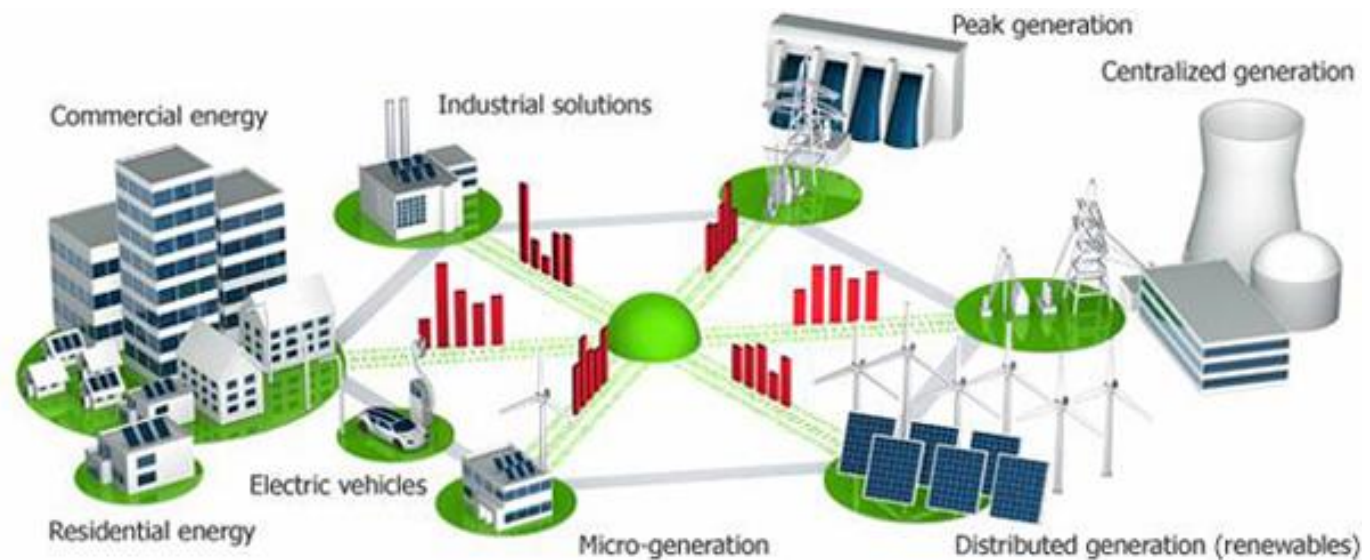


Micro Grids – Test & Compliance Challenges for Distributed Energy Resource (DER) Manufacturers

March 2017

Mike Hawes

R&D Planning Manager
Keysight Technologies
Automotive and Energy Solutions

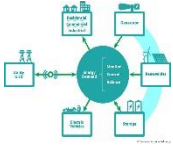


Biography

Currently Mike is the Automotive & Energy Solutions Planning Manager for Keysight Technologies, Inc. He is responsible for developing Keysight's roadmap for automotive and energy test solutions in the Smart Grid, HEV/EV, Battery and Power Semiconductor segments of the market. Mike has work for Hewlett Packard, Agilent Technologies and Keysight Technologies for over 30 years, with extensive experience in automotive R&D and manufacturing test solutions. He also has had extensive experience in Asia, living in Hong Kong in 2000 and 2001. Mike has a Bachelor's Degree in Electrical Engineering from Washington State University (1982) and a Master Degree in Biomedical Engineers from Colorado State University (2012). Mike currently lives in Fort Collins Colorado.



Agenda



- Microgrids & Distributed Energy Resources (DER)



- Test Challenges of Grid-Connected DERs & other associated standards



- DER Test Solutions

What is Distributed Generation

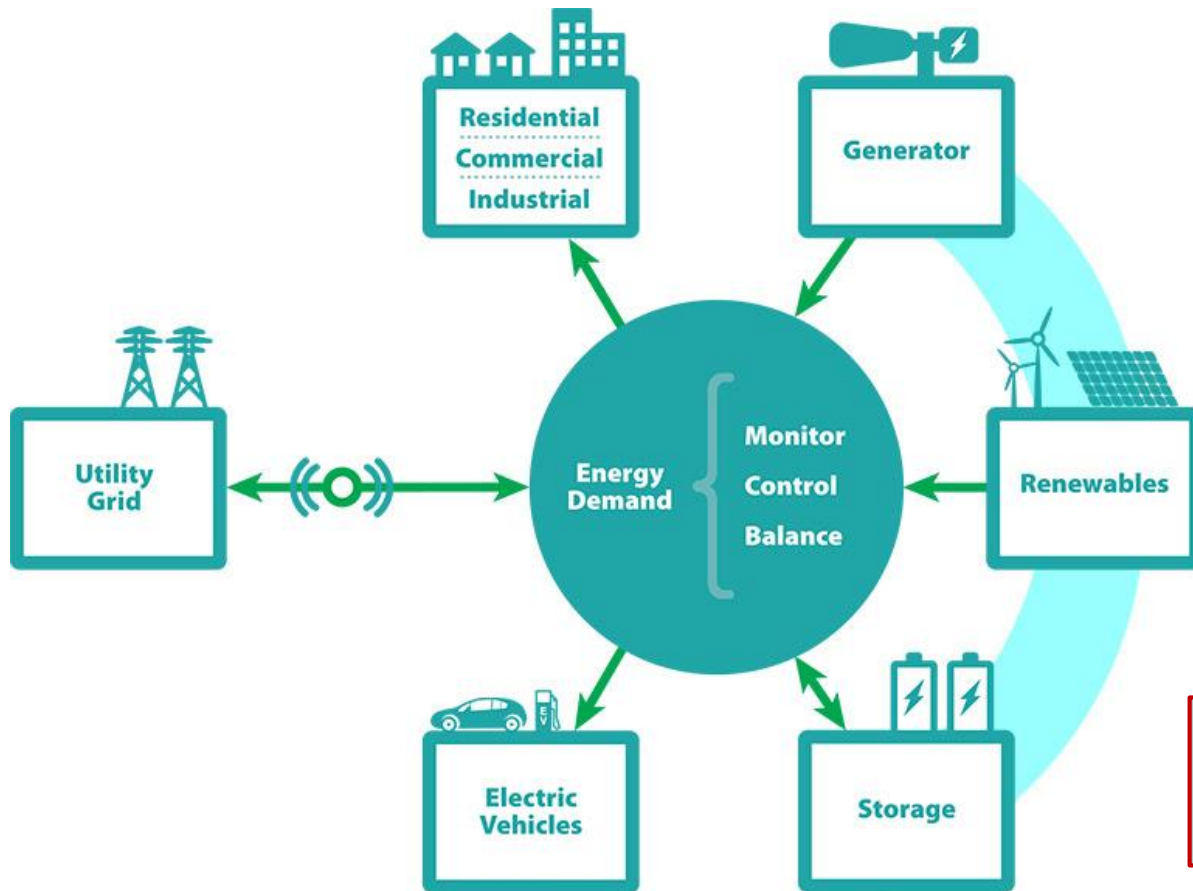
The Smart Grid is Quickly Taking Shape



- Utilities are moving from Centralized Generation to Distributed Generation
- Solar, Wind, Grid Connected Battery Storage, EVs, Microgrids, HEMS, BEMS
- Energy Quality and Grid Management complexity is increasing → Smart Grid

Microgrids

“A microgrid is a group of interconnected loads and distributed energy resources (DERs) within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.” – US DOE definition



Benefits

- Increased power reliability & self-sufficiency
- Cyber & physical security
- Reduces utility costs
- Reduces carbon emissions
- Reduces transmission and distribution losses
- Renewable or Non-renewable operation
- Supports grid PF balancing

**WW Market Size:
Projected \$40B by 2020**

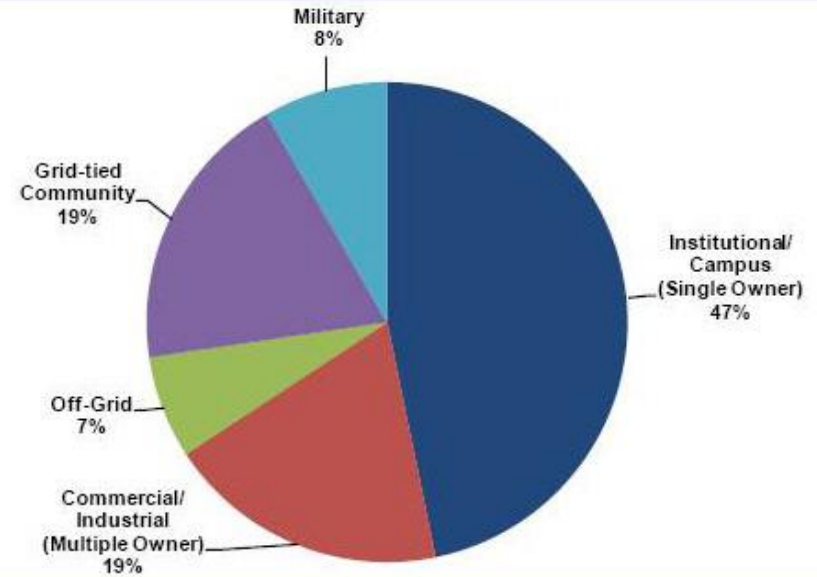
Source: Navigant Research

Microgrids

Segmentation

- Residential: HEMS
- Commercial/Industrial facilities: BEMS, FEMS
- Institutional
 - Hospitals (Univ. of Illinois Hospital)
 - Universities (Hangzhou Dianzi University, University of Sand Diego)
 - Jails (Santa Rita, CA)
- Data Centers (Arizona Public Service)
- Military Bases or remote operations (Fort Carson, CO)
- Remote “off-grid” communities (Huatacondo, Chile; Hartley Bay, British Columbia)
- Municipalities (Sendai, Japan)

Market Sector Revenue Breakdown, North America: 2015

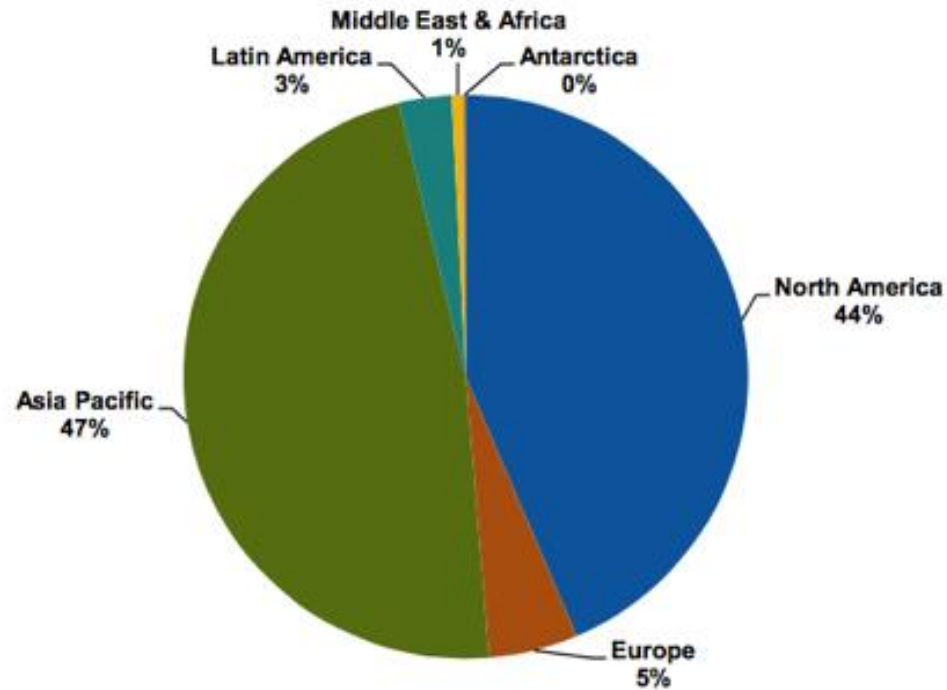


(Source: Pike Research)

Microgrids

Regional View

Chart 1.1 Total Microgrid Capacity Market Share by Region, World Markets: 2Q 2015



(Source: Navigant Research)

- China planning to add 4GW of Microgrids in the next 5 years

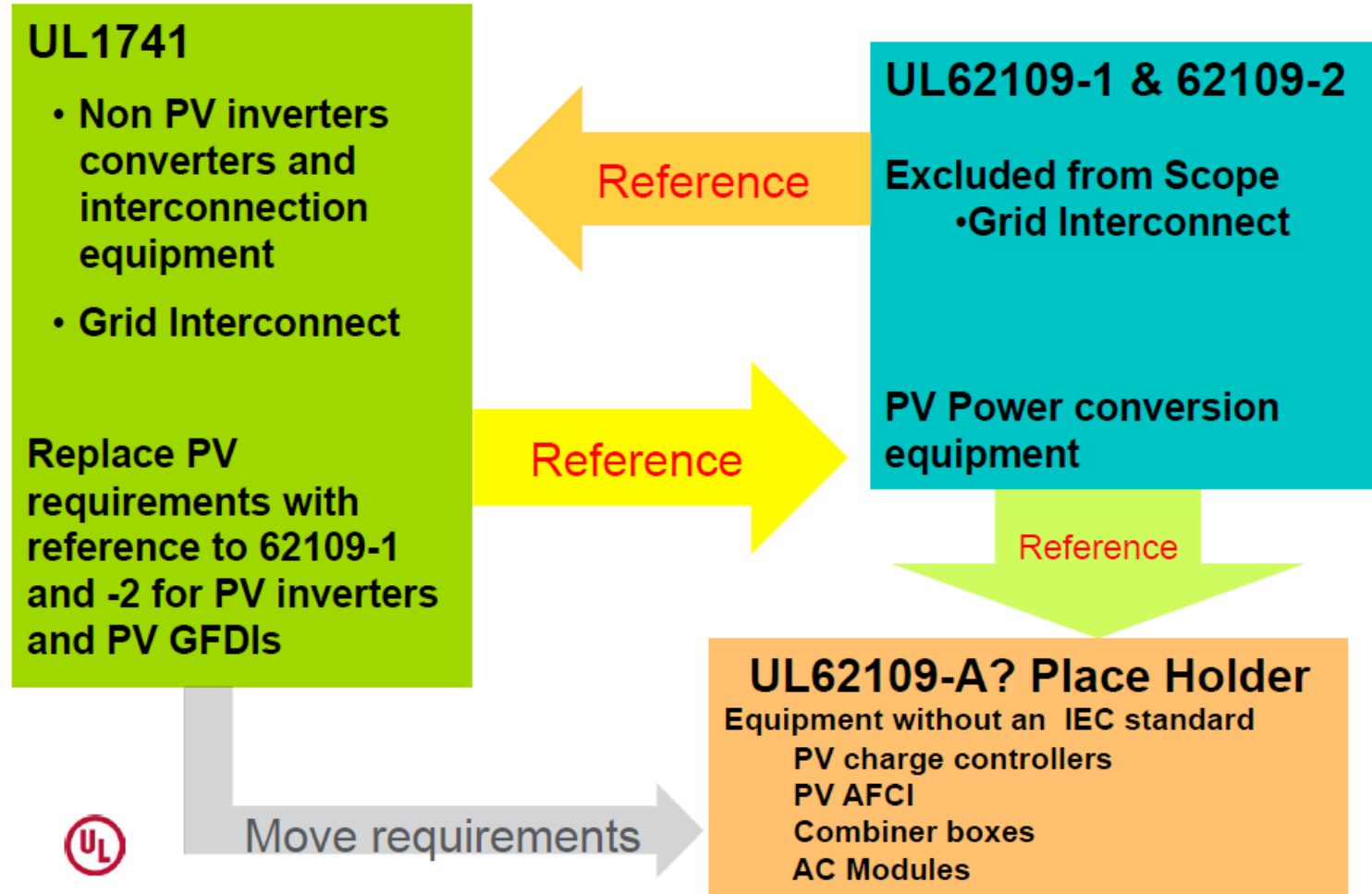
Stringent Testing for Grid Connected Devices

Region and Utility specific standards/regulations

	Europe	IEC	North America	China	Others
Safety Standards	Low Voltage Directive: 2006/95/EC EN 62109-1/2 PV Inverters EN 50178 Wind & Fuel Cells EN 60730-1 FS CE Mark	IEC 62109-1 IEC 62109-2	US: UL 1741 UL 62109-1 IEEE 1547 NEC 2014 / 2017 UL 1699B (AFCI) Canada: C22.2 / 107.1	Golden Sun	Japan: JET PVm Technical Standard for electrical equipment Australia: AS 3100
EMC Requirements	EMC Directive 2004/108: EN 61000-3-2/12 EN 61000-6-1/2/3/4 EN 61000-3-3/11 EN 55011	IEC 61000 Series CISPR11	IEEE 1547 / 1 IEEE C37.90 IEEE C62.41.2 IEEE C62.45 IEEE C90.2 FCC Part 15		
Performance Standards	EN 3744 EN3746 (noise) EN 50530 Inverter efficiency EN 61683 Conversion efficiency	ISO 3744 ISO 3746 IEC 61683	ANSI C12.1 Sunspec Inverter Control California: CEC efficiency New Jersey - efficiency	Golden Sun	India: IEC 61683 IEC 60068-2
Utility Requirements	EN 50438, EN 62116, EN 61727 Germany: BDEW, VDE 0124-100, VDE-AR-N 4105, VDE 0126-1 Italy: CEI 0-21, CEI 0-16, ENEL UK: G59/3, G83/2 Spain: RD1699/RD661	IEC 61727 IEC 62116	IEC 1547/1/A CA – Rule 21 1547/Grid Support CSA C22.2 107.1 UL 1741 SA Advanced inverter testing for CA Rule 21 and other SRD's	CGC/GF004:2011 CNCA/CTA 0004-2009A NB/T32004-2013	Australia: AS 4777.2/3 Japan: JEAC 9701 Korea: PV certification program Brazil: ABNT NBR 16149 ABNT NBR 16150 ABNT NBR IEC 62116 South Africa: SAGC
Software	EN 60730-1	IEC 60730-1	UL 1998 UL 60730-1 UL 61508		

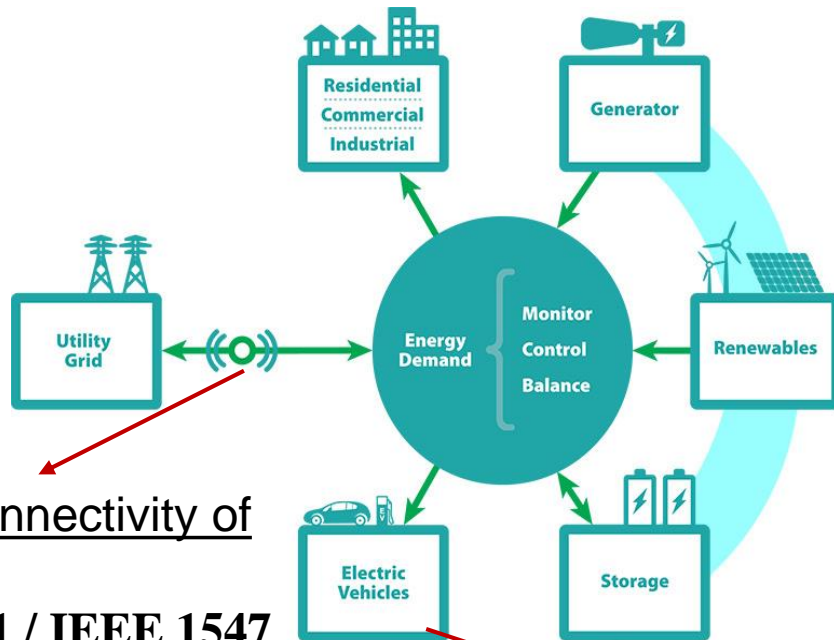
Consolidation and Alignment of Standards

UL1741 & UL 62109



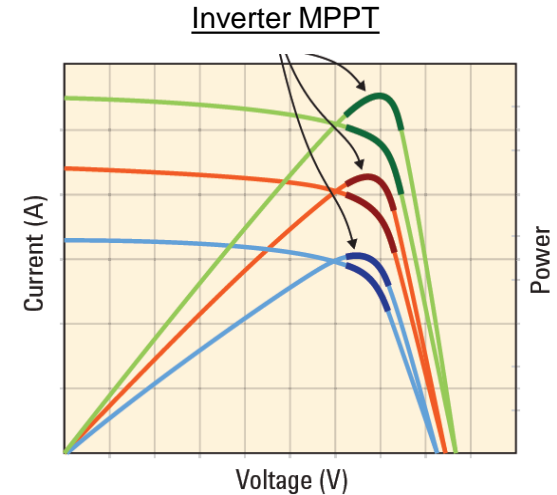
Source: Underwriters Laboratories Inc.– ‘Inverter Standards and Changes’: Author: Tim Zgonena, UL LLC, October 23, 2014

Examples of Test Requirements/Standards



2. Maximum Power Point Tracking

- **EN 50530**



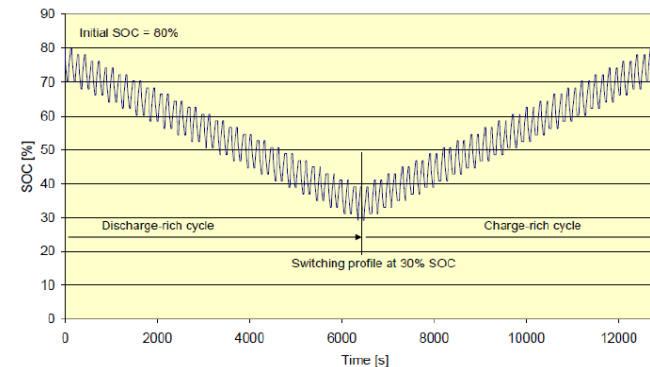
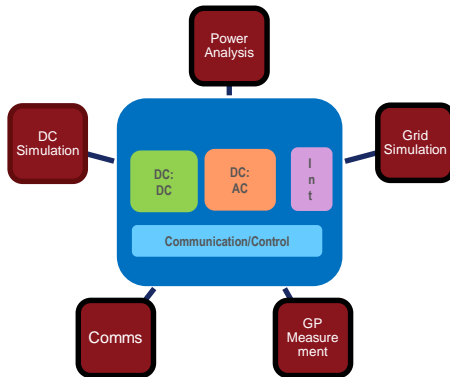
1. Grid Connectivity of DER

- **UL 1741 / IEEE 1547**

© Center for Sustainable Energy

3. Battery Characterization for Traction Batteries in EVs

- **ISO 12405 & IEC 62660**

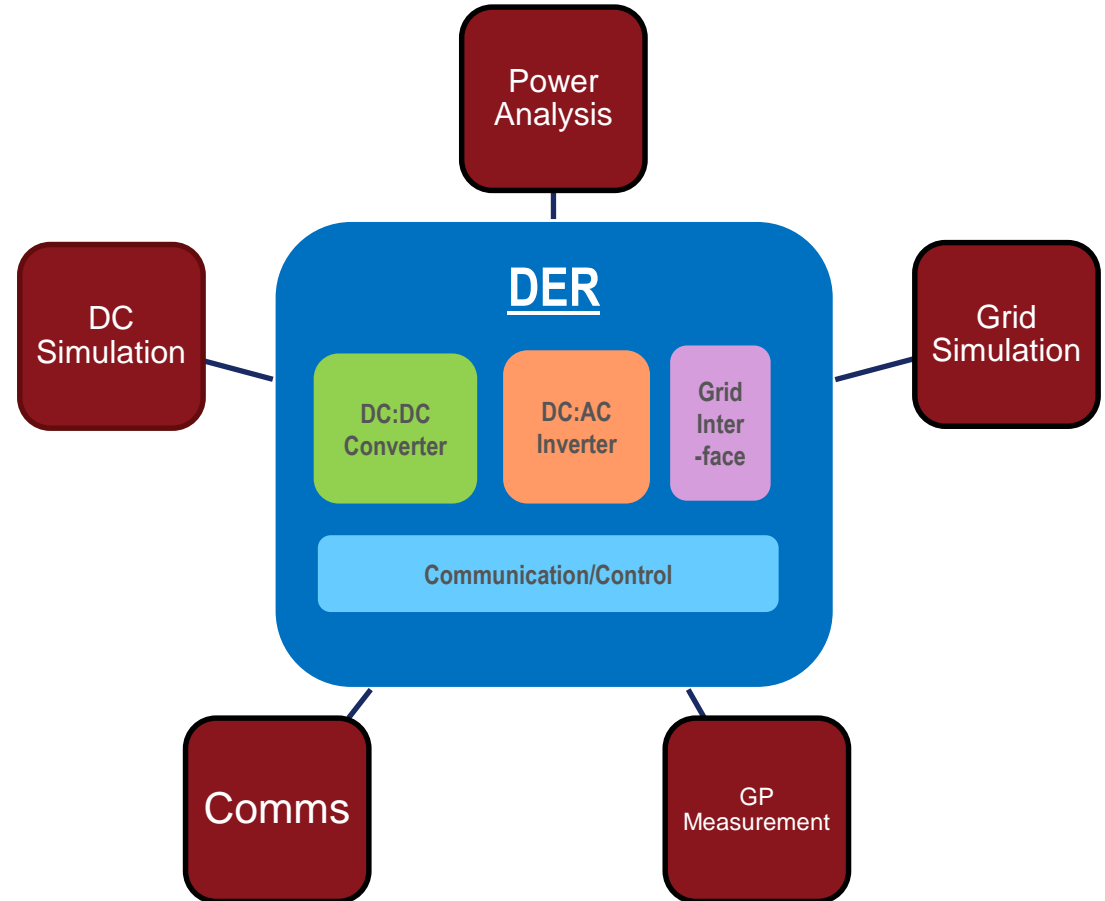


Grid Connectivity and Performance Test Requirements

UL 1741 / IEEE 1547

Tests

- Temperature Test (-40°C - 50°C)
- Dielectric Strength
- Output Characteristics
- Voltage/Frequency Variation
- Voltage/Frequency Disconnect Characteristics
- Reconnection to Grid
- Open Phase Test
- Anti-islanding Test
- Loss of Control
- Abnormal Operation
- Load Transfer Test
- Ground Impedance Test



Test Challenge – Months to complete Certification

Grid Support Utility Interactive Inverters/Converters

New Test Requirements with UL 1741 Supplement A (SA)

UL 1741 SA published September 2016; different from “utility interactive inverters”

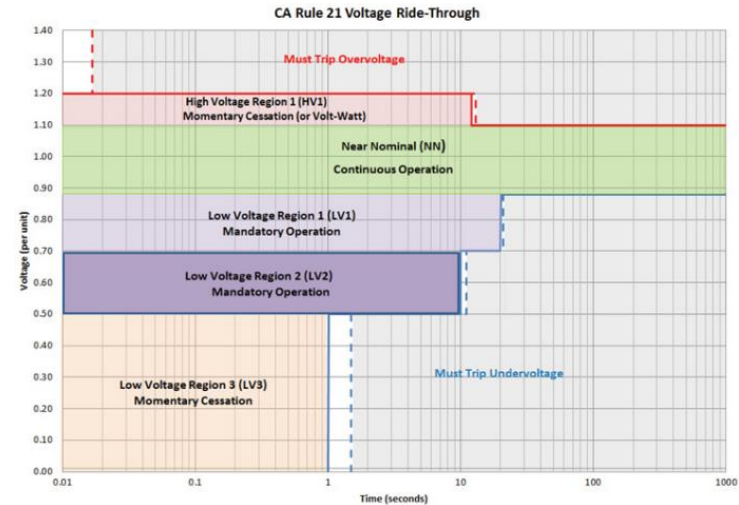
Certification mandatory in CA (Rule 21) & HI (Rule 14H) by September 2017

Key Focuses for Grid Support:

- “Must not trip” requirements during grid excursions
- Provide frequency stability and voltage regulation
- Enable momentary cessation w/automatic return-to-service

Tests:

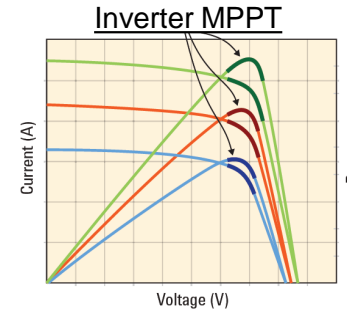
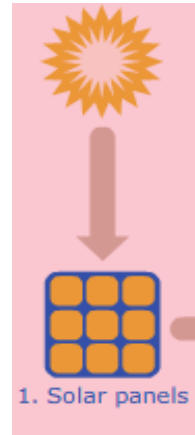
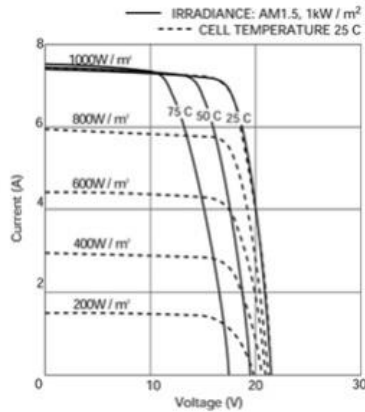
- Anti-Islanding w/Grid Support Enabled
- Low and High Voltage Ride-Through
- Low and High Frequency Ride-Through
- Normal and Soft-Start Ramp Rate Response
- Operation at Specified Power Factor
- Volt/Var Mode; Reactive Power Response
- OPTIONAL: Grid Frequency Support (Frequency-Watt Function)
- OPTIONAL: Grid Voltage Support (Volt-Watt Function)



Test Challenges:
Test parameters vary by SRD
Testing w/o automation takes >2mos

Maximum Power Point Tracking (MPPT) Simulation

EN 50530

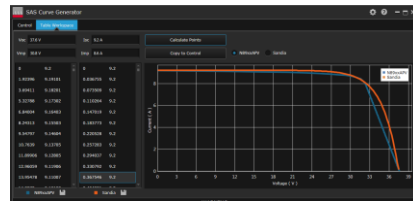


Solution:

- N8900APV Photovoltaic Array Simulator (Up to 150kW)
- Automated EN 50530 Testing with licensed software

Test Challenge – Simulating dynamic temperature and irradiance panel conditions

Emulate changing environmental conditions in a controlled Lab



PV Array Simulator

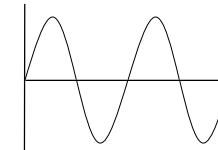
DC



PV Solar Inverter

DUT

AC

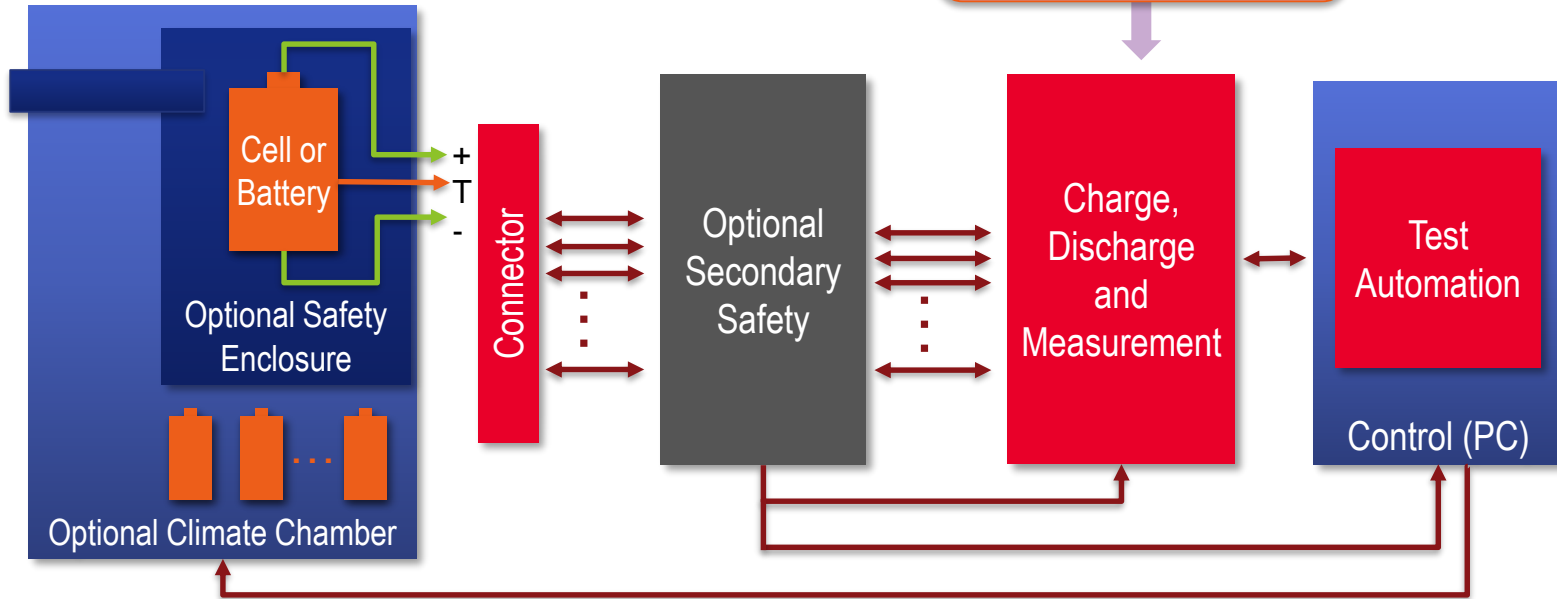


AC Power Grid or AC Load

Li-Ion Traction Cell and Battery Characterization

ISO 12405 & IEC 62660

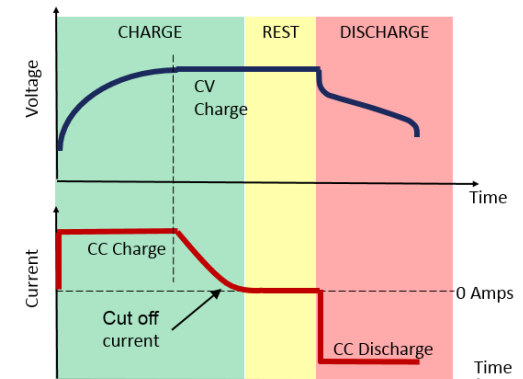
Scalable
Number of channels
Voltage, current per channel



Characterization Tests

- Energy and capacity at room temperature
- Energy and capacity at different temperature and discharge rates
- Power and Internal Resistance
- No-load SOC loss
- SOC loss at storage
- Cranking power at low/high temperature
- Energy Efficiency
- Cycle Life

Test Challenge – Safety for
Li-Ion cell combustion



Summary of Test Challenges for DERs

Test Challenge – Complexity of different requirements for Regions/Utilities

Test Challenge – Continually evolving standards

Test Challenge – Months to complete Certification

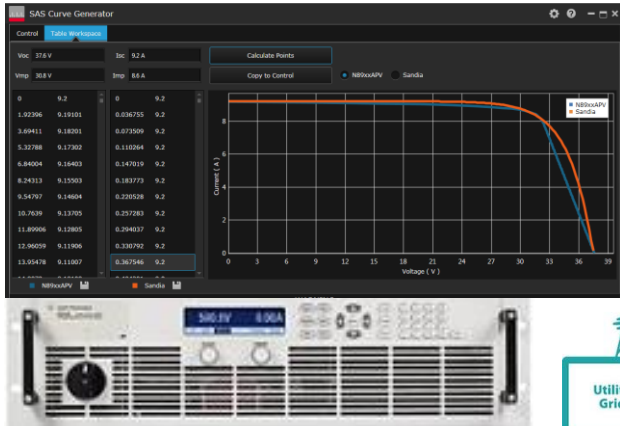
Test Challenge – Test parameters vary by SRD

Test Challenge – Simulating dynamic temperature and irradiance panel conditions

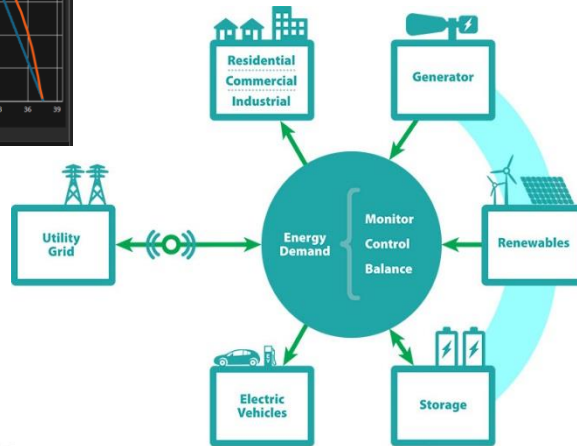
Test Challenge – Safety for Li-Ion cell combustion

DER Test Solutions

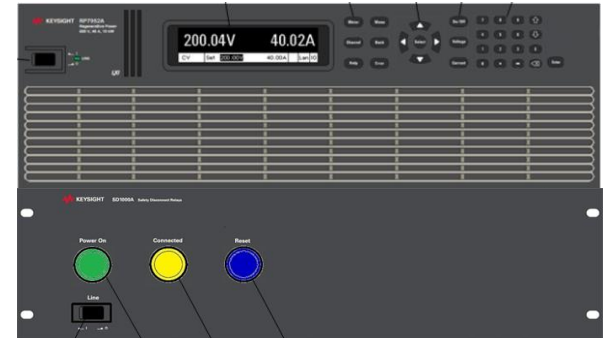
1500V PV Array Simulator (N8937APV) – EN 50530



Award Winning IntegraVision Power Analyzer (PA2200A)



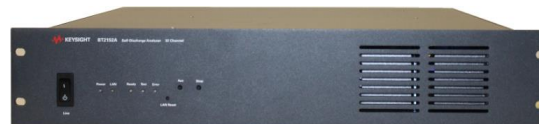
HEV/EV OBC & DC:DC Converter Test Solution with integrated Safety Disconnect



Cell Forming Solution



Cell Self Discharge Solution

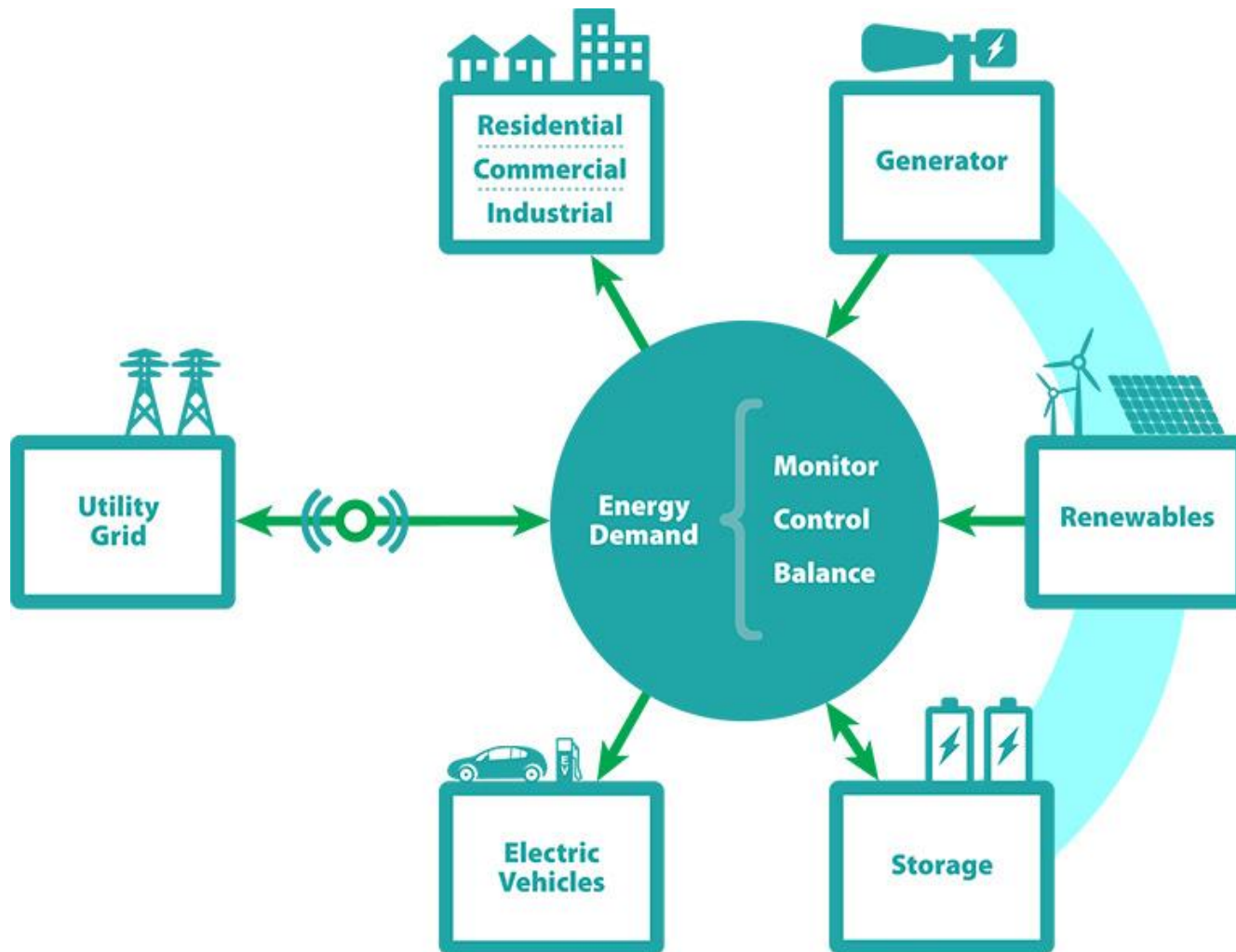


Cell Characterization Solution



[url: www.keysight.com](http://www.keysight.com)

Questions



© Center for Sustainable Energy