Multiple batteries in series. All balancing circuits are connected and work as one system

Balancing act

Series-connected battery cells must be balanced, but what is the best method?

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The cells in a battery are balanced when every cell in the bank possesses the same state of charge (SoC). SoC refers to the remaining capacity of an individual cell relative to its maximum capacity as it charges and discharges. For example, a 100Ah cell with 20Ah of remaining capacity has a 20% state of charge.

All cells must be kept within a certain SoC range to avoid damage. The minimum and maximum allowable SoC levels vary from application to application. In certain applications where battery runtime is of primary importance, all cells may operate between a minimum SoC of 10% and a maximum of 100% – a fully charged state.

It is generally safe to assume that cells connected in parallel will auto-balance with respect to each other. That is, over time, the SoC will automatically equalize between parallel connected cells as long as a conducting path exists between the cell terminals.

It is also safe to assume that the SoC for battery cells connected in series will tend to diverge over time due to a number of influential factors. Gradual SoC changes may occur due to temperature gradients throughout the pack, or differences in impedance, self-discharge rates or loading from cell to cell.

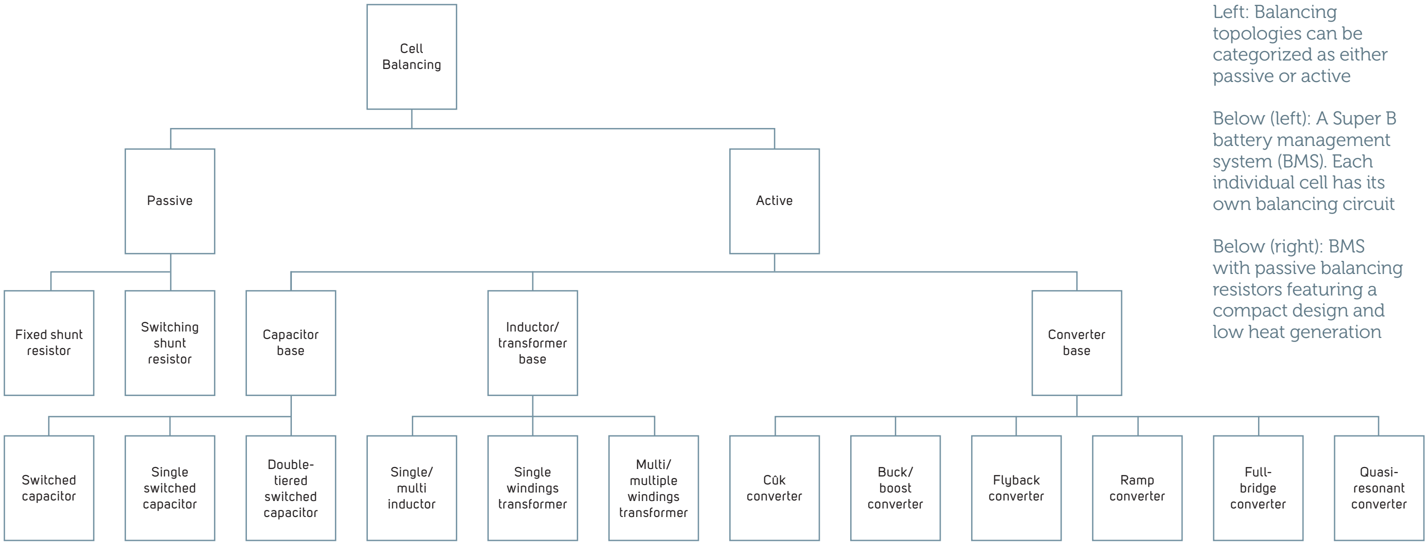
Although the battery pack charging and discharging currents tend to dwarf these cell-to-cell variations, the accumulated mismatch will grow unless the cells are periodically balanced.

Compensating for gradual changes in SoC from cell to cell is the most basic reason for balancing series-connected cells. Typically, a passive balancing scheme is adequate to rebalance SoC in a stack of cells with closely matched capacities.

All series-connected cells in a battery need to be balanced, and all batteries connected in series need to be balanced.

Balancing methodologies

The most commonly used balancing topologies can be categorized as passive and active balancing (see diagram overleaf).



Left: Balancing topologies can be categorized as either passive or active

Below (left): A Super B battery management system (BMS). Each individual cell has its own balancing circuit

Below (right): BMS with passive balancing resistors featuring a compact design and low heat generation

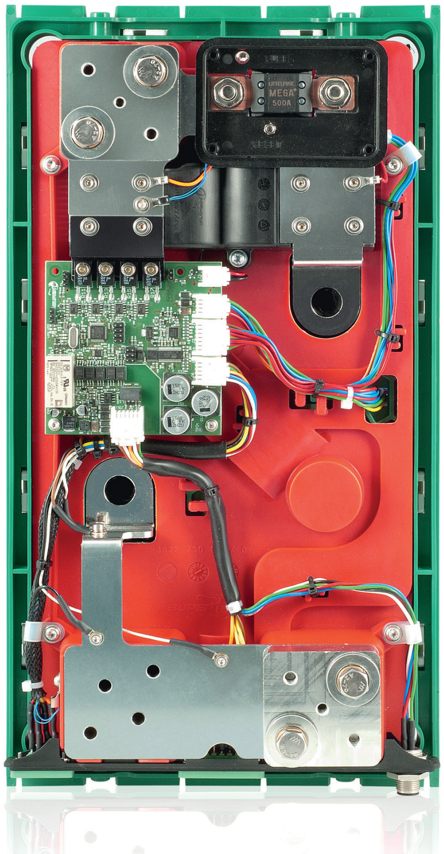
Passive balancing methods remove the excess charge from the more fully charged cell(s) through passive resistors until the charge matches that of the lower cells in the pack or a charge reference. The resistor will be in either fixed mode or switched.

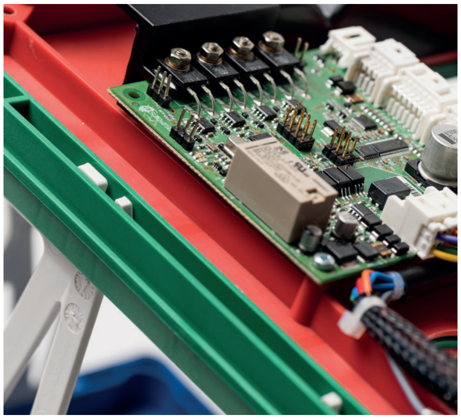
Active balancing methods remove charge from higher energy cell(s) and deliver it to lower energy cell(s). There are different topologies according to the active element used for storing the energy – such as a capacitor and/or inductive component, as well as controlling switches or converters.

The choice of balancing method depends on three things: the quality of the cells, how they are interconnected, and the use of the battery system.

Cell considerations

Super B battery cells are matched on capacity, open cell voltage and DC resistance. High-quality cells that are properly matched tend to age at a very similar rate and therefore require only moderate balancing, even at the end of their life.





Temperature has a big influence on the aging of cells. When they are stacked, such as in pouch cells, the cells in the middle operate at a higher temperature than those on the outside. Therefore, aging is different for each cell and a more aggressive balancing method is required.

Another factor is the interconnection between the cells. If the DC resistance between the cells is not equal, the voltage drop over the interconnection tabs will influence the charge of each individual cell.

Controlled shunting

The controlled-shunting resistor is based on removing the energy from the higher cell(s) – not continuously, but controlled using switches. This can work in two modes: continuous mode, where all the switches are controlled by the same on/off signal; or detecting mode, where the voltages and SoC of each cell module are monitored.

Super B uses switching shunt resistors in detecting mode. When imbalance conditions are sensed, the system decides which resistor should be shunted. This method is more efficient than the fixed-resistor method.

For a 1C charge of a 160Ah battery, the amount of energy that needs to be balanced is 150mAh. As such, a switching shunt balancing mechanism is the preferred choice for Super B batteries.

Super B batteries are continuously balanced, meaning that during charge or discharge the system automatically balances. These systems can operate continuously, without interrupting charge or discharge for balancing.

A state-of-the-art, in-house developed adaptive balancing software algorithm ensures minimum heat generation and a very short balancing time.