

Advancements in the Integration of PV and Energy Storage Systems

APEC March 2016



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Principal Engineer

Distributed Energy Resources
Equipment

UL LLC

WE ARE A GLOBAL FORCE FOR GOOD

22 BILLION UL MARKS
APPEAR ON
PRODUCTS
ANNUALLY

**700
MILLION**
CONSUMERS
WERE REACHED
BY UL IN ASIA,
EUROPE
AND NORTH
AMERICA



MORE THAN
580K
FOLLOW-UP
INSPECTION
VISITS WERE
CONDUCTED
BY UL

1,485
CURRENT STANDARDS
FOR SAFETY PUBLISHED
BY UL

20,268
TYPES OF PRODUCTS
EVALUATED BY UL

69,795
MANUFACTURERS
PRODUCING UL
CERTIFIED PRODUCTS

90,304
PRODUCT EVALUATIONS
CONDUCTED BY UL

10,715 EMPLOYEES



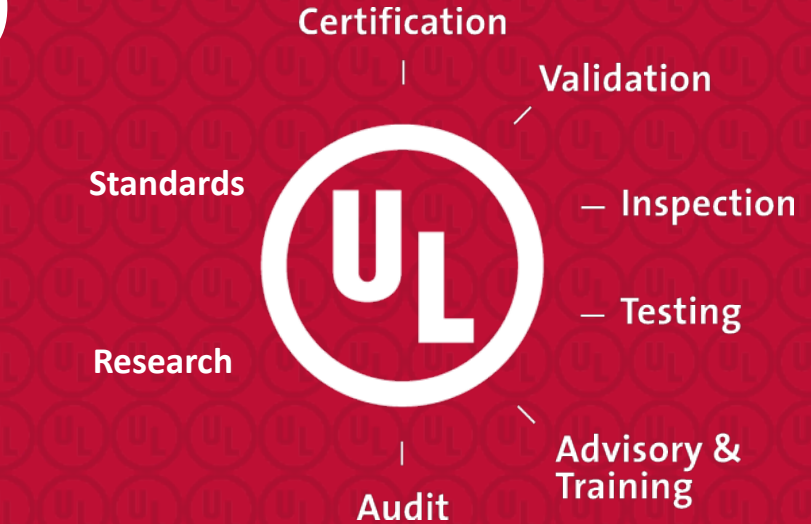
152
LABORATORIES TESTING
& CERTIFICATION
FACILITIES



SERVICING
CUSTOMERS IN



106
COUNTRIES



Where we are



North America

- Canada
- United States

Latin America

- Argentina
- Brazil
- Mexico

Europe

- Denmark
- France
- Germany
- Italy
- Netherlands
- Poland
- Spain
- Sweden
- Switzerland
- Turkey
- United Kingdom

Africa

- South Africa
- Tunisia

Asia

- Australia
- Bangladesh
- Greater China
- India
- Japan
- Malaysia
- New Zealand
- Philippines
- Singapore
- South Korea
- Thailand
- UAE
- Viet Nam



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Overview

Short Description: To enable the integration of PV and Energy Storage Systems – standards, codes and deployment guidelines must improve and advance in parallel with technological innovation and increased demand for cleaner energy.

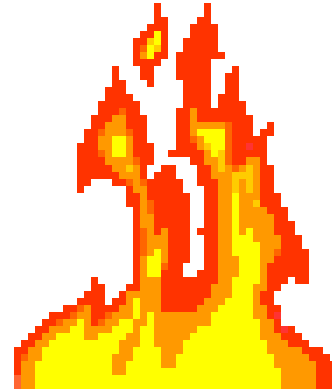
In this session we will address:

- Safety, performance, and interoperability considerations
- Interconnection Standards and Certifications, including IEEE 1547 amendments and revisions, (Long Term)
- Advanced inverter test protocols for California Rule 21 grid interconnection and UL 1741 SA supplement, (Short Term)
- Energy Storage standards including UL9540
- Regulatory overview



Most Traditional UL Equipment Safety Standards Evaluate

Functionality
Electrical Hazards
Fire Hazards
Mechanical Hazards
Verification of electrical ratings



VOLTS

AMPS

Hz

These hazards are evaluated and tested under normal and foreseeable abnormal conditions



Renewable Energy Standards for Power Conversion and Grid Interconnection

USA

- UL1741
- UL62109
 - UL62109-1 General Published
 - UL62109-2 Inverter specific in process (Q3 2015)
- IEEE 1547 and IEEE 1547.1

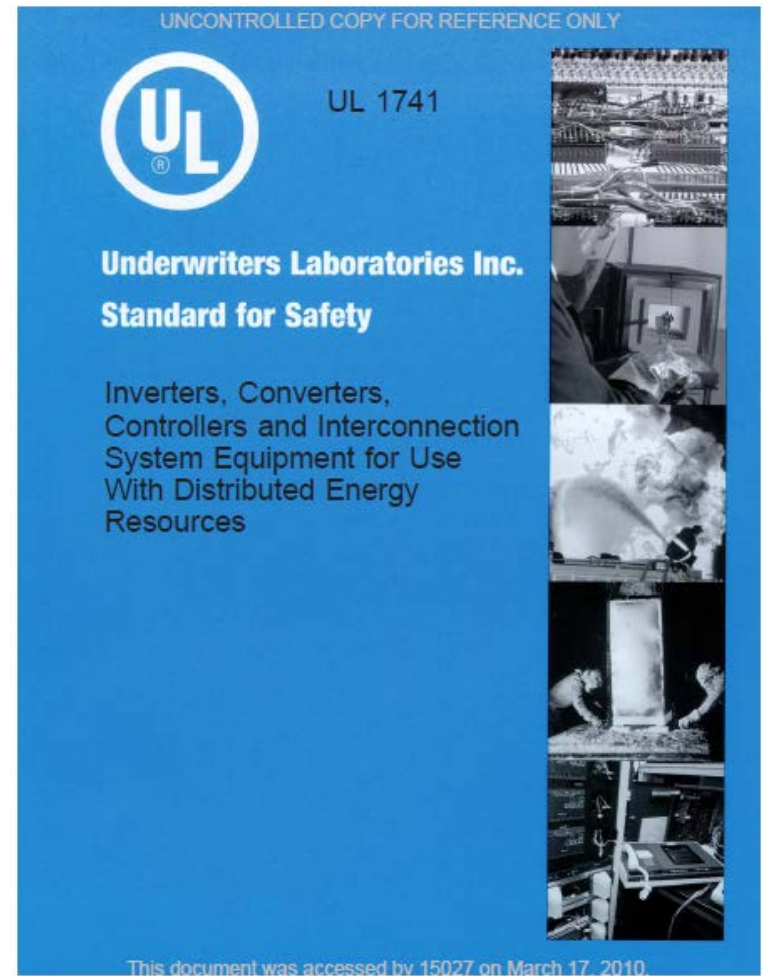
Canada

- CSA C22.2 No. 107.1 (present)
- CSA 62109 (future)
 - Allows for use of IEEE 1547 and 1547.1



UL 1741 Covers Power Conversion and Protection Equipment for the Following Types of DR products:

Photovoltaics, PV
Fuel Cells
Micro-turbines
Wind and Hydro Turbines
Engine Generator Set
Utility Interactive Inverters
Stand Alone Inverters
Multi-Mode Inverters
AC Modules
Charge Controllers
PV Balance of Systems,
Combiner Boxes, GFDIs, etc





IEC 62109-1

Edition 1.0 2010-04

INTERNATIONAL STANDARD



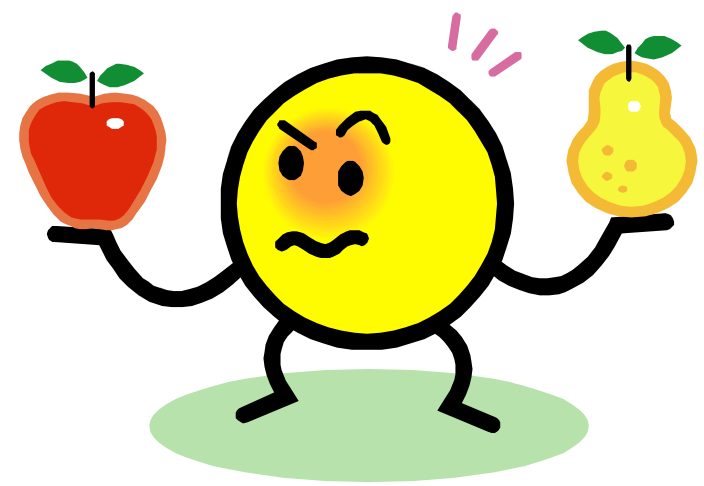
UL 62109-1

Safety of power converters for use in photovoltaic power systems –
Part 1: General requirements

STANDARD FOR SAFETY

Safety of power converters for use in photovoltaic
power systems – Part 1: General requirements

IEC 62109 and UL1741



The scope of UL 1741 includes sections that are not published in IEC 62109, such as:

- Requirements for other renewable energy sources like fuel cells, rotating machines, etc,
- Grid interconnection systems equipment.
- We will have both UL1741 and UL62109 standards and the STP will determine the best way to address interactions and overlaps between both.



Utility Grid Compatibility and Interconnection



IEEE 1547 – Interconnecting Distributed Resources with Electric Power Systems, was written to address major electric utility concerns: utility worker safety, user safety, equipment safety, power reliability and power quality.



Grid Interconnection Standards

IEEE 1547 Interconnection System Requirements

- Voltage Regulation
- Grounding
- Disconnects
- Monitoring
- Islanding

IEEE 1547.1

•Interconnection System Testing

- Temperature Stability
- Response to Abnormal Voltage
- Response to Abnormal Frequency
- Synchronization
- Protection from EMI
- Surge Withstand
- Paralleling Device
- DC Injection
- Unintentional Islanding
- Reverse Power
- Open Phase
- Reconnect after disturbance
- Harmonics

UL 1741

Power Conversion and Interconnection Equip

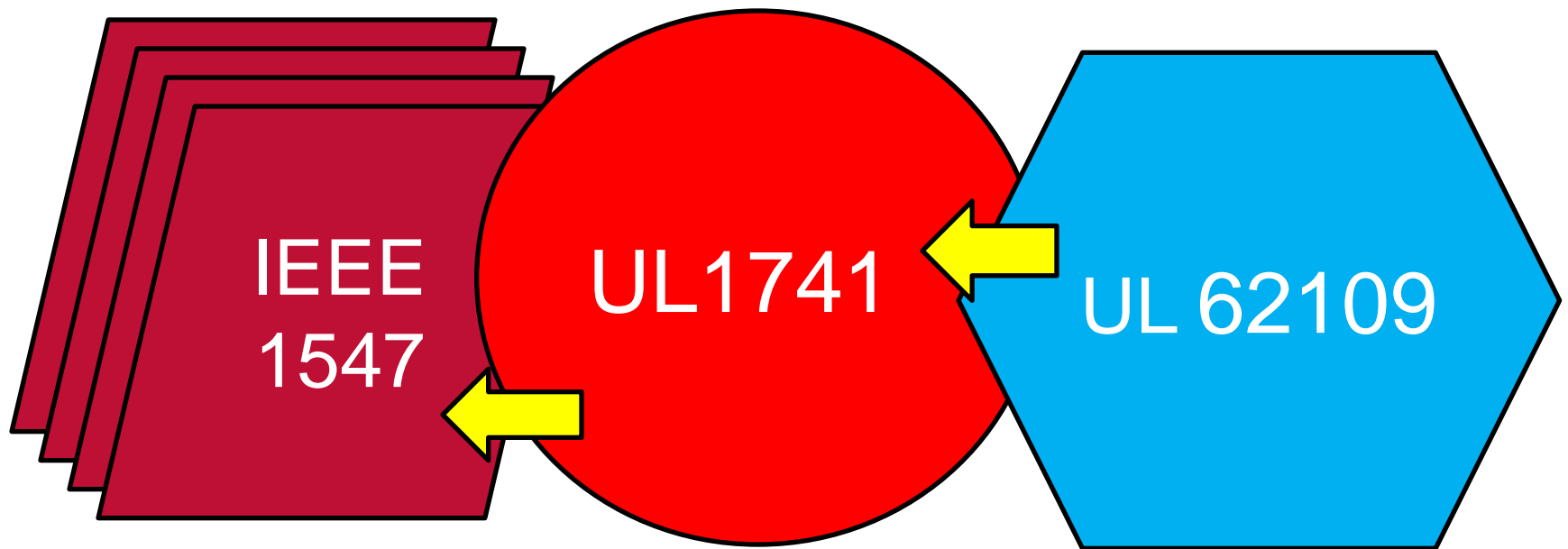
- Construction
- Testing normal and abnormal
- Protection against risks of injury to persons and connected equipment.
- Ratings, Markings and Instructions
- Specific DR Tests for specific technologies
- Production line testing
- Certifications address NEC and electric utility interconnection needs.

This linkage between UL1741 and IEEE 1547 established a set of standardized interconnection requirements and procedures that are being used to evaluate utility interconnected DG products for both electrical safety and utility grid interconnection to address the needs of Electrical AHJs and Utility Interconnection Engineers.

Note - These products work well for lower percentages of grid penetration.



Standards Interactions and Overlaps



Need for New Grid Support Inverter Requirements and Certifications

IEEE 1547A & 1547.1A
Short term fixes and expansion

CPUC Rule 21 Phases 1- 3

Ongoing IEEE 1547 and 1547.1 revisions

UL1741 SA - Grid Support Utility Interactive Supplement to “**bridge the gap**” until the new IEEE 1547 and IEEE 1547.1 Grid Support revisions are completed.

UL1741 New Supplement for Grid Support Utility Interactive Inverters

Excellent Task Group! – weekly meetings to
develop the UL1741 Supplement for >2yrs

- Inverter Industry
- Electric Utilities – CA, HI and AZ
- National Labs – SANDIA and NREL
- EPRI
- NRTLs / Test Labs



Draft is being formatted after addressing 429 STP
comments in preparation for a ballot in April 2016.



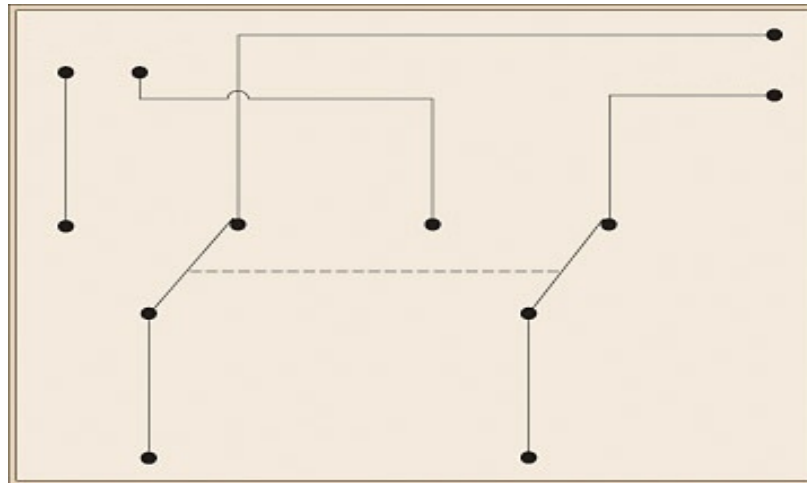
UL1741 New Supplement for Grid Support Utility Interactive Inverters

- Anti-Islanding
- L/HVRT
- L/HFRT
- Must Trip Test
- Normal Ramp Rate
- Soft-Start Ramp Rate
- Specified Power Factor
- Volt/Var Mode
- Other / Optional
- Frequency Watt
- Volt Watt



UL1741 Multi-Mode Task Group and Upcoming Microgrid Task Group

- UL is working with industry and California electric utilities to enhance the UL1741 and UL62109-2 requirements for multiple mode inverters.
- Make use of the IEEE 1547.1 Synchronization Tests.
- Need to better define how and when multi-mode products transition from grid support / ride through functionality to stand alone operation to supply critical local loads.
- A Microgrid task group is being formed to develop microgrid equipment requirements.



Need to Clearly Differentiate

The differences between utility interactive generation products:

- Utility Interactive
- Grid Support Utility Interactive
- Special Purpose Utility Interactive products

Clearly define product functions, ratings and requirement compliance within the product markings, ratings, manual, certification documentation and new certification categories.



UL1741SA Consensus Process



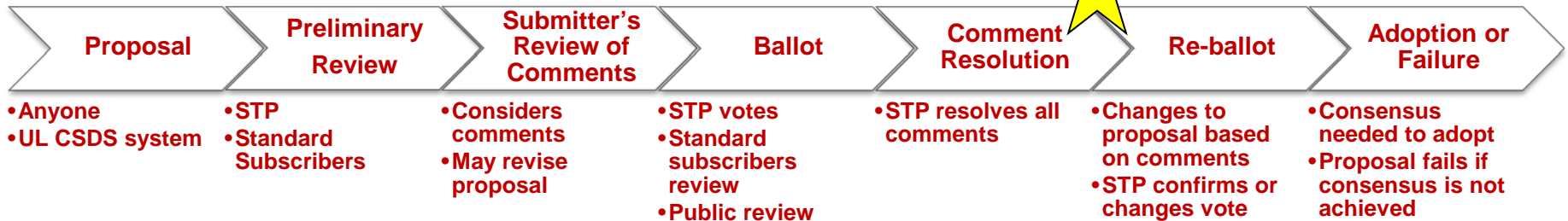
Standards Development Organization



Standards Technical Panel

- 26 Producers
- 5 Users
- 7 Government
- 7 AHJ
- 13 Supply chain
- 19 General
- 4 Testing & Stds

Draft is being formatted after addressing 429 STP comments in preparation for a 30 day re-ballot in April 2016.



Energy Storage Applications



Utility



Commercial



Residential

Energy Storage Codes and Standards



UL Safety Standards:

- ANSI UL 9540, Energy Storage Systems and Equipment (*under development*)
- ANSI UL 1973, Batteries for Use in Light Electric Rail (LER) and Stationary Applications
- UL 1974, Evaluation Of Batteries For Repurposing (*under development*)
- ANSI UL 1741, Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

IEC TC 120 Standards (*under development*):

- IEC CD 62934, Unit Parameters and Testing methods of Electrical Energy Storage (EES) Systems
- IEC CD 62935, Planning and Installation of Electrical Energy Storage Systems
- IEC CD 62936, Environmental issues of EES systems
- IEC CD 62937, Safety Considerations Related to the Installation of Grid Integrated Electrical Energy Storage (EES) Systems

Codes and Standards



IEEE C & S related to ES:

- IEEE 1679, Recommended Practice for the Characterization and Evaluation of Emerging Energy Storage Technologies in Stationary Applications
- IEEE 1547, Interconnecting Distributed Resources with Electric Power Systems
- IEEE P2030.2, Guide for the Interoperability of Energy Storage Systems Integrated with the Electric Power Infrastructure (under development)
- IEEE P2030.3, Standard for Test Procedures for Electric Energy Storage Equipment and Systems for Electric Power Systems Applications (under development)

NFPA C & S updates related to ES:

- NFPA 70, National Electrical Code (NEC), Article 706 (under development) addressing energy storage

Other committee documents:

- PNNL 22010, Protocol for Uniformly Measuring the Performance of Energy Storage Systems
- PNNL 23618, Inventory of Safety-related Codes and Standards for Energy Storage Systems
- PNNL 23578, Overview of Development and Deployment of Codes, Standards and Regulations Affecting Energy Storage System Safety in the United States

UL 9540 - Scope

Safety of energy storage systems:

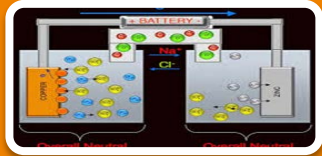
- Includes energy storage systems that are:
 - Standalone to provide energy for local loads
 - For use in utility-interactive applications in compliance with UL1741, IEEE 1547 and IEEE 1547.1 or
 - Other applications intended to provide grid support functionality,
 - Able to perform multiple operational modes
 - May include balance of plant and other ancillary equipment of the system



Overview of UL 9540 Requirements

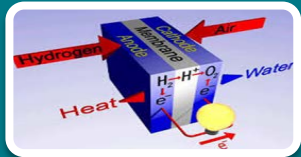


Types of Energy Storage Systems



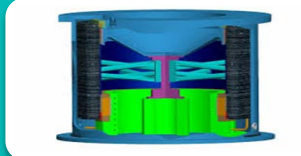
Electrochemical

- UL 1973



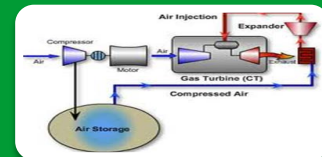
Chemical

- CSA FC1, NFPA 2, UL 2200, etc.



Mechanical (*fly wheel, CAES systems - under development*)

- ASME B & PV Code, ASME B31 piping codes



Thermal (*Thermal heat system – under development*)

- ASME B & PV Code, ASME B31 piping codes

UL 9540 Tests

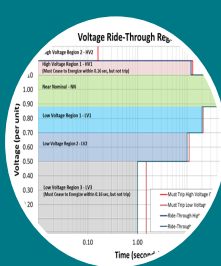


UL 9540 EESS system technology tests



Electric tests

- Normal operations
- Dielectric voltage withstand
- Grounding and bonding
- Insulation resistance



Grid Interconnection tests

- UL1741
- IEEE 1547 & IEEE 1547.1
- UL1741 SA Supplement for Grid Support Utility Interactive
- UL 1741 Special Purpose Utility Interactive (mfr and utility defined)



Mechanical tests

- Over speed test
- Faulted securement test
- Broken part



Fluid containment tests

- Leakage
- Strength

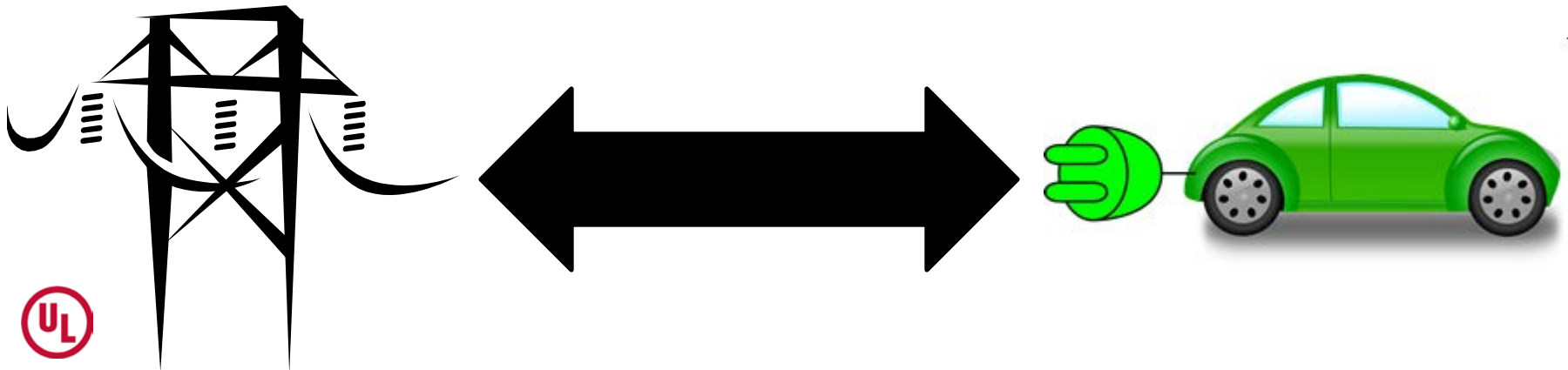


Environmental tests

UL 9741

Safety of Bidirectional Electric Vehicle Charging Systems and Equipment.

- This published document combines the applicable EV and DG requirements.
- These requirements will cover bidirectional electric vehicle charging equipment that charge electric vehicles from an electric power system and also include functionality to export power from the electric vehicle to an electric power system.



Transition from new conceptual designs into marketable products

- Many new fantastic innovative product ideas.
- Most of these new products will need to comply with building codes before they can be accepted for general use in the US or Canada.
- Sometimes these new and innovative products do not neatly fit into existing codes, standards and certification categories.
- UL works with industry to develop new codes and standards to facilitate getting new technologies certified and accepted in the field.



Certification for the Purpose

NEC moving toward equipment certified for the purpose.
Field failures related to incorrect applications for equipment.

- Reprogrammed motor drives used a utility interactive inverters
- UPS used as dynamic Var compensator
- Industrial control equipment used for power generation applications
 - Electrical Spacings (Creepage and clearances)
 - Overvoltage category
 - Pollution degree
 - Operating temp range
 - Environmental ratings
 - Electrical ratings and markings for the application and sources



Coordination of System Equipment

- **System components need to operate safely under normal and foreseeable abnormal system conditions**
- **Differentiate between system faults to which equipment need to respond to vs single fault failures within a piece of equipment**
- **Interaction between energy sources and power conversion equipment**
- **Operation ranges of system equipment**
- **Protection from system faults**
- **Source parameters**



Protection of Sources

Renewable power sources have specific installation and protection requirements to maintain them within their safe operating parameters and limits to prevent electric shock, fire and mechanical hazards.

Photovoltaics (PV)

Wind turbines

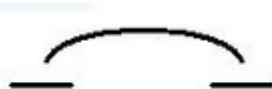
Hydro turbines

Fuel Cells

Batteries

EVs

Others



Maximum system voltage

Maximum normal current

Charge discharge current

Maximum fault current

Reverse current

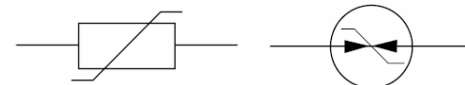
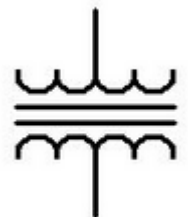
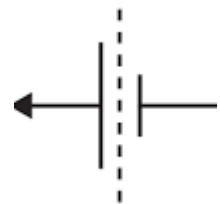
Ground faults

Arc faults

Overload

Overspeed

Thermal limits



UL3001 Safety for Distributed Energy Generation and Storage Systems



Draft Scope

This standard covers the safety and performance of distributed energy resource systems. These systems may be comprised of distributed energy sources such as photovoltaic arrays or wind turbines in homogenous or hybrid configurations, energy storage systems, grid interface equipment and related equipment to accomplish functionality of the distributed energy system.

These requirements address the safety of system design, integration and operation. They also cover the performance of these systems as it relates to grid operability, interface with premises wiring systems, and

performance of the equipment in the various modes of system operation.

STATUS: Forming the Standards Technical Panel

Standards Need Regular Revisions to Keep Pace with Rapid Growth Industries

Standards and codes in renewable energy areas are processing revisions more rapidly to keep up with technology innovations.

UL regularly partners with industry to develop, validate and write new standards and codes to support new technologies.



UL Energy Partnerships

To address the needs of national and international energy stakeholders, UL works closely with;

- Manufacturers
- Regulators
- Government agencies
- Industry experts
- Test labs
- Other certification agencies
- Other standards and code writing agencies



UL's relationships and partnerships with key Energy industry stakeholders is a foundation upon which we write relevant safety and performance standards for cutting edge products and systems.



UL Participation in International Energy Standards for Safety and Performance

UL is an active member in IEC, International Electrotechnical Commission. UL participates in all of the energy related Technical Committees and provides UL standards and Subject documents as draft material for the development of IEC standards.

TC82 Photovoltaics
TC 69 EV Charging Equip
TC 23 EV Connectors
TC105 Fuel Cells
TC 21, TC69 Batteries
TC88 Wind Turbines



IEC 62109-1

Edition 1.0 2010-04

**INTERNATIONAL
STANDARD**



Safety of power converters for use in photovoltaic power systems –
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Equipment Certifications

Local AHJs evaluate power conversion equipment certification & ratings for compliance with the local installation codes to determine acceptability of the installation within that jurisdiction.

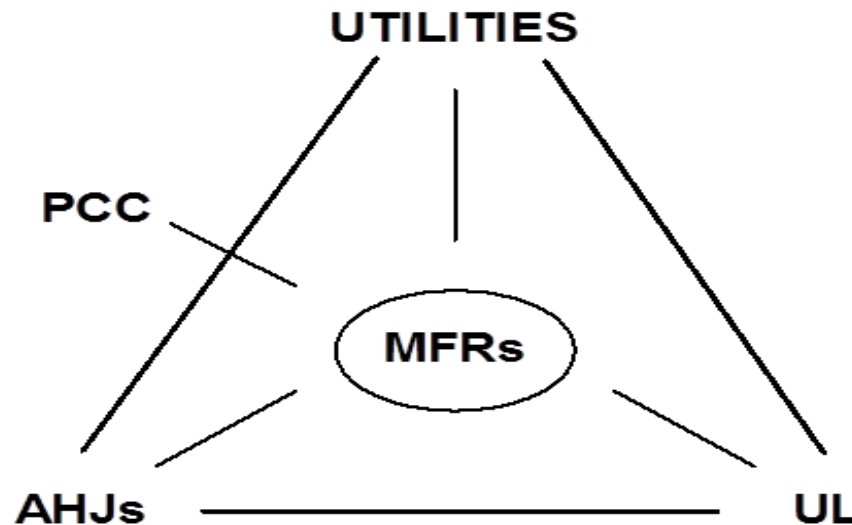
Utility grid interactive products get reviewed by both local electrical inspectors and electric utility engineers for acceptance.

Installation codes rely upon certifications to US national standards for the specific application.



Performance and Safety

Many of the performance issues associated with the grid interactive operation of Distributed Generation (DG) products are important Safety Issues.



NFPA 70 NEC 2014

Article 625 EV Charging Systems

Article 690 Photovoltaics (PV)

Article 692 Fuelcells

Article 694 Wind Turbines

Article 705 Interconnected Electric Power Production Sources. The above articles reference 705 for electric utility interactive systems.

Note: 705 requires UL1741 Listed utility interactive inverters.

2017 NEC

691 Large Scale PV

706 Energy Storage (passed)

710 Microgrids (failed)

712 DC Microgrids (passed)



Ultimate Goal

Increase renewable energy safety with the help of the renewable energy industries, thought leaders, AHJs, Utilities and other interested parties, develop and maintain appropriate installation codes, standards and certifications.

This will permit easier entry for manufacturers into their target markets.

Facilitate a streamlined process where renewable energy equipment and systems may be designed, produced, evaluated, certified, sold, installed and operated in a smooth and agreeable manner for all parties.



Questions?

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