Battery Energy Storage System fire: A hot topic

Growth in energy storage systems and the risk of li-ion battery fires

Battery Energy Storage Systems (BESS) are increasingly being installed at facilities to supplement renewable energy installations with energy storage and stability in electrical supply.

The use of Lithium-ion (li-ion) batteries in portable devices has seen a substantial growth in the last decade, and they are also popular for use in BESS.

As a result, li-ion battery fires have been subject to much attention (see emerging risk report #72 e-bike battery fire) and we may see more larger scale fires unless adequate quality, monitoring and protection are implemented.

How a BESS fire caused damage at a major university

A fire occurred in a Battery Energy Storage System (BESS) at a major university. The fire broke out in the evening and activated a fire alarm in the room which alerted university security. Emergency services attended the scene a short time later.

The BESS was housed in a room on the upper floor of a building with access from a breezeway along the exterior. The room was found secured and when fire crews forced entry into the room, a flashover (rapid growth in fire) occurred. A resulting fireball from the doorway caused a minor injury to a firefighter falling against the opposite wall of the breezeway.

The fire was extinguished but there was extensive damage to the contents of the room, and chemical analysis later found high concentrations of various toxic elements in soot deposits. The room was isolated from adjacent areas but the university is investigating if there has been any damage to the concrete in the immediate vicinity of the fire.

Background and what we know

The BESS had been installed at the university about 7 years earlier and consisted of two banks of lithium-ion batteries on a shelving unit in the room, along with the battery management unit and switchgear. Inverters for the battery banks were located in a separate room.

The batteries were imported from a small to medium size li-ion battery maker in China with no Australian office. Each battery bank consisted of several strings of battery cells connected in series. The Battery Management Unit (BMU) was designed and supplied by a local company. Battery cells were a prismatic type, using lithium ferrophosphate ($LiFePO_4$), housed in plastic casings and with cathodes, anodes, separators, and electrolyte. The electrolyte is thought to have consisted of organic co-solvents typical in Li-ion batteries. The cells were provided with factory set overpressure vents.

Chemical analysis of residues after the fire registered some unexpected elements – suggesting there might have been impurities in the materials made to manufacture the batteries.

Analysis of the data from the day of the fire also indicated that the BESS had been operating stably up until the event when there was a sudden voltage drop over 15 seconds in a single battery cell. The cell group's temperature rapidly increased over the next 30 seconds and the cell group above immediately followed. There was severe damage at the seat of the fire, suggesting that one battery failed catastrophically, and the ensuing fire spread to involve adjacent cells.

A chain reaction spreading the fire

The investigation suspects a 'thermal runaway' causing the failed battery cell to progressively heat up - although this condition would be considered a link in the chain of events rather the root cause. Runaway events can be initiated from mechanical abuse, electro-chemical abuse from overcharging or over-discharging, or internal short circuiting of the cell which may be caused by a manufacturing defect and/or age.

These conditions can lead to elevated temperatures and exothermic (heat-releasing) decomposition of the cell materials which raises the temperature further accelerating the decomposition – a runaway event. The pressure increases and electrolyte is either vented or the cell ruptures.

The elevated temperatures and the release of organic solvent electrolyte causes a fire which then starts to heat adjacent cells leading them to also fail, spreading the fire. Such events are marked by rapid escalation.

The root cause is hard to determine

The initial failure is thought to have been caused by a short circuit in the battery cell, but it is difficult to conclusively determine the root cause due to thermal damage from the fire and subsequent arcing. Experience and literature indicate that it was most likely one of the following:

- Growth of dendrites (needle-like structures) out from the electrodes eventually piercing the separator within the battery, causing battery failure
- A manufacturing defect leading to a short circuit occurring
- Damage from either transport or installation, but which didn't manifest until age also became a factor

Several batteries had been replaced soon after the BESS was installed due to swelling and deformation of the casings. The reason for the deformation was not investigated and there were no further issues until the BESS fire event occurred.

Overcharging and room temperature can be other problem areas for a BESS but don't appear to have been an issue in this incident.

Lessons Learnt:

- Li-ion battery fire can lead to very high heat releases due to organic co-solvent used in the electrolyte. Once thermal runaway and battery failure occurs, a fire is likely to spread very quickly to involve other batteries.

- Location, location, location! BESS units should preferably be placed outside; either in appropriate IP (Ingress Protection) rated modules or containerised. Containment for any residual released electrolyte and exposure to other assets needs to be considered. If an inside facility is used, it should be fire-separated from adjacent assets. If outside, it should be fenced to prevent unauthorised access.

- It's important to use reputable battery suppliers and installers, and UL (Underwriters Laboratories) listed batteries are preferred.

- Inspect the batteries on a regular basis. If there are any issues with deformation, the unit should be replaced, and the cause investigated.

- Due to rapid escalation of a fire after an initial failure, conventional fire detection or even high sensitively air aspirating smoke detection is unlikely to provide early warning. Fire protection contractors have started to address this issue and have released off-gas probe systems that can detect vented products of electrolyte decomposition prior to a battery going into thermal runaway and cell rupture. The off-gas monitoring can be setup to have the Battery Management Unit shut off power, send alarms to the Building Management System and be integrated with a fire suppression system to discharge a fire suppression ahead of a rupture and fire. Considering ventilation air flows is also important in determining the location of probes. This form of monitoring should be considered for BESS facilities.

- Due to the materials used in battery construction, residues after the fire are likely to present issues for clean-up.

Note: Although not a factor in this incident, the Battery Management Unit (BMU), charging, environment, temperature and battery inverters are also critical considerations in the design of a safe and well-functioning BESS.

Other useful links

https://spectrum.ieee.org/energywise/energy/batteries-storage/dispute-erupts-over-what-sparked-an-explosive-liion-energy-storage-accident

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