Invited lecture at EDPE 2023, High Tatras, Slovakia

Title:

Safe Second-Life for Large Lithium-Ion Batteries through Handling of Fast Thermal Runaway

Abstract

Lithium-ion batteries are used as high energy density electrical storage element in industrial and commercial applications for 3 decades. For most mobile applications, Lithium ion batteries exhibit their strength in high energy also at higher output power over a wide temperature range and are superior over other electro-chemical battery technologies of the past. Lithium ion batteries play an extremely important role with respect to energy source, weight, volume, and cost in today's electric vehicles. Further mobile applications for Lithium ion batteries for providing traction energy include locomotives and trains, also boats to ships and to a limited amount, even aeroplanes. Also fixed-location use starts to become accepted generally and moves into commercial level. Peak power delivering applications to stabilize the grid are in use. The industrial scale enters the Mega-Watt-hour range within one unit. Some experience is gained for these applications through events where the fast thermal runaway destroys most of the appliance. Home-storage units are nicely sold. Industrial production has reached a rather high quality and safety level. Actually, it is not so easy to establish a fast thermal runaway of a Lithium-ion battery but through crude force like heating up to temperatures above 200 °C. Can the inherent risk for a fast thermal run-away be ignored by today?

Any commercial product is subject to fatigue and ageing. Some remaining risk of a production-based problem still remains. Only relying on statistics ("it shall not hit me") and a hopefully paying insurance company appears not being a nice solution. We have to encounter the facts and prepare accordingly.

This is even more important when Lithium-ion batteries used in mobile applications are found obsolete there because of the general loss of energy storing capacity after many cycles. A cycle number of 5000 is possible when taking good care to keep well inside of the not 100 % discharge range. 80% remaining capacity usually define the end of the mobile service life. Re-cycling should be seen in the general way that includes re-use, not only recovering the expensive materials from out-of-service Lithium-ion batteries. This re-use creates the chance of a so-called "second life" for the battery as a fixed location electrical energy storage element.

A new approach to safety for the second life of Lithium-ion batteries has to be implemented. The higher risk for occurrence of a fast thermal runaway has to be met by additional measures.

We shall have to design a battery management system at industrial level: Self-test capability and included protection shall be implemented. This covers operation. Practically, we cannot guarantee that never ever a fast thermal runaway shall emerge. If it comes from deep inside a cell, we should detect it as early as possible. The measurement of temperature increase speed, cell voltage changes, gaseous contents known to be produced at fast thermal runaway development like carbon monoxide and hydrogen together with some carbon-hydrogen molecules open new opportunities for increasing the safety level and allow starting counter-measures against fire propagation in a very early stage. We shall consider also fire extinction methods especially by cooling the critical area and this as soon as possible. In any case, we have to undertake several different actions for avoiding that the battery fire,

starting at a single cell, finalizes in a funeral for the whole battery. When electrical light-arcing occurs through internal short circuits, we get temperatures even in excess of 10 000 °C. The voltages and current ratings of electric vehicle batteries easily allow light arcing structures. Examples will be presented.

Once we have a Lithium ion battery system in its second life, it can be easily interfaced to Uninterruptible Power Supplies (UPS) that usually rely on lead-acid batteries. Through this also the UPS finds a second life and is a cheap variant for a home storage system in combination with photovoltaics.