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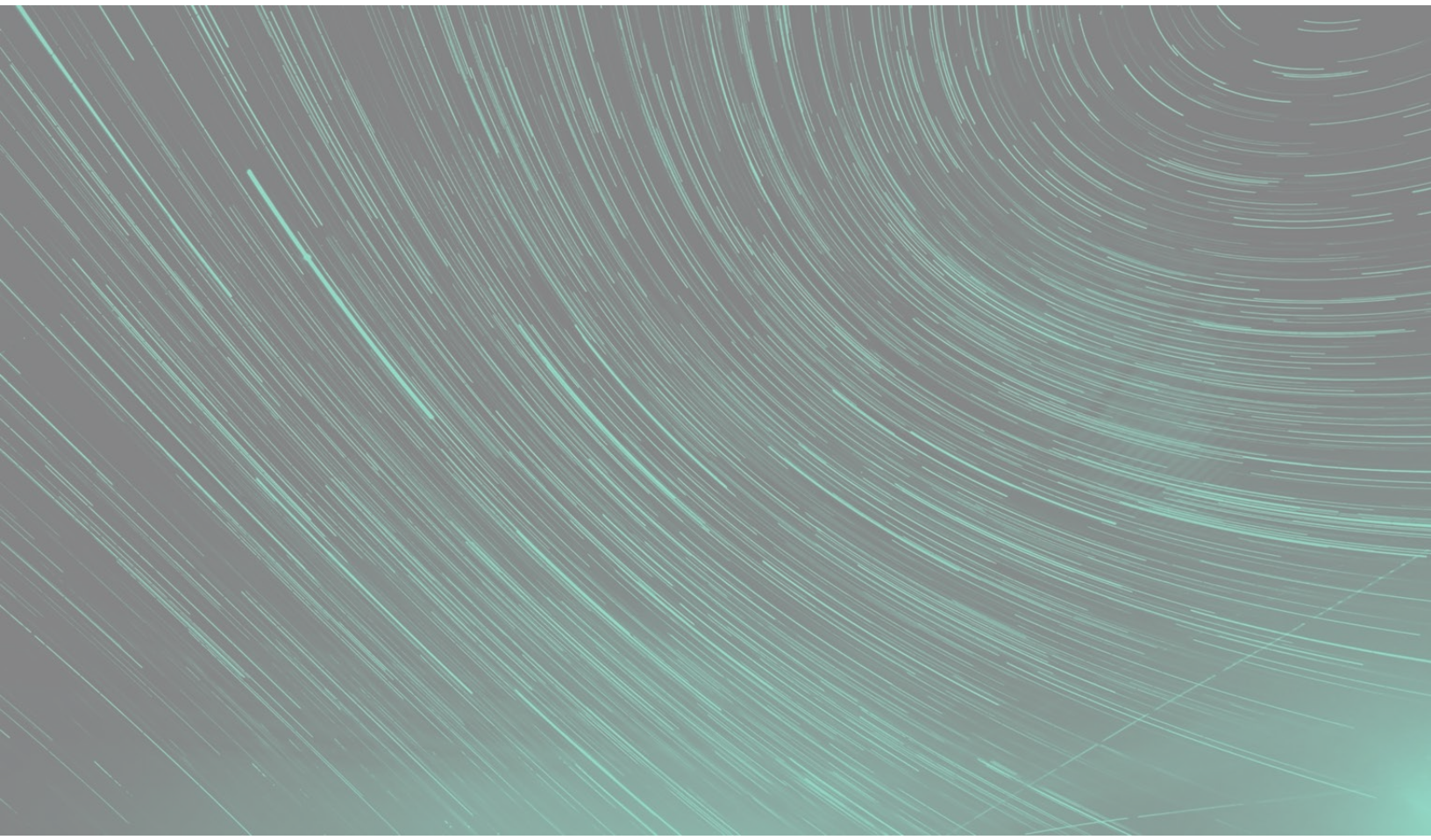

March 2022

POWIN'S APPROACH TO SAFETY (STACK750E)

PRODUCT GUIDE

CONFIDENTIAL

Powin

Powin has pioneered a cost-effective, safe, and scalable battery energy storage system (BESS) that is purpose-built for the demands of utility scale, commercial and industrial, and microgrid applications. Our BESS also features a modular architecture and streamlined installation process. Behind our industry-leading products is an unrivaled team of experts from across the energy industry, almost three decades of supply chain management expertise and extensive battery management software development proficiency.

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For any questions regarding the safe use and maintenance of this product, please contact Customer Support at:

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Table of Contents

List of Tables

List of Figures

1.0 Purpose

This document details the core safety features and potential hazards associated with Powin's Stack750E (Centipede). This document supplements published data sheets and product manuals and is intended primarily to support conversations with customers and AHJs.

2.0 Scope

Powin's latest generation of Stack750E product line.

3.0 Powin's Layered Approach to Safety

There is nothing more important to Powin than ensuring that our customers, field service technicians, first responders, and anyone else interacting with Powin's products go home safely at the end of the day.

To that end, Powin's energy storage products are safe by design, with multiple, redundant layers of hardware and software working together to ensure cell to system safety. We extensively model and perform large scale testing of our systems in real-world scenarios, including UL 9540A unit level testing. We leverage third-party expertise and continuously analyze field data to improve product and process safety.

Through our vertically integrated structure, Powin controls the design, manufacture, and testing of all product components - including hardware, software, and firmware - giving us unparalleled control over the safety of every system delivered to our customers.

3.1 Standards Compliance

Powin's cells and Stacks collectively are compliant with the below standards.

Table 1. Current and expected compliance with various standards

STANDARD	DESCRIPTION
UL 9540A	Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
UL 1973	Standard for Batteries for Use in Stationary, Vehicle Auxiliary Powerand Light Electric Rail (LER) Applications
UL 9540 (Field Certification)	Standard for Energy Storage Systems and Equipment
NFPA 855	Standard for the Installation of Stationary Energy Storage Systems
IFC	International Fire Code
NEC 2017	National Electrical Code

4.0 Fire & Thermal Event Safety

4.1 Prevention

The first line of defense against fire and thermal runaway is prevention. From cell to system, Powin designs Stack750E with high quality hardware and software that work together to minimize the likelihood that any one failure will turn into a propagating thermal event.

4.1.1 Cell

Powin uses only Lithium Iron Phosphate (LFP) batteries, which is the safest lithium-ion chemistry available today. LFP cells generally require temperatures at least 50°C higher than common oxide chemistries, such as NMC, to enter thermal runaway. This means:

a. The quantity of heat released by a venting cell is lower than other chemistries;

b. The temperature at which LFP batteries decompose is much higher;

c. There is no oxygen release from the LFP batteries to create fuel for fire.

Testing to date on Powin Stack750E shows that thermal runaway in a single cell does not propagate to neighboring cells unless an external heat source is continually applied. The oxygen atoms in the cathode of LFP cells are not easily accessible as a fuel meaning higher temperatures are required to trigger a cascading thermal event in LFP cells than is generated by the cells themselves during thermal runaway.

Each cell includes a safety vent to provide a controlled release of internal pressure during abnormal conditions and a rigid aluminum exterior providing an added degree of protection against external impacts.

All cells used are designed and manufactured by top tier vendors for the purpose of stationary storage. Individual cells undergo rigorous inspection and safety testing prior to module assembly and are certified to UL 1642 or UL 1973.

4.1.2 Stack

Powin's Stack750 Segments are rated to IP 56 (NEMA 4) and provide robust protection against environmental and physical exposures, ensuring the continued integrity of electrical components for the life of a system.

Powin provides comprehensive environmental controls to ensure proper temperatures and humidity, preventing corrosion and premature failure of electrical components. This requires coordinated control of Stack fans and HVAC that is made possible through a specialized environment controller developed by Powin's engineering team.

Conditioned HVAC supply air is ducted directly to the modules via heatsinks that cell are directly placed upon. If any cell temperature is outside of the normal operating range, HVAC and heaters will turn on and stay on until normal operating temperatures are achieved (25C to 32C).

- Extensive CFD analysis and real-world testing shows that HVAC is sufficient to maintain cell temperatures in a safe range during all normal operating scenarios.

Stack-level fusing and automatic disconnects prevent electrical faults from propagating and minimize arc flash potential.

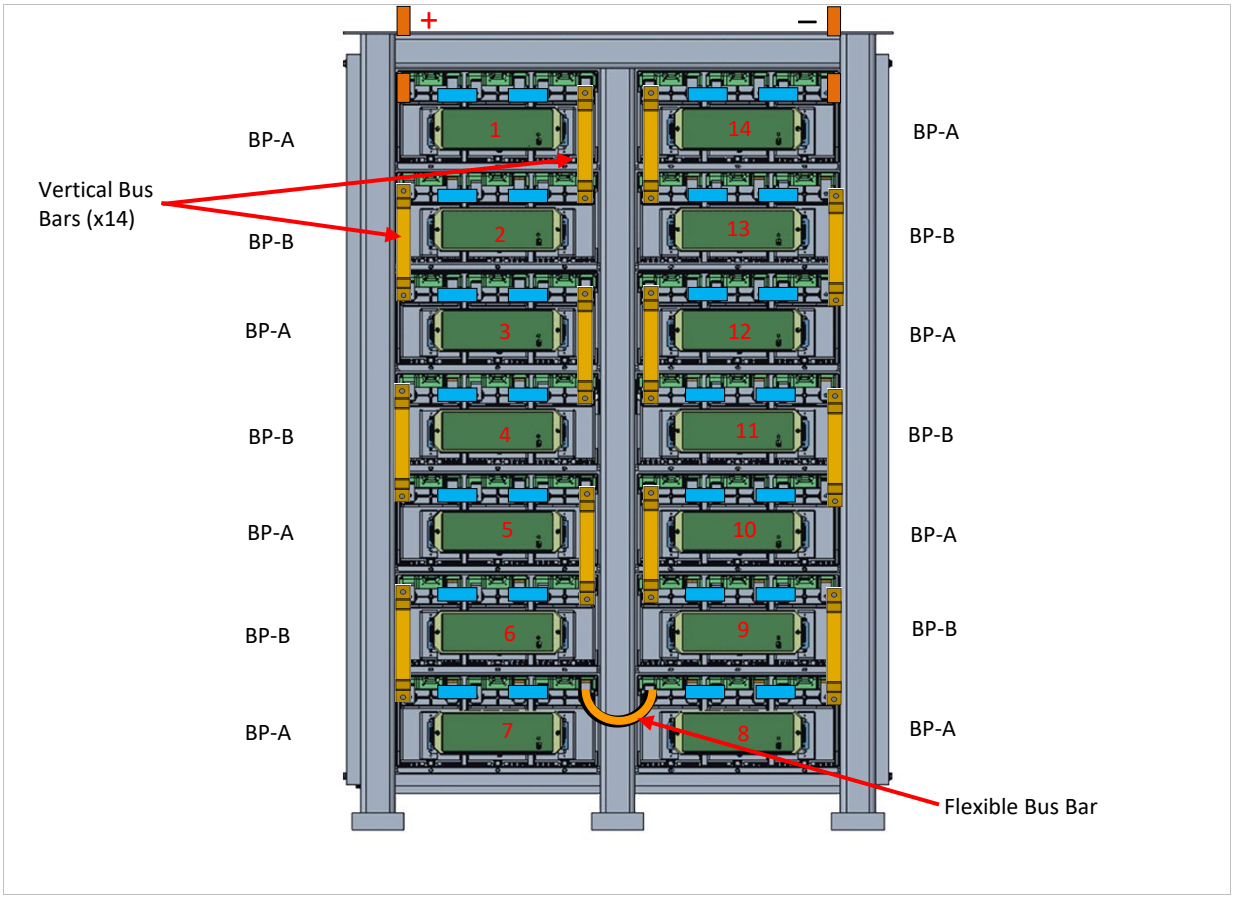

Figure 1. Stack750E shown with front doors removed.

4.1.3 System Software

All software and firmware used in Powin Stack750E are developed, tested, and managed in-house by Powin's engineering team. We do not rely on software provided by foreign battery manufacturers or outsource software development to third parties.

The Korean government investigations into domestic ESS fires determined that a lack of information sharing between safety and control software (i.e., Battery Management System and Energy Management System), as well as erroneous charge/discharge processes, were contributing factors to the many unfortunate fires that occurred there over the past several years. Powin believes these software deficiencies were largely the result of uncoordinated engineering efforts between multiple entities that traditionally "layer" software together to control energy storage systems.

Powin develops safety and control software in-house and can ensure adequate margin of safety at the source code level. For example, we can be assured that software controlling a Powin system will not violate cell voltage or current safety limits even before field testing, which has the potential to miss edge cases.

As part of the UL 1973 certification process, firmware at the Stack level is evaluated to ensure that Stacks can automatically protect themselves from unsafe conditions and disconnect from the DC bus.

4.2 Detection

Powin's Stack750E systems are monitored in real time for correct operation down to the individual cell level by Powin's Remote Operations Center (ROC). This secure facility provides 24/7 monitoring and technical engineering support by phone or email across our entire global fleet. Detection measures exist not only to identify if a fire or thermal runaway event has occurred, but also if conditions are evolving that could lead to a potential thermal event. If an unsafe condition is detected, the ROC team and customers are notified through Powin's Alert Management System and mitigation measures are automatically initiated.

4.2.1 Cell Level Monitoring

The voltage and temperature of every cell in every Powin Stack750E is monitored in real time by onsite software purpose-built to ensure system safety. These measurements, taken multiple times per second, automatically shut down the system and disconnect all Stacks from the DC bus if abnormal conditions arise.

Powin runs automated "cell health scans" daily across its global fleet to detect behavior that may indicate a current or impending failure. If these analyses identify any suspect cells, the Stacks containing those cells are removed from operation by Powin's ROC team or, if preferred by the customer, their own operations team. Cells data is interrogated and, in most cases, visual inspections are performed prior to replacement or return to service.

4.2.2 Fire & Off-Gas Detection

The status of all safety-related equipment, such as HVAC, gas detection, fire suppression, and ground fault detection, is monitored in real-time by the Powin ROC.

Stack750E Segments come standard with heat and smoke detectors that automatically trigger the Fire Safety System (FSS) to take necessary action and notify the local fire authority. An optional, aerosol-base fire suppression is available. For more information, see Section 4.3.3, **Fire Suppression**.

Stacks750E Segments come standard with redundant and highly sensitive hydrogen gas detectors calibrated to detect hydrogen at 1% concentration, or 25% of the lower explosive limit (LEL). The hydrogen detectors trigger the HVAC system to ventilate the segment with fresh outside air. For more information, see Section 4.3.2, **Emergency Ventilation**.

All detection sensors and networking equipment are backed up by a 5kW UPS giving a runtime of 10 minutes, ensuring continued safety and visibility even with a loss of auxiliary power. Critical alarms related to fire or off-gas automatically shut down the system and disconnect all Stacks from the DC bus.

4.3 Mitigation

The primary hazard associated with Powin Stack750E is the uncontrolled combustion of explosive gases from cell(s) in thermal runaway, not large-scale fire caused by cells in thermal runaway. In the unlikely scenario that all preventative measures have failed to stop thermal runaway, the primary mitigation measures are intended to minimize the concentration of explosive gases released such that explosive levels are never achieved. Secondary mitigation measures are focused on preventing external events that could force cells into thermal runaway, such as a prolonged electrical fire.

4.3.1 Module Design

Modules are isolated from each other by steel barriers which act as structural members and thermal barriers. Scheduled/anticipated internal and UL 9540A testing to date demonstrates that these thermal barriers effectively stop thermal runaway from propagating from one module to another. Powin utilizes Gen 3 modules for its Stack750E product line.

Relative to industry standards, Stack750E modules contain fewer cells. In the improbable scenario of cell-to-cell thermal runaway propagation where an entire module is consumed, the amount of explosive gas release is minimized. Stack750E modules contain 10 cells, which represents approximately 1% of the cells in a Stack.

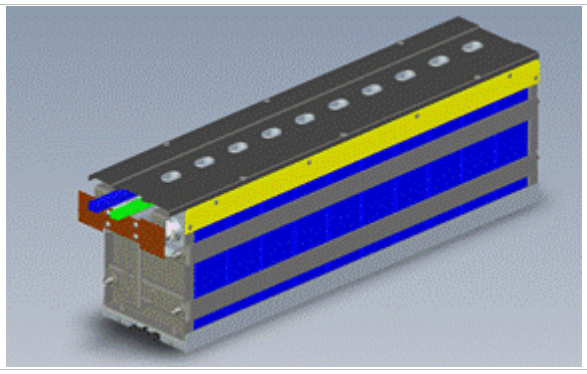

Figure 2. Powin Gen3 Module design

4.3.2 Emergency Ventilation

UL 9540A testing indicates that hydrogen gas makes up approximately 50% of the explosive gas mixture released by an LFP cell in thermal runaway. The hydrogen detectors used in Powin's modules are calibrated to detect hydrogen levels at 1%, well below the concentration that would cause an explosion.

If hydrogen is detected, the HVAC ceases to operate. Next, the system enters Active Ventilation Mode and brings in fresh outside air at a rate of at least 325 cfm, which is sufficient to fully exchange the air in the segment 2 times per minute. 8 booster fans augment Active Ventilation, ensuring explosive gases are quickly diluted and maintained below 25% of the LEL.

In case power supply to booster fans fail, Passive Ventilation takes over. The vents are shut open by means of a fail-open actuator which enables venting gases out through natural buoyancy.

In the case a fire alarm is activated, with or without fire suppression, Emergency Ventilation Modes and all HVAC functions will be overridden to stop airflow within the Stack750E to prevent fueling the fire.

CFD and ventilation analysis support that even in the worst probable case of multiple cells entering thermal runaway, explosive gases are maintained below the lower explosive limit and compliance with NFPA 69 is maintained.

In the highly improbable scenario where more than one cell is affected by a propagating thermal event, analysis shows that the HVAC system can successfully eliminate and dilute gases and condition the environment to well below flammable temperature limits. This conclusion is predicated on worst case assumptions where many early-stage safety measures fail to operate as designed, including the Battery Management System (BMS).

Activation of emergency ventilation automatically triggers an Emergency Stop (E-Stop) which immediately shuts down the system and disconnects all Stacks from the DC bus.

4.3.3 Fire Suppression

Powin performs extensive fire testing at our third-party laboratories. In all UL 9540A testing to date on fielded products, a single cell is forced into thermal runaway at the module and stack level using heaters or other external means. The anticipated outcome In each case is that cells do not catch fire and thermal runaway does not propagate to neighboring cells.

All testing and analysis support that fires can only be caused by events external to the cells themselves, such as direct and prolonged exposure to a large electrical fire. Given this, the primary purpose of the fire suppression systems installed in Powin modules is to extinguish a fire that could force cells into thermal runaway, not to stop in progress thermal runaway.

Activation of the fire suppression system automatically triggers an Emergency Stop or "E-Stop", which immediately shuts down the system and disconnects all Stacks from the DC bus. Activation of the fire suppression system also shuts down the HVAC system including emergency ventilation that may have been triggered by the detection of Hydrogen within the segment. The HVAC system can only be reactivated by resetting the fire control panel directly and will resume normal operation 5 minutes after reset.

4.3.3.1 FDC Dry Standpipe

The dry standpipe connection can flood the segment with water at a rate of 250 gallons per minute. The dry standpipe has a 1.5” NPT type connection, threaded at both ends.

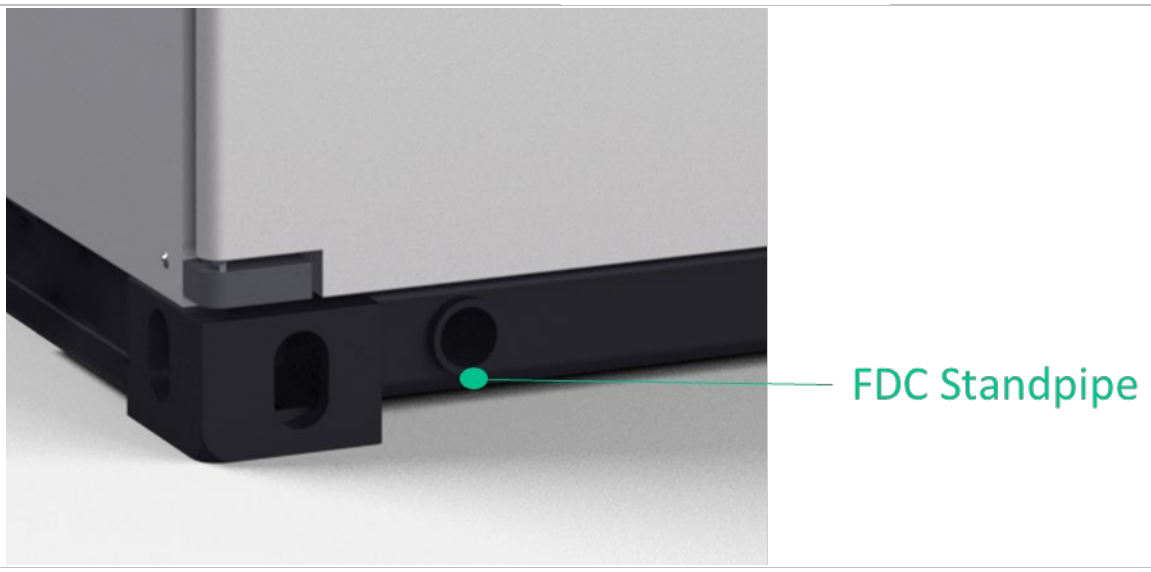

Figure 3. Stack750E dry standpipe connection.

4.3.3.2 Gas-Based Fire Suppression

Powin provides an optional Stat-X fire suppression in its Stack750E segments which is an aerosol-based system specifically design for enclosed spaces. Stat-X extinguishes fires by interrupting a fire's reaction pathway - specifically, 1–2-micron potassium particles are injected into the module that eliminate the O, H, and OH free radicals required for the fire to continue. Stat-X is non-toxic, non-ozone depleting, and does not rely on displacing oxygen, therefore the module need not be perfectly sealed for the system to be effective.

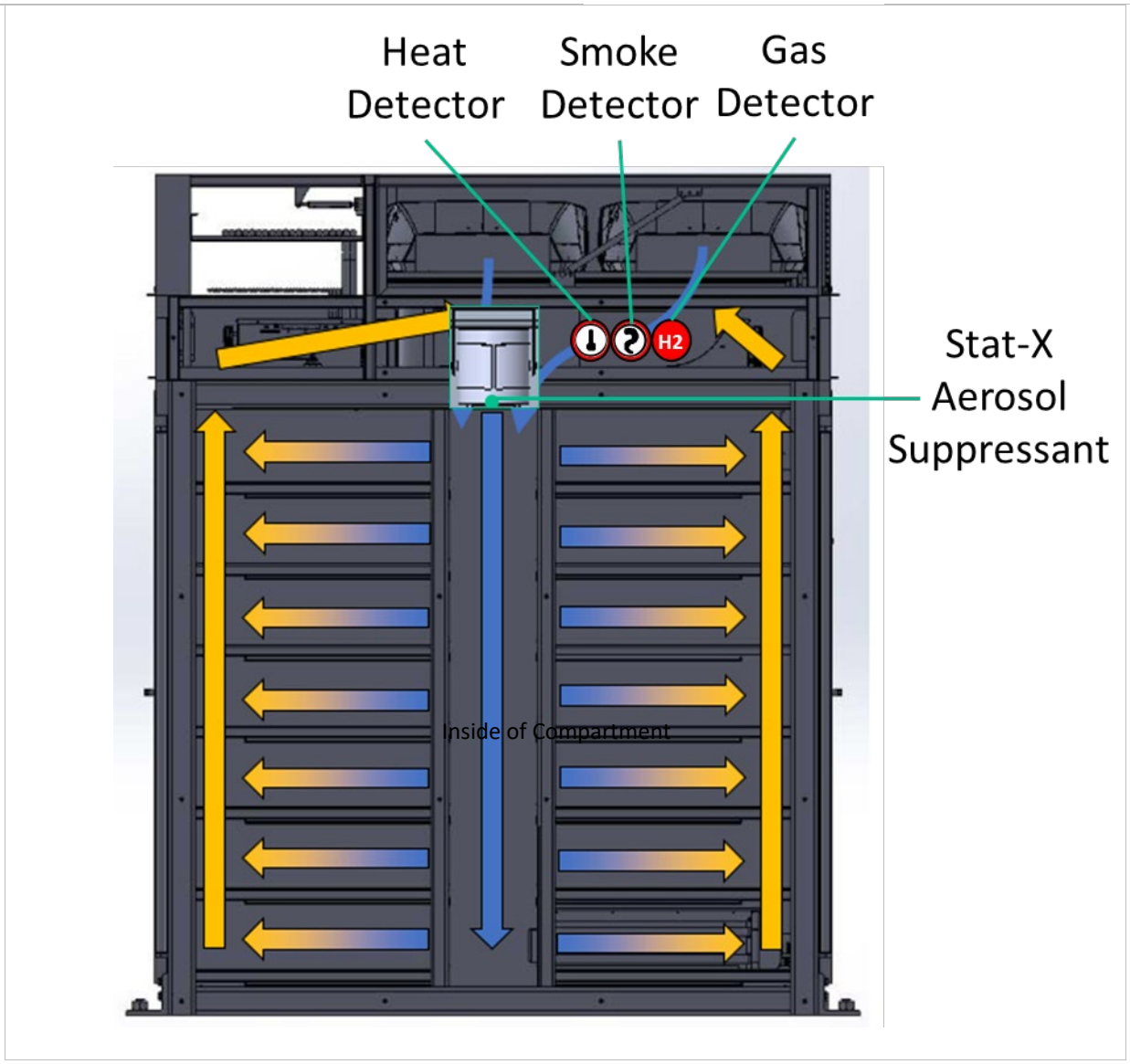

Figure 4. Stat-X Fire Suppression System Device Layout

4.3.4 Site Design

Fires will not propagate from one module to another or to surrounding areas. Powin's site designs require at least eight (8) feet of separation from the adjacent battery segment array and intentional setbacks from native fuels to provide a buffer for minimizing the likelihood of engaging materials beyond site boundaries.

With the setbacks identified below, Stack750E modules can be safely installed in locations lacking access to water without worrying about the risk of multiple modules burning down should a fire consume one unit.

4.3.5 First Responder HMI

Powin's Stack750E will come standard with the Powin for First Responders™ HMI. This screen, illustrated in Figure 5 and Figure 6, is intended to supplement onsite signage and module-based horns and strobes. It will show First Responders the status of heat, gas, smoke, fire suppression, and

communications for each module and provide emergency procedures and contact information for Powin's ROC team.

The HMI can be installed anywhere onsite, such as a substation building or dedicated command center at the edge of the facility, and it receives data from the local network, so it does not require an internet connection to function properly.

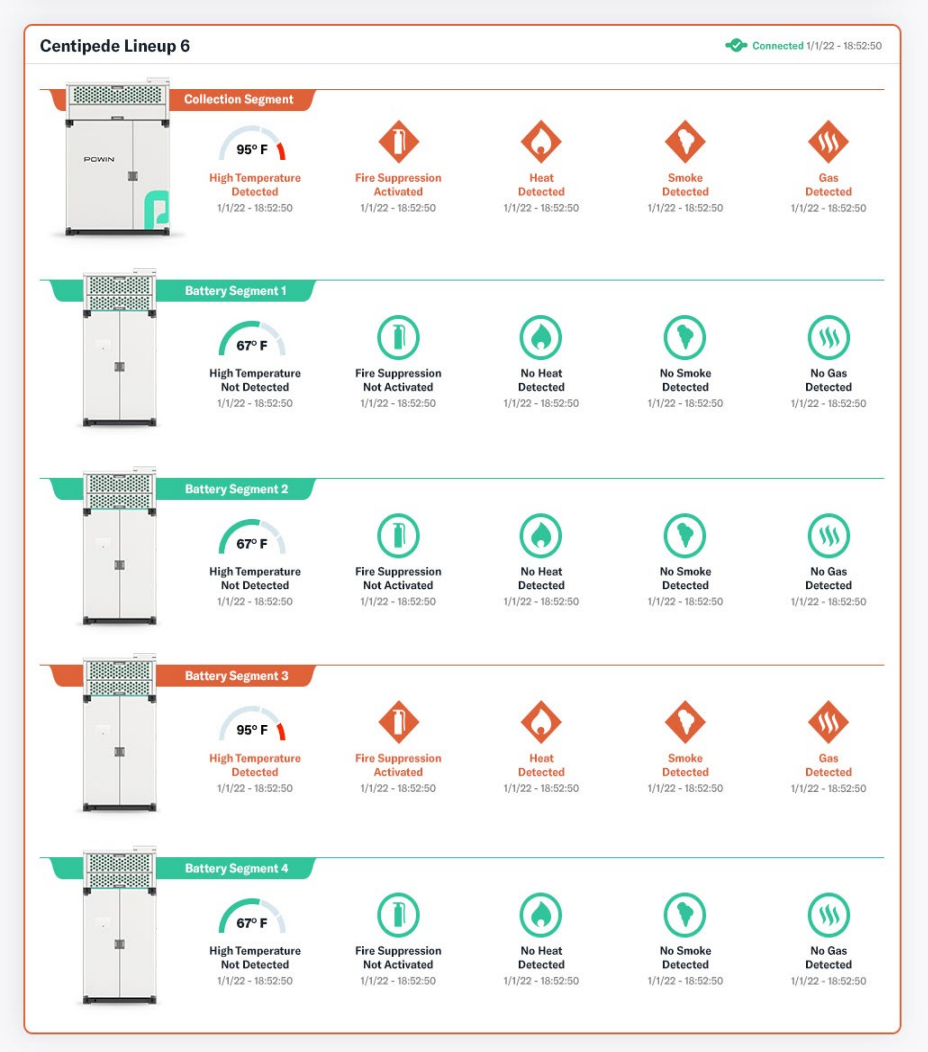

Figure 5. Stack750E Status Page of the Powin for First Responders HMI

5.0 Personnel Safety

Below are highlights of hardware and software safety measures beyond those discussed above that are specifically meant to protect personnel. For more information about Powin's safe work processes in the field, refer to the Energy Control Program & Maintenance Manual for the Stack750 - the manual covers topics such as tools and equipment, PPE requirements, and lockout/tagout.

5.1 Stack-Level

Powin's Stack750E design greatly minimizes the need to connect live, high-voltage DC components during installation at stack level because, unlike traditional rack systems, the battery modules are pre-populated into Stacks when they arrive onsite needing only controls, communication and power cable connections.

Stack750E has an exterior access door providing field service technicians full access to safety perform visual inspection, diagnosis and maintenance as needed. Some of the Stack level safety features are:

- A set of String controllers with DC contactors that can disconnect the Stack from the DC bus and allow basic maintenance, limiting exposure to arc flash potential.
- A screen on each side of the Segment that displays if a Stack is healthy or faulted and moving power or not, improving situational awareness.

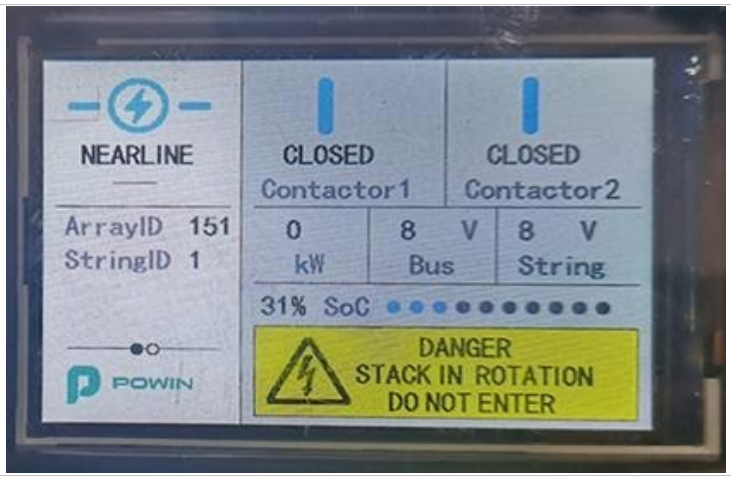

Figure 6. Status Screen

5.1.1 Pack-Level

Stack750E Battery packs are configured with three (3) modules in two orientations: “A” and “B”. “A” battery packs are assembled with terminals in opposite orientation to “B” battery packs. The battery Stack is assembled with alternating “A” and “B” battery packs, top-to-bottom, starting with an “A” battery pack installed under the String controller. This allows the battery packs to be connected in series in a compact way with less cabling and interaction with field personnel.

5.1.2 Module-Level

Each Stack750E module is preassembled with ten (10) cells completely wired to limit the possible interaction between field personnel and electrical components.

6.0 References

The following documents are referenced in this procedure.

- Stack750E Product Manual (MP-S750E)
- Energy Control Program and Maintenance Procedure
- E-Stop Overview (PE-ESO)

7.0 Revision History

NAME	DATE	REASON FOR CHANGES	VERSION
Kevin C.	2021.11.08	Approved for Release	C01
G. Moffet	2021.11.08	Initial Release	C01
S. Kumar	2022.03.10	Technical Updates to Sections 4.2.2, 4.3.1, 4.3.2, 4.3.4, 4.3.5 Updated Figure 3, Figure 4, and Figure 6	0
G. Moffet	2022.03.14	Removed Section 4.3.5 Renumbered following sections as needed Removed Figure 5 Renumbered following figures as needed General wording and formatting updates	0
K. Considine	2022.03.14	Approved for Release	0

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