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Expedite UL 1741 SB Certification with QualityLogic

Today's Presenters

- **Steve Kang, GM, QualityLogic**

  Steve is a leading technical expert on IEEE 2030.5 and CA Rule 21 based Common Smart Inverter Profile (CSIP) implementation guide. He is the General Manager responsible for delivering leading testing products and services for the Smart Energy industry.

- **William Martins, Compliance Engineer, QualityLogic**

  William is the lead compliance engineer with extensive experience testing inverters for UL 1741 compliance testing. He has over 10 years of industry experience performing compliance testing of smart inverters for various regional codes.

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QualityLogic's Role in the Smart Energy Industry

- Focused on providing the industry with Smart Energy Testing Products, Training and Consulting
  - IEEE 2030.5, OpenADR, IEEE 1547/UL 1741 SB, V2G, 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
- 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

IEEE Advancing Technology for Humanity
UL Standards & Engagement
openADR ALLIANCE
SAE INTERNATIONAL
CHARIN
SUNSPEC ALLIANCE
MESA Open Standards for Energy Systems

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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 – interoperability tests
- UL 1741 SB is the official safety certification standard for DERs to be compliant to IEEE 1547 requirements
  - Directly references IEEE 1547-2018 and 1547.1-2020 standards

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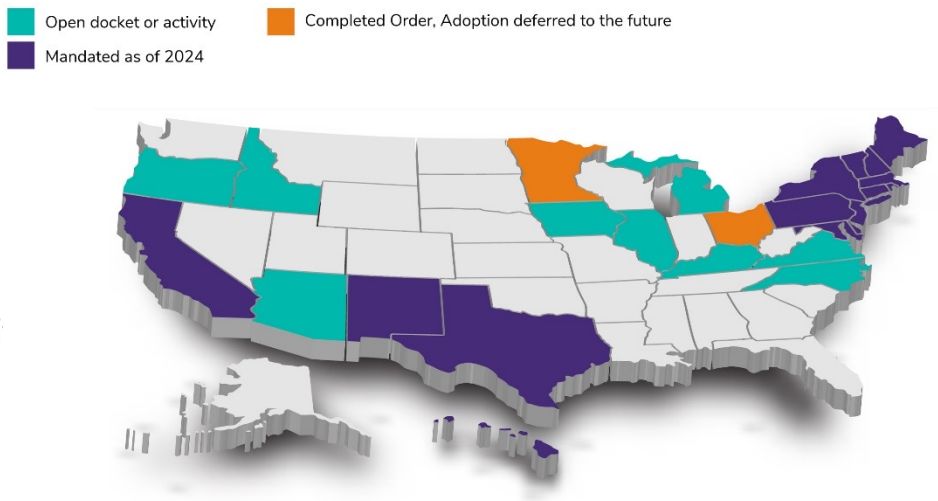
Adoption of IEEE 1547 in the US

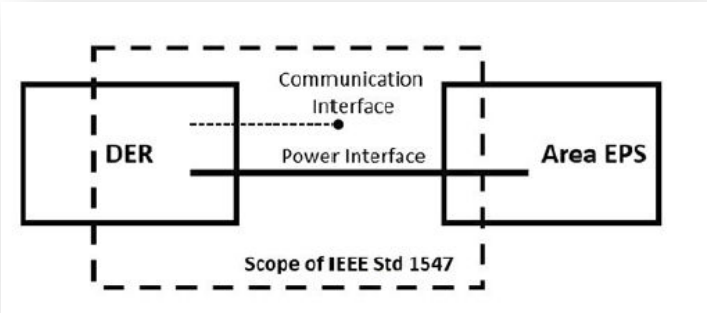
- On February 12, 2020, NARUC approved a resolution recommending state commissions adopt IEEE 1547-2018
- UL 1741 SB Revision adopted September 28, 2021– certification testing starts
- NRTLs are in full certification testing mode
- IREC survey Aug-Sep 2021 (3 leading NRTLs)
  - Estimates of 8-12 weeks testing per inverter family
  - >1 year to certify ~80% of inverter families tested on CEC list
  - Plus time for certification processing, listing by CEC and distribution of certi inverters
- CA, HI, MA, NJ, MD, NY, PA, TX, NM require SB
  - OR, VA, IA – open docket



IEEE-1547-2018_States-and-ISOs-RTOs-Adoption_IEEE-Format_2022-05.pdf)
IEEE Std 1547-2018 (Revision of IEEE Std 1547-2003) - IEEE Standards Coordinating Committee 21 (SCC21)

IEEE 1547 Goals

- Interconnection and interoperability of DERs with electric power systems
- Different categories of devices and abnormal conditions to qualify
- Reference Point of Applicability (RPA) is location where interconnection/interoperability requirements shall be met – at the PCC
- Performance requirements apply to interconnection of either single DER unit based on that unit's ratings or multiple DERs within a single local EPS based on aggregate rating of all the DER units, ex. microgrid or EMS.
- Communication interface must be local to the DER unit itself, ex. not living on the cloud
- Measurement accuracies are specified in IEEE 1547-2018 Section 4.4 (see later slides)



Cited from IEEE 1547-2018 standard

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Categories of Devices

- OEMs determine which categories they want to be certified to.
- Categories change the way tests are performed
- Normal Category B and Abnormal Category III are the most capable/harshest conditions.
- Jurisdictions may require specific categories they will accept.

For categories related to reactive power capability and voltage regulation performance requirements (Clause 5):

— Category A covers minimum performance capabilities needed for Area EPS voltage regulation and are reasonably attainable by all DER technologies as of the publication of this standard. This level of performance is deemed adequate for applications where the DER penetration in the distribution system is lower,[12] and where the overall DER power output is not subject to frequent large variations.

— Category B covers all requirements within Category A and specifies supplemental capabilities needed to adequately integrate DERs in local Area EPSs where the aggregated DER penetration is higher or where the overall DER power output is subject to frequent large variations.

For categories related to response to Area EPS abnormal conditions (Clause 6):

— *Abnormal operating performance Category* I is based on essential *bulk power system* (BPS) stability/reliability needs and reasonably attainable by all DER technologies that are in common usage today.

— *Abnormal operating performance Category* II covers all BPS stability/reliability needs and is coordinated with existing reliability standards[13] to avoid tripping for a wider range of disturbances of concern to BPS stability.[14]

— *Abnormal operating performance Category* III is based on both BPS stability/reliability and distribution system reliability/power quality needs and is coordinated with existing interconnection requirements for very high DER penetration.[15]

Cited from IEEE 1547-2018 standard

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IEEE 1547.1 Type Tests for Grid Support Functions

- Type Tests are defined in Section 5 of the IEEE 1547.1 Standard
- Includes grid support functional testing plus other tests such as anti-islanding, temperature stability, EMI, open phase and others
- Focusing on grid support functional tests in this webinar
- 5.2 Priority of responses – specific order of priority of functions by DER (disable permit service, must trip, ride through, VoltWatt/FreqDroop, Limit Active Power then Reactive Power as lowest priority
- 5.4 Test for response to voltage disturbances - Voltage trip and ride through functions
- 5.5 Test for response to frequency disturbances – Frequency trip and ride through functions + ROCOF
- 5.6 Enter service – DER energizes and ramps to produce power

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IEEE 1547.1 Type Tests for Grid Support Functions

- 5.13 Limit active power – controlling DER's active power generation
- 5.14 Voltage regulation – grid voltage responses such as VoltVar, VoltVar Vref, VoltWatt, PF, WattVar
- 5.15 Frequency support – grid frequency responses such as FreqDroop
- 5.16 Test for prioritization of DER responses – testing of above 5.2 priority order
- Type tests include testing of various test characteristics under various conditions
- Section 6 (Interoperability) leverages above tests and requires DER communication (2030.5, SunSpec Modbus 7xx, IEEE 1815 (DNP3). Interop tests sample two of the Type test settings
  - DER must support at least one of the above protocols to pass Interoperability

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Type Test Example – VoltVar

a) Connect the EUT according to the instructions and specifications provided by the manufacturer.
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).
k) Step the *ac test source* voltage to *a*v above *V*4.
l) Step the *ac test source* voltage to *a*v below *V*H.

…additional steps follow to step the grid voltage up/down from Vhigh to Vlow back to Vref. Same set of test steps are repeated for different Voltvar characteristic curves and % of rated power (Char#1 curve at 100%, 20%, 66% rated power, Char#2 curve @ 100%, Char#3 curve @ 100%)

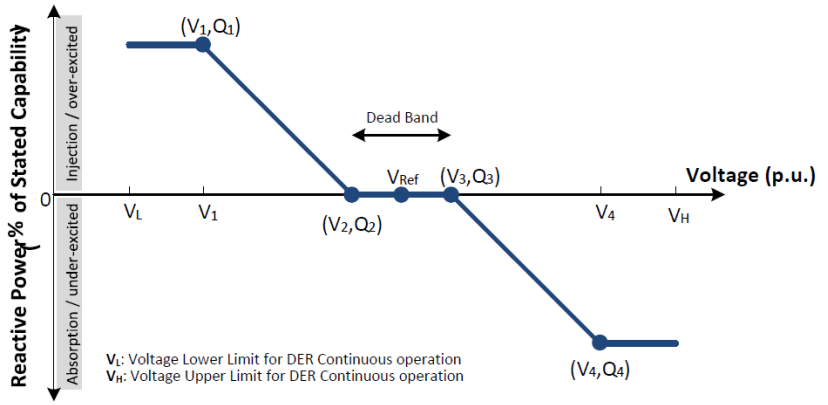

Figure 9—Example voltage-reactive power characteristic

Table 25—Characteristic 1:
Default voltage-reactive power settings for normal operating performance Category A and Category B DER

Voltage-reactive power parameters	Default values for DER	
	Category A	Category B
V_{Ref}	V_N	V_N
V_2	V_N	0.98 V_N
Q_2	0	0
V_3	V_N	1.02 V_N
Q_3	0	0
V_1	0.9 V_N	0.92 V_N
Q_1	25% of nameplate apparent power rating, injection	44% of nameplate apparent power rating, injection
V_4	1.1 V_N	1.08 V_N
Q_4	25% of nameplate apparent power rating, absorption	44% of nameplate apparent power rating, absorption
Open loop response time, T_r	10 s	5 s

Above figures cited from IEEE 1547-2018 standard

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1547.1 Interoperability Test Section

- New section introduced in IEEE 1547.1-2020 standard to include communication requirements
- Requires the DER device to support at least one of IEEE 2030.5, SunSpec Modbus 700, IEEE 1815 (DNP3)
- Includes the following types of tests:
  - Nameplate Tests – reporting of DER's nameplate data
  - Configuration Tests – testing of configuration of different nameplate/settings of DER
  - Monitoring Tests – reporting of metering/status data by DER
  - Management Tests – testing of 10 of the Type Tests functions
- If Type tests (Section 5) are executed using above DER protocol, the Management tests can be skipped

Test	Management Function	Adjustable Settings (References to IEEE Std 1547-2018)	Criteria (References to functional test criteria within this document)
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
11	Limit maximum active power test	10.6.12, Table 40	5.13

Above figures cited from IEEE 1547-2018 standard

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QualityLogic's IEEE 1547.1 Certification Test Product

- Licensed by OEMs, NRTLs, utilities and research labs for official UL 1741 SB Certification for grid support tests
- Automates Testing of Type and Interoperability Tests
  - Supports all three DER protocols required in 1547 – IEEE 2030.5, SunSpec Modbus 700 and 1815 (DNP3)
  - Controls lab equipment connected to the DUT being tested – grid simulators, power analyzers, oscilloscope, DC Supply/PV simulators
  - Implements each step described in the 1547.1-2020 test procedures including UL 1741 SB clarifications
- Recently introduced Automated Data Analysis that analyzes the data collection set against required performance requirements
- QL has assisted number of OEMs in implementing their inverter control system through 1547 workshop and technical consulting
  - Automated Data Analysis is based on the expertise gained through helping OEMs pass certification with NRTLs
  - OEMs have submitted the results from the QL 1547 Test Tool including our analysis

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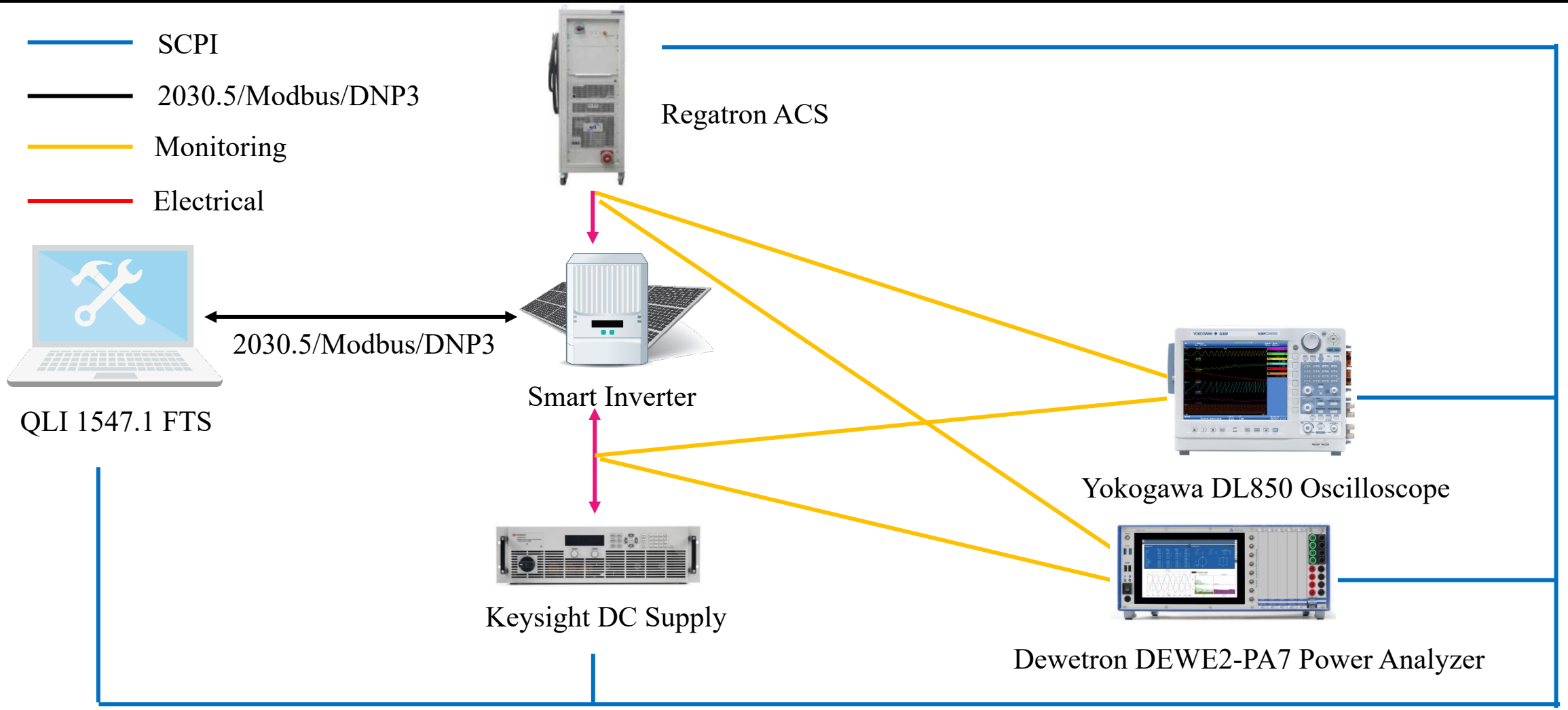
1547.1 Product Details – Test Equipment Control Features

- QLI 1547.1 FTS will remotely control and monitor each test equipment
  - Grid simulator, power analyzer/meters, oscilloscope and DC/PV simulators
  - Remotely control through use of SCPI or OEM API
- Each 1547.1 test case requires configuring and monitoring these equipment to analyze the inverter's electrical behavior
- Monitor power data collected from data collection devices (power analyzer, oscilloscope) 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
  - Magna-power SL Series, Chroma, TerraSAS, Keysight, Regatron, TDK, Ametek SGX DC power supply
  - Ametek MX/RS Series, NHR Grid Simulator, Chroma, NF, Keysight, Regatron grid simulators
  - New models added based on customer requests

Demonstration Inverter Lab Overview



EVSE/EV Lab Setup

SCPI

2030.5/Modbus/DNP3

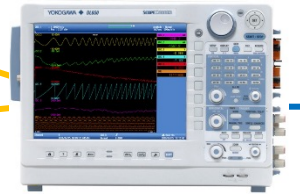
Monitoring

Electrical

Keysight

QLI 1547.1 FTS

Charging Station



Yokogawa DL850 Oscilloscope

Dewetron DEWE2-PA7 Power Analyzer

Load

EV Emulator

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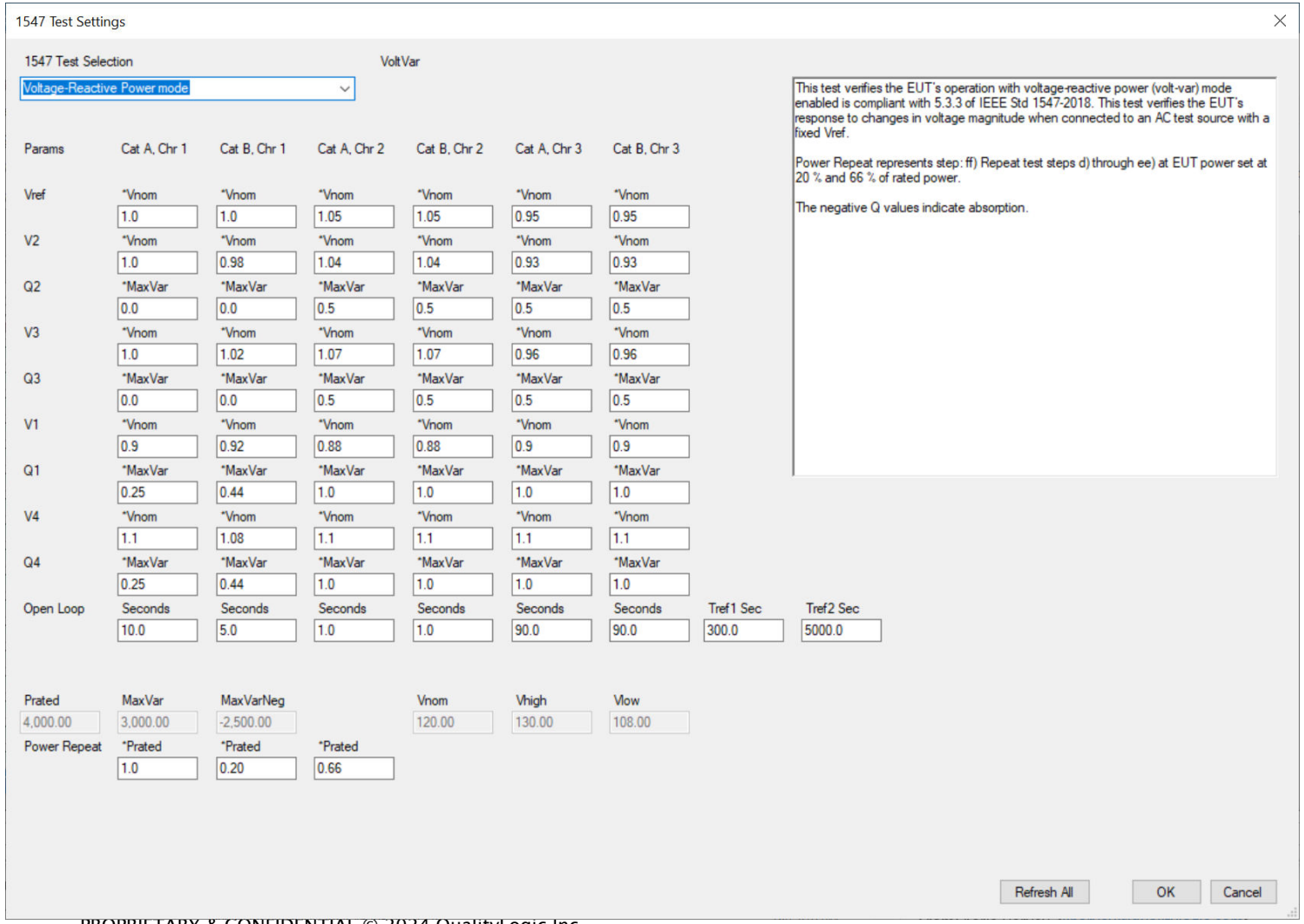
Grid Support Test Configuration



- Customer can change test values by using the test tool's GUI
- VoltVar Configuration example – each column represents VoltVar curve points
- Similar GUI for other grid support functions
- Customer can change this to test regional grid codes

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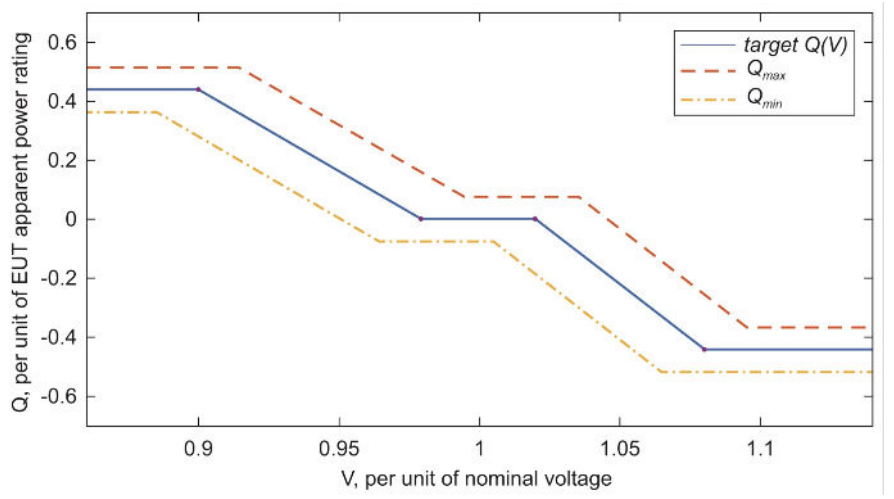
Automated Data Analysis – New Feature

- 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 fall 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

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



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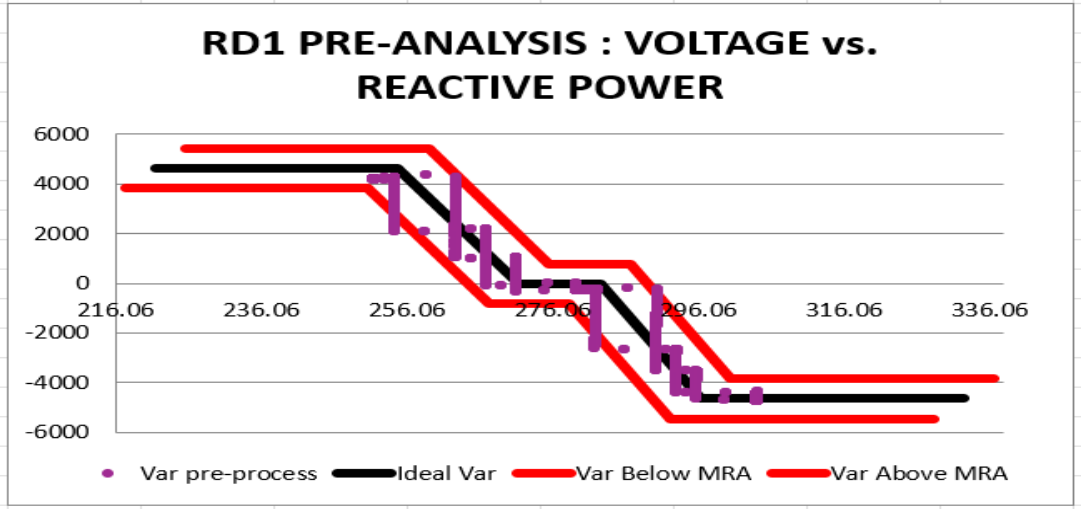
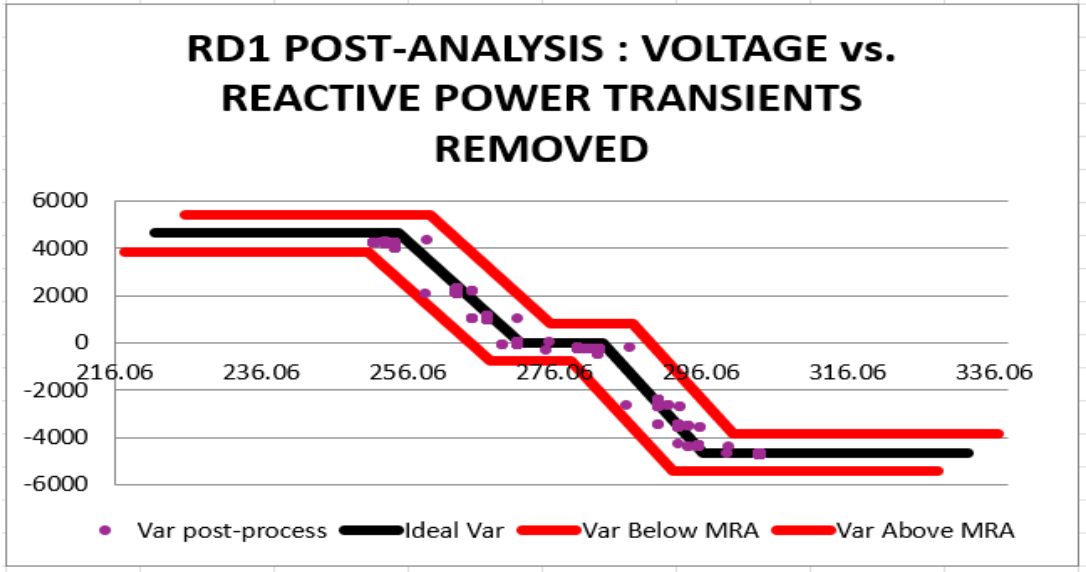
Automated Data Analysis from QL

- Covers each of the 1547.1 Type Tests including Management
- Analysis files are generated at the completion of each function test in 1547
- Compatible with all DAS QL test tool currently supports
- All analysis files generated are calculated using the strict MRA requirements of the 1547 standard.
- Auto removes all allowed transient points
- Auto detects and calculates steady state measurements
- Future release to include:
  - Offline analysis feature to process previously run tests
  - Compliant results are displayed and flagged as PASS
  - Noncompliant results are displayed and flagged as FAIL





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Challenges observed during 1547 Testing

- **Interoperability execution** – Typical failures that commonly happens are scale factor issues, adopting of curve, number of curve points, 2030.5 event creation and ending, and many more. QL test tool enables OEMs to find these issues early on during development.
- **Analyzing data** – Volt Var has 5 rounds when running type test. Each round collects a data file that needs manual processing. Processing data includes plotting MRA boundaries, removing transients, zooming in and out specific areas. This is done automatically when running QL test tool.
- **Must trip** tests have many corner cases that make testing difficult to execute. For example, how to test OV1 at 1.2p.u. at 13s when OV2 is fixed at 1.2p.u. at .16s. The QL test tool provides multiple methods to perform Must Trip tests that enables options for users to select.
- **Equipment Automation** – Creating voltage and frequency scripts that follow the strict standard requirements prove to be difficult. In 1547.1-2020, there now is a ROCOF (rate of change of frequency) requirement for all frequent steps that is done. There are also many voltage changes. QL test tool automates all voltage/frequency transient steps required in 1547 compliance testing.

Live Demonstration

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Products and Services from QualityLogic to accelerate 1547 compliance

- QualityLogic IEEE 1547.1 Test Product - for more info, click this link
  - Fully automated for each of the Type and Interoperability tests for grid support functions including grid simulator and other lab equipment
  - Automated data analysis of the power measurements to determine your device's compliance
  - Licensed by NRTLs who certify UL 1741SB, OEMs in different domains including inverters, storage, EVSE/EV, Utilities and research organizations worldwide
- Multiday Technical Workshop – for more info, click this link
  - Deeper training on technical standards (IEEE 1547, 1547.1, UL 1741SB), protocols and execution of 1547 tests using a live inverter lab
  - Trained NRTLs, OEMs, Utilities and research organizations worldwide
  - Available onsite or remote
- Consulting to support development/testing of products to comply with IEEE 1547/UL 1741SB
- QualityLogic IEEE 2030.5/CSIP Certification Test Product and Multiday Technical Workshop

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Summary

- IEEE 1547/UL 1741 SB certification is well under way for various US states
- Overview of tests included in these standards today
- Demonstrated how QualityLogic 1547 Test Product can accelerate testing
- Multiday technical workshop from QualityLogic available for deeper understanding
- Q&A
  - Please include them in the Q&A panel
  - Any questions we aren't able to cover today, we will review them and provide responses as follow-up to this webinar registrants
  - We will follow-up via email with information about webinar recording, Q&A responses
- Thank you! Contact smartenergynews@qualitylogic.com for any further questions