Concerns regarding the Current Standard for BESS Safety, especially the UL 9540A standard being adopted by many agencies

A fire in a Battery Energy Storage System (BESS) with associated toxic smoke and particulates presents a constant danger to site personnel, Fire and Rescue Services and local residents. The Lithium-ion battery cells which form any BESS are intrinsically dangerous and need careful treatment. There are defined strict limits to how they are used either electrically, thermally or mechanically. Operating outside these limits is termed 'abuse'. An individual Lithium-ion cell can lead to thermal runaway when subjected to various types of abuse *viz* overheating, over-charge or over-discharge, an internal short circuit or physical penetration by a metal object.

The current standard safety test is UL 9540A developed by UL Solutions in https://www.ul.com/about. The test has been further developed over many years and covers Lithium-ion battery systems ranging from a single cell to a full BESS stack.

The principle behind UL9540A is to simulate the abuse of a lithium-ion cell leading it into thermal runaway. This is done by steadily heating a selected cell. Once the cell is found to be self-heating *i.e.* exothermal chemical reactions have begun, the heaters are switched off and allow the cell to proceed to thermal runaway. Thermocouples are placed on the selected cell and also on adjacent cells in the BESS. The temperatures of all the cells are continuously measured through the process. The volume and pressure of the various gases are also measured.

UL 9540A currently demonstrates the results of overheating a single cell. However, it is difficult to conceive of a situation where this is likely to occur. One possibility is that a bad cell connection might generate heat, though that heat might not propagate itself into the cell itself. A more likely possibility would be the failure of the cooling system, in which case, all the cells in the rack would be overheating. The measurements of the gas volume and pressure emitted for the heating of a single cell should therefore be scaled up to take into account the similar outgassing of every constituent cell in the stack.

In a recent comprehensive study by Liu *et a*l (University of Science and Technology, Hefei, China https://doi.org/10.1007/s10694-022-01287-2) report that there is a marked difference in a Lithium-ion cell's response to over-heating as opposed to overcharge. The thermal runaway process which results is both qualitatively *and* quantitively different in each case. Importantly, thermal runaway as a result of overcharge results in markedly higher values for the total heat released, the heat release rate, the peak temperature and the peak temperature rate.

Thermal Runaway occurs with the shrinkage or collapse of the separator. However, the occurrence of an internal short circuit is fundamentally different where metallic lithium dendrites or whiskers pierce the separator and electrically connect the cathode and the anode. An instantaneous and very high current is produced within the cell, together with a rapid and significant release of heat. This version of thermal runaway has led to explosions, destruction of the container, and in one instance the death of two firefighters. Critically, such behaviour cannot be simulated *via* UL9540A.

In conclusion, thermal runaway in lithium-ion batteries is more complex than hitherto has been assumed. It is now recognised that there are distinct behaviours arising from overheating, over-charge and internal short circuit. UL9540A tests *only* for the response to overheating.

It is highly dangerous to rely on the results of a UL 9540A test of a BESS system as the foundation of an acceptable safety plan.

It is strongly recommended that local Fire and Rescue Services advise their Local Planning Authorities to insist that all applicants for BESS planning permission need to produce evidence that their BESS is safe not only against overheating but also against over-charge, and internal short circuit.

This issue deserves urgent attention: The UK Government must put in place rigorous safety standards and regulations recognising the various processes leading to thermal runaway in lithium-ion batteries before any more BESS facilities are approved or installed.

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