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Mitigating Hazards in Large-Scale Battery Energy Storage Systems

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Experts estimate that lithium-ion batteries represent 80% of the total 1.2 GW of electrochemical energy storage capacity installed in the United States.[1] Recent gains in economies of price and scale have made lithium-ion technology an ideal choice for electrical grid storage, renewable energy integration, and industrial facility installations that require battery storage on a massive scale. While this is welcome progress, the flammable hydrocarbon electrolyte and high energy density of some lithium-ion batteries may lead to fires, explosions, and the release of toxic combustion products upon failure. It is important for large-scale energy storage systems (ESSs) to effectively characterize the potential hazards that can result from lithium-ion battery failure and design systems that safely mitigate known hazards.

The lithium-ion battery thermal characterization process enables the large-scale ESS industry to understand the specific fire, explosion, and gas emission hazards that may occur if a particular battery fails. This is typically done by inducing a failure of the cells or batteries; measuring their heat release rate (HRR) during a fire; collecting and analyzing the gases that emanate from the battery's exhaust vent during a failure (including CO, CO2, O2, H2, CH4); and performing combustion tests to understand the explosibility of the gases. ESS manufacturers and end users can then leverage these insights to determine how best to mitigate fire and explosion hazards. Examples may include 1) designing a fire suppression system that effectively extinguishes the battery fire and 2) incorporating explosion vents to release burning gases and avoid over-pressurization of enclosures upon failure.

A 2016 report authored by Exponent for the National Fire Protection Association's (NFPA) Fire Protection Research Foundation (FPRF) concluded that local authorities having jurisdiction (AHJs), ESS integrators, and ESS installers lacked clear direction regarding the fire hazards of ESS installations and had few, if any, technical studies, reports, or scientific articles to rely on when making decisions regarding the safe installation of these systems.[2] Exponent has also performed research for the FPRF to characterize the fire hazards of batteries and evaluate the effectiveness of fire suppression systems on battery and ESS fires. Work characterizing the fire and explosion hazards of batteries and energy storage systems led to the development of UL 9540, a standard for energy storage systems and equipment, and later the UL 9540A test method for characterizing the fire safety hazards associated with a propagating thermal runaway within a battery system.[3,4] NFPA 855 is another standard

[1] U.S. Energy Information Administration. U.S. Battery Market Storage Trends. May 2018. https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf

[2] National Fire Protection Association. Hazard Assessment of Lithium Ion Battery Energy Storage Systems. February 2016.

[3] Underwriters Laboratory. UL 9540 Standard for Energy Storage Systems and Equipment.

[4] Underwriters Laboratory. UL 9540A Test Method.

currently in development that provides guidance for a wide range of ESS systems on complex issues such as installation, ventilation, maintenance, operation, decommissioning, and fire prevention.[5] The first edition of NFPA 855 could be published as soon as early 2019. These new standards will complement the more general fire and explosion protection methods outlined in NFPA 13, NFPA 68, and NFPA 69 and should provide large-scale ESSs with more specific guidance to mitigate hazards.[6]

As standards have evolved, both the large-scale ESS industry and their lithium-ion battery suppliers have increasingly requested assistance characterizing a battery's fire and explosion properties. This process requires an in-depth knowledge of the unique properties of lithium-ion batteries, which companies may not always possess, along with specialized equipment and critical safety precautions. Even well-respected research and industrial facilities have encountered surprise explosions while testing protection systems for batteries in their R&D labs. This has prompted many to turn to third-party experts who can safely and effectively characterize lithium-ion batteries and evaluate systems to mitigate the risk of potential hazards.

Exponent's multidisciplinary team of engineers, scientists, and statisticians are backed by five decades of failure analysis experience and have investigated hundreds of small-scale and large-scale battery failures across the globe. Exponent can partner with both the ESS industry and lithium-ion battery suppliers to effectively characterize batteries and proactively build ESS protection systems that mitigate fire and explosion hazards and promote user safety.

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[5] National Fire Protection Association. NFPA 855 for Installation of Stationary Energy Storage Systems. NFPA Journal. May/June 2018.
[6] National Fire Protection Association. NFPA 68 Standard on Explosion Protection by Deflagration Venting. NFPA 69 Standard on Explosion Prevention Systems.

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