



Fire Dynamics and Inter-Module Thermal Runaway Propagation in Battery Energy Storage Systems

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As power grids worldwide have increased their penetration of intermittent renewable energy sources, battery energy storage systems (BESS) have become a prevalent and growing means for grid stabilization. The basic building block in a BESS is typically the lithium-ion battery (LIB), due to its high energy density and cycle life. Several LIBs are packed together in an enclosure to form a module, and multiple modules are assembled into a rack. Racks are typically housed within a container, which constitutes one of potentially several units in a BESS. Under conditions of abuse, particularly thermal, mechanical or electrical abuse, a LIB can undergo thermal runaway (TR). TR simultaneously causes the generation of a large quantity flammable gas, rupturing the LIB, as well as rapid self-heating, which thermally abuses neighboring LIBs. This initiates a cell-to-cell cascading failure known as TR propagation (TRP). The vented gas produced by TRP is expelled from vents and openings on the module body, posing a fire and explosion hazard. In particular, a vented gas-fueled fire can drive other modules within a rack into TR via flame-heating, i.e., inter-module TRP.

The objective of this study is to develop predictive modeling capabilities of inter-module TRP within a numerical solver, and to determine this phenomenon's key controlling parameters and sensitivities. To this end, we discuss our development and implementation of a TRP sub-model within the LES solver FireFOAM [1]. We will compare our numerical results to experiments conducted at FM at increasing levels of scale and complexity, namely single-LIB TR [2], single-module TRP [3] and two-module inter-module TRP [4], and show how these comparisons are used to calibrate open parameters within our sub-model. Lastly, we will show comparisons of our calibrated model results to a rack-scale inter-module TRP experiment [5], and provide insights into the fire dynamics of this large-scale BESS failure mode.

References

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