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Navigating IEEE 1547.1 & UL 1741 SB Certification for DERs

Agenda

- Introductions
- Latest Updates of IEEE 1547 and UL 1741 SB Mandates
- New Features in QualityLogic's IEEE 1547.1 Test Tool
- Live Demonstration of QualityLogic's IEEE 1547.1 Test Tool with Pacific Power Source's Grid Simulator
- Key considerations for HW/SW test solutions by Pacific Power Source
- Q&A

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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 8 years of industry experience performing compliance testing of smart inverters for various regional codes.

Today's Presenters

Pacific Power Source

George Liu – Field Applications Engineering Manager, Pacific Power Source: George has over 15 years of electrical engineering experience, with a strong foundation in test equipment across AC and DC systems. His expertise stems from hands-on experience testing a wide range of power applications including power conversion, grid, renewable energy, batteries, and energy storage systems.

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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/UL 1741 SB, OpenADR and others
  - First vendor to offer 1547.1 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

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

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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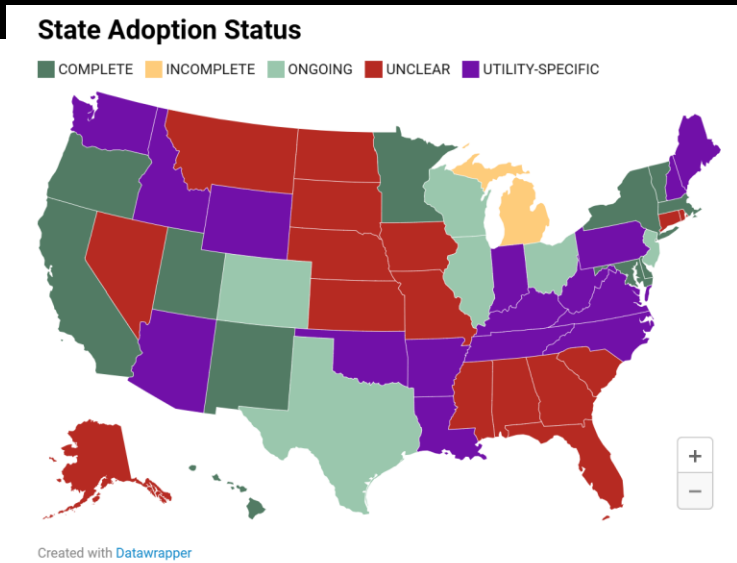
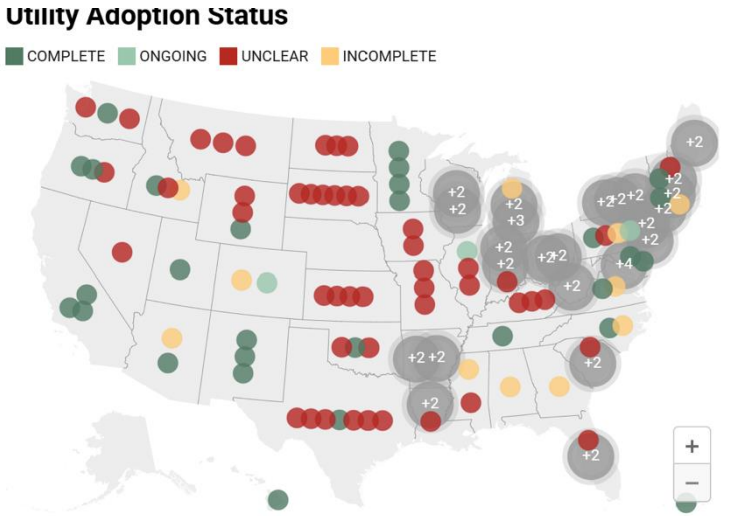
Adoption of IEEE 1547 in the US

- **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 started**
- **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 certified inverters
- **Currently, many states have required 1547-2018 as shown in the maps**
  - California, Hawaii, Oregon, Utah, New Mexico, New York, Minnesota, Massachusetts and other states require UL 1741SB with many more to follow
  - CEC's listing has 548 SB certified grid support inverters currently - growing





https://irecusa.org/resources/ieee-1547-2018-adoption-tracker/

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, voltage frequency priority**
- **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
  - Combination of protocol communication and verification of type tests requirements
- **QualityLogic's multiday IEEE 1547 workshop provides in depth training**
  - Includes walk through of IEEE 1547-2018, 1547.1-2020 and UL 1741 SB standards
  - Overview of all 3 communication protocols
  - Common implementation issues observed in the industry
  - Live inverter lab based training using QualityLogic's IEEE 1547 Test Tool

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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

QualityLogic's IEEE 1547.1 Certification Test Product

- **Trusted by OEMs, NRTLs, utilities and research labs for official UL 1741 SB Certification for grid support tests**
- **Accelerates Testing of Type and Interoperability Tests through fully validated automation**
  - 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
- **Automated Data Analysis that provides convenient 1547.1 measurement compliance to user**
  - Automatically determine if the DER device is compliant to the 1547.1 physical power responses
  - Methodology 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 to NRTLs to pass certification
  - Supported during live test execution or offline analysis

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New Features in Version 4.7

- **New Lab Equipment Models from Pacific Power**
  - Pacific Power AZX/AGX/RGS/GSZ AC Power/Grid Simulator Series
- **Enhanced Must Trip Functions: For Yokogawa Oscilloscopes**
  - Analysis is done by plotting vertical/horizontal cursers, adjusting time/division and adding automatic trigger. Includes List Command implementation
- **1547 GUI Upgrades**
  - New look GUI for 1547 configurations page. New visual graphs for all curve functions. Easier adjustable grid codes
- **SunSpec Modbus Conformance Test**
  - Covers testing of SunSpec Modbus Conformance Tests
  - Convenient way to discover OEM's implementation issues
  - Free for Modbus licensee of 1547 test tool – for a limited time

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**
  - Grid Simulators - Ametek MX/RS/Sequioa Series, Chroma, ITech/Rexgear, Keysight, Pacific Power, NF, NHR Grid Simulator, Regatron
  - Power Analyzers - Yokogawa WTx000, PX8000, Chroma, Dewetron, Virtrek
  - Oscilloscopes - Yokogawa DL, Tektronix, Agilent, Instek, Virtrek, Teledyne & Lecroy, Rodhe&Schwarz
  - DC Power Supply – ITech, Chroma, TerraSAS, Keysight, Regatron, Magna-power SL Series, TDK, Ametek SGX
  - New models added based on customer requests

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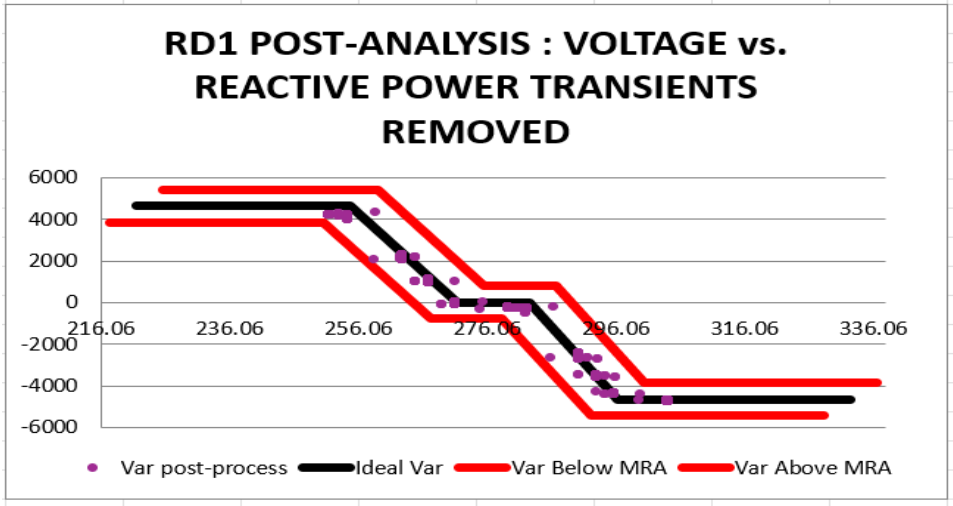
Automated Data Analysis – New Feature

- **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, QualityLogic has developed an automated data analysis as a new feature to the 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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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 for all Management tests
- **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
  - 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

Actual QL Test Results

Total Run time (Hours)	32.0166667

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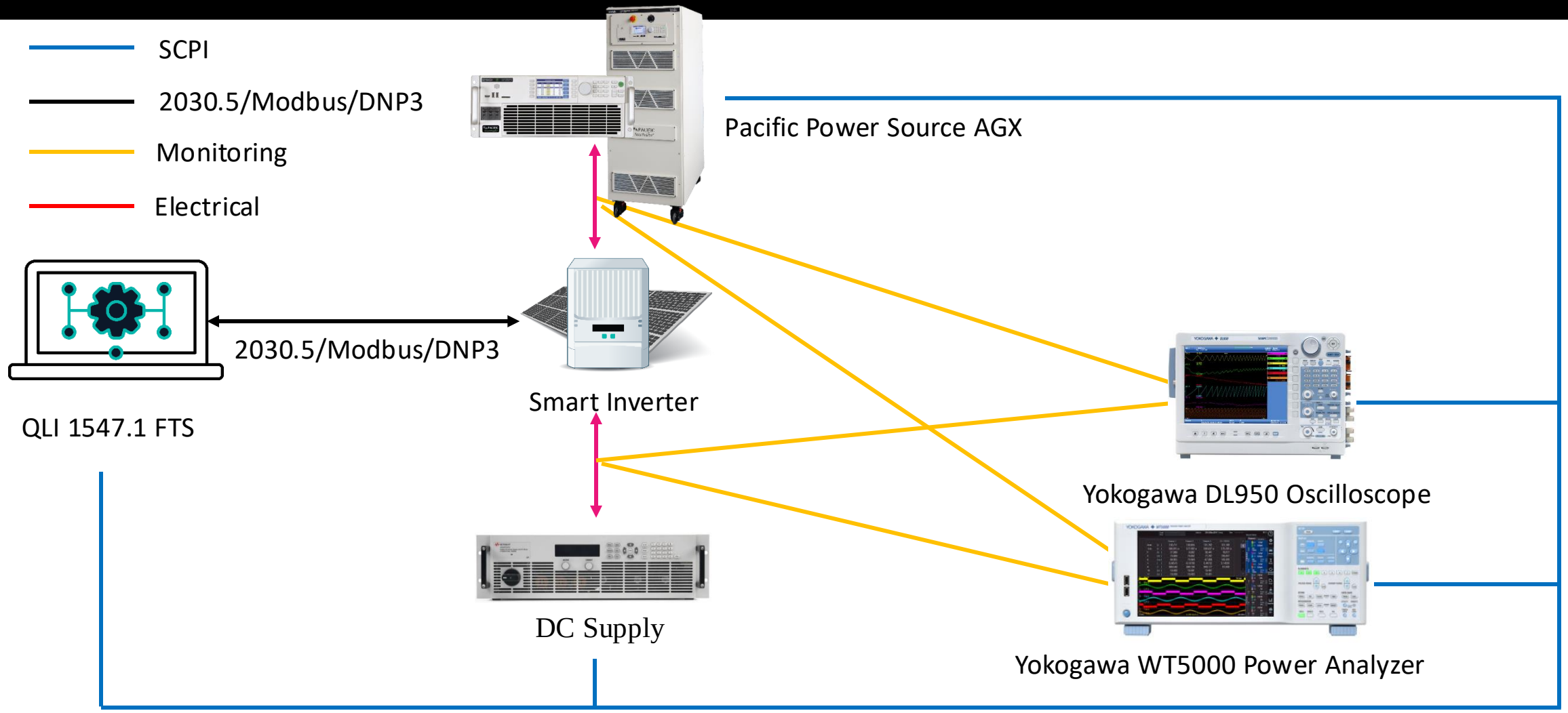
Demonstration of QualityLogic 1547.1 Test Tool

 | April 8, 2025

Demonstration Inverter Lab Overview



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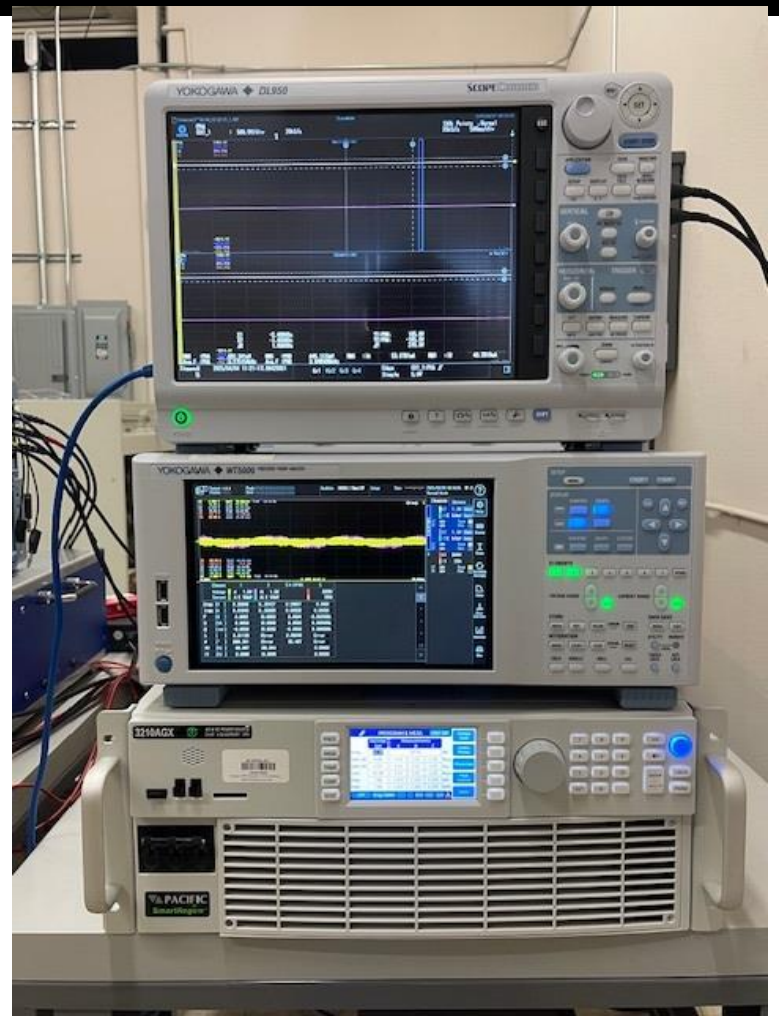
Lab Setup



Yokogawa DL950 Oscilloscope

Yokogawa WT5000 Power Analyzer

Pacific Power Source AGX

Function Under Test – High Voltage Must Trip

Table 13—DER response (shall trip) to abnormal voltages for DER of abnormal operating performance Category III (see Figure H.9)

Shall trip function	Shall trip—Category III			
	Default settings[a]		Ranges of allowable settings[b]	
	Voltage (p.u. of nominal voltage)	Clearing time (s)	Voltage (p.u. of nominal voltage)	Clearing time (s)
OV2	1.20	0.16	fixed at 1.20	fixed at 0.16
OV1	1.10	13.0	1.10–1.20	1.0–13.0
UV1	0.88	21.0	0.0–0.88	21.0–50.0
UV2	0.50	2.0	0.0–0.50	2.0–21.0

5.4.2.2 Procedure

This procedure uses the step function defined in A.3. For these tests, voltage is substituted for the variable *P* as indicated in the procedures defined in Annex A.

a) Connect the EUT according to the instructions and specifications provided by the manufacturer.

b) Set all source parameters to the nominal operating conditions for the EUT.

c) Set (or verify) all EUT parameters to the nominal operating settings. If the overvoltage setting is adjustable, set the EUT to the minimum overvoltage setting, but no less than the nominal voltage plus twice the *minimum required accuracy* for voltage.

d) Set the trip time setting to the minimum.

e) Record applicable settings.

For single-phase units, adjust the applicable voltage to parameter starting point Pb, as defined in A.3, to a value greater than or equal to the setpoint value determined in step c) minus 200% of the MRA.[23] The source shall be held at this voltage for a period t_h.[24]

At the end of this period, initiate a step of the voltage to a level less than or equal to the setpoint value plus 200% of the MRA using the procedure specified in A.3. For *multiphase* units, adjust voltage on one phase using the values above. Verify that remaining phases are held at nominal ±0.02 p.u.

f) Record all voltage magnitudes when the unit trips.

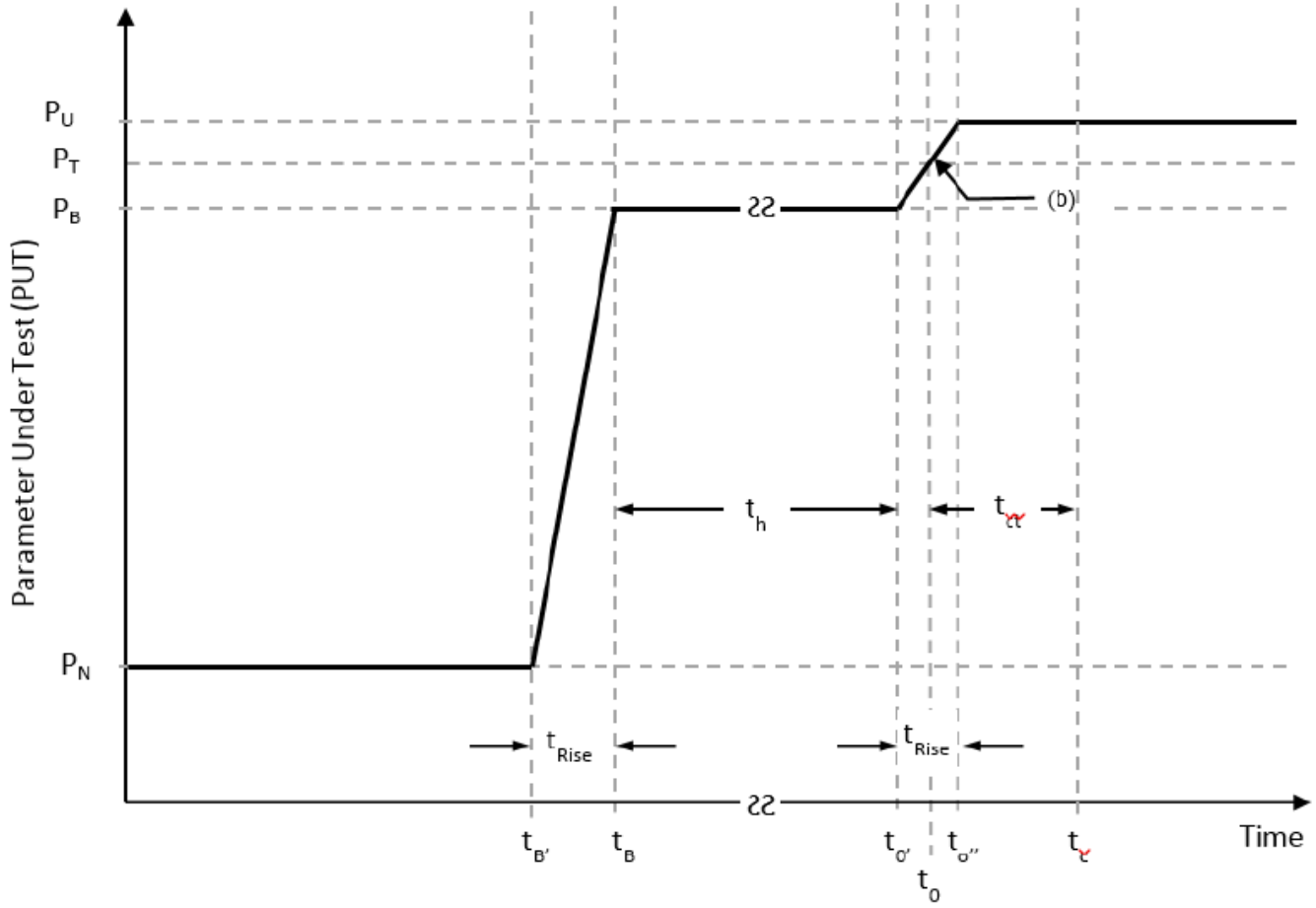
g) Repeat steps e) through f) four times for a total of five tests.

h) For *multiphase* units, repeat steps e) through g) for the applicable voltage on each phase or phase pair individually, and all phases simultaneously.

i) If the trip magnitude is adjustable, repeat steps e) through h) at the maximum of the range.

j) Set the trip time setting to the maximum and repeat steps e) through i).

k) Repeat steps c) through k) for each overvoltage operating trip region.



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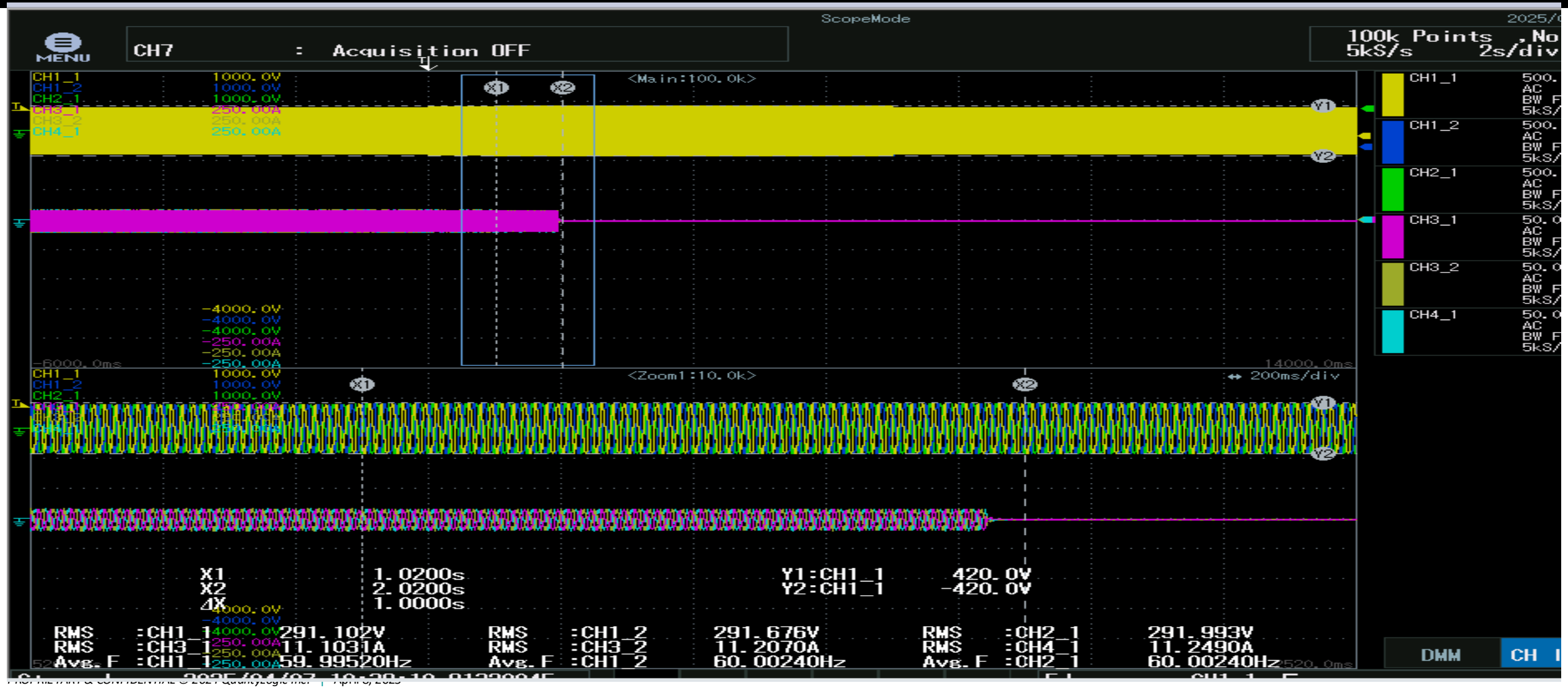
Live Testing Results



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Over 50 Years

Industry Leading AC & DC Test Solutions

- **Regenerative Grid Simulators**
- **AC & DC Power Sources**
- **AC & DC Electronic Loads**
- **EMC Test Systems**
- **Custom System Integration**

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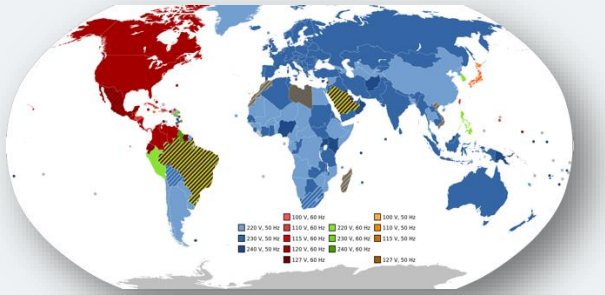
Test & Simulate Applications Across the Microgrid

Solar ESS Wind EV & V2G Generator

AC-DC or DC-AC Inverter

Utility Grid

Facility/Load



Test to Global Standards

Examples:

- UL 1741SA, IEEE 1547.1
- IEC 62116; IEC 61000-4-11, 4-13, 4-14, 4-28
- Europe EN50438, Germany VDE026-1-1
- International IEC61727, etc.

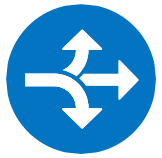
10 Key Considerations for Selecting a Grid Simulator

Modular & Scalable Power
Get what you need now, flexibility to scale later

Easy Set-up and Reconfiguration
Not a fixed solution

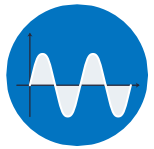
Widest Voltage Range
Test broad range of systems with a single unit

Extra Current Availability
No over or under sizing AC Source. Get more current at lower voltage



Multi-Channel Flexibility & Mixed Modes
Test AC and DC; different operation modes on separate channels

Built-in Safety
Full galvanic isolation provides added safety and reduces safety risks.



Load Option
Eliminates need for additional equipment

Advanced Programmability
Easily create, edit and run test sequences

Smart Controller
Saves time and increases productivity

Ease of Use
Multiple control options, smart design simplifies test

Regenerative Grid Simulator Overview

AGX or RGS Series

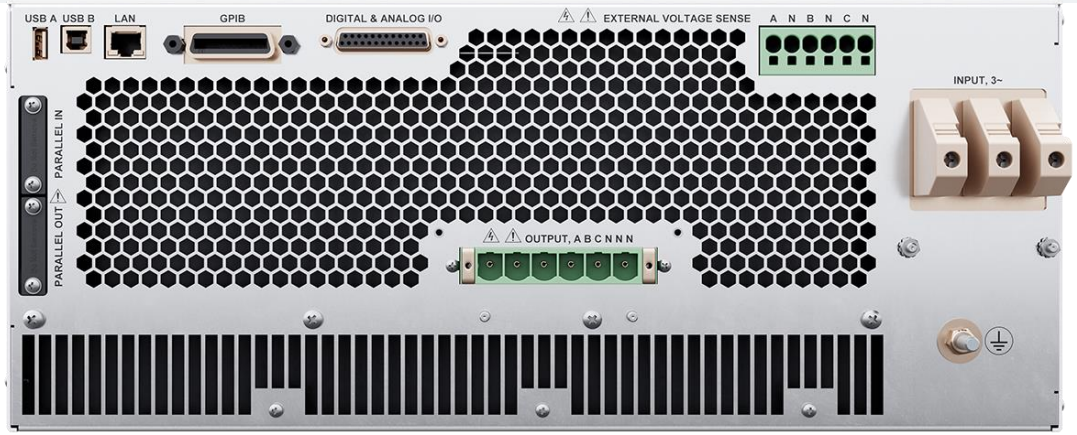
- Up to 21kW in 4U
- Parallel up to 252kW
- System configurations up to 756kW

AZX or GSZ Series

- 30, 45, 55kW;
  Parallel cabinets up to 550kW
- System configurations 1.1MW+

Key Advantages

- ✓ Modular, Scalable Power
- ✓ Widest Operating Envelope
- ✓ Exceptionally **High AC Current**
- ✓ Full Galvanic Isolation, Built in Safety
- ✓ Harmonics & Inter-harmonics
- ✓ Unique 6 Form Mix Modes Configuration
- ✓ SmartSource Suite Remote Control



Multiple Control Interfaces Available

- LAN
- GPIB
- USB
- ModBus
- RS232

LabVIEW

QualityLogic

GPIB RS232 USB UNIVERSAL SERIAL BUS LAN

Unique 6 Form Configuration for Ultimate Testing Flexibility

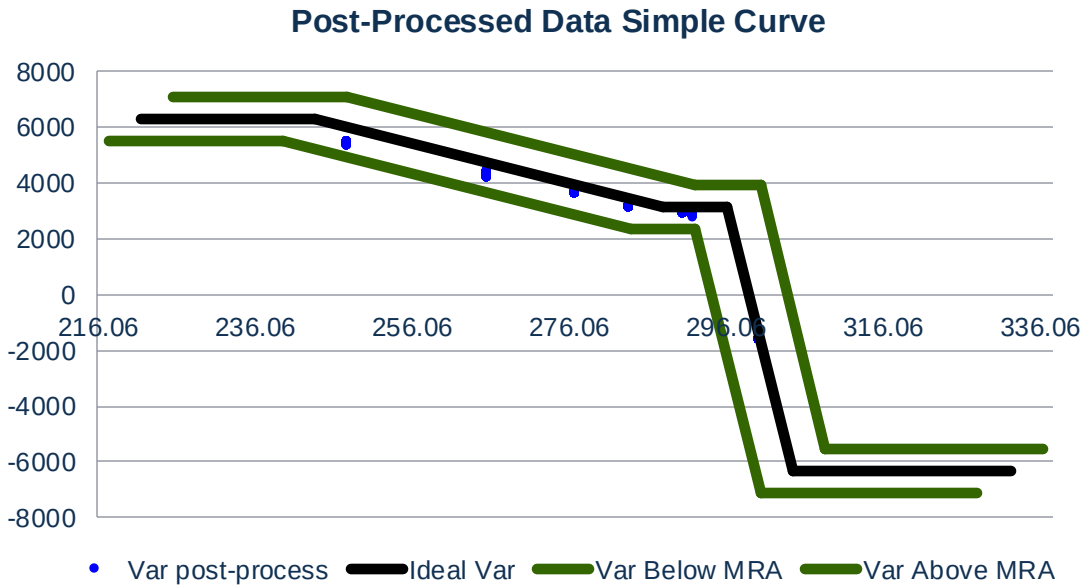
Multiple Output Modes

- Test AC or DC in Source or Load Mode *Simultaneously*
- Mix and Match Operation Modes on Separate Channels (Source or Load)
- Beyond just Single, Split and Three-Phase Modes

	Phase A	Phase B	Phase C
Form 1	Single Phase		
Form 2	Split Phase		
Form 3	Three Phase		
Form 4	Single Phase	Single Phase	
Form 5	Single Phase	Single Phase	Single Phase
Form 6	Split Phase		Single Phase

Test Broad Range of Grid-Tied Products

Simplify Compliance Testing to Global Standards



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Enables Test Automation

- High Performance Grid Simulator with Wide Operating Envelope
- Fast Transients with Precise Timing
- Ultimate Flexible Configuration with Mix Modes
- Grid simulator, DC/AC supply product lines

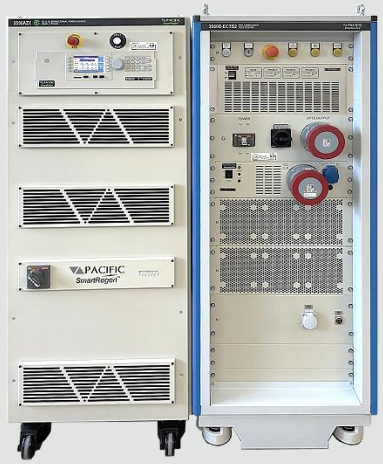
Drives IEEE 1547 Test Execution

- End to end instrumented test execution – from DER communication, lab equipment control and automatic analysis for IEEE 1547 certification tests
- Integrated pass/fail criteria based on measurements
- Automated evaluation & event triggering

Comprehensive AC & DC Test Solutions

2-in-1 Grid Simulators & Optional Load Systems up to 1.1MW

EMC Testing: Emissions & Immunity



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 | April 8, 2025

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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
  - NEW: SunSpec Modbus Technical Workshop including explanation of common Modbus implementation issues
  - Available onsite or remote
- **QualityLogic IEEE 2030.5/CSIP/CSIP-Australia Certification Test Product and Multiday Technical Workshop – click this link**
  - Only approved certification test tool for CSIP
  - Over 10 years of IEEE 2030.5 experience and contribution

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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**
- **Introduction to Pacific Power product line**
- **Survey**
- **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 info@qualitylogic.com for any further questions**