Loss Prevention Standards – Asset Class(es)

Grid Scale Battery Energy Storage Systems – Natural Catastrophe

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Grid Scale Battery Energy Storage Systems are operational in many countries and climates across the globe and as such, are exposed to a wide range of weather conditions, and the associated risks of loss or damage.

This Loss Prevention Standard discusses these exposures and provides helpful guidance to reduce the potential for loss events.

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Grid Scale Battery Energy Storage Systems – Natural Catastrophe

Introduction

Grid scale Battery Energy Storage Systems (BESS) are a means of capturing and storing energy. They are used globally, including in areas which may be exposed to extreme weather and natural catastrophes.

The causes of natural catastrophe events are varied. Whilst tectonic movements are the main cause of earthquake, the risks of seismic events can be impacted by localising mining or geothermal energy extraction. Global climate change is also unfortunately producing more frequent and severe extreme weather events including tropical cyclones, storms, flooding, and wildfire.

These elements, and other factors, can result in grid scale BESS being exposed to harsh weather conditions and therefore require careful management to avoid loss or damage.

This document provides useful guidance to help prevent losses or damage to grid scale BESS caused by natural catastrophes.

Note: This document is focussed on Property loss prevention in relation to grid scale lithium-ion battery BESS. It is not intended to address small scale BESS installations, although the guidance may be helpful in some areas, nor Liability exposures. The presumption is that all regulatory requirements, Fire Risk Assessments, and compliance with requirements placed by the local authority having jurisdiction which would include licencing, building permissions, regulations, codes, or standards, have or will be met.

Understanding the Risks

Earthquake. Earthquakes occur in many parts of the world, although the largest centre around three belts:

- Around 80% of the largest earthquakes have occurred around the edges of the Pacific Ocean on the Circum-Pacific 'ring of fire' Seismic Belt. This exposes the west coast of North and South America, Oceania, parts of Asia (South, Southeast, Northeast, and East) and the Russian east coast to earthquakes and tsunami events.
- The Alpide earthquake belt, which extends from Indonesia through the Himalayan region and central Asia and into the Atlantic via the Mediterranean sea, accounts for about 17 percent of the world's largest earthquakes.
- The mid-Atlantic Ridge runs from the Arctic under Iceland and down to Southern Africa.

Earthquakes can cause land movements and structurally damage property, valuable assets and infrastructure including BESS. Risks include:

- Structural damage to the enclosure and internal battery components from excessive vibration.
- Unsecured components or equipment moving and leading to internal damage, or failure of the BESS.
- Impact and debris damage from other structures.

Flood. Many parts of the world are vulnerable to flooding events, most commonly those found in low-lying areas, on flood plains, and near rivers and seas.

Floodwater ingress within BESS can damage and contaminate internal components including electrical systems and the battery cells. Risks include:

- Short circuiting causing damage to electrical systems.
- Malfunctioning electrical and safety systems.
- Corrosion and degradation of cables and protectors.
- Thermal runaway in battery cells.
- Debris and dirt into cooling systems.
- Contamination on electrical terminals e.g. short circuit, sparking, arc flash etc.

Wildfire. Long periods of hot, dry weather and lack of rain can lead to forestry and vegetation drying out and becoming vulnerable to ignition. Ignition sources can be natural, such as lightning, volcanic eruptions, sparks from rock falls, spontaneous combustion or human related e.g. arson, discarded smoking waste, barbecues, campfires, accidental ignition involving matches. Wildfire can spread rapidly, often worsened by increased wind speeds, and can cause extensive damage to property, infrastructure and communities.

BESS located in such areas can be damaged by fire, smoke particles and firefighting water penetrating the internal areas and affecting the batteries. The ferocity of wildfires can also limit emergency access and response at the site.

Tropical Cyclones. Tropical cyclone is a generic term used to describe hurricanes, typhoons, and cyclones (name dependant on geographical location), which are rotating clouds and thunderstorms with a sustained wind speed of over 120 Kph, originating over tropical or subtropical waters with closed, low-level circulation.

A number of locations worldwide are impacted by such weather systems including the Caribbean and USA, Mexico, Southeast Asia, Australia, South Pacific, India, and the Indian Ocean islands.

The damage caused by tropical cyclones is often catastrophic, with wind damage to infrastructure and storm surges that result in inland flooding. BESS are vulnerable to both types of damage as well as wind driven water ingress.

Extreme Temperatures. Extreme heat / cold affects many continents and countries across the globe.

Heatwaves, which are primarily caused by slow-moving high-pressure systems trapping warm air and preventing it from dissipating, with the temperature on the land then increasing as a result, and ongoing extreme heat, can affect BESS in several ways with the battery cells requiring close temperature monitoring, which can place increased strain on cooling systems.

Cold weather-related events such as snowstorms and blizzards, along with ongoing extreme cold can also significantly affect system performance. BESS enclosures will be especially reliant on heating systems during such periods which can be overworked or develop faults, leaving the BESS highly vulnerable to damage. Heavy snow can drift and potentially violate or block ventilation systems. Such conditions can also make responding to BESS related emergency events, carrying out repairs, or completing ongoing maintenance challenging.

Hail. Hail can occur in both cold and warm regions but is primarily associated with strong thunderstorms. Hail balls are made of ice and can range in diameter from between 5mm and 150mm in size. Larger hailstones have the potential to cause significant impact damage to property, and valuable assets including BESS enclosures and associated equipment such as switch cabinets, transformer, inverters etc., which may impact system integrity.

Managing the Risks

Earthquake

The foundations and BESS equipment are vulnerable to seismic related damage.

- The risks of earthquake, and the likely severity of damage, at the planned BESS location should be considered either within, or in addition to the site Geotechnical Report(s) and should be undertaken for all grid scale BESS regardless of the location and previous seismic activity.
- The earthquake report will recommend risk control actions in relation to seismic hardening of foundations for the BESS enclosures and associated equipment such as the transformers, inverters, and switchgear cabinets, along with other mitigations such as the use of shock absorbing rubber pads or strengthened enclosure bracing.
  - ✓ The design recommendations should be followed closely, and the installation and commissioning works verified and approved as meeting the design specification with the Original Equipment Manufacturer (OEM).
  - ✓ Not complying with professional guidance and published standards in this regard may impact warranties and contract conditions, including insurance arrangements.

- Ensure the BESS is installed in compliance with local regulations, codes and/or recognised standards.
  - ✓ These are likely to provide specific earthquake requirements and guidance in areas prone to such events.
- The contents of the BESS enclosures should be adequately braced to prevent toppling, falling or general movements during a seismic event which might place the BESS components under stress.
  - ✓ This might involve the use of over-specified fixings and brackets.
- The area around the BESS enclosures and associated equipment should be maintained clear of objects that may topple or collapse to help reduce the risks of impact damage.
  - ✓ The separation distance should reflect the height of any such objects, the anticipated weight of debris and the expected lateral spread of debris/ejected components.
- Earthquake Early Warning (EEW) systems should be installed to the grid scale BESS installation to ensure early warning of seismic events.
  - ✓ Such systems operate by detecting the initial seismic from the earthquake and send automated emergency notice alerts to BESS control systems.
  - ✓ EEW systems should be interlocked to the BESS and associated equipment to safely isolate upon notifications being received.
  - ✓ Ensure workers are trained to respond to EEW alerts.
    - Formalised emergency response procedures should be produced. Refer Aviva Loss Prevention Standard **Emergency Response Teams** for further guidance.

Flood

The foundations and BESS infrastructure are vulnerable to flood related damage. Long standing flood waters can damage the foundation slab and supporting ballast or piles, as well as damage the BESS enclosures and equipment within. Even minor water ingress incidents can cause disproportionate damage to vulnerable and/or sensitive equipment via corrosion, humidity etc. Limited accessibility to and around the site could also delay or prevent essential maintenance, repairs and inspections.

- BESS should not be installed on land prone to flood incidents and the flooding potential should be risk assessed for all Grid Scale BESS sites.
  - ✓ The flood risk assessment should be completed by a competent company and should cover both fluvial and pluvial flood exposures and groundwater, including an assessment of the vulnerable points at the site.
  - ✓ The report findings and recommendations should be closely observed.
  - ✓ Ensure any ‘made ground’ areas, which may be particularly vulnerable to rising groundwater incidents, are assessed and deemed suitable for supporting the BESS infrastructure.
  - ✓ The risks of damage to the foundation slab will be assessed within the Geotechnical report, and recommendations should also be closely observed.
- Other precautions include:
  - ✓ Ensuring the BESS enclosure meets the appropriate water ingress protection rating and complies with appropriate design standards for the assessed flood exposure.
  - ✓ Installing the BESS infrastructure on support platforms at a height that exceeds the predicted maximum flood water levels for the expected lifetime of the BESS installation, including future climate change considerations.
  - ✓ Where the size of the BESS installation permits, install flood barriers to the vulnerable locations of the site, designed to prevent rising water from reaching the BESS infrastructure.
  - ✓ Diverting nearby land drains to flood meadows.
  - ✓ Installing sufficient drainage to prevent water accumulating.
  - ✓ Relocating vulnerable components within the BESS enclosures to higher levels.
  - ✓ Formalising responsibility and duties for ongoing maintenance of flood defences.

- Ensure any local and national flood agency alerts, which provide early warning of flood incidents, are adopted. Useful sources include:
  - ✓ UK - National Flood Forum.
  - ✓ Europe - European Flood Awareness System (EFAS) - Designed to support preparatory measures prior to flood events.
  - ✓ United States of America - Federal Emergency Management Agency (FEMA).
  - ✓ Global - FloodList provides information about floods and flooding from around the world.

Refer to Aviva Loss Prevention Standard **Flood Guidance and Mitigation (Global)** and **Flood Guidance and Mitigation (UK)** for further guidance.

Wildfire

A number of precautions should be considered to help reduce the potential for loss or damage if the BESS installation is located in an area prone, or vulnerable to wildfire e.g. previous wildfire events or high seasonal temperatures combined with moderate to high winds, public access and a fire load presented by forestry, grasslands etc.

- The fire load should be reduced as far as achievable. This can be achieved by removing vegetation from the immediate vicinity of the BESS equipment and replacing with hard standing, ballast material e.g. gravel, chippings etc.
- A fire break should also be installed around the site to effectively prevent wildfire reaching the BESS installation due to a lack of combustible 'fuel'.
  - ✓ Fire breaks should achieve at least 10 metres, however this should be increased where the vegetation comprises forestry or significant areas of tall and dense foliage, based on the findings of a risk assessment.

  Important: Vegetation outside of the fire break areas should be maintained at appropriate heights to limit the potential for fire breaching the fire breaks and reaching BESS equipment. This may be expressly stated within some insurance policies.

- Fire breaks can be natural features such as dirt tracks/roads, water drainage etc., or constructed features such as gravelled edging/borders, tarmacadam surfaces, concrete slabs etc.
  - ✓ Ensure any fire breaks are maintained clear of vehicles and combustible goods which support fire 'bridging' between combustible vegetation and infrastructure.
- Smoke can be damaging to sensitive BESS equipment due to its corrosiveness.
  - ✓ Ensure active ventilation, passive deflagration protection systems and air intake systems are controllable and can be closed remotely to prevent ingress of smoke from nearby wildfire events.
    - This is likely to require temporary shutdown of the BESS installation until the immediate threat of wildfire related smoke damage has passed.
    - Ensure the BESS enclosures are configured to isolate safely upon automated ventilation closure.
- Preventing public access to restricted areas can help prevent wildfires.
  - ✓ Ensure the grounds around the BESS installation are adequately fenced and warning signage displayed.
  - ✓ Prohibit camping, vehicle parking, the use of barbecues etc., in the area.
  - ✓ Carry out regular self-inspections of the grounds to ensure:
    - Combustible goods are removed from within and around buildings and valuable assets.
    - The public are not breaching prohibition notices and accessing the site (The site should be limited to authorised access only).
    - Vegetation is adequately maintained.
    - Fire breaks are in good order and not compromised.
    - Smoking rules are not being breached.

- Ensure any local and national wildfire agency alerts, which provide early warning of developing wildfires, are adopted. Useful sources include:
  - ✓ UK – The Met Office provide regular updates to their Fire Severity Index in England and Wales. Fire danger assessments are provided by the Scottish Fire Forum in Scotland.
  - ✓ Europe – The European Forest Fire Information System EFFIS provides information and data on wildfires in Europe.
  - ✓ United States – The National Interagency Fire Center (NIFC), National Weather Service (NWS) and National Oceanic and Atmospheric Administration (NOAA) provide helpful guidance and information on wildfires.
  - ✓ Global – The Global Wildfire Information System (GWIS) provides useful guidance and data on wildfires.

Tropical Cyclones

Tropical cyclones can cause catastrophic losses to property including BESS systems and associated equipment.

- Any plans to locate BESS in an area prone, or vulnerable to, tropical weather systems, should be thoroughly considered and relocated where possible.
- Where this is unachievable, ensure a risk assessment has been completed by a competent company and appropriate controls installed. These include:
  - ✓ Including water ingress protection for BESS enclosures, ensuring the IP rating is assessed and deemed adequate for the location and exposures.
  - ✓ Installing the BESS in such a way that utilises the natural topography and features of the site to shield the equipment.
    - Trees, hillsides, valleys etc., can all provide increased protection from cyclone conditions.
  - ✓ Installing reinforced defensive walling in key locations to help deflect the main storm forces, including rising waters, from the BESS equipment.
  - ✓ Installing ground anchoring systems for all vulnerable infrastructure.
    - Local and national building regulations, standards and codes typically incorporate standards for wind resistance and structural integrity.
  - ✓ Ensuring BESS enclosures and externally located equipment are sufficiently resilient and/or protected from damage by wind driven water ingress and debris e.g. suitable IP rating, compliance with local design standards & protective cages etc.

Extreme Temperatures

Lithium-ion batteries are particularly vulnerable to damage when operating outside of their safe operating temperature window.

- Ensure the system design adequately considers the risks of damage associated with high temperature weather conditions.
  - ✓ Review the manufacturer's specifications and guidelines for operating temperature ranges. This information will indicate whether the BESS is designed to perform efficiently in the climate of the site.
  - ✓ Ask for performance data of the BESS operating in similar climatic conditions. This can provide insights into safety, performance and reliability during periods of excessively hot weather.

BESS installations feature cooling systems in respect of the enclosure and battery racks and liquid cooling is recommended for use in areas that achieve high temperatures, due to their effectiveness at dissipating large amounts of heat and maintaining uniform temperatures within BESS enclosures.

- Closed loop liquid cooling systems should be utilised where possible.
  - ✓ These systems help prevent external contaminants entering the enclosure.
  - ✓ Cooling systems should be designed to appropriately function for the temperatures of the site.

- The optimal operating temperature within a BESS enclosure is maintained by the battery management system, and the battery management system should be configured to alarm and isolate the BESS if temperatures exceed specified temperature thresholds.
- The whole enclosure and all battery racks should be cooled evenly to help prevent hot spots developing.
  - ✓ The use of monitored thermographic cameras can help identify cooling issues within the enclosure and are recommended in areas prone to high temperatures.
- Ensure cooling systems electricity source is auxiliary loop and are not powered by the BESS system.
- Air cooled systems are not recommended in high temperature environments.
- Venting systems should be configured to automatically operate in the event of cooling system failure.

In respect of cold climates:

- Ensure the system design adequately considers the risks of damage associated with cold temperature weather conditions.
  - ✓ Review the manufacturer's specifications and guidelines for operating temperature ranges. This information will indicate whether the BESS is designed to perform efficiently in cold climates.
  - ✓ In addition, ask for performance data of the BESS operating in similar climatic conditions. This can provide insights into safety, performance and reliability during periods of excessively cold weather.
- BESS enclosures should be adequately designed for the climate.
- Automatically operating and controlled heating systems should be installed to maintain stable temperatures with the BESS enclosures.
- Regularly clear snow and ice from around the BESS vent ports to prevent blockages and ensure proper ventilation.
  - ✓ Use of onsite CCTV cameras to monitor for snow loading and guide snow clearance approach to maintain BESS operational integrity.
  - ✓ Accumulated snow and ice can also add extra weight and pressure on the structure.
  - ✓ Snow can block vents and weight of snow could affect effectiveness of deflagration pressure relief panels.
  - ✓ Ice accumulation can also cause damage to vital components, cooling system, heat exchanger etc.
- Ensure that the BESS is adequately weatherproofed to prevent moisture ingress.
  - ✓ This includes sealing any gaps and using weather-resistant materials for enclosures.
- Ensure monitoring systems are adequately tracking BESS performance during cold weather periods.
  - ✓ This can help detect any issues early and allow for timely maintenance.
- Ensure adequate access routes and suitable transport are provided for maintenance visits to the site during cold weather conditions.

Hail

- Any plans to locate BESS in a region prone to hailstorms should be thoroughly considered and relocated where possible.
- Where this is unachievable, ensure a risk assessment has been completed by a competent company and appropriate controls installed. These include:
  - ✓ Ensuring the enclosures and externally located equipment and fittings are suitably resilient to hail.
  - ✓ Installing additional protective barriers around BESS enclosures and other vulnerable equipment.
  - ✓ Conducting post hail event inspections to ensure water ingress into the BESS enclosure has not occurred.
  - ✓ National and local regulations, standards and codes should be consulted when constructing the grid scale BESS in any are prone to hail.
  - ✓ These documents are likely to provide specific requirements and guidance for weather protection and structural integrity.

Business Continuity Planning

Business Continuity Plans should be reviewed to ensure disaster recovery and continuity arrangements remain adequate. Any actions generated should be addressed promptly. Please refer to the Aviva Loss Prevention Standard **Business Continuity** for further guidance.

Emergency Response

An emergency response plan should be produced specifically developed to outline key responsibilities and actions in a Natural Catastrophe. The emergency response plan should include responses to all likely property and business interruption related events as described in this Loss Prevention Standard. It should also include the actions key individuals should take during emergency events including the liaison with emergency services and other agencies.

The emergency response rules should be formally documented, and appropriate training provided. Refer to Aviva Loss Prevention Standard **Emergency Response Teams** for further guidance.

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Sources and Useful Links

- CFPA-E Guideline No 09: 2023 N - Protection against hail damage
- NFPA 855 Standard for the Installation of Stationary Energy Storage Systems
- Federal Emergency Management Agency (FEMA)
- FM Property Loss Prevention Data Sheets

Additional Information

Relevant Aviva Loss Prevention Standards include:

- **Grid Scale Battery Energy Storage Systems**
- **Small Scale Battery Energy Storage Systems**
- **Self-Inspections**
- **Emergency Response Teams**
- **Housekeeping - Fire Prevention**
- **Flood Guidance and Mitigation (Global)**
- **Flood Guidance and Mitigation (UK)**
- **Business Continuity**

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