

LEARISK TECHNICAL BULLETIN

04.26 BATTERY ENERGY STORAGE SYSTEMS (BESS)

Key risks and loss prevention

A rapidly expanding market with specific risks

Battery Energy Storage Systems are playing an increasingly important role in modern power networks. Lithium-ion batteries are susceptible to thermal runaway, a self-propagating process that can lead to fire, explosion and extensive property damage.

What should insurers, lenders and project stakeholders consider?

No extinguishing agent has demonstrated consistent effectiveness at utility scale once thermal runaway is established.

Flooding and water damage can lead to the total loss of the installation, rather than only one container.

Separation distances, the BMS and standards such as NFPA 855, UL 9540A and FM 5-33 are central to risk management.

FOR

Insurers	Re insurers	Brokers
Risk Managers	Companies	Retail brokers

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ENERGY STORAGE FOR ELECTRICAL SYSTEMS

Battery Energy Storage Systems (BESS) are playing an increasingly important role in modern power networks, supporting the integration of renewable energy sources and enhancing grid flexibility. By storing electricity during periods of surplus generation or low demand and releasing it when required, these systems help balance supply and demand while improving energy resilience.

The rapid growth of BESS installations is being driven by the global energy transition and the increasing deployment of solar and wind generation. Lithium-ion batteries remain the dominant technology, with both Nickel-Manganese-Cobalt (NMC) and Lithium Iron Phosphate (LFP) chemistries widely used. In recent years, however, the market has shifted markedly towards LFP batteries, reflecting their economic advantages and growing acceptance across utility-scale projects. At the same time, outdoor containerised installations are increasingly replacing traditional indoor battery facilities, introducing new opportunities as well as distinct risk considerations.

In this circular, we highlight the key technical and risk issues that insurers, lenders and project stakeholders should consider when evaluating BESS facilities during both construction and operational phases.

THERMAL RUNAWAY

Lithium-ion battery systems are susceptible to thermal runaway, a self-propagating process that can lead to fire, explosion, and extensive property damage. Experience has shown that batteries based on Nickel-Manganese-Cobalt (NMC) chemistry are generally less stable and can reach significantly higher temperatures during a thermal runaway event than Lithium Iron Phosphate (LFP) batteries. However, LFP technology is also associated with its own challenges, particularly the generation of large volumes of flammable and potentially explosive gases. Consequently, both battery chemistries require robust risk management and protection measures.

Thermal runaway may be triggered by a variety of factors, including:

- **Mechanical damage:** Physical impact, crushing, penetration, or vibration during manufacturing, transportation, installation, or operation can damage cells and create latent defects that may eventually initiate thermal runaway.
- **Thermal exposure:** Elevated ambient temperatures, inadequate cooling, external heat sources, direct solar radiation, or overheating of adjacent equipment can compromise cell integrity and increase the likelihood of failure.

- **Electrical abuse:** Internal or external short circuits, overcharging, excessive discharge, and other abnormal operating conditions can result in rapid temperature increases. Fast-charging regimes may further accelerate battery degradation. For this reason, the Battery Management System (BMS) plays a critical role as the first line of defence, continuously monitoring and controlling charging, discharging, and cell operating parameters.

While these initiating events are often associated with the battery system itself, external hazards can also contribute to severe incidents. Natural catastrophes, equipment failures, or damage to supporting infrastructure may impair cooling systems, disrupt power supplies, or create short-circuit conditions, thereby increasing the probability and severity of thermal runaway events.



The McMicken plant, located in Arizona, USA, (2 MWh) suffered a fire that caused an explosion when the container door was opened.

Each outdoor module contained 28 LG NMC technology batteries and there were also a BMS (Battery Management System) module.

The incident, which occurred on 19 April 2019, was caused by thermal runaway resulting from a design defect in the batteries.

In addition to the accumulation of high temperatures and flammable gases, the clean agent gas system with which the BESS was equipped not only prevented the escape of toxic gases to the outside, but also led to a greater accumulation of gases due to the lack of ventilation.

Following this incident, extensive investigations were carried out, leading to significant changes in regulations and safety standards. Since then, the NFPA and other regulatory bodies have updated their guidelines on the design, operation and response to energy storage incidents.

NATURAL HAZARDS

In addition to the phenomenon of thermal runaway, several external factors can compromise the safety and operability of BESS installations. These include environmental events such as wildfires, earthquakes, extreme heatwaves, high humidity, flooding, and damage caused by local wildlife (for example, rodents).

Flooding and water damage poses a particularly high risk, as it can lead to the total loss of the installation rather than just a single container. The presence of saltwater exacerbates this hazard by accelerating corrosion and creating conditions conducive to short circuits, which may in turn initiate a thermal runaway event.



In July 2021, during commissioning tests of the Victorian Big Battery lithium-ion battery energy storage system (300 MW / 450 MWh) in Australia, a fire broke out affecting two of the 212 outdoor Tesla Megapack units (3 MWh each). The fire, caused by a leak in the cooling system that led to a short circuit and thermal runaway, burned for three days.

An updated database of all BESS incidents can be found on the following page:
https://storagewiki.epri.com/index.php/BESS_Failure_Incident_Database

RECOMMENDATIONS FOR RISK PREVENTION AND MITIGATION

Why prevention and containment are decisive

At present, no extinguishing agent has proven capable of penetrating a lithium-ion battery cell and arresting the chemical reactions once thermal runaway has been initiated. As a result, the process is generally allowed to run its course until the available energy within the affected cells is exhausted. Although extensive research is underway into gaseous, liquid, and aerosol-based suppression systems aimed at interrupting or slowing these reactions, no solution has yet demonstrated consistent effectiveness at utility scale.

Consequently, water remains the most effective firefighting medium available. While it cannot stop thermal runaway within affected cells, it is highly effective in cooling adjacent equipment, limiting heat transfer, and reducing the likelihood of fire propagation to neighbouring modules or containers.

Given these limitations, the most effective risk management approach is prevention combined with fire containment. The objective should be to minimise the probability of thermal runaway occurring and, should an incident develop, to prevent its escalation beyond the affected battery unit. In practice, a controlled burn strategy, often referred to as "let it burn", may become the preferred response once thermal runaway is fully established, provided that adequate measures are in place to protect surrounding assets, personnel, and critical infrastructure.

Key risk mitigation measures include:

- **Layout and separation distances:** Adequate separation between BESS units is essential to prevent fire spread. Site layouts should comply with the requirements and recommendations of recognised standards, particularly NFPA and FM. Where possible, BESS installations should be located outdoors and at safe distances from occupied buildings and critical equipment. Indoor installations should be housed in dedicated fire-rated compartments designed specifically for battery storage applications.
- **Equipment manufacturer selection:** Preference should be given to proven technologies supplied by experienced manufacturers with a demonstrable track record in utility-scale projects. Prototype technologies and first-of-a-kind installations should be approached with caution.
- **Construction and resilience considerations:** Physical barriers and compartmentation should be incorporated to limit fire propagation between battery sections. Design measures should also address natural hazards, including seismic resistance in earthquake-prone areas and elevated platforms or flood protection measures in areas exposed to flooding.
- **Inspection and maintenance practices:** Battery systems should be inspected, tested, and maintained in accordance with the manufacturer's recommendations and recognised industry standards throughout their operational life.
- **Battery management and operational controls:** The Battery Management System (BMS) represents the most important preventive safeguard against thermal runaway. The BMS continuously monitors cell temperature, voltage, current, and state of charge, identifying abnormal operating conditions before they become critical. Advanced systems can automatically respond to overheating, overcharging, excessive discharge, overcurrent, and other fault conditions. Proper operating procedures, avoidance of mechanical damage, and strict adherence to manufacturer-approved charging equipment are also essential elements of loss prevention.

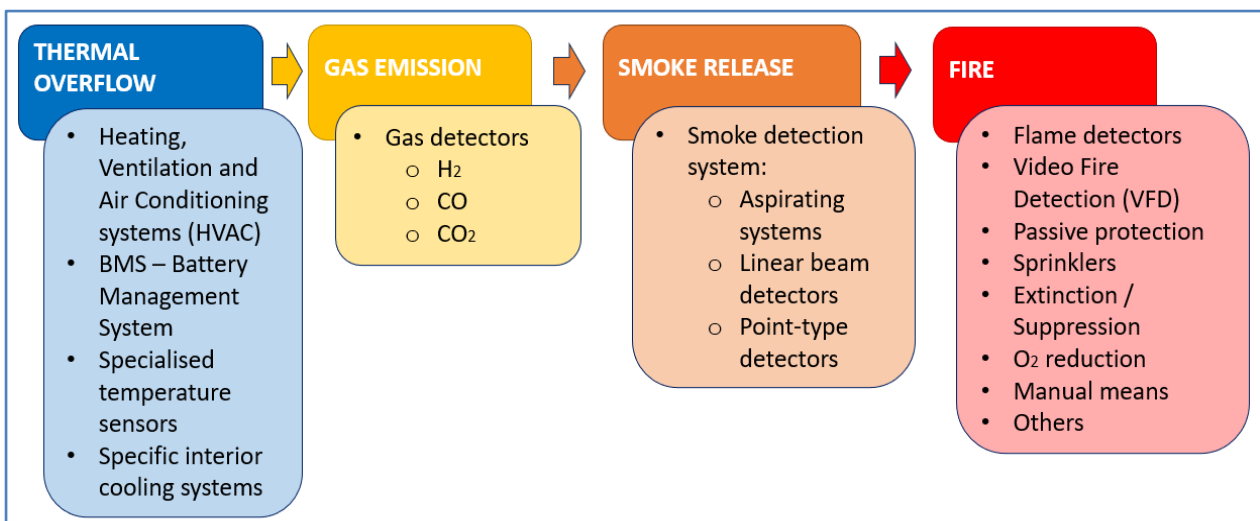
On 24 June 2024, a fire at a lithium battery factory in Hwaseong, South Korea, claimed the lives of 22 people.

Firefighters determined that spraying water would not extinguish the fire, so dry sand was used instead. Water was only used as a cooling method to prevent the fire from spreading to nearby factories.



One of the most significant events took place in January 2025 at the Moss Landing plant in California (USA). A fire originating in one of the LG modules installed inside buildings (NMC technology) caused a considerable emission of toxic smoke and forced the evacuation of thousands of people. (NMC technology tends to reach higher temperatures than LFP during a “thermal runaway” event).

- **Emergency plan:** Development and implementation of an internal and external emergency plan (with the fire brigade and the community).
- **Detection/suppression systems:** The fire extinguishing system for BESS will depend on many circumstances, and each case must be analysed individually to determine the best alternative, depending on the stage of the fire is intended to be controlled.



Fire risk mitigation systems at different stages of a BESS incident

APPLICABLE STANDARDS AND CERTIFICATIONS

To ensure the safety, reliability and proper performance of battery energy storage systems (BESS), various international standards and certifications apply, including:

UL (Underwriters Laboratories) Certifications:

- **UL9540:** Standard that evaluates the safety of the entire energy storage system (ESS), including batteries, inverters, control and protection systems.
- **UL9540A:** Test method for evaluating the risk of thermal propagation in battery systems. It is used to characterise behaviour in extreme thermal events, such as fires.
- **UL1973:** Establishes safety and performance requirements for stationary and light mobility batteries, focusing on their use in critical applications such as BESS. Compliance is necessary to ensure the safety, reliability and proper functioning of battery components.
- **UL1741:** Standard applicable to inverters, converters and control equipment interconnected with the electrical grid, evaluating safety, performance and interoperability.

NFPA (National Fire Protection Association) standards:

- **NFPA 855:** Standard for the safe installation of energy storage systems. It defines design, location, fire protection, ventilation and minimum distances requirements.
- **NFPA 68 and 69:** Complementary standards that may be applied for explosion mitigation (explosion ventilation and active suppression).
- **NFPA 13:** Related to automatic sprinkler systems.

IEC (International Electrotechnical Commission) standards:

- **IEC 62933-1:2018:** European standard defining terms for electrical energy storage systems, including parameters, testing methods, installation and safety considerations.

FM (Factory Mutual) standards:

- **FM 5-33 (Lithium-Ion Battery Energy Storage Systems):** Published in January 2017 and revised in April 2025, it provides loss prevention guidance regarding the design, location,

compartmentation, detection and suppression systems, operation, maintenance, and testing of stationary lithium-ion ESS exceeding 20 kWh. It is a key resource for understanding and mitigating risks.

Technical note

This technical bulletin is intended for information and loss-prevention purposes. The recommendations should be assessed in relation to the specific design, location, operating conditions and contractual requirements of each BESS facility. The document does not replace a detailed engineering assessment, fire protection study, emergency response plan or review of applicable codes and standards.



RISK ENGINEERING SERVICES

WHO WE ARE

We are a company specialized in risk engineering with over 50 years of experience in the sector.

We provide independent consulting and services to identify, prevent, and mitigate risks affecting insured assets. Additionally, we offer industrial asset valuation and detection of underinsurance situations.

We have an interdisciplinary team composed of engineers from various specialties, architects, accountants, and NFPA-certified specialists (among others).

We operate in several countries across the Americas, Europe, Africa, and Asia, providing risk engineering services with a global reach.



Since 2005, we have implemented a quality management system based on ISO 9001 and continuously specialize in advanced technologies, such as catastrophic event simulators, hydraulic fire protection design, and virtual training platforms.

WHAT CAN WE OFFER

We have experience in:

- Power Generation and Renewable Energy
- Petrochemical, Oil, and Gas
- Mining and Heavy Industry
- Manufacturing and Construction
- Industry and Services
- Properties
- Jewelry Block
- Agriculture

Risk Engineering (Insurers, Brokers, and Policyholders)

- Property Risks (large and small); Machinery Breakdown; BI (Business Interruption); Construction/DSU (Damage to Works Under Construction); Maximum Loss Estimates (PML/EML); Civil Liability; Others (e.g., Jewelry Block).

Risk Assessments and Asset Valuations (Industrial and Non-Industrial Companies)

- BCP (Business Continuity Plan); Customized Risk Assessments for Clients; Risk Mapping; BI/DSU Exposure (Business Interruption/Damage to Works Under Construction); Fire System Performance Evaluation; Emergency Preplanning.

Engineering

- HAZOPS, ATEX, DHA; Fire System Design; Engineering Support.
- Determination of insured sums, valuations for accounting purposes, construction progress.