FIRE PROTECTION AND SAFETY SYSTEMS IN BESS

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The purpose of this document is to provide a comprehensive and detailed overview of all the protection systems integrated into the energy storage solutions developed and supplied by Master Battery. Protection in a battery system is not merely a technical or regulatory requirement; it is a fundamental pillar to ensure operational safety, long-term reliability, and overall system efficiency throughout its entire life cycle.

Today, the use of Energy Storage Systems (ESS) has become a key component in residential, commercial, industrial, and large-scale applications, contributing to the transition toward a more sustainable energy model. However, factors such as high energy density, the complexity of control electronics, and variable operating conditions demand the integration of advanced protection mechanisms to safeguard both the equipment and the users.

As a company specializing in energy storage solutions, Master Battery integrates into its systems a combination of electronic, mechanical, and intelligent management protections that work in coordination. These solutions not only comply with international standards and safety regulations, but have also been optimized through extensive real-world project experience, adapting to different installation environments.

Therefore, this document will not only describe the storage methods and technologies employed by Master Battery, but will also delve into the design criteria, redundancy strategies, and fault response protocols that form the core of its safety philosophy. It will also address how these protection systems are integrated into various scenarios, from stationary self-consumption applications to hybrid systems with renewable generation or critical installations, highlighting the importance of remote monitoring and predictive maintenance in maximizing the system's service life and performance.

Ultimately, this document aims to serve as a reference for understanding how Master Battery combines technological innovation with comprehensive safety in its energy storage solutions, providing confidence to end users, system integrators, and energy system operators alike.

Context of Action

Although LFP batteries offer greater thermal stability and lower reactivity compared to other chemistries such as NCA or NMC, they are not free from risk. In the event of thermal, electrical, or mechanical abuse, a thermal runaway event may occur, leading to the release of flammable gases, the generation of toxic smoke, fire, or even a delayed deflagration if the accumulated gases reach the **Lower Flammable Limit (LFL)** and encounter an ignition source.

Prismatic Cells with Self-Sealing Valve

In this system, prismatic LFP cells are used, characterized by a rigid casing, typically made of aluminum or steel, which provides high mechanical resistance to impacts, vibrations, and deformations. This structural robustness is a decisive advantage in terms of passive safety, as in the event of thermal runaway, the casing retains its shape and integrity for a longer period than other formats, delaying the sudden release of heat and gases.

This initial retention capability helps minimize the immediate propagation of the event to adjacent cells, providing an additional reaction window for early detection and mitigation systems—such as emergency cooling or automatic suppression—to activate.

Compared to pouch cells, prismatic cells are considerably safer in these scenarios due to the rigid encapsulation they employ. While a pouch cell's flexible enclosure can fail unpredictably under overpressure, causing irregular releases of gases and electrolyte, in a prismatic cell, the release occurs in a much more predictable and controlled manner.

A key safety feature of this design is the incorporation of a self-sealing valve integrated into each cell. This valve is calibrated to release gases only when the internal pressure exceeds a safe threshold, thus preventing random ruptures in the casing. When activated, it directs the gas flow towards ducting systems or gas collectors, reducing the risk of internal ignition and allowing forced extraction through emergency ventilation.

This controlled venting mechanism significantly lowers the probability of random dispersion of flammable aerosols inside the container, reducing not only the risk of deflagration but also secondary effects such as internal contamination of equipment, sensor fouling, or damage to nearby electrical and electronic components.

Overall, the combination of a rigid casing and a self-sealing valve provides a cell solution with a high level of intrinsic safety, facilitating both the prevention and mitigation of fires in large-scale energy storage environments.

HV Box

All our BESS systems are composed of multiple clusters, each of which contains prismatic LFP cells. Each cluster is equipped with a **slave BMS**, responsible for real-time monitoring of critical parameters such as the individual voltage of each cell, temperature, State of Charge (SoC), and State of Health (SoH).

If any anomaly is detected in these parameters, the slave BMS immediately sends a signal to the **master BMS**, which analyzes the received information and executes the necessary control actions to prevent or mitigate the issue. These actions may include power limitation, cell balancing, disconnection of the affected cluster, or activation of protection systems, thus ensuring the safety and operational integrity of the energy storage system

Cluster Bank

These clusters are grouped into different battery banks, which reach a voltage of around 1,000 V, depending on the type of BESS selected . Each bank is managed by a master BMS, responsible for centralizing and processing the information received from the slave BMS units in the clusters.
If the master BMS receives an anomaly alert from a slave BMS, or detects it directly—whether due to overcurrent, overvoltage, undervoltage, overtemperature, or any other critical parameter out of range—the system automatically executes the necessary corrective actions.

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These include:

- Active cell balancing to correct voltage imbalances.
- Activation of the cooling system to maintain the temperature within the optimal operating range.
- Initiation of the fire suppression protocol and alarm activation, in coordination with smoke detectors, voltage sensors, and temperature sensors.

All cluster banks are interconnected, which means that if any master BMS issues a shutdown command for safety reasons, a complete system shutdown is automatically executed, stopping all cluster banks in a coordinated manner. This design ensures that a localized failure does not escalate into a larger event, thereby preserving system integrity and the safety of the facilities.

Cluster Bank

BMS Master

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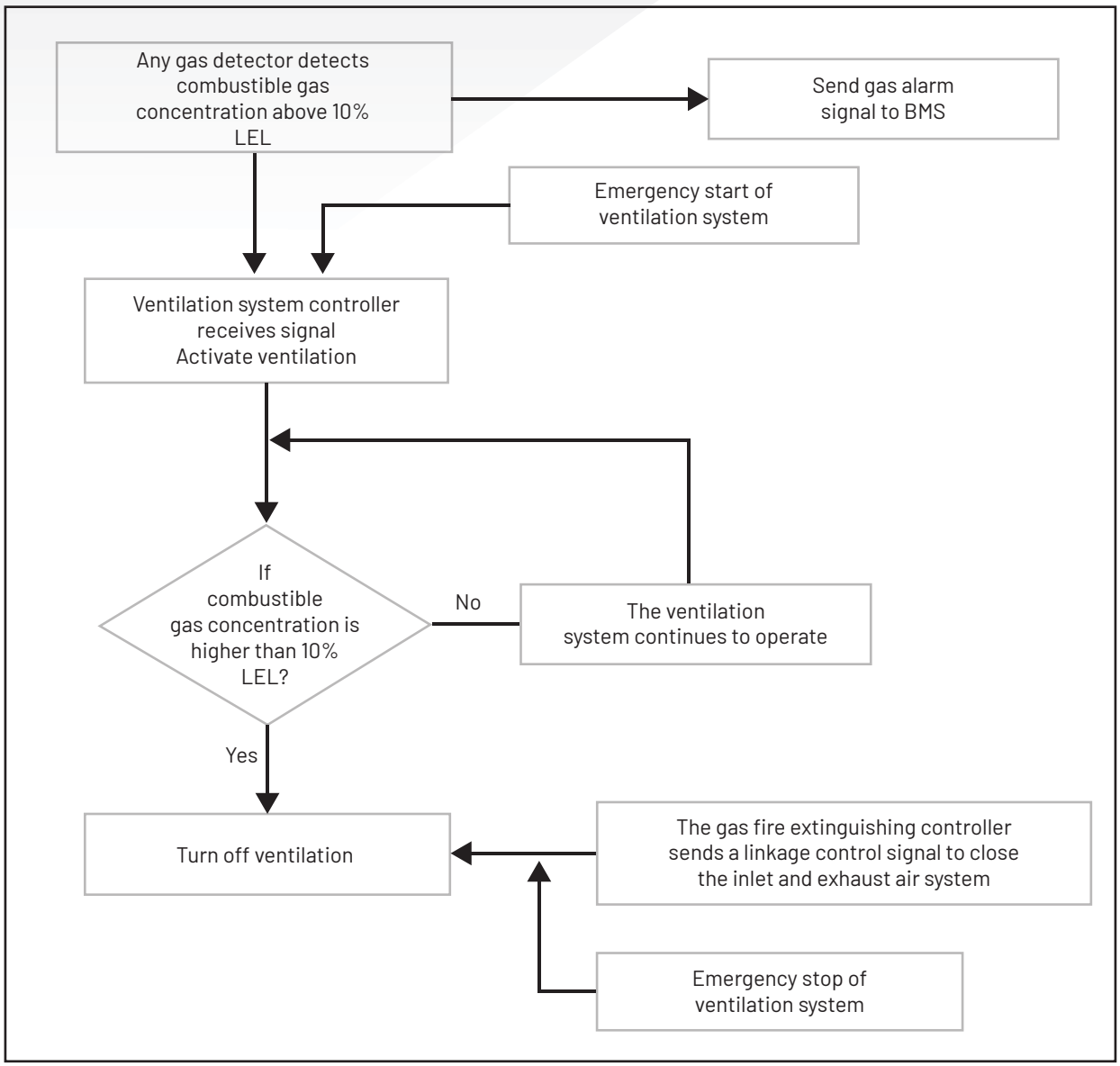
Fire Detection Logic System



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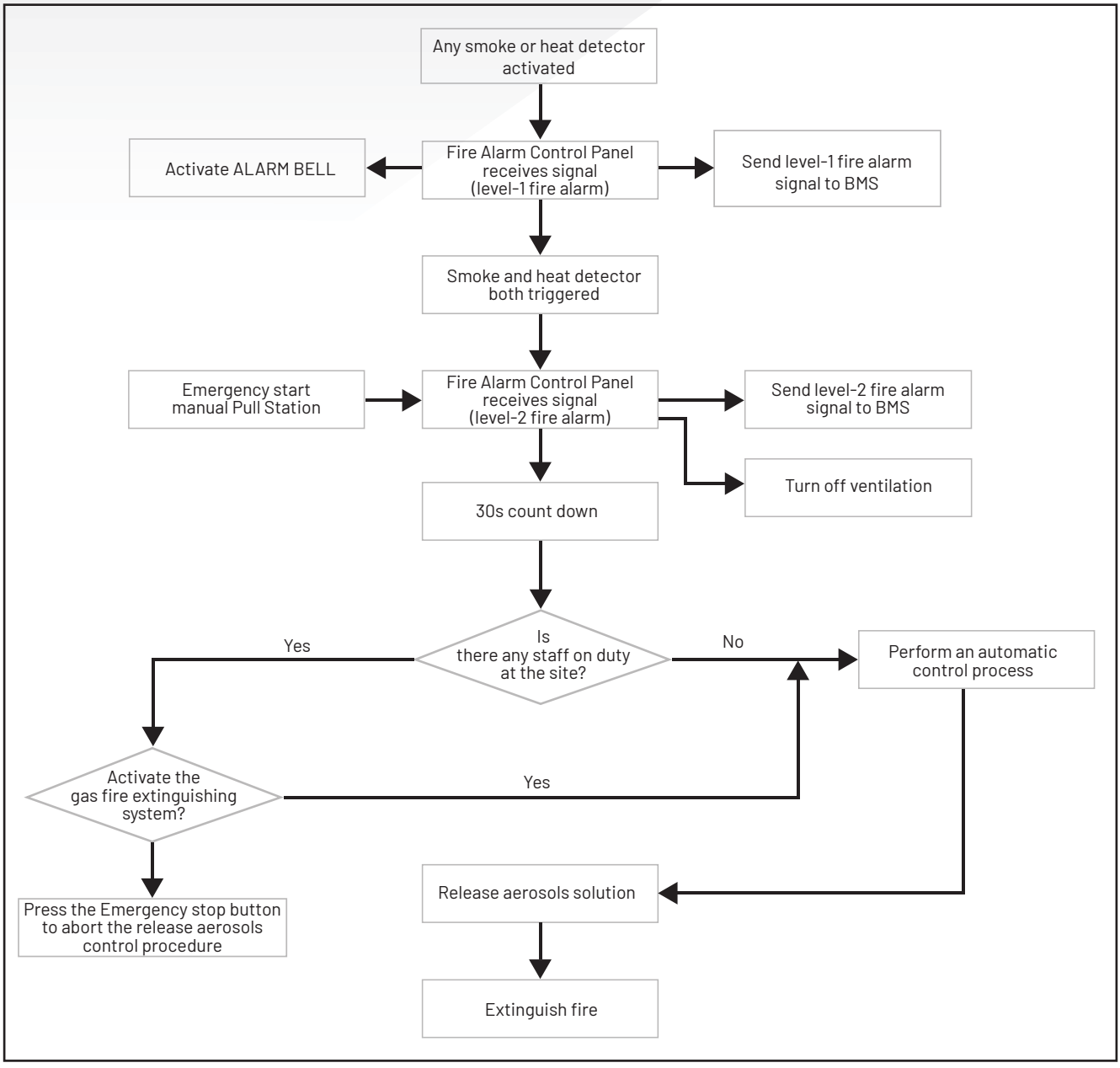

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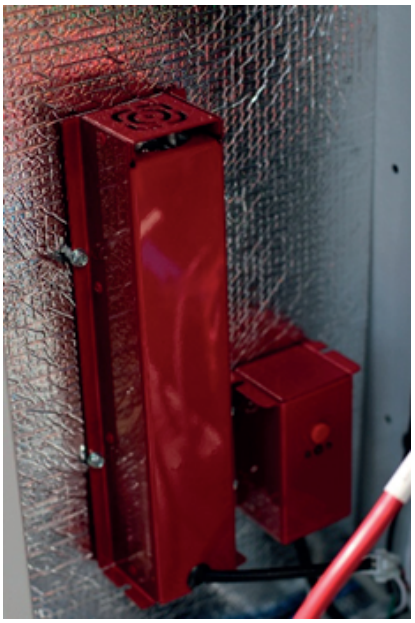
Fire Protection Systems

As an example, the fire protection system installed in the BESS at Master Battery's facilities is presented. In this case, it is a BESS with a capacity of **100 kWh**, so the size and capacity of the extinguisher are dimensioned in accordance with the system's energy characteristics and risk profile.

Similarly, in future projects, the selection of the extinguisher and the suppression system should be proportionally adjusted to the capacity and configuration of the BESS to be installed, thus ensuring effective protection in compliance with applicable regulatory and safety requirements.

Alarm Sound



Fire extinguisher

Level protection strategy

	Condition Detected	System Response
Level-One	Abnormal single unit voltage Abnormal unit temperature Unitary voltaje imbalance	Generate alarm messages Limit power
Level-Two	Multiple temperatura anomalies Slow drop in voltage of single unit Sudden drop in capacity	Generate alarm messages Stop running
Level-Three	Sudden drop in cell voltage Rapid rise of cell temperature Cell temperature excedes the upper limit Gas monitoring alarm	Generate alarm messages Initiates aerosol fire suppression
Level-Four	Single unit temperatura exceed upper limit Gas monitoring alarm Rapid rise in temperature of multiple cells	Generate alarm messages Notify Matrix-Controller of power failure

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Safety Certifications and Regulatory Compliance

The batteries manufactured by Master Battery are certified with:

- IEC 62619: Safety requirements for stationary industrial batteries.
- UL 1642: Safety certification for lithium cells.
- Complete EMC report in accordance with Directive 2014/30/EU (electromagnetic immunity and emissions).
- MSDS (Material Safety Data Sheet) specifying procedures in the event of fire, leakage, explosion, or contact.

These certifications ensure that both the chemical design and the electronic components (BMS, fuses, ventilation, etc.) comply with the required technical standards to limit and manage risks.