Energy Storage System Safety – Codes & Standards

David Rosewater

Presentation for
EMA Energy Storage Workshop
Singapore
August 2015
Acknowledgements

Special thanks to the following presentation contributors:

- David Conover (PNNL)
- Steve Willard (EPRI)
- Lana Kimmel (SNL)
- Ana Beare (SNL)
- Jaci Hernandez (SNL)
Energy Storage Integration Council (ESIC)

- **Guide to Safety in Utility Integration of Energy Storage Systems**
  - The ESIC is a forum convened by EPRI in which electric utilities guide a discussion with energy storage developers, government organizations, and other stakeholders to facilitate the development of safe, reliable, and cost-effective energy storage options for the utility industry.
Safety Standards & Certification

Structure of safety management in the ESS integration process
Energy Storage System Safety Standards
# Energy Storage System Components

<table>
<thead>
<tr>
<th>Energy Storage System Components</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures</td>
<td>UL 489</td>
</tr>
<tr>
<td>Electrochemical Capacitors</td>
<td>UL 810A</td>
</tr>
<tr>
<td>Lithium Batteries</td>
<td>UL 1642</td>
</tr>
<tr>
<td>Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources</td>
<td>UL 1741</td>
</tr>
<tr>
<td>Batteries for Use in Stationary Applications</td>
<td>UL 1973</td>
</tr>
</tbody>
</table>
## Energy Storage Systems Standards

<table>
<thead>
<tr>
<th>Energy Storage System Type</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary Energy Storage Systems with Lithium Batteries – Safety Requirements</td>
<td>IEC 62897</td>
</tr>
<tr>
<td>(under development)</td>
<td></td>
</tr>
<tr>
<td>Flow Battery Systems For Stationary Applications – Part 2-2: Safety requirements</td>
<td>IEC 62932-2-2</td>
</tr>
<tr>
<td>Recommended Practice and Requirements for Harmonic Control in Electric Power Systems</td>
<td>IEEE 519</td>
</tr>
<tr>
<td>Standard for Interconnecting Distributed Resources with Electric Power Systems</td>
<td>IEEE 1547</td>
</tr>
<tr>
<td>Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation</td>
<td>NFPA 791-2014</td>
</tr>
<tr>
<td>Outline for Investigation for Safety for Energy Storage Systems and Equipment</td>
<td>UL 9540</td>
</tr>
</tbody>
</table>
## Energy Storage Installation Standards

<table>
<thead>
<tr>
<th>Energy Storage Installation</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transportation Testing for Lithium Batteries</strong></td>
<td>UN 38.3</td>
</tr>
<tr>
<td>Safety of primary and secondary lithium cells and batteries during transport.</td>
<td>IEC 62281</td>
</tr>
<tr>
<td><strong>Shipping, receiving and delivery of ESS and associated components and all materials, systems, products, etc. associated with the ESS installation.</strong></td>
<td>DOT Regulations</td>
</tr>
<tr>
<td><strong>Worker safety</strong></td>
<td>Federal and state OSHA</td>
</tr>
<tr>
<td><strong>Competency of Third Party Field Evaluation Bodies</strong></td>
<td>NFPA 790</td>
</tr>
<tr>
<td><strong>Fire and smoke detection</strong></td>
<td>NFPA 1, NFPA 101, NFPA 5000, IBC, IFC, state and local codes</td>
</tr>
<tr>
<td><strong>Fire suppression</strong></td>
<td>NFPA 1, NFPA 13, NFPA 15, NFPA 101, NFPA 850, NFPA 851, NFPA 853, NFPA 5000, IBC, IFC, state and local codes</td>
</tr>
<tr>
<td><strong>Fire and smoke containment</strong></td>
<td>NFPA 1, NFPA 101, NFPA 5000, IBC, IFC, state and local codes</td>
</tr>
</tbody>
</table>
## ES Installation (continued)

<table>
<thead>
<tr>
<th>Energy Storage Installation</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilation, exhaust, thermal management and mitigation of the generation of hydrogen or other hazardous or combustible gases or fluids</td>
<td>NFPA 1, IEEE/ASHRAE 1635, IMC, UMC, state and local codes</td>
</tr>
<tr>
<td>Egress (operating and emergency)</td>
<td>NFPA 1, NFPA 101, NFPA 5000, IBC, IFC, state and local codes</td>
</tr>
<tr>
<td>Access (operating and emergency)</td>
<td>NFPA 1, NFPA 101, NFPA 5000, IBC, IFC, state and local codes</td>
</tr>
<tr>
<td>Working space</td>
<td>OSHA 29 CFR 1910.305(j)(7) and OSHA 29 CFR 1926.441 (if applicable), NFPA 70E, Article 320</td>
</tr>
<tr>
<td>Physical security</td>
<td>NFPA 1, NFPA 101, NFPA 5000, IBC, IFC, state and local codes</td>
</tr>
<tr>
<td>Illumination (operating and emergency)</td>
<td>NFPA 1, NFPA 101, NFPA 5000, IBC, IFC, state and local codes</td>
</tr>
</tbody>
</table>
## Energy Storage Installation (Continued II)

<table>
<thead>
<tr>
<th>Energy Storage Installation</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire department access</td>
<td>NFPA 1, NFPA 101, NFPA 5000, IBC, IFC, state and local codes</td>
</tr>
<tr>
<td>Anchoring and seismic protection</td>
<td>NFPA 5000, IBC, state and local codes</td>
</tr>
<tr>
<td>Buildings, enclosures and protection from the elements</td>
<td>IEC 60529, UL 96A,</td>
</tr>
<tr>
<td></td>
<td>NFPA 5000, IBC, state and local codes</td>
</tr>
<tr>
<td>Signage</td>
<td>ANSI Z535, IEEE C-2, NFPA 1, NFPA 70E,</td>
</tr>
<tr>
<td></td>
<td>NFPA 101, NFPA 5000, IBC, IFC, state and local codes</td>
</tr>
<tr>
<td>Emergency shutoff</td>
<td>IEEE C-2, NFPA 1, NFPA 101, NFPA 5000, IBC, IFC, state and local codes</td>
</tr>
<tr>
<td>Spill containment, neutralizing and disposal</td>
<td>NFPA 1, IPC, UPC, IFC, IEEE1578, state and local codes</td>
</tr>
<tr>
<td>Electrical safety</td>
<td>IEEE C-2 (National Electrical Safety Code),</td>
</tr>
<tr>
<td></td>
<td>NFPA 70E, FM Global DS 5-10, DS 5-1, DC 5-19</td>
</tr>
<tr>
<td>Communications networks and management systems</td>
<td>IEC 61850</td>
</tr>
</tbody>
</table>
## Commissioning Standards

<table>
<thead>
<tr>
<th>Energy Storage Commissioning</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended Practice for Commissioning of Fire Protection and Life Safety Systems</td>
<td>NFPA 3</td>
</tr>
<tr>
<td>Building and Systems Commissioning</td>
<td>ICC 1000</td>
</tr>
</tbody>
</table>
## ES Operation and Maintenance

<table>
<thead>
<tr>
<th>Energy Storage Operations and Maintenance</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazardous materials storage, handling and use</td>
<td>NFPA 400</td>
</tr>
<tr>
<td>Standard on Maintenance of Electrical Equipment</td>
<td>NFPA 70B</td>
</tr>
</tbody>
</table>
## Incident Preparedness Standards

<table>
<thead>
<tr>
<th>Incident Preparedness</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard for Technical Rescuer Professional Qualifications</strong></td>
<td>NFPA 1006</td>
</tr>
<tr>
<td><strong>Standard for Fire Fighter Professional Qualifications</strong></td>
<td>NFPA 1001</td>
</tr>
<tr>
<td><strong>Standard for Fire Department Occupational Safety</strong></td>
<td>NFPA 1500</td>
</tr>
<tr>
<td><strong>Standard System for the Identification of the Hazards of Materials for Emergency Response</strong></td>
<td>NFPA 704</td>
</tr>
<tr>
<td><strong>Guide for Substation Fire Protection</strong></td>
<td>IEEE 979</td>
</tr>
<tr>
<td><strong>Fire Fighting</strong></td>
<td>Emergency Planning and Community Right-to-Know Act (EPCRA)</td>
</tr>
<tr>
<td><strong>Fire and Explosion Investigations</strong></td>
<td>NPFA 921</td>
</tr>
<tr>
<td><strong>Fire Safety Concepts Tree</strong></td>
<td>NFPA 550</td>
</tr>
</tbody>
</table>
Inventory of Safety Codes and Standards

- Complete as of September 2014 for US and many international Safety CSRs
- Not eclectic utility specific
- Organized by the same integration stages
Certification

Note: Sandia does NOT participate in Energy Storage device/equipment/system certification.

- 3 US Certification Companies: (In no specific order)
  - DNVGL
  - Intertek
  - UL
Certification Challenges

Complex System → Complex Investigation

- Challenges to Testing
  - Large systems present a challenge to testing
    - Multiple labs may be required for testing
    - Environmental chamber limitations
    - Availability of samples for testing
    - Fire Testing
    - Lab safety
  - Unique/New chemistries may present a challenge

- Challenges to construction review
  - Stakeholders unfamiliar with process
  - FMEA
  - Functional Safety
  - Components without appropriate
    - Certifications/ratings
    - Determine cells are within operating region
  - Obtaining necessary information to determine compliance
Certification Combined with Hazard Analysis and Testing

- Code compliance is primarily focused on standardization
- Compliance alone will not guarantee system safety
- Only a combination of hazard analysis and code compliance will enable risk to be factored into business decisions
Thank you!

Additional resources available at:
Appendix
Codes/Standards
Extended & Facilitated Discussion
D. Rosewater Presentation
EMA Technical Workshop

- Construction Criteria
  - Materials
  - Enclosures
  - Electrical Spacings
  - Electrical Wiring and Controls
  - FMEA and Functional Safety
  - Thermal management systems
  - Cells and electrochemical capacitors
    - Lithium ion, nickel, sodium, LA, flow, electrochemical capacitors
  - Marketing and Instructions

- Tests
  - Electrical
    - Overcharge
    - Short Circuit
    - Overcharge Protection
    - Imbalanced Charging
    - Temperature
    - Dielectric Withstand
    - Grouping Continuity
    - Failure of Cooling/Thermal Stability System
  - Mechanical Tests
    - Enclosure Tests
    - Drop Test
  - Environmental Tests
    - External Fire
    - Internal Fire
    - IP Exposure Tests
UL Subject 9540

- **ES Technology References**
  - Batteries
    - UL 1973
  - Electrochemical Capacitors
    - UL 1973 and UL 810A
  - Fuel Cell Systems
    - CSA-America FC1
  - Hydrogen Storage and Equipment
    - NFPA 2 (ISO 22734-1, -2)
  - Engine Generators
    - UL 2200
  - Flywheels
    - SAE, AIAA, ISO

- **Equipment Standard References**
  - Inverters
    - UL 1741, IEEE 1547 series
  - Electrical Equipment
    - NFPA 70, IEEE C2
  - Functional Safety
    - IEC 61508, IEC 60730-1, UL 991/1998
  - Pressure Vessels
    - ASME B & PV Code
  - Piping Systems
    - ASME B31 series
  - Hazardous Locations
    - NFPA 70, NFPA 497
### Impact on UL Standards Development

- **UL Standards development process is ongoing**
  - Not subject to a specific development schedule
  - Proposals can be submitted for review and balloting at any time
  - Lessons learned from certification experience may impact standards development

- **UL New & Innovative Investigation Program**
  - New technology/product
  - No current published requirements
  - Development of requirements through discussions
    - Client
    - UL Technical Staff
    - UL Councils
Certification Programs

- **Disclaimer**: SNL and DOE DO NOT do certifications.

- **UL ES Certification Programs**
  - UL Certification Programs including evaluation and ongoing production evaluation
  - UL 1973
    - BBFX, BBFX7, BBFX8
  - UL Subject 9540
  - To be set up after publication

- **UL Field Evaluation Program**
  - Applied to one product (not ongoing production)
  - Often conducted after installation of production

- **IECEE Certification Program**
  - **CB Scheme**
    - Applied to IEC standards determined to be part of the CB Scheme
    - Does not include ongoing production inspections
    - CE marking is a manufacturer’s self declaration
  - **ETF13 BATT**
    - IEC 62133
    - IEC 60896-1
    - IEC 60896-21
    - IEC 60896-22
    - (IEC 62619, 62485-2, etc.)
    - Includes IEC 62282 fuel cell standards
  - CE marking is mfg.’s self cert. mark
UL Certification Options

Is the Energy Storage System –

- Part of a family of systems?
- Intended for multiple locations?
- A modular design?
- A one of a kind design intended only for one site?

Regular UL Listing or Recognition

- Has ongoing production inspections

Field Evaluation

- Is a one time event