Fire Risk Assessment for Outdoor, Remote, Non-Walk-in BESS Enclosures

26 Nov 2019 Rev 1 for SMART Projects

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Contents

Purpose

This assessment provides justification and explanation for the Fire Safety Design, Implementation and Operation of the AES BESS enclosure for outdoor, remote, non-walk-in type enclosures for energy storage facilities owned and operated by AES in an area under access control to only qualified individuals.

Part 1. Fire Safety Analysis Based on NFPA 551 and NFPA 550

This part of the analysis uses the concepts outlined in NFPA 551 on Evaluation of Fire Risk Assessments, and NFPA 550 on a Fire Safety Concepts Tree (Figure 1). First, the fire safety objectives are defined. Then, there is an examination on preventing a fire, and how to manage the impact of the fire if one does occur.

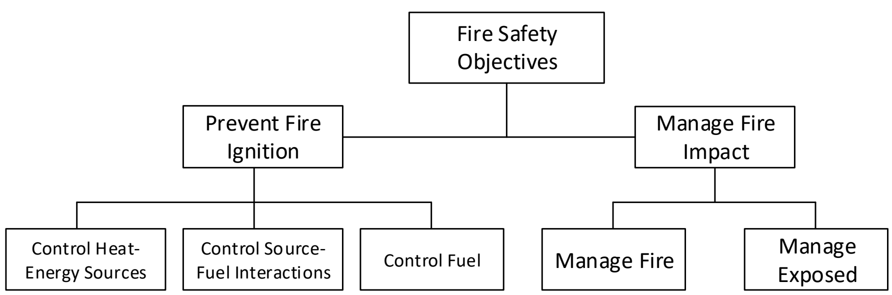

Figure 1 Fire Safety Concepts Tree

1. Fire Safety Objectives

The fire safety objectives for this product are:

1. No harm to personnel, including operators, first responders and bystanders outside the project boundary.
2. Minimize impact to the environment.
3. Minimize the fire risk to assets.

Risk Criteria

- No harm to personnel is acceptable
- Negligible harm to assets with an Occasional probability
- Marginal harm to assets with a Remote probability
- Critical and Catastrophic harm to assets should be Improbable

Protection of Human Life

Since these enclosures are non-walk-in, and access is restricted, the fire hazard harm to people would be the result of a fire, or explosion that escapes the boundary of the enclosure to a person in the vicinity.

Thus, if a fire were to occur, containing it, preventing an explosion, and making sure people are not in the vicinity during a fire is the priority.

Protection of Property

There is a significant investment in the assets within the enclosure. The priority for protecting these assets from fire damage is preventing the fire in the first place. If there is a fire of any significance, it would be undesirable to re-use the batteries and equipment. After a fire event, the probability of a compromised material that could due further damage to the system is high. Therefore, there is no value is preserving the equipment in the enclosure if a fire event happens.

There is value in preserving the property assets within the vicinity of the BESS enclosure, such as the PCS and transformers. Thus, if a fire were to occur, containing it and preventing an explosion are the asset protection priorities.

Protection of Business

Any fire event would negatively impact the business in terms of operating revenue, reputation, and the ability to execute additional projects. Again, the priority is not to have a fire in the first place. Any fire that did occur would require the replacement of the BESS equipment. The generating plant would not be operational, which would result in lost revenue.

Fire Scenarios

The fire assessment considers the following Fire Scenarios, as described in NFPA 551:

(1) **Fire ignition**. Often based on the most probable event in a particular setting, for example, cigarette ignition of a couch in a living room. Prevention education would reduce the probability of occurrence of this event and the consequential risks.

(2) **Fire growth**. Based on all probable developments of a fire, from smoldering to flashover fires. Fire protection systems such as sprinklers, compartmentation, and door closers may help to contain these fires and to reduce their consequential risks. The reduction in risk depends on the reliability and effectiveness of the fire control systems.

(3) **Smoke spread**. Based on smoke spread to critical egress routes and other parts in a building. Fire protection systems such as smoke control and stairwell pressurization may help to contain the smoke and to reduce its consequential risks. The reduction in risk depends on the reliability and effectiveness of the smoke control systems.

(4) **Exposure of occupants**. Based on smoke and fire blocking egress routes. Fire protection systems such as fire alarms, voice communication, clear egress routes, and refuge areas may help to provide early warning to occupants and to direct them either to evacuate the building or to seek refuge in certain areas. The reduction in risk depends on the reliability and effectiveness of the warning and evacuation systems.

(5) **Failure of fire department to respond**. Based on no response or late response. Proper notification procedure and adequate fire department resources would help to rescue the trapped occupants or to control the fire. The reduction in risk depends on the reliability of the notification procedure and the adequacy of fire department resources.

2. Prevent Fire Ignition

Combustible Materials and Mitigation

The BESS enclosure structural elements are mostly metal, or other non-combustible materials. Combustible materials in the BESS enclosure include:

1. Electrochemical components of the batteries, namely the electrolyte,
    - The combustion properties of the Samsung batteries have been studied and tested according to UL9540A. Although most of the report is confidential, a redacted portion of that report is submitted as a reference in this report, which includes gas compositions and flame spread properties. In a multi-rack test, fire that was initiated in one rack did not spread to the adjacent racks. The latest Samsung E4L test (March of 2022) was a Container Test that concluded:
        - The surface temperature of modules within the BESS units adjacent to the initiating BESS unit did not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8. (Maximum target surface temperature: 46°C, vent temperature from cell level test: 150°C)
        - There was no flaming outside the container
        - There was no observation of detonation.
        - There was no observation of deflagration
        - Heat flux in the center of the accessible means of egress did not exceed 1.3 kW/m2 - Measured heat flux : 0.1kW/m2
        - There was no observation of re-ignition within the initiating unit after the installation test had been concluded and the fire suppression system was discontinued
2. Plastic in the housing of the battery modules,
    - The effects of the plastic housing are included Samsung's UL9540A findings.
3. Some enclosure barrier walls to control air flow,
    - The material is a construction grade polycarbonate and contains a Flame Retardant, listed as an ASTM E84-01 Class A material.
4. Some auxiliary component housings
    - Minimal material in the form of plastic fittings and covers.
5. Polyurethane spray foam under the steel floor
    - Contains fire retardant to meet E-84 Class 1 approvals.
6. Electrical cable insulation
    - All cables are rated for the voltage and installation location, according to the NFPA 70E type and UL listing.
    - Most common conductor insulation types are NFPA 70E types MTW and RHW-2.
7. Potential unwarranted combustible materials not part of the system that would be placed inside the container counter to signage, policy, and training.
    - The site is fenced and monitored. The container is locked. Door switches alarm if a door is opened and the system shuts down automatically if a door is opened during operation.

Potential Causes of Ignition and Mitigation

The most common ignition of fires in BESS containers are:

1) Electrical fires caused by resistance heating due to:
   a) Conductors sized too small
      - The design has been reviewed and all conductor sizes are sufficient to prevent overheating
   b) Conductors with loose interconnections connections.
      - All electrical connections require torque marks to be checked during QC steps
      - All electrical connections require lock-nuts or spring washers to ensure tight connections
      - Annual Maintenance checks review major electrical connections to ensure connections remain tight over the life of the project
2) Chemical fires caused by heating of the batteries due to:
   a) Exceeding State of Charge (SOC) limits by over-charging or discharging the batteries
      - The SOC is managed and tracked by the BMS. Alarms and automatic shutdowns occur if the SOC limits are exceeded.
   b) Exceeding Rate of Charge/Discharge (C-rate) limits
      - The C-rate is managed and tracked by the BMS. Alarms and automatic shutdowns occur if the SOC limits are exceeded.
   c) Poor State of Health (SOH) due to degradation of the batteries
      - The SOH is managed and tracked by the BMS. Alarms and automatic shutdowns occur if the SOH drops below a minimum threshold.
   d) Exceeding acceptable interior environmental controls, hot air temperature or condensation
      - An HVAC system controls the interior environment. This system in monitored by the PPC against lockouts, high or low air temperatures, and high humidity. Alarms and automatic shutdowns occur if the temperature or humidity threshold limits are exceeded.
   e) Failure of a battery component
      - Component failures would result in temperature and/or voltage variances. Temperatures and voltages of all cells are monitored at 1 second intervals by the BMS. Alarms and automatic shutdowns occur if the temperatures or temperature variations exceed safe thresholds. Alarms and automatic shutdowns occur if the voltages or voltage variations exceed safe thresholds. Alarms detected by the BMS are watched by the PPC and SCADA to alert operational staff of hazards, and the PPC has a watchdog timer to monitor communication status to the BMS. The PPC has additional redundant protection measures based on temperatures and voltages that it monitors.
3) Arson
   a) The container is set fire due to criminal activity.
      - The site is fenced and monitored. The container is locked. Door switches alarm if a door is opened and the system shuts down automatically if a door is opened during operation.

3. Manage Fire Impact

Fire Detection

In addition to fire detection, strategies also include detection of flammable gases that could increase the chance of a fire.

1) Smoke Detectors. There are four detectors in the enclosure at locations to meet the design guidelines of NFPA 72. The detectors are tied to the Fire Control Panel, which provides alarm signals to the PPC through the enclosure PLC.

2) Air Temperature Sensors. There are 6 temperature sensors located in the enclosure. Heat from a fire could be detected by these sensors. High temperature alarms are handled by the PPC.

3) Battery Cell Temperature Sensors. There are 3 temperature sensors in every module. These temperature sensors would capture off-gassing threshold temperature and run-away temperature thresholds. Temperatures and alarms are monitored by the BMS and PPC.

Fire Control

1) Fire Suppression

Samsung E4L batteries utilize a "Direct Injection Method" of fire suppression. As with previous models, Novec 1230 ($C_6F_{12}O$) is still used as a fire suppressant to both extinguish and cool the compromised area. American Fire Technologies have tested Samsung's Direct Injection Method on E4L batteries and found the following: "*The results of the UL9540A Unit Level Tests with the direct injection thermal management system and subsequent tests performed by Samsung SDI successfully demonstrates the effectiveness of the innovative design. The Samsung SDI direct injection design is proven to successfully cool and extinguish the onset of single cell thermal runaway, successfully extinguish flames generated by an exothermic reaction, and limit propagation to adjacent cells by keeping cell surfaces well below critical onset temperatures."*

2) Explosion Control, NFPA 68 and 69

NFPA 69: Explosion Control

There is no flammable gas released during the normal operation of the unit. Therefore, a continuous or intermittent ventilation system is not required, nor desirable.

If several operational safety stops fail, and a hazard occurs that brings the batteries to exceed 150 °C, then thermal decomposition could occur, during which flammable gas could be released from the batteries. The first method for predicting a potential flammable gas condition checks for excessive battery temperature and voltage readings. This method is the most reliable. If excessive voltage and temperatures are detected by the rBMS, sBMS, or PCS controller, the system is automatically shut down, and AES operators are notified.

As a secondary detection method, gas detectors for Hydrogen (H2), Carbon Monoxide, (CO), and/or methane (CH4), can be added and connected to an active exhaust system. Based on testing of the gases vented from a battery, these three have the highest fraction as shown in Table 1. When one of these flammable gasses are detected at a level of 10% LFL, the exhaust system activates. The exhaust system blows at about 3000 cfm, so for an empty 40' HC container size enclosure, the turnover time is about 1 minute. For a fully loaded BESS enclosure, turnover takes approximately 35 seconds.

Gas	Measured v/v%	Component LFL
Hydrogen	24.7%	4.0%
Carbon Monoxide	284%	10.9%
Methane	6.1%	4.4%
Other Various HC Gasses*	10.5%	~2%
Non-Flammable CO2	30.2%	N/A

*Various C2-C5 hydrocarbons released, but none > 7.5% and most > 1%.

Table 1. Measured Gas Composition of a Vented E4 Cell (SDI Confidential Information)

When the HVAC blower is on, a CFD study showed sufficient mixing of the air in the container that nowhere in the container does the gas mixture reach the LFL until over 15 cells off-gas. As soon as a 10% of the LFL is reached, the Flam gas detector turns on the ventilation system which ventilates the system well below the Lower Flammability Limit (LFL).

When the HVAC is not on, the CFD showed the flammable gas (mostly H2) rises to the top of the container and could form a flammable gas mixture. This however is unlikely because the conditions that could cause a cell to vent occur also cause the HVAC to turn on.

Multiple mitigation methods are employed to prevent a flammable gas situation. A flammable gas situation would require multiple simultaneous failure points including: a failure of the PCS control system to allow an operation condition that could overheat the batteries, a failure of the BMS to stop a condition where the batteries overheat and allow a run-away condition, a failure of the direct injection system to allow thermal runaway propagation to multiple cells, and a failure of power to the HVAC units to allow a localized buildup of flammable gas.

NFPA 68: Deflagration Venting

Because the system has a flammable gas detection and active exhaust system, deflagration protection is not required by NFPA 68. Even so, the calculations per NFPA 68 were calculated for informative purposes. Deflagration venting using the off-gassing data from Samsung's UL9540A tests would require a rupture area of 5 m^2 to prevent the internal pressure from rising above the safe requirements of a low strength structure (<0.5 bar-g rise). There are 105 meters of linear door seal area with a width of 2 cm (2 m^2) that would also blow out in an explosive event. In an explosive event the pressure inside the container could reach 3.5 bar-g with the rupture vents and doors seals release according to high strength structure calculations. Such a deflagration event could only occur upon the failure of all four levels of protection that are in place.

3) Fire Spread and Exposures

Containers are spaced a minimum of 8 feet from other electrical equipment, and at least 16 feet from any combustible materials. This separation reduces the likelihood that a fire originating in the battery container will spread to other equipment, or that fire originating outside the battery container will spread to the container.

Fire Emergency Response

First responders should not approach the container if there is a fire in the BESS. Fire control management should be restricted to protect property surrounding the site and prevent the fire from spreading beyond the site.

AES will provide a *Fire Mitigation Person* in the event there is a fire. This person will be one of the AES operations members in the area and assigned to that site.

Part 2. Fire Safety Analysis Based on NFPA 855

NFPA 855 is the newest Fire Code specifically written to address safety for large stationary battery systems. This assessment reviews NFPA 855 for the sections specific to the Hazard Analysis. Adherence to requirements of NFPA 855 regarding the general design, construction and operation are incorporated in the project design documents.

Chapters 1, 2 and 3 are informative.

Chapter 4

The design, construction, and operation of the system complies with the relevant sections of Chapter 4.

Section 4.1 General and 4.14 Hazard Mitigation Analysis

The General requirement in Section 4.1 have been followed for this system.

The following responds to NFPA 855, Section 4.1.4 Hazard Mitigation Analysis.

4.1.4.1 A hazard mitigation analysis shall be provided to the AHJ for review and approval when any of the following conditions are present:*

- *(1) When technologies not specifically addressed in Table 1.3 are provided.*
- *(2) More than one ESS technology is provided in a room or indoor area where adverse interaction between the technologies is possible.*
- *(3) When allowed as a basis for increasing maximum stored energy as specified in 4.8.1 and 4.8.2.*

Items 1 and 2 do not apply. Item 3 applies as the Max Stored energy in Table 4.8 is 600 kWh and this project stores up to 6245 kWh in an enclosure.

4.1.4.2 The analysis shall evaluate the consequences of the following failure modes and others deemed necessary by the AHJ:

- *(1) Thermal runaway condition in a single module, array, or unit*
- *(2) Failure of an energy storage management system*
- *(3) Failure of a required ventilation or exhaust system*
- *(4) Failure of a required smoke detection, fire detection, fire suppression, or gas detection system*

4.1.4.2.1 Only single failure modes shall be considered for each mode given in 4.1.4.2.

These 4 items have been included in the FMEA:

1) Thermal runaway conditions in a single module, array and rack have been evaluated and reported by Samsung in their UL 9540A report. In summary, it was found that off gassing of a cell occurs at temperature greater than 150 °C, thermal runaway occurs at temperatures greater than 180 °C. With the direct injection system, a thermal runaway propagated to other cells in a single module but did not propagate to other modules. And, a thermal runaway in one rack did not propagate to another rack. There were no re-ignitions after the initial event and no flaming occurred during the test. Each cell can release up to 212L of gas during complete thermal decomposition. To reach the combined combustible gas mixture LFL (7.0%) during off-gassing, over 15 cells would have to vent gas.

2) A failure of power or communications of the BMS or PPC results in the automatic shutdown of the system and disconnection of strings from the DC bus. This puts the system in a safe condition from electrical fires caused by faults, overcharging, or undercharging.
   a) The BMS protection map is found in the Troubleshooting section of the Samsung O&M Manual.
   b) The PPC protection map is found in the GPTech PPC Signal List, v0.5.1 or newer.
3) There is no continuous exhaust ventilation required for this system. A failure of the flammable gas detection and ventilation system could result in a combustible gas mixture in the enclosure, which could result in an explosion, ONLY IF THE FOLLOWING ADDITIONAL FAILURES TAKE PLACE:
   a) The PPC fails to detect and act on an over or undercharging condition; and
   b) The BMS fails to detect and act on an over or undercharging condition; and
   c) The PPC and BMS fail to detect cell temperatures that exceed the off-gassing limits; and
   d) The fire suppression direct injection system fails to operate correctly; and
   e) A significant number of cells simultaneously reach the critical temperature for off gassing such that the Flammability Limits are reached; and
   f) An ignition source is available that initiates combustion of the gasses.

The probability that all these failure events would occur is considered improbable and is not necessary to consider according to 4.1.4.2.1. One condition where such simultaneous failures could take place would be a large site fire that started externally and engulfed the battery enclosure, which is made unlikely through the separation from combustible materials.

4) The fire suppression system installed in the container is primarily to limit the possible spread of an electrical or other non-battery fire. The fire suppression system is monitored by the PPC, which will shut down the system if communication is lost or the fire suppression system triggers a system lockout as a result of an internal error.

4.1.4.3 The AHJ shall be permitted to approve the hazardous mitigation analysis as documentation of the safety of the ESS installation provided the consequences of the analysis demonstrate the following:

   (1) Fires will be contained within unoccupied ESS rooms for the minimum duration of the fire resistance rating specified in 4.3.6.
   (2) Suitable deflagration protection is provided where required.
   (3) ESS cabinets in occupied work centers allow occupants to safely evacuate in fire conditions.
   (4) Toxic and highly toxic gases released during normal charging, discharging, and operation will not exceed the PEL in the area where the ESS is contained.
   (5) Toxic and highly toxic gases released during fires and other fault conditions will not reach concentrations in excess of immediately dangerous to life or health (IDLH) level in the building or adjacent means of egress routes during the time deemed necessary to evacuate from that area.
   (6) Flammable gases released during charging, discharging, and normal operation will not exceed 25 percent of the LFL.

   1) This requirement is not applicable as the BESS enclosure is not in the vicinity of any occupied building or structure.

2) Deflagration protection is provided by prevention and detection of flammable gases, and finally the failure of the door seals and rupture vents. See the section below on deflagration analysis.
3) This requirement is not applicable as the BESS enclosure is unoccupied.
4) There are no toxic gases released during normal operation.
5) Since the enclosure is non-occupied, this section does not apply. The hazard was investigated for personnel that may be in the vicinity, external to the enclosure. During thermal off gassing and combustion of the Samsung batteries, there was minimal toxic gases produced, the most abundant being carbon monoxide as shown in **Error! Reference source not found.**.
6) There are no flammable gasses released during normal operation.

Gas	CO	CO2	H2	CH4	C2H4	C2H6	C3H6	C3H8	C3H4	C4 (total)	C5H12	n-C5H12	C6H14
% Measured	28.382	30.241	24.7	6.175	7.439	1.369	0.999	0.12	0.027	0.523	0.003	0.007	0.012

Figure 2 – Gas evolved from thermal run-away tests of a Samsung Battery Cell (112Ah).

4.1.4.4 The hazard mitigation analysis shall be documented and made available to the AHJ and those authorized to design the operate the system.

This report will be made available as required.

4.1.4.5 Construction, equipment, and systems that are required for the ESS to comply with the hazardous mitigation analysis shall be installed, tested, and maintained in accordance with this standard and the manufacturer's instructions.*

This requirement is met by the Quality Control procedure and documents as part of the system commissioning.

The overall site Operations and Maintenance manual includes all necessary commissioning tests, which may be repeated from time to time to ensure ongoing safe operation of the system.

Section 4.2 Equipment

The section relates to the design and operation of the system. The system complies with the applicable requirements.

Section 4.3 and 4.4 Installation Requirements and Location

The BESS facilities assessed are considered Outdoor, Remote, and Non-occupied. As a result, many of the requirements in Section 4.3 and 4.4 do not apply

4.4.3.1 Remote outdoor locations include ESS located more than 100 ft (30.5 m) from buildings, lot lines that can be built upon, public ways, stored combustible materials, hazardous materials, high-piled stock, and other exposure hazards not associated with electrical grid infrastructure.

Sections 4.5 4.6, 4.7, 4.8, & 4.9

Section 4.5 on Mobile systems does not apply.

Section 4.6. Per 4.6.1, Size and Separation restrictions do not apply for this system.

Section 4.7 Occupied Work Center restrictions does not apply.

Section 4.8 Maximum stored energy restrictions do not apply.

Section 4.9 Exhaust Ventilation does not apply.

Section 4.10 Smoke and Fire Detection

4.10.1 All fire areas containing ESS systems located within buildings <u>or structures</u> shall be provided with a smoke detection system in accordance with NFPA 72.

Smoke detectors are included in the design per NFPA 72 Sections 17.7.

Section 4.11 Fire Control and Suppression

Fire Suppression systems are not required for this system (outdoor, remote, non-walk-in) according to 4.11.1, as it is not required elsewhere in the standard. NFPA-855 Chapter 9 requires thermal runaway mitigation, which can be addressed through other means. Section 4.11.4-9 specifically exempt several types of systems, namely 4.11.9:

4.11.9 When approved by the AHJ, ESS shall be permitted to be installed in outdoor walk-in enclosures <u>without the protection of an automatic fire control and suppression system</u> where large-scale fire testing conducted in accordance with 4.1.5 documents that an ESS fire does not compromise the means of egress and does not present an exposure hazard in accordance with 4.4.3.3 and 4.4.3.4.

There seems to be a section missing that exempts outdoor non-walk-in enclosures, in which the hazard is significantly less.

Although not required, the BESS system includes a clean-agent, direct injection, fire suppression system.

Section 4.12 Explosion Control

Explosion control is required from NFPA-855 Chapter 9. Explosion Control involves 1) explosion prevention and 2) deflagration venting.

4.12.2 Explosion prevention and deflagration venting <u>shall not be required</u> where approved by the AHJ based on largescale fire testing in accordance with 4.1.5 that demonstrates that flammable gas concentrations in the room, building, or walk-in unit cannot exceed 25 percent of the LFL in locations where the gas is likely to accumulate.

The BESS system addresses explosion control as described in Section 3 of Part 1 of this document.

Section 4.13 Water Supply

Water is not supplied for these systems, so requirements of NFPA 1142 apply.

Sections 4.14, 4.15

Section 4.14 Spill Control does not apply to this system per section 9, table 9.2.

Section 4.15 Neutralization does not apply to this system per section 9, table 9.2

Section 4.16 Remediation Measures

4.16.2.1 When, in the opinion of the AHJ, it is essential for public safety that trained personnel be on site to respond to possible ignition or reignition of damaged the ESS, the owner, agent, or lessee shall provide one or more fire mitigation personnel, as required and approved, at their expense.
4.16.2.2 These personnel shall remain on duty continuously after the fire department leaves the premises until the damaged ESS is removed from the premises or the AHJ indicates they can leave.
4.16.2.3 On-duty fire mitigation personnel shall have the following responsibilities:
(1) Keep diligent watch for fires, obstructions to means of egress, and other hazards
(2) Immediately contact the fire department if their assistance is needed to mitigate any hazards
(3) Take prompt measures for remediation of hazards and extinguishment of fires that occur
(4) Take prompt measures to assist in the evacuation of the public from the structures

Section 4.16 specifies that AES is to provide trained personnel to respond and be on site in the event there is a fire. AES has an operations crew in the area for this purpose.

Chapter 5. System Interconnections

5.1 General. All electrical connections and wiring to and from an ESS or the components of an ESS shall be in accordance with NFPA 70 or IEEE C2 based on the location of the ESS in relation to and its interaction with the electrical grid.*

The system design meets the specifications of Section 5 where applicable.

Chapter 6, 7 & 8

Chapter 6 Commissioning, Chapter 7 on Operation and Maintenance, and Chapter 8 on Decommissioning does not contain material for the Hazard Analysis. These elements are addressed in the BESS O&M Manual.

Chapter 9 Electrochemical Energy Storage Systems

Chapter 9 specifies that Lithium-Ion ESS need compliance with thermal runaway, explosion control and size and separation, but do not need exhaust ventilation, spill control, neutralization, or safety caps.

Chapters 10, 11, 12, 13, 14, & 15

These chapters do not apply to this system.

Part 3. Fire Safety Analysis Based on NFPA 1 Chapter 52

Chapter 52 of NFPA 1 up until 2018 was a code addressing safety of battery systems in buildings, specifically for facility standby power, emergency power, or uninterrupted power supplies. The 2018 version was expanded to include stationary battery systems of all types; however, still heavily focused on batteries in or associated with occupied buildings, so most of this code is not applicable to this BESS project system. The requirements of NFPA 1 Chapter 52 are compatible, although less specific for this type of project, than the requirements in NFPA 855. The following addresses each part of Chapter 52.

Section 52.1 General and 52.2 Permits

Energy storage systems shall comply with Chapter 52. Permits, where required, shall comply with Section 1.12 of NFPA 1, which provides requirements for AHJ permitting.

Section 52.2 PbAcid & NiCd, Section 52.3.3 Capacitors

Lead-Acid, NiCd, and Capacitors – Not applicable to this project.

Section 52.3.2.1 Location

This section specifies requirements for outdoor, non-walk in systems to be in noncombustible enclosures that are locked and accessible only to authorized persons. The enclosure shall be separated from other buildings, lot lines by at least 5'; and separate from any means of egress from other buildings by 10'.

Section 52.3.2.2 and 3 Max Allowable Quantities, Battery Arrays

Section *.2 addresses batteries in occupied buildings or rooms and does not apply. In addition, the BESS system for this study has undergone a hazardous mitigation analysis and the battery system has large scale fire and fault testing performed (UL9540A) by the battery manufacturer.

Per this section *.3, the BESS system studied here should be permitted to exceed the capacity limits of table 52.3.2.2.1 because the system has undergone large-scale fire and fault conditions testing showing that a fire involving one array will not propagate to an adjacent array and be contained within the room per 53.3.2.1.3 (which does not apply because it is for inhabited buildings).

Section 52.3.2.4 Hazard Mitigation Analysis

An FMEA has been performed for the BESS system studied in this report, and thus provides further allowance to increase the quantities specified in Table 52.3.2.2.1. Most of this section refers to occupied buildings, which is not applicable to this project. There are no toxic or flammable gasses released during charging, discharging, or normal operation.

Equipment and Systems required to comply with the hazard mitigation analysis shall be installed, maintained, and tested per national standards. The BESS system studied here complies as all components of the safety systems are UL listed.

Section 52.3.2.5 Listings

The batteries in this BESS project are UL 1973 listed. The project system studied here is a custom design by Professional Engineers and sealed accordingly; it is not a prepackaged or pre-engineered system. The battery enclosure includes environmental control to meet conditions within the battery manufacturers specifications. The system will be field listed to UL9540.

Section 52.3.2.6 Installation

The project system contains an advanced BMS and SCADA that addresses requirements of article *.1. The charger is the PCS, a UL listed pre-engineered component meeting article *.2. The battery system is protected from vehicle impacts per article *.3. There is no combustibles stored in the container, which meets article *.4. Signage for the project system is included in the design set and has been reviewed to meet article *.5.

Sections 52.3.2.6. 6, 7 & 8. Seismic, Caps and Mixed Batteries.

The project system is designed per seismic code. Vented caps are not required for Li-Ion systems. There are small Lead Acid back-up batteries for the controls and Fire Safety System in the enclosure with the Lithium Ion batteries, and there is no unsafe interaction between them.

Section 52.3.2.7 Fire Suppression and Detection

The project system is not a building or habitable room, so an automatic sprinkler system is not required. The enclosures contain a Clean Agent Fire Suppression system. The project system contains a Fire Safety System with detection, alarms and monitoring meeting article *.2.

Section 52.3.2.8 & 9 Ventilation and Spill Control

For the Project System, Ventilation is not required for lithium ion systems per 52.3.2.11.1. Spill Control and Neutralization is not required for Lithium ion systems per 52.3.2.11.1.

Section 52.3.2.10 and 11 Thermal Runaway for Lithium Ion Batteries

A device or method shall be provided to preclude, detect, and control thermal runaway is required per 52.3.2.11.1. The FMEA analysis and the accompanying Alarm and Protection tables for the SCADA, BMS, physical design and Fire Safety System describe this compliance.

Section 52.3.2.12 Testing, Maintenance, and Repairs.

This section states testing and maintenance shall be in accordance with the manufactures instructions, by which the compliance is explained in the project design and operation documentation.

Definitions

- BESS – Battery Energy Storage System – Overall system for storing electrical energy, including the battery modules, containers, power converters, controls, and protection devices.
- BMS – Battery Management System – Controller responsible for management of the battery bank, including module-level data such as voltage and temperature, rack-level data such as min/max temperature and state of charge, and bank-level data such as # of racks connected, state of health, and alarms.
- PLC – Programmable Logic Controller
- PPC – Power Plant Controller – Controller responsible for closed-loop power control at the point of interconnection. Manages inverter and power converter power levels, and site-level alarms.
- SOC – State of Charge – Current charge of the battery bank, from 0-100%.
  SOH – State of Health – Current battery capacity as a percentage of the beginning of life value.

***Table A.5.2.5(a) of NFPA551**

Severity	**Impact**
Negligible	The impact of loss will be so minor that it would have no discernible effect on the facility, its operations, or the environment.
Marginal	The loss will have an impact on the facility, which may have to suspend some operations briefly. Some monetary investments may be necessary to restore the facility to full operations. Minor personal injury may be involved. The fire could cause localized environmental damage.
Critical	The loss will have a high impact on the facility, which may have to suspend operations. Significant monetary investments may be necessary to restore to fulfill operations. Personal injury and possibly deaths may be involved. The fire could cause significant reversible environmental damage.
Catastrophic	The fire will produce death or multiple deaths or injuries, or the impact on operations will be disastrous, resulting in long-term or permanent closing. The facility would cease to operate immediately after the fire occurred. The fire could cause significant irreversible environmental damage.

***Table A.5.2.5(a) of NFPA551**

Probability	**Description**
Frequent	Likely to occur frequently, experienced (P>0.1)
Probable	Will occur several times during system life (P>0.001)
Occasional	Unlikely to occur in a given system operation ($P>10^{-6}$)
Remote	So improbable, may be assumed this hazard will not be experienced ($P<10^{-6}$)
Improbable	Probability of occurrence not distinguishable from zero (P ~ 0)

Reference Documents

Codes and Standards:

- UL 9540 Energy Storage Systems and Equipment
- UL 9540A Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (BESSs)
- UL 1973 Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications
- NFPA 1 Fire Code, Ch 52, Stationary Storage Battery Systems
- NFPA 68 Explosion Protection by Deflagration Venting
- NFPA 69 Explosion Prevention Systems
- NFPA 70/NEC Article 706
- NFPA 550 Fire Safety Concepts Tree
- NFPA 551 Evaluation of Fire Risk Assessments
- NFPA 855 Stationary Energy Storage Systems
- NFPA 2001 Clean Agent Fire Extinguishing Systems
- IEEE/ASHRAE 1635 Guideline 21 Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications
- IFC Chapter 12 Energy Systems, Section 1206 Electrical Energy Storage Systems
- FM Global Property Loss Prevention Data Sheet # 5-33, Electrical Energy Storage Systems

Publications:

- DOE OE Energy Storage Systems Safety Roadmap, PNNL-SA-126115, SAND2017-5140 R
    - Codes and Standards Update, March 2019, SNL.
- Energy Storage Safety: 2016, EPRI, SAND2016-6297R

Equipment Specific Information

- Samsung O&M Manual
- Samsung UL9540A report
- GPTech Operations Manual
- GPTech PPC Signals List
- Notifier Fire Control Panel Manual
- Siex Fire Suppression Design