The Coming V2G Evolution: The Role of IEEE 1547-2018

IEEE 1547 for the V2G Community: V2G for the IEEE 1547 Community

December 2022

QualityLogic

Today's Presenters

- **James Mater, Director of Strategy, Smart Energy, QualityLogic**

  James is one of the industry-leading experts on smart grid standards, interoperability, and the maturity of eco-systems of products based on these standards. James has given dozens of presentations and authored multiple papers on interoperability in the smart grid. He is a member of both the IEEE 1547.1 and 1547.2 Work Groups.

- **Steve Kang, General Manager, Smart Energy, QualityLogic**

  Steve is a leading technical expert on IEEE 2030.5 and CA Rule 21 based Common Smart Inverter Profile (CSIP) implementation guide. He has been involved with IEEE 2030.5 since 2010 and has taught hundreds of people around the globe on IEEE 2030.5. Steve is leading the QualityLogic IEEE 1547.1 test tool effort.

Agenda

- QualityLogic Introduction
- Why do IEEE 1547 and EVs matter to each other?
- Overview of IEEE 1547
- Overview of V2G in the US
- 1547 and V2G
- Challenges for V2G in the US

QualityLogic's Role in the Smart Energy and EV Industries

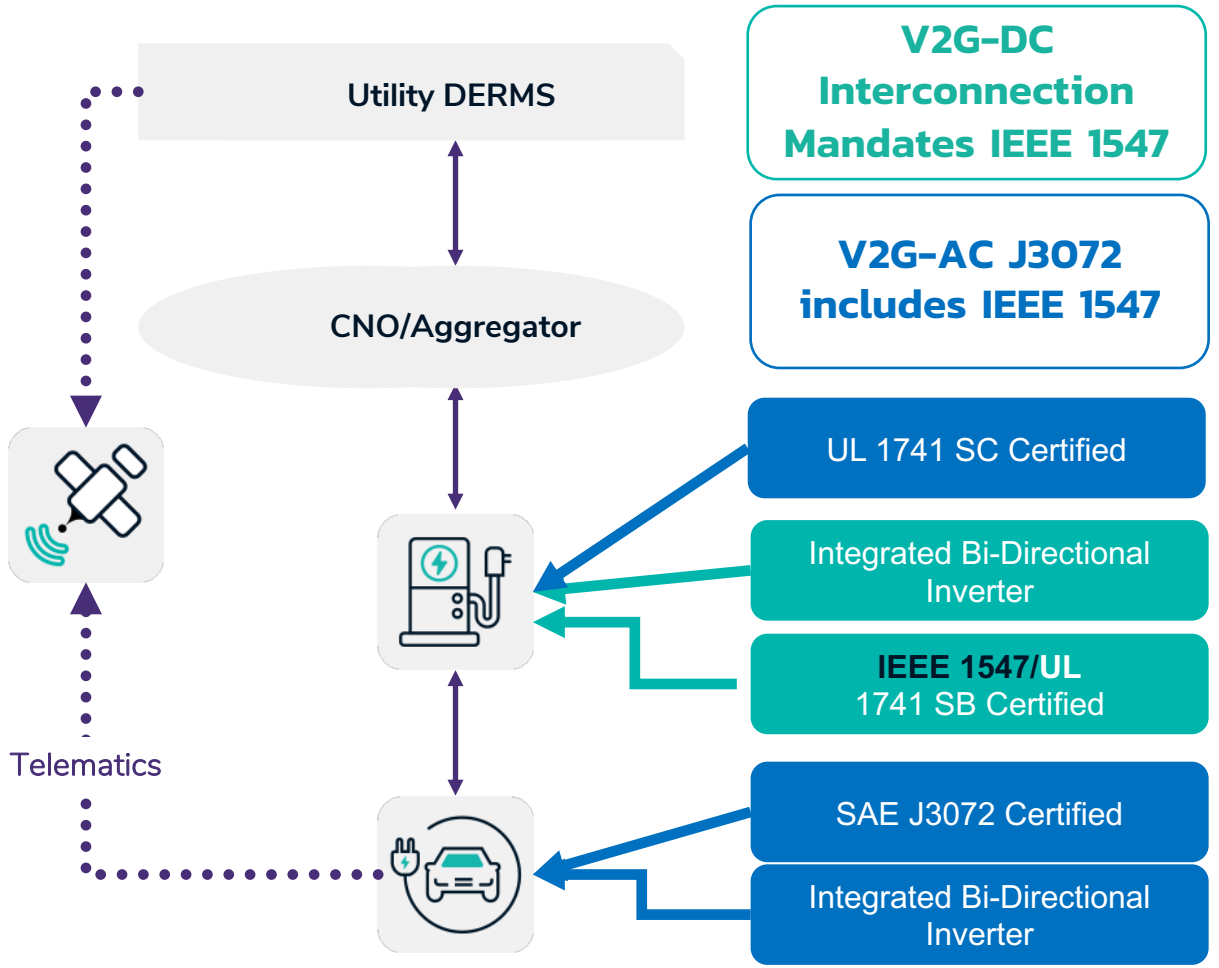
- **QualityLogic is focused on Smart Energy Testing and Training**
  - IEEE 2030.5, OpenADR, IEEE 1547/UL 1741 SB and WiSUN
    - Used by NRTLs, Vendors, Utilities and Research labs to perform Testing/Certification
  - Technical Training and Consulting: 2030.5, 1547/UL1741SB, OpenADR and others
  - First vendor to offer 1547.1 Conformance Test Tools
- **QualityLogic is a Contributor to IEEE 2030.5/CSIP, IEEE 1547, UL 1741 and other standards**
  - Member of IEEE 2030.5, 1547-2018 and 1547.1-202 working groups
  - Member of UL 1741 STP (SB revisions)
  - SunSpec Modbus, SunSpec J3072 IEEE 2030.5 Profile, UL 1741 SC
- **Active in Standards and Certification Program Development**
  - IEEE 2030.5, CSIP, 1547/1547.1, OpenADR, MESA-DER, UL 1741 SC, SAE J3072

QualityLogic Product Portfolio

- **We're best known for our IEEE 2030.5 CSIP and IEEE 1547.1 Test Tools**
- **BUT also**
  - The official OpenADR certification test harness
  - Official Wi-SUN FAN Test Bed Controller
- **And Test Tools for EV Vehicle Grid Integration Efforts**
  - V1G – Managed Charging
  - V2G – EVs as DER
  - End-End Test Tools

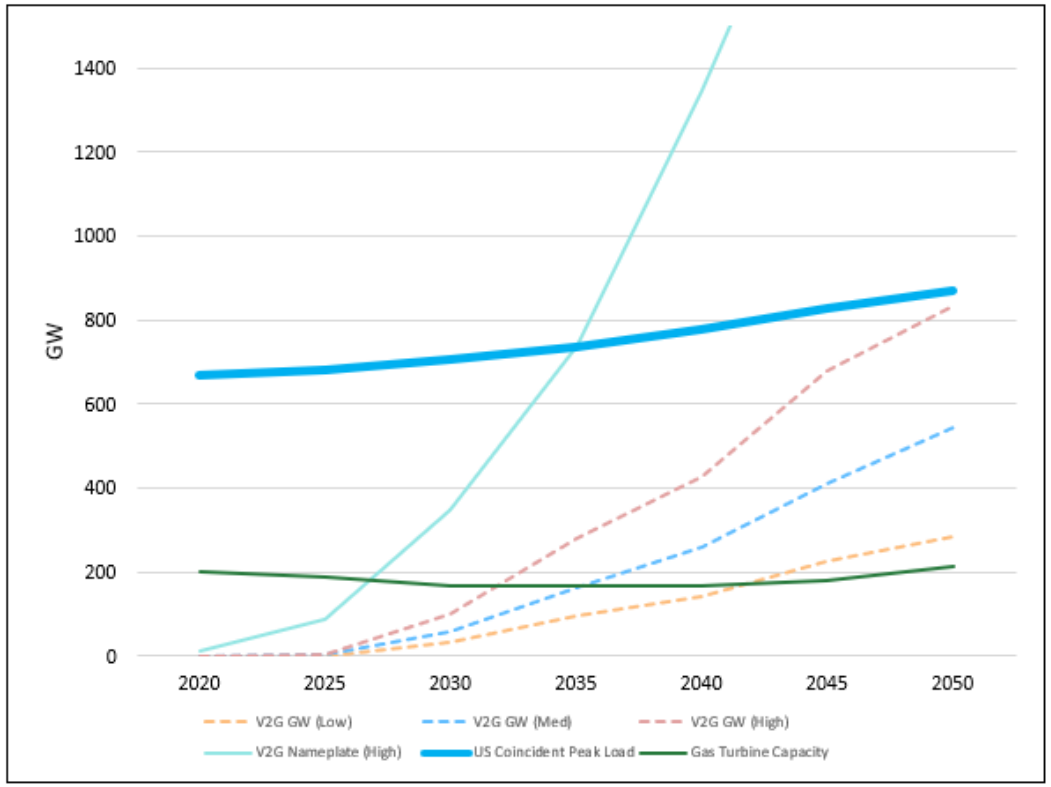
EV Community: Why IEEE 1547 Matters

- **IEEE 1547 is a REQUIREMENT for V2G**
  - Interconnection standard for all DERs in the US
  - ANY EXPORT to the Grid requires IEEE 1547 compliance.
  - IEEE 1547-2018 is the latest version and is required starting in 2022
  - SAE J3072 requires IEEE 1547 conformance in onboard grid support inverters
- **EVs as DERs are treated like other DERs: subject to Utility Interconnection requirements**
  - UL 1741 SB is the new certification requirement
  - V2G-DC can be interconnected with UL 1741 certification TODAY!



IEEE 1547 Community: Why V2G Matters

- **Huge potential to upend how we make, store and use electricity:**
  - EPRI estimates just for CA, V2G is $1 billion/year in potential value
  - Total EV battery capacity will exceed total US electricity demand in 2035
- **EVs as DERs are treated like other DERs: subject to Utility Interconnection requirements**
  - INCLUDES UL 1741 SB
  - SAE J3072 requires IEEE 1547 conformance in onboard grid support inverters
- **However, EVs as DER more complex**
  - Scheduling, charging level, location, transportation purpose



Presented at an October 2022 EPRI Webex. Based on EIA projections of EV populations

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Introduction to IEEE 1547

Overview, History, Scope, Interop Requirements

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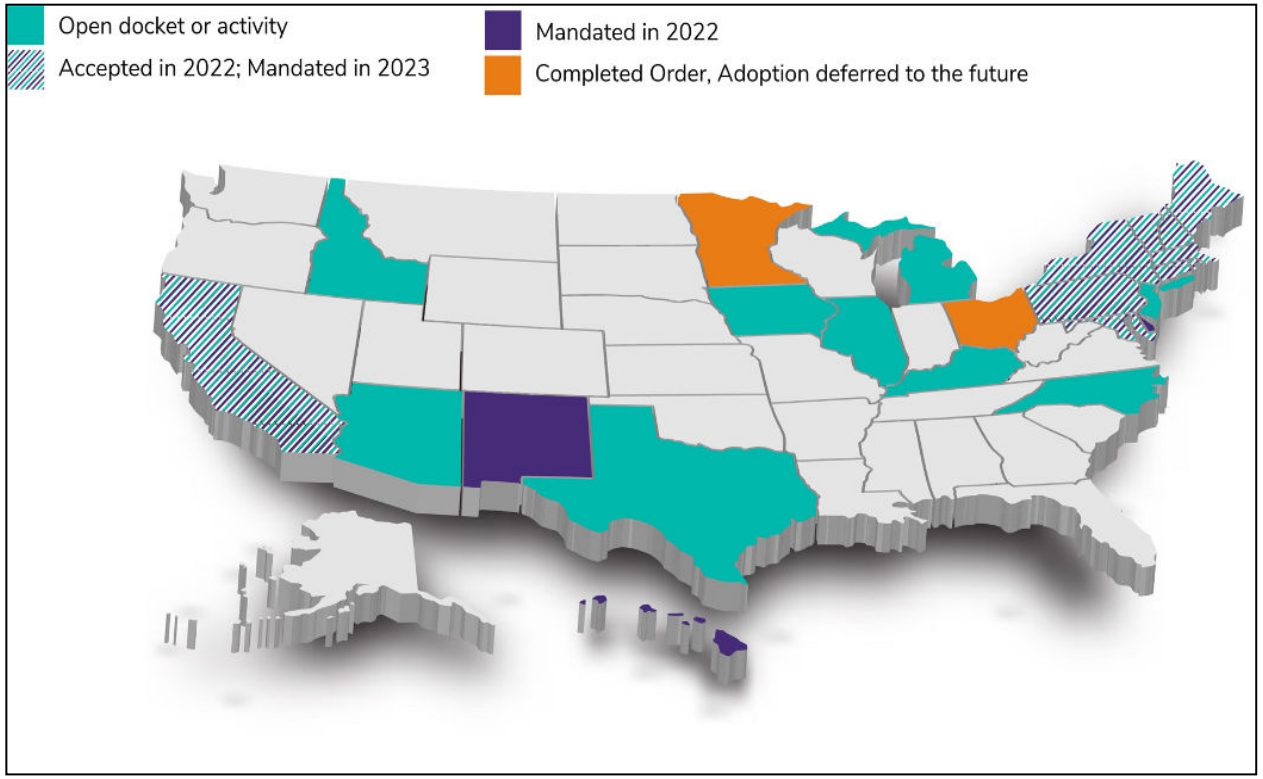
IEEE 1547 Background

- **IEEE 1547 and 1547.1 were initially approved in 2003 after 3 years of intense debate and development**
  - Standardized behavior of interconnected DER in abnormal conditions. Primary concerns were grid stability and safety.
- **For the United States, the Energy Policy Act of 2005 established IEEE 1547 as the interconnection standard for distributed generation resources**
  - *Interconnection services shall be offered based upon …IEEE Standard 1547 for Interconnecting Distributed Resources with Electric Power Systems, as they may be amended from time to time.*
- **Revised in 2014 to address changing grid requirements for DER**
  - Addressed voltage regulation, voltage response and frequency response to Area EPS abnormal conditions.
  - IEEE 1547.1 was also revised in 2014 and 2015.
- **IEEE 1547 was revised again in 2018 and 1547.1 approved in 2020**
  - As DERs were seen as potential grid resources, the need for additional functionality and interoperability drove the most recent 1547 update.
  - The need for communications was recognized in the standard for the first time.

Adoption of IEEE 1547 in the US

- **On February 12, 2020, NARUC approved a resolution recommending state commissions adopt IEEE 1547-2018.**
- **UL 1741 SB Revision adopted September 28, 2021 – certification testing starts.**
- **NRTLs are in full certification testing mode..**
- **IREC survey Aug-Sep 2021**
  - Covered 60% of inverter families on CEC list
  - 3 leading NRTLs
  - Estimates of 8-12 weeks testing per inverter family
  - >1 year to certify ~80% of inverter families tested
  - Plus time for certification processing, listing by CEC and distribution of certified inverters
- **Early Adoption Schedules**
  - Early Adopter Phase (SB accepted) starting September 2022: Full compliance required March 2023
  - HI stopped accepting SA Jan 1, 2022. SB mandated starting October 1, 2022



Based on information from the "Forum on Inverter Grid Integration Issues (FIGII)", August 26, 2022, Minutes"., EPRI Map September 2021 (IEEE-1547-2018_States-and-ISOs-RTOs-Adoption_IEEE-Format_2022-05.pdf), and IEEE (IEEE Std 1547-2018 (Revision of IEEE Std 1547-2003) - IEEE Standards Coordinating Committee 21 (SCC21), last updated May 2022..

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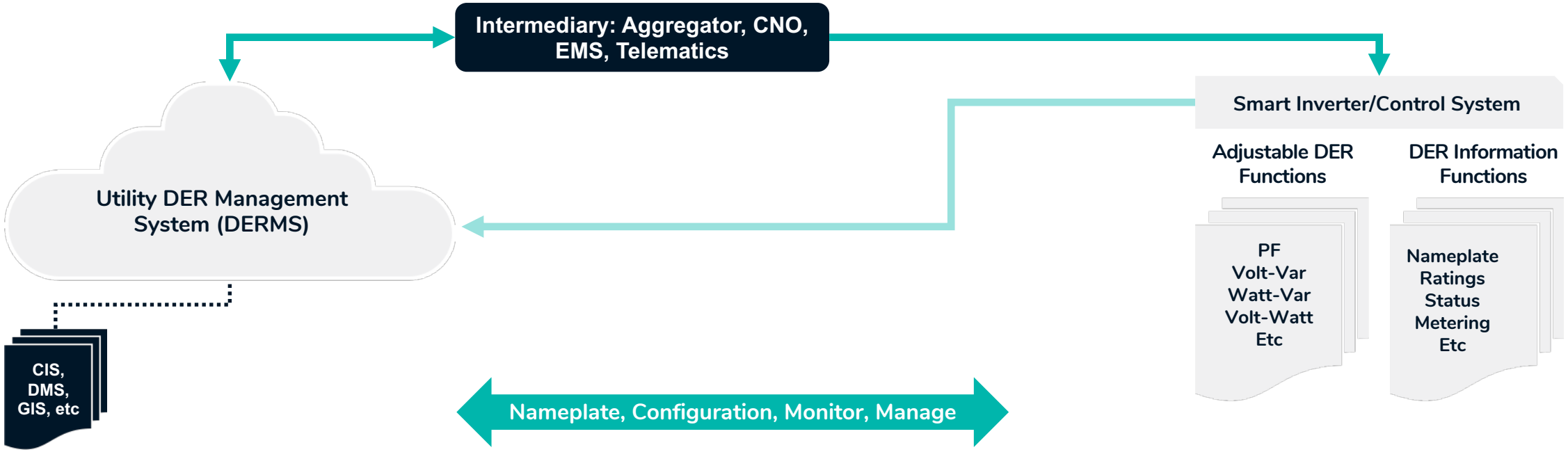
IEEE 1547-2018 Includes Interoperability

- **IEEE 1547 has evolved to be both a functional and safety standard – i.e., in order to be a "safe" grid resource, the functionality has had to become much more sophisticated and standardized**
- **A critical aspect of "safety" is to be able to configure, monitor and manage DERs in a standardized way to insure both effective protection and control of the grid by distribution system operators.**

Need for Interoperability

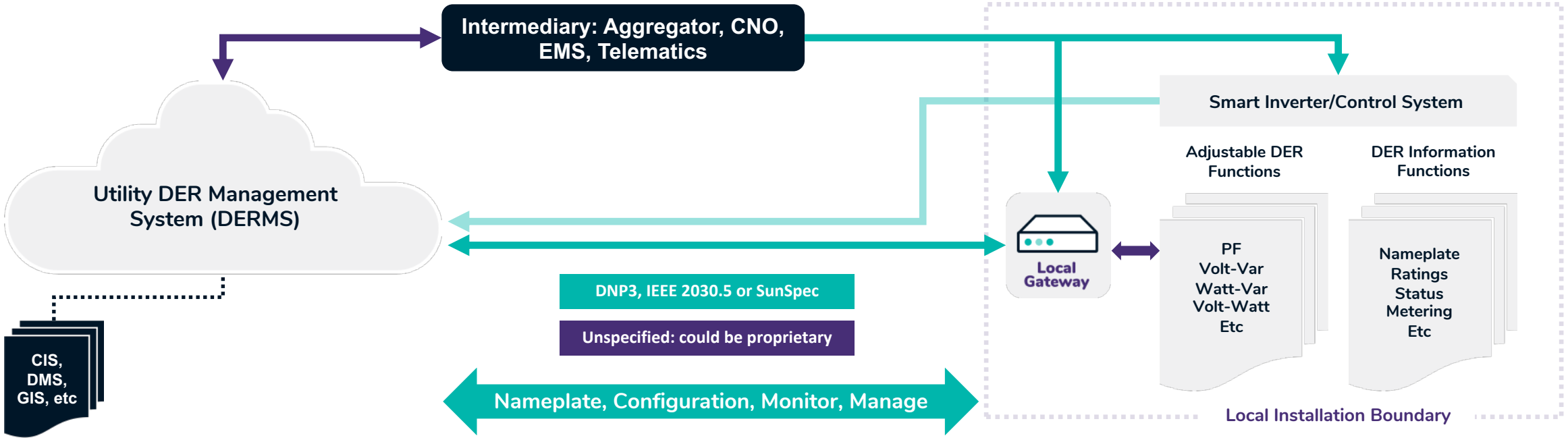
- **With required programmable functions, communications is also required**



IEEE 1547 Specified Interop Protocols – Local Only

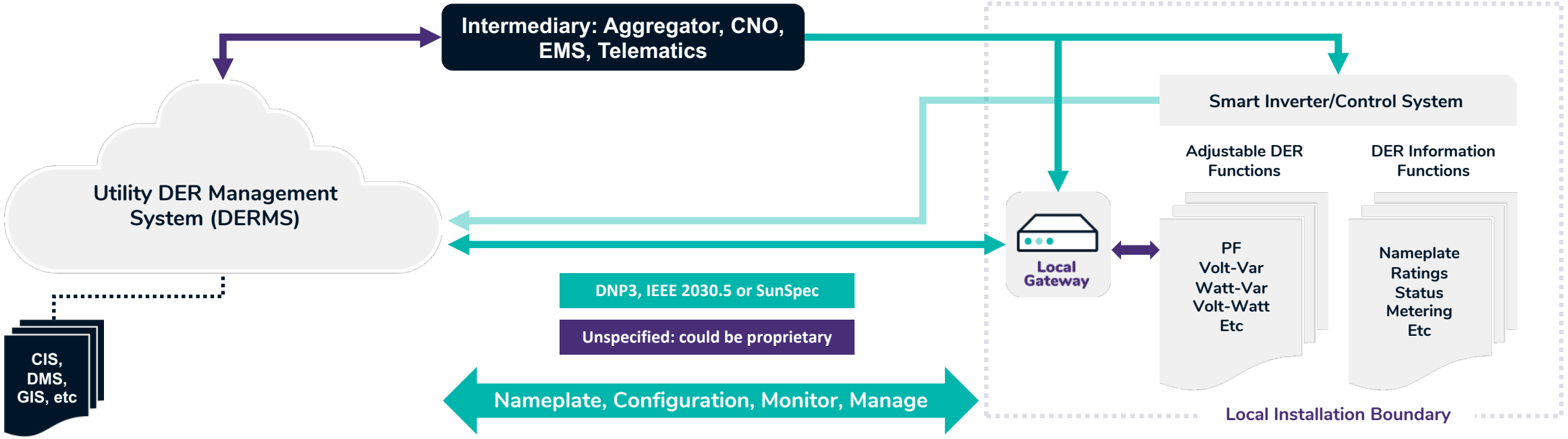
- **1547 Interop requires compliance using one of 3 named protocols.**
  - IEEE 1815 DNP3
  - IEEE 2030.5
  - SunSpec Modbus

- **The interface (Inverter Control System or local Gateway) must be local and must support one of the protocols. This is to insure standard communications in the event of a network failure.**



Which Protocol to Use?

- **The 3 named protocols have differing strengths and applications.**
  - IEEE 1815 DNP3 is best suited for larger scale DERs operated as part of real-time SCADA
  - IEEE 2030.5 is best suited for internet based, behind-the-meter DER where greater security and group management are required
  - SunSpec Modbus is most useful between a local gateway and an inverter control system that supports SunSpec



UL 1741 SB Type and Interop Tests

TYPE TEST	IEEE 1547.1 Reference	INTEROP TESTS
Overvoltage Trip	5.4.2	✓
Undervoltage Trip	5.4.3	✓
Low-voltage Ride-Through	5.4.4	
Unbalanced Voltage	5.4.5	
High-voltage Ride-Through	5.4.7	
Over frequency Trip	5.5.1	✓
Under frequency Trip	5.5.2	✓
Low-frequency Ride-Through	5.5.3	
High-frequency Ride-Through	5.5.4	
Rate of Change of Frequency	5.5.5	
Voltage Phase-angle Change Ride-Through	5.5.6	

TYPE TEST	IEEE 1547.1 Reference	INTEROP TESTS
Enter Service	5.6.2	✓
Unintentional Islanding	5.10	
Powerline permissive signal	5.10.3	
Minimum import active-power	5.10.5	
Limit Active Power	5.13	✓
Constant Power Factor	5.14.3	✓
Voltage-reactive (volt-var)	5.14.4	✓
Voltage-active (volt-watt)	5.14.9	✓
Active power (watt-var)	5.14.7	✓
Constant reactive power	5.14.8	✓
Frequency-droop	5.15.2	✓

IEEE 1547.1 Type Tests

- **IEEE 1547.1 Type Tests (Section 5) define all the grid support functional test procedures plus others, such as temperature testing of the DER unit.**
- **Type tests define the detailed test procedures for each grid support function**
- **Test tables (characteristics) define the various values to test for each grid support function**
  - Ex. Different VoltVar DER values
- **Type tests iterate through different test variations**
  - Ex. VoltVar test iterates through different Vnominal %, EUT output % and multiple characteristics tables

Table 26 —Characteristic 2:
Voltage-reactive power settings for normal operating performance Category A and Category B DER

Voltage-reactive power parameters	Values for DER	
	Category A	Category B
V_{Ref}	1.05 V_N	1.05 V_N
V_2	1.04 V_N	1.04 V_N
Q_2	50% of nameplate reactive power capability, injection	50% of nameplate reactive power capability, injection
V_3	1.07 V_N	1.07 V_N
Q_3	50% of nameplate reactive power capability, injection	50% of nameplate reactive power capability, injection
V_1	0.88 V_N	0.88 V_N
Q_1[a]	100% of nameplate reactive power capability, injection	100% of nameplate reactive power capability, injection
V_4	1.1 V_N	1.1 V_N
Q_4	100% of nameplate reactive power capability, absorption	100% of nameplate reactive power capability, absorption
Open loop response time, T_r	1 s	1 s

1547.1 Interoperability Test Section 6

- **Four different test categories that includes 47 test areas**
- **Nameplate data – verify nameplate data can be read from the DER**
- **Configuration Information – verify that DER configurations can be changed thru updated nameplate values**
- **Monitoring Information – verify that DER reports set of metered data**
- **Management Information – verify that DER can act upon set of grid functions as requested thru protocol**
  - Leverages 1547.1 Type tests with less iterations

Table 44—Management Information Test List

Test	Management Function	Adjustable Settings (References to IEEE Std 1547-2018)	Criteria (References to functional test criteria within this document)	Notes
1	Constant Power Factor Mode	10.6.2, Table 30	5.14.3.3	
2	Voltage-reactive power mode	10.6.3, Table 31	5.14.4.3 and 5.14.5.3	
3	Active power-reactive power mode	10.6.4, Table 32	5.14.7.3	
4	Constant reactive power mode	10.6.5, Table 33	5.14.8.3	
5	Voltage-active power mode	10.6.6, Table 34	5.14.9.3	
6	Voltage trip test	10.6.7, Table 35	5.4.2.4 (over voltage trip settings) and 5.4.3.4 (undervoltage trip settings)	
8	Frequency trip test	10.6.8, Table 37	5.5.1.4 (over frequency trip) and 5.5.2.4 (under frequency trip)	
9	Frequency droop (frequency/power or frequency-watt) test	10.6.9, Table 38	5.15.2.3 (above nominal frequency) and 5.15.3.3 (below nominal frequency)	
10	Enter service and Cease to energize and trip tests	10.6.10, Table 39, 10.6.11	5.6.4	NOTE—This management function relates to permit service.
11	Limit maximum active power test	10.6.12, Table 40	5.13	

IEEE 1547/UL 1741 SB Conformance Background

- **IEEE 1547.1-2020 defines the test procedures for verifying inverter's functionality**
  - Section 5 – Type Tests define the grid support and other tests for DERs
  - Section 6 - Interoperability tests that use any of the 3 DER protocols (IEEE 2030.5, SunSpec modbus 700 and DNP3)
  - Approved by IEEE in March 2020
- **UL 1741 SB updated to reflect latest 1547.1 test requirements**
  - First publication on September 2020 that define the certification tests that DERs get certified to
  - 1741 SB revised to reflect 1547 spec issues/gaps – updated in Sept 2021 as UL 1741 Edition 3
- **1547.1 Interoperability test section requires use of the protocols to trigger/monitor the inverter**
  - Includes nameplate, configuration, monitoring and management tests
  - Leverages "Type" functional tests in 1547.1 Section 5
- **NRTL's estimate that total UL 1741 SB tests may take 8-12 weeks to conduct**

Introduction to V2G

Managed charging, DC and AC Charging

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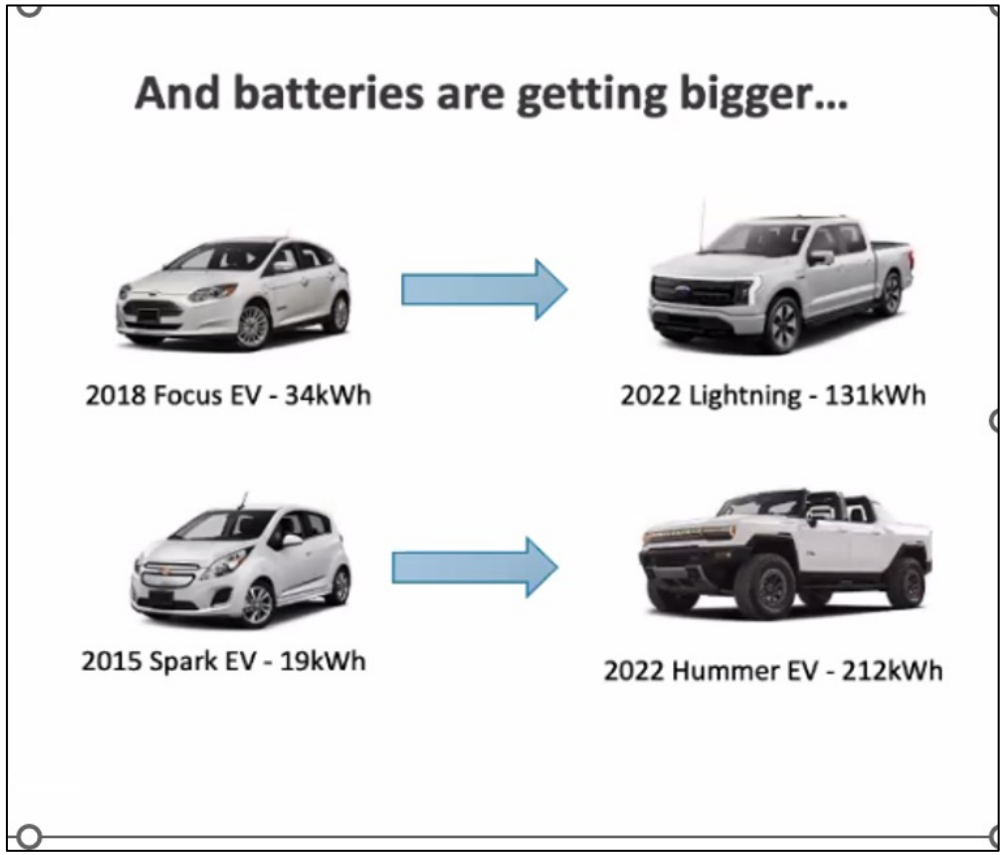
Bi-Directional Charging: Catching on

- **Publicly (or reported) announced plans for bi-directional capabilities on EVs**



Source: Flex Power Control presentation during Veloz Webinar 8/23/2022 and SGO DR and DER Conference, October 13, 2022

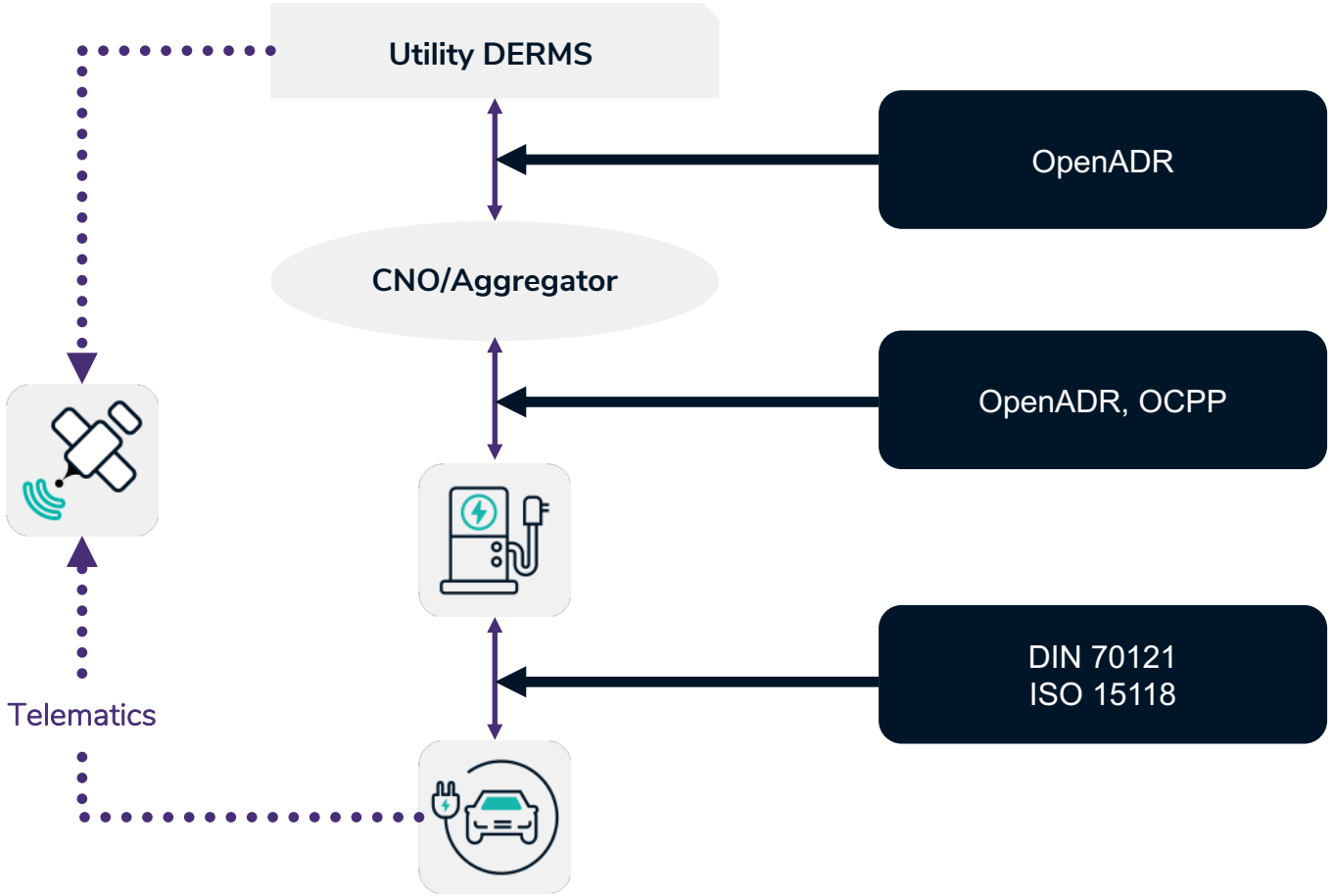
What is V2G?

- **Vehicle to Grid has different definitions**
  - Simple V2G – vehicle puts power back to the grid – export power
  - US and others – Simple V2G plus grid support functions at the inverter
- **Grid support functions required for PV/smart inverters here in the US and elsewhere**
  - Voltage/freq must trip, voltage/freq ride through, VoltVar, PowerFactor, VoltWatt, WattVar, FreqDroop, Enter service, Limit Watts, Limit VARs
  - These functions help stabilize the electrical grid if utilities control inverter systems
- **ISO 15118 supports simple V2G but not grid support functions – not yet**
- **SAE J3072 fills that gap where all the 1547 grid support functions are supported**
  - IEEE 1547 is mandated in the US and smart inverters are certified to 1547 (UL 1741 SB)
  - Co-existence of 15118 and V2G Infrastructure in the US

US Market V1G: Standards

Use Case: V1G Charge Management

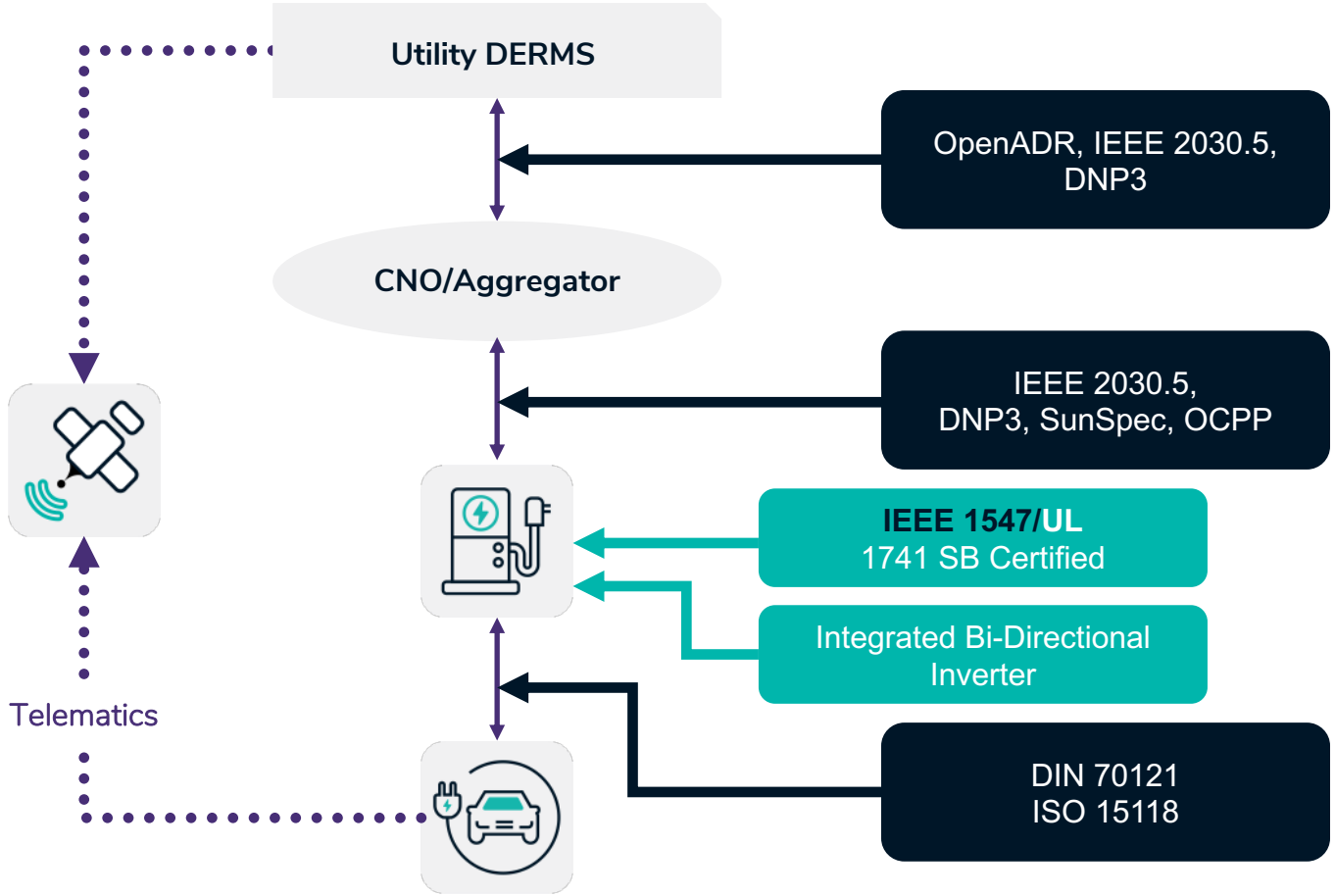
- One directional EVSE power flow
- Grid Operator interactions – when to charge, charge rate, etc
- Mitigation of demand spikes – duck curve
- But no energy/power support for the grid



US Market V2G-DC: Standards

Use Case: V2G=DC Charge + Energy + Power Management

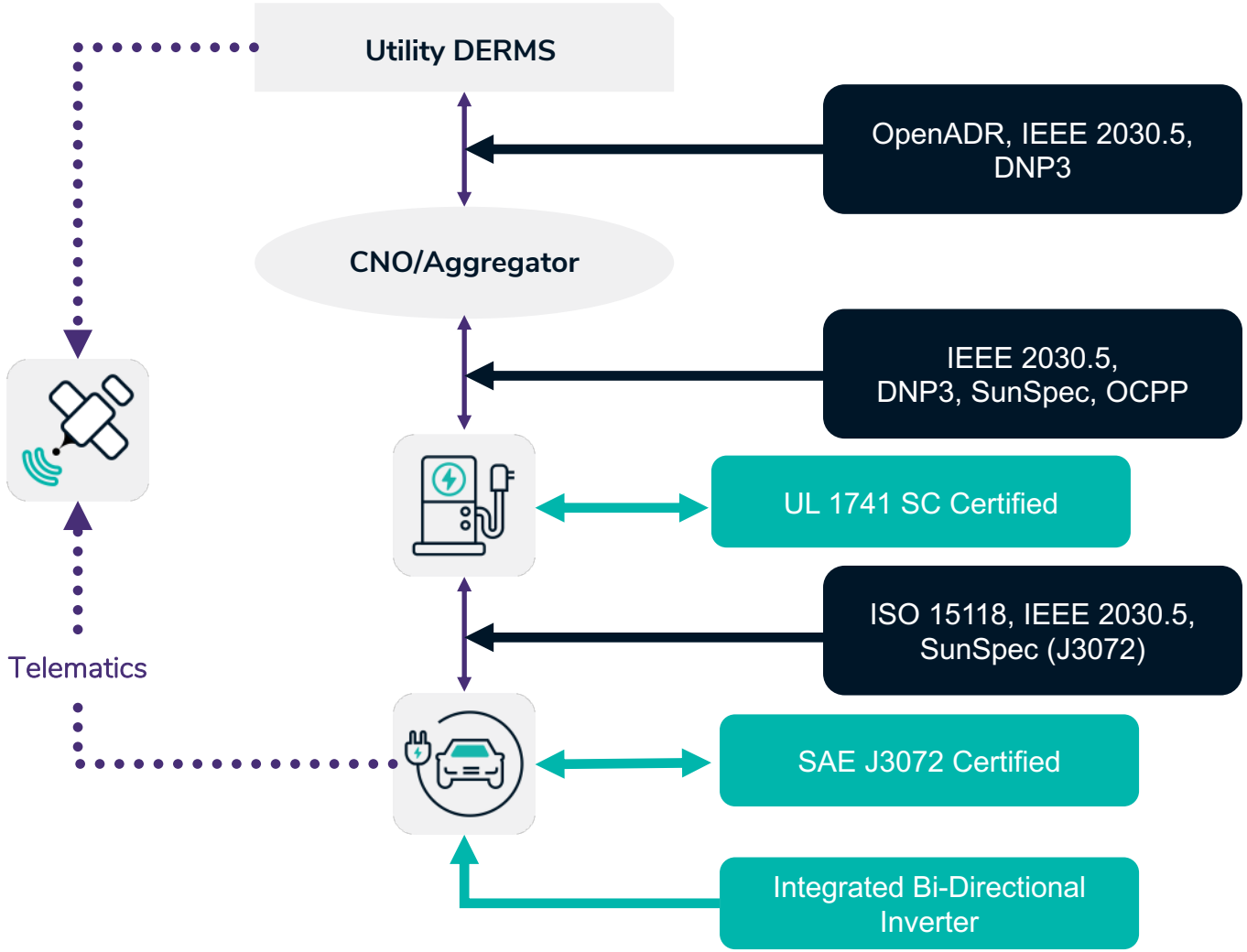
- Bi-directional EVSE Inverter
- Interconnected at the UL 1741 SB EVSE
- Grid interactions – charge/export time, power settings, IEEE 1547 Curves and Controls



US Market V2G-AC: Standards

Use Case: V2G-AC Charge + Energy + Power Management

- Bi-directional J3072 EV Inverter
- Interconnection at a UL 1741 SC Certified EVSE
- Grid interactions – charge/export time, power settings, IEEE 1547 and J3072 Curves and Controls



Overview of SAE J3072 (V2G-AC) + Related Activities

- **STANDARD: SAE J3072 and related standards are open standard from the Society of Automotive Engineers (SAE)**
  - J3072 was first published in 2015 and revised in 2021. It specifies on-board inverter requirements (V2G-AC) and communications between an EVSE and EV. Defines conformance to IEEE 1547-2018 or IEEE 1547-2003
  - Specifies the use of two of the three IEEE 1547-2018 protocols (IEEE 2030.5, DNP3 and SunSpec Modbus) for EV-EVSE communications.
  - Parallel UL 1741 SC Standard being developed to support J3072 EVSE and communications requirements (three 1547 protocols for external communications requirements proposed)
- **VGI FUNCTIONS: J3072 and related standards designed specifically to address V2G-AC Applications,**
  - Exchanging EVSE and EV limits and capabilities
  - Providing the EV with IEEE 1547 Jurisdictional Settings (Curves and Ride-Throughs)
  - EVSE provides permission to discharge based on several criteria
  - EV providing EVSE with status, measurements, and operational information
- **J3072 specific certifications and interconnections are 1-2 years off.**

The EV Infrastructure Challenge

A US V2G Infrastructure in an OCPP/15118 World

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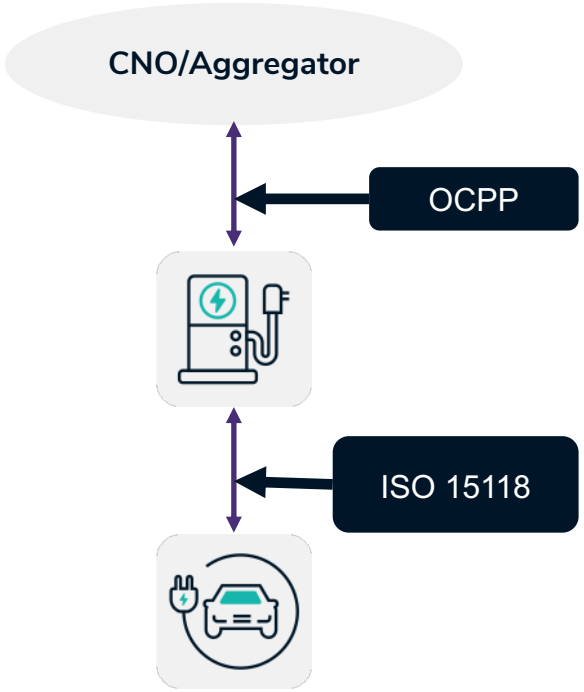
ISO 15118/OCPP and J3072

- **Co-existence of ISO 15118/OCPP and J3072 IEEE 2030.5/SunSpec communication required to support US V2G requirements**
- **Two major issues: control of the EV/EVSE behaviors and communicating IEEE 1547 grid support functions**

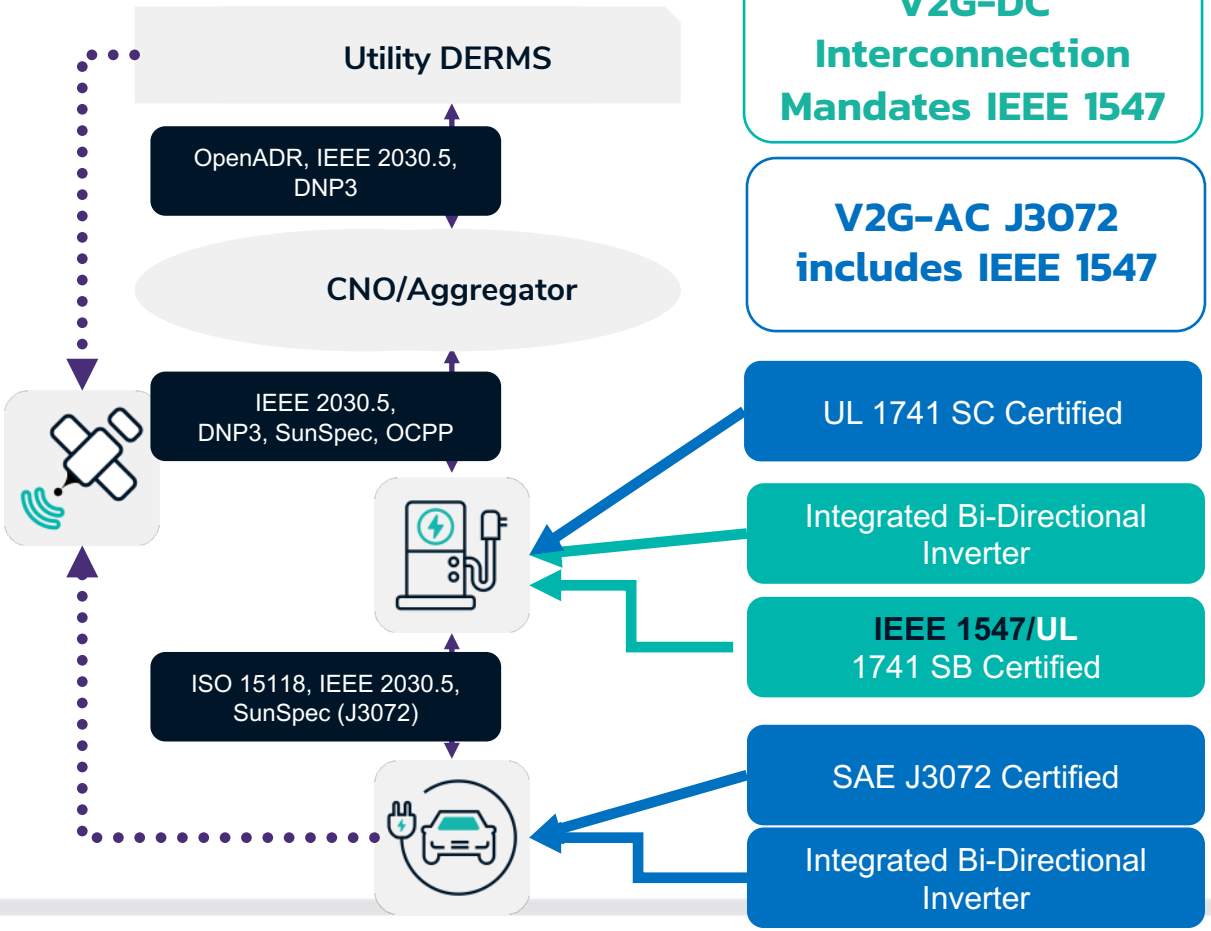
OCPP/ISO 15118 Charging Infrastructure and V2G

How does a US V2G infrastructure co-exist with an OCPP/15118 Charging Infrastructure?

CHARGING INFRASTRUCTURE



V2G INFRASTRUCTURE



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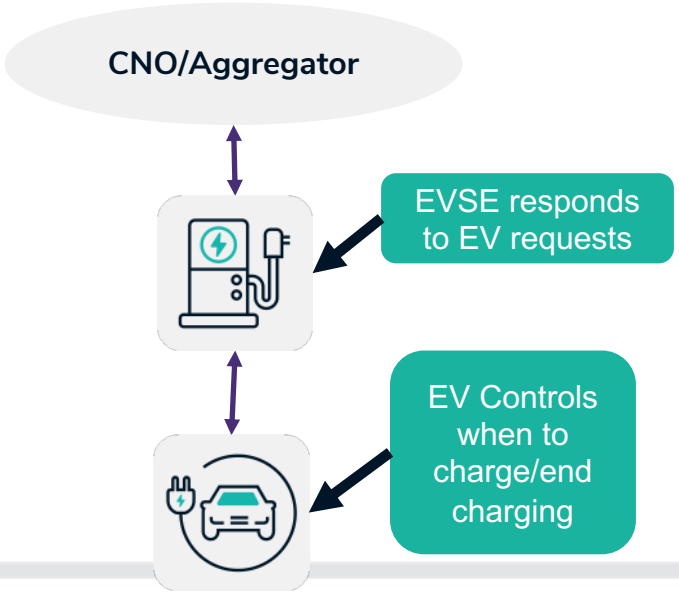
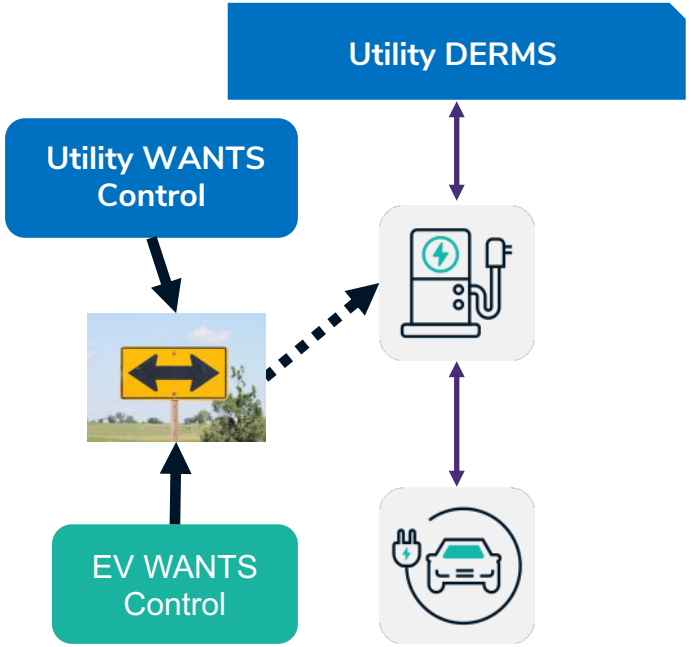
Multiple Challenges

- **Regulatory, Business and Technical (scope of the V2G Forum)**
- **Two key V2G technical issues**
  - Control of the EV/EVSE actions
  - Grid Support functions

CHARGING CONTROL MODEL



V2G CONTROL MODEL ON CHARGING MODEL



Multiple Challenges

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  - Control of the EV/EVSE actions
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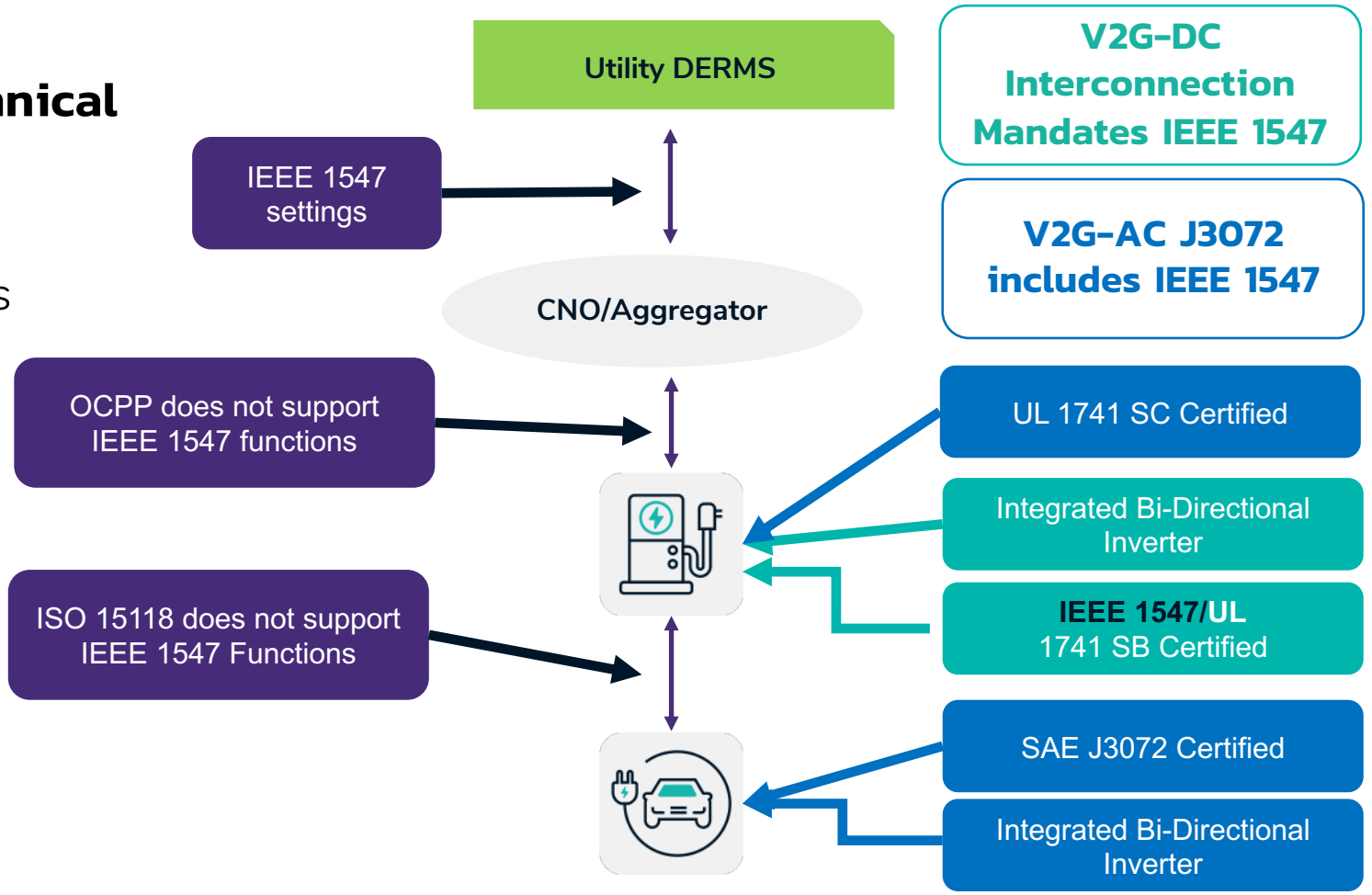

To learn more, join us at

- **V2G Forum March Feb 28–Mar 1**
- **DRAFT Agenda**
  - Stakeholder Perspectives on Value Proposition for V2G
  - Follow the $: Delving into the Value of the Top Business Models for V2G
  - What is V2G About?
  - What Are the Obstacles to V2G Success, and How Do We Address Them?
  - Facilitated Discussion Breakout Sessions, Round 1: Identifying and Ranking Challenges
  - Facilitated Discussion Breakout Sessions, Round 2: Identifying Solutions Standards Technology Working Group Meetings

Summary

IEEE 1547 critical for US V2G

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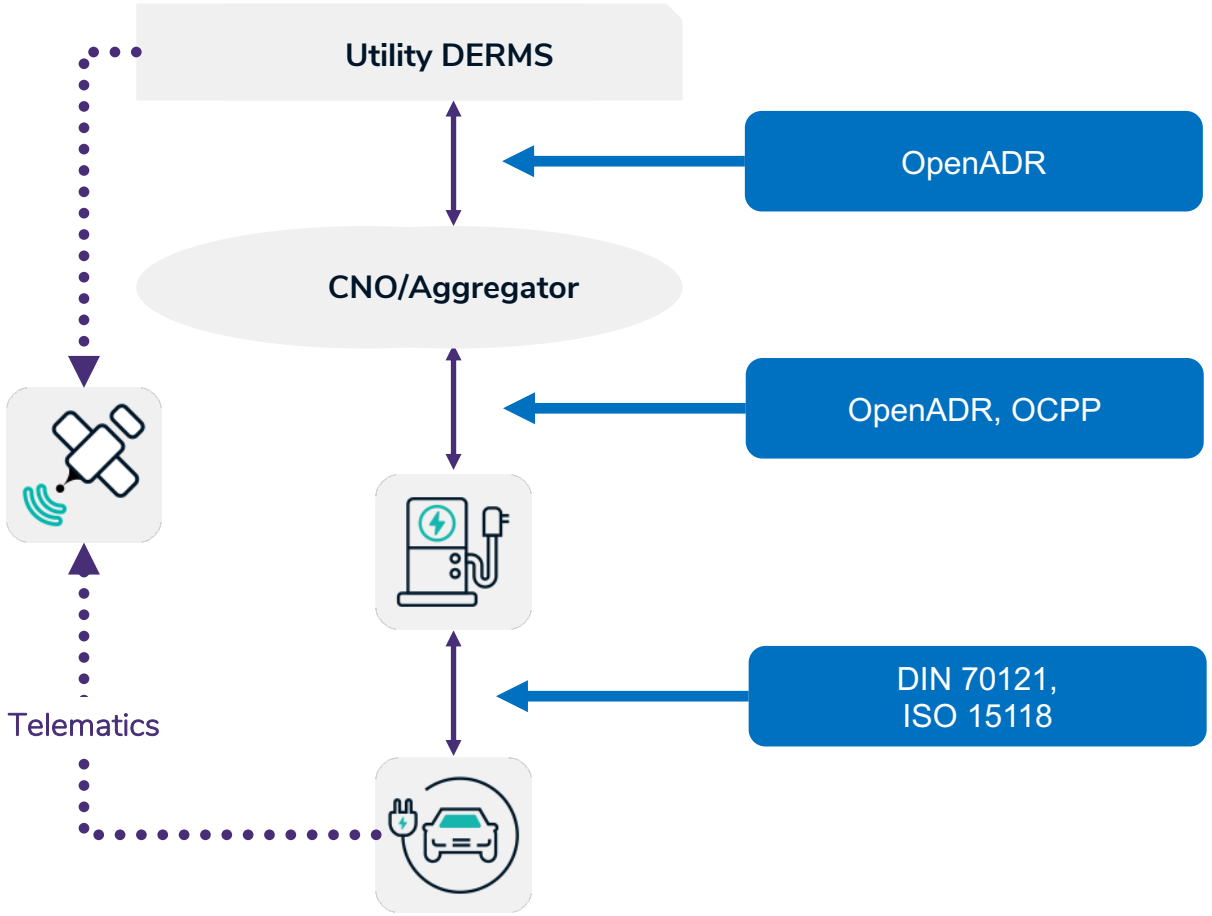
Summary

- **IEEE 1547 is a critical standard for V2G in the US**
  - Both for V2G-DC and V2G-AC
  - Defines interconnection requirements for EV systems as V2G DER
- **IEEE 1547 is Certified with UL 1741 for V2G-DC (EVSE only)**
- **IEEE 1547 compliance is required for V2G-AC (both EV and EVSE)**
  - Certified based on J3072 (certifications in development)
- **US Charging Infrastructure moving to OCPP and ISO 15118**
  - Creates challenges for V2G in the US
- **QualityLogic's role: enable standardized, interoperable eco-systems for charging, V1G and V2G infrastructures**
  - Through training and engineering/certification test tools

US Market V1G: QualityLogic Tools and Services



Tools Available Today

- **OpenADR Test Suite**

Training Available Today

- **OpenADR**

Future Products

- **ISO 15118 Interop Test System**

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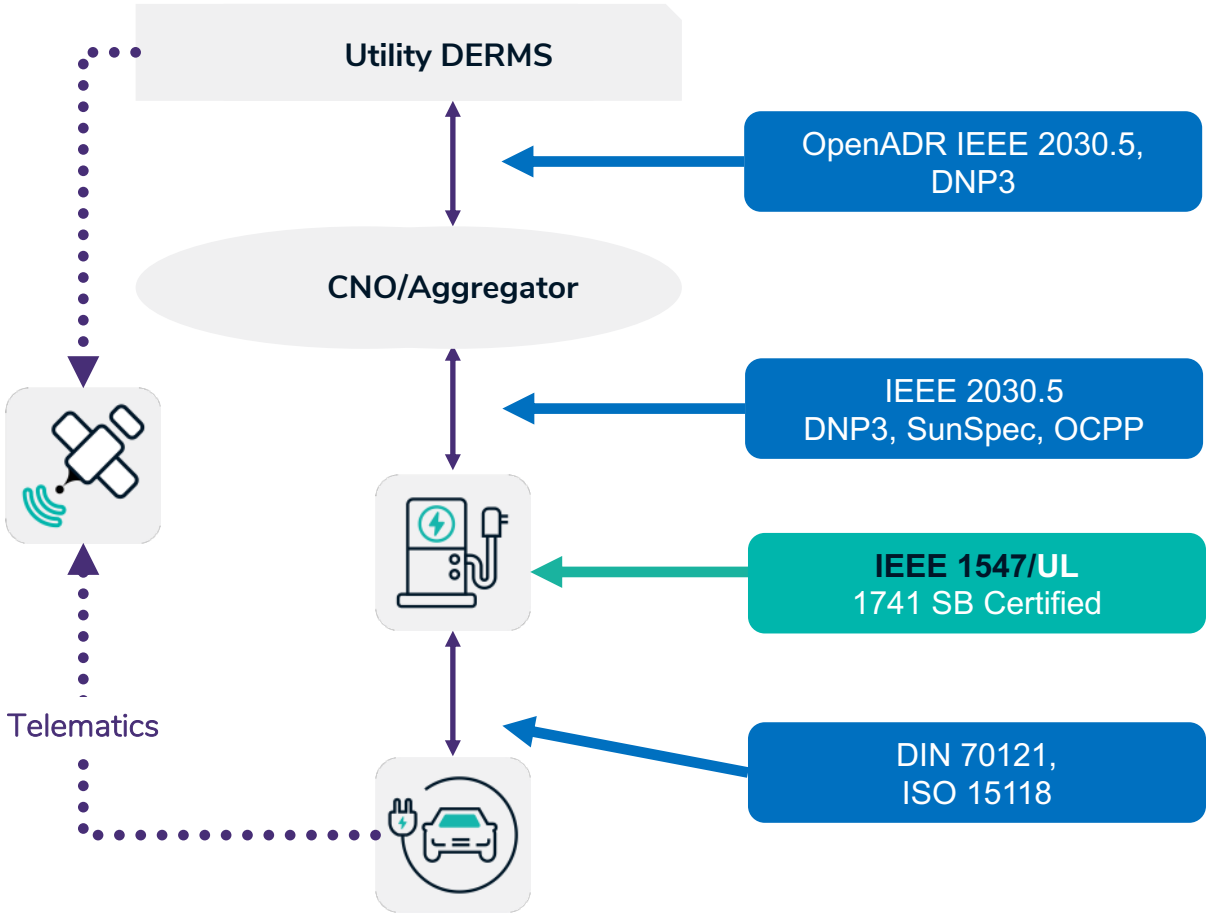
US Market V2G-DC: QualityLogic Tools and Services



Tools Available Today

- **OpenADR Test Suite**
- **IEEE 2030.5 CSIP Test Suite**
- **IEEE 2030.5 Ad Hoc Tests**
- **DNP3 for IEEE 1547 Interop**
- **SunSpec Modbus for IEEE 1547**
- **IEEE 1547/UL 1741 SB Certification Test System**

Training Available Today

- **OpenADR**
- **IEEE 2030.5**
- **IEEE 1547**

Future Products

- **ISO 15118 Interop Test System**

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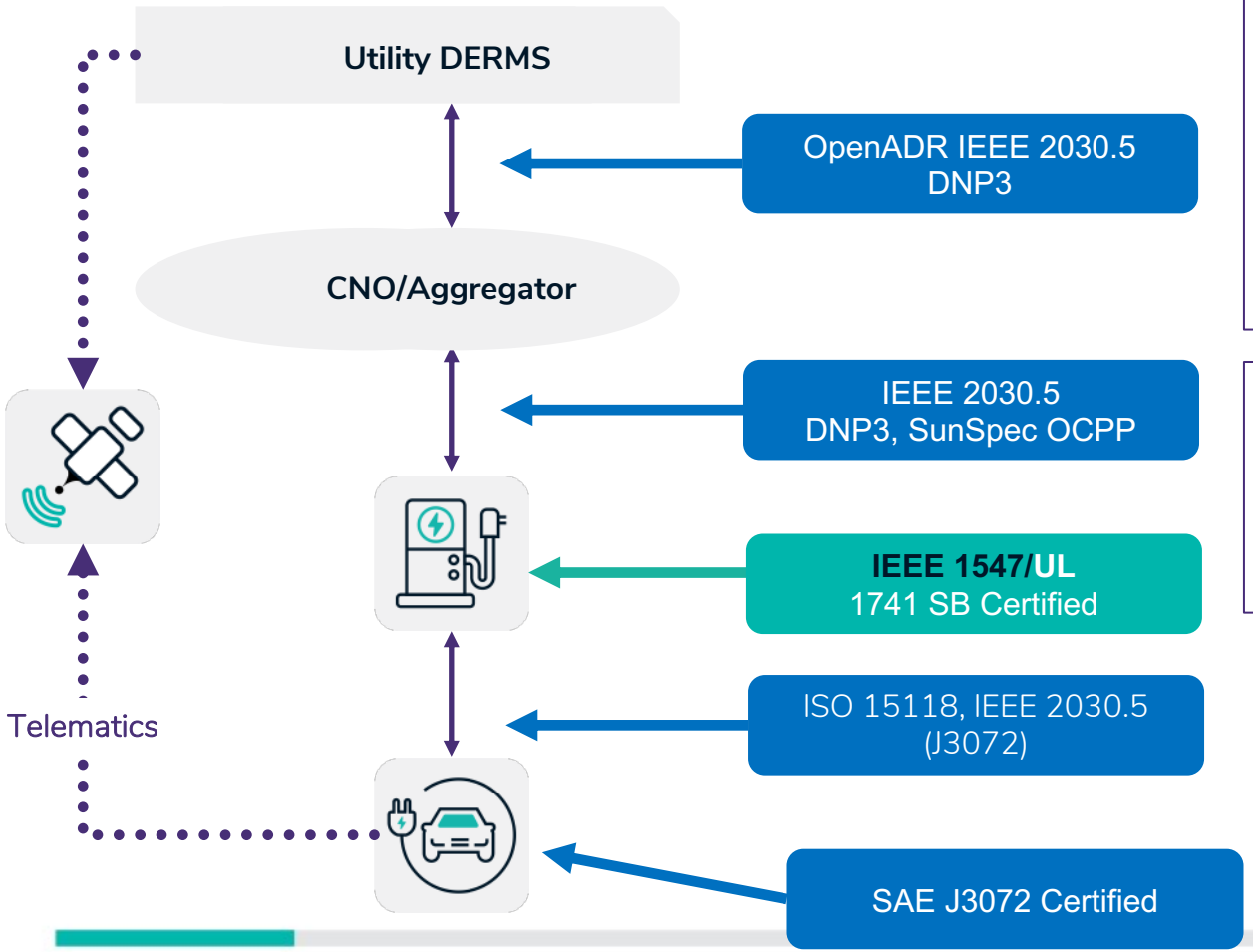
US Market V2G-AC: QualityLogic Tools and Services



Tools Available Today

- **OpenADR Test Suite**
- **IEEE 2030.5 CSIP Test Suite**
- **IEEE 2030.5 Ad Hoc Tests**
- **DNP3 for IEEE 1547 Interop**
- **SunSpec Modbus for IEEE 1547**

Training Available Today

- **OpenADR**
- **IEEE 2030.5**
- **IEEE 1547**

Future V2G Products

- **SunSpec SAE J3072 IEEE 2030.5 Profile**
  - Ad Hoc in development
  - Certification tests waiting on SunSpec Test Spec
- **UL 1741 SC EVSE Certification Test Suite**
  - Pending completion of Standard
- **SAE J3072 EV Test System**
  - Modified IEEE 1547/UL 1741 SB test system
- **ISO 15118 Interop Test System**

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Questions?

Contacts: info@qualitylogic.com

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