BESS Incidents - Recent failures and risk management considerations

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This is a follow-up to an article published in February 2022 on Battery Energy Storage Systems (BESS), which was the sixth in a series as follows:

1. Battery Failure Analysis and Characterization of Failure Types
2. BESS Frequency of Failure Research
3. Review of Fire Mitigation Methods for Li-ion BESS
4. Consequences of BESS Catastrophic Failure
5. Evaluation and Design of Structures to Contain Lithium-ion Battery Hazards

Incident Review

Since this series was first issued, there have been at least sixteen further incidents of BESS failures[1] around the world that have resulted in fires and damage to property, although there are no reports of significant injuries. As shown in Figure 1, some 10-15 incidents are reported each year against an increasing number and size of BESS projects that are being installed around the world.

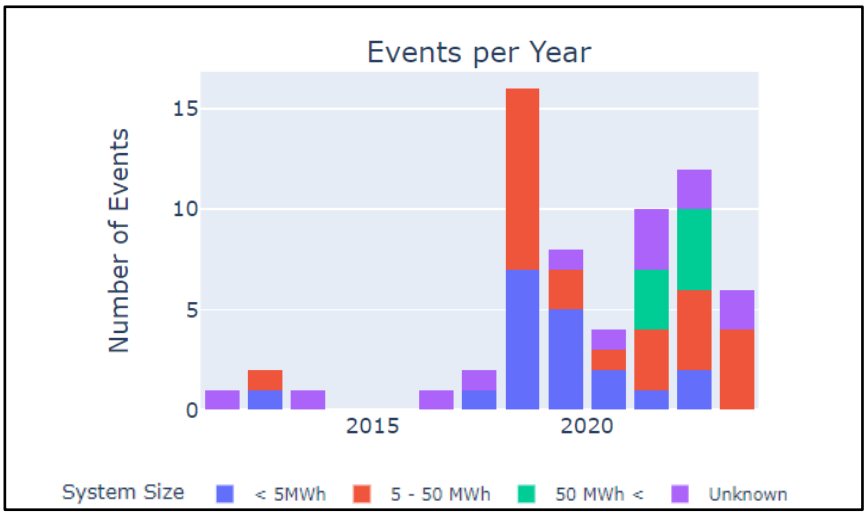

Figure 1 – Annual BESS incidents since 2011 (source EPRI [1])

[1] EPRI database; https://storagewiki.epri.com/index.php/BESS_Failure_Event_Database

The only reported explosion involved a lead-acid BESS (Figure 2), which appears to have been a result of a hydrogen explosion, not a thermal runaway of a Lithium system.

Figure 2 – Lead acid battery explosion (likely due to hydrogen)[2]

The most recent event occurred near Lake Ontario in New York state and took some four days to extinguish.[3] Firefighters appear to have taken a sensible approach and kept a reasonable distance away from the burning container, as shown below in Figure 3.

Figure 3: Firefighters at Chaumont, New York State, July 2023

[2] https://krcrtv.com/north-coast-news/eureka-local-news/battery-storage-container-explodes-rocking-rio-dell-rv-park

[3] CTIF; photo credit Three Mill Bay Fire Company Inc. https://ctif.org/news/solar-farm-lithium-ion-battery-fire-took-four-days-extinguish

In contrast, at an earlier incident in South Korea in January 2022, unaware of the potential risk of an explosion during a BESS fire, the responding fire brigade entered the building. Fortunately, no explosion occurred, although the situation caused great controversy in the region.[4]

Figure 4: Firefighters at Gunwi-gun, North Gyeongsang Province, S Korea, January 2022

A fire in April 2022 involving one containerized unit at Chandler, Arizona, burnt for over ten days. To keep the temperature down, an automatic sprinkler system was left running the entire time. A robot was eventually used to open the doors of the container, which kept the responders at a safe distance in case of an explosion.

At least three of the fire incidents over the last 12 months have involved Lithium Iron Phosphate (LFP) batteries—a type that some references had previously stated were inherently safe (or at least safer) from cascading thermal runaways. While they might be safer, LPF batteries are still subject to these runaway conditions and, like lithium ion batteries, they typically contain ethylene carbonate electrolyte, which can generate flammable gases if the battery undergoes thermal runaway. An example of an incident involving an LFP BESS is shown in Figure 5.

[4] (http://www.e2news.com)

Figure 5: Reported LPF Battery fire at in Longjing District, Taichung City, Taiwan, July 2023[5]

Two incidents occurred on consecutive days in June 2023, in two separate locations at Warwick in New York State, both involving the same company and same model of batteries. The resulting fires were reported to be smouldering for more than a week and although no official report is yet available, there were reports that the initiating event may have been weather-related.

There were three further incidents in S Korea, two of which appear to have involved BESS units in larger buildings, in which the entire buildings were destroyed by fire. The third incident destroyed "at least one of 24 BESS buildings".

Discussion

It is clear that the risks associated with BESS are here to stay and with the ever-increasing number of installations, there will be more incidents. The learnings from events are trickling through the industry, although there is no one solution or design that is inherently safe, i.e., that cannot go into a cascading thermal runaway with the potential to spread to other units if they are too close together. Where BESS units are inside large buildings, this does appear to present the greater risk, as the total loss of the building is a credible outcome.

The industry continues to learn and has identified, for example, certain battery designs that should be avoided. Various recalls of BESS that used a certain LG Energy Solutions design manufactured in 2017 and 2018 have been made,[6] including those installed in some vehicles or domestic systems.

NFPA 855 specifies a minimum clearance from buildings, rights of way, combustible/hazardous materials etc. of 10 ft (3 m), reducing to 3 ft (0.9m) based on fire and explosion testing to UL9540A or equivalent.

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5 https://udn.com/news/story/7320/7279049

6 https://www.prnewswire.com/news-releases/lg-energy-solution-announces-plan-for-replacement-of-certain-energy-storage-system-ess-batteries-to-strengthen-confidence-in-the-ess-industry-and-further-enhance-safety-301298584.html

Furthermore, BESS units that contain modules that are larger than 50 kWh and/or with separation distances between modules of less than 3 ft (0.9m), must undergo UL9540A testing, to determine whether a runaway would be contained, or propagate to other modules or units. Although this provides great opportunities for design refinements, such as internal separation distances, fire barriers, and other mitigation systems, it does not guarantee that a runaway would be contained in all circumstances.

There is still plenty of debate over the benefits and disadvantages of suppression systems (that could lead to a subsequent explosion) and water sprinklers (that may help to prevent an escalation). The insurer, Allianz, recommends installing sprinkler protection within BESS rooms and ideally within BESS containers.[7] Allianz also notes that other agents, such as aerosol or gaseous extinguishing systems, will extinguish the fire, but they do not provide cooling. This allows the heat to rapidly spread back through the battery, providing an opportunity to reignite any remaining active sections.

The industry is demanding ever increasing power densities, which goes against the concept of providing space between units, which can help to reduce the potential for thermal runaway.

The responding agencies are continuing to learn the best and safest ways to tackle such incidents and to keep their distance, so hopefully, there will be no other loss of life due to people being too close to any potential deflagrations in the future.

In the meantime, the familiar simplified Bow-Tie diagram for Lithium-ion battery thermal runaway with various protection layer (barrier) concepts is shown in Figure 6. Although only a few barriers are included in the figure, many additional barriers could be added to both sides of the diagram.

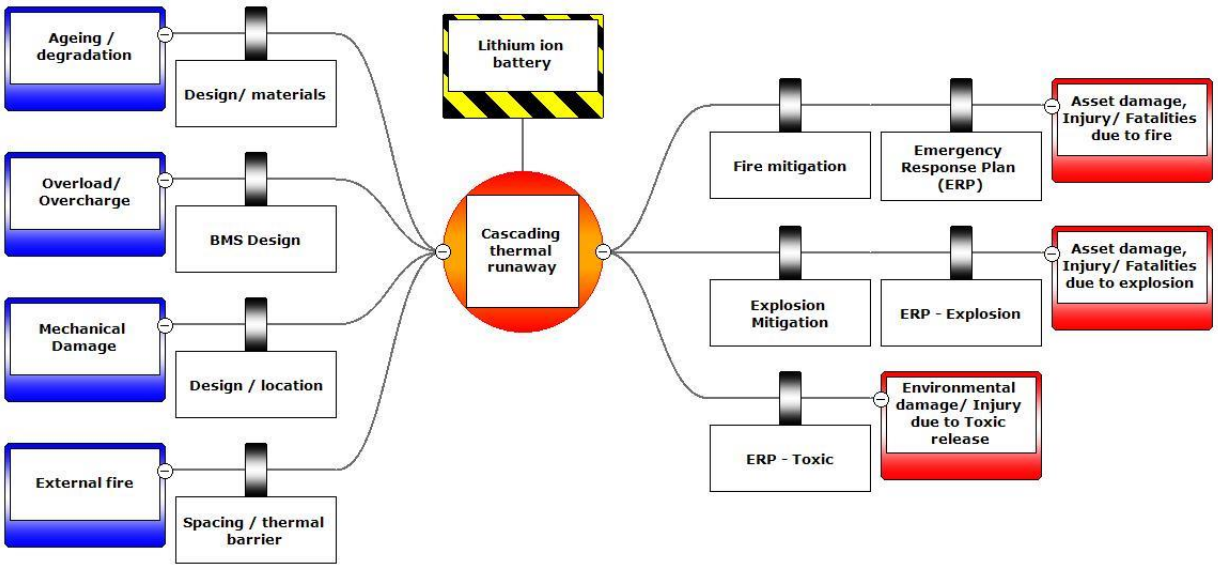

Figure 6: Simplified Bow Tie diagram for Thermal Runaway of Lithium-Ion Batteries

[7] Allianz Global, Battery Energy Storage Systems (BESS) using Li-Ion Batteries, Tech Talk Volume 26, available from: https://commercial.allianz.com/news-and-insights/risk-advisory/tech-talk-volume-26-bess-english.html

Recommendations

It appears that the best course of action is still to design the BESS container system assuming that the worst-case runaway will occur and that all of the cells/modules/racks within the container will be involved.

The objective should be to first and foremost prevent injury to personnel, then prevent escalation of the event to adjacent containers, while providing suitable means for emergency response teams (ERT)/fire brigade personnel to provide cooling for adjacent containers and other equipment from a decent standoff distance. The responding agencies must be informed of the potential risks of deflagration and any water sprinklers (dry or wet) should be confirmed to be in working order and have valves/connection points that are a safe distance from the container.

It may be appropriate to design BESS containers with tethered wall and/or roof explosion relief panels that are sized to release to the outside at pressures well below those that might cause any structural damage to the container.

We have noted a variety of separation distances between BESS containers located outside, ranging from less than 0.3m (1ft) to more than 3 metres. There has been some discussion in the insurance industry about spacing BESS containers up to 25ft apart. [8]

From the insurance and risk tolerance viewpoint, the total loss of an entire BESS container and its contents should be assumed to be a credible event provided that sufficient separation distance exists between BESS containers. Even if fire suppression/firefighting has prevented 100% involvement of the equipment, it is unlikely that there would be any value in the salvage. If separation distances are inadequate, there is the potential for further damage and the involvement of any adjacent BESS units. Installations within a large building also carry a risk of an incident escalating to include the entire building. Environmental damage and clean-up costs could be significant where firewater and lithium-ion cell electrolytes contaminate the ground/water courses, such that secondary containment should be considered.

Throughout this series, it has been our intention to educate and inform the reader about the hazards and risks of Lithium-ion battery energy storage schemes based on current knowledge. Other battery types are also being developed, such as Lithium-air, solid state and flow batteries, and as experience with BESS increases, it is important to keep up to date with this rapidly evolving technology. BakerRisk continues to monitor developments and will provide further updates as more information and knowledge becomes available.

[8] Mylenbusch IS, Claffey K, Chu BN. Hazards of lithium-ion battery energy storage systems (BESS), mitigation strategies, minimum requirements, and best practices. *Process Saf Prog*. 2023;1-10. doi:10.1002/prs.12491