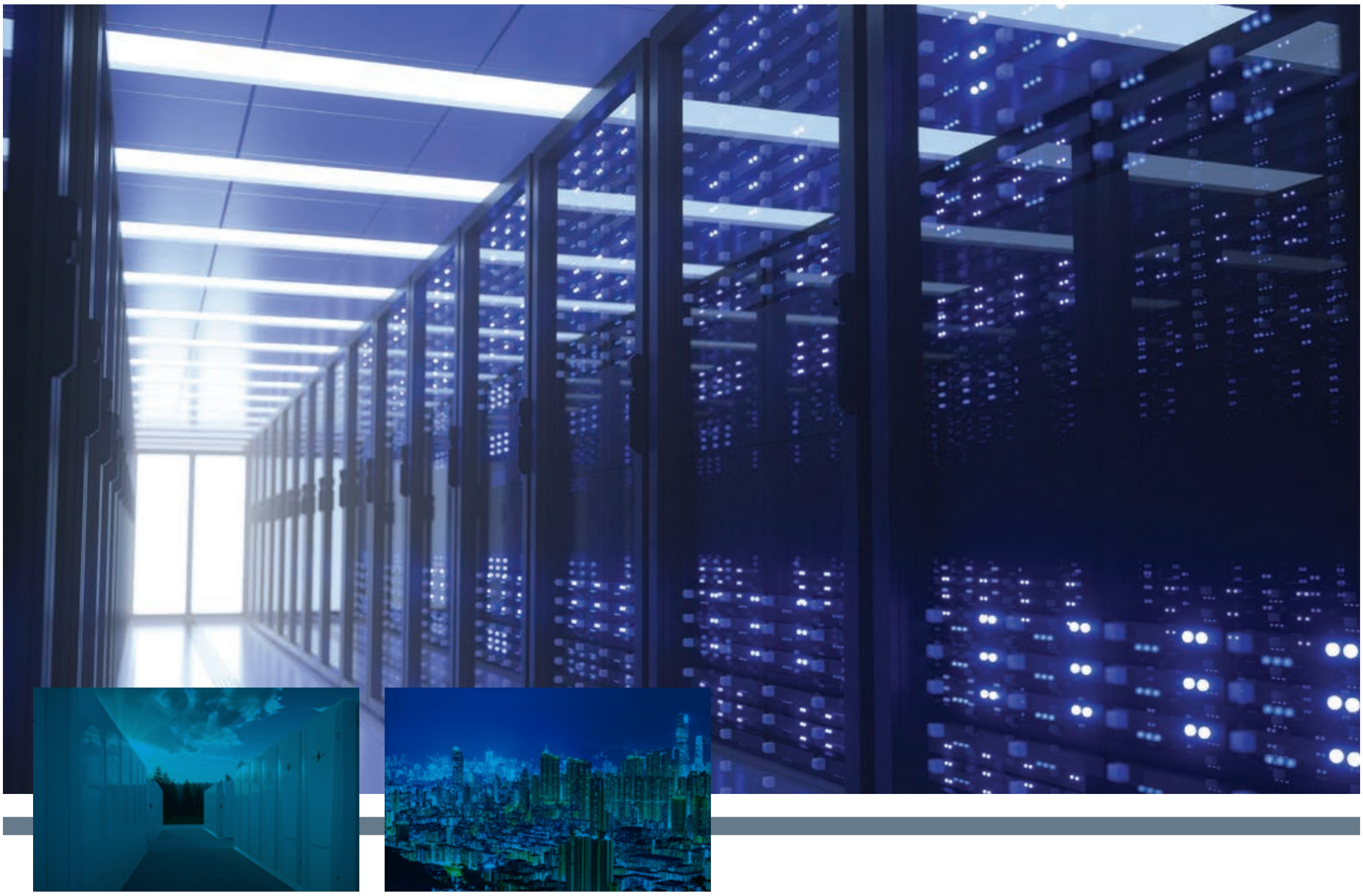
LI-ION TAMER®

HOW TO PREVENT LITHIUM-ION BATTERY FIRES IN DATA CENTERS



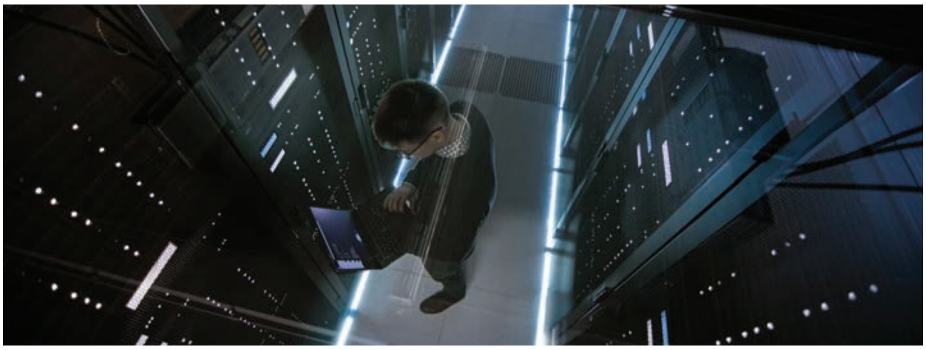
PREVENTING THERMAL RUNAWAY WITH OFF-GAS DETECTION

Lithium-ion (Li-ion) batteries are becoming the energy storage technology of choice for data centers. Used in uninterruptible power supply (UPS) systems, they are rapidly replacing traditional valve-regulated lead-acid (VRLA) batteries.

According to Bloomberg New Energy Finance, in 2025 Li-ion batteries will account for 5.6GWh of data center battery backup capacity, as compared to 8.3GWh for traditional VRLA batteries.[1]

There are clear benefits to using Li-ion batteries in data centers, but there are also potentially major downsides. Li-ion batteries can be a serious fire hazard which can put mission-critical power at risk.

This guide looks at the main risks associated with Li-ion battery energy storage systems (BESS) in data centers. It examines the limitations of traditional fire detection and suppression technology and illustrates how to overcome these with the detection of electrolyte solvent vapours (off-gas phase) that occurs in the early stages of a failing li-ion battery.



WHY ARE LI-ION BATTERY CELLS A FIRE HAZARD?

As the demand for Li-ion batteries continue to rise, prices continue to drop. While VRLA technology may still be cheaper, Li-ion can lead to significant cost savings over time. Compared to VRLA batteries, Li-ion batteries:

- Have two to three times longer life expectancy;
- Have higher power density;
- Can fully charge in two to three hours (compared to 10-12 hours);
- Have a much smaller footprint; and
- Can operate at higher temperatures, requiring less cooling.

Despite all these advantages, Li-ion batteries can pose a fire risk. This is mainly due to their highly-flammable, organic electrolyte and the significant amount of energy they store. This is why Li-ion batteries must be constantly kept within specific environmental conditions and electrical parameters. Even with a Battery Management System (BMS) in place, failures can still occur.

A single failing Li-ion cell is enough to trigger a process known as thermal runaway. When this happens, the surrounding cells soon start overheating too and go into thermal runaway, which can quickly lead to damaging fires.

Thermal runaway is an exothermic reaction that causes the Li-ion battery internal temperature to rise and may eventually ignite the electrolyte. If the electrolyte catches fire, it may lead to catastrophic fires, which can be extremely hard to extinguish.

“ A single failing cell can quickly overheat the surrounding cells, causing them to go into thermal runaway ”

The four stages of battery failure are:

1. Abuse factor

This can be electrical, thermal or mechanical and cause the electrolyte to change from a liquid to gaseous state. Electrical abuse is caused by exceeding the battery voltage limits during charge or discharge.

Thermal abuse is caused by the operational temperature exceeding the temperature limits of the batteries.

Mechanical abuse is caused by physical or mechanical damage such as a crush, indentation or puncture.

2. Battery electrolyte solvent vapours venting (off-gassing)

If the abuse factor continues, more of the liquid electrolyte will continue to convert to gas, causing an internal pressure build up inside the battery.

Off-gassing is defined in NFPA 855[2] as the event in which the cell case vents electrolyte solvent vapours due to the rise of internal pressure in the cell.

3. Smoke

If the abuse factor continues, reactions in the cell will become increasingly exothermic, causing the release of smoke. At this stage thermal runaway is imminent and can no longer be prevented.

4. Fire

At this stage, the battery catches fire and enters thermal runaway. Temperatures can often exceed 1000°C, but a thermally abused battery can enter thermal runaway at temperatures as low as 130°C.

CONSEQUENCES OF LI-ION BATTERY FIRES

Li-ion battery fires present unique challenges.

According to a study from the Underwriters Laboratories (UL) Firefighter Safety Research Institute, challenges include:[3]

- Explosive nature of the gases and vapours released during thermal runaway;
- Vapour cloud formation and dispersion;
- Dynamics of deflagrations and blast wave propagation; and
- Ineffectiveness of fire suppression

The consequences of thermal runaway fires can be severe. Data center staff may be exposed to toxic gas leaks, fires and even explosions.

Battery fires may also have unintended economic and social implications. They can bring an entire data center facility to a halt, affecting data proccessing, storage and transmission. They can even damage servers and other essential hardware, causing loss of critical data.[4]

Another outcome may be fines and other legal consequences for data center operators, especially if injuries occur.

The reputational damage may also have long-lasting financial consequences.

FIRE SAFETY CODES, STANDARDS AND REGULATIONS IN DATA CENTER APPLICATIONS

Minimum fire safety requirements for data centers are determined by standards and regulations. These norms may vary from region to region.

"Fire tests of unconfined Li-ion batteries have demonstrated that cell explosions can cause projectiles to travel up to 40 meters (133 feet)[5] "

Yet, the adoption cycle of these norms can be slow, taking a minimum of three years on average. This means the standards might be behind the curve in terms of advancements in fire safety technology or methods. They should be regarded as a starting point to build upon with additional solutions.

Some important norms to consider are:

- Li-ion battery cell-related standards such as UL 1642 / IEC 62133
- Module-related standards such as UL 1973
- Rack-level standards such as UL 9540 / IEC 62619
- System-level regulations such as NFPA 855 / IFC Chapter 12
- Installation standard - NFPA 75 (Standard for Fire Protection of Information Technology Equipment)

Market entry in many countries is often dependent on compliance with these standards.

One of the latest and most important standards to bear in mind is UL 9540A. It is mandated by NFPA 855[2] and involves large-scale fire testing of BESSs.

BMS, TRADITIONAL DETECTION AND FIRE SUPPRESSION METHODS: KEY CHALLENGES IN LI-ION APPLICATIONS

BMSs

The main purpose of a BMS is to monitor voltage, current and temperature as well as to prevent abuse to the batteries. This technology alone is not enough to minimize the risk of thermal runaway.

The main reason for this is that BMS are unable to resolve single cell temperatures or voltages. Even with temperature sensors on every cell, hot spots may go undetected. With a typical data center relying on hundreds of Li-ion battery cells and sensors, it is not difficult to imagine how faults may at some point occur.

Detection Technologies

Traditional detection technologies include: smoke detection, fire detection, carbon monoxide monitoring, and hydrogen monitoring. Each of these has an important role to play and should be part of a comprehensive safety solution. The main downside of these technologies, though, is that they do not activate until thermal runaway has already occurred, which may already be too late to prevent it from spreading further.

A recent report published by UL shows that traditional gas detectors, such as carbon monoxide and hydrogen, and smoke detection does not indicate abnormal conditions in the battery system until after thermal runaway has begun.[6]

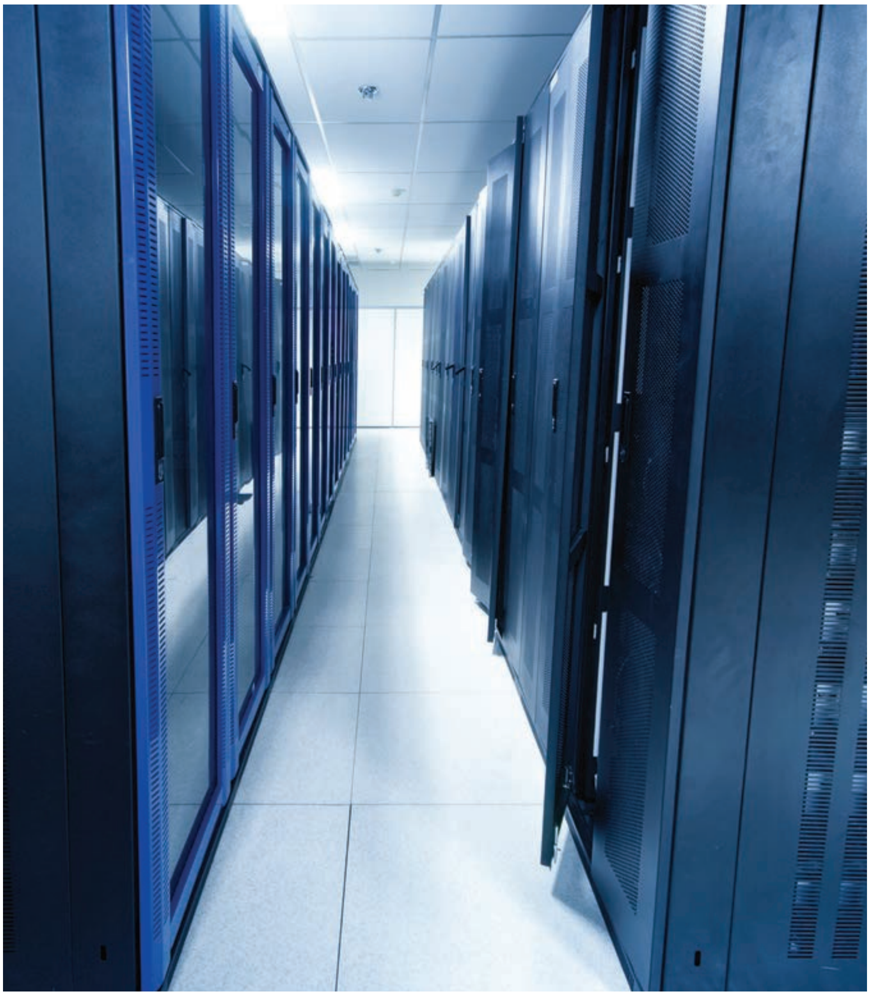
This is because, as noted above, smoke and fire do not occur until a cell has reached thermal runaway. Even carbon monoxide and hydrogen are often not present in large enough concentrations to be detectable until several cells have already failed.

Fire suppression systems

Suppression is a data center's last line of defense against fire.

Yet, according to a recent study published last year in the Journal of the Electrochemical Society, none of the main suppression methods are entirely effective in containing Li-ion fires.[7]

A DNV study from 2019 came to similar conclusions, finding that none of the suppression systems analyzed provided a 'silver bullet' solution to Li-ion fires.[8]



WHAT IS OFF-GAS DETECTION?

Off-gas detection refers to the detection of electrolyte vapours as soon as a li-ion cell starts failing and is key to preventing thermal runaway and, ultimately, avoiding destructive fires. A recent UL Firefighter Safety Research Institute study found that the cells vented prior to thermal runaway in each of the three test conducted.[6]
This is where off-gas detection comes in.

Off-gas detection solutions are tailored to the specifics of the BESS, including geometry, volume, cell type, spatial layout and air flow patterns. A distributed network of strategically-placed gas sensors enables data center operators to receive the earliest indication of failure and intervene to prevent thermal runaway.

"Off-gas detection solutions are designed to the specific characteristics of the environment "

The location and number of sensors is optimized to deliver the earliest detection using the least number of sensors, providing a cost-effective solution to data centers.

How can the detection of battery electrolyte vapours (off-gas phase) prevent thermal runaway?

A recent study by DNV[8] put three technologies to the test to assess their effectiveness in detecting early signs of thermal runaway:

- Lower Explosion Limit (LEL) sensors
- Off-gas specific sensors
- Cell voltage sensors.

As illustrated in the table below, the test demonstrated that neither LEL sensors nor voltage sensors could activate until after thermal runaway had already started. By contrast, the off-gas detector activated, on average, only 10 seconds after the release of electrolyte solvent vapours started to occur, and more than six minutes before thermal runaway started to take place.

	Electrolyte Solvent Vapours Release	Off-Gas Sensor	Thermal Runaway	Cell Voltage	LEL Sensor
Average time of occurrence relative to thermal runaway (seconds)	-381	-371	0	+7	+28

Table 2: Average responses from different sensors and indication mechanisms tested in cell level tests (source: DNV[8])

Testing also showed how by electrically isolating the battery system once electrolyte solvent vapours were detected, the cell temperature ceased to increase. This demonstrated the effectiveness of a correct mitigating action at the earliest indication of gas presence.

CONCLUSION

As Li-ion batteries become more economical and offer operating cost savings, the ongoing transition from VRLA to Li-ion in data centers is likely to accelerate in years to come.

The detection of electrolyte vapours (off-gas phase) is a critical solution that provides the earliest indication of cell failure, serving as a barrier against thermal runaway and the devastating consequences this can have. Thanks to off-gas detection, data centers can now safely deploy Li-ion batteries and take advantages of their unique benefits.

For more information on how to install and use off-gas detection effectively, download our LI-ION TAMER RACK MONITOR DESIGN GUIDE.

For more in-depth information on this topic download THE ULTIMATE GUIDE TO FIRE PREVENTION IN LITHIUM-ION BATTERY ENERGY STORAGE SYSTEMS.

ABOUT THE AUTHOR

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ABOUT XTRALIS

Xtralis is a leading global provider of powerful solutions for the very-early and reliable detection of smoke, fire and gas threats. Our technologies prevent disasters by giving users time to respond before life, critical infrastructure or business continuity is compromised.

We protect highly valued assets and infrastructure belonging to the world's top governments and businesses.

To learn more, please visit us at www.xtralis.com

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