

228-PSS-OP Ampeak Energy AW1 BESS Project – Uskmouth Power Station

Battery Storage Safety Management Plan

Revision 2

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Site Location:

The proposed site is Located on land at Uskmouth Power station, West Nash Road, Nash, Newport.



Figure 1 Site Location

The site coordinates are: ST 32988 84012 (north) and ST 33046 83967 (south).

Directions:

At junction 28, take the A48 E exit to Casnewydd

A46 Continue onto Southern Distributor Rd/A48

Keep right to stay on Southern Distributor Rd/A48

Continue to follow A48

At Maesglas W, take the 1st exit onto Docks Way/Southern Distributor Rd/A48

At the roundabout, take the 2nd exit onto Southern Distributor Rd/Usk Way/A48

At the roundabout, take the 2nd exit onto Southern Distributor Rd/A48

At the roundabout, take the 3rd exit onto Nash Rd

Turn right to stay on Nash Rd

Turn right onto W Nash Rd

Abbreviations

BESS	Battery Energy Storage System
BMS	Battery Management System
BOP	Balance Of Plant
BSSMP	Battery Storage Safety Management Plan
CFM	Cubic Feet per Minute
CMU	Cell Monitoring Unit
DMC	Distribution & Control Cabinet
DNO	Distribution Network Operator
EMS	Energy Management System
EoL	End of Life
ERP	Emergency Response Plan
FACP	Fire Alarm Control Panel
FMEA	Failure Modes Effects Analysis
FRS	Fire & Rescue Service
IMD	Insulation Monitoring Device
LEL	Lower Explosive Limit
LFL	Lower Flammability Limit
LFP	Lithium Iron Phosphate (battery)
LFST	Large Scale Fire Testing
LOTO	Lock out/Tag out
MSDS	Material Safety Data Sheet
NFCC	National Fire Chiefs Council
NFPA	National Fire protection Agency (US)
OCPD	Over-Current Protection Device
OEM	Original Equipment Manufacturer
PCS	Power Conversion System
SCADA	Supervisory Control & Data Acquisition
SOC	State of Charge
SOH	State of Health
TMS	Thermal Management System
UL	Underwriters Laboratory
UPS	Uninterruptable Power Supply
VOC	Volatile Organic Compound(s)

Consultation

The original draft of this report was produced in January 2026 in anticipation of liaison with South Wales Fire & Rescue.

Their response provided by Dominic Lijertwood (AlfireE) Station Manager of South Wales Fire and Resue Service on 4th March is as follows:

The Battery Storage Safety Management Plan and Water Supply report compiled by Mick Carr are comprehensive and in line with the latest guidance, so we have no comments on those.

The hydrant positions are justified in the reports, so we agree with the planned locations. It would be beneficial for crews to have a brief overview of the hydrant locations and firefighting report available upon attendance so if there is any way of having those secured on site in a tamper proof box it would be greatly appreciated.

The FRS subsequently visited site on the 21st March and had no further comments, and we will be hosting site visits for each of the local station's watches (12 in total) in the coming weeks.

Background of the Author:

Mick Carr is a qualified Mechanical Engineer, and holds the following memberships:

- Member of the Institute of Fire Safety Managers (MIFSM)
- Associate Member of the Institute of Fire Protection Officers (AMIFPO) (Note the term Associate in this case is used at a level just below Fellow, not in a lower or corporate sense)
- Affiliate Member of the Institute of Fire Engineers
- Member of the Institute of Engineering & Technology (MIET)
- Technical member of the Institute of Safety & Health (Tech IOSH)

He is also qualified to degree level in construction & civil engineering and holds numerous safety qualifications including those related to Fire and DSEAR. He has over 40 years' experience having worked worldwide on many large projects in senior positions.

1. Executive summary

This report has been prepared on behalf of Ampeak Energy Ltd in relation to Afon Wysg Battery Energy Storage System (AW1) on land at Uskmouth Power Station, West Nash Road, Newport.

The proposed battery storage system (E-Storage's Solbank 3.0 containerised system) has key components including:

- Battery chemistry & cells: SolBank 3.0 uses high-density Lithium-Iron Phosphate (LFP) cells (314 Ah),
- Pack & rack configuration: The system comprises multiple battery packs — each pack is series-wired, and the racks combine multiple packs. The standard container houses all battery racks internally.
- Battery Management System (BMS): Active balancing at pack/rack level with continuous monitoring of cell voltage, temperature, state-of-charge (SOC) and other parameters. This enables early detection of abnormal conditions and automatic disconnection of faulty strings.
- Thermal Management System (TMS): A smart liquid-cooling/heating system that keeps battery temperature within safe and optimal ranges (e.g., ~20–35 °C during charge/discharge). This is more efficient than simple air cooling and helps maintain performance and longevity.
- Containerised modular design: SolBank 3.0 comes in a standard 20-ft high-cube container, encapsulating all necessary battery, cooling, control and safety equipment. This modular containerised approach simplifies deployment.
- High energy capacity & density: The system offers around 5 MWh nominal capacity in a single container.
- High power output: Rated DC power up to ~2.35 MW.
- Compatibility and flexible integration: SolBank 3.0 supports various power conversion system (PCS) topologies. Its modular, plug-and-play design helps reduce project-schedule risk and simplifies commissioning.
- Robust enclosure & environmental protection: Battery packs in SolBank 3.0 are sealed to a high ingress-protection rating (e.g., IP67 on pack)—protecting against dust, moisture, and water condensation.
- Multi-level safety and fire protection: The system includes fire and gas-detection (heat, smoke, combustible gas detectors), fire alarm (audio + visual), ventilation/off-gas valves, and suppression.
- Electrical redundancy and abnormal condition detection: Redundant safety systems, plus BMS-based monitoring, deliver early detection of abnormal performance and automated isolation of affected strings.
- Thermal isolation & containment of events: In 2025, SolBank 3.0 passed a large-scale fire test: it was able to contain thermal events within a single enclosure — a critical demonstration of its safety design in the event of thermal runaway.

The site is planned to occupy the north-eastern area of the industrialised Uskmouth Power Station Site. It is currently occupied by the redundant cooling towers and infrastructure associated with Uskmouth B Power Station.

The 120MW/240MWh project will consist of three lines of battery energy storage units running East-West across the site with 26 double e-Storage Solbank 3.0 units, 3 single units, 18 twin skid inverter units, associated auxiliary transformers and a switchroom.

Once operational, the plant will be designed to operate unmanned with access required for maintenance only, and with a minimum Operational Life of 40 years.

Before beginning to explain the purpose, scope and finer details of the Solbank 3.0 system the reader should be aware of the latest large-scale fire test of the system carried out in June 2025.

This test was carried out in controlled environment at a CSA Group (testing agency) site.

The system underwent a protocol called “Large-Scale Fire Testing (LSFT).

- Specifically, the test was conducted under the standard CSA C-800:25 §9.7
- The objective was to simulate a fully developed fire in one battery-enclosure unit, and assess whether the fire would propagate to adjacent enclosures
- Independent witnessing and verification by third-parties consisted of the CSA Group and Energy Safety Response Group (ESRG).

The key finding was that the SolBank 3.0 system successfully contained the thermal event inside the initiating unit — no fire spread to neighbouring units/enclosures. The structural integrity of target (adjacent) units remained intact: doors, louvers, structural elements remained closed/undamaged throughout the fire, and the system met the safety objective of the test, aligning with the more general standard NFPA 855 (which governs energy storage system safety, fire propagation, etc.).

This was vitally important for a number of reasons:

- Fire propagation between battery storage enclosures is a major risk in large-scale BESS deployments: a single event can cascade to adjacent units if containment is inadequate. The test demonstrates that the Solbank 3.0’s passive containment architecture is capable of mitigating that risk.
- It provides evidence to regulators, insurance companies, project developers, and first responders that the system meets a high standard of fire safety.
- As energy storage becomes more widespread, particularly at utility scale, these kinds of tests become a differentiator for system suppliers in terms of permitting, risk mitigation, and public confidence.

Implications for deployment

- This test result is a strong indicator of fire containment performance.
- However, this document understands and expands upon the fact that fire safety is also about system design, installation practices, site layout, separation distances, ventilation, etc. and that the processing around the system (EPC, commissioning, maintenance) matters as much as the product itself.
- For first responders, knowledge that the system is designed to contain an event to one enclosure means training and emergency response protocols can be tailored (but always assume worst-case).

2. Introduction & System Overview

Prior to any entry to site, an overview of the necessary basic PPE to be worn is as follows:

Item	Remarks
Hard hat	To protect head from impacts from falling objects and other hazards
Safety gloves	To protect hands against cuts, abrasion, and other hazards
Safety glasses	To protect eyes from contact with foreign objects and airborne debris
Safety steel toecap boots	To protect feet from heavy objects and equipment
Hearing protection	To protect ears from loud noises generated by machinery and other tools
High visibility vest	To ensure all personnel are seen by equipment operators
Specialty PPE	Arc flash PPE, fall prevention harnesses, and other hazard specific PPE as required by the site conditions and the site EH&S manager or local laws and regulations

Table 1 PPE Requirements

The SolBank 3.0 System integrates all power electronics, controls, and safety features required to support the DC side of a battery energy storage system. An overview of the SolBank 3.0 layout and key features is shown in Figure 1 below and further described in Table 1.

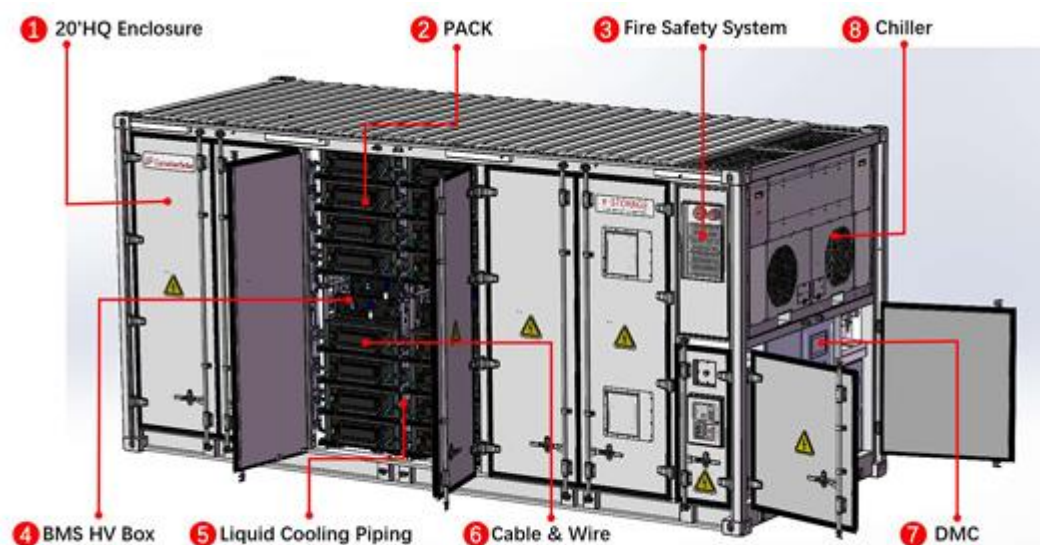


Figure 1 Solbank key features

The SolBank's main safety equipment and features are:

No.	Name	Remarks
1	Standard Enclosure and Rack	All models of the SolBank3.0 series utilise a standard IP55 rated 20ft HC container and battery rack design allowing for enhanced system modularity.
2	Pack	The SolBank3.0 series contains 48 Lithium Iron Phosphate (LFP) battery packs, each consisting of 104 series wired battery cells.
3	Fire Protection System	The SolBank3.0 series combines heat, smoke and gas detection with a deflagration and ventilation system.
4	BMS Box	The SolBank3.0 series contains 12 BMS boxes. These are easily accessed for installation and maintenance within the middle line of the container. The BMS ensure optimal battery functionality and safety.
5	Liquid Cooling piping	The liquid-cooling piping connecting the chiller to the packs.
6	Cable & Wire	High-voltage connection and low-voltage communication power cable.
7	DMC	The Distribution and Control Cabinet houses all aux power distribution equipment including 2-hour backup UPS; system 8communication, control, and monitoring hardware including network switch, and Local EMS, and all required customer communication, signal, and aux power interfaces.
8	Chiller	The SolBank3.0 series' liquid cooling/heating system facilitates improved battery temperature management efficiency relative to traditional forced air systems. Each battery pack is liquid cooled, allowing for greater heat dissipation and uniform cell temperature management. During charge and discharge, cell temperature is maintained between 20°C - 35°C.

Table 1 main safety equipment

2.1 Purpose and scope of the BSSMP

The purpose of this Battery Storage Safety Management Plan (BSSMP) is to set out the safety, operational, and emergency management arrangements for the safe installation, commissioning, operation, maintenance, and decommissioning of the Battery Energy Storage System (BESS) at the AW1 Site.

The objectives of this plan are to:

Ensure Legal and Regulatory Compliance:

Demonstrate compliance with relevant UK legislation, guidance and standards, including but not limited to:

- Health and Safety at Work etc. Act 1974
- Management of Health and Safety at Work Regulations 1999
- Electricity at Work Regulations 1989
- Construction (Design and Management) Regulations 2015 (where applicable)
- UK Fire and Rescue Service / NFCC Guidance on BESS Safety
- Relevant BS/EN/IEC standards for lithium-ion and energy storage systems

In addition, it aims to:

- **Manage Safety Risks Associated with BESS Technology:** Identify and control hazards including thermal runaway, fire, explosion, electrical hazards, gas release, environmental contamination, confined spaces, and high-energy systems.
- **Provide a Robust Emergency Response Framework:** Detail emergency actions, communication pathways, coordination with the local Fire & Rescue Service, isolation procedures, and incident escalation protocols.
- **Define Operational Responsibilities and Safety Governance:** Set out roles, responsibilities, authorisations, and competency requirements for all personnel involved in the operation and maintenance of the BESS.
- **Support Safe and Reliable Operation Through the Asset Lifecycle:** Provide clear procedures for commissioning, inspection, maintenance, monitoring, and end-of-life management to ensure long-term safe and effective operation.

Scope of the BSSMP:

This BSSMP applies to the entire Battery Energy Storage System installation at AW1, covering all safety-critical aspects from construction to decommissioning within the UK.

The scope includes, but is not limited to:

Physical System Coverage

- Battery modules / racks
- Battery containers or enclosures
- Battery management systems (BMS) and energy management systems (EMS)
- Inverters, transformers, switchgear and associated electrical infrastructure
- Thermal management systems
- Fire detection, alarm and suppression systems
- Venting and gas dispersion systems
- AC/DC cabling and protection devices
- Fencing, access routes, signage, and site security

Activities Covered

- Site establishment and construction work
- Commissioning of BESS units
- Normal operational activities and remote system monitoring
- Maintenance, inspection, testing, and repair
- Emergency response operations and incident management
- Decommissioning and safe disposal or recycling of battery components

Safety and Risk Management Arrangements

- Hazard identification and risk control measures
- Electrical safety procedures, including isolation and lockout/tagout (LOTO)
- Fire safety and thermal runaway management
- Hazardous substances, off-gassing, and ventilation controls
- Personal protective equipment (PPE) and site access rules
- Contractor management and permit-to-work systems

Environmental Protection Measures

- Prevention of soil and water contamination from electrolytes or firewater runoff
- Waste management and handling of hazardous battery materials
- Spill response and pollution control procedures

Roles, Competency and Training

- Safety responsibilities for operators, maintainers, emergency responders and site managers
- Competency, qualifications, authorisation levels and refresher requirements
- Induction and training needs for site personnel

Communication and Stakeholder Interfaces

- Engagement with the local Fire & Rescue Service and relevant authorities
- Reporting mechanisms for incidents, near misses and dangerous occurrences
- Liaison with the Distribution Network Operator (DNO), National Grid, stat bodies or landowner (as applicable)

2.2 Description of the BESS

The proposed BESS units are Solbank 3.0 Energy Storage Systems produced by e-Storage, a subsidiary of Canadian Solar.

The particular model is the S-5016-2h-EU. As most of the units are deployed in a twin configuration the mirror image is the S-5016-2h-EU-LH so they can sit back-to-back.

The battery chemistry is Lithium-Ion Phosphate (LFP) and has the following configuration:

- Pack configuration: 1P104S (104 Cells)
- Rack configuration: 1P416S (4 Packs)
- System configuration: 12P416S (12 racks)

The SolBank3.0 series contains 48 Lithium Iron Phosphate (LFP) battery packs, each consisting of 104 series wired battery cells. Each battery pack has a nominal voltage of 332.8VDC and is wired in series with five other battery packs to achieve a nominal string voltage of 1,331.2VDC. The battery pack housing is constructed from a material with a flame-resistant rating of 5VA. The SolBank3.0 series contains 48 x 1P104S battery packs and 12 BMS. A typical battery string consists of 4*1P104S battery packs wired in series and connected to a single BMS.

It has a nominal capacity of 5016 kWh and a nominal DC voltage of 1331.2 V with an operational voltage of 1164.8 v – 1497.6 v.

The enclosure is a 20ft. high-cube container with an IP55 rating, measuring 6058 x 2438 x 2896mm weighing 43,000kg. It has a RAL9003/C4 coating.

BMS details

The SolBank3.0 series contains 12 BMS HV boxes. These are easily accessed for installation and maintenance within the middle line of the container. The BMS ensure optimal battery functionality and safety.

The SolBank 3.0 BMS has the following functions/features:

- Active balancing: The BMS actively balances the individual battery cells and/or racks to optimise capacity utilisation and extend life.
- Abnormal condition detection & protection: The BMS monitors for anomalies (such as over/under voltage, over-temperature, over-current, cell/rack faults) and triggers automatic protection or shutdown. For example, 20% faster detection of abnormal and automatic protection.
- Multi-layer/ hierarchical monitoring: The BMS is a “triple-layer BMS” providing comprehensive monitoring & control across pack, rack, and system level.
- String-level management & switching: The BMS supports string-level management (i.e., managing individual strings or modular groups of cells/racks), and automatic switching of single strings on/off to maintain availability.
- Integration with thermal management & fire safety systems: The BMS works together with the thermal management system (TMS) and fire detection/protection systems. For instance, the pack design is “IP67 rated”, and there is “multi-level fire protection” alongside BMS features.
- Data accuracy & communication: The BMS algorithm provides a 50 % boost in data accuracy compared to traditional systems. Also supports communication (Ethernet/Modbus TCP) for system integration.
- Safety and availability emphasis: The BMS helps ensure both safety (by early detection/protection) and availability (by active balancing and modular switching) with availability > 98 %.

Other Key Equipment

Operation of the SolBank3.0 series is enabled via the installation of several other pieces of key equipment. Provided below is a list of key ESS equipment included in the ESS architecture and notable requirements for integration with the SolBank3.0 series.

Power Conversion System (PCS)

The PCS is the *power electronics module* that interfaces between the battery DC side (at high voltage) and the grid or AC side (medium/heavy voltage) or other loads. It typically handles:

- DC ↔ AC conversion (bi-directional inverter/rectifier)
- Grid synchronization (voltage, frequency, power factor)
- Control of charging/discharging rates and safe operation
- Protection, switching, isolation for battery and grid side
- Communication with the BMS/EMS for coordinated operation

Auxiliary Power Distribution

A dedicated auxiliary power feed supports the ESS aux loads such as HVAC equipment, controls and communication devices, and other SolBank3.0 series internal components.

The auxiliary power equipment includes a dedicated transformer, metering, power distribution bus bar and circuit protection.

Balance of Plant (BOP)

The “twin skid” arrangement that sits alongside the Solbank units consists of:

- Power Electronics Twin Skid Compact that:
- Integrates two central inverters (PCSK) on a single steel skid
- Includes the step-up transformer and associated equipment

2.2.1 Technology Type

The SolBank contains 48 Lithium Iron Phosphate (LFP) battery packs, each containing 104 LFP cells. During transportation and maintenance, the power harness in series between the battery packs needs to be disconnected. When the power harness is disconnected, the DC voltage in the battery box is only 332.8V, which greatly reduces the risk of fatal electric shock. Note that during normal operation and fully installed, the battery pack nominal voltage can exceed 1331.2Vdc.

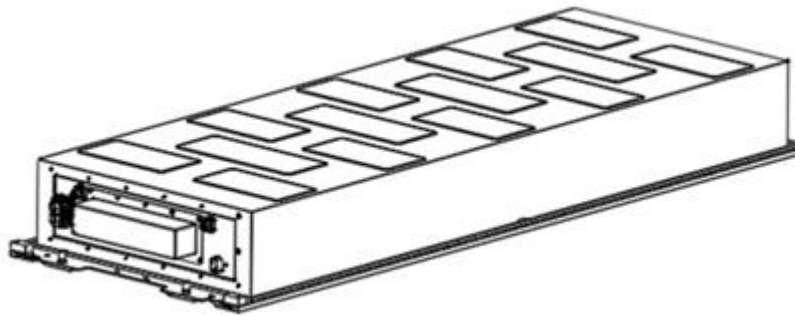


Figure 2: Solbank 2.0 series battery pack

The electrolyte contained within the SolBank battery packs consist of a volatile hydrocarbon-based liquid and a dissolved lithium salt such as lithium hexafluorophosphate. The electrolyte solution can be combustible under certain circumstances and does pose a health risk when exposed to personnel.

Additional materials used in the construction of the LFP battery pack are indicated in Table 2. Location: 4575L (1208.6gal) of electrolyte is contained within the SolBank's 48 battery packs (4992 battery cells). The battery packs are located within 6 steel racks.

Dimensions	
Height	248 ± 5m
Width	790 ± 3mm
Length	2180 ± 5mm
Weight	670 ±15kg
Electrical Parameters	
Nominal voltage	332.8 V
Nominal Capacity	314Ah
	104.5kWh
Charge Mode	CP
Charge Current	157A (Standard Continuous Charge Current@25°C)
	240A (Max. Continuous Charge Current@25°C, ≤30min)
Charge Cut-off Voltage	3.60V/Battery Cell
Discharge Mode	CP
Discharge Cut-off Voltage	2.80V/Battery Cell
Discharge Current	157A (Standard Continuous Discharge Current@25°C)
	240A (Max. Continuous Discharge Current @ 25°C, ≤60min)
Operating conditions	
Operating Temperature	0~+55°C
Storage Humidity	≤90%

Table 2 Battery Rack Specifications

2.2.2 Rated Capacity (kW/MW, kWh/MWh)

Charging/Discharging Mode	0.5 P / 0.5 P
Rated DC Power	2350 kW
Initial Storage Capacity	4700 kWh
Duration @Rated DC Power	2hrs
Round Trip Efficiency (RTE)	93%
Auxiliary Load (Standby/Peak)	1.5 kVA / 50 kVA
Max. Short Circuit Current	10 kA*12

Table 3 Rated capacity

2.2.3 Location and Environmental Conditions

The Solbank 3.0 is designed to operate in various environmental conditions with an operating temperature of -30°C to 55°C in a relative humidity of ≤95% (non-condensing). It can operate at an altitude of ≤400m.

2.3 Summary of applicable codes and standards (NFPA 855, UL 9540/9540A, IEEE 1547, local fire codes)

Design regulations for worldwide compliance:

- NEC – National Electrical Code® IEEE C84.1 – Standard Preferred Voltage Ratings for Alternating-Current
- Electrical Systems IEEE 693 – Recommended Practice for Seismic Design of Substations
- IEEE 1584-2018 – Guide for Performing Arc Flash Hazard Calculations
- NFPA 855 – Installation of Energy Storage Systems
- NFPA 70E® – Standard for Electrical Safety in the Workplace®
- NFPA 72 – National Fire Alarm and Signaling Code
- IEC62933-5-2 – Safety requirements for grid integrated EES systems - Electrochemical-based systems
- AS3000 - Electrical installations “Wiring Rules”

Product certification for worldwide compliance:

- IEC 60529 – Degrees of protection provided by enclosure
- UL 60730-1 – Standard for safety: Automatic Electrical Controls – Part 1: General Requirements
- NFPA 69® – Standard on Explosion Prevention Systems
- NFPA 68® – Standard on Explosion Protection by Deflagration Venting
- UL9540A – Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems
- UL1973 – Standard for safety: Batteries For Use In Stationary And Motive Auxiliary Power Applications
- UL9540 – Standard For safety: Energy Storage Systems And Equipment
- UN38.3 – Recommendations on the Transport of Dangerous Goods: Manual of Tests and Criteria

Product certification for EU compliance:

- IEC62619 – Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications
- IEC63056 – Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries for use in electrical energy storage systems
- IEC/EN 62477-1 – Safety requirements for power electronic converter systems and equipment - Part 1: General
- IEC/EN 61000 – Electromagnetic compatibility (EMC)

Fire Protection and Safety for EU compliance:

- BS 5839-1 – Fire detection and fire alarm systems for buildings
- BS 7273 -1 – Code of practice for the operation of fire protection measures
- BS EN 54 Pt1- 21 – series for equipment
- BS EN 15004-1: -2019 – Fixed firefighting systems. Gas extinguishing systems. Design, installation and maintenance.
- BS EN 15004-2:2020 – Fixed Firefighting Systems-Gas Extinguishing Systems FK-5-1-12
- BS 6266:2011 – Fire protection for electronic equipment installations– Code of practice
- BS EN 12094-1:2003 – Fixed firefighting systems. Components for gas extinguishing systems Requirements and test methods for electrical automatic control and delay devices

3.0 Hazard Identification & Risk Assessment

The primary hazards associated with installation and operation of the SolBank are indicated in Table 4 and discussed in the following sections.

Classification	HAZARD	DESCRIPTION	QUANTITY	RISK
Electrical hazards	DC voltage	Primary voltage of storage system	1500VDC	Electrocution
	AC voltage	Primary voltage of auxiliary power supply	400VAC	Electrocution
Chemical hazards	Ethylene Glycol	Coolant used in battery liquid cooling system	200L	See MSDS
	R513a Refrigerant	Refrigerant used in Chiller system	8 kg	See MSDS
	Li-ion Electrolyte	Battery electrolyte used in LFP battery cells	4575L	See MSDS
	Lead Acid Electrolyte	Battery electrolyte used in UPS	0.3L	See MSDS
Fire & Explosion Hazards	Electrical Fire	Fire caused by cable fault or component failure		Fire
	Thermal Runaway	Thermal runaway from battery fault or heat		Off-gassing
	Battery off-gassing	Off-gassing resulting from thermal runaway		Explosion

Table 4 Additional Battery Rack Specifications

Signage

A UK BESS site must display clear, durable, and strategically positioned safety signage to ensure workers, contractors, and emergency responders are fully aware of the hazards associated with high-energy electrical and lithium-ion battery systems. Mandatory signage includes high-voltage and electrical danger warnings, arc-flash and DC hazard notices, fire safety and no-smoking signs, and chemical hazard symbols identifying risks from electrolyte leakage or toxic off-gassing. Access control signs—such as “Authorised Personnel Only,” “Restricted Area,” and CCTV/security notices—must be placed at all entry points. Each BESS container should carry identification labels, lithium-ion hazard warnings, emergency shutdown instructions, and indicators for gas detection and ventilation systems. Emergency equipment, muster points, spill kits, and fire-fighting resources must be clearly marked with compliant British Standard signage. Together, these signs provide essential visibility of risks, reinforce safe behaviour, and support regulatory compliance across the operational site.

3.1 Technology-Specific Hazards

The electrolyte contained within the SolBank battery packs consist of a volatile hydrocarbon-based liquid and a dissolved lithium salt such as lithium hexafluorophosphate. The electrolyte solution can be combustible under certain circumstances and does pose a health risk when exposed to personnel. Additional materials used in the construction of the LFP battery pack are indicated in Table 5.

3.1.1 Thermal Runaway

Due to excessive heat build-up from external sources (i.e. electrical fire), or internal cell failure, it is possible that one, or many of the SolBank’s LFP cells may be pushed into a state of thermal runaway. Once this occur, the design of the LFP cell and battery pack is designed to reduce the propagation of thermal runaway to adjacent cells, a process called “cascading thermal runaway”.

3.1.2 Off-Gassing, Smoke, Flammable Gases

When Li-ion batteries go into thermal runaway, toxic and combustible gases are released in a process called off-gassing. During cascading thermal runaway events, when many cells are consumed, sufficient gas can build up within a confined space to create conditions sufficient for explosion.

3.1.3 Electrical Faults (Short Circuits, Ground Faults)

As a result of short circuit, failed OCPD (over-current protection device), or other electrical component failure, electrical fires are possible within the SolBank.

Personnel will be exposed to voltages up 1500 VDC from the SolBank3.0 series’ battery packs. Battery packs cannot be de-energised. Low and medium voltage AC is also present – exposure levels will depend on site specific conditions. Risk of arc flash and electrocution is omnipresent at an ESS site. E-STORAGE encourages full compliance with the practices and procedures indicated in NFPA 70E including use of Personal Protective Equipment (PPE) sufficient to mitigate any hazards identified in a site-specific arc flash study. Emergency Response Personnel should rely on Standard Operating Procedures (SOP) for responding to incidents at electrical generating facilities.

3.1.4 Fire and explosion risks

The SolBank3.0 series contains combustible fuels, ignition sources, and sufficient oxygen to result in propagation of fire. Fire and other sources of extreme heat, if not properly mitigated, can lead to battery cascading thermal runaway and the release of combustible gases. These combustible gases, if present in sufficient density, pose a risk of explosion. If a fire, or other indications of thermal runaway are present within the SolBank3.0 series or at the ESS site, first responders are advised to maintain a safe perimeter until it can be verified that entry into the ESS site is safe per the site-specific Emergency Response Plan (ERP) and SOP.

3.1.5 Mechanical failures

Despite the most stringent construction techniques used in the building of Solbank 3.0 it is acknowledged there are several potential mechanical failures that can affect **any** BESS unit including:

Enclosure / Structural Failures:

- Door / Latch / Hinge Failure: Hinges seize or corrode, Doors not sealing properly, Latch mechanism misalignment, Failure to achieve fire-rated closure
Impact: Loss of fire containment, water/dust ingress, security risk
- Structural Fatigue / Frame Distortion: Thermal cycling of container, Inadequate foundation support, Transport or lifting damage
Impact: Misalignment of racks, poor door sealing, vibration issues
- Roof or Panel Leaks: Gasket aging, Sealant breakdown, Mechanical damage during O&M
Impact: Water ingress → short circuits or corrosion
- Corrosion: Coastal or high-humidity environments, Coatings damaged during installation

Impact: Weakening of enclosure, rack alignment deviations

HVAC / Thermal Management System (TMS) Mechanical Failures:

- Overheating, loss of refrigerant, motor burnout,
Impact: Cooling loss → container overheating
- Fan Failure (Primary & Redundant): Bearing wear, Motor seizure
Impact: Uneven temperature distribution → accelerated thermal aging
- Blocked Airflow / Filter Obstruction: Dust buildup, Vegetation/debris near intake
Impact: Reduced heat dissipation, hot spots
- Refrigerant Line Damage: Vibration fatigue, Mechanical abrasion
Impact: Reduction or complete loss of cooling capacity
- Damper / Louver Mechanical Failure: Jammed open or closed, Motor failure

Impact: Poor ventilation → gas buildup risk or reduced HVAC efficiency

Fire Protection Mechanical Failures:

- Fire Dampers Failing to Close/Open: Corroded hinge, Damaged actuators
Impact: Compromised fire containment and ventilation control
- Pressure Relief Panel (PRP) Mechanical Failure: Panel seized shut, Incorrect mounting
Impact: Overpressure event → structural rupture
- Gas Extraction Fan Failure: Motor burnout, Blocked exhaust duct
Impact: Increased deflagration risk in gas-release scenarios

Rack & Battery Pack Mechanical Failures:

- Rack Misalignment
- Transport shock
- Foundation settlement

Impact: Stress on DC cables, connectors loosenin

Loose Mechanical Fasteners:

- Vibration during shipping
- Insufficient torque during assembly

Impact: High-resistance connections, potential heating

Damaged Module Casing:

- Handling damage during replacement

Impact: Reduced ingress protection, internal stress

Connector Mechanical Wear:

- Repeated disconnect/reconnect cycles

Impact: Poor contact → hot spots, arcing

Cable Strain / Mechanical Fatigue:

- Improper routing
- Sharp bends

Impact: Internal conductor breakage

Twin Skid / PCS BOP Mechanical Failures:

Transformer Cooling System Failure:

- Oil pump failure
- Fan failure

Impact: Transformer overheating

Skid Vibration / Loosening:

- Inadequate anchoring
- Resonance with inverter switching harmonics

Impact: Component fatigue, connector failures

Mechanical Relay / Contactor Wear:

- Repeated switching cycles

Impact: Contact pitting, stuck contacts

MV Switchgear Mechanical Failure:

- Breaker mechanism welds shut or fails to open

Impact: Protection malfunction, arc-flash hazard

Environmental / Site-Driven Mechanical Failures:

Foundation Settlement or Uneven Support:

- Poor compaction
- Freeze–thaw cycles

Impact: Rack misalignment, door misfit, stress on conduits

Rodent or Wildlife Intrusion:

- Chewing of insulation
- Blocking of intakes

Impact: Electrical shorts, HVAC failure

Human-Driven Mechanical Failures:

Incorrect Torquing of Bolts:

- Too tight → thread damage
- Too loose → vibration loosening

Impact: Electrical/mechanical instability:

Improper Door Closure After Maintenance:

- Door left unlatched

Impact: Environmental exposure, security risk, fire-rating compromised

Dropped Tools / Mishandling Battery Modules:

- Dented module shells or bent racks
- Impact: Latent failure risk

Improper HVAC Access Panel Re-installation:

- Leaving gaps

Impact: Reduced cooling efficiency, dust intrusion

3.2 Failure Mode and Effects Analysis (FMEA) or Hazard and Operability Study (HAZOP)

A full FMEA analysis is currently being developed. However, for the purposes of this document an abridged version is included:

FMEA – SolBank 3.0 Battery Energy Storage System (BESS)

Failure Modes & Effects Analysis (FMEA)

Scoring conventions (typical industry scale):

- Severity (S): 1–10 (10 = catastrophic)
- Occurrence (O): 1–10 (10 = frequent)
- Detection (D): 1–10 (10 = undetectable)
- $RPN = S \times O \times D$ (Risk Priority Number)

FMEA Table

Failure Mode	Cause	Effect	S	O	D	RPN	Existing Controls (SolBank 3.0) / Recommended Actions
Thermal runaway in a cell	Internal defect, overcharge, aging	Gas/heat release, module fire	9	3	3	81	Triple-layer BMS, LFP chemistry, active balancing, fire detection Check gas mapping, & enhanced predictive analytics
Thermal propagation across modules	Unmitigated runaway	Container-level fire	10	2	3	60	Passed CSA full-scale fire test; passive containment Verify fire dampers annually
Propagation to adjacent containers	Extreme heat flux	Multi-container loss	10	1	3	30	LSFT: no propagation observed locate high-risk loads away from BESS
HVAC / thermal management failure	Compressor fault, blocked airflow	Overheating, accelerated aging	7	4	3	84	Rack-level temp sensors, auto derating Quarterly HVAC inspection
High-voltage DC arc fault	Loose connections, water ingress	Personnel injury, fire	10	2	4	80	IP67 packs, DC contactors, protection relays Annual torque checks; IR thermography scans
PCS (inverter) failure	Electronics failure, grid issues	Loss of charge/discharge, trip	6	4	3	72	Certified PCS, auto trip, EMS control Maintain firmware updates
DC overcurrent / short circuit	Cable failure, insulation damage	Bus damage, fire	9	2	3	54	DC relays, BMS shutdown, fusing Cable routing inspections semi-annually
Gas accumulation in container	Off-gas from cells, HVAC off	Deflagration / explosion risk	10	2	4	80	Gas & smoke sensors, automated ventilation Gas extraction fan interlocks

Failure Mode	Cause	Effect	S	O	D	RPN	Existing Controls (SolBank 3.0) / Recommended Actions
Water ingress	Gasket damage, flooding	Electrical short, corrosion	8	1	3	24	IP67 battery packs, sealed housing Inspect seals yearly
Cybersecurity breach (BMS/EMS/PCS)	Weak credentials, remote access	Loss of control, unsafe commands	9	4	6	216	Role-based access, network controls
Human error during maintenance	No LOTO, improper switching	Shock, arc flash, equipment damage	9	4	4	144	LOTO procedures, restricted access Mandatory annual training, digital work permits
Fire detection failure	Sensor fault	Undetected early-stage TR	9	2	5	90	Dual-layer smoke/thermal detection Annual full-system fire test
Communication loss (BMS-PCS-EMS)	Networking fault	Reduced control, unsafe cycling	6	3	3	54	Redundant comms paths
Container over-pressure	Rapid off-gas	Structural damage	9	1	4	36	Pressure relief panels Regular inspection of vent panels

Table 5 FMEA outline

Ranked Risks (Highest RPN → Lowest)

1. Cybersecurity breach – RPN 216
2. Human error (maintenance switching) – RPN 144
3. HVAC/TMS failure – RPN 84
4. Gas accumulation – RPN 80
5. HVDC arc fault – RPN 80
6. PCS failure – RPN 72
7. Thermal runaway – RPN 81

(Note: Some values tie; list groups by RPN band.)

Interpretation

- Dominant risk drivers: operational & cyber, not the battery chemistry.
- Technical fire risk is strongly mitigated by SolBank's design (LFP + LSFT fire containment).
- HVAC and DC faults remain key operational concerns.
- Cybersecurity and human factors exceed the physical risks — consistent with modern BESS deployments.

SolBank 3.0 – Operational Risk Assessment Table

Hazard	Causes	Consequences	Likelihood	Severity	Initial Risk	Existing Controls	Residual Risk
Thermal runaway (cell-level failure)	Cell defect, overcharge, internal short, aging	Heat release, smoke, TR propagation, container fire	Low	High	Medium	Triple-layer BMS, LFP chemistry, active balancing, fast anomaly detection, internal fire barriers	Low
Fire propagation to adjacent containers	Full container fire, external heat flux	Multi-container loss, extended outage	Very Low	Critical	Medium	LSFT-tested containment (CSA C-800), NFPA 855 spacing, structural integrity	Very Low
HVAC/TMS failure	HVAC fault, blocked airflow, aux power loss	Overheating, battery aging, increased TR risk	Medium	Medium	Medium	Redundant fans, temp monitoring, derating/shutdown, PM schedule	Low
DC arc flash / electrical fault	Loose terminations, maintenance error, isolator fault	Severe injury, fire, equipment loss	Low	Critical	Medium	IP67 packs, DC contactors, protection relays, LOTO, restricted access	Low
PCS / inverter fault	Component failure, overcurrent, grid disturbance	Trip events, energy loss, internal damage	Medium	Medium	Medium	PCS protections, transformer protection, EMS coordination	Low
Gas accumulation	TR off-gassing, ventilation failure	Explosion/deflagration, personnel exposure	Low	High	Medium	Gas/smoke detection, ventilation, IP67 modules	Low
Water ingress	Seal failure, storm event, drainage failure	Shorts, corrosion, system shutdown	Very Low	High	Medium	IP67 packs, raised foundation, sensors	Very Low

Hazard	Causes	Consequences	Likelihood	Severity	Initial Risk	Existing Controls	Residual Risk
Cybersecurity breach	Network exposure, poor credential control	Unauthorized control, unsafe operation	Medium	High	High	Firewalls, VLANs, RBAC, encrypted comms, logging	Medium
Human error	Incorrect isolation, mis-switching, training gaps	Arc flash, equipment damage, outages	Medium	High	High	LOTO, training, OEM certification, permits	Medium
Transformer/MV gear failure	Overload, insulation failure, protection failure	MV fault, fire, downtime	Low	High	Medium	MV relays, inspections, thermal scanning	Low
EMS/SCADA malfunction	Software fault, data loss, config error	Incorrect dispatch, power swings	Low	Medium	Medium	Redundant comms, validation, change controls	Low
Seismic event	Ground movement, vibration	Mechanical damage to racks/cabling	Very Low	High	Medium	Anchored foundations, seismic-rated racking	Very Low

Table 6 Risk Ranking & Mitigation

4 System Safety Features

4.1 Battery Management System (BMS)

The SolBank's battery packs are wired as 12 strings of 4 packs, as shown in Figure 3. Each string is controlled and monitored by a dedicated Battery Management System (BMS). The BMS constantly monitors cell and pack level voltage, temperature, State of Charge (SOC), and other parameters to ensure early detection of pre fault conditions, and immediate detection of fault events. Should any parameter exceed a permissible value, the BMS will disconnect the effected string and surface an alarm to the site EMS.

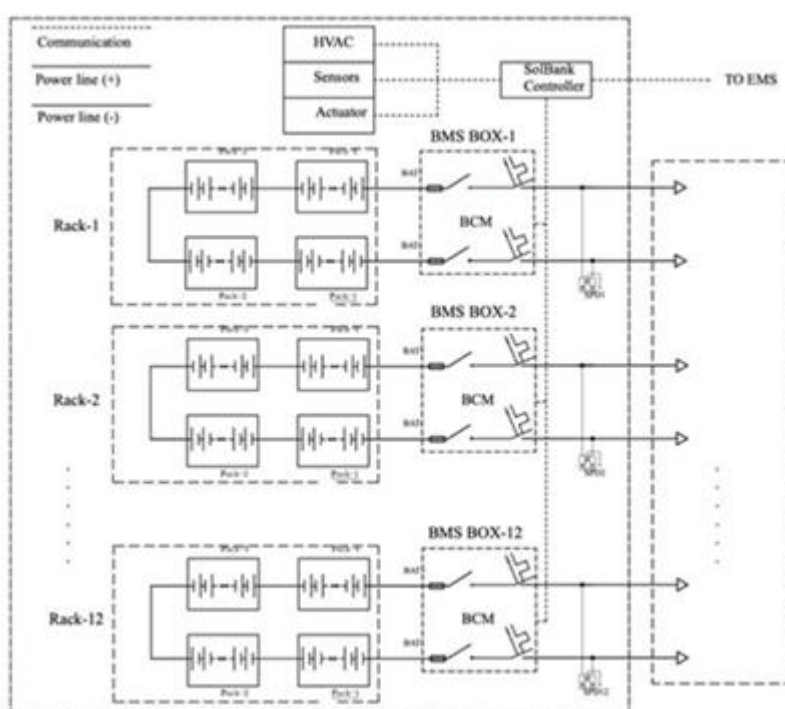


Figure 3 battery pack wiring

4.1.1 Cell and pack monitoring (voltage, current, temperature)

SolBank 3.0 uses a hierarchical, multi-layer BMS architecture to monitor cell, module/rack, and pack/system-level voltage, current, and temperature.

Below is a clear breakdown of how it works and what each layer does.

SolBank 3.0 is built around a triple-layer BMS:

- Cell Monitoring Unit (CMU) – cell-level sensing
 - Rack BMS – module/rack aggregation + safety logic
 - Pack / System BMS – container-level control + PCS/EMS interface
- SolBank 3.0 emphasises faster anomaly detection and active balancing.

Cell-Level Monitoring (CMU)

What is monitored:

- Cell voltage (each individual cell)
- Cell temperature (multiple thermistors per module)

Rack / Module-Level Monitoring

Each rack has a Rack BMS that aggregates data from each module CMU.

What it monitors:

- Rack voltage (total)
- Rack current (via sensor or shunt)
- Rack temperature profile (averages + hotspots)
- Module health (status of each module's CMU)

Pack / Container-Level BMS

This is the master controller for the entire SolBank 3.0 container.

What it monitors:

- Total pack voltage (1,164–1,500 V range)
- Total pack current (charge/discharge)
- Container average/maximum temperatures
- HV contactor status
- DC bus parameters (state for PCS coordination)

Safety actions:

- Rapid shutdown if any rack-level or cell-level violations occur
- Thermal derating or HVAC override
- Fire system integration (shutdown & isolation during alarms)

4.1.2 State of charge (SOC) and state of health (SOH) limits

If the SolBank is used for charging and discharging on a daily basis, the battery will not remain in a state of less than 2% or greater than 99% SOC for an extended period. However, in case the SolBank is not required for a longer duration due to special circumstances, the following SOC recommendations apply:

- For a storage period of up to 1 week: It won't have a significant impact on the battery's life to leave it at 0% or 99% SOC during this time.
- For a storage period exceeding 1 week but not exceeding 6 months: It is recommended adjusting the SOC to around 30% before storing SolBank.
- In the case of anticipated storage without operation for more than 6 months: It is recommended adjusting the SOC to approximately 50%.

During the Storage Condition, the SolBank should be kept within an ambient temperature range of -30°C and 45°C, with further restrictions on a cumulative period of 736 hours during which the temperature exceeds 35°C, and a separate cumulative period of 736 hours during which ambient temperature drops below -20°C

4.1.3 Automated shutdown logic and fault responses

In the event of an emergency on site, the SolBank can be shut down locally, or remotely. A system shutdown will result in electrical isolation of the battery strings and cessation of battery charging or discharging. A system shutdown will not de-energize the battery bank, nor will it guarantee that a fault or thermal runaway event has been stopped. Do not open the SolBank until deemed safe to do so by an individual qualified to direct such decision. Procedures for shutdown of the site and isolation from the grid should be dictated within the ERP.

If safe to approach the SolBank, as agreed upon by all stakeholders and per the project Emergency Response Plan, SOPs, Emergency Incident Commander, or other qualified on-site personnel, the F-stop button located on either end of the SolBank can be pushed. See Figure 4 for the location of the F-stop buttons. This should only be done if remote shutdown is not possible. When the F-stop is pushed, the SolBank BMSs will disconnect all battery strings from the main system bus, thereby stopping all charging and discharging. Simultaneously, the plant PCS will shut down if properly configured to do so.

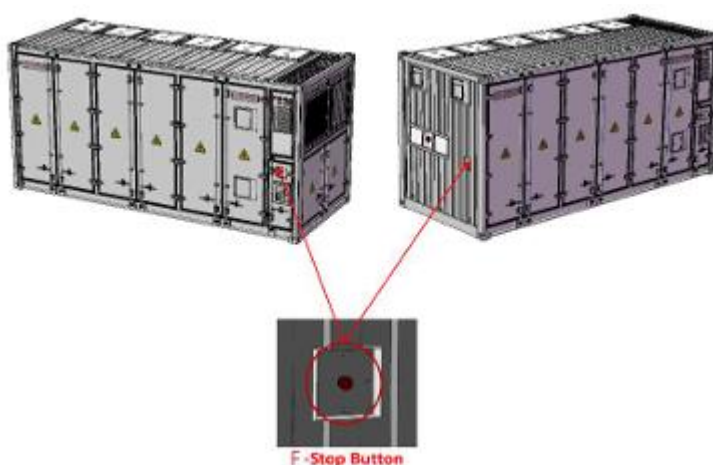


Figure 4 F-Stop Button Locations

Pressing the F-stop while charging and discharging places considerable stress on the system.

Only use the F-Stop to stop the system during an emergency. Before restarting the system, the F-stop must be pulled out to its original position. If indications of a fire within the SolBank exists, such as smoke emanating from the SolBank, or activation of the fire alarm strobe, it is recommended to immediately evacuate the area and maintain a safe perimeter. System shut down should be attempted remotely. Do not open the SolBank access doors.

During normal operation, the SolBank will be under the control of a site Energy Management System (EMS). The EMS in turn will communicate with, and be controlled by, an offsite fleet controller, SCADA operations center, or other third-party dispatch and monitoring entity. SolBank alarms will be forwarded to such remote operations, and in turn, remote operations personnel can shut down the SolBank if determined to be necessary. On-site personnel witnessing an emergency should not however assume automated alarms have reached the EMS or that they have been passed onto remote operations. Such personnel are advised to first call 999, and then contact remote operations directly in addition to other key stakeholders identified in the ERP.

4.2 Fire Detection & Suppression

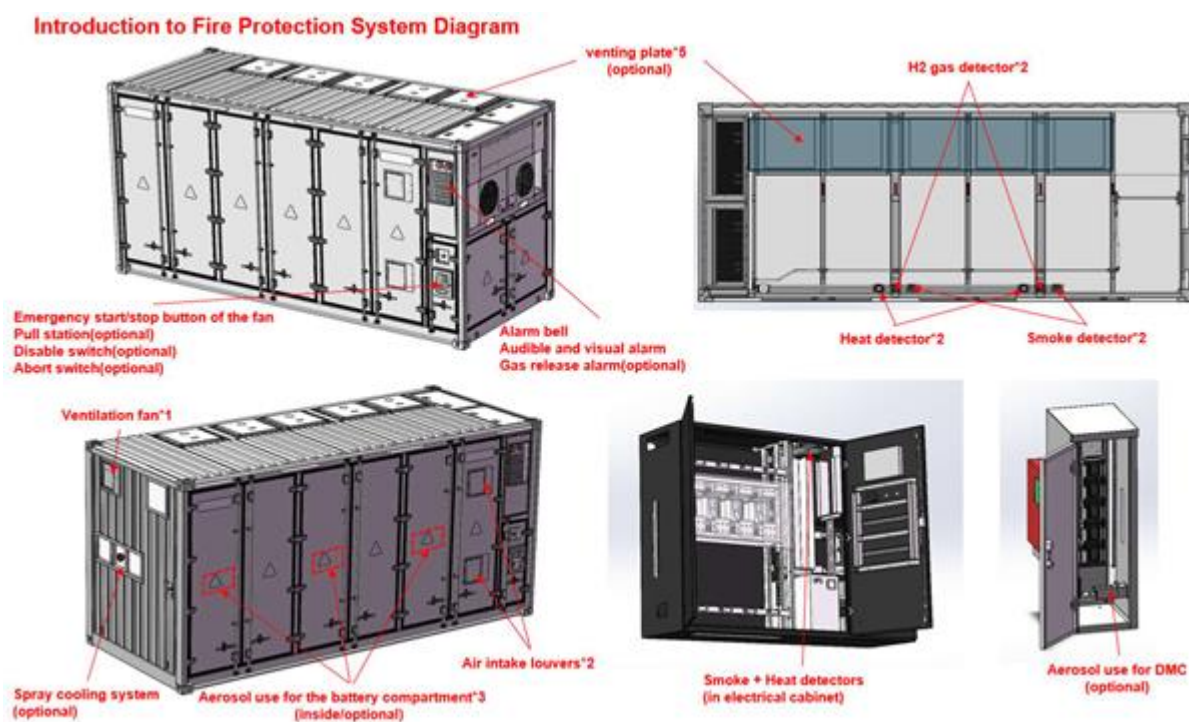


Figure 5 Solbank fire detection & suppression systems

List of fire safety equipment

	Name	Quantity	Remark
1	Fire Alarm Control Panel	1	Standard
2	Smoke detector	3	Standard
3	Heat detector	3	Standard
4	Audible and visual alarm	2	Standard
5	Alarm bell	1	Standard
6	H2 detector	2	Standard
7	Air intake louver	2	Standard
8	Ventilation fan	1	Standard
9	Emergency start/stop button of the fan	1	Standard

Table 7 Fire safety equipment

Alarm responses:

Combustible gas level 1 alarm	Combustible gas level 2 alarm	Smoke detector alarm	Heat detector alarm	Ventilation Fan	Alarm Bell	Horn-Strobe (fire)	Horn-Strobe (gas)	Aerosol Based Fire Suppression	Running status of the energy storage system
x	x	x	x	Close	Close	Close	Close	Close	No fire alarm, the system runs normally
✓	x	x	x	Open	Open	Close	Open	Close	Combustible level 1 alarm, the system does not charge and discharge, auxiliary AC switch and DC contactor are closed
✓	✓	x	x	Open	Open	Close	Open	Close	Combustible level 2 alarm, the system does not charge and discharge, auxiliary AC switch and DC contactor are disconnected
x	x	✓	x	Close	Open	Close	Close	Close	Fire alarm level 1, the system does not charge and discharge, auxiliary AC switch and DC contactor are closed
✓	x	✓	x	Open	Open	Close	Close	Close	Combustible, fire alarm level 1, the system is prohibited to charge and discharge, auxiliary AC switch and DC contactor are closed
✓	✓	✓	x	Open	Open	Close	Open	Close	Combustible alarm level 2, fire alarm level 1, the system is forbidden to charge and discharge, auxiliary AC switch and DC contactor are disconnected
x	x	x	✓	Close	Open	Close	Close	Close	Fire alarm level 1, the system does not charge and discharge, auxiliary AC switch and DC contactor are closed
✓	x	x	✓	Open	Open	Close	Open	Close	Combustible, fire alarm level 1, the system is prohibited to charge and discharge, auxiliary AC switch and DC contactor are disconnected
✓	✓	x	✓	Open	Open	Close	Open	Close	Combustible alarm level 2, fire alarm level 1, the system is forbidden to charge and discharge, auxiliary AC switch and DC contactor are disconnected
x	x	✓	✓	Close	Open	Open	Close	Open	Fire alarm level 2, the system does not charge and discharge, auxiliary AC switch and DC contactor are disconnected
✓	x	✓	✓	Open	Open	Open	Open	Close	lose Combustible level 1, fire level 2 alarm, the system forbids charging and discharging, auxiliary AC switch and DC contactor are disconnected
✓	✓	✓	✓	Open	Open	Open	Open	Close	Combustible level 2, fire level 2 alarm, the system forbids charging and discharging, auxiliary AC switch and DC contactor are disconnected

Table 8 Alarm Responses

4.2.1 Smoke / heat detectors

The SolBank3.0 series incorporates heat and smoke detection. The below alarm sequence will be programmed into the SolBank3.0 series. Refer to Fire Safety System Flow Chart for more information.

- **Level 1 Smoke/Heat Alarm:** If a single detector (heat or smoke) is triggered, the fire alarm control panel will receive the signal and the exterior mounted alarm bell will activate, notifying on-site personnel of a potential fire within the SolBank3.0 series. Simultaneously, the SolBank3.0 series will communicate the alarm condition to the site EMS. Charging and discharging are not allowed.
- **Level 2 Smoke/Heat Alarm:** If both heat and smoke detectors are triggered, the fire alarm control panel will receive the signal and the exterior mounted alarm siren and visible strobe will activate, notifying on-site personnel that both elevated heat and smoke exist within the SolBank3.0 series. Simultaneously, the SolBank3.0 series will communicate the alarm condition to the site EMS. All BMS DC contactors will open and auxiliary power will be disconnected from the SolBank. The SolBank will continue to operate critical loads by UPS backup power.

4.2.2 Gas detection (hydrogen, VOCs)

- **Level 1 Gas Alarm:** If a single gas detector detects > 10% LEL, the fire alarm control panel will receive the signal and the exterior mounted alarm bell and exterior mounted alarm siren and visible strobe will activate, notifying on-site personnel that elevated gas levels exist within the unit. Simultaneously, the SolBank 3.0 will activate the ventilation system to purge the SolBank3.0 series of any gases. The SolBank3.0 series will communicate the alarm condition to the site EMS, and charging and discharging are not allowed.
- **Level 2 Gas Alarm:** In addition to the Level 1 gas alarm actions, all BMS DC contactors will open and auxiliary power will be disconnected from the SolBank. The SolBank will continue to operate critical loads by UPS backup power.

4.2.3 Fire suppression

The Solbank 3.0 has x3 off FP-500S FirePro Fire Extinguishing Generator FP-500S which each have 500g of FPC compound. It also has x1 FP80T FirePro Fire Extinguishing Generator which hold 80g of FPC compound. The positions of these are highlighted in the figures below.

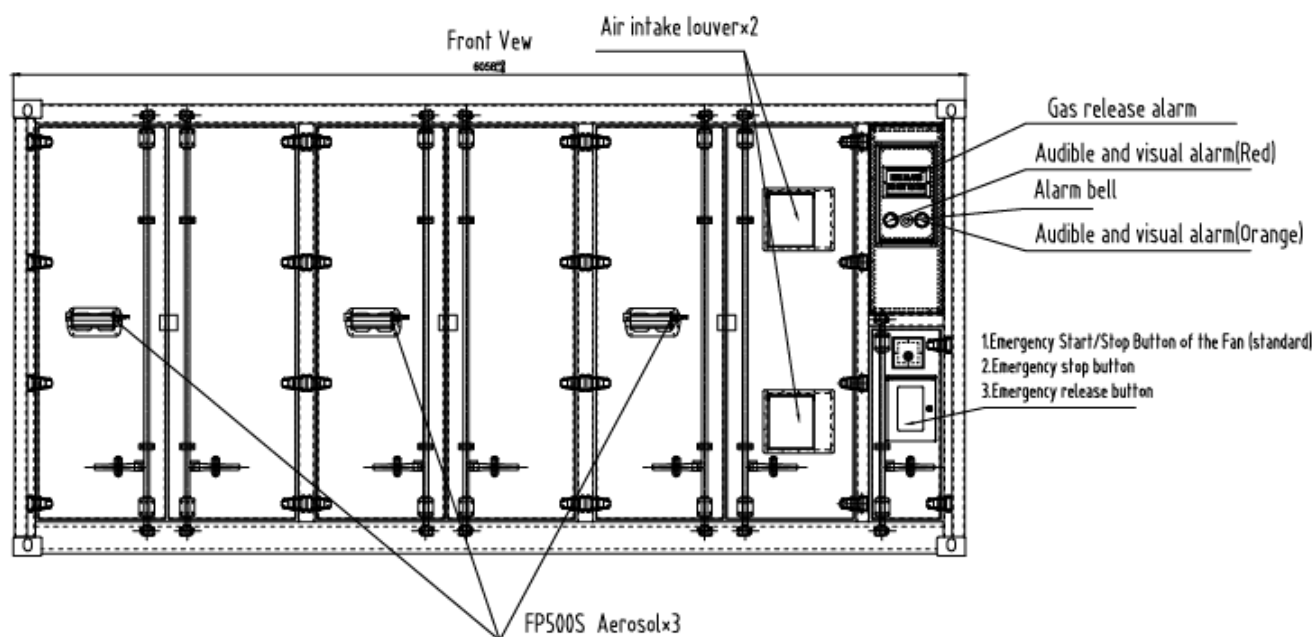


Figure 6 Fire safety positions (front)

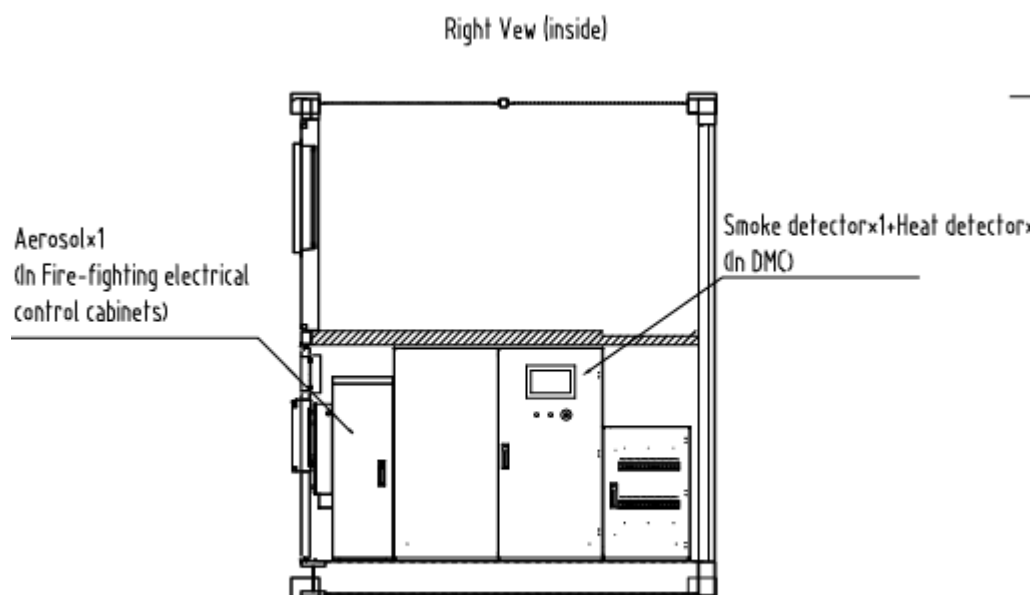


Figure 7 Fire safety positions (side)

4.2.4 Isolation Distances & Separation Barriers

The BESS units are widely spaced despite the results of the LSFT showing much reduced spacings are eminently possible. In an East-West orientation the units are placed in excess of 11m apart and North-South in excess of 12m. Even where the units are set as 'doubles' with LH/RH units they are >3m apart.

These spacings far outweigh standard guidelines in NFPA and NFCC guidance. All BESS units are also >25m away from the nearest occupied buildings, public rights of way and site boundaries.

4.3 Thermal Management System

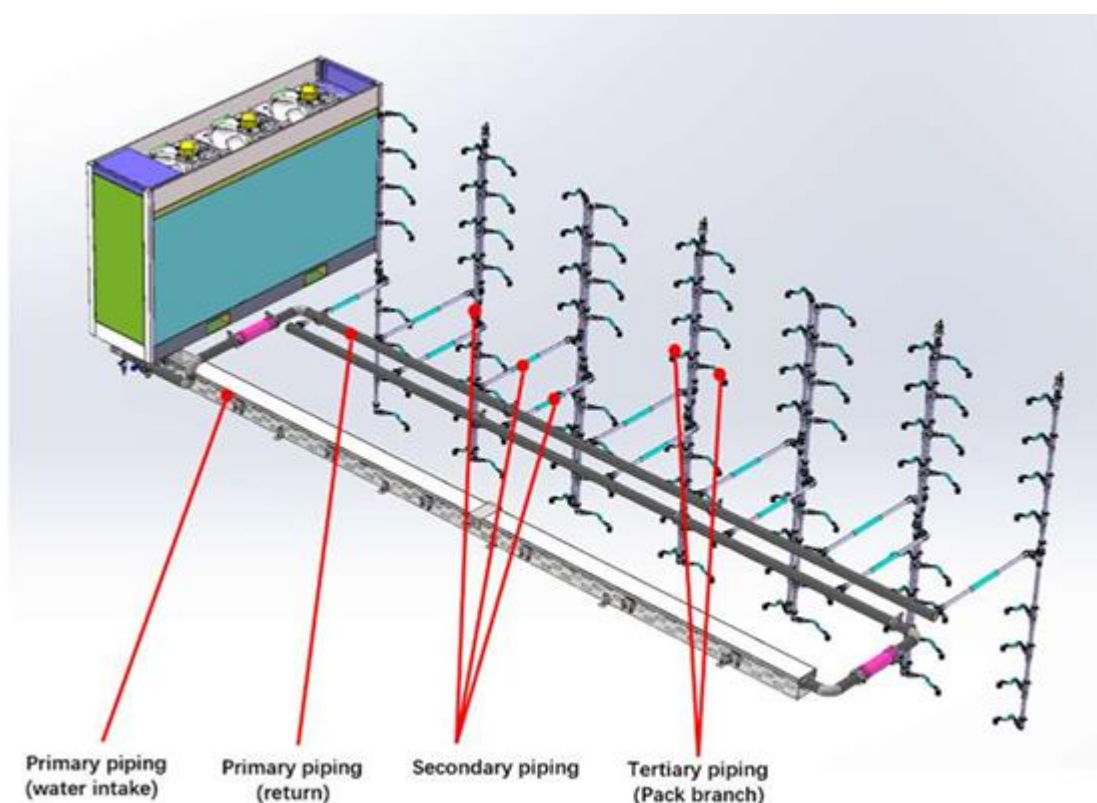


Figure 8 Thermal Management SystemTable

4.3.1 Cooling Methods (HVAC, Liquid Cooling, Forced-Air)

The SolBank's air conditioning system circulates R513a refrigerant to the entire Chiller system. R513a can be combustible under certain circumstances and does pose a health risk when exposed to personnel in sufficient quantity. See the safety data sheet (SDS) contained in Attachment A for further details. Location: R513a circulates throughout the Chiller shown in Figure 9. Compressor and other supporting equipment can be found in the Chiller cabinet.

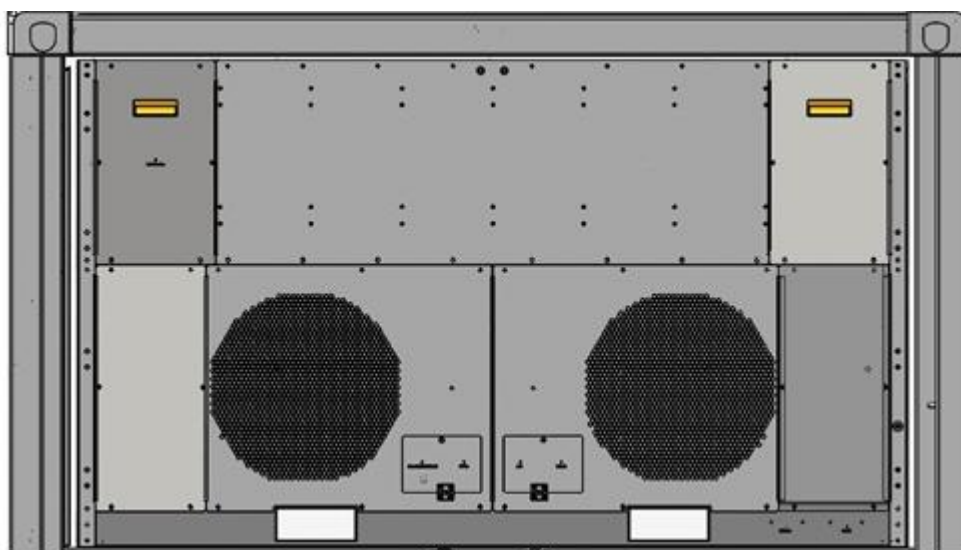


Figure 9 Chiller configuration

4.3.2 Thermal Runaway Propagation Protection

The Solbank 3.0 has a multi-layer approach to preventing, reducing the risk of TR and propagation of the same, via the following protection layers.

Cell / pack level

- Chemistry:
 - 48 × LFP packs, each with 104 cells (so 4,992 cells per container). LFP has a higher thermal runaway onset temperature than typical NMC systems, which inherently helps with runaway risk.
- Pack architecture:
 - 12 strings × 4 packs; each string has its own BMS, which can be isolated independently.
- Liquid cooling:
 - Each pack has liquid cooling/heating, with a chiller and piping, maintaining cell temps roughly 20–35 °C during operation. Tight thermal control reduces the likelihood of local hot spots leading to runaway.

Although the SolBank Safety Manual explicitly states that while cell-to-cell thermal runaway can occur, the pack and system are designed to reduce “cascading thermal runaway” to adjacent cells and modules.

Detection, control & shutdown:

- BMS functions
 - Continuous monitoring of cell & pack voltage, temperature, SOC.
 - If any parameter exceeds limits, the BMS trips that string, isolates it from the DC bus and reports alarms to the EMS.
 - Access interlocks
 - Door position switches: opening the external access door during operation forces an immediate system shutdown and string isolation from the main bus.
 - F-Stop buttons: two emergency stop buttons (one at each end of the container) that force shutdown + isolation of all strings.

- Power & comms resilience
 - A 2-hour UPS backs up the control/monitoring and fire-alarm logic so that detection & alarms continue during outages.

These layers are predominantly about *stopping the fault from growing* (preventing over-charging, over-temp, etc) and reducing the energy available once something goes wrong.

Fire, gas & explosion management

- Detection:
 - - Smoke detector (spot type), calibrated to ~3.5 %/ft obscuration.
 - Heat detector with threshold 85 °C, ceiling-mounted.
 - Combustible gas detector, calibrated for 10–20 % LEL (two alarm levels).
- Fire alarm panel, sounder, horn-strobe.

Actions / sequences of operation:

- On gas or fire alarms, the system:
 - Stops charge & discharge.
 - Opens/closes aux AC and DC contactors according to alarm level.
 - Starts ventilation fan.
 - Activates audible/visual alarms.
 - At “Fire alarm level 2”, the aerosol fire suppression output and horn-strobe are activated (where an aerosol system is installed).

Explosion / gas management:

- Container includes:
 - Deflagration / explosion-relief & ventilation system: off-gassing valves that open on gas alarm to exhaust combustible gases before they reach explosive concentrations.
- Relevant standards:
 - Designed with NFPA 68 (deflagration venting) and 69 (explosion prevention systems) in scope for product design and certification.

Fire suppression:

- Aerosol-based suppression In practice, you can configure SolBank as a “let it burn, but contain it” system (relying primarily on containment, venting and spacing) or add internal aerosol for an active-suppression design.

Enclosure & mechanical aspects

- Enclosure: 20-ft high-cube, IP55 / NEMA 3R container with C4 anticorrosion coating; rated for high-seismic environments.
- Deflagration & venting hardware: The manual describes a combined fire-protection system incorporating deflagration and ventilation, integrated with the gas-detection logic (gas level → open off-gassing valves).

Testing & standards – thermal runaway propagation

Key points:

- UL 9540A:
 - SolBank 3.0 is tested to UL 9540A at cell/module/unit level to evaluate propagation and off-gas behaviour.
- Large-Scale Fire Testing (LSFT):
 - Canadian Solar / e-STORAGE conducted LSFT under CSA C-800-type protocol
 - Four SolBank 3.0 containers, fully charged, were arranged back-to-back with only 150 mm spacing.
 - A single container was intentionally set on fire, with open flame for ~10 hours, and no thermal runaway propagation or combustion in the three adjacent containers; their internal cells remained stable and the trigger container kept structural integrity.

The LSFT results are the main quantitative evidence that SolBank can contain a worst-case fire to one enclosure without relying on suppression.

4.4 Ventilation

The SolBank 3.0 system incorporates a dedicated ventilation and gas-management system designed to prevent the accumulation of flammable gases and to mitigate deflagration hazards arising from abnormal battery conditions, off-gassing, or thermal runaway. The system integrates forced-air ventilation, gas detection, active exhaust capability, and passive over-pressure relief, and is designed in alignment with the principles of NFPA 69 (Explosion Prevention Systems) and NFPA 68 (Deflagration Venting).

Integration with Thermal-Runaway Mitigation

The ventilation system is one component of the SolBank 3.0's thermal-runaway and propagation-mitigation strategy, functioning alongside:

- Cell, pack and string-level monitoring
- BMS-controlled shutdown and isolation
- Container-level fire and heat detection
- Optional internal aerosol/or dry-pipe suppression systems
- Structural containment tested under UL 9540A and large-scale fire testing

During a thermal-runaway event, the ventilation system operates to remove flammable gases, limit explosive atmospheres, and maintain enclosure integrity while preventing hazard transmission to adjacent units.

Passive Venting and Over-Pressure Protection

If power is unavailable or if pressure rises faster than the mechanical exhaust system can relieve, the enclosure incorporates:

- Passive pressure-relief panels / vents, and
- Dedicated off-gassing ports

These components provide a fail-safe path for pressure release and flammable-gas discharge, preventing excessive enclosure over-pressure in accordance with NFPA 68 deflagration venting principles.

4.4.1 Normal and Emergency Ventilation Rates

Under standard operating conditions the BESS utilises forced-air container ventilation in conjunction with the internal liquid-cooling system. The ventilation maintains acceptable environmental conditions for electrical equipment and battery packs, ensuring even air distribution throughout the enclosure.

Gas Detection and Alarm Integration

Each SolBank 3.0 enclosure is equipped with a multi-point combustible gas detection system. The detectors continuously monitor for hydrogen, carbon monoxide and other off-gas indicators. Two alarm thresholds are used:

- Gas Alarm Level 1 ($\approx 25\%$ LFL):
Initiates active exhaust ventilation, opens ventilation louvers, isolates charging, and reports alarms to the site SCADA.
- Gas Alarm Level 2 ($\approx 50\%$ LFL or coincident smoke/heat detection):
Triggers maximum-rate exhaust, isolates DC contactors, and activates fire-response sequences including any internally installed suppression system.

The gas detection and ventilation control panel are backed by a 2-hour UPS, allowing continued operation during loss of site power.

Active Ventilation / Exhaust System

For emergency gas control, each enclosure includes an active exhaust ventilation system sized to rapidly dilute and remove off-gases during an abnormal event.

The system comprises:

- Two exhaust fans rated at 200 CFM each (total 400 CFM)
- Motorised air-intake and exhaust louvers
- CFD-validated extraction capacity designed to maintain internal gas concentrations below 25% of the Lower Flammability Limit during fault conditions

Based on the internal volume of a SolBank 3.0 enclosure, the exhaust system provides the equivalent of approximately 20–25 air changes per hour in emergency ventilation mode.

4.4.2 Explosion Venting or Deflagration Panels (if applicable)

There are no deflagration panels deployed on the SolBank's for this site. However, each SolBank enclosure is equipped with an explosion prevention system designed to exhaust the flammable byproducts of cell off-gassing, if detectable levels were to accumulate within the unit. Two (2) combustible gas detectors are installed at the top of each cabinet interior to detect flammable off-gassing that may be generated during a potential failure condition. The detectors are calibrated to activate upon detection of 10-20% of the lower explosive limit (LEL). Upon activation, the combustible gas detector will send a signal to activate the exhaust ventilation fan and to open the fresh air louvers. The exhaust fan has a rated capacity of 23.5 m³/min (830 CFM). The system is designed to maintain average flammable concentrations below 25% LEL within the enclosure, as per the requirements of NFPA 69 Standard on Explosion Prevention Systems.

4.5 Electrical Protection

This section covers key protections for DC/AC circuits, monitoring/isolation, human-safety interlocks and system redundancy.

Battery Management System (BMS) String-level Protection

- The system uses 12 BMS boxes: one per string (each string = 4 battery packs) in the container
- The BMS monitors at cell and pack level: voltage, temperature, State of Charge (SOC) and other parameters. If any monitored value exceeds permissible limits, the BMS disconnects the affected string from the main DC bus and issues an alarm to the EMS.
- The packs are LFP chemistry (Lithium Iron Phosphate), which provides inherently higher thermal stability compared to some other lithium chemistries.

String / Main DC Bus Isolation

- When the BMS detects a fault, string isolation is executed via contactors/relays so that the faulty string is disconnected from the main bus. (From Safety Manual: "each string ... controlled and monitored by a dedicated BMS ... should any parameter exceed a permissible value, the BMS will disconnect the effected string and surface an alarm.")
- The nominal DC voltage for the system is ~1,331 V, with a range 1,164.8 V to 1,497.6 V.

Access / Human Interlocks & Emergency Shutdown

- External access doors are equipped with door-position sensors: opening an external door during operation results in immediate system shutdown and string isolation.
- F-Stop (emergency stop) buttons located at each end of the container: pressing the F-Stop results in isolation of all strings and shutdown of charging/discharging.
- Remote shutdown capability: the system supports remote EMS/SCADA commands to shut down the battery system when needed.

Auxiliary Power & Control System Redundancy / UPS

- The Distribution & Control Cabinet (DMC) houses auxiliary power distribution equipment, communications, local EMS, network switch etc.
- The system includes an uninterruptible power supply (UPS) for control / monitoring / safety systems so that critical protection functions remain operational even during grid/auxiliary outages. For example, the datasheet lists “Container level UPS for 2-hr control system backup; dedicated fire-safety UPS for 24-hr fire alarm backup.”

Short-Circuit / Over-Current Protection

- The datasheet for SolBank 3.0 (Plus) lists a Max Short Circuit Current $10 \text{ kA} \times 12$ for the system.
- Over-current/over-voltage protection is part of the BMS and main bus protection design (implied in documentation though not always quantified).

Electrical Hazard Compliance & Safety Standards

- The Safety Manual lists relevant standards such as:
- NFPA 70E (Electrical Safety in the Workplace) for arc-flash & electrical safety.
- IEEE 1584-2018 (Guide for Performing Arc-Flash Hazard Calculations) is referenced.
- The system complies with NEC (National Electrical Code), IEEE, UL standards for safety and system design.

Thermal / Pack Temperature Monitoring & Protection

- Liquid cooling systems maintain temperature band (e.g., $20\text{-}35^\circ\text{C}$) for battery packs, reducing risk of over-temperature faults.
- The BMS monitors temperature continuously and will act if the temperature exceeds preset thresholds. (See Section 5.2 of Safety Manual)

4.5.1 Fuses, Breakers, and Insulation Monitoring

The SolBank 3.0 incorporates an internal protection scheme comprising string-level fuses and/or circuit breakers, main DC bus breakers/contactors rated to interrupt a maximum short-circuit current of 10 kA per section ($\times 12$), per manufacturer data. While detailed fuse/trip curves are engineering-documented, it is verified that the BMS monitors each string and initiates isolation upon detection of over-voltage, over-temperature, or other fault condition. An insulation monitoring device (or equivalent) is also anticipated on the high-voltage DC bus, consistent with best practice for high-voltage battery installations, though detailed IMD settings shall be provided by the vendor for commissioning.

PROTECTIVE DEVICE	CIRCUIT DESCRIPTION	VOLTAGE	AMPS
	Supplies aux power system POWER	480Vac (US)	63A
Breakers of Cooling system	Supplies Liquid HVAC system	480Vac (US)	63A
Breakers of SPD	Supplies Surge Protection Device switch	480Vac (US)	32A
Breaker of Fire Safety System	Supplies fire safety system	277Vac (US)	6A
Breaker of Fan in DMC	DMC Fan power supply	277Vac (US)	6A
Breaker of UPS	Supplies UPS input	277Vac (US)	16A
Breakers of BMS boxes	Supplies 1~12#BMS BOX	277Vac (US)	10A
Breaker of 24V AC/DC module	Supplies AC/DC (24VDC)	277Vac (US)	6A
Breaker Fan in Container	Container Fan power supply	277Vac (US)	6A

Table 9 Auxiliary power overcurrent protection devices index

4.5.2 DC Isolation Devices

The SolBank3.0 series' DC Junction box contains all primary DC busbar, fusing, Surge Protection Devices (SPD), and power monitoring required to safely exchange power between the SolBank3.0 series and the Power Conversion System (PCS). All field wiring, to include system ground, primary DC cables, and communication cables enter the base of the DC Junction Box. See the SolBank3.0 Installation Manual for further details.

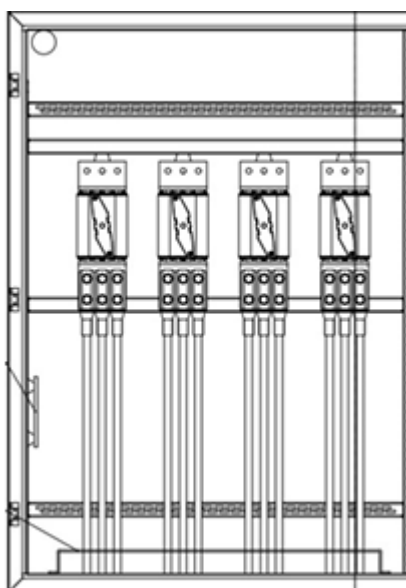


Figure 10 Isolation arrangement

4.5.3 Grounding and Bonding

SolBank3.0 series grounding auxiliary material size needs to be configured according to the box stainless steel grounding bus and fixing bolt size. Step 3: Each SolBank3.0 series is equipped with 4 grounding points, and at least one pair of diagonal grounding points (set 1 or set 2) is required for installation, as shown in Figure 11 below.

The SolBank 3.0 container is required to be connected to the site earthing/grounding system in accordance with NEC 250 / IEC 60364 (or local code). A dedicated earthing conductor shall be installed from the container earth terminal to the main earth-bar of the BESS yard. The earthing conductor shall be copper (size as per site fault-current calculation, minimum 4/0 AWG or equivalent).

All metallic parts of the container enclosure, racks, doors, equipment frames, cable trays and PCS support structure shall be bonded to the earthing conductor to ensure equipotential bonding.

An insulation-monitoring device (IMD) shall monitor the high-voltage DC battery bus for leakage to earth and issue alarms or isolation if threshold values are exceeded.

The earthing system shall be commissioned with an earth-resistance test ($\leq 0.5 \Omega$ or as required by local code) and inspect continuity of bonding paths. Earth-grid/rod installations shall be designed based on site soil resistivity, fault-clearance requirements and BESS safety standards. Documentation of earthing continuity and insulation resistance measurements shall be retained in the BESS commissioning report.

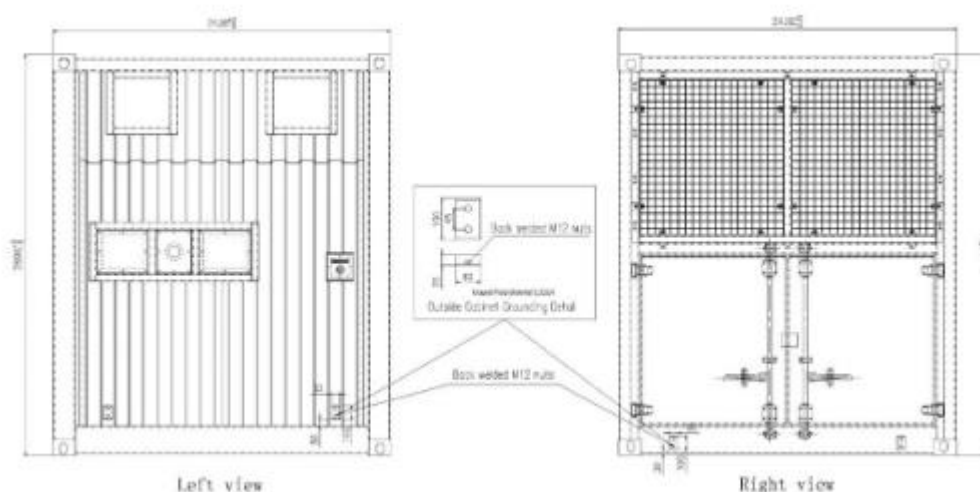


Figure 11 Grounding arrangements

4.6 Safety Interlocks

The SolBank 3.0 Battery Energy Storage System (BESS) incorporates a comprehensive set of hardware and software interlocks to ensure safe operation under normal, abnormal, and emergency conditions. These interlocks form a core part of the system's defence-in-depth approach, preventing human exposure to hazardous voltages, inhibiting unsafe operational states, and supporting rapid isolation during fault or fire conditions.

Overview of Interlock Philosophy

SolBank 3.0 deploys multiple layers of automatic and manual interlocks designed to:

- Prevent unauthorised or unsafe access
- Detect abnormal electrical, thermal or environmental conditions
- Automatically isolate affected battery strings or the entire enclosure
- Control ventilation and flammable gas concentrations
- Support safe shutdown under operator or emergency-services command
- Maintain critical safety functions during auxiliary-power loss

The interlock system is integrated with the Battery Management System (BMS), Energy Management System (EMS), Fire Alarm Control Panel (FACP), and ventilation/explosion-prevention systems.

Safety Interlock Matrix

Interlock / Safety Function	Trigger Condition	System Response / Action	Purpose / Safety Outcome
Door Position Interlock	External access door opened during normal operation	Immediate system shutdown; all strings isolated from DC bus	Prevents personnel exposure to energised HV circuits; ensures safe access
Emergency Stop (F-Stop) Buttons	F-Stop button pressed	Full system shutdown; all battery strings isolated; charging/discharging stopped	Human-initiated emergency shutdown
BMS Over-Voltage Protection	Cell/pack/string voltage exceeds limit	BMS isolates affected string; alarm raised	Prevents electrical overstress and thermal runaway initiation
BMS Under-Voltage Protection	Voltage below permissible minimum	String isolated; alarm raised	Prevents deep discharge damage
BMS Over-Temperature Protection	Cell/pack temperature exceeds threshold	Isolation of affected string; system derating or shutdown	Mitigates thermal runaway risk
BMS Under-Temperature Protection	Temperature below charging threshold	Charging inhibited	Prevents charging in unsafe conditions
BMS String Fault / Imbalance	Abnormal imbalance detected	String isolated; alarm raised	Contains fault to single string
Smoke Detector Interlock	Smoke detection triggered	System shutdown; ventilation activated; alarms triggered	Early fire detection and escalation prevention
Heat Detector Interlock	Heat > 85°C	System shutdown; DC contactors isolation; ventilation activated	Detects hidden fire or hot-spot
Gas Detector Level 1	Gas reaches ~25% LFL	Ventilation fans start; louvers open; charging disabled	Controls flammable atmosphere
Gas Detector Level 2	Gas ~50% LFL or escalated	Max ventilation; DC isolation; shutdown; alarms; suppression if installed	Deflagration prevention
Off-Gas Valve Activation	Gas/pressure buildup	Off-gas valves open	Pressure relief and explosion mitigation
Fire Alarm Panel Output	Fire alarm level 1 or 2	Signals to EMS/SCADA; activates suppression; manages sequences	Coordinates fire-protection actions
Remote Shutdown Interlock	Remote EMS/SCADA shutdown	Full shutdown and isolation	Allows off-site emergency secure
UPS-Backed Safety Logic	Aux power loss	UPS maintains safety systems	Maintains detection and ventilation during outages
Electrical Over-Current Protection	Short-circuit/over-current detected	Breaker/fuse operation; isolation	Protects from short-circuits and arc faults
PCS/BESS Communication Loss	Loss of comms	System enters safe state; charging disabled	Prevents uncontrolled operation

Interlock / Safety Function	Trigger Condition	System Response / Action	Purpose / Safety Outcome
HVAC / Cooling Fault Interlock	Cooling system failure	Derating or shutdown; alarms	Prevents overheating
Maintenance Lock-Out/Tag-Out	LO/TO applied	Prevents re-energisation	Ensures safe maintenance

Table 10 Safety interlock matrix

Interaction with Fire Protection and Ventilation Systems

Several interlocks interact directly with the SolBank's fire-detection, gas-management, and ventilation systems:

- Gas Detector Interlocks (Level 1 and Level 2):
Trigger activation of active ventilation (400 CFM total), opening of intake/exhaust louvers, and possible off-gas valve operation to maintain concentrations below 25% LFL.
- Smoke/Heat Detection Interlocks:
Coordinate with FACP to isolate battery strings, inhibit charging/discharging, and activate alarms.
- Off-Gas Valve and Pressure Relief Systems:
Operate as part of the deflagration-prevention system, ensuring safe venting if internal pressure increases.
- UPS-Backed Safety Logic:
Ensures continued operation of BMS, gas detection, ventilation, fire detection and alarms for a defined period during auxiliary-power loss.

Human Safety Interlocks

Human-machine interface safety is provided by:

- Door position switch preventing access while energised
- E-stop buttons permitting rapid manual isolation
- Remote shutdown capability
- Lock-Out/Tag-Out compliance supported by automatic isolation upon access
- SCADA/EMS logging of interlock events, enabling operators to verify that unsafe states have not been bypassed

These interlocks ensure the enclosure cannot remain energised during maintenance or emergency access.

Role in Fault and Thermal-Runaway Mitigation

The interlock system supports thermal-runaway prevention and containment by:

- Preventing charging during abnormal thermal or environmental conditions
- Isolating faulty strings before faults escalate
- Controlling gas concentrations
- Triggering enclosure shutdown and isolation automatically
- Coordinating with internal suppression (if installed) and passive deflagration vents
- Maintaining detection and ventilation even during power loss

Together, these features support the SolBank's demonstrated performance in UL 9540A testing and large-scale fire testing (LSFT), where thermal-runaway propagation was contained within a single enclosure.

4.6.1 Door Access Switches

The external access door on the SolBank has integrated position sensors. When the external access door is opened during system operation, the SolBank will immediately shut down and all BMS will isolate their battery strings from the main system bus.



Figure 12 Solbank Doors

4.6.2 Emergency Stop (F-stop) Buttons

Each SolBank contains two F-Stop buttons on each end of the enclosure. When pushed, the SolBank will immediately commence shut down, and all BMS will isolate their battery strings from the main system bus. See Figure 4 for additional details.

4.6.3 Lock-out/tag-out (LOTO) Provisions

Lock-out-tag-out (LOTO) procedures should be implemented to prevent accidental energization of equipment.

For the SolBank 3.0 container and associated equipment, a Lock-Out/Tag-Out (LOTO) procedure shall be followed for any maintenance, inspection or servicing activity. All energy sources must be identified, isolated, locked out and tagged. Each authorised person shall apply a unique lock and tag. Isolation verification shall be performed (voltage test, attempt to start) prior to permitted work. At completion, restoration to service must follow documented start-up protocols. The system remains energised internally even after normal shutdown, hence full LOTO and verification are mandatory. A LOTO log shall be retained and annual auditing undertaken.

5.0 Monitoring, Alarming & Control

5.1 SCADA integration

The SolBank 3.0 is equipped with Ethernet communication via Modbus TCP/IP and is designed to interface with the site Energy Management System (EMS) and broader SCADA operations centre. The EMS receives system alarms and status, transmits remote control commands (including system shutdown), and supports fleet-level monitoring. The system supports remote shutdown of the battery strings from the SCADA/EMS as described in the manufacturer's Safety Manual.

5.2 Alert thresholds and alarm hierarchy (Warning, Critical, Emergency)

The Solbank uses a "Level 1 / Level 2" scheme rather than explicitly "Warning / Critical / Emergency," so the following is interpreting them in those terms below.

Alarm levels and thresholds:

- The system is equipped with combustible-gas detection calibrated to 10%–20% LEL (Lower Explosive Limit).
- Heat detector threshold: 85 °C.
- Smoke detector sensitivity: 3.5%/ft for the spot-type detector.
- BMS monitors cell pack voltage, temperature, SOC etc, and raises alarms when parameters exceed "permissible values."
- Example BMS limits (from a SolBank fire/safety overview):
 - Charge limit for the cell spec: 3.65 V; SolBank charge-limit alarm starts at ~3.55 V; no charging allowed above ~3.6 V.
 - Discharge limit: cell spec 2.5 V; alarm starts ~2.9 V; no discharge allowed below ~2.8 V.

Alarm hierarchy / Sequence of operations:

- The system uses two main levels of fire/gas alarm: **Level 1** and **Level 2**.
- Table 3 in the manual summarises logic of actions depending on combinations of combustible-gas level1/level2, fire alarm level1/level2, smoke/heat detectors. For example:
 - Combustible gas level 1 alarm → system prohibits charge/discharge; ventilation fan opens; system remains connected (contactor closed) but operation stops.
 - Combustible gas level 2 alarm → system *disconnects* (auxiliary AC switch and DC contactor disconnected).
 - Fire alarm level 1 (smoke or heat) → system stops charge/discharge; auxiliary AC switch remains closed; DC contactor may remain closed.
 - Fire alarm level 2 → system does not charge/discharge; auxiliary AC switch and DC contactor are disconnected.
 - "Level 1" corresponds to a "fault will be stopped" state: e.g., level 1 fire alarm, level 1 gas alarm, overtemperature, high/low SOC.
- "Level 2" corresponds to a more severe condition: "unit will be disconnected" (level 2 fire/gas, severe high/low voltage or SOC).
- The hierarchy is: Warning / Fault → Level 1 Stop → Level 2 Disconnection → Emergency

Response (evacuation, etc).

- The "warning" or "information" stage is mentioned: BMS detects abnormal battery in early stage → reports status to trigger warning or alarm.

Mapping to “Warning / Critical / Emergency” terms

Based on the above, you can interpret the alarm hierarchy as:

- **Warning / Pre-fault:** Early abnormal parameter detection (cell voltage drifting, temperature rising, SOC out of nominal range) → system flags a warning/information status.
- **Critical (Level 1):** For example, gas level at 10% LEL threshold, smoke/heat detector triggered, charge/discharge stopped but system still connected.
- **Emergency (Level 2):** For example, gas level at ~20% LEL threshold, fire alarm level 2, system disconnected (aux AC & DC contactor opened), evacuation response.

5.3 Remote Monitoring Procedures

The typical ESS network design is built upon a hierarchical control and communication structure. System dispatch commands are often sent to a site EMS controller from remotely located ESS fleet controllers, cloud-based EMS interfaces, or Automatic Generation Control (AGC) dispatchers. These commands get passed down to the PCS and BMS via the SolBank3.0 series. Conversely, system status and alarms are communicated back to the EMS and remote operations personnel from the SolBank3.0 series and other devices. See Figure 9 for an example network block diagram.

The SolBank3.0 series communicates with other equipment within the ESS via multiple communication protocols. Chief among them are Modbus TCP, Modbus RTU, and CANbus. Please reference the Auxiliary Distribution and Communication Schematic provided by E-Storage for further details.

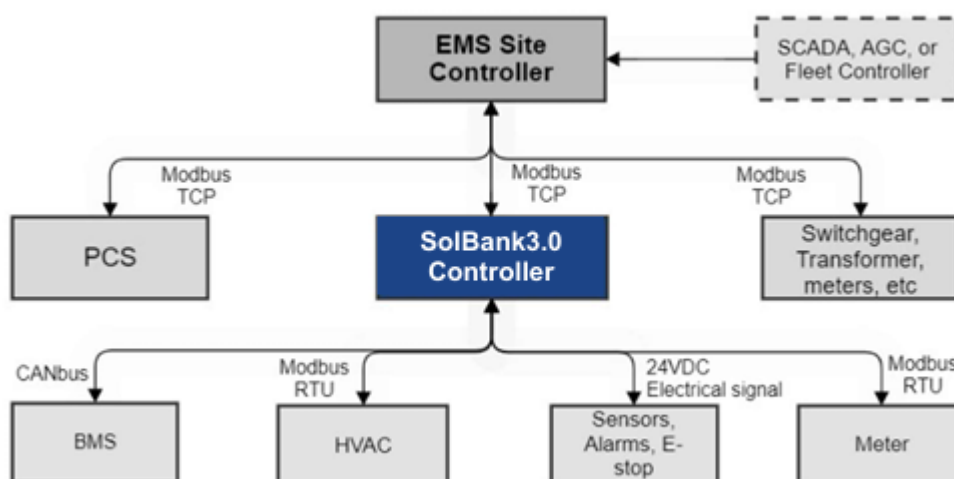


Figure 13 Solbank Controller

5.4 Cybersecurity Requirements (NIST 800-53/82 where applicable)

As one might expect E-Storage do not provide great detail of their cybersecurity model except to state it is aligned with industry standards, including ISO 27001 and NIST 800-53.

Cybersecurity will form a fundamental part of the system design and architecture as there is an increasing focus in this area from national and international regulatory bodies. International standards such as IEC 62443, UL 1741, IEEE 1815, and IEEE 1547.3 will be consulted and guidance from national sources such as National Cybersecurity Centre inform the implementation and protection measures. Reference should be made to the Health and Safety Executive (HSE) Operational Guidance document OG86.

UL published 'UL 2941 (2023) Outline of Investigation for Cybersecurity of Distributed Energy and Inverter-Based Resources'. UL 2941 provides testable requirements for photovoltaic inverters, electric vehicle chargers, wind turbines, fuel cells and other resources essential to advancing grid operations. These new requirements prioritise cybersecurity enhancements for power systems that deal with high penetration inverter-based resources, including those interfacing with bulk power systems for periods of instantaneous high wind, solar and hybrid/storage generation. UL 2941 promotes the necessity to have cybersecurity designed into new inverter-based resources (IBR) and distributed energy resource (DER) systems, and the BESS system supplier at the detailed design stage will conform to these requirements.

6.0 Operations & Maintenance Procedures

6.1 Normal Operation

The SolBank3.0 series can be placed into the operational modes indicated in Table 12. Further indicated below is the status of key system components and switching devices when in a given mode, in addition to a brief summary of each mode of operation.

MODE	MAIN DC DISCONNECT STATUS	BMS CONTACTOR STATUS	LOCAL/ REMOTE KEYED SWITCH	ON/OFF KEYED SWITCH	ENABLED LOCALLY OR REMOTELY
Operation Mode	Closed	Closed	Remote	On	Remotely
Idle Mode	Closed	Open	Remote	On	Remotely
Eco Mode	Closed	Open	Remote/Local	On/Off	Remotely
Failure Mode	Closed	Open	Remote	On	Automatic
Debug Mode	Open/Closed	Open/Closed	Local	Off	Locally

Table 11 Operational modes

When in Operation Mode, the SolBank3.0 series can charge and discharge energy from its battery bank in response to commands from the site EMS. To transition into Operating Mode, a "Run" command must be received from the site EMS to do so. Each BMS will in-turn close their internal DC contactors and energize the SolBank3.0 series' main DC bus. To enter Operation Mode, 1 or more BMS must successfully respond the "Run" command. When Operation Mode is exited (i.e. "Stop" command is sent), all BMS contactors will open and the main DC bus will de-energize.

Idle Mode

When in Idle Mode, the system is in a state ready to receive a "run" command from the EMS. All manually operated disconnects are closed, and the BMS DC contactors are open. The main DC bus will not be energized. The SolBank3.0 series will enter Idle Mode when a "Stop" command

is issued by the BMS or after resolution of a system fault (i.e. Failure Mode is exited).

Eco Mode

When the SolBank3.0 series is placed in Eco Mode, a load shedding scheme is automatically implemented by the SolBank3.0 series' EMCU, shutting down specific auxiliary loads to conserve energy. Specifically, disconnecting the BMS box power and system fans power. Communication and control systems, Detectors and alarms, and HVAC systems will remain operational. Eco Mode can be enabled remotely by the EMS only when the SolBank3.0 series is in Idle Mode. Additionally, when the external auxiliary power supply is lost, the SolBank3.0 series will also enter Eco Mode. However, in this event, HVAC systems will power off, and all critical loads will be supported by the UPS. Note, when in Eco mode, relay will momentarily close once per 24-hour period to obtain BMS system status data (cell temperature, voltage, etc). Upon completion of data upload, relay will reopen.

Failure Mode

The SolBank3.0 series will automatically enter Failure Mode when all 12 of the string BMS fail to respond to a "Run" command from the site EMS. In this state, the BMS DC contactors will remain open. If 1 or more string BMS returns to operational readiness, the system will automatically transition to Idle Mode.

Debug Mode

Debug Mode is enabled locally when a need arises to modify BMS software parameters or investigate system faults. Debug Mode should only be enabled by qualified E-STORAGE technicians. When the Debug Mode is enabled, remote operation of the SolBank3.0 series is prevented.

6.1.1 Startup/Shutdown Procedures

Prior to initiating SolBank3.0 series operation, please ensure the following items are addressed. Note, the below pre-operation checklist may not represent a complete list of all items requiring inspection or completion prior to operating the SolBank3.0 series or the ESS within which it is installed. The following is provided for general advisement only.

Safety Checklist

- All on-site personnel have proper PPE as dictated by the project specific EHS plan, and safety codes and regulations
- Task specific safety training and orientation has been completed as required
- All personnel are properly trained and qualified to operate the SolBank3.0 series
- The site is clean, orderly and all hazards have been mitigated to the extent possible and required by law
- All enclosures containing electrical or chemical hazards are secured to prevent access during operation
- The site is secured to prevent access by unqualified personnel
- All safety placards and arc flash labels are installed and clearly visible

Operational Readiness Checklist

- The SolBank3.0 series has been fully commissioned and deemed ready for service by E STORAGE personnel
- All required routine SolBank3.0 series maintenance and inspections have been performed per the SolBank3.0 Maintenance Manual
- All other ESS BOP equipment required for safe and reliable operation of the SolBank3.0 series has been fully commissioned and deemed ready for service by appropriately qualified commissioning personnel and AHJ.
- All required ESS BOP routine maintenance and inspections have been performed per OEM recommendations and requirements.
- Remote operations personnel have been notified of pending operation as required

Functional Checklist

- Site auxiliary power is energised, and all ESS BOP equipment aux power systems are on and ready for service
- Site communications are active and site ESS EMS HMI (local and remote) are free of system alarms. Note: this may be an iterative check, performed as system components are powered up.
- All manually operated up-stream switching devices, external to the SolBank3.0 series are closed as required. Utility side of PCS AC disconnect should be energised. Remotely operated AC switching devices which are part of startup sequence may remain open if necessary

Initial System Startup

The following steps describe the initial startup sequence of the SolBank3.0 series. Typically, this process should be used as part of or after i) initial system commissioning, ii) maintenance activities requiring full system shutdown and component isolation, or iii) periods of extended system storage.

- Step 1: Ensure completion of the Pre-Operation Checklists contained in Section 7.
- Step 2: Power on the circuit breaker of BMS boxes 1-12.
- Step 3: Power on the circuit breakers of SPD. Before powering up, measure the voltage value at the input separately with a multimeter.
- Step 4: Power on the circuit breaker of chiller and close the AC relay. The thermal management system will turn on automatically. At the same time, pay attention to the coolant level and whether the chiller is operating normally.
- Step 5: Power on the circuit breaker of Transformer
- Step 6: Power on the circuit breaker of Fire Safety System.
- Step 7: Power on the circuit breaker of Fan in DMC.
- Step 8: Power on the circuit breaker of UPS.
- Step 9: Power on the circuit breaker of BMS boxes in DMC.
- Step 10: Power on the circuit breaker of 24V AC/DC module.
- Step 11: Power on the control supply switch.
- Step 12: Power on the circuit breaker Fan in Container

Emergency System Shutdown

In the event of an emergency on-site, the SolBank3.0 series can be shut down locally or remotely. A system shutdown will result in electrical isolation of the battery strings and cessation of battery charging or discharging. A system shutdown will not de-energize the battery bank, nor will it guarantee that a fault or thermal runaway event has been stopped. Do not approach or open the SolBank3.0 series until deemed safe to do so by an individual qualified to direct such decision. Procedures for the safe shutdown of the site and isolation from the grid should be dictated within the project-specific ERP.

Local emergency shutdown

If safe to approach the SolBank3.0 series, as defined by the project Emergency Response Plan, SOPs, Emergency Incident Commander, or other qualified on-site personnel, the F-stop button located on the either end of the SolBank3.0 series can be pushed. When the F-stop is pushed, the SolBank3.0 series BMSs will disconnect all battery strings from the main system bus, thereby stopping all charging and discharging. Simultaneously, the plant PCS will shut down if properly configured to do so. When multiple SolBank3.0 series exist on a single site, their F-stop circuits can be interconnected, resulting in total system shutdown when a single F-stop button is triggered.

Pressing the F-stop while charging and discharging places considerable stress on the system and ideally should be executed during no-load conditions. Only use the F-stop to stop the system during an emergency. Before restarting the system, the F-stop must be pulled out to its original position.

If indications of a fire within the SolBank3.0 series exists, such as smoke emanating from the SolBank3.0 series, or activation of the fire alarm strobe, it is recommended to immediately evacuate the area and maintain a safe perimeter. System shut down should be attempted remotely as described in the section below. Do not open the SolBank3.0 series access doors. See the SolBank3.0 Safety Manual for further details.

Remote Emergency Shutdown

During normal operation, the SolBank3.0 series will be under the control of a site Energy Management System (EMS) or Local Plant Controller (LPC). The EMS or LPC in turn will communicate with, and be controlled by, an offsite fleet controller, SCADA operations center, or other third-party dispatch and monitoring entity. SolBank3.0 series alarms will be forwarded to such remote operations, and in turn, remote operations personnel can attempt to shut down the SolBank3.0 series (and/or the PCS connected to it) by sending a "Stop" command if determined to be necessary.

On-site personnel witnessing an emergency should not assume automated alarms have reached the LPC or EMS or that they have been passed onto remote operations. Such personnel are advised to first call 911, and then contact remote operations directly in addition to other key stakeholders identified in the ERP.

Partial System Shutdown

The following sequence describes the steps required to transition the SolBank3.0 series from normal operation to a state of safe isolation from the primary interconnection circuit. At the conclusion of this process, the auxiliary power system will remain energized in support of SolBank3.0 series thermal management, safety, and communication systems. This process should typically be used when there exists a need to perform maintenance or inspections on the PCS or upstream devices.

- Step 1: Suspend operation of the SolBank3.0 series by sending a “Stop” command through site EMS and confirm (through local or remote HMI) the PCS has opened automatic AC and DC disconnects through remote or local HMI.
- Step 2: Prevent subsequent startup of the SolBank3.0 series by turning the keyed switch on the external side of the SolBank3.0 series to “Off.”
- Step 3: Open the access door to the User Interface Cabinet.
- Step 4: Verify absence of voltage on the main DC bus as indicated by the SolBank3.0 series Power Meter.
- Step 5: Prevent remote control of the SolBank3.0 series by turning the keyed switch on the Distribution and Control Cabinet to “local.”
- Step 6: Open the SolBank3.0 series’ main DC disconnect, thereby isolating the SolBank3.0 series’ DC bus from the PCS and upstream devices.
- Step 7: Perform LOTO as necessary.
- Step 8: Close and secure access door to User Interface Cabinet.

Full System Shutdown

The following sequence describes the steps required to transition the SolBank3.0 series from normal operation to a state of complete system shutdown. At the conclusion of this process, all primary SolBank3.0 series components will be deenergized to the extent possible through normal user interfaces. This process should typically be used when there exists a need to perform comprehensive maintenance on the SolBank3.0 series.

- Step 1: Suspend operation of the SolBank3.0 series by sending a “Stop” command through site EMS and confirm (through local or remote HMI) the PCS has opened automatic AC and DC disconnects.
- Step 2: Prevent subsequent startup of the SolBank3.0 series by turning the keyed switch on the external side of the SolBank3.0 series to “System Stop.”
- Step 3: Open the access door to the User Interface Cabinet.
- Step 4: Prevent remote control of the SolBank3.0 series by turning the keyed switch on the Distribution and Control Cabinet to “local.”
- Step 5: Open the SolBank3.0 series’ main DC disconnect, thereby isolating the SolBank3.0 series’ DC bus from the PCS and upstream devices.
- Step 6: Disconnect each battery string from the main SolBank3.0 series DC bus by manually opening the 12 DC disconnects located on the front of each BMS. Note, DC contactors will be open at this stage.
- Step 7: Turn off all 12 BMS via the power switch located in the upper left of each device.
- Step 8: Open all auxiliary breakers, disconnecting all grid supplied auxiliary power from the SolBank3.0 series.
- Step 9: Turn off the SolBank3.0 series’ Uninterruptable Power Supply (UPS). Caution, communication and fire safety equipment will power down. UPS should not be turned off

unless necessary to do so for maintenance purposes.

- Step 10: Perform LOTO as required.
- Step 11: Close and secure User Interface Cabinet access door. Note that the battery pack cannot be powered off. However, the battery pack voltage can be reduced by isolating the battery cells by unplugging the battery pack power connector. See the SolBank3.0 Maintenance Manual for details.

6.2 Maintenance

6.2.1 Preventive maintenance schedules

Component Category	Service Descriptions	Frequency
Battery	Set battery maintenance (system check, cell balancing)	Annual
	Battery cable, appearance, grounding, dust removal	Annual
	Inspect battery management system alarms	Annual
	Visual inspection of all electrical terminations using thermal imager	Semi-annual
DMC/Junction Box/ Auxiliary System/ Miscellaneous	Auxiliary equipment maintenance and inspection	Annual
	Enclosure dust removal	Annual
	Inspect cable entry, grounding, sealing, dust removal	Annual
	Critical sensor calibration check	Annual
	Maintenance report	Annual
Fire Safety System	Fire alarm and detection system inspection	Semi-annual
	Fire alarm and detection system maintenance	Semi-annual
	Fire suppression System Inspection	Semi-annual
Thermal Management System	Thermal management system inspection	Semi-annual
	Thermal management system maintenance	Semi-annual
	Clean Filters by rinsing with Water	Semi-annual
	Electric Heater - Dust accumulation on the coil, signs of overheating on the heater frame, traces of water or rust on the electric heater control box.	Semi-annual
	Coolant tester Visual inspection	Semi-annual
General	System configuration check	Annual

Table 12 Maintenance schedules

Corrective Maintenance

Under an executed long term service agreement, Canadian Solar shall provide corrective maintenance as listed below.

Reporting and Diagnostics	Inspection, maintenance reports and recommendations	Monthly
	Technical support and fault diagnosis	As required
	Data server connectivity check	Monthly
	Inspect battery running status, provide operating recommendations and maintain battery	Monthly

6.2.2 Battery Inspections (cells, modules, racks)

Battery Cabinet Maintenance

Battery Rack Visual Check (power-off)

- Check whether battery rack is distorted or bent
- Check whether the welding of battery rack is damaged or loose
- Check whether the mounted bolts on the battery rack is loose or missing

BMS Control Box Visual Check (power-off)

- Check the BMS control box for visual defects such as dirt, distortion, damages and scratches on the enclosure
- If visual defects are present, repair these immediately
- Check whether DC switchgear handle and rocker switch is damaged; If it is damaged, replace it with spare parts immediately.

Battery Pack Visual Check (power-off)

- Check whether battery pack is mounted tightly
- Check whether battery pack is swelling
- Check whether there is obvious crystallization or electrolyte on the surface of battery pack shell
- Check whether there is obvious aromatic flavor from the battery pack
- Check whether battery jumper cable or copper-bar is damaged or burnt
- Check whether the torque stamp of battery jumper copper-bar mounting is loose

Battery Cabinet Cleaning (power-off)

Clean the dust on the surface of battery rack and module with a soft brush and vacuum.

6.2.3 Electrical and Mechanical Checks

DMC Maintenance

DMC Visual Check (power-off)

- If visual defects are present, repair these immediately.
- Check whether the door can open and close fluently; If not, lubricate all moving parts of the latch.
- Check whether box sealing joint strip is broken or damaged;
- Check whether the components inside the box are mounted tightly, no damaged or burned

Auxiliary Power Connection Check (power-off)

Check the auxiliary power connection in DMC for visual torque confirmation. Make sure all the bolts and nuts are marked with obvious torque stamp. If not, referring to the Annex 2 for the prescribed requirement, test and tighten the bolts or nuts with torque wrench and mark it.

Wiring Connection Check (power-off)

Check whether there is any wiring connection of terminal, power supply, relay and controller inside the cabinet loose, broken or damaged. If there is, tighten or replace the wiring with screwdriver.

DMC Cleaning (power-off)

Open the box and clean the dust on the surface of the components with a soft brush and vacuum.

DMC Components Tests (power-on)

Power Supply Test (power-on) Use multi-meter to test the DC output voltage of power supply in power control box. Check whether DC voltage is in the proper range. (For 24V power supply, the standard is $24 \pm 0.2V$; for 12V power supply, the standard is $12 \pm 0.2V$).

If the DC voltage is not in the proper range, adjust the voltage switch on the power supply.

UPS Battery Capacity Test (power-on)

Refer to the auxiliary power distribution drawing, open the MCB breaker to cut off the power input of UPS and record the time. UPS will go into the battery load support state. Record the time when UPS is shut down. The difference will be the load support time.

SolBank controller Tests (power-on)

SOC calibration (power-on) The battery system needs a full charge and discharge at least once every three months to calibrate the SOC.

BMS measurement check (power-on)

Use the SolBank Controller's display interface to check the status of the battery system, fault conditions, etc., to check whether there is a system failure or a failure of the controller itself and make a record.

Insulation resistance check (power-on) Disconnect all BMS BOX disconnect switches to ensure that the system racks cannot be connected in parallel and then check the insulation detection of each rack via the SolBank Controller's display interface.

Junction Box Maintenance

9.3.1 Junction Box Visual Check (power-off) λ Check the junction box for visual defects such as dirt, distortion, damages and scratches on the enclosure; λ If visual defects are present, repair these immediately. λ Check whether the door can open and close fluently; If not, lubricate all moving parts of the latch. λ Check whether cabinet sealing joint strip is broken or damaged; λ Check whether the components inside the box are mounted tightly, no damaged;

9.3.2 Junction Box Main Power Circuit Torque Checking (power-off) Check the junction box main power circuit for visual torque confirmation. Make sure all the bolts and nuts are marked with obvious torque stamp. If not, referring to the Annex 2 for the prescribed requirement, test and tighten the bolts or nuts with torque wrench and mark it.

Junction Box Cleaning (power-off)

Open the junction box and clean the dust on the surface of the components with a soft brush and vacuum.

Fire Safety System Maintenance

Note: For any function test, please contact the local fire contractor.

Fire Detection Components Check

- Check whether the temp and smoke detection sensors are mounted tightly
- Check whether the temp and smoke detection sensors are blocked or dirty
- Check whether the indicator of temp and smoke detection sensor is blinking periodically while powered on

Fire Safety System Cleaning (power-off)

Clean the dust on the detection sensor with a soft brush and vacuum.

Gas detector Check

- Check the shielding and external damage of combustible gas detectors
- Connect the combustible gas detector to check whether it has reached the calibration date and whether the equipment has faults
- Spray combustible gas for actual linkage test to check whether it can linkage inlet and exhaust system
- Equipment should be unpacked, installed, operated, maintained and otherwise used by qualified, trained and authorised technicians. Electrical installation and commissioning by authorised professionals

Fire suppression System Inspection (If selected)

A periodic inspection of the aerosol fire extinguishers and fire extinguishing systems to check the following parts:

- electrical wiring
- electrical circuit
- thermal actuator port
- terminals of the electrical activator
- electrical contacts
- fixing bolts

Auxiliary System Maintenance

Safety Label Check (power-off)

- Check whether safety labels on enclosure is damaged, fallen or aging
- Check whether nameplate is loose or fallen

Enclosure Check (power-off)

- Check whether there is any flammable object or anything that could endanger operational safety inside or around the enclosure
- Check whether enclosure is rusting or deformed and whether painting is fallen
- Check whether enclosure door can be opened and closed easily
- Check whether the sealing joint strip of enclosure is fallen or aging

Grounding Check (power-off)

- Check whether grounding cables on both sides of enclosure is loose or damaged
- Check whether the grounding copper bars on both sides of enclosure is rusted or oxidised

Enclosure Sealing Check (power-off)

- Check whether the sealing of DC power cable interface is intact
- Check whether the sealing of Auxiliary power cable interface (power control box) is intact
- Check whether the sealing of communication cable interface is intact
- Check whether there is any sign of water leak or dripping

Thermal Management System Maintenance Note: For Thermal Management System maintenance, please contact the local Thermal Management System contractor. Below is a brief summary and description of Thermal Management System maintenance. For details, please refer to < Thermal Management System User Manual>.

6.2.4 Firmware updates and calibration

There is no publicly available information regarding this. E-Storage are being contacted to provide information.

6.3 Fault Response Procedures

6.3.1 Over-temperature events

The SolBank 3.0 uses a layered fault-response strategy for over-temperature events. The sequence is designed to reduce thermal stress, prevent cell damage, and avoid escalation to thermal runaway.

Early-Stage Over-Temperature (Warning Level)

Trigger:

- Battery cell, pack, or string temperature rises above the normal operating threshold but below the critical limit.

Automatic System Actions:

- System derates power output (reduces charging/discharging).
- Liquid-cooling system increases flow and cooling effort.
- Alarms are sent to the EMS/SCADA as a “Warning” or “Abnormal Condition.”

Outcome:

Stops heat accumulation early and gives operators time to intervene.

Elevated Over-Temperature (Fault Level)

Trigger:

- Cell/pack temperature exceeds safe operational range, approaching manufacturer fault limit.

Automatic System Actions:

- Affected battery string immediately isolated by the BMS.
- Remaining strings may derate or continue operation depending on conditions.
- EMS/SCADA receives a Fault and logs the event.
- Cooling system remains at maximum output.

Operator Actions:

- Verify ventilation system is operating.
- Inspect SCADA data for pattern (single pack vs string-wide anomaly).
- Prepare for container shutdown if temperatures continue to rise.

Outcome:

Stops electrical/chemical energy input to the overheating section and prevents propagation.

Critical Over-Temperature (Emergency Level)

Trigger:

- Temperature reaches critical limit (manufacturer-defined), indicating risk of thermal runaway.
- May coincide with smoke/gas detection if decomposition begins.

Automatic System Actions:

- Full container shutdown: charge/discharge disabled.
- All strings isolated.
- Ventilation activated, louvers open to manage heat/off-gas.
- FACP may escalate to a Fire Alarm Level 1.
- Alarms forwarded to remote operations.

Operator Actions:

- Treat enclosure as “potential thermal-runaway risk.”
- Do *not* enter container.
- Follow ERP protocols for remote monitoring & site cordon.

Outcome:

Moves system into a controlled, non-energised condition while containing the thermal anomaly.

Escalation to Fire / Thermal-Runaway Precursor

Trigger:

- Heat continues rising OR gas detectors trip (typically at ~25% LFL).
- Possibly smoke detection before visible flames.

Automatic System Actions:

- Fire Alarm Level 1/2 triggered.
- Maximum ventilation and off-gas valves activated.
- Optional suppression system (aerosol/dry-pipe) may discharge depending on site configuration.
- System enforces lockout; door interlock prevents access.

Operator / First Responder Actions:

- Maintain safe perimeter; do not open the container.
- Continue monitoring from SCADA and thermal cameras (if installed).
- Allow system to follow containment strategy (“let burn inside enclosure” principle if runaway proceeds).

Outcome:

Prioritises containment and responder safety while preventing propagation to other containers.

Overall Logic

The SolBank 3.0’s over-temperature response follows this structured escalation:

1. Temperature warning → Derate + cool
2. Over-temperature fault → Isolate affected string
3. Critical over-temperature → Full shutdown + ventilation
4. Thermal-runaway precursor → Fire/gas response + containment

This aligns with SolBank’s UL 9540A-informed design and large-scale fire test strategy, where early detection, controlled isolation, and robust containment prevent escalation and cross-container propagation.

6.3.2 BMS Alarms

The Battery Management System (BMS) continuously monitors every cell, pack and string within the SolBank 3.0. When abnormal electrical, thermal or operational conditions occur, the BMS initiates a structured fault-response sequence to protect the equipment, prevent escalation, and maintain safety.

Alarm Detection

The BMS monitors:

- Cell voltage
- Pack/string voltage
- Temperature (cell/pack)
- SOC/SOH
- Imbalance between packs/strings
- Communication status
- Electrical parameters such as over-current, under-voltage, insulation faults (if equipped)

When any monitored condition deviates from the permissible range, the BMS flags a Warning, Fault, or Critical Fault depending on severity.

First-Level Response – Automatic Protective Action

Upon detection of out-of-range conditions:

- Warning-level alarms
System logs the issue and reports it to EMS/SCADA. Charging may be reduced or inhibited depending on parameter.
- Fault-level alarms
The affected string is automatically isolated via its DC contactor.
This prevents propagation of abnormal behaviour beyond the faulty pack or string.
- Critical alarms (e.g. severe over-voltage, rapid temperature rise, major imbalance)
The BMS forces an enclosure-wide shutdown, signalling all strings to isolate and halting charge/discharge operations.

The system simultaneously raises alarms to the fire panel and EMS/SCADA.

Communication to SCADA / EMS

Every alarm is transmitted to the site Energy Management System (EMS) and onward to SCADA/fleet control.

SCADA operators receive:

- Alarm type and severity
- Affected string/pack
- Recommended operator response
- Status of system actions taken (e.g., “String 3 isolated”)

This allows remote monitoring personnel to judge whether escalation or remote shutdown is needed.

Safety Interlocks Triggered

Depending on the nature of the BMS alarm:

- Over-temperature or suspected thermal event triggers fire-detection logic and ventilation adjustments
- Over-voltage/under-voltage faults isolate the string and inhibit charge/discharge
- Imbalance faults isolate the affected string to prevent overstress
- Communication failures place the unit into a safe state with charging disabled
- Multiple simultaneous BMS faults lead to full container shutdown

All these actions occur automatically without operator intervention.

Operator / Engineer Response

Once notified of a BMS alarm, operators must:

1. **Acknowledge the alarm** in SCADA/EMS
2. Review real-time system status (temperature, voltages, SOC, isolation states)
3. Determine if the condition is resolved or persistent
4. For isolated strings:
 - Investigate likely root cause (temperature, cell imbalance, voltage anomaly)
 - Record the event in the site log
 - Plan inspection/LOTO if physical access is required
5. For critical faults:
 - Follow the site Emergency Response Plan (ERP)
 - Maintain standoff distances and treat as a potential thermal event
 - Notify fire services if fire/gas indications accompany the alarm

Remote shutdown may be executed if required.

Verification and Reset

A BMS alarm is not cleared simply by acknowledging it.

To reset the system:

- Identify and correct the underlying cause (e.g., restore temperature, replace faulty pack, resolve comms issue).
- Verify all parameters are back within normal operational ranges.
- Confirm that all strings are safe to re-engage.
- Reset BMS alarms via EMS/SCADA or local interface.
- Bring isolated strings back online one by one to avoid inrush or unstable transitions.

If door access is required, the door interlock ensures the system remains fully isolated until safe.

Documentation

Each BMS alarm event should be documented:

- Alarm type, time, and affected string
- Automatic actions taken
- Operator/fleet response
- Results of investigation
- Any corrective actions or resets
- Lessons learned for future prevention

This supports asset management, insurance obligations, and regulatory compliance.

6.3.3 Fire Detection System Activation

When the SolBank 3.0 fire-detection system detects smoke, abnormal heat or fire conditions, the system automatically enters a controlled safety mode designed to isolate electrical energy, manage thermal runaway, protect responders, and maintain enclosure integrity. The sequence of events is broadly as follows:

Initial Detection

Trigger:

- Smoke detector activation ($\approx 3.5\%$ obscuration/ft), or
- Heat detector activation ($>85\text{ }^{\circ}\text{C}$).

Automatic actions:

- Fire alarm panel declares Fire Alarm – Level 1 or Level 2, depending on severity.
- Alarm is sent to the Energy Management System (EMS) and SCADA.
- Audible/visual alarms activate on the enclosure.

Immediate Electrical Isolation

Upon fire-alarm activation:

- Charging and discharging stop immediately.
- DC contactors open, isolating battery strings from the main bus.
- All affected strings are taken offline by the BMS.
- The Power Conversion System (PCS) is placed in a safe, non-energised state.

Purpose:

Prevent additional energy flow and reduce escalation or propagation risk.

Ventilation & Gas-Management Activation

The fire-alarm condition activates the enclosure's integrated explosion-prevention system:

- Active ventilation is enabled (≈ 400 CFM exhaust), drawing gases out of the container.
- Intake and exhaust louvers open automatically.
- Off-gas / pressure-relief valves open if internal pressure or gas concentration increases.
- Gas levels are actively managed to remain below 25% LFL (per CFD-validated design).

Purpose:

Control flammable gas buildup, prevent deflagration, and maintain container integrity.

Fire Suppression Activation

The container is configured with internal suppression:

- Aerosol suppression activates automatically at Fire Alarm Level 2.
- Fire-suppression signal is triggered by the fire panel and integrated with the BMS/EMS.

Purpose:

Suppress localised fire and reduce thermal escalation.

Remote Alarm and Operator Notification

- SCADA/EMS forwards high-priority fire alarms to remote operations.
- Operators may initiate remote shutdown (secondary confirmation), though the system is already isolated.
- If site procedures require it, automated or manual callout to emergency services is made.

Purpose:

Ensure coordinated response and early engagement of fire-service protocols.

Site Access Restrictions

- No personnel should enter the container due to the risk of thermal runaway, toxic gases, or explosion.
- Fire-service personnel maintain standoff distances per NFPA/NFCC guidance (typically 25–50 m).
- Only after manufacturer or qualified technician clearance may the container be opened.

Purpose:

Protect responders from hidden or delayed ignition hazards.

Monitoring & Stabilisation

- SCADA monitors temperatures, gas concentrations, and status of internal systems.
- Operators maintain continuous observation for signs of thermal runaway propagation.
- Fire Service follows a “non-intrusive defensive strategy” unless life-saving intervention is required.

Purpose:

Allow the event to stabilise safely while avoiding unnecessary exposure.

Post-Incident Actions

Once the fire detection event has ceased and the container is stable:

- System remains isolated and locked out until inspected.
- Manufacturer/EPC conducts post-event diagnostics.
- Fire detection equipment is tested/reset.
- A full incident report is completed.

Purpose:

Ensure safe recovery, root-cause analysis, and prevention of recurrence.

6.3.4 Grid Faults or Islanding

Under grid-fault conditions (voltage/frequency excursions, short-circuits, or loss of mains), the behaviour of the BESS is governed primarily by the PCS in accordance with UL 1741 / IEEE 1547 and the applicable grid code. On detection of an abnormal grid condition, the PCS will either ride through (within the defined envelope) or cease energising the grid and open its AC disconnection device. Correspondingly, the SolBank BMS disables charging and discharging and isolates the battery DC strings from the main DC bus.

Unintentional islanding is not permitted: loss-of-mains protection will cause the PCS to cease energisation and isolate the BESS from the network. The SolBank remains energised internally but in a non-exporting, safe state.

Where intentional island operation is implemented, the PCS may be commanded via the EMS to transition to island mode (voltage and frequency forming) in accordance with the project-specific control philosophy. Reconnection to the grid is only permitted after network conditions are verified and synchronisation criteria are met.

All such events are alarmed via the EMS/SCADA. Operators shall follow the site Emergency Response Plan: confirm grid status with the DNO/TSO, maintain BESS isolation as required, and only recommence normal operation following fault clearance and authorisation.

7.0 Emergency Response Plan

The Emergency Response Plan is currently being developed alongside the final design. However, it is anticipated the following headings will be included:

- Roles & Responsibilities
 - Site operators
 - Emergency response teams
 - Fire department contacts
- Emergency Scenarios
 - Thermal runaway event
 - Fire and smoke incidents
 - Gas detection alarms
 - Flooding or HVAC failure
 - Grid isolation or blackout
- Evacuation & Communication
 - Muster points
 - On-site emergency communication system
 - Notification procedures
 - Fire Department Coordination
 - Pre-incident planning documentation
 - Access routes and site maps
 - Firefighter training and annual refreshers

8.0 Training & Competency Requirements

The final training matrix will be dependent upon a blend of inputs from various sources but it is suggested the following be included:

8.1 Safety and Hazard Awareness Training

BESS Training Matrix Template (UK)
Training Categories Key
GA – General Awareness (all personnel)
OP – Operators / Control Room
TECH – Technicians / Engineers
HV – HV-Authorised Personnel
FM – Fire Marshals / Emergency Response
MGT – Supervisors / Managers
CTR – Contractors

Training Module	GA	OP	TECH	HV	FM	MGT	CTR	Frequency
Site Induction (General Safety)	✓	✓	✓	✓	✓	✓	✓	On start + annual
BESS Hazard Awareness	✓	✓	✓	✓	✓	✓	✓	Annual
Electrical Safety Awareness	✓	✓	✓	✓	✓	✓	✓	Annual
High Voltage Authorisation	–	–	–	✓	–	–	–	3 yearly
LOTO	–	✓	✓	✓	–	–	–	Annual
Permit-to-Work	–	✓	✓	✓	–	✓	✓	Annual
Fire Safety & Extinguisher Use	✓	✓	✓	✓	✓	✓	✓	Annual
BESS Fire Behaviour & Emergency Response	–	✓	✓	✓	✓	✓	–	Annual
Chemical & Gas Hazard Training	–	✓	✓	✓	✓	✓	–	2 yearly
Gas Detection & Alarm Response	–	✓	✓	✓	✓	✓	–	Annual
SCADA / BMS Monitoring	–	✓	✓	✓	–	✓	–	Annual
Thermal Runaway Recognition	✓	✓	✓	✓	✓	✓	–	Annual
Emergency Shutdown Procedures	–	✓	✓	✓	✓	✓	–	Annual
Container / Module Entry Procedures	–	✓	✓	✓	–	–	–	Annual
First Aid	✓	✓	✓	✓	✓	✓	–	3 yearly
Manual Handling	✓	–	✓	–	–	–	✓	3 yearly

Table 13 Training matrix

8.2 Documentation of training records

All training completed under the BESS Safety Management Plan shall be formally recorded, maintained, and periodically audited to ensure compliance and workforce competency. Training records should include the participant's name, role, date of completion, trainer or provider, course content or syllabus reference, assessment outcomes (where applicable), and the next required refresher date. Records should be stored securely in a centralised digital system accessible to authorised personnel, with backups in accordance with company data-retention policies. Supervisors are responsible for ensuring that all personnel—staff and contractors—have valid and current training corresponding to the Training Matrix before undertaking work on or near the BESS. Any expired, missing, or insufficient training must be flagged and rectified immediately through refresher sessions or competency reassessment. Regular internal audits should verify completeness, accuracy, and ongoing compliance with HSE expectations and site requirements.

9.0 Incident Reporting & Investigation

9.1 Required reporting thresholds

A suggested incident reporting & investigation threshold table is highlighted below but this will be finalised by the Client, Operators and other stakeholders.

Category	Trigger / Threshold	Required Action
Immediate Reporting	Injury requiring first aid or above; fire/smoke/off-gas; electrical contact/shock; hazardous substance release; emergency system activation; evacuation; major equipment failure; pollution reaching environment.	Report to site management/control room immediately (within minutes). Initiate emergency response if required.
Internal Reportable Events (24 hrs)	Minor injuries; minor fires; equipment damage; incorrect LOTO/PTW; unauthorized access; environmental spills contained on site; near misses; safety observations.	Log incident within 24 hours in reporting system; supervisor review.
Investigation Level 1	Minor first-aid injury; non-hazardous near miss; low-impact damage.	Supervisor review and basic root-cause identification. Document corrective actions.
Investigation Level 2	Medical treatment injury; significant equipment damage; fire/smoke without propagation; repeated near misses; PTW/LOTO breach.	Formal internal investigation by supervisor + H&S. Complete root-cause analysis.
Investigation Level 3	Lost-Time Injury; HV electrical injury; thermal runaway; major environmental release; fire requiring external response; high-potential incidents.	Management-led full investigation with detailed root-cause methodology (e.g., ICAM).
RIDDOR Reporting	Death; specified injuries; >7-day incapacitation; unintentional explosion; fire stopping plant >24 hrs; hazardous substance release risking injury.	Notify HSE without delay in accordance with RIDDOR requirements.
External Notifications	Grid protection faults; significant failures; pollution risk; major damage; fire & rescue involvement.	Notify DNO/TSO, insurer, Environment Agency, OEMs, or Fire Service as required.

Table 14 Required reporting thresholds

9.2 Post-Event Forensic Investigation

Following any significant incident involving the BESS—such as thermal runaway, fire, electrical failure, gas release, or extensive equipment damage—a structured post-forensic investigation shall be undertaken to establish root causes, contributing factors, and lessons learned. This investigation should include detailed inspection of affected modules, racks, cabling, and control systems; analysis of BMS, SCADA, and protection-system data logs; examination of physical evidence such as char patterns, melted components, or deformation; and review of environmental and operational conditions preceding the event. Where required, specialist third-party experts, OEM engineers, and insurers should be engaged to conduct laboratory testing of failed components, electrolyte sampling, metallurgical analysis, or diagnostic teardown of cells and modules. Findings should be compiled into a formal report detailing causation, failure mechanisms, systemic influences, and recommended engineering or procedural improvements. All outcomes must feed directly into updates to risk assessments, operating procedures, training, and design or equipment modifications to prevent recurrence.

9.3 Root Cause Analysis Method (e.g., 5-Whys, Fishbone)

All significant incidents, dangerous occurrences, and high-potential near misses shall be subject to a structured root cause analysis to ensure that underlying technical, human, and organisational factors are fully identified. The methodology selected should be appropriate to the complexity and severity of the event. For routine or lower-level incidents, simple tools such as the 5-Whys method may be sufficient to identify immediate and contributory causes. For more complex failures—particularly those involving electrical faults, thermal events, control-system anomalies, or multi-factor interactions—more robust techniques such as a Fishbone (Ishikawa) diagram, Fault Tree Analysis (FTA), or a formal ICAM or TapRooT-style investigation should be used. The chosen method must systematically evaluate technical failures, human performance, procedural adequacy, equipment condition, environmental influences, and organisational controls. The outcome should clearly define the root causes, contributory factors, and effective corrective actions that prevent recurrence.

9.4 Corrective and Preventive Actions (CAPA)

Corrective and preventive actions shall be developed and implemented following any incident investigation, audit finding, or identified safety deficiency to ensure that immediate hazards are controlled and underlying causes are eliminated. Corrective actions should address the specific issues identified—such as repairing damaged equipment, revising procedures, updating training, or strengthening supervision—while ensuring temporary risk controls are applied until permanent solutions are in place. Preventive actions must focus on broader system improvements that stop similar incidents from occurring elsewhere in the operation, including design modifications, enhanced monitoring, procedural updates, engineering controls, or changes to organisational practices. All CAPA measures should be assigned an owner, deadline, and verification method, with progress tracked and effectiveness reviewed after implementation. Lessons learned must be communicated across the organisation and integrated into the site's continuous improvement processes.

10.0 Environmental & Disposal Management

10.1 End-of-life Battery Handling

End-of-life (EoL) batteries shall be managed in accordance with UK environmental regulations, manufacturer guidance, and industry best practice to ensure safe handling, storage, and disposal. All removed or decommissioned modules must be treated as potentially hazardous, retaining residual charge and possible thermal instability. EoL batteries should be electrically isolated, inspected for damage, and packaged in approved containers designed for lithium-ion transport, with appropriate labelling and documentation. Only trained personnel may handle or move EoL units, and they must use suitable PPE and follow procedures that prevent short circuits, mechanical impact, or exposure to electrolyte. Temporary on-site storage must be in a secure, ventilated, fire-resistant area with segregation from active systems. Collection, transport, and recycling shall be carried out by licensed waste carriers and authorised treatment facilities, ensuring full traceability and compliance with the Waste Batteries and Accumulators Regulations. Records of transfer, condition assessments, and disposal certificates must be maintained as part of the site's environmental management system.

10.2 Recycling Requirements

Grid-scale BESS batteries are regulated as industrial batteries under the Waste Batteries and Accumulators Regulations 2009. That means the battery producer (manufacturer/importer putting them on the UK market) is legally obliged to: (1) register as an industrial battery producer; (2) take back waste industrial batteries free of charge from end-users in a reasonable timeframe when requested, provided they are of the same chemistry and the producer is (or recently was) placing that chemistry on the market; and (3) ensure that all waste batteries they take back are sent to an approved battery treatment operator (ABTO) or approved battery exporter (ABE) for proper treatment and recycling.

For you as a BESS owner/operator, the key recycling requirements are to:

- Treat decommissioned packs/modules as waste industrial batteries (not general WEEE or scrap),
- Not landfill or incinerate them under any circumstances,
- Either exercise your right to free take-back via the producer or contract directly with a licensed waste/battery recycler,
- Ensure the batteries are transferred only to authorised ABTO/ABE or other appropriately permitted facilities, with full duty-of-care documentation and consignment notes retained, and
- Build these obligations into your commercial contracts so that EoL responsibilities, costs and practical arrangements for removal, transport and recycling are clearly allocated between parties.

10.3 Spill Containment

Spill containment once operational shall be managed through a combination of engineered controls, defined procedures, and trained personnel to ensure that any release of electrolyte, coolant, or hazardous substances is safely contained and prevented from reaching soil, drainage, or watercourses. All BESS enclosures and transformer areas should incorporate integral bunding, sealed flooring, or secondary containment systems capable of holding the maximum foreseeable spill volume. Spill kits appropriate to lithium-ion electrolytes—such as absorbents compatible with organic solvents, HF-neutralising materials, and PPE—must be strategically located and clearly signposted. In the event of a leak or suspected leak, personnel must isolate the area, stop the source if safe to do so, and deploy absorbents to prevent migration of liquids, ensuring ventilation is maintained due to potential off-gas hazards. Contaminated materials must be handled as hazardous waste and disposed of via licensed carriers. All spill incidents must be recorded, investigated, and followed by replenishment of spill materials and review of controls to prevent recurrence.

10.4 Hazardous Waste Management

Hazardous waste on the site—including electrolyte-contaminated materials, damaged battery modules, fire residues, PPE, absorbents, and any components containing oils or chemicals—must be managed in full compliance with UK hazardous waste regulations and the site's Environmental Management System. All hazardous wastes must be segregated at the point of generation, clearly labelled, and stored in secure, weatherproof, bunded areas with appropriate fire resistance and ventilation. Damaged or suspect lithium-ion modules should be placed in approved insulated containers or UN-certified drums, with terminals isolated and the units stabilised to prevent thermal, mechanical, or electrical hazards. Waste must only be transferred to licensed waste carriers and authorised treatment facilities, accompanied by accurate consignment notes and duty-of-care documentation. Temporary storage limits, compatibility requirements, and inspection frequencies must be adhered to, with housekeeping checks ensuring containers are intact, spill kits are present, and segregation is maintained. Staff involved in waste handling must be trained in hazardous waste identification, safe handling, emergency response, and record-keeping. All waste movements and disposal certificates must be logged and periodically reviewed to ensure compliance, traceability, and continuous improvement.

11.0 Documentation & Recordkeeping

11.1 Maintenance Logs

Comprehensive maintenance logs shall be maintained to provide a continuous and auditable record of all preventative, corrective, and predictive maintenance activities carried out on the BESS and its associated infrastructure. Each log entry should include the date, time, asset or component worked on, description of the task, findings, parts replaced, test results, and the name and competency level of the technician performing the work. Logs must also capture BMS/SCADA alarms reviewed, firmware or software updates applied, and any deviations from standard procedures. All entries should be recorded in a centralised digital maintenance management system, enabling traceability, trend analysis, and proactive identification of recurring faults or deteriorating performance. Completed actions, outstanding defects, and follow-up requirements must be clearly documented, with critical issues escalated promptly to supervisory personnel. Maintenance logs are to be retained in accordance with regulatory and insurance requirements, supporting compliance, warranty conditions, and long-term asset performance management.

11.2 Alarm and Event Logs

Alarm and event logs shall be continuously recorded and retained to provide a complete, time-stamped history of all system alerts, status changes, protection operations, and BMS/SCADA-reported conditions across the BESS. These logs form a critical part of operational monitoring and incident reconstruction, enabling operators to identify abnormal trends, early signs of cell imbalance, thermal anomalies, communication faults, inverter issues, or protection trips. All alarms—whether transient, acknowledged, or cleared—must be captured with associated data such as asset ID, severity level, operator actions taken, and system responses. Logs should be stored within a secure, centralised system with controlled access and sufficient retention to meet regulatory, OEM warranty, and insurance requirements. Routine review of alarm patterns, nuisance alarms, and recurring events must be conducted to identify underlying issues and trigger appropriate maintenance, engineering adjustments, or procedural updates. Alarm and event logs must be readily retrievable for audits, investigations, and performance analysis, and integrated into the site's continuous improvement and reliability framework.

11.3 Training Certifications

All personnel involved in the operation, maintenance, and oversight of the BESS must hold valid training certifications appropriate to their role, ensuring they possess the competencies required to safely manage high-energy electrical storage systems. Certifications should cover core areas such as electrical safety, high-voltage authorisation, BESS hazard awareness, fire and emergency response, permit-to-work procedures, and OEM-specific equipment training. Each certificate must be formally issued by a qualified training provider, include the participant's name, course title, completion date, expiry date, and assessment results where applicable. Copies of certifications must be securely stored within the site's training management system and be accessible for audits, regulatory inspections, and insurance verification. Expiring certifications must be monitored proactively, with refresher courses scheduled in advance to prevent competency gaps. Only personnel with current, verified certifications may perform safety-critical tasks or access restricted areas, supporting a robust and compliant competency management framework.

11.4 Safety Audit Reports

Safety audit reports shall be produced following each scheduled internal or external audit to provide a clear, evidence-based assessment of compliance with safety procedures, legal obligations, technical standards, and site-specific operational controls. Each report must document the scope of the audit, areas inspected, methodology used, and detailed findings including non-conformities, observations, and good practices. Particular attention should be given to high-risk elements such as electrical safety, thermal management, emergency response readiness, hazardous waste handling, and the integrity of fire detection and suppression systems. Audit reports must also include root-cause evaluations for any deficiencies identified, along with prioritised corrective and preventive actions, assigned owners, and defined timescales for closure. Completed reports should be reviewed by site management, communicated to relevant personnel, and stored within the site's safety management system for traceability. Trends from successive audits must be analysed to drive continuous improvement and ensure the long-term safe operation of the BESS.

11.5 Compliance Documentation

Compliance documentation for a UK BESS operation must be maintained in an organised, auditable format that demonstrates adherence to all relevant legislation, industry standards, and regulatory requirements. This includes evidence of compliance with the Electricity at Work Regulations, PUWER, Fire Safety Order, Hazardous Waste Regulations, Environmental Permitting obligations (where applicable), and the Waste Batteries and Accumulators Regulations. Key documents such as risk assessments, safe systems of work, emergency response plans, training records, maintenance logs, environmental monitoring data, and hazardous waste consignment notes must be kept up-to-date and readily accessible for inspection by regulators, insurers, clients, and auditors. Documentation should also include OEM instructions, commissioning certificates, grid connection agreements, and records of statutory inspections for electrical and fire safety systems. Regular reviews must be conducted to ensure documents reflect operational changes, regulatory updates, and lessons learned from incidents. Robust control of compliance documentation supports operational integrity, legal defensibility, and the safe, efficient running of the BESS.

12.0 Continuous Improvement

12.1 Annual Safety Audits

Annual safety audits shall be conducted to provide a thorough, independent assessment of the BESS site's compliance with UK health, safety, and environmental regulations, as well as internal policies and OEM requirements. These audits must evaluate the effectiveness of risk controls related to high-voltage systems, battery safety, fire detection and suppression, hazardous material management, emergency preparedness, access control, and competence management. The audit should review documentation, inspect physical infrastructure, interview personnel, and analyse trends from incident reports, alarm logs, and maintenance records. Findings must be clearly documented, prioritised by risk, and accompanied by corrective and preventive action recommendations. Senior management shall review the audit outcomes, allocate resources for improvements, and track closure of actions within agreed timescales. Annual audits also serve as a benchmark for continuous improvement, ensuring that operational practices evolve in line with regulatory updates, technological changes, and lessons learned from industry-wide BESS incidents.

12.2 Lessons-Learned Integration

Annual safety audits shall be conducted to provide a thorough, independent assessment of the BESS site's compliance with UK health, safety, and environmental regulations, as well as internal policies and OEM requirements. These audits must evaluate the effectiveness of risk controls related to high-voltage systems, battery safety, fire detection and suppression, hazardous material management, emergency preparedness, access control, and competence management. The audit should review documentation, inspect physical infrastructure, interview personnel, and analyse trends from incident reports, alarm logs, and maintenance records. Findings must be clearly documented, prioritised by risk, and accompanied by corrective and preventive action recommendations. Senior management shall review the audit outcomes, allocate resources for improvements, and track closure of actions within agreed timescales. Annual audits also serve as a benchmark for continuous improvement, ensuring that operational practices evolve in line with regulatory updates, technological changes, and lessons learned from industry-wide BESS incidents.

12.3 Technology Updates

Technology updates—including firmware revisions, software patches, BMS or SCADA enhancements, inverter updates, cybersecurity upgrades, and OEM-issued modifications—must be managed through a controlled change management process to ensure system integrity, safety, and regulatory compliance. All proposed updates should undergo a documented risk assessment and compatibility review, considering potential impacts on battery performance, protection settings, data integrity, communications, and warranty conditions. Updates must only be applied by competent, authorised personnel following OEM instructions and site procedures, with pre-update backups and rollback plans in place where feasible. Maintenance windows should be planned to minimise operational disruption, and all changes must be tested, verified, and logged in the site's configuration and maintenance records. Post-update monitoring should confirm stable operation and identify any unintended effects. Regular review of OEM bulletins, cybersecurity advisories, and industry guidance ensures the system remains current, secure, and aligned with best practice.

12.4 Stakeholder Review Procedures

Stakeholder review procedures ensure that all relevant internal and external parties—such as site operators, asset owners, OEMs, maintenance providers, grid operators, insurers, and regulatory bodies—are appropriately engaged in key decisions, performance reviews, and safety assessments for the BESS. Regular review cycles should be established to share operational performance data, incident findings, audit results, and planned changes, ensuring transparency and alignment across all stakeholders. Meetings or review sessions must be formally scheduled, with agendas, minutes, and action logs maintained to track commitments and follow-up activities. Stakeholder feedback should be captured systematically and used to refine risk assessments, operational procedures, maintenance strategies, and emergency preparedness plans. Where updates have significant safety, technical, environmental, or commercial implications, formal sign-off should be obtained from the relevant authorities or responsible persons before implementation. Effective stakeholder review processes promote collaborative decision-making, ensure regulatory and contractual compliance, and support continuous improvement of the BESS throughout its lifecycle.

13.0 Life phases of the project

The SolBank 3.0 Battery Energy Storage System is deployed as a factory-assembled, containerised unit designed for outdoor installation. Site construction activities must ensure that all civil, electrical, safety, and environmental requirements are satisfied prior to energisation. This section outlines the construction arrangements, physical site works, and integration requirements necessary to support the safe installation and operation of the SolBank 3.0 system.

This Life-Phase Battery Safety Management System (BSMS) outlines the safety, environmental, and operational controls required to manage SolBank 3.0 Battery Energy Storage Systems throughout their full lifecycle. It ensures compliance with UK legislation, OEM requirements, insurer expectations, and industry best practice while providing consistent, risk-based safety management from early project planning through to decommissioning.

13.1 Pre-Construction Information Requirements

- Conduct Hazard and Operability Studies (HAZOP)
- Perform fire engineering assessments
- Complete Construction Phase Plans (CPP)
- Prepare thermal runaway mitigation strategies
- Integrate OEM documentation and safety manuals into design

13.2 Construction of the SolBank 3.0 BESS Site

- Implement safe systems of work for HV and lifting operations
- Store and inspect batteries safely
- Maintain environmental controls for spills and waste
- Provide construction-phase emergency preparedness

13.3 Commissioning Phase

- Perform pre-energisation checks for mechanical, electrical, and fire systems
- Follow controlled energisation procedures with authorised personnel
- Conduct full functional testing and validation
- Complete handover documentation

13.4 Operational Phase

- Maintain maintenance logs, alarm/event logs, and inspections
- Train staff in BESS hazards, fire response, and HV safety
- Perform annual safety audits and continuous improvement reviews

13.5 Decommissioning Phase

- Prepare a Decommissioning Method Statement
- Safely de-energise and isolate the system
- Treat removed batteries as industrial hazardous waste
- Restore site and complete regulatory communications