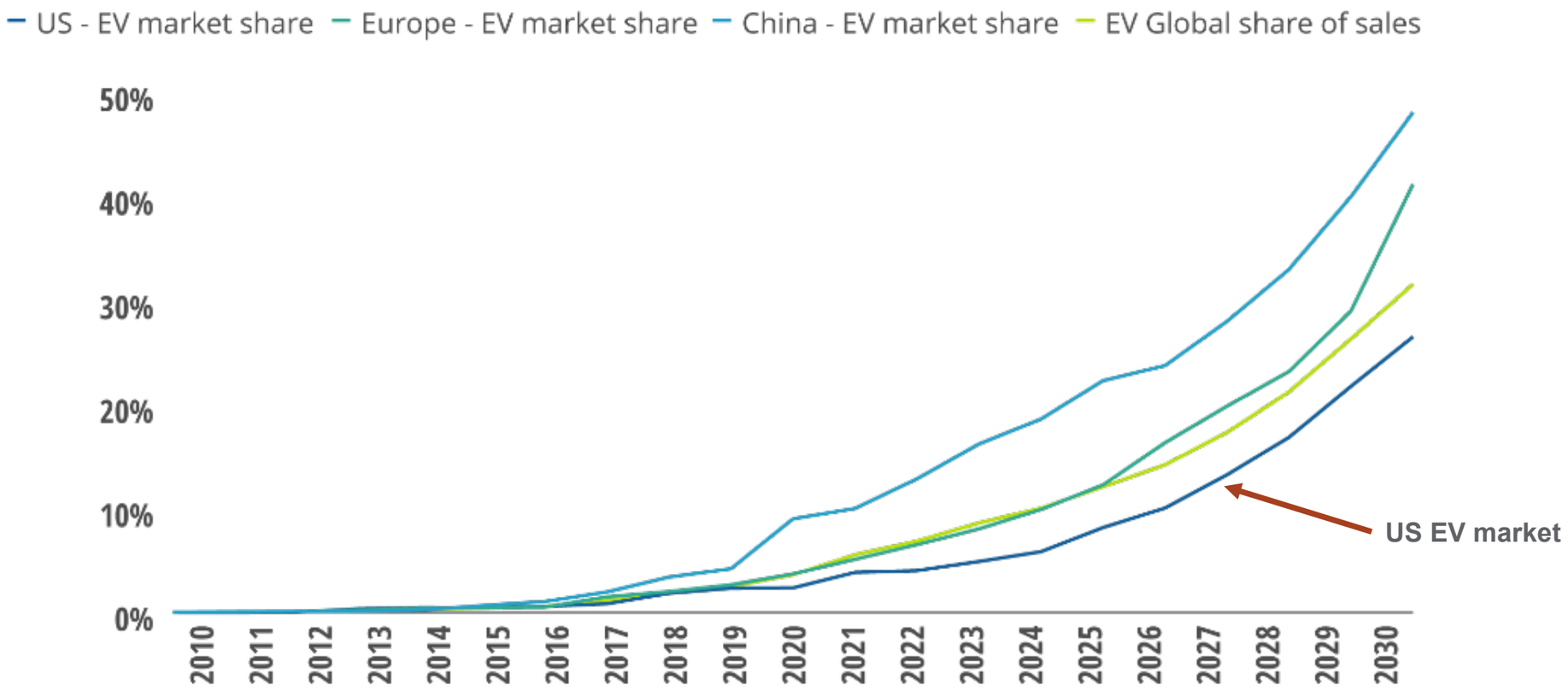
Outline

- EV and Vehicle to Grid (V2G) background
- EV impacts to electric distribution systems
- V2G standards landscape
- Hybrid systems considerations, *generalize related standards development and other solutions to address V2G-adoption needs*

EV Penetration 2020 forecast

FIGURE 3

Outlook for EV market share by major region



Source: Deloitte analysis, IHS Markit, EV-Volumes.com[17]

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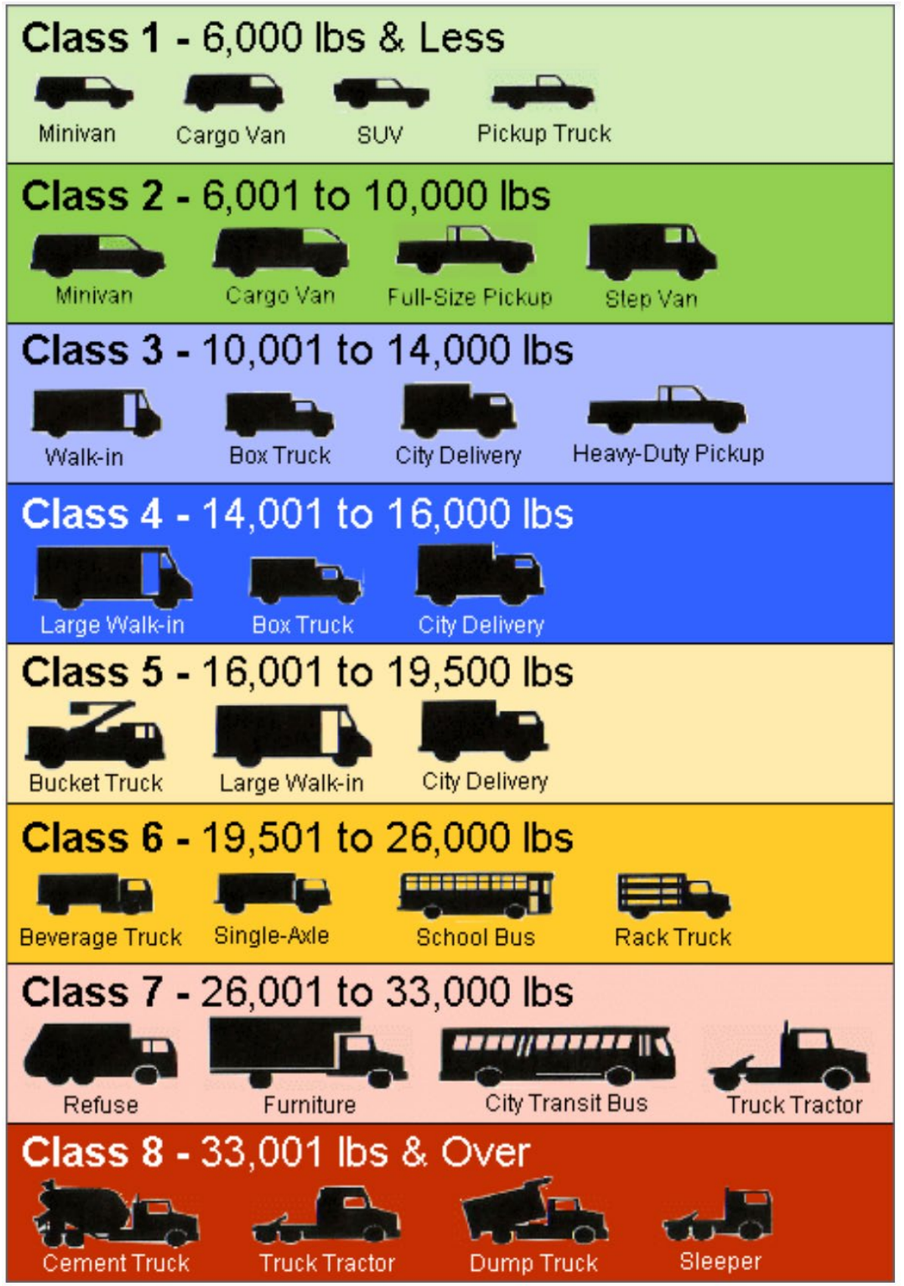
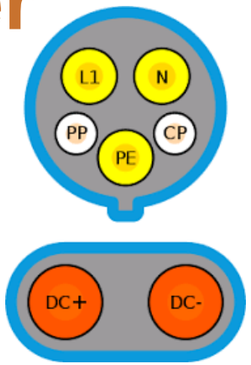
Vehicle classification

- J1772 Coupler dominates today – AC and DC
  - 1.4kW-400kW(dc)
- SAE J3271 Megawatt Charging System
  - Connector can manage 350 kW w/out cooling
  - 1MW w/ cooling today
  - 4.5MW future target



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



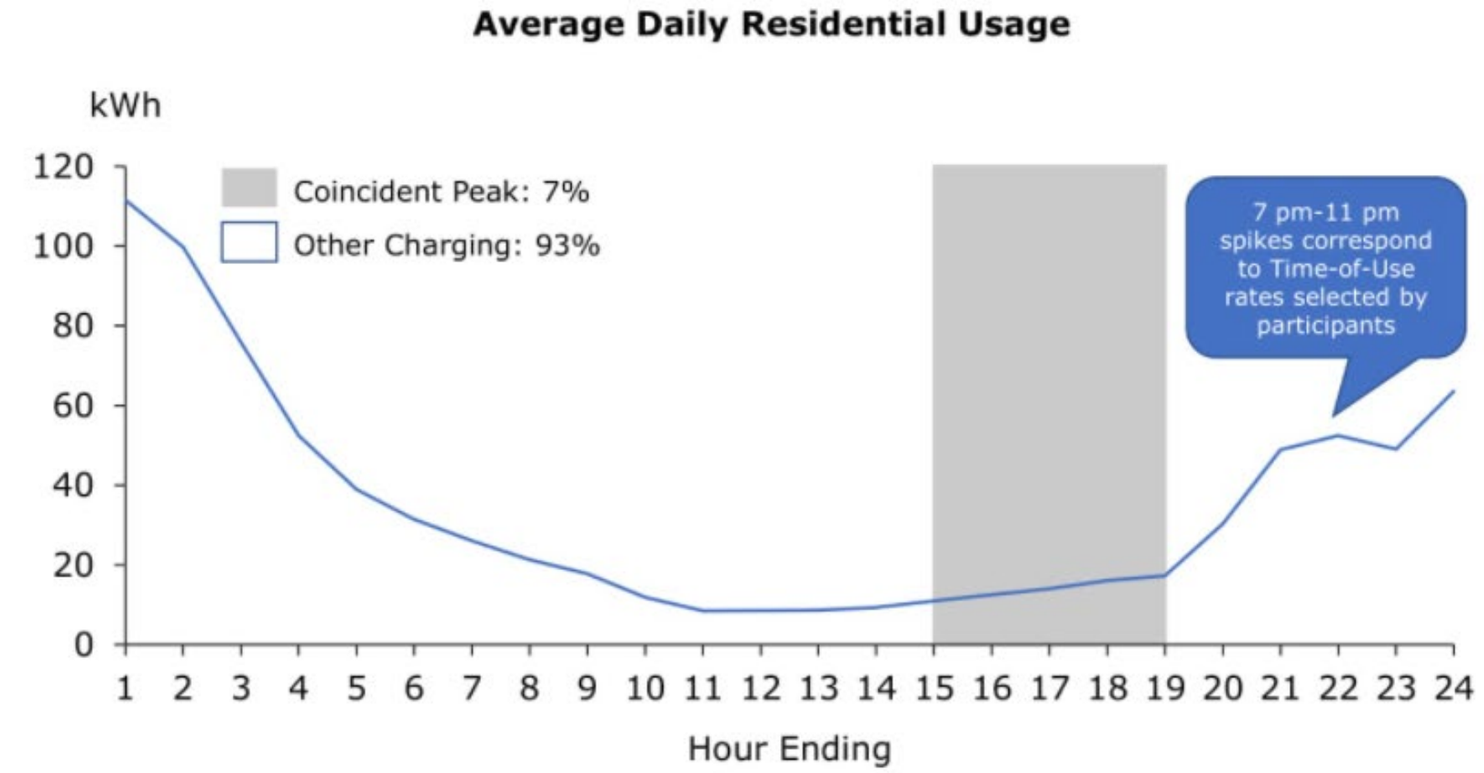
Electrical Ratings

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

DTE Report

In its first Annual Status Report filed in May 2020, the team found 93% of residential charging was outside of the coincident peak window



The second Charging Forward Annual Status Report will be filed May 2021

EV-Impact Insights from Early Industry Studies and Pilots

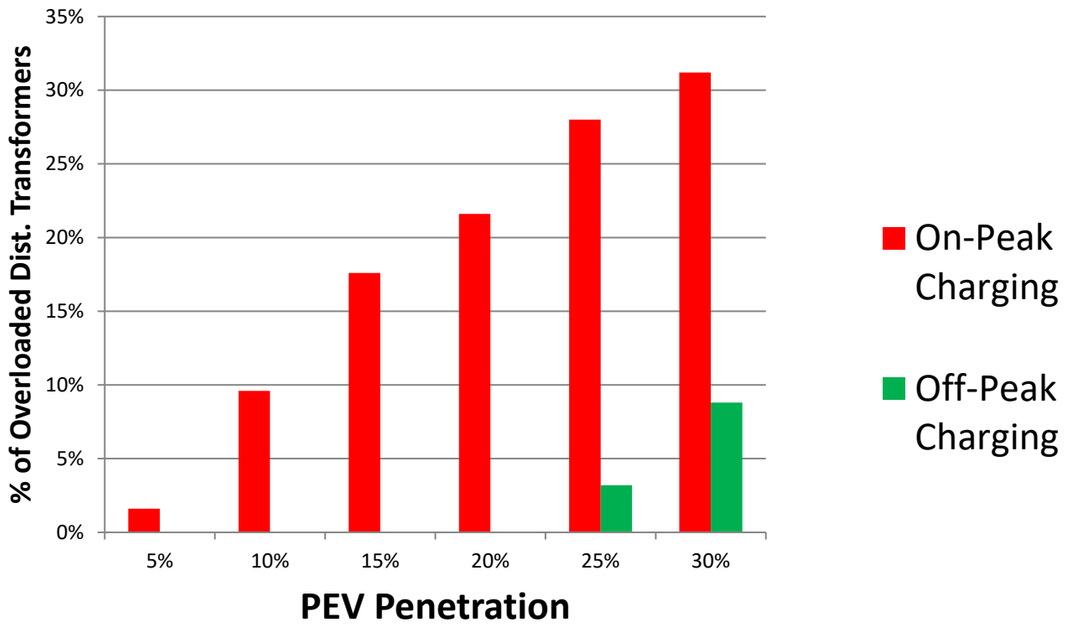
- Loading and unbalance concern
  - Transformers and load carrying elements
- Low voltage issues
- Transformer loss of life – accelerated aging
- Local loading and voltage concern
- Utility pilot projects showed similar results
  - Field evaluation of EV installations performed
  - Initial adoption is manageable
  - No appreciable local system issues
- The distribution grid can manage initial low adoption
- As EV adoption increases managing EV charging becomes more important

Any different than ES-DER in general?

Charging Impact on Distribution System

Heavily Loaded Circuit – Worst Case Scenario – 3.3 kW charging

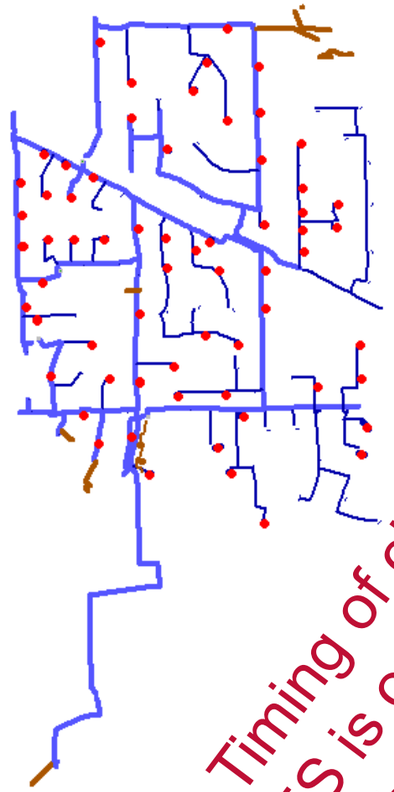
PEV Impacts on the Distribution System
On-Peak vs Off-Peak Charging



- Red bars – Percent overloaded transformers with uncontrolled charging
- Green bars – Percent overloaded transformer with controlled charging after 11 pm

*There are a total of125 distribution transformers on the distribution circuit

Studying PEV Charging on a Distribution Circuit



Timing of charge is critical:
ES is one temporal solution,
Enhanced controls is another.
V2G a mechanism to mitigate EV impacts? V1G?

Opportunities for Lowering Barriers to Adoption

- EV adoption over next 10-years is manageable
  - Need to work on how to manage charging
- School busses and fleet yards are an opportunity to work on:
  - Tariffs
  - ***Demo projects such as demand management (V1G) and V2G***
- DERMS is still in early product maturity and adoption stage
- Aggregation of EVs is an evolving topic – need to be ready
- ***Rely on Standards as much as possible***

DERMS = distributed energy resource management system

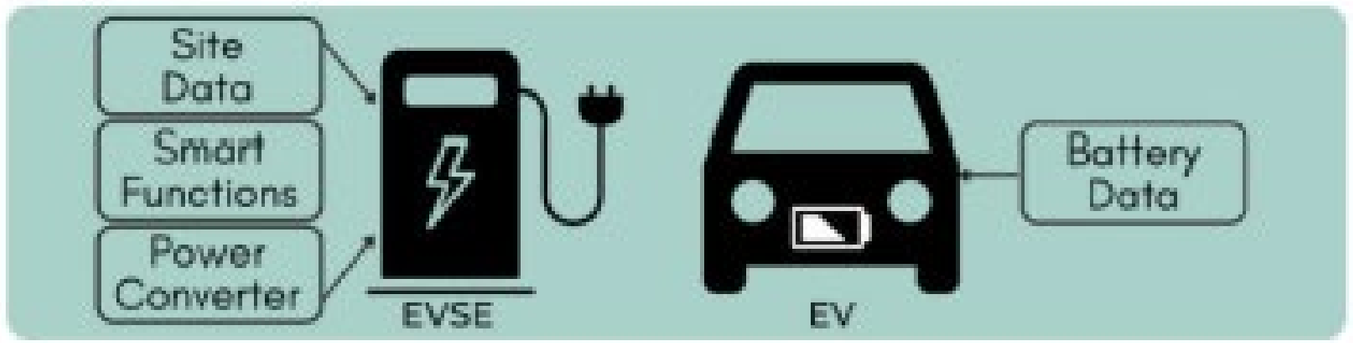
What is V2G *for purposes of this discussion*?

'Capable of bi-directional exchange of power between an EV and an electric power system'

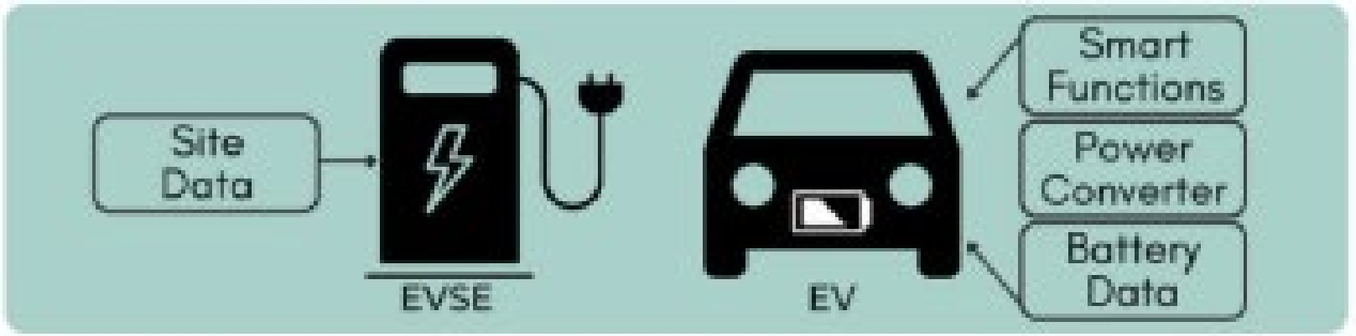
Types of V2G Inverter Systems

- V2G-DC the EVSE contains the grid interactive inverter that interacts with the EV and the local EPS
  - UL 9741 listing for grid interactive inverter – references UL 1741
- V2G-AC the EVSE interacts with the on-board EV inverter and the local EPS
  - UL 1741 SC (draft)

V2G-DC



V2G-AC



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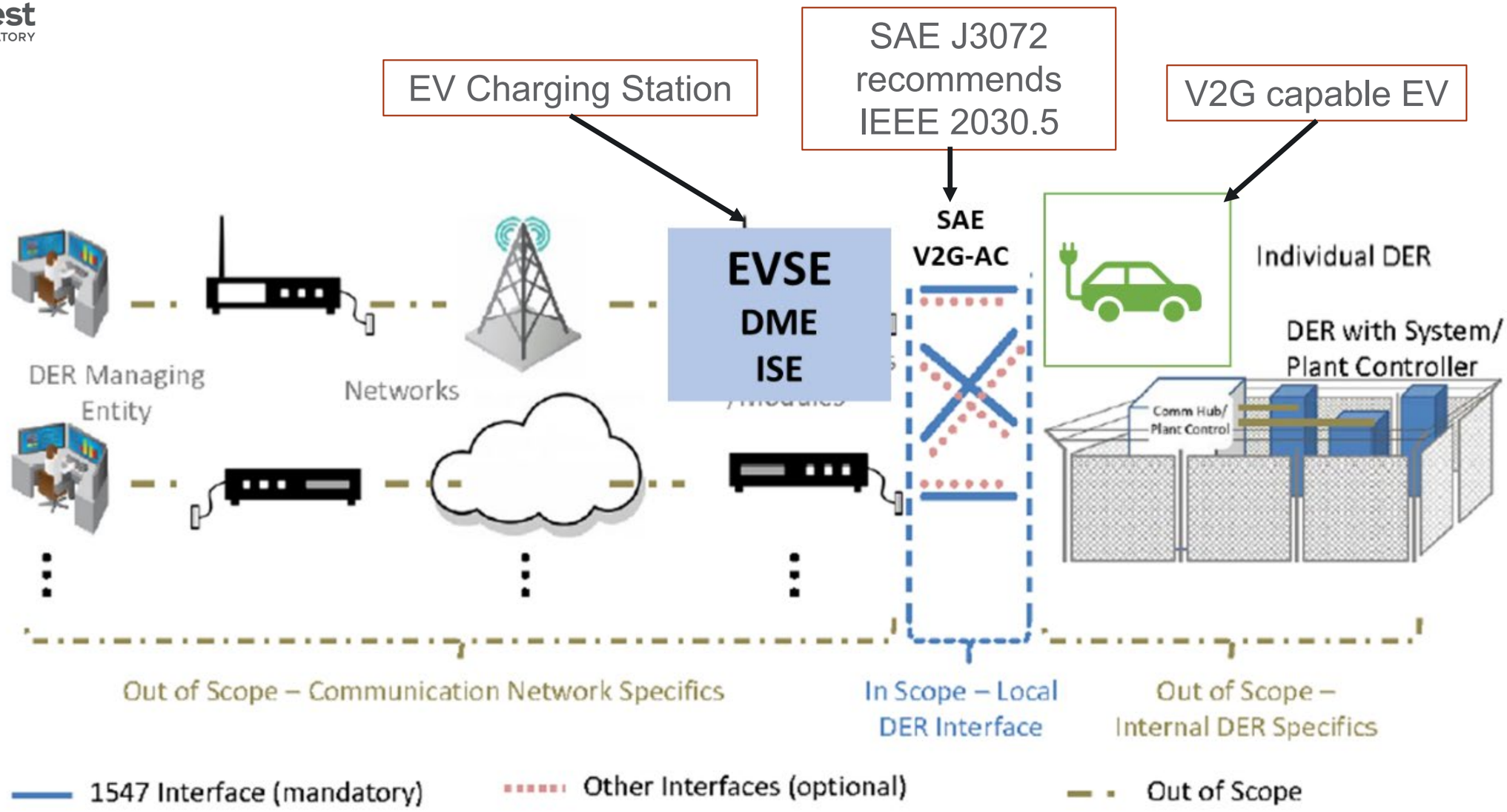
V2G-AC Standards Summary

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

Coordinating across separate industry SDO's, i.e. SAE and IEEE, is a major V2G-advancement challenge

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

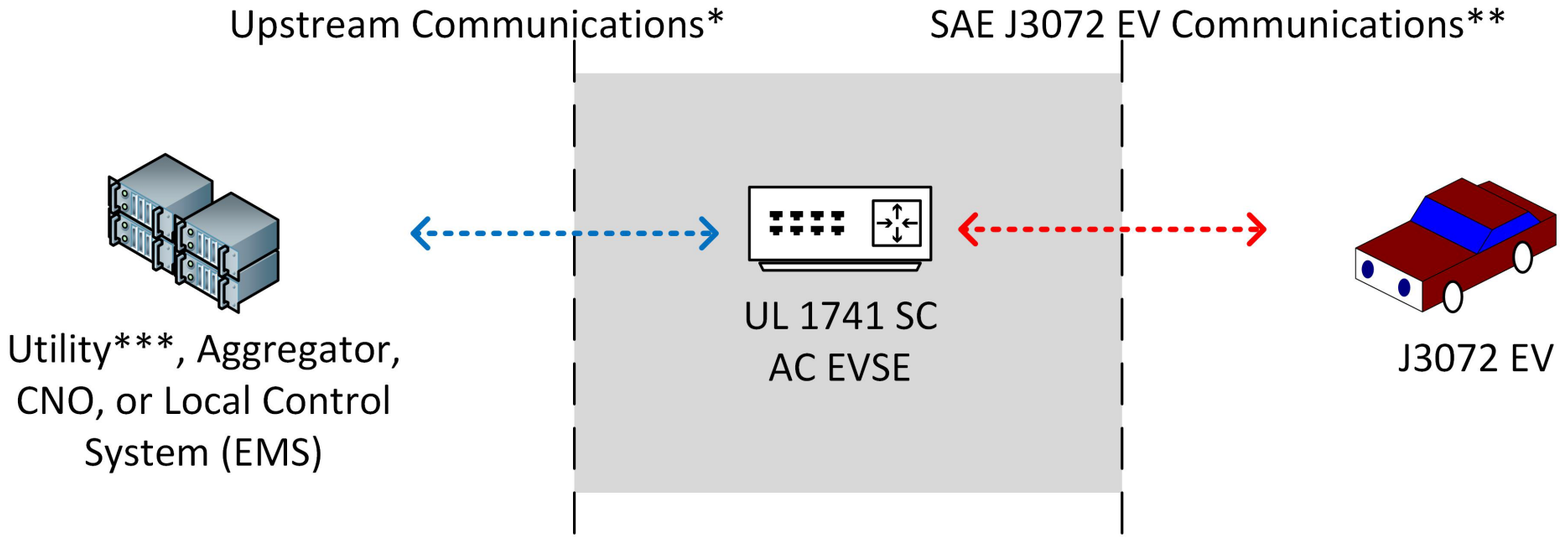
V2G-AC Communication and control illustration



Source: IEEE 1547-2018, 10.7 Communication protocol requirements

UL 1741 SC Pending

System controllers can be tested and certified….



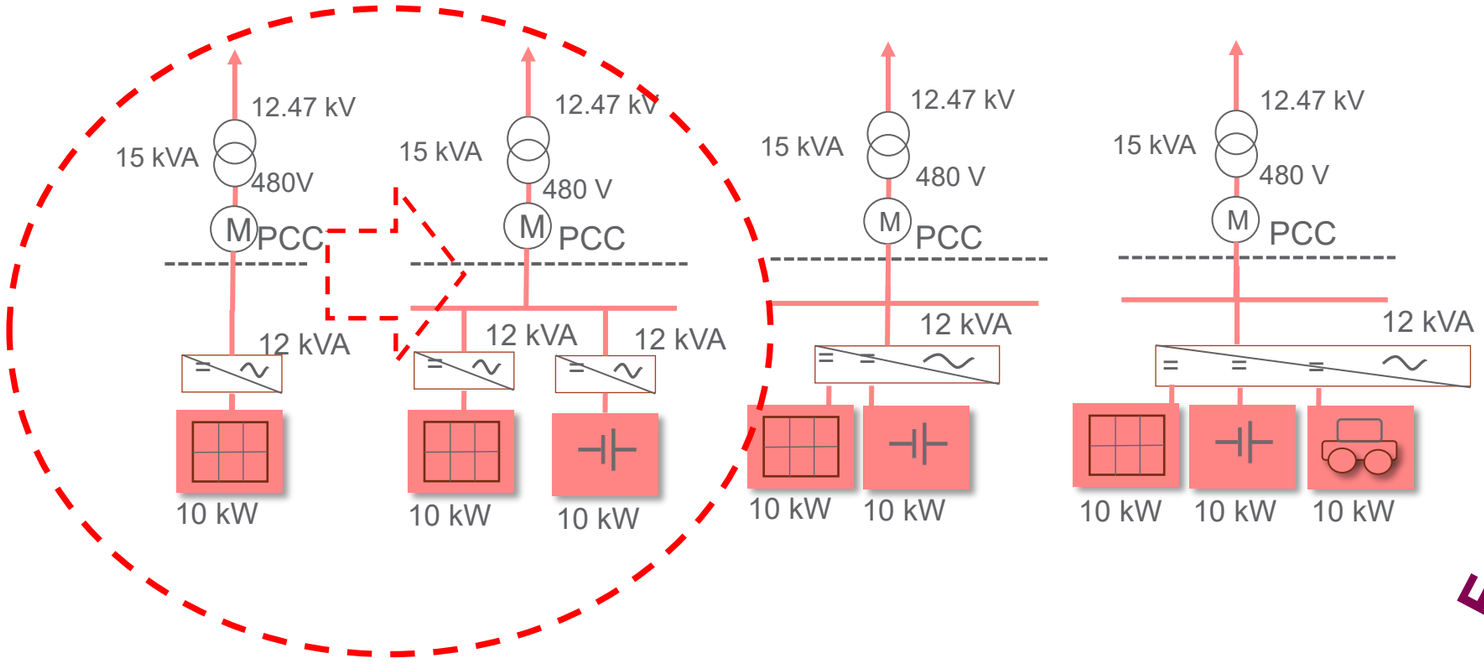
In Scope for UL 1741 SC

*The UL 1741 SC EVSE/ISE shall include a local DER Interface that complies with IEEE 1547-2018 Section 10.7

**Section 4.6 of SAE J3072 requires compliance with IEEE 1547-2018 Section 10.7

***Utility may specify its interface

Flexibility and Hybrid PV+ES, Challenge & Opportunity



Fed Clean Energy Investment Tax Credit implications?
Informing DC coupling and DC microgrid concepts?
Fleet system management?
And much more…

What's the interconnection rating and/or requirement at the PCC?
Who determines? On what basis?

IEEE 1547-2018's recognition of "system" and "controls" based compliance helps.
Versus depending on listed-equipment-based compliance only.
(However, the simple summing of 'nameplate capacity' approach remains a useful 'fast-track' interconnection review screen, for smaller simple ESSs).

DCFC with Energy Storage as buffer,

Prospective platform for implementing MW-scale V2G systems

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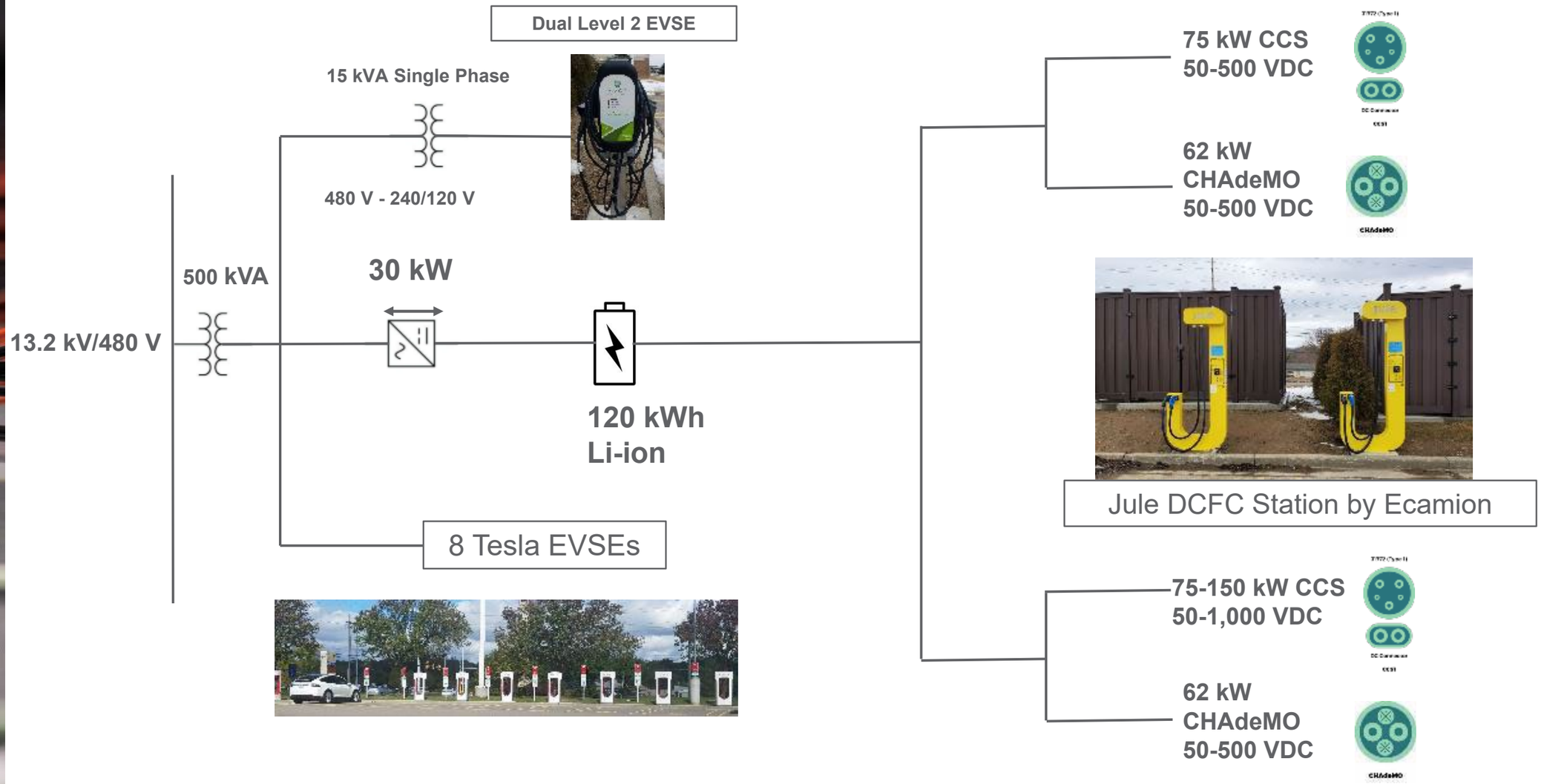

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Thank you

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Supplemental slides

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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: Institute of Electrical and Electronics Engineers
  - 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

GRADIENT OF EV CHARGING COUPLERS WITH POWER LEVELS/VEHICLES

- **Light duty vehicles**, some school buses use **AC SAE J1772 Level 2** (208/240vac-80A) chargers; 30A/7kW nominal; 80A/**19.2kW max.**
- **Medium Duty (commercial) vehicles** can use **SAE J3068** AC; 3-phase; 63A/480v**(53kW)**
  Advanced versions on J3068 can handle 120A/480v**(99kW)**, or **Tesla** at 160A**(120kW dc)**
  Higher voltage SAE J3068-DC6 can push 320A(2x160A) **up to 1000vdc (600vdc today)**
- **Light-Medium Duty vehicles;** can use **J1772-CCS** 1000vdc/350A-500A **(up to 500kW)**
- **Medium/Heavy Duty bus** (port/drayage trucks) can use **SAE J3105 (/1, 2, 3) <600kW**
- **Medium/Heavy Duty trucks** can use SAE J3271**;** under 1000vdc/1000A **(1MW)** today, potential for **1500v/3000A (4.5MW)** in the future

J1772->19.2kW

J3068->53kW-99kW(ac)
120kW-320kW (DC6)

J1772-CCS
350-500kW(DC)

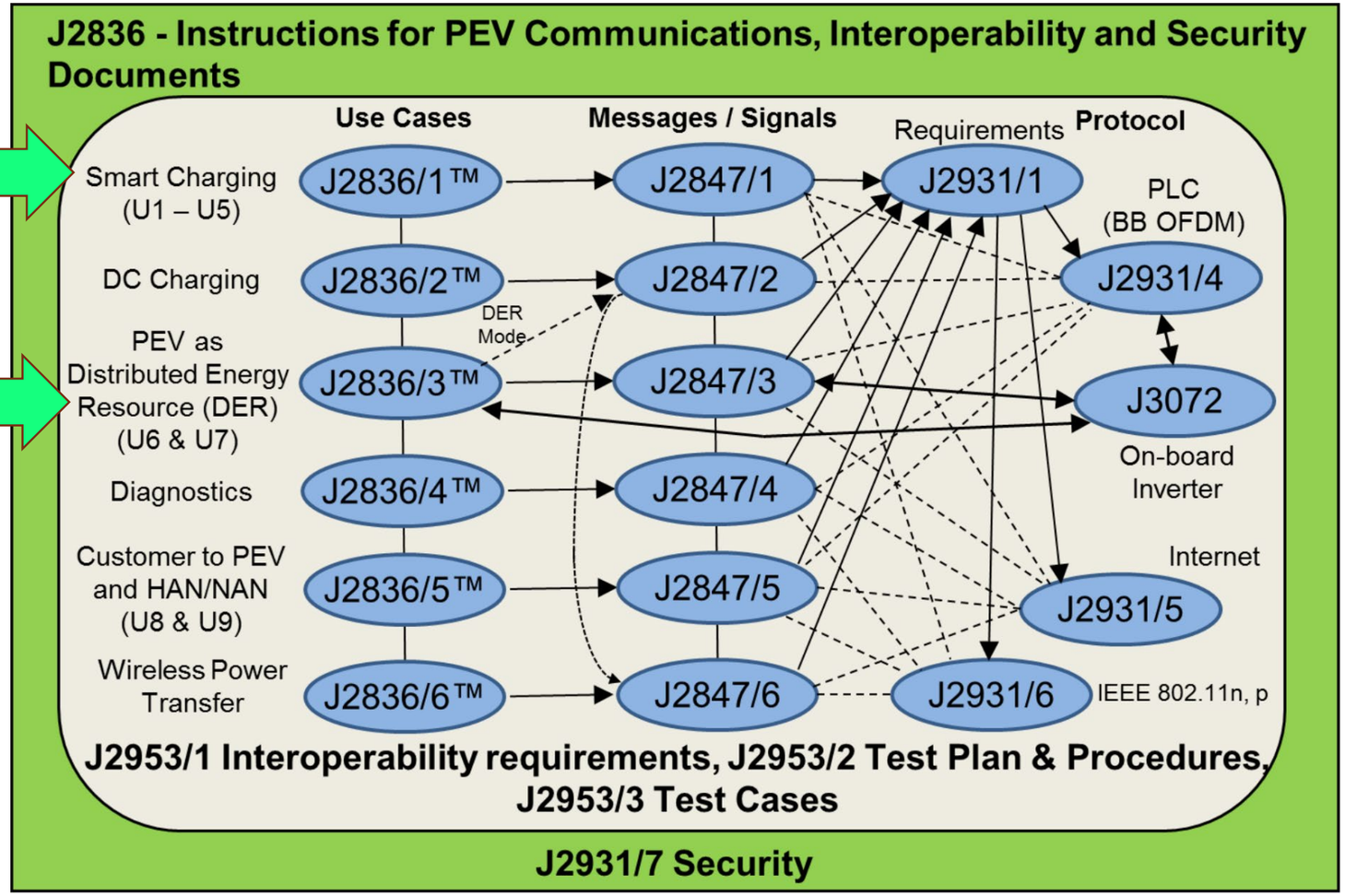
J3105->600kW

J3271-MCS 350kW-1.5MW

SAE Plug-in Electric Vehicle Documents

V1G

V2G



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 - 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

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 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.
- The EVSE needs to be certified by UL 1741 to conform to SAE J3072 requirements and in turn IEEE 1547

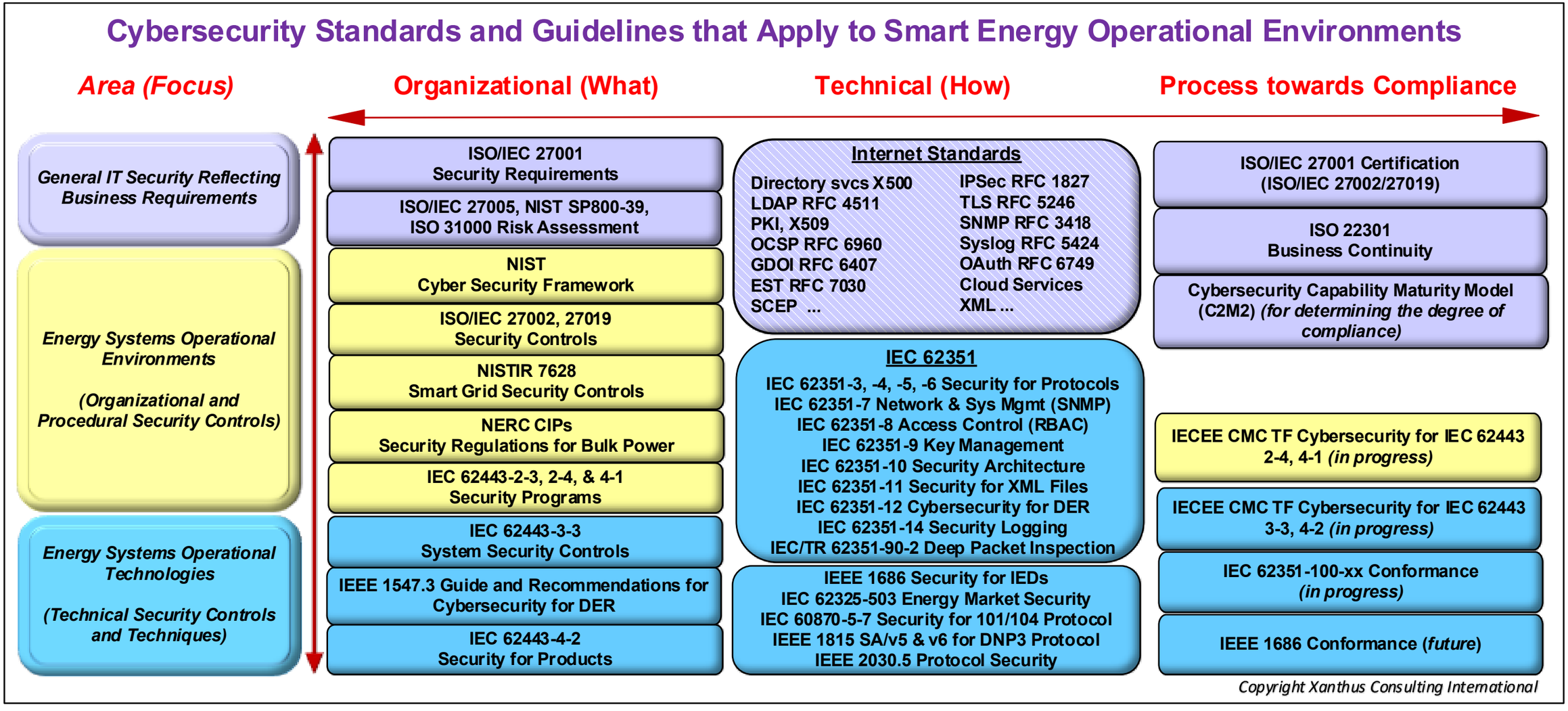
IEEE P1547.10 Recommended Practice for Distributed Energy Resources (DER) Gateway Platforms

- **Scope of proposed standard:** This document defines recommended specifications for a Distributed Energy Resources (DER) gateway platform in grid applications across various domains. A description of DER gateway implementation options (local or distributed platform, for legacy or intelligent DERs) is included. Gateway platform functions and communications, including operational procedures and data collection recommendations are described. Recommended procedures for cybersecurity, centralized manageability, monitoring, grid edge intelligence and control, multiple entities management, error detection and mitigation, events tracking and notification, communication protocol translation, and communication network performance monitoring are also described.

IEEE P2030.13- Guide for Electric Transportation Fast Charging Station Management System Functional Specification

This document provides a guide for the development of a functional specification for electric transportation fast charging station management and control systems, including the energy management and grid interaction functions. The fast charging station may incorporate local energy sources, including renewable energy resources such as solar photovoltaic (PV) generation, and battery energy storage systems. The document develops guiding principles for the implementation and deployment of fast charging station control systems and the basic functional requirements for the control system and presents a set of core functions. These include electric transportation energy storage discovery and evaluation of charging requirements; monitoring and control of charging profiles; charging station energy estimation, energy scheduling and management; charging station grid interaction and interaction and grid power exchange management. Grid code requirements and ancillary services provision are addressed.

Key Cybersecurity Standards and Guidelines



Future Consideration
FERC/NERC/Aggregation – Distribution/BPS

Mobile Energy Storage