Kidde Fire Systems

Guide for BESS and Lithium-ion Batteries

Fire Protection in Battery Energy Storage Systems

KiddeFenwal

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With higher energy density, faster charging times and longer lifespan, lithium-ion batteries transformed battery energy storage systems (BESS) from a niche technology to a scalable solution for grid level energy storage. BESS captures the energy from different sources and stores it in rechargeable batteries for later use. As a result, they're often combined with renewable energy sources such as solar panels and wind turbines to gather renewable energy during an off-peak time and deploy it when needed. BESS is playing an increasingly significant role in powering today's world.

Battery Energy Storage Systems are utilized across a variety of fields, each reaping distinct benefits from their use:

Grid Stabilization: Utilities use BESS for grid balancing, peak shaving, and regulating frequency and voltage, which enhances grid reliability.

Renewable Energy Integration: Wind and solar energy, both intermittent sources, are stabilized with BESS, enabling continuous power even when conditions aren't optimal for generating power.

Backup Power Supply: Data Centers, industries, hospitals, and even homes rely on BESS as a backup during power outages, ensuring uninterrupted operation.

Industrial and Commercial Applications: Factories, warehouses, and large facilities use BESS to manage their power loads efficiently, reducing energy costs and promoting sustainable operations.

Benefits of Battery Energy Storage Systems

Reliability: By storing energy and supplying it during shortages, BESS improves grid stability and reduces dependency on fossil-fuel-based power generation.

Cost Savings: BESS users can save significantly on energy costs by storing energy during low-demand, low-cost periods and utilizing it during peak demand times.

Environmental Impact: BESS systems used in conjunction with solar and wind-based generation could reduce the need for fossil fuel power, playing an important role in lowering greenhouse gas emissions and helping countries achieve their climate goals.

While the initial purchase price of lithium-ion batteries is often higher than traditional lead-acid batteries, they are currently the technology of choice for BESS offering several key advantages:

- **Extended lifespan:** Lithium-ion batteries last approximately 2-3 times longer than lead acid batteries, resulting in fewer replacements and reduced maintenance costs over the lifetime of the system. They are not prone to “memory effect” where frequent partial charging can reduce their capacity and can be charged at any time without impacting the lifespan.
- **Higher energy density:** Lighter weight and smaller sized, lithium-ion batteries can store more energy in the same space as lead-acid batteries.
- **Faster charging:** Lithium-ion batteries charge faster than lead-acid batteries, a major advantage when situations where quick power restoration is required.
- **Lower maintenance:** Lithium-ion batteries generally require less maintenance compared to lead-acid batteries because they naturally lose charge at a minimum rate when not in use. They can be stored for extended periods without significant capacity loss and are less prone to problems like uneven distribution of materials within the battery.
- **Higher Temperature tolerance:** Lithium-ion batteries can operate effectively in higher ambient temperatures compared to lead-acid batteries, which is important in data centers with high heat loads.
- **Scalability:** Lithium-ion batteries can be easily scaled to meet the growing power needs of a data center by adding additional battery modules as needed.
- **Improved reliability:** Advanced battery management systems (BMS) in lithium-ion batteries monitor and protect the battery health, ensuring consistent performance and preventing potential safety concerns.

BESS Implementation

Depending on purpose of end-use, Battery Energy Storage Systems are very often implemented in standard containers sizes including those of 20’, 30’and 40’ length optimizing ease of transportation and integration into an existing container farm.

BESS and Fire Safety

Due to their high energy density, proper handling and fire safety protocols are crucial when installing and managing lithium-ion batteries. Concerns have been raised regarding the safety of BESS facilities because lithium-ion batteries contain flammable electrolytes. The electrolytes and the breakdown products of electrolytes can catch fire in the presence of high heat as a result of a short circuit between anode and cathode of a cell. These conditions can trigger a process called thermal runaway, spread through propagation to the other cells and even ignite nearby flammable materials. Thermal runaway occurs at different temperatures for different types of lithium-ion batteries. This risk is amplified in confined spaces like BESS where ventilation might be limited.

Key factors contributing to the fire risk:

Overheating:

Excessive heat from charging or environmental factors can trigger thermal runaway, causing the battery to rapidly overheat and potentially ignite.

Physical damage:

Impacts, punctures, or crushing can damage the battery's internal components, leading to short circuits and heat generation. Newer batteries have become very densely packed resulting in reduced separation between the positive and negative (anode and cathode) plates, making them even more prone to damage by jarring and impacts.

Manufacturing defects:

Faulty battery cells can spontaneously generate heat and ignite.

Overcharging:

Charging a battery beyond its capacity can cause excessive heat build-up, leading to thermal runaway.

Propagation:

The intense heat generated once a lithium-ion battery starts to burn, can trigger a chain reaction to other nearby cells in the system.

Fire Spread:

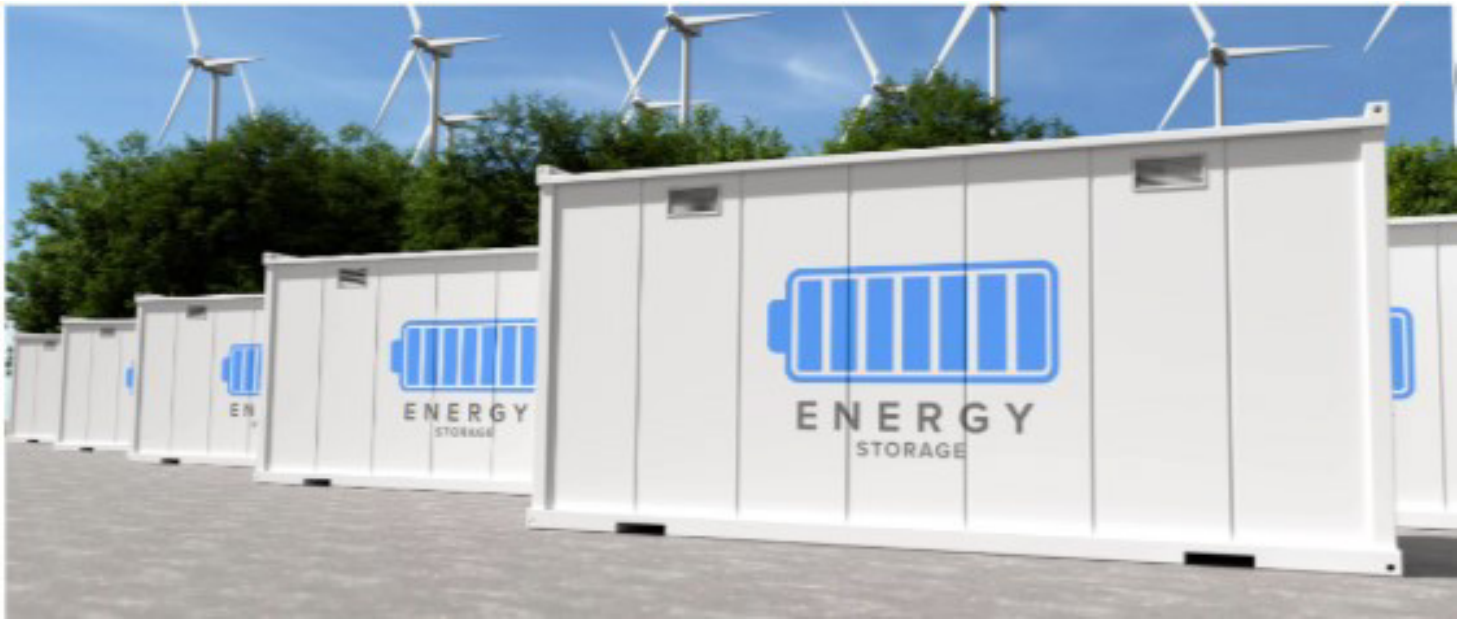
Intense heat can cause explosions, quickly spreading fire to other nearby flammables.

Toxic fumes:

Lithium-ion battery fires release harmful gases like lithium vapor which can be toxic if inhaled.

Explosion:

In extreme cases, a lithium-ion battery fire can lead to an explosion due to the rapid release of gas.



Stages of battery failure

Stage 1 - Abuse

- Electrical, thermal, or mechanical can cause the electrolyte to change from a liquid to gaseous state.
- Electrical abuse occurs when the battery voltage limit is exceeded during the charge or discharge cycle.
- Thermal abuse occurs when the operational temperature exceeds the temperature limits of the batteries.
- Mechanical abuse occurs when the battery is subjected to physical or mechanical damage such as crushing, indentation, or puncture.

Stage 2: - Off-Gas:

If the abuse continues, the liquid electrolyte will continue to convert to gas, causing internal pressure build-up inside the battery. Due to the rise of internal pressure the cell case may rupture.

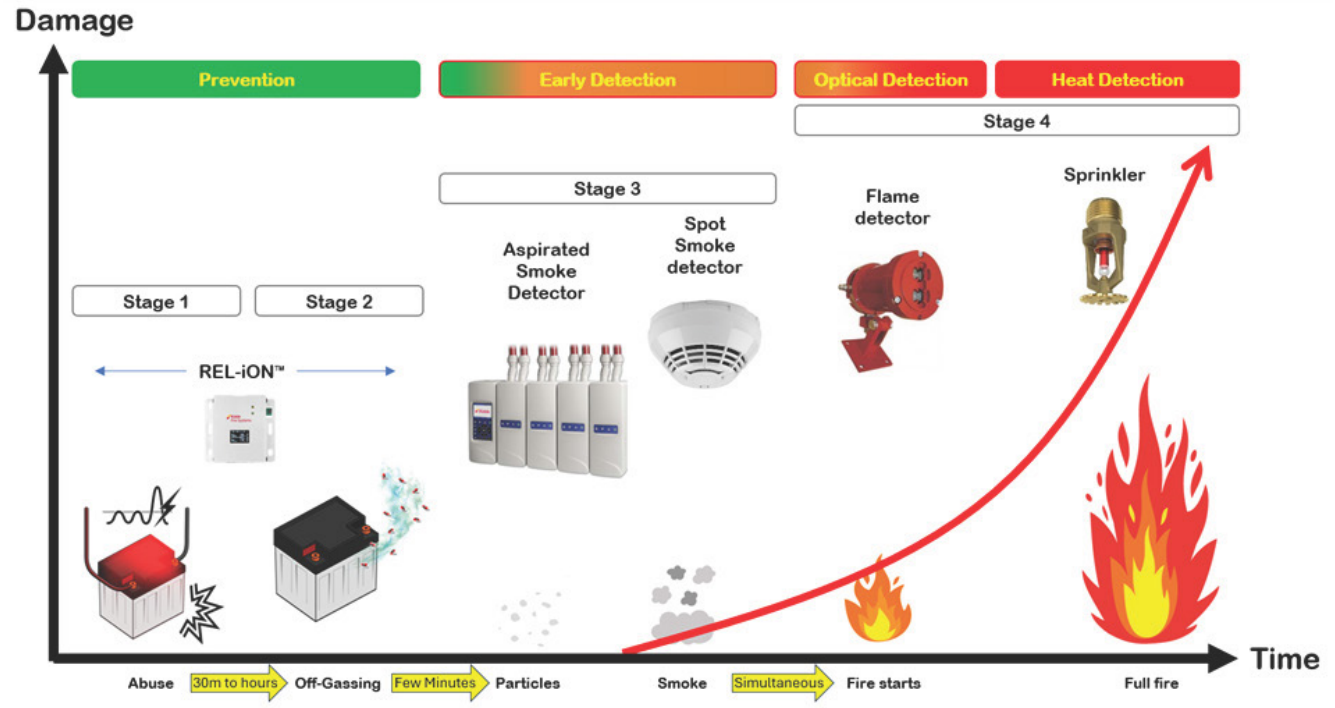
Stage 3 - Smoke:

If the abuse factor continues, the temperature in the cell will increase, causing the release of smoke. Thermal runaway can no longer be prevented.

Stage 4 - Fire:

At this stage, the battery catches fire and enters thermal runaway and if unchecked may spread through propagation.

Stage of Thermal Runway



BESS and Fire Prevention

Battery energy storage solutions (BESS) offer many benefits, while also coming with significant risk as lithium-ion batteries can pose a serious fire hazard.

While traditional detection technologies, such as smoke detection, fire detection, carbon monoxide monitoring and hydrogen monitoring can be part of a comprehensive safety solution, they're all reactive approaches. These technologies engage when smoke and fire are present, and thermal runaway has already occurred. If a single cell has reached the point where it starts emitting smoke or fire, it may already be too late to try and prevent it from spreading to surrounding cells.

Kidde Fire Systems is uniquely positioned to address the full spectrum of fire safety needs, with a comprehensive, single-branded solution that encompasses Prevention, Detection, Control, Notification, and Suppression for BESS and other Lithium-ion battery applications.

Prevention:

To mitigate the risk of thermal runaway events, a crucial approach involves the utilization of sensors capable of detecting several different external abuses (Stage 1 events), while also detecting off-gases or initial venting occurrences (Stage 2 events). Kidde Fire Systems REL-iON™ Battery Monitoring System is a modular sensor platform with the ability to detect both Stage1 and 2 anomalies.

Stage 1 prevention involves continuous monitoring of various factors, including environmental conditions, mechanical stress, power fluctuations, and thermal conditions. This monitoring is crucial to proactively prevent potential thermal runway. Several different sensors can be deployed for preventive monitoring, such as Water Leak, Temperature and Humidity, Solid Contaminants, Real-Time Corrosion, Air Flow, Vibration, etc.

Stage 2 detection begins just before a complete thermal runaway occurs. Malfunctioning lithium-ion batteries will vent gases due to internal pressure build-up, leading to the rupture of the battery's enclosure. The optimal sensor for this task is one that can identify volatile organic compounds (VOCs). However, when employing liquid-cooled batteries, it is imperative to include Hydrogen (H2) sensors as well. In such cases, battery failures can occur at typical operating temperatures, releasing H2 gas before any other gas. The REL-iON™ Battery Monitoring System extends off-gas detection beyond just volatile organic compounds (VOCs) electrolyte vapors, seamlessly incorporating the analysis of other dangerous vented gases such as CO2 and H2.

Typical areas within a BESS where the above detection devices can be used are:

			LOCATION			
Stage	**Sensor Type**	**Model Number**	**In-Cabinet**	**Room / Sub-Floor**	**HVAC System**	**Cable Trays**
1	Water Ingress Detection	31-ENV-LEAK		X		
1	Temperature	31-ENV-TEMP	X	X		
1	Temperature + Humidity	31-ENV-THUM		X	X	
1	Corrosion	31-ENV-CORROSION		X		
1	Air Particulate	31-ENV-PARTICLE		X		
1	Thermal Imaging	31-ENV-THIMG-x		X		X
1	Linear Heat Detection	31-ENV-LHD		X		X
1	Air Flow	31-ENV-AIRFLOW		X	X	
1	Door Opening	31-SEC-DOOR	X	X		
1	Differential Pressure	31-ENV-AIRPRESSURE		X	X	
2	VOC	31-GAS-VOC	X			
2	VOC + H2	31-GAS-H2-VOC	X	X		

Detection & Suppression Control

REL-iON sensors communicate with Kidde Fire Systems range of fire suppression control panels. By processing incoming signals, the control panel monitors the environment for signs of fire or smoke. In the event of an emergency, the panel takes decisive actions, such as activating alarms, triggering notification devices, and coordinating responses.

The conventional AEGIS™-PHX fire panel is suitable for small applications with 1 -2 suppression zones.

The ARIES®-SLX manages fire response events from detection and alarm to suppression system release. Perfect for medium-sized applications with up to 10 suppression zones, the ARIES®-SLX unit provides pre-planned, sequential system response or immediate system actuation, depending on the requirements of the application.

The ARIES™-MLX is a fully featured, multi-loop, intelligent, addressable and networkable Fire Suppression Control Unit is designed for large commercial, industrial and high-tech facilities with 10 or more suppression zones.

Dependability and maximum protection against inadvertent release are hallmarks of Kidde Fire Systems sensors and control panels. Built in safeguards ensure no single component failure or combination of abnormal operating conditions, including main-microprocessor failure which can result in an accidental release activation.

Suppression:

Fires are caused by a combination of fuel, oxygen, and heat – often referred to as the “fire triangle”. Clean Agents absorb heat from the surface of the burning material and effectively lower its temperature below the ignition point – thereby disrupting the fire triangle and suppressing the fire without harming equipment or personnel in the protected room. Clean Agents offer fast extinguishment, suppressing fires within seconds of the agent being discharged into the protected area. The agents are ventilated out of the space and do not leave behind a residue to be cleaned up, typically allowing the facility to get back to work immediately. Clean Agents are non-toxic when used in compliance with NFPA Standard 2001. They do not impair breathing or obscure vision in an emergency, providing an added measure of safety for personnel.

The Kidde Fire Systems Clean agent fire suppression line is available in a range of options.

Kidde Fire Systems offers Fluoro-K™ (FK-5-1-12) and HFC-227ea ‘chemical’ fire suppression clean agents in versatile total flood type delivery system platforms including ECS™, ECS™-500™ and ADS™. The ECS™ platform is standard and delivers either a small amount of agent at a moderate distance or a large amount of agent at a short distance. ECS™-500™ offers design flexibility for small to medium volume hazards by enabling smaller diameter pipes for longer distances. ADS™ offers significant enhancement in distance traveled for systems with large agent volumes.

The Kidde Fire Systems NATURA™ Inert Gas System is an alternative to ‘chemical’ clean agents. Inert gases suppress fire by lowering the oxygen content in the room to a level where the process of combustion is no longer supported – which means that the fire won’t continue to burn. These gases are environmentally responsible, having an ozone depletion potential (ODP) of zero and a global warming potential (GWP) of zero. At room temperature, inert gases are odorless and colorless.

Inert gases are safe for human exposure under limited conditions and criteria. According to NFPA 2001, in occupied areas, people can breathe Inert gas blends at extinguishing concentrations below 52% for very brief periods of time thereby aiding egress. There are no toxicological factors associated with the use of Inert gases as they will not decompose or produce any by-products when exposed to a flame.

The NATURA™ system offers a choice of 4 different inert gases - two are pure gases present naturally in the environment and two are blends of those gases and one of them includes C02. All four are listed in NFPA 2001 and are approved by the ISO committee. The selection of which one to use should be made based on regional availability approved agents to suit re-charge conditions and any unique specification requirements.

Delivery System	ECS™	ECS™-500	ADS™	NATURA™	NATURA™
Storage Pressure[1] psi (Bar)	360 PSI (25 Bar)	500 PSI (35 Bar)	1,800 psi[2] (124 Bar)	2900 psi (200 Bar)	4350 psi (300 Bar)
Distance[3] feet (meters)	120' (36.5 m)	140' (42.7 m)	245' (74.7 m)	500' (152.4 m)	500' (152.4 m)
Storage Footprint[4] ft x ft (m x m)	13.5' x 2.5' (4.1m x 0.77m)	13.5' x 2.5' (4.1m x 0.77m)	26' x 3.5' (8m x 1.1m)	80 Liter: 34' x 3.5' (10.4m x 1.1m) 140 Liter: 27' x 4' (8.2m x 1.21m)	80 Liter: 25' x 3.5' (7.6m x 1.1m) 140 Liter: 18.5' x 4' (5.6m x 1.21m)
Nozzle Height[5]	16'	16'	16' – 18.5'[6]	16'	16'

[1] Nominal system storage pressure at 70° F (21° C)
[2] Pressure indicated is that of the separate Nitrogen driver. Agent cylinder pressure depends on the agent 44 psi for HFC-227ea and 360 psi for Fluoro-K™
[3] Distance is defined as the distance measured from the agent storage location to the asset room being protected.
[4] Storage footprint is the space required to house the armed agent cylinders. In this example of a 10,000 square foot Data Center with 12-foot height, the storage footprint is calculated assuming Fluoro-K™ in 6 x 900 lb. cylinders each with 819 lb. (4,914 lb. total) for the ECS and ADS™ platforms and IG-100 in an 80 Liter cylinder at 300 Bar for the Natura™ platform.
[5] Maximum nozzle mounting height from the floor or the vertical interval between levels of nozzles for rooms with high ceilings.
[6] The maximum mounting height of the ADS™ nozzle depends on the agent used – it is 16 ft for HFC-227ea and 18.5 ft for Fluoro-K™

NATURA™ Acoustic Nozzles

For use in applications requiring a system discharge generating a lower sound output than a standard suppression nozzle
- Quieter, reduces sound levels to below 110dB (between 500 Hz and 10 kHz when measured at 1 m)
- Aesthetically pleasing alternative to bulky nozzle-silencer combinations
- Can replace existing discharge nozzles without major pipe modifications

For decades, Kidde Fire Systems has been an industry leader in fire prevention, detection & control, and suppression. Our name is backed by a strong commitment to product quality, innovation, and expertise in system design, installation, and service. We operate globally through a network of trained and authorized Engineered Systems Integrators/Distributors that excel in initial hazard analysis, system design, installation, testing and commissioning as well as aftermarket service including parts, refills and code-mandated periodic testing and maintenance.

Contact us to learn more about our extensive fire protection portfolio.

About Kidde Fire Systems:

Kidde Fire Systems products and services set the benchmark for special hazard fire suppression. For over 100 years, we've been trusted to protect people and property from the danger of fires. That trust is reinforced by the quality we instill in everything we do, from manufacturing fire and safety systems to providing system design and technical support.

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