Early Warning Detection System

Li-Ion batteries in critical infrastructure

The battery backup design in many critical systems is based on a battery energy storage solution (BESS) using the Li-Ion type of battery. Users favour the Li-Ion over the legacy lead-acid type due to the many advantages, such as higher energy density, lower weight, longer life, and a lower TCO.

Therefore, the Li-Ion battery is predicted to replace legacy battery types on a broader scale and will probably be the only realistic alternative in both mobile and stationary applications for the foreseeable future.

Image A - Example of a Li-Ion battery cabinet, a common part in large BESS systems which can easily hold > 1 MW of power

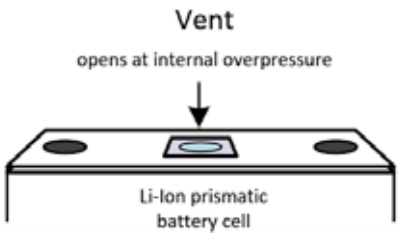


Image B - Example of a Li-Ion cell with a vent for overpressure

Li-Ion and safety

The early Li-Ion batteries had issues with instability, sensitivity to shock, high temperatures, and overloads, to mention some areas of concern.

The Li-Ion batteries of today have been improved in many ways and are considered safe to use.

However, there are still risks, mainly due to the complexity of the Li-Ion battery – the mechanics of the cell design, the electrolyte chemistry and the watchdog required to monitor what's happening in the battery system (also called BMS). The many variables in design and chemistry, the many proprietary designs, the many battery monitoring solutions, and the growing number of suppliers with different approaches to safety and quality are and will continue to be a challenge from a user safety perspective.

Thermal runaway

A worst-case scenario could reach a phenomenon known as "thermal runaway", where the battery cell enters an exothermal reaction that can be irreversible if not mitigated. The batteries release toxic gases at this stage. and may catch fire or explode after a while.

Major incidents have caused damage, serious injuries, or worse, lost property and, not to forget, lost credibility.

Li-Ion applications that reside in sensitive indoor environments like hospitals, datacentres, central offices, large car garages, and other confined spaces, the risk is accelerated while, quite often, the possible dramatic consequences of an incident are not properly addressed.

The li-Ion battery system can be made safer and more capable of managing a critical situation before thermal runaway. Dafo's Early Warning Detection System provides a second independent protection layer, allowing your critical system to continue operating with no or very limited impact on the uptime of your critical system. The Li-IonFire system will automatically detect, analyse, decide and selectively shut down a failing battery cabinet or the entire battery system as a final resort to stop the escalation.

Early detection of CO-gas

The Early Warning Detection System provides very early detection of CO-gas emitted from a failing battery cell in the system. It uses the time window which occurs between cell venting and thermal runaway. This window can vary depending on battery type and brand but generally takes 4-10 min. It works proactively to analyze and provide appropriate action to mitigate a critical situation.

Not only does it detect early, but it also uses smart algorithms to decide which battery cabinet must be shut down so that the critical system can sustain its operations with only a limited impact on BESS performance.

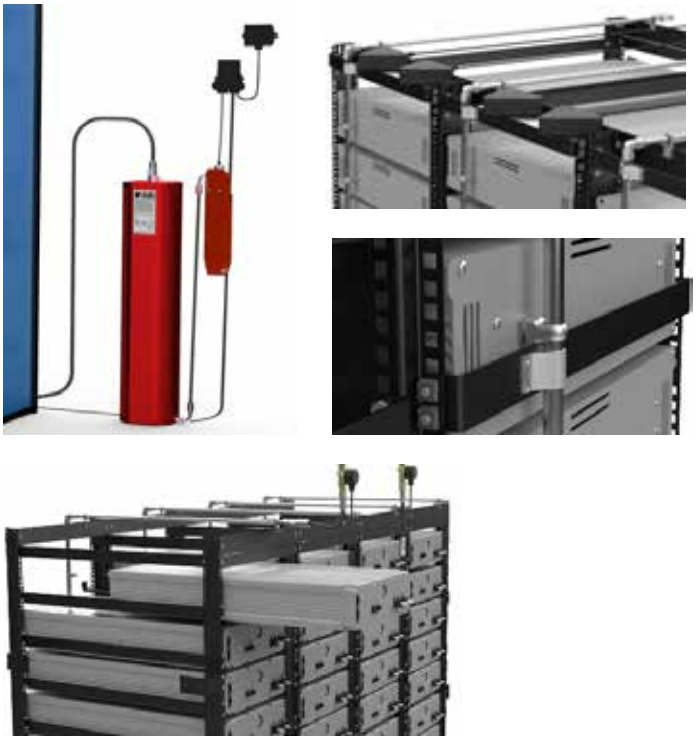
The system uses a very sensitive gas sensor technology patented by DAFO Vehicle Protection. This sensor provides early detection of CO-gas from any type of Li-Ion battery used today.

Graph A - Graph shows the action window the system uses

Cooling and fire suppression

The system can be extended with cooling/suppression functionality for applications requiring further protection, operated by our controller system. A special cooling agent can then be injected into the battery modules to reduce temperatures quickly.

This would require battery modules with injection nozzles, piping that reaches every battery module, valves on each battery cabinet and one or more tanks for the special Forrex cooling and suppression agent.



Images C - Suppression system injecting Forrex cooling agent into battery modules

Features of the Early Warning Detection System

√ Ability to recognize and select the battery cabinet with a failing battery cell and automatically shut down this cabinet – by using algorithms that compare the CO concentration levels between cabinets and between cabinets and a room reference sensor. Comparison is also made by temperature and humidity readings. If there is a conflict or uncertainty in the decision making, the system shuts down all cabinets as a safety measure.

√ Independency from the Li-Ion systems internal monitoring system (BMS) – the protection system is working independently from the battery vendor BMS to ensure that a fault in the BMS will not impact the Dafo Early Warning Detection System.

√ High reliability and robustness – the system uses redundant sensors and control electronics that communicate by CAN bus SAE J1939. Interface to the Scada is through the OPC UA protocol by default.

Image D – a top box containing sensors, fan and beacon

Intuitive and easy to navigate human interface

The system has two touchscreens, one in the actual battery room for service purposes and another placed outside the room for emergency staff. Screens are easy to understand and navigate, provide actual status on CO levels temperature, and show warnings, alarms, and full Event Logs of the system. Screens also indicate if a cabinet(s) has been shut down.

Image E - The display shows the affected cabinet in red

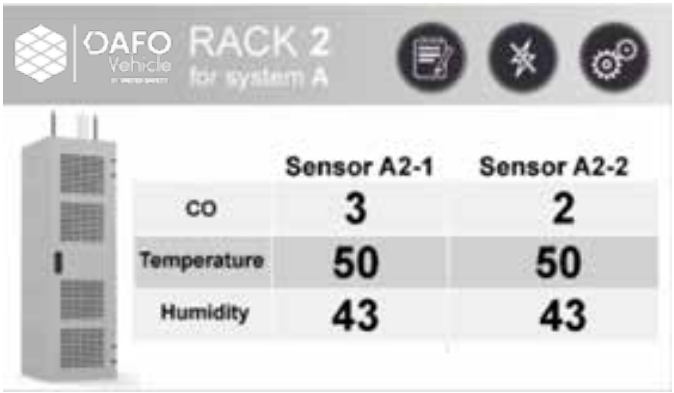


Image F - By pressing the affected rack, actual details will show up

√ Early detection of CO being released from a Li-Ion cell – performed by a sensitive and self-calibrating CO gas detector (0-1000 ppm)

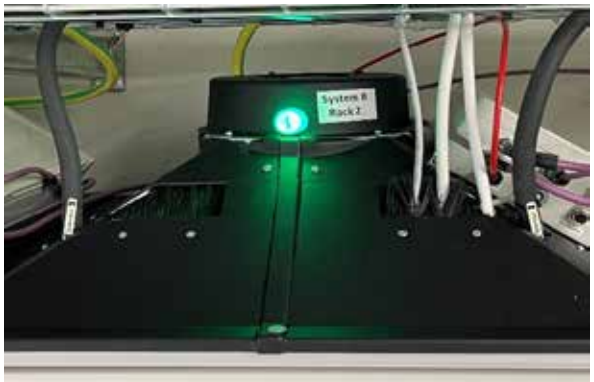


Image G – retrofit hood with fans, sensors, beacon and a control box on cabinet roof

√ Clearly visible warnings - each cabinet is equipped with a gas collection and fan assisted hood, including sensors placed on the cabinet roof. A red/green beacon provides a quick overview of the cabinet's status.

Images H – system power supply (UPS) with touchscreens for service and OPC UA gateway

√ Possible to use as a retrofit in existing Li-Ion installations – the modular approach enables retrofit to standard battery cabinets and does not require intervention into the battery modules.

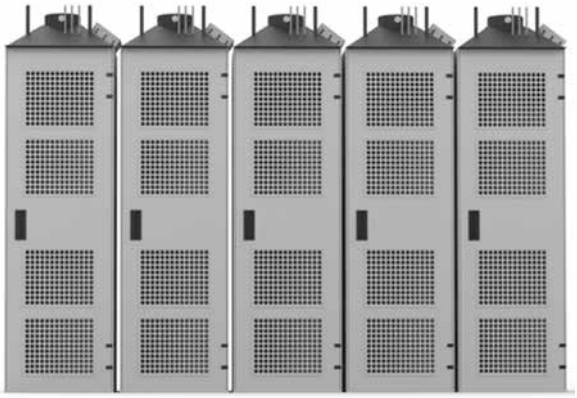


Image I – Li-Ion battery cabinets with retrofit hoods and Dafo Early Warning Detection System.

References and documentation

ESS fire incident in Drogenbos Belgium on 11 November 2017

Lessons learned report Engie Laborelec and Federal Knowledge

Four Firefighters Injured in Lithium-Ion Battery Energy Storage System Explosion – Arizona

UL Firefighter Safety Research Institute Columbia, MD 20145

Authors: Mark B. McKinnon, Sean DeCrane, Stephen Kerber

Tesla Megapack caught fire at Victorian Big Battery site in Australia (cnbc.com)

“Li-Ion is one of the best battery systems, but it is unforgiving in fail-mode. Many Li-ion batteries keep performing even when a fault develops. An analogy is an ageing steam engine that still delivers full power with a boiler that no longer meets safety requirements.”

Author: Isidor Buchmann, Assuring the safety of Lithium-ion in the workforce.

IEEE Spectrum 2020: The April 2019 accident near Phoenix put plans on hold to further deploy battery energy-storage systems across Arizona

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