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Beyond the PHA: Major Hazard Management for Battery Energy Storage Systems Using Bow Tie Analysis

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ABSTRACT

Battery Energy Storage Systems (BESS) are being rapidly deployed across Australia to support the energy transition, including at sites near existing industrial facilities and populated areas. While hazard identification studies such as Preliminary Hazard Analyses (PHAs), together with established design standards (including NFPA, UL, and IEC), provide an essential foundation for safe design, they do not ensure effective management of major hazards across the operational period.

BESS present credible major hazard scenarios, including thermal runaway, that may result in toxic and flammable gas release, fires, and explosion. International and Australian battery incidents, as documented in the EPRI BESS Failure Incident Database, have resulted in extended emergency responses, evacuation or shelter in place of surrounding communities, and recorded injuries and fatalities. These events have heightened public concern and highlight the need for a systematic major hazard management approach that extends beyond early stage hazard identification and compliance with standards. This is particularly relevant where BESS locations introduce interface risks with existing hazardous facilities.

This paper presents the application of bow tie analysis as a structured framework for managing BESS hazards beyond the PHA stage. Bow tie analysis is used to translate hazard identification studies into diagrams to communicate cause to consequence pathways and identify the controls critical to preventing thermal runaway or mitigating consequences. The approach draws on established management practices used in Major Hazard Facilities and other high hazard industries, adapted to address BESS failure mechanisms.

A case study is presented using a bow tie developed for thermal runaway within a lithium-ion BESS, including escalation to adjacent containers and off-site impacts. The case study illustrates how bow tie analysis can be used to identify the controls, and integrate these controls within a Safety Management System. This includes defining performance standards for battery management systems, detection and ventilation systems. The case study highlights that controls may depend on early detection, remote response or third-party intervention, as many BESS installations operate with limited or no on-site personnel.

The findings demonstrate that this systematic approach enables BESS hazards to be managed beyond initial design and compliance with standards. Embedding bow tie outputs within the Safety Management System supports procurement, assurance monitoring, and the *incorporation of additional controls as BESS technology and industry knowledge continue to develop. Framing thermal runaway as a major hazard and utilising bow tie analysis allows BESS hazards and controls to be systematically managed throughout the operational and maintenance phases.*

KEY WORDS

Battery Energy Storage Systems (BESS), Major Hazard Management, Bow Tie Analysis, Thermal Runaway, Lithium-ion Batteries, Critical Controls, Safety Management Systems, Risk Management

BIOGRAPHY

Michela is a chemical engineer specialising in major hazard risk management, with over 15 years of industry experience. She has worked closely with a number of Major Hazard Facilities in the preparation of Safety Cases and the ongoing management of critical controls, including facilities in the energy and resources sectors. She has assisted Comcare in conducting audits of safety management systems and controls for multiple Major Hazard Facilities.

Michela has experience in consequence modelling, quantitative risk analysis and facilitating hazard identification and HAZOP workshops. This experience has extended to Battery Energy Storage Systems and other sectors, including water and electricity generation.

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