Energy Storage Safety – Information for the Fire Service

A fact sheet for the fire service developed in support of the DOE Energy Storage Safety Strategic Plan.

Prepared for Unlimited Distribution by the Safety Outreach and Incident Response Team of the DOE Energy Storage Safety Working group (ESSWG)

Intro to Energy Storage

Energy storage is emerging as an integral component to a resilient and efficient electrical grid through a diverse array of potential applications. The evolution of the electrical grid that is currently underway will result in a greater need for services best provided by energy storage. Energy storage technologies include many systems installed in homes and businesses and go far beyond the 'battery rooms' familiar to many in the fire service. The increase in demand for specialized energy services will further drive energy storage research to produce systems with greater efficiency and capability at a lower cost, which will lead to increased deployment of new energy storage technologies and chemistries across the country. In order to ensure that deployments of energy storage systems (ESS) are safe, the fire service will play a key role reviewing, inspecting and approving storage technologies and ensuring their continued operational safety.

Safety of any new technology can be broadly viewed as having three intimately linked aspects, as follows: 1) the system must be engineered and validated to the highest level of safety and installed to ensure the safety built into the system can be realized when it is commissioned and operated; 2) techniques and processes must be developed to minimize the probability of incidents and then support those responding to any that might occur whether initiated by the system or associated with external situations that could impact the system; and 3) best practices and system requirements must then be reflected in codes, standards and regulations (CSR) so that there are defensible, uniform, consistent, and understandable criteria that can form the basis for documenting and verifying system safety associated with the design and construction of systems, their installation and their subsequent commissioning and operation.

Energy Storage Types and Maturity

Each storage technology has unique design and operational characteristics. In addition the technologies in use today are each at different maturity levels, are widely varied in terms of type and chemistry and are each being deployed in varying amounts and in many different locations. These differences must be taken into consideration when addressing safety because the likelihood of an incident can increase as low maturity technologies reach market and begin to proliferate. The different levels of maturity and deployment also illustrate the criticality of pinpointing which systems can be assessed and documented as incurring sufficiently low risk in a manner that is not onerous and is repeatable, defensible and readily accepted. Figure 1 lists technologies based on their present degree of use.

Storage technologies such as batteries, flywheels, thermal storage and others, though now representing a small portion of storage on the grid, are a quickly growing part of the makeup of the electrical grid. These systems can be located in large central plants, at electrical substation, or in homes or businesses on the customer side of the meter. Among these deployed storage technologies, the DOE OE Strategic Plan for Energy Storage Safety focuses primarily on batteries, with some attention to flywheels and thermal storage due to the rapid growth seen in these relatively new storage technologies.

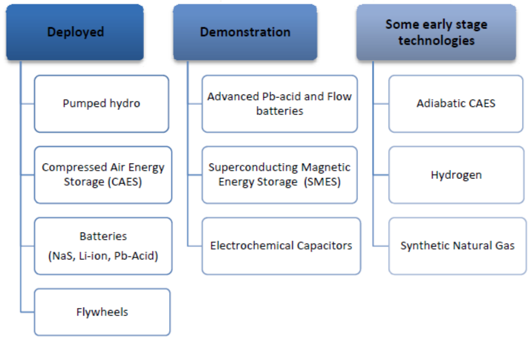

Figure 1 Energy Storage Technology Maturity Levels

Safety Codes and Standards

The criteria by which the fire service would evaluate storage technology safety, as memorialized through Codes Standards and Regulations (CSR), provides those seeking to move ESS into the market and those responsible for public safety, a framework on which to base a determination that the system and its installation are "safe." As existing CSR are updated and/or new CSR are developed that specifically address the range of ESS technologies and installations, and those CSR are then adopted, it becomes easier to document what is safe and determine what can be approved in a uniform and timely manner. Until CSR are updated to address the newer energy storage technologies, those seeking approval would have to document the safety of the technology and its application under the 'equivalency clause' or ‘alternative methods and materials’ provisions of CSR. Code officials would then have to assess the documentation provided, with the assistance of an approved third party when necessary. Some recent efforts in advancing CSRs for energy storage, in which DOE ESS safety efforts have been involved, include: development of the proposed new Article 706 on Energy Storage that if approved would appear in the 2017 National Electrical Code (NFPA 70), Underwriters Laboratories development of UL Standard 9540 addressing the safety of Energy Storage Systems and Equipment (e.g. the product), proposed revisions to the International Fire Code (IFC) of the International Code Council (ICC) and the National Fire Protection Association Fire Code (NFPA 1) to better address the safety of ESS installations and the establishment by NFPA of a technical committee to develop a new standard addressing the design, construction, installation, and commissioning of stationary energy storage systems (which will use a draft pre-standard developed through DOE research as a basis for their initial work). The following is a list of some important factors to consider when reviewing an energy storage installation for approval.

Table 1 Permitting Considerations for First Responders

Access/egress for the responder	Signage
Safety Data Sheet availability	Drainage for water runoff
Available water sources and fire suppression appliances for the fire fighters	Other Hazardous Materials present in the vicinity of the ESS
Location within the building (can cause accessibility issues)	Emergency shutdown locations identified for the ESS
Occupancy of the building (hotel, residential, hospital, school)	Emergency numbers for the ESS manufacturers
Exposure levels inside / outside the building	Exit stairway
Ventilation techniques and exhaust points	Contingency Preplanning
Smoke travel (containment within the room)	Normal and Emergency Lighting

Research and Development

In parallel to and in support of updating CSR there are a number of research and development activities underway. These can serve to facilitate appropriate CSR criteria, serving as a basis for review and approval of systems under equivalency clauses and alternative materials and methods provisions until CSR are updated and adopted.

Materials Science R&D

The topic of lithium-ion battery safety is rapidly gaining attention. Research is underway to find materials with the necessary properties, especially the required thermal behavior, to ensure failures during operation are able to be contained and controlled. The main failure modes for these battery systems are either latent (manufacturing defects, operational heating, etc.) abusive (mechanical, electrical, or thermal) or result from system integration design issues (power electronics, battery management, or software). Research on materials enables better designs against or around each of these failure modes.

Engineering controls and system design

The monitoring needs of batteries, the effectiveness of means to thermally separate battery cells and modules, and various fire suppression systems and techniques in systems are being studied extensively. Detailed testing and modeling are being done to fully understand the needs in system monitoring and containment of failure propagation. Rigorous design of safety features that adequately address potential failures are under development in most technology areas.

System Testing and Analysis

Validation techniques are guided primarily by CSR. Standard validation techniques are most evolved in the areas of lead-acid and lithium-ion battery technologies due to their use in vehicle technologies. This approach first reached maturity in the vehicle battery space, and work was done to reapply testing methods to grid storage. Tests are either under development or have been developed for certain energy storage technologies at every level of the system, shown in Figure 2, to validate systems safety.

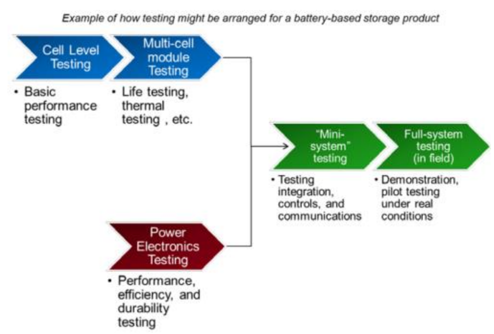

Figure 2 Levels of integration at which safety validating testing is performed

Emergency Preparedness

Incident preparedness activities, which are extremely important to the fire service, can be divided into two categories: engineered controls and administrative controls. Administrative controls include activities such as pre-planning for an incident, codes and standards, and risk management tools. Engineered controls include aspects of the system and its installation such as fire suppression, storage system design, and fail-safes.

Engineered controls

The first step in ensuring safety of any system is to ensure that the system is designed to the highest possible level of safety. The engineering of safety into a system must start at the materials level and be designed all the way through to deployment. Fixed facilities may have the added benefit of fire suppression systems, central station alarm monitoring, emergency power-off systems, site access control, ventilation systems, and on-site facilities or trained engineering staff. Current fixed-facility suppression systems utilize extinguishing agents that typically include water, dry chemical, clean agents, or other inert gas agents. Challenges include the increased amount of certain chemicals associated with some storage technologies, close proximity of energy storage installations to building occupants, and ensuring appropriate fire service access when needed.

Administrative controls

Two main components of the administrative controls for energy storage system safety are the emergency preparedness plans and the validation of compliance with adopted CSRs. The former guides first responders as to what actions to take in an emergency, and the latter dictates the facility signage, processes and procedures that are available pursuant to verification of compliance with CSR. Because of the low frequency of energy storage incidents, the wide variety systems sizes and technologies, and deployment options local fire departments may be unfamiliar with certain energy storage technologies. Fire service engagement during the review and permitting process will help ensure that first responders are adequately prepared if an incident occurs. Fire department training and operational tactics for the fire service are also critical components of emergency preparedness. Many of the tactics developed for hybrid and electric vehicles can be used on battery energy storage systems (see references for more information). However, aspects such as electrical grounding and higher voltages can produce additional hazards in grid ESS making situational awareness very important.

Conclusion

Energy storage systems are "enabling technologies"; they do not generate electricity, but they support critical advances to modernize the electric grid including the integration of renewables power. Energy storage systems can also serve as an emergency backup power source to improve a customer's resilience. Safety is critical to energy storage systems being able to provide these benefits. A track record of safe operation will instill confidence in the community of stakeholders who are impacted by the technology. Efforts to develop codes, conduct research, and educate stakeholders help build user confidence in the safety, reliability, and dependability of grid energy storage technologies. The fire service and its work to ensure the safe deployment of emerging technologies is critical to realizing the benefits that energy storage can provide to electrical customers and the grid at large.

References for More Information

There are a number of resources to draw on for more information on energy storage safety.

DOE Energy Storage Safety Strategic Plan

The discussion within the Safety Strategic Plan explores the current landscape of energy storage and identifies specific areas in validation techniques, incident response and safety codes, standards and regulations (CSR) where the community should focus its efforts.
energy.gov/oe/services/technology-development/energy-storage

Global Energy Storage Database

The DOE Global Energy Storage Database provides free, up-to-date information on grid-connected energy storage projects and relevant regional policies.

www.energystorageexchange.org/

DOE/EPRI Energy Storage Handbook in Collaboration with NRECA

The handbook serves as an information resource for all stakeholders, providing the latest developments in technologies and tools to build their understanding of energy storage. www.sandia.gov/ess/publications/

Fire Fighter Safety and Emergency Response for Electric Drive and Hybrid Electric Vehicles

The goal of this project by the NFPA's Fire Protection Research Foundation was to assemble and widely disseminate core principle and best practice information for fire fighters, fire ground incident commanders, and other emergency first responders to assist in their decision making process at emergencies involving electric drive and hybrid electric vehicles. Much of this guidance is applicable to incidents involving battery energy storage systems. http://www.nfpa.org/news-and-research/fire-statistics-and-reports/research-reports/for-emergency-responders/fireground-operations/fire-fighter-safety-and-emergency-response-for-electric-drive-and-hybrid-electric-vehicles

Tactical Considerations for Extinguishing Fires in Hybrid and Electric Vehicles

This video takes the data gathered through the HEV/EV high voltage battery burn study conducted by the NFPA's Fire Protection Research Foundation and breaks it down into a series of tactical considerations and best practices for extinguishing fires in HEV and EVs. https://www.youtube.com/watch?v=mtCk3srID_w

Energy Storage System Guide for Compliance with Safety Codes and Standards

The Compliance Guide (CG) is intended to provide assistance to those that need to document compliance with current safety-related codes and standards in order to develop and deploy ESS and guidance to those responsible for the approval and/or acceptance of ESS or for verifying compliance with those same codes and standards on an ongoing basis. Available online at: www.sandia.gov/ess/docs/safety/

Inventory of Codes and Standards for Energy Storage Safety

The purpose of the inventory is to identify laws; rules; model codes; and codes, standards, regulations (CSR) specifications related to safety that could apply to stationary energy storage systems (ESS) and experiences to date securing approval of ESS in relation to CSR. Available online at: www.sandia.gov/ess/docs/safety/

Energy Storage Safety Working Group

The DOE Energy Storage Safety Working Group (ESSWG) provides a single location for information relevant to people and organizations engaged or with interest in R&D efforts in grid storage safety, ESS safety codes, standards, and regulations, and safety outreach to first responders and other stakeholders. For information about how to join one or all three of the sub-groups, please email energystorage@sandia.gov.

Research and Development Subgroup

The R&D working group creates and executes strategic plans to address key safety technology and knowledge gaps that require exploration. Research will be guided by working group experts in the associated topic areas (e.g., fire suppression) and conducted through a coordinated effort involving all entities willing to collaborate on that research.

Codes Standards and Regulations Subgroup

Based on gaps between existing CSR and ESS technology, the CSR effort is to facilitate stakeholder collaboration in revising existing and developing new codes and standards so that they effectively guide energy storage system safety and do not become barriers to deployment.

Safety Outreach and Incident Response Subgroup

The Safety Outreach and Incident Response (SO&IR) workgroup educates, engages, and trains stakeholder communities on applying codes and standards to ensure that systems are safe when placed into service. This group also works to ensure that the first-responder community is equipped to respond, if there is an incident involving an energy storage system, in a manner that results in no loss of life and minimal property loss.

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Pacific Northwest National Laboratory is the U.S. Department of Energy's premier chemistry, environmental sciences, and data analytics national laboratory—managed and operated by Battelle since 1965, under Contract DE-AC05-76RL01830, for the DOE Office of Science. PNNL-SA-120438