Stationary Battery Standards: Current Landscape and What's Coming Soon

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When developing energy storage systems, it is important that due diligence is given to system safety and that the design meets or even exceeds applicable safety standards and codes. This process of considering safety standards and codes should start at the design stages to avoid costly and time consuming re-designs.

When analyzing an energy storage system's safety, a hazards base assessment approach should be taken. Potential hazards associated with energy storage systems include energy hazards that could result in potential fires and explosions, electric shock hazards, physical hazards to those persons that may be in proximity to the system, hazardous materials that may be contained or that could vent from the system such as flammable or toxic fluids, hazardous electrolyte leakage, etc. Energy storage systems can be complex, and ensuring safety requires an understanding of both:

- the system -- how the parts of the system interact in order to keep the system operating within safe boundaries, and
- the application -- the intended environment to which the system will be exposed.

Reviewing the system in a step by step, organized fashion will help to ensure that all impacts to safety have been considered.

Failure Modes and Effects Analysis (FMEA)

In order to analyze any energy storage system, it is important to have a process for identifying potential safety hazards, categorizing their impact to safety and evaluating the methods inherent in the system for mitigating these hazards. This process is often referred to as a Failure Modes and Effects Analysis or FMEA. There are several different procedures for conducting this analysis and standards have been developed for guidance including IEC 60812 and the functional safety standard series International Electrotechnical Commission (IEC) 61508, Society of Automotive Engineers (SAE) J1739, and the US Department of Defense military standard, MIL-STD-1629A.

The FMEA process is a step-by-step process where the system is reviewed to identify potential faults that could occur. This process typically is a single fault consideration; however, if there is reason for more stringent safety, there may be double fault consideration for some are all aspects of the energy storage system. In addition to identifying the fault, determining the probability of the fault to occur and to be detected by the system is also required. Then the method of mitigating the hazard is identified, as well as the reliability of the mitigation method.

The FMEA process results in a ranking based upon severity of the fault, probability of occurrence of the fault and ability to mitigate the fault. This ranking system indicates any needs for further action.

Fault Tree Analysis (FTA)

Another methodology which assists in the evaluating of specific faults is the Fault Tree Analysis (FTA), as outlined in IEC 61025. The FTA process enables users to analyze faults using logic "trees" to pinpoint the causes of the hazards and the potential of occurrence. The results of an FTA analysis can then be used to build the FMEA. Those controls and components of the system identified as critical to safety through this process should be evaluated for reliability, including the software and electronics controls relied upon for safety. If electronics and/or software have been identified as critical to the safety of the energy storage system, then they should be evaluated for functional safety, and an appropriate safety integrity level (SIL) or equivalent should be determined for the controls.

Safety Standards

In addition to conducting an appropriate safety analysis of the energy storage system, the system should be evaluated to appropriate safety standards. Safety standards will often include a minimum set of construction requirements with which the system should comply, as well safety performance tests.

The construction criteria is a method for determining the potential of the system to operate safely over the anticipated life of the system, and that components of the system which impact safety are being employed within their ratings. The construction requirements can address material requirements, electrical spacing requirements, wiring criteria, requirements for controls and other components, FMEA and functional safety requirements, markings, signage and instructions.

The safety tests are a check of the system design to ensure that it operates safely under normal use and foreseeable misuse conditions. They verify system safety and can include tests for:

- normal operation, such as a temperature test,
- anticipated abnormal events, such as a short circuit test or other test outside of normal parameters that can occur through a fault condition,
- electrical spacings and insulation, such as a dielectric voltage withstand test, and
- environmental conditions, such as exposure to water or other environmental stresses.

Some standards take a "test only" approach, but this approach is incomplete when evaluating the safety of the system. It is important to have some level of minimum safety construction through the use of FMEA and a review of the parts of the system to ensure they are going to function as anticipated. Electrical spacings criteria, for example, are critical to ensuring that insulation levels are adequate, and tests such as the dielectric voltage withstand are the final check of the system insulation.

There are published safety standards that can be utilized to evaluate the safety of energy storage systems. The standards are often divided into technology specific and/or application specific. There are some that are intended for specific regions such as the USA and others written as international standards, which can be adopted nationally with some modifications.

For battery energy storage systems, many of these standards specifically address more traditional technologies such as lead acid or NiCad chemistries. Some of these published documents are in the form of guides or recommended practices rather than standards such as the Institute of Electrical and Electronics Engineers (IEEE) 1375, *IEEE Guide for the Protection of Stationary Battery Systems*, but they contain useful information for determining the safety of the system. Some standards such as American National Standard's Institute (ANSI) UL 1973, *Standard for Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications* are not technology specific and cover any number of battery chemistries as well as electrochemical capacitors (i.e. ultracapacitors). Some applications have their own standards that must be applied. Telcordia GR-3150-CORE, *Generic Requirements for Secondary Non-aqueous Lithium Batteries,* which includes both performance and safety requirements for lithium ion battery systems used for telecom applications. The Telcordia battery standards are also technology specific and there are standard covering lead acid, nickel and lithium ion at this time. The ANSI UL 1973 standard is for North America and work is underway for this standard to become a bi-national standard for the USA and Canada. Another standard under development that is not technology specific but is application specific is UL Subject 9540, *Safety for Energy Storage Systems and Equipment*. This document will cover various types of energy storage systems including batteries, but will be specific to utility grid interactive systems.

There are also international standards that address stationary batteries for energy storage applications. These standards are often technology specific with currently published standards for nickel and lead acid technologies such as the IEC 62845-2, *Safety Requirements for Secondary Batteries and Battery Installations – Part 2: Stationary Batteries*. There are IEC safety standards under development that address lithium ion technologies. These standards are IEC CD 62619, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications* (not published) and IEC NP 62687, *Stationary Energy Storage Systems with Lithium Batteries – Safety Requirements*. The first standard is a general stationary battery standard that addresses cells and the battery interaction with the battery management system (BMS). The new work item proposal IEC NP 62687 scope is safety of lithium ion battery systems for residential applications. The table 1 below is a list of some of the standards addressing stationary battery safety either in whole or part.

When determining which standard would apply, the technology of the system and the intended application will affect which standard or similar document would apply. All of the standards noted above can apply to stationary batteries, but some are very specific to the application such as the Telcordia standards. Many of the standards are technology specific, but then some, such as UL 1973 are agnostic to technology and include requirements for many different battery technologies and include electrochemical capacitors or hybrid systems in the scope. Some standards such as the IEC 60896-11, IEC 60896-21 and IEC 60896-22 include both performance and safety criteria. The safety guide, IEEE 1375, contains recommendations for battery system safety but do not include tests or specific requirements that must be applied to a battery system and only applies to more traditional technologies such as lead acid and nickel battery systems used in energy storage.

Table 1 - Stationary Battery and Energy Storage Standards that Address Stationary Battery Safety.

Standard No.	Title	Tech.	Appl.	Locat.
ATIS-0600330	Valve-regulated lead-acid batteries used in the telecommunications environment	X	X	X
Telcordia GR-3020-CORE	Nickel cadmium batteries in the outside plant	X	X	X
Telcordia GR-3150-CORE	Generic requirements for secondary non-aqueous lithium batteries	X	X	X
Telcordia GR-4228-CORE	VRLA battery string certification levels based on requirements for safety and performance	X	X	X
UL 810A	Electrochemical Capacitors	X		X
UL 1973	Batteries for use in Light Electric Rail (LER) and Stationary Applications			X
UL Subject 9540	Standard for Safety for Energy Storage Systems and Equipment (under development)		X	X
IEEE 1375	Guide for the Protection of Stationary Battery Systems	X		
IEEE 1679	Recommended Practice for the Characterization and Evaluation of Emerging Energy Storage Technologies in Stationary Applications			
IEC 60896-11	Stationary lead-acid batteries - Part 11: Vented types - General requirements and methods of tests	X		
IEC 60896-21	Stationary lead-acid batteries –Part 21: Valve regulated types –Methods of test	X		
IEC 60896-22	Stationary lead-acid batteries Part 22: Valve regulated types – Requirements	X		
IEC 62485-2	Safety requirements for secondary batteries and battery installations – Part 2: Stationary batteries	X		
IEC CD 62619	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications (under development)	X		
IEC NP 62687	Stationary Energy Storage Systems with Lithium Batteries – Safety Requirements (under development)	X	X	
CENELEC EN 50272-1	Safety Requirements for Secondary Batteries and Battery Installations Part 1: General safety information	X		X
CENELEC EN 50272-2	Safety Requirements for Secondary Batteries and Battery Installations Part 2: Stationary Batteries	X		X

Codes and Regulations

In addition to standards to consider, there are also codes and regulations that will impact the energy storage system. Location of the energy storage system will have the primary impact regarding the codes that will apply, but technology and application will also determine applicable codes.

If the system is to be located in the USA, the codes affecting energy storage systems include electrical installation codes such as the National Fire Protection Association (NFPA) 70 *National Electrical Code* (NEC) or the IEEE C2 *National Electrical Safety Code* (NESC) depending upon whether or not the energy storage systems are utility systems. Both of these codes contain energy storage sections, but other areas of the codes including wiring methods, grounding criteria, signage, enclosures, etc. impact energy storage system safety. Local electrical codes will typically adopt some version of the NEC as part of their codes with what they feel may be necessary modifications specific to their location. Building and fire codes may adopt some version of the International Code Council (ICC) codes, which may impact an energy storage system. Because energy storage systems contain electronics that can have electromagnetic interference, there are Federal Communications Commission (FCC) regulations that would apply to ensure that energy storage systems are not unintended radiators. Energy storage systems, depending upon their technology, may also be affected by regulations addressing hazardous materials such as Pipeline and Hazardous Materials Safety Administration (PHMSA) transport regulations for lithium ion batteries or the Environmental Protection Agency (EPA) or local material recycling regulations such as those for lead acid batteries and control of hazardous wastes or other materials that are utilized by the system. Local building and fire codes will also impact energy storage system, so it is important to know which local codes apply to your system. Building codes include requirements for battery rooms, spill containment, and fire protection for areas containing energy storage. The table 2 below outlines some applications codes and standards which may affect the energy storage system.

Table 2 - Some codes that may affect energy storage systems

Code/Regulation	Title	Impact
NFPA 70	National Electrical Code (NEC)	Basis for many local building electrical codes
IEEE C2	National Electrical Safety Code (NESC)	Electrical Code for utilities
ICC IFC	ICC International Fire Code	Used in many local building fire codes
49CFR173.185 (PHMSA)	Code of Federal Regulations - Part 173, Section 173.185 - Lithium cells and batteries.	Transport of systems that use lithium ion batteries
47CFR15.109 (FCC)	Code of Federal Regulations - Part 15, Section 15.109 Radiated Emissions limits	System needs to meet FCC criteria for emissions
29CFR1910 Occupational Safety and Health Administration (OSHA)	Code of Federal Regulations – Part 1910, Occupational Safety and Health Standards	Regulations regarding workplace safety

If the system were to be installed in Europe for example, the regulations that should be reviewed include the European directives, which can include low voltage, machine and electromagnetic compatibility (EMC) directives and requirements for example. In addition, there are environmental types of regulations for Europe such as the battery directive, which may impact certain technologies.

When considering safety for an energy storage system, it is important to review the system and evaluate to appropriate safety standards to determine that the system meets an acceptable level of safety. The technology of the system, where it is located and intended application will affect what standard should be used as well as the codes and regulations that would apply.