Establishing Safety of Energy Storage – an Overview of UL Safety Standards

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Leader in Advanced Battery Safety Science

Gain ready access to experienced safety engineering experts with UL

Research

Design Advisory

Testing & Certification

Battery Standards

Thought Leadership

UL 810A: Electrochemical Capacitors
UL 1973: Stationary Applications
UL 2271: Light Electric Vehicles
UL 2580: Electric Vehicles
UL 9540: Energy Storage Systems
Agenda

Mitigating risk – a safety approach
• Identifying and addressing hazards
• UL 1973 and safety approach

Introduction to UL 9540
• UL 9540 - Scope
• UL 9540 - Overview
• UL 9540 - Status

Certification options
• Certification and labelling options

US DOE and code activities
• US DOE activities
• Code activities
Mitigating risk - A safety approach
Identifying and addressing hazards

What are the potential hazards associated with ESSs?

Energy
• Fire
• Arc flash
• Explosion

Electrical
• Electric shock

Mechanical
• Over pressure
• Noise
• Moving parts

Chemical
• Toxic and hazardous substance exposure
Identifying and addressing hazards

Safety design analysis

- **Failure Modes and Effects Analysis (FMEA), IEC 60812**
- ID Failure mode
- Effect/Severity of failure
- Probability of occurrence of failure
- Detection/mitigation scheme effectiveness

Reliability Protection Number (RPN)

\[ \text{RPN} = \text{S} \times \text{O} \times \text{D} \]

Where

S – Severity of failure
O – Probability of occurrence
D – Reliability of detection
Identifying and addressing hazards

Risk Reduction Hierarchy:
• Risk elimination/reduction by design
• Risk reduction through safeguards
• Risk reduction through use of warnings, information and PPE

Example:
Hazardous live parts

Mitigation of Risk:
• Who has direct access to the ESS?

Through design?
• Enclosure to prevent access to live parts

Through safeguards
• Install in restricted location
• Guarding

Through warnings, PPE
• Caution labels and information
Identifying and addressing hazards

Compliance to safety standards
- Components
- Reliability of critical components
- System
- Constructions and testing
- Protection
  - Design
  - Safeguarding
  - Warnings & Instructions

Compliance to Codes
- Safe installation and connection to utilities

Functional Safety
Software & Programmable controls relied upon for safety as ID’d in the FMEA
- Comply with appropriate safety integrity level (SIL), Class of control function, etc.
UL 1973 and Safety Approach

UL 1973, Batteries for Use in Light Electric Rail (LER) and Stationary Applications

Safety standard

Non technology specific
- Includes specific criteria for: lead acid, Nickel, Sodium Beta, Lithium ion, Flow Batteries, Electrochemical Capacitors and battery/capacitor hybrid systems

Construction requirements, Tests, and Production tests

Can be used for certification of battery systems
UL 1973 and safety approach

Safety Analysis
- Analysis of battery with single fault conditions
  - FMEA, FTA, etc.

Construction
- Materials
- Enclosure
- Electrical
  - Spacings
  - Insulation
  - Wiring and Components
- Safety controls/protection
- Cells

Testing
- Electrical
- Mechanical
- Environmental

Markings, Instructions, Production tests
UL 1973 and safety approach

Safety Analysis
- Applies to parts, components and circuits affecting safety

Risk assessment, FMEA, FTA, etc.
- IEC 60812, IEC 61025, etc. can be used as a guide
- ID critical safety controls
- Single fault conditions

Safety critical electronics and software
- Must meet functional safety requirements
- UL 991/UL 1998, UL 60730-1, IEC 61508
- Determine severity level, performance level or class
UL 1973 and safety approach

Battery Electrical Tests
- Overcharge
- Short Circuit
- Overdischarge Protection
- Imbalanced Charging
- Temperature & Operating Limits Check

Battery Mechanical Tests
- Static Force
- Drop Impact
- Wall Mount Fixture/Handle Test

Battery Environmental Tests
- Continuity
- Failure of Cooling/Thermal Stability System
- Mold Stress
- Resistance to Moisture
- Salt Fog
- External Fire Exposure
- Internal Fire Exposure

Working Voltage Measurements
Introduction to UL 9540
Energy storage systems and equipment:

- Safety Standard
- Includes energy storage systems that are:
  - standalone to provide energy for local loads;
  - in parallel with an electric power system, electric utility grid; or
  - able to perform multiple operational modes.
- for use in utility-interactive applications in compliance with IEEE 1547 and IEEE 1547.1 or
- other applications intended to provide grid support functionality,
- may include balance of plant and other ancillary equipment of the system,
## UL 9540 - Overview

### Types of Energy Storage Systems

<table>
<thead>
<tr>
<th>Type</th>
<th>Examples</th>
<th>Related Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrochemical</td>
<td>(e.g. batteries)</td>
<td>UL 1973</td>
</tr>
<tr>
<td>Chemical</td>
<td>(e.g. hydrogen storage)</td>
<td>CSA FC1, NFPA 2, UL 2200, etc.</td>
</tr>
<tr>
<td>Mechanical</td>
<td>(e.g. fly wheel system - under development)</td>
<td>ASME B &amp; PV Code, ASME B31 piping codes</td>
</tr>
<tr>
<td>Thermal</td>
<td>(under development)</td>
<td></td>
</tr>
</tbody>
</table>
UL 9540 - Overview

Utility Grid Interaction Requirements

Operate safely through various conditions
- Compliance to UL 1741 and
- Referenced requirements of IEEE 1547 and IEEE 1547.1
- Requirements for special purpose utility interactive features

Tests & Updates
- Tests of UL 1741
- Bulletin out to update UL 1741 to include a supplement for advanced grid support utility interactive inverter requirements to address the changing needs of the electric utility like CA Rule 21, HI and AZ.
UL 9540 - Overview

**Enclosures & Guarding**
- Walk in systems

**Electrical**

**Fluid handling & containment**

**Fire detection & suppression**
- Dependent upon size and location, etc., of energy storage system

**Markings, signage and instructions**
## UL 9540 - Overview

### ES system technology Tests

#### Electric tests
- Normal operations
- Dielectric voltage withstand
- Grounding and bonding
- Insulation resistance

#### Mechanical tests
- Over speed test
- Faulted securement test

#### Fluid containment tests
- Leakage
- Strength

### Environmental tests
UL 9540 - Status

June 30, 2014
UL 9540
• Published as an OOI
• Non-consensus standard

July 2015
ANSI UL 9540
1st Ed Bulletin
• Published in June 2015

4th quarter 2015
ANSI UL 9540
1st Ed. Publication
Certification options
Certification and Labelling Options

Why bother with 3rd party certification/labelling?

- Ease of installation
- Local requirement – AHJ

What does certification/labelling entail?

- Listing Certification Process
  - Compliance to UL 9540
  - Listed under UL CCN (FTBW)
  - Ongoing production inspection
  - UL Listing mark

- Field Evaluation Labelled
  - Conducted on installed product with cooperation of AHJ
  - Non-destructive evaluation
  - No production inspections
  - Field label marking
DOE and Code Activities
US DOE Activities

US DOE Work:

Safety Work Shop: February 18, 2014 in Albuquerque NM

- **PNNL 23618**, Inventory of Safety Related Codes and Standards for Energy Storage Systems (September 2014)
- **US DOE Energy Storage Safety Strategic Plan** (December 2014)

Energy Storage Safety Working Group (ESSWG) (March 2015)

- Working Groups to address strategic objectives:
  - Safety Validation and Risk Assessment R&D Working Group
  - Codes and Standards Working Group
  - Safety Outreach and Incident Response Group
Code Activities

NFPA Activity:

• NFPA 70 EESS task group
  • New NEC Article (706 Energy Storage Systems)
  • Article accepted for 2017 NEC & will go through development process
• NFPA 1
  • Proposal for EESS sent as placeholder for code cycle
• New installation standard for EESS (future project)

ICC Activity:

• ICC’s Fire Code Action Committee’s WG on Battery & Energy Storage Systems
  • Develop revised language to propose for ICC IFC and IRC addressing EESS
THANK YOU.

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