Grid Scale Battery Energy Storage System planning – Guidance for FRS

Grid scale Battery Energy Storage Systems (BESS) are a fundamental part of the UK's move toward a sustainable energy system. The installation of BESS systems both in the UK and around the globe is increasing at an exponential rate. A number of high profile incidents have taken place and learning from these incidents continues to emerge.

In the UK, approval for the majority of BESS installations takes place through the Local Authority planning process. Fire and Rescue Services (FRSs) may be engaged throughout the planning process, but this is not a statutory requirement. However, the National Fire Chiefs Council would encourage early engagement with the local FRS, continuing throughout the planning process.

The NFCC's expectation is that a comprehensive risk management process must be undertaken by operators to identify hazards and risks specific to the facility and develop, implement, maintain and review risk controls. From this process a robust Emergency Response Plan should be developed.

Given the rapidly developing nature of the technology, and ever evolving understanding of risks and mitigation measures, there is a need for guidance to support FRSs in providing consistent and evidence-based contributions to the planning process.

The guidance does not seek to provide a full specification or opinion on the entirety of a BESS system design. Instead, the aim is to limit the content to such matters that directly relate to facilitating a safe and effective response, by the fire and rescue service, to a fire or vapour cloud release involving a BESS installation. This includes factors such as facilities for the fire and rescue service, and design factors that contribute to reducing the escalation in the severity of an incident.

This guidance relates specifically to grid scale (typically 1 MW or larger) BESS in open air environments, using lithium-ion batteries.

The guidance is based upon a range of supporting materials including academic research, national and international standards, case studies, and industry guidance. The content of this document is the result of analysis of that supporting material with subsequent professional judgement applied. Every BESS installation will be different and fire and rescue services should not limit themselves to the content of this guidance. Particular reference has been made to the following:

- State of Victoria (County Fire Authority) (2022), *Design Guidelines and Model Requirements: Renewable Energy Facilities*
- FM Global (2017) *Property Loss Prevention Data Sheets: Electrical Energy Storage Systems Data Sheet 5-33*
- NFPA (2023) *Standard for the Installation of Stationary Energy Storage Systems*

Further advice and guidance can be obtained through the NFCC Alternative Fuels and Energy Systems lead officer.

This document contains guidance on:

1. Information requirements
2. System design, construction, testing and decommissioning
3. Detection and monitoring
4. Suppression systems
5. Site access
6. Water supplies
7. Emergency plans
8. Environmental impacts
9. Recovery

Principles

This guidance has been developed with the safety of the public and emergency responders in mind. It is based on trying to help reduce the risk as far as reasonably practicable, whilst recognising that ultimate responsibility for the safe design and running of these facilities rests with the operator.

The guidelines are a starting point and cannot cover every eventuality or type of design.

In developing these guidelines the hazards and risks from lithium-ion batteries, identified in National Operational Guidance, has been considered.

The following principles should be considered by Fire Services, when liaising with owners and operators, and form the basis of this guidance[1]:

1. Effective identification and management of hazards and risks specific to the siting, infrastructure, layout, and operations at the facility.
2. Impact on surrounding communities, buildings, and infrastructure.
3. Siting of renewable energy infrastructure so as to eliminate or reduce hazards to emergency responders.
4. Safe access for emergency responders in and around the facility, including to energy storage infrastructure and firefighting infrastructure.

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[1] State of Victoria (County Fire Authority) (2022), *Design Guidelines and Model Requirements: Renewable Energy Facilities*, p.4

5. Provision of adequate water supply and firefighting infrastructure to allow safe and effective emergency response.
6. Vegetation sited and managed so as to avoid increased bushfire and grassfire risk.
7. Prevention of fire ignition on-site.
8. Prevention of fire spread between site infrastructure (solar panel banks, wind turbines, battery containers/enclosures).
9. Prevention of external fire impacting and igniting site infrastructure.
10. Provision of accurate and current information for emergency responders during emergencies.
11. Effective emergency planning and management, specific to the site, infrastructure and operations.
12. Owner to have a comprehensive Emergency Response Plan, showing full understanding of hazards, risks, and consequences.

Information Requirements

Grid scale BESS should form part of FRS planning in accordance with arrangements required under section 7(2)(d) of the Fire and Rescue Services Act (2004). Site Specific Risk Information (SSRI) should be made available to crews in the form of an effective Emergency Response Plan.

Details of any site access arrangements, such as key codes, should be provided to the FRS.

System design, construction, testing and decommissioning

Information is required as early as possible from the applicant /developer/designer/manufacturer etc., to allow an initial appraisal of the BESS to be made. This information should be provided to the FRS (via the Local Authority Planners in the first instance), with appropriate evidence provided to support any claims made on performance, and with appropriate standards cited for installation.

Such information should also be made available to FRSs for inclusion in Site Specific Risk Information (SSRI) records.

System design and construction

Information required:

1. The battery chemistries being proposed (e.g. Lithium-ion Phosphate (LFP), Lithium Nickel Manganese Cobalt Oxide (NMC)). Because:
    a. Battery chemistries will directly affect the heat released when a cell goes into thermal runaway[2]
    b. Battery chemistries will influence vapour cloud formation.

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[2] https://www.nasa.gov/sites/default/files/atoms/files/nabw20_fire_gas_char_studies_liion_cells_batt_djuarez-robles.pdf

    c. An understanding of the battery chemistry is useful when requesting scientific advice during an incident.
2. The battery form factor (e.g. cylindrical, pouch, prismatic)
3. Type of BESS e.g. container or cabinet
4. Number of BESS containers/cabinets
5. Size/capacity of each BESS unit (typically in MWh)
6. How the BESS units will be laid out relative to one another.
7. A diagram / plan of the site.
8. Evidence that site geography has been taken into account (e.g. prevailing wind conditions).
9. Access to, and within, the site for FRS assets
10. Details of any fire-resisting design features
11. Details of any:
    a. Fire suppression systems
    b. On site water supplies (e.g. hydrants, EWS etc)
    c. Smoke or fire detection systems (including how these are communicated)
    d. Gas and/or specific electrolyte vapour detection systems
    e. Temperature management systems
    f. Ventilation systems
    g. Exhaust systems
    h. Deflagration venting systems
12. Identification of any surrounding communities, sites, and infrastructure that may be impacted as a result of an incident.

Testing

Details of any evidence based testing of the system design should be requested, for example, results of UL 9540A testing.

Design

Design features should be made clear. These may include:

- Rack layout and setup
- Thermal barriers and insulation
- Container layout and access arrangements

Detection and monitoring

An effective and appropriate method of early detection of a fault within the batteries should be in place, with immediate disconnection of the affected battery/batteries. This may be achieved automatically through the provision of an effective Battery Management System (BMS) and/or a specific electrolyte vapour detection system.

Should thermal runaway conditions be detected then there should be the facility in place for the early alerting of emergency services.

Detection systems should also be in place for alerting to other fires that do not involve thermal runaway (for example, fires involving electrical wiring).

Continuous combustible gas monitoring within units should be provided. Gas detectors should alarm at the presence of flammable gas (yes/no), shut down the ESS, and cause the switchover to full exhaust of the ventilation system[3]. Sensor location should be appropriate for the type of gas detected e.g. hydrogen, carbon monoxide, volatile organic compounds.

External audible and visual warning devices (such as cabinet level strobing lights), as well as addressable identification at control and indicating equipment, should be to linked to:

1. Battery Management System (when a thermal runaway event is identified)
2. Detection and suppression system activation

This will enable first responders to understand what the warning is in relation to. This will aid in their decision-making.

Suppression systems

Suitable fixed suppression systems should be installed in units in order to help prevent or limit propagation between modules.

Where it is suggested that suppression systems are not required in the design, this choice should be supported by an evidence based justification and Emergency Response Plan that is designed with this approach in mind (for example, risk assessed controlled burn strategies, and external sprinkler systems).

Whilst gaseous suppression systems have been proposed previously, current research indicates the installation of water based suppression systems for fires involving cell modules is more effective.

The installation of gaseous suppression systems for electrical fires that do not involve cell modules may be appropriate but should be built into a wider suppression strategy.

FM Global cite the following reasons for not recommending gaseous protection systems[4]:

1. **Efficacy relative to the hazard**. As of 2019, there is no evidence that gaseous protection is effective in extinguishing or controlling a fire involving energy storage systems. Gaseous protection systems may inert or interrupt the chemical reaction of the fire, but only for the duration of the hold time. The hold time is generally ten minutes, not long enough to fully extinguish an ESS fire or to prevent thermal runaway from propagating to adjacent modules or racks.

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[3] FM Global (2017) *Property Loss Prevention Data Sheets: Electrical Energy Storage Systems*, para. 2.5.5.2
[4] FM Global (2017) *Property Loss Prevention Data Sheets: Electrical Energy Storage Systems*, para. 3.3

2. **Cooling**. FM Global research has shown that cooling the surroundings is a critical factor to protecting the structure or surrounding occupancy because there is currently no way to extinguish an ESS fire with sprinklers. Gaseous protection systems do not provide cooling of the ESS or the surrounding occupancy.
3. **Limited Discharge**. FM Global research has shown that ESS fires can reignite hours after the initial event is believed to be extinguished. As gaseous protection systems can only be discharged once, the subsequent reignition would occur in an unprotected occupancy

The choice of a suppression system should be informed by liaison with a competent system designer who can relate the system choice to the risk identified and the duration of its required activation. Such a choice must be evidence based.[5]

Any calculations for sufficient water supply for an appropriate suppression system will need to be completed by a competent person considering the appropriate risk and duration of any fire.

Water run-off and potential impact on the environment, along with mitigation measures, should be considered and detailed in the Emergency Response Plan.

Lack of sufficient water supplies at a particular site location should not be considered as the basis for a suppression system choice. Such an approach could result in potentially ineffective and/or dangerous system designs.

Deflagration Prevention and Venting

BESS containers should be fitted with deflagration venting and explosion protection appropriate to the hazard. Designs should be developed by competent persons, with design suitability able to be evidenced.[6] Exhaust systems designed to prevent deflagration should keep the environment below 25% of Lower Explosive Limit (LEL).

Flames and materials discharged as a result of any venting should be directed outside to a safe location and should not contribute to any further fire propagation beyond the unit involved or present further risk to persons. The likely path of any vented gasses or materials should be identified in Emergency Response Plans to reduce risk to responders.

Explosion/deflagration strategies should be built into the emergency plan such that responders are aware of their presence and the impact of their actions on these strategies.[7]

Where emergency ventilation is used to mitigate an explosion hazard, the disconnect for the ventilation system should be clearly marked to notify personnel or first responders to not disconnect the power supply to the ventilation system during an evolving incident.[8]

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[5] NFPA (2023) *Standard for the Installation of Stationary Energy Storage Systems*, para C.3
[6] BS EN 16009:2011 *Flameless Explosion Venting Devices*; BS EN 14373:2021 *Explosion Suppression Systems*; BS EN 14797:2007 *Explosion Venting Devices*.
[7] UL FRSI (2020) *Four Firefighters Injured in Lithium-ion Battery Energy Storage System Explosion – Arizona*, pp. 47-49
[8] NFPA (2023) *Standard for the Installation of Stationary Energy Storage Systems*, para G.1.4.3.3

Access

Site access

Suitable facilities for safely accessing and egressing the site should be provided. Designs should be developed in close liaison with the local FRS as specific requirements may apply due to variations in vehicles and equipment.

This should include:

- At least 2 separate access points to the site to account for opposite wind conditions/direction.
- Roads/hard standing capable of accommodating fire service vehicles in all weather conditions. As such there should be no extremes of grade.
- A perimeter road or roads with passing places suitable for fire service vehicles.
- Road networks on sites must enable unobstructed access to all areas of the facility.
- Turning circles, passing places etc size to be advised by FRS depending on fleet.

Access between BESS units and unit spacing

In the event of a fire involving a BESS unit, one of the primary tactics employed will be to prevent further unit to unit fire spread. Suitable access for firefighters to operate unimpeded between units will therefore be required. This should allow for the laying and movement of hose lines and, as such, access should be free of restrictions and obstacles. The presence of High Voltage DC Electrical Systems is a risk and their location should be identified. Exclusion zones should be identified.

A standard minimum spacing between units of 6 metres is suggested[9] unless suitable design features can be introduced to reduce that spacing. If reducing distances a clear, evidence based, case for the reduction should be shown.

Any reduction in this separation distance should be design based by a competent fire engineer. There should be consideration for the fire separation internally and the total realistic load of fire. Proposed distances should be based on radiant heat flux (output) as an ignition source.

The NFCC does not support the stacking of containers/units on top of one another on the basis of the level of risk in relation to fire loading, potential fire spread, and restrictions on access.

Distance from BESS units to occupied buildings & site boundaries

Individual site designs will mean that distances between BESS units and occupied buildings/site boundaries will vary. Proposed distances should take into account risk and mitigation factors. However, an initial minimum distance of 25 metres is proposed prior to any mitigation such as blast walls. Reduction of distances may be possible in areas of lower risk (e.g. rural settings). Where possible buildings should be located upwind.

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[9] FM Global (2017) *Property Loss Prevention Data Sheets: Electrical Energy Storage Systems*, para. 2.3.2.2

Site Conditions

Sites should be maintained in order that, in the event of fire, the risk of propagation between units is reduced. This will include ensuring that combustibles are not stored adjacent to units and access is clear and maintained. Areas within 10 metres of BESS units should be cleared of combustible vegetation and any other vegetation on site should be kept in a condition such that they do not increase the risk of fire on site. Areas with wildfire risk or vegetation that would result in significant size fires should be factored into this assessment and additional cleared distances maintained as required.

Water Supplies

Water supplies will depend on the size of the installation. In the majority of cases, initial firefighting intervention will focus on defensive firefighting measures to prevent fire spread to adjacent containers. As a result, proposals for water supplies on site should be developed following liaison with the local fire and rescue service taking into account the likely flow rates required to achieve tactical priorities. This should also take account of the ability of/anticipated time for the fire and rescue service to bring larger volumes of water to site (for example through the provision of High Volume Pumps).

IP ratings of units should be known so that risks associated with boundary cooling can be understood.

As a minimum, it is recommended that hydrant supplies for boundary cooling purposes should be located close to BESS containers (but considering safe access in the event of a fire) and should be capable of delivering no less than 1,900 litres per minute for at least 2 hours. Fire and rescue services may wish to increase this requirement dependant on location and their ability to bring supplementary supplies to site in a timely fashion.

Water supply for any automatic suppression system will be covered by the relevant standard/design depending on which system chosen as appropriate for the risk. For manual water, amounts should come from performance based requirement rather than a reference to a code, unless it can be proven that the code specifically covers BESS. Regarding water storage tanks, volumes will again need to be informed on a performance-based need. Isolation points should be identified.

Any static water storage tanks designed to be used for firefighting must be located at least 10 metres away from any BESS container/cabinet. They must be clearly marked with appropriate signage. They must be easily accessible to FRS vehicles and their siting should be considered as part of a risk assessed approach that considers potential fire development/impacts. Outlets and connections should be agreed with the local FRS. Any outlets and hard suction points should be protected from mechanical damage (e.g. through use of bollards).

Consideration should be given, within the site design, to the management of water run-off (e.g. drainage systems, interceptors, bunded lagoons etc).

Signage

Signage should be installed in a suitable and visible location on the outside of BESS units identifying the presence of a BESS system. Signage should also include details of:

- Relevant hazards posed
- The type of technology associated with the BESS
- Any suppression system fitted
- 24/7 Emergency Contact Information

Signs on the exterior of a building or enclosure should be sized such that at least one sign is legible at night at a distance of 30 metres or from the site boundary, whichever is closer[10].

Adherence to the Dangerous Substances (Notification and Marking of Sites) Regulations 1990 (NAMOS) should be considered where the total quantity of dangerous substances exceeded 25 tonnes.

Emergency Plans

Site operators should develop emergency plans and share these with the Fire and Rescue Service. These include:

A Risk Management Plan should be developed by the operator, which provides advice in relation to potential emergency response implications including:

- The hazards and risks at and to the facility and their proposed management.
- Any safety issues for firefighters responding to emergencies at the facility.
- Safe access to and within the facility for emergency vehicles and responders, including to key site infrastructure and fire protection systems.
- The adequacy of proposed fire detection and suppression systems (eg., water supply) on-site.
- Natural and built infrastructure and on-site processes that may impact or delay effective emergency response.

An Emergency Response Plan should be developed to facilitate effective and safe emergency response and should include:

- How the fire service will be alerted
- A facility description, including infrastructure details, operations, number of personnel, and operating hours.
- A site plan depicting key infrastructure: site access points and internal roads; firefighting facilities (water tanks, pumps, booster systems, fire hydrants, fire hose reels etc); drainage; and neighbouring properties.

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[10] NFPA (2023) *Standard for the Installation of Stationary Energy Storage Systems*, para G.1.4.2.1.1

- Details of emergency resources, including fire detection and suppression systems and equipment; gas detection; emergency eye-wash and shower facilities; spill containment systems and equipment; emergency warning systems; communication systems; personal protective equipment; first aid.
- Up-to-date contact details for facility personnel, and any relevant off-site personnel that could provide technical support during an emergency.
- A list of dangerous goods stored on site.
- Site evacuation procedures.
- Emergency procedures for all credible hazards and risks, including building, infrastructure and vehicle fire, grassfire and bushfire

Environmental impacts

Suitable environmental protection measures should be provided. This should include systems for containing and managing water runoff. System capability/capacity should be based on anticipated water application rates, including the impact of water based fixed suppression systems.

Sites located in flood zones should have details of flood protection or mitigation measures.

Recovery

The operator should develop a post-incident recovery plan that addresses the potential for reignition of ESS and de-energizing the system, as well as removal and disposal of damaged equipment.[11]

[11] FM Global (2017) *Property Loss Prevention Data Sheets: Electrical Energy Storage Systems*, para. 2.8.2.3