RISKS AND INSURANCE IN BATTERY ENERGY STORAGE SYSTEMS (BESS)

ENERGY STORAGE FOR ELECTRICAL SYSTEMS

The main purpose of a BESS is to store electrical energy for later use in residential or industrial grids, particularly facilitating the integration of variable renewable energy sources such as solar or wind power. These systems accumulate energy during periods of high production or low demand and release it when needed.

The most widely used technologies in BESS installations are lithium-ion batteries with Nickel-Manganese-Cobalt (NMC) and Lithium Iron Phosphate (LFP) chemistries. In recent projects, there has been a marked shift towards LFP batteries, driven by their lower cost. Installations with outdoor modules are gradually replacing those built indoors.

THERMAL RUNAWAY

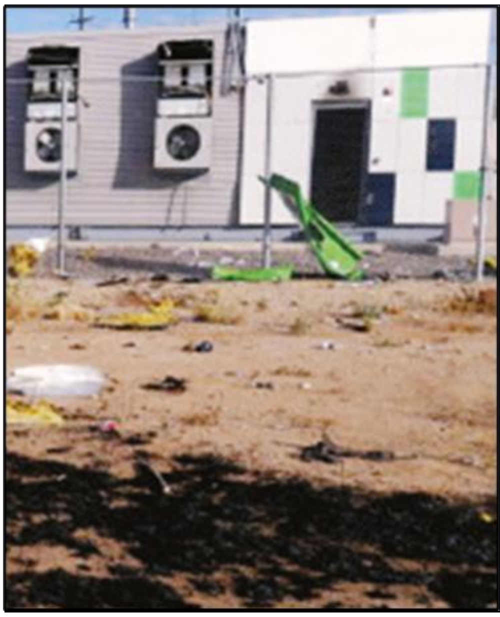
Lithium-ion cell-based systems can experience “thermal runaway”, leading to fires and explosions. Batteries with NMC technology have proven to be more unstable and reach higher temperatures than LFP technology during a thermal runaway phenomenon. However, LFP technology has been shown to generate large amounts of potentially explosive gases; therefore, each of these technologies presents challenges for risk control.

To learn more about the "Thermal Runaway" effect, we recommend reading our LEARISK 06.22 technical bulletin https://www.learisk.com/uploads/circulares/2023/05/06-22-thermal-runaway-incendio-de-baterias_.pdf.

Thermal runaway can be caused by various factors, such as:

- **Mechanical damage**: Physical impact or penetration during manufacturing, transport, installation, and operation. Impacts can cause defects that may lead to thermal runaway.
- **Thermal damage**: Exposure to high temperatures, such as overheating, external heat, or exposure to sunlight.
- **Electrical misuse**: Short circuit, improper charging or discharging (overcharging or excessive discharging). Fast charging is more likely to damage batteries. For this reason, the Battery Management System (BMS), which regulates charging and discharging and is the first line of defence against fires, is very important.

Although not always directly related to the storage system itself, such risks can result in infrastructure failures, impair cooling systems, or trigger short circuits, thereby increasing the likelihood of severe incidents.



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 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

At present, there is no extinguishing agent capable of penetrating the fire plume and halting the chemical reactions occurring within lithium cells once thermal runaway has begun; the fire can only cease naturally. Although research and testing are being conducted with gases and liquids in an attempt to stop or slow down this reaction, to date there is no proven large-scale solution. In this context, water remains the most effective agent for cooling components and controlling the spread of fire, even though it does not fully extinguish it.

At the day, the most effective strategy for addressing such incidents lies in implementing preventive measures that minimise the likelihood of their occurrence and the fire "control" to avoid spread ("let it burn") will probably become the most common strategy.

Some recommendations are the following:

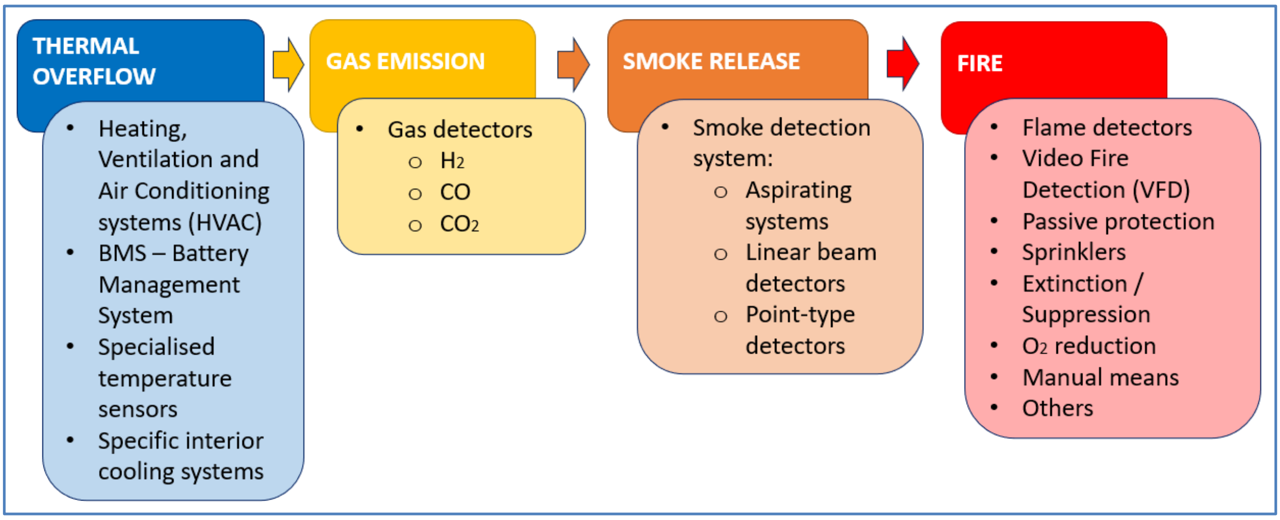
- **Layout and separation distances**: Limiting the spread of fire through adequate separation distances is essential. Follow the guidelines outlined in relevant standards, primarily NFPA and FM. The ideal location for BESS units is outdoors, at safe distances from other buildings. If installed indoors, they must be in dedicated rooms with high fire-resistance walls and comply with specific construction requirements.
- **Equipment manufacturer selection**: Consider the experience of both the manufacturer and the project leader. Avoid using prototypes.
- **Construction considerations:** Use barriers to prevent a fire in one section from spreading to the rest of the system. Likewise, construction features should address natural hazards, incorporating seismic-resistant structures and elevated platforms to mitigate the effects of flooding.
- **Maintenance practices**: An adequate maintenance plan is required, following the manufacturer's instructions.
- **Battery care**: Avoid impacts, rapid overcharging/discharging and exposure to extreme temperatures. The Battery Management Systems (BMS) is the most important preventive component. It controls and monitors the state of charge and temperature, preventing defects that cause "thermal runaway". An advanced BMS can interrupt overheating, overcurrent, overcharging, excessive discharge and overdemand situations. ALWAYS use the original chargers supplied by each battery manufacturer.

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.