Accelerating Grid Code Testing for Inverters and V2G

QualityLogic

Introduction to Speaker/Authors

Steve Kang, GM, QualityLogic - Speaker

Steve is a leading technical expert on IEEE 2030.5 and CA Rule 21 based Common Smart Inverter Profile (CSIP) implementation guide. He has trained many companies worldwide in understanding IEEE 2030.5, CSIP and IEEE 1547 technical standards. He is the General Manager responsible for delivering leading testing products and services for the Smart Energy industry.

James Mater, Director of Strategy, 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 IEEE 2030.5 WG, the IEEE 1547.1 and 1547.2 Work Groups, UL 1741 SC, SunSpec J3072 Profile, OpenADR Profile WG and more.

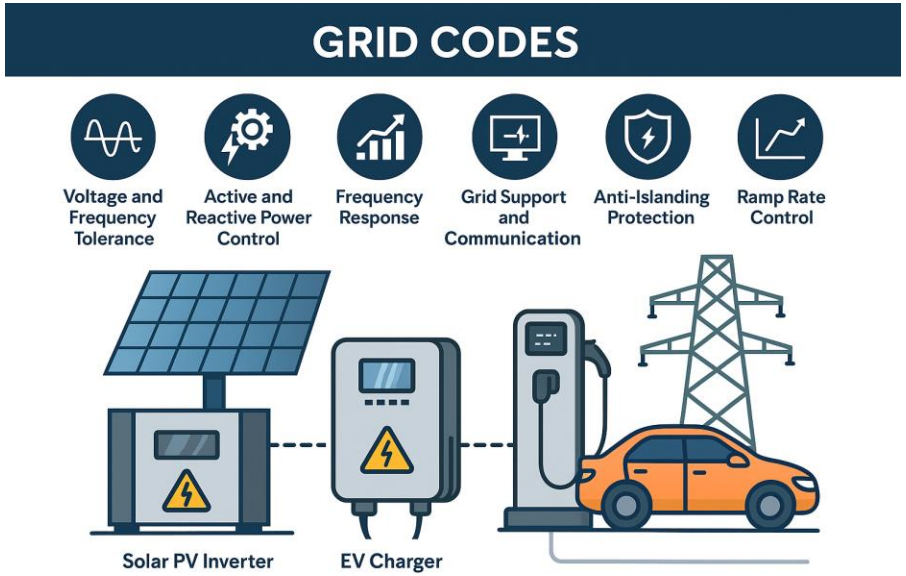
QualityLogic's Role in the Smart Energy Industry

- Focused on providing the industry with Smart Energy Testing Products, Training and Consulting to accelerate certification
  - IEEE 2030.5, OpenADR, IEEE 1547/UL 1741 SB, V2G, and CCS
  - 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/UL 1741SB Certification Test Tools
- Contribute to development of international standards
  - Member of IEEE 2030.5, 1547-2018 and 1547.1-2020 working groups
  - Member of UL 1741 STP (SB revisions)
  - SunSpec Modbus, SunSpec J3072 IEEE 2030.5 Profile
  - OpenADR, MESA-DER, UL 1741 SC, SAE J3072, CharIN
- Founding member of V2G Forum to help harmonize V2G standards
  - Includes EV/EVSE manufacturers, utilities, alliances and government agencies

Test Lab Partners

What are Grid Codes?

- Goal is to support the power grid and improves its stability
- Power grid can be unstable and interconnected DERs must tolerate and respond to abnormal grid conditions
- Grid codes define the various functions that each DER device must be certified to
- Summary of grid code functions include:
  - Abnormal Voltage and Frequence Response – ride through conditions, must trip based on voltage/frequency conditions
  - Active and Reactive Power Controls – controls amount of active/reactive power being generated or absorbed by the DER device
  - Frequency Response – adjustments of active power based on grid frequency
  - Voltage Regulation – adjustment of active/reactive power based on grid voltage
  - Anti-islanding – DER must trip/disconnect from the grid when grid shuts down
  - Ramp rate – rate of active power generation when DERs energize the grid
  - Remote communication – provides utilities to remotely control these functions



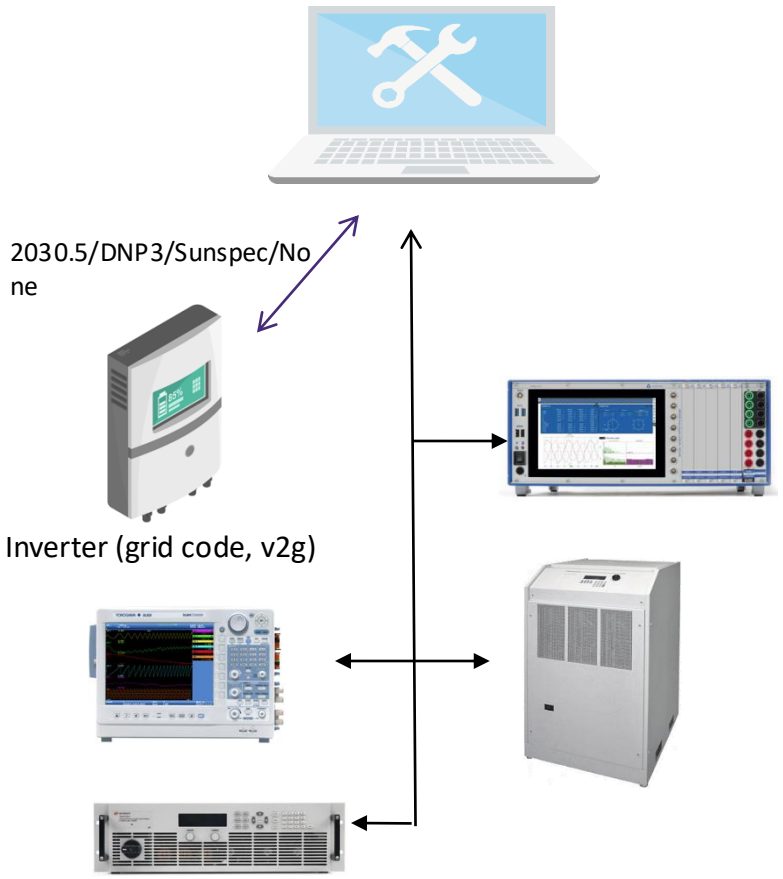
Grid Codes Around the World

- Grid code functions can have different defaults for each region
- Each region/country defines their own grid code requirements based on local grid needs
- Examples of Grid Codes around the world
  - IEEE 1547 and UL 1741 defines grid codes for the US

QualityLogic 1547.1 Test Tool Product Overview

- Base 1547.1 FTS includes Interop test cases for one protocol (user selects)
  - Implements the protocol communication required to manage the smart inverter for the Interop tests
  - REST API to execute tests through automation scripts/programs
- Add-on Features include:
  - Equipment Automation: test tool controls grid simulator, power analyzer, oscilloscope, etc.
  - Type tests (1547.1 Section 5 which includes other grid support tests beyond Interop)
  - Additional protocols for devices that support more than one – working with Mesa alliance on DNP3
  - Automated Data Analysis – QL test tool will automatically analyze collected power measurements
  - Yearly maintenance and support contracts
- Fully automated execution through equipment automation and automated data analysis
- Updates from UL 1741 SB revision implemented in the Test Tool – member of working group
- Used by customers to pretest & get certified – Tesla (1st to be certified in 2021) plus many others
- Actively supporting many OEMs to explain how 1547.1 functions work and analyze DER's performance

1547.1 Product Architecture



- QLI 1547.1 FTS will remotely control and monitor each test equipment
  - Grid simulator, power analyzer/meters, oscilloscope and DC simulators
  - Remotely control through use of SCPI or OEM's API
- Each 1547.1 test case requires configuring and monitoring these equipment in order to analyze the inverter's electrical behavior
- Monitor power data collected from data collection devices (power analyzer, oscilloscope) in order to analyze the test criteria
- Current list of equipment supported
  - Yokogawa WTx000, PX8000, Chroma, Virtrek, Dewetron Power Analyzers
  - Yokogawa DL, Tektronix, Agilent, Instek, Virtrek, Teledyne & Lecroy, Rodhe&Schwarz, oscilloscopes
  - ITECH, Magna-power SL Series, Chroma, TerraSAS, Keysight, Regatron, TDK, Ametek SGX DC power supply
  - Ametek MX/RS/Sequioa (NEW) Series, Chroma, NF, Keysight, NHR Grid Simulator, Regatron, ITECH (NEW) grid simulators, Pacific Power (NEW)
  - Other models can be added based on customer's requests

General Test Flow

- Test tool executes the 1547.1 test steps (see left example)
- Test equipment is controlled and set by following the 1547. test procedure
- Customer provides nameplate and related equipment configuration by using test tool's GUI
- Test tool will communicate with the inverter using the selected DER protocol to set the grid support functions
- During test execution, test tool will control and monitor various equipment such as grid simulator, power analyzer, etc.
- Data collected from power analyzer and oscilloscope as configured by user
- Test tool will automatically analyze the data collection during tests or offline

b) Set all voltage trip parameters to the widest range of adjustability. Disable all reactive/active power control functions.

c) Set all *ac test source* parameters to the nominal operating voltage and frequency.

d) Adjust the EUT's available active power to P_{rated}. For an EUT with an electrical input, set the input voltage to V_{in_nom}. The EUT may limit active power throughout the test to meet reactive power requirements.

e) Set EUT volt-var parameters to the values specified by Characteristic 1. All other function should be turned off. Turn off the autonomously adjusting reference voltage.

f) Verify volt-var mode is reported as active and that the correct characteristic is reported.

g) Once steady state is reached, Begin the adjustment to V_H. Step the *ac test source* voltage a_v below V_3.

h) Step the *ac test source* voltage to a_v above V_3.

i) Step the *ac test source* voltage to $(V_3 + V_4)/2$.

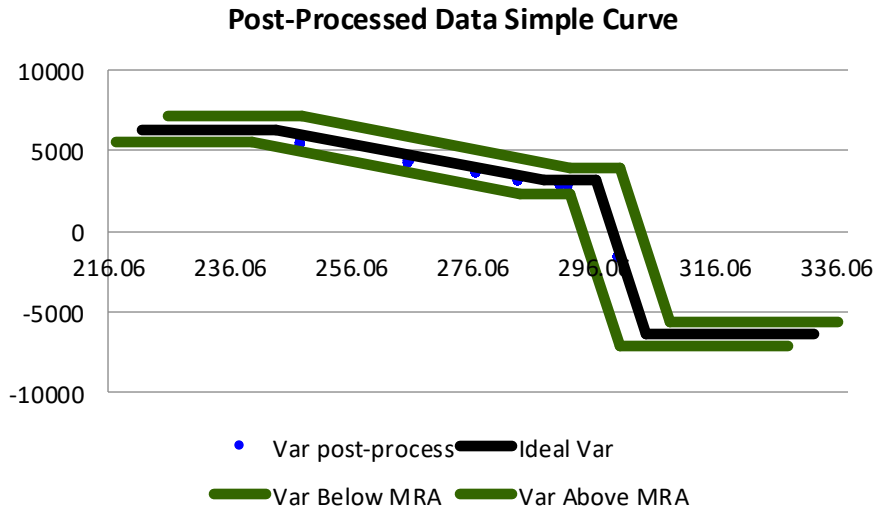
j) If V_4 is less than V_H step the *ac test source* voltage to a_v below V_4, else skip to step l)

Automated Data Analysis – New Feature

- Monitoring the DUT's behavior at the output power level is central to determining the pass/fail of the 1547/UL 1741SB
- IEEE 1547/UL 1741SB calls for strict Minimum Required Accuracies (MRAs) that DUTs must fal within.
- QualityLogic's IEEE 1547 test tool fully controls all equipment and collects measurements at intervals supported by each equipment type
  - Customers/NRTLs have analyzed these collected data and performed analysis for the DUT being tested/certified – time intensive step when done manually.
  - QL has assisted many customers in performing these analysis for them before/during NRTL certification
- Based on the expertise, QL has developed an automated data analysis as a new feature to IEEE 1547 test tool
  - With this feature, users can automatically analyze DER's response to 1547 tests including pre/post analysis set of visual charts
  - Supports Type tests and Management tests data analysis
  - Offline processing – analyze previously collected data
  - Test tool will generate an excel output file that includes analyzed data and charts

Table 3—Minimum measurement and calculation accuracy requirements for manufacturers[a]

Time frame	Steady-state measurements			Transient measurements		
Parameter	Minimum measurement accuracy	Measure-ment window	Range	Minimum measurement accuracy	Measure-ment window	Range
Voltage, RMS	(± 1% V_{nom})	10 cycles	0.5 p.u. to 1.2 p.u.	(± 2% V_{nom})	5 cycles	0.5 p.u. to 1.2 p.u.
Frequency[b]	10 mHz	60 cycles	50 Hz to 66 Hz	100 mHz	5 cycles	50 Hz to 66 Hz
Active Power	(± 5% S_{rated})	10 cycles	0.2 p.u. < P < 1.0 p.u.	Not required	N/A	N/A
Reactive Power	(± 5% S_{rated})	10 cycles	0.2 p.u. < Q < 1.0 p.u.	Not required	N/A	N/A
Time	1% of measured duration	N/A	5 s to 600 s	2 cycles	N/A	100 ms < 5 s



Accelerate your 1547 testing through QualityLogic

- QualityLogic fully automates the end to end testing of DER systems for IEEE 1547 compliance
  - Performs communication with DER to configure specific grid support function and test values
  - Controls grid simulator through each 1547.1 test step by changing grid conditions as required
  - Monitors and collects DER's behavior from the connected power analyzer and oscilloscope
  - Automatic data analysis of the collected power analyzer data to determine DER's pass or fail
- QualityLogic's test tool provides users with convenient and accelerating testing to meet UL 1741SB compliance saving customers valuable testing time
  - All the grid support Types tests for a bidirectional inverter can be performed in 32 hours – based on actual testing using QualityLogic's 1547.1 Test Tool
    - Includes all the steps listed above
    - Significant time savings for OEMs and NRTLs
  - IREC's estimate of 8-12 weeks of NRTL testing for SB compliance can be reduced significantly

		Test Function	No.Of Rounds	Measured time for execution in MODBUS (mins)
TYPE TESTS	MANAGEMENT TESTS	1	Const PF	6	48
		2	Volt- Var	5	130
		3	Volt- Var Vref	1	45
		4	Watt- Var	3	42
		5	Const VAR	12	108
		6	Volt- Watt	5	115
		7	Volt Watt P'	5	116
		8	Freq Droop OF	6	15
		9	Freq Droop OF P'	7	17
		10	Freq Droop UF	2	7
		11	Freq Droop UF P'	3	10
		12	Max Limit Power	9	43
		13	HVMT (Neutral Disabled)	4	20
		14	LVMT (Neutral Disabled)	6	76
		15	HFMT	6	512
		16	LFMT	6	512
		17-22	Service test	6	200
		23	Abn HVRT (Neutral Disabled)	2	20
		24	Abn LVRT (Neutral Disabled)	2	20
		25	Abn HFRT	1	19
		26	Abn LFRT	1	19
		27	Volt Watt Imb P'	1	4
		28	Volt-Var Imb	1	3
		29	Volt- Watt Imb	1	2
		30	Volt-Freq Prioirity	1	18

Total Run time (Hours)	32.0166667

IEEE 1547/EN50549 Technical Workshop

- Multi-day technical workshop (remote or onsite) that covers IEEE 1547/UL1741SB and European EN 50549 standards
- Includes review of IEEE 1547, UL 1741SB and EN 50549 standards for each test
- Includes live inverter lab session demonstrated by QL compliance engineer
- Offered since 2022 to manufacturers, NRTLs, utilities and research organizations

Just some of those taking the workshop

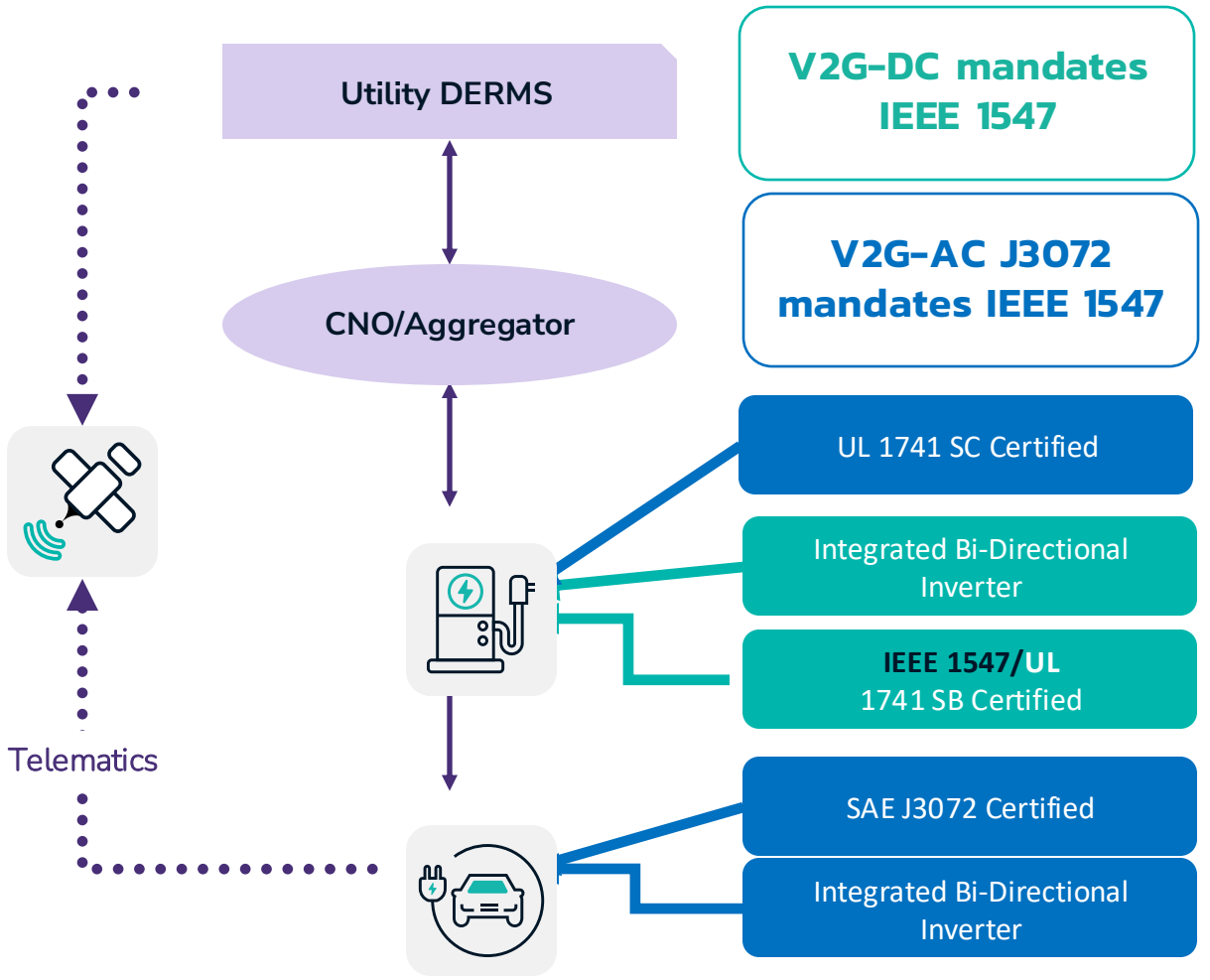
- Course Outline:
  - Session 1: Introduction to IEEE 1547-2018
  - Session 2: Introduction to IEEE 1547.1-2020
  - Session 3: Introduction to UL 1741 SB
  - Session 4: EN 50549 Overview
  - Session 5: 1547 and 50549 Comparison
  - Session 6: EN 50549 Testing
  - Session 7: QualityLogic Test Tools
  - Session 8: Conducting Tests using QualityLogic Test Tools
  - Session 9: Reviewing Test Results from QualityLogic Test Tools

What is V2G?

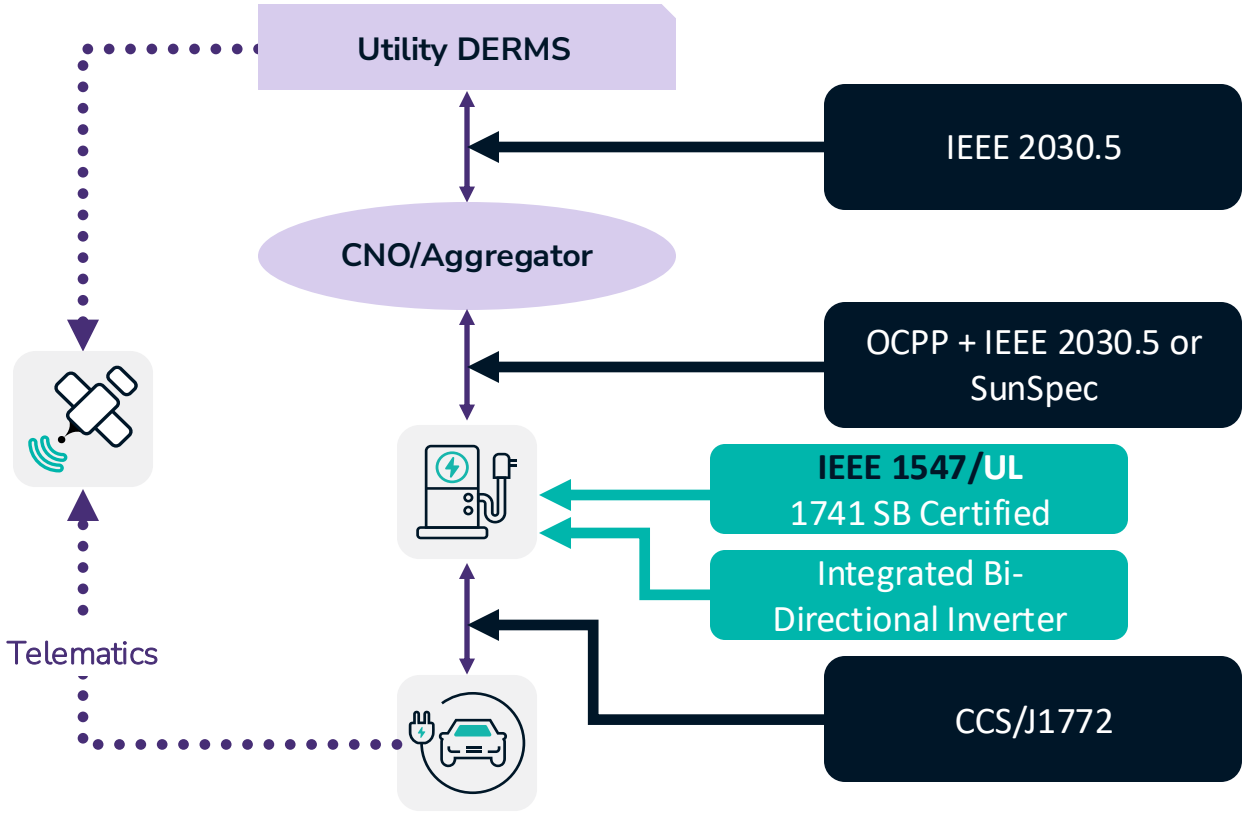
- Vehicle to Grid has different definitions
  - Simple V2G – vehicle puts power back to the grid – export power
  - US and others – Simple V2G plus supporting grid support functions at the inverter
- Grid support functions required for PV/smart inverters here in the US and elsewhere
  - Voltage/freq must trip, voltage/freq ride through, VoltVar, PowerFactor, VoltWatt, WattVar, FreqDroop, Enter service, Limit Watts, Limit VARs
  - These functions help stabilize the electrical grid by utilities controlling inverter systems
- ISO 15118 supports simple V2G but not grid support functions – not yet
- SAE J3072 IEEE 2030.5 profile 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 2030.5 from EVSE to EV for AC discharging

Interconnection for EVSE as DER

- IEEE 1547 is a REQUIREMENT for V2G in the US
  - Interconnection standard for all DERs
  - ANY EXPORT to the Grid requires IEEE 1547 compliance (Energy Policy Act of 2005)
  - 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 – certifies IEEE 1547 Compliance
  - V2G-DC can be interconnected with UL 1741 certification TODAY!



US Market V2G-DC: Standards

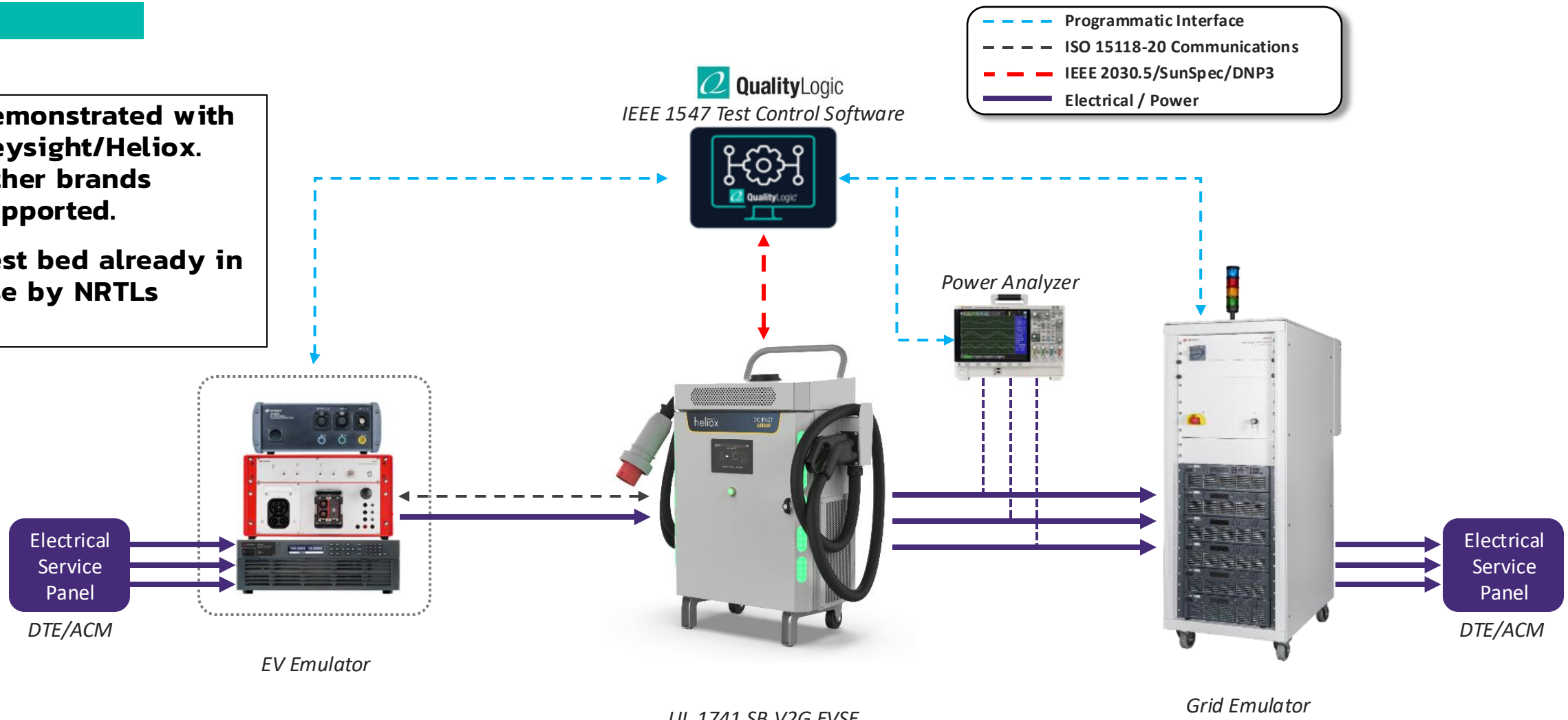


Use Case 2: V2G=DC Charge + Energy + Power Management

- Bi-directional EVSE Inverter
- Grid interactions – charge/export time, power settings, IEEE 1547 curves and controls
- Interconnected at the UL 1741 SB EVSE
- CA Rule 21 (September 2020 CPUC D.20-09-035) requires UL 1741 SA/SB Certification

UL 1741 SB Compliance Testbed – demonstrated at V2GForum

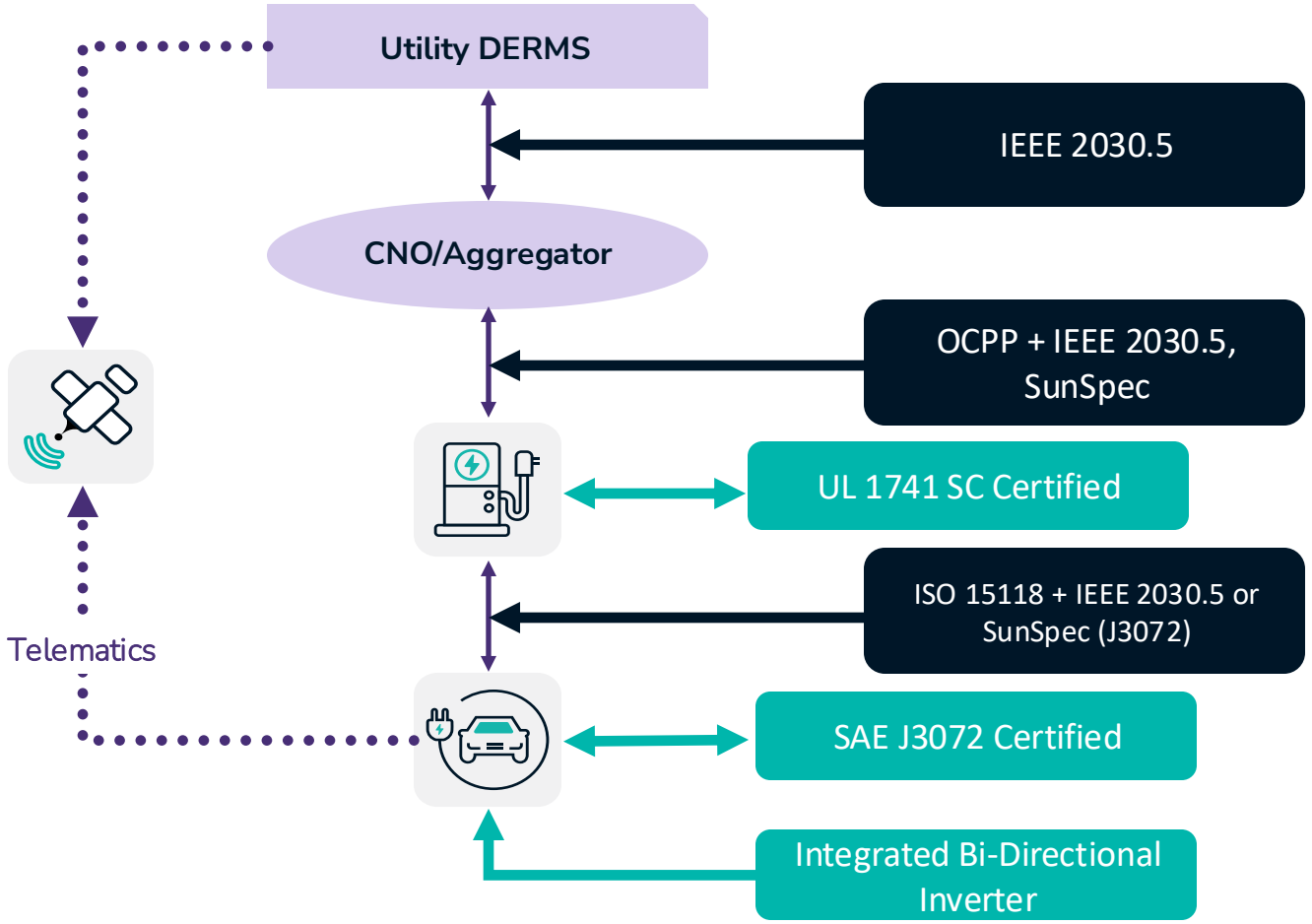
- **Demonstrated with Keysight/Heliox. Other brands supported.**
- **Test bed already in use by NRTLs**



US Market V2G-AC: Standards

Use Case 2: V2G-AC Charge + Energy + Power Management

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



QualityLogic Product Portfolio

- Industry leading IEEE 2030.5 Test Tools for CSIP certification and Technical Workshop
  - Includes CA Rule 21/CSIP, CSIP Australia, SAE J3072/V2G, Metering specifications
  - Used by NRTLs, SunSpec Authorized Test Labs, OEMs, Utilities and others
- First IEEE 1547.1/UL 1741SB Certification Test Tools and Technical Workshop
  - Used by major inverter manufacturers and NRTLs for 1547.1/UL1741SB certification testing
- Official OpenADR Certification Test Tool and Technical Workshop
  - OpenADR Alliance funded and supported test tool
  - Used by all OpenADR Authorized Test Labs and must be used for certification
- Consulting to Utilities on various Smart Energy technologies
  - IEEE 2030.5, OpenADR, 1547, MESA-DER, SunSpec, V2G, etc
- CCS Analyzer to help solve EVSE/EV charging interoperability issues
  - Analyzes DIN 70121, ISO 15118-2, ISO 15118-20 charging sessions without h/w
- V2G standardization and support through above products

Summary

- QualityLogic offers products and services for international certification requirements
  - Communication Protocol Certification – IEEE 2030.5, OpenADR, CSIP, CSIP Australia, SunSpec Modbus and DNP3 (1815.2 for DER)
  - DER Certification - IEEE 1547.1/UL 1741SB Test Tool for smart inverters, EVSE, EV and V2G
- Active contributor to the IEEE 2030.5/CSIP, 1547/UL1741SB, OpenADR, J3072 and UL 1741SC standards development
- Qualitylogic already plays a role in testing protocols used in EV charging
  - New products for ISO 15118 and J3072 technologies
- Products and services used by manufacturers, utilities and test labs globally
- Our test tools significantly accelerate your certification readiness
- Thank you! For further questions, contact Steve Kang, General Manager:
  - Email to skang@quailtylogic.com