Insight: Utility Scale Battery Energy Storage Systems

Recognizing the Risk

With the push for more renewable energy and the need for battery energy storage systems (BESS), the number of installations has been significantly increasing globally. While the use of batteries is nothing new to the electric generation industry, the use of batteries within the electrical grid to support large electrical loads is. This quick expansion has led to added risk and questions about proper fire protection.

Batteries can be found in a wide range of consumer product applications from mobile phones to electric vehicles. A wide range of types of power-generating facilities e.g., renewable and traditional also utilize batteries - typically with BESS that contain multiple lithium-ion batteries (LIBs) in each unit. LIBs have many advantages including efficiency, long life expectancy, and relatively low maintenance. But disadvantages include significantly increased fire risk and difficulty in fire control once a fire has started.

Large BESS systems are still a relatively new technology and application for LIBs with many power-generating sites only recently installing or planning installations. The LIBs integrated in these BESS systems are a reason for the increased fire hazard concern.

Thermal Runaway occurs when LIBs experience a quickly escalating overheating event which can lead to fires or explosions which then cascade to adjacent cells in the batteries. These types of fires are difficult to put out and are extremely hazardous, produce toxic fumes, and create electrical hazards. This type of failure has recently occurred at BESS facilities across the world resulting in large property damage and business interruption costs.

As a result of a significant failure in 2019, the National Fire Protection Association (NFPA) developed NFPA Standard 855* to address the *fire protection* of these systems. In this standard, UL 9540A is recognized as a BESS testing standard and, UL 9540 is the standard for listing and labeling BESS systems. However, there has been some confusion about the purpose of UL 9540A as discussed below.

Controlling the Hazard

As these large BESS facilities continue to be built to support the growth of renewable energy, increasing focus has been placed on making safer and more reliable systems. However, the only truly effective way to prevent fire from spreading across a BESS is adequate spacing between the units.

- Many risk reduction methods including fire monitoring, control, and suppression systems can be useful when combined with response planning; however, in at least one loss, inadvertent operation of an installed water-based fire suppression system caused a thermal runaway and the ensuing fire.
- Gaseous fire suppression systems have proven to be ineffective without adequate unit seperation.

When designing a large-scale BESS installation, the most important design considerations are location and physical layout. Currently, BESS units are installed in exterior locations, inside new application-specific buildings, and also retrofitted buildings. Industry loss experience has shown that indoor locations have significant added risk from rapid fire spread across BESS units after ignition. Thus outdoor locations are the recommended preference when possible.

Outdoor BESS locations detached from building structures are preferred as this typically reduces the threat of building damage while allowing adequate spacing between units. There is currently no industry standard for the correct spacing between BESS units. But, based on industry experience AIG has adopted a minimum 10 ft (3.0 m) spacing recommendation. While adequate spacing will not necessarily prevent a fire, it will likely minimize fire spread between units (and significantly reduce the size of the loss).

What determines a “fire safe” BESS? Underwriters Laboratories (UL) Standard 9540A (UL 9540A) establishes a test method for evaluating BESS thermal runaway propagation and is widely recognized thoughout the industry now as a reliable

reference. The results of a UL 9540A test help manufacturers develop installation guidelines, ventilation requirements, appropriate fire protection methods, and strategies for fire department emergency response. It is important to note however a UL 9540A test is not a safety certification protocol – it is only a reference for collecting important data to help manufacturers verify the effectiveness of their BESS system designs in the protection from hazards such as fire. U.L., however, does have a standard for testing and certifying actual BESS units - UL Standard 9540.

There is some confusion as some test results used during UL 9540A development have shown that in some cases adequate fire separation spacing could be achieved with reduced spacing down to less than 1 ft (0.3 m) for certain manufacturer's equipment. However, industry loss experience has shown that this has not been consistently true and thus cannot be considered a reliable guide. Additionally, UL 9540A utilizes certain variable criteria such as wind speed which could theoretically cool adjacent BESS containers limiting overall damage. But this also has unproven variances in real-world installations. For example, higher wind speeds could also push a fire from one BESS unit to another speeding fire propagation. Thus, while UL 9540A provides useful thermal runaway propagation guidance, it does not truly address variable environmental conditions and their impact on fire spread. This is only done by adequate spacing.

The design of units also needs to take into account the location of explosion vents or other penetrations to ensure they are placed in a way that directs any hot gases away from surrounding equipment or buildings.

Although not all BESS LIB fire risks can be eliminated, available measures and best practices should be incorporated into the design to help monitor and mitigate battery failure events that could lead to a fire. Battery management systems play an important role in monitoring and controlling BESS function within safe operating limits and, control preventive measures where possible when exceedance of these limits are detected. Advanced battery monitoring systems are also able to collect and process a large amount of data that provides valuable information and determines the overall health of each cell. Battery management systems should monitor cell temperature, capacity, state of charge, voltage, and current while charging and discharging. Monitored functional safety limits should activate trip functions and sound alarms when established safe limits are exceeded.

Large-scale BESS facility construction and installations are increasing exponentially across the globe with no signs of slowing down. As the industry continues to gain experience and technology advances, mitigation strategies will also evolve. But based on current BESS designs and fire history, the most important consideration is physical location and, layout. While battery monitoring systems and fire suppression systems are important, today’s BESS LIB technology brings unique fire risks that are new to the industry. The current solution? Spacing, Spacing, Spacing!

Resources / Standards

NFPA 855: Standard for the Installation of Stationary Energy Storage Systems

UL 9540: Energy Storage Systems and Equipment

UL 9540A: Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

*While NFPA documents are the global standard used by AIG, international equivalents may be acceptable.

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