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SOC Needs for optimal active or passive Li-ion balancing techniques

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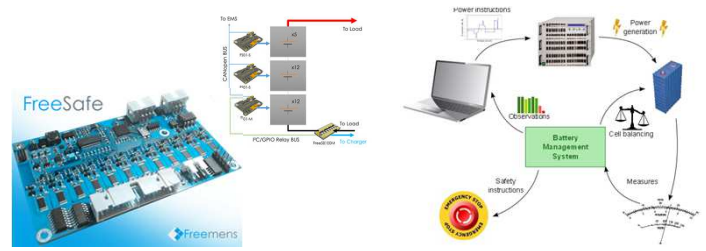
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Battery Management Systems

Battery management systems (BMS) are used in batteries with series connected cells to ensure the **battery safety**, the **optimization of the battery answer** to any power requests and the **access to reliable data on the battery state**.

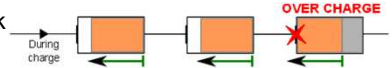
One of the most critical point to complete these functionalities is the accuracy of the implemented indicators used to estimate the battery state.



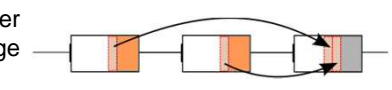
Cells disparities

Battery indicators such the *State Of Charge* (SOC) or *State Of Health* (SOH) are usually expressed at battery level for cells with homogeneous behaviors [1]. However this assumption is invalid when the cells present disparities in their initial characteristics and especially under aging conditions [2].

Example 1: increased risk of cell overcharge



Example 2: charges transfer for State Of Charge equalization



Legend: Capacity loss (grey), Stored charges (orange), Transferred charges (dotted orange), Charges stored during charge (green arrow)

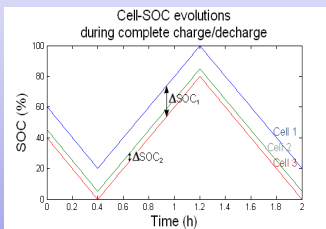
Effective maximum capacity Q_{max_bat} and SOC_{bat}

Q_{cell} denotes the present charge amount stored in the cells, Q_{max} and Q_{max_cell} the initial and the present maximum charge amounts that the cells can store and I_{cell} the current in the cells.

$$SOH_{cell} = \frac{Q_{max_cell}}{Q_{max}} \quad SOC_{cell}(t) = \frac{Q_{cell}(t)}{Q_{max_cell}}$$

1st case study Cells with the same SOH

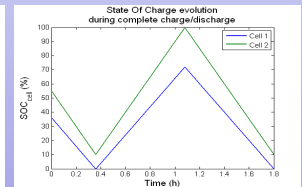
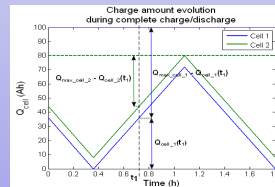
$$\begin{cases} Q_{max_bat} = Q_{max} * SOH * (1 - \max(\Delta SOC)) \\ SOC_{bat}(t) = \min_{1 \leq i \leq N} (SOC_{cell_i}(t)) * \frac{1}{1 - \max(\Delta SOC)} \end{cases}$$



2nd case study

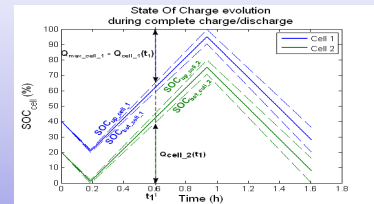
Cells with the SOH_{cell} disparities

$$\begin{cases} Q_{max_bat} = \min_{1 \leq i \leq N} (Q_{cell_i}(t)) + \min_{1 \leq i \leq N} (Q_{max_cell_i} - Q_{cell_i}(t)) \\ SOC_{bat}(t) = \frac{\min_{1 \leq i \leq N} (Q_{cell_i}(t))}{Q_{max_bat}} \\ Q_{max_bat} = Q_{max} * \left[\min_{1 \leq i \leq N} (SOH_{cell_i} * SOC_{cell_i}(t)) + \min_{1 \leq i \leq N} (SOH_{cell_i} * (1 - SOC_{cell_i}(t))) \right] \\ SOC_{bat}(t) = \frac{Q_{max} * \min_{1 \leq i \leq N} (SOH_{cell_i} * SOC_{cell_i}(t))}{Q_{max_bat}} \end{cases}$$

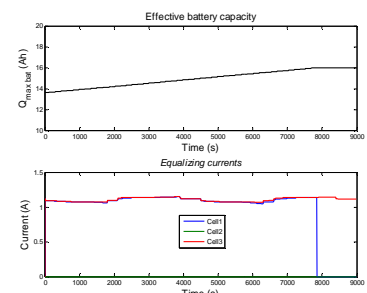
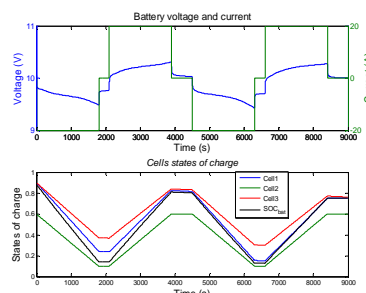
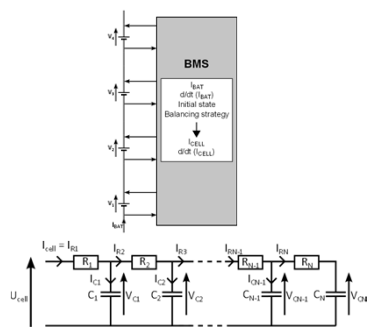


3rd case study With uncertainties on SOC estimations

$$\begin{cases} Q_{max_bat}(t) = Q_{max} * \left[\min_{1 \leq i \leq N} (SOH_{cell_i} * SOC_{bot_cell_i}(t)) + \min_{1 \leq i \leq N} (SOH_{cell_i} * (1 - SOC_{up_cell_i}(t))) \right] \\ SOC_{bat}(t) = \frac{Q_{max} * \min_{1 \leq i \leq N} (SOH_{cell_i} * SOC_{bot_cell_i}(t))}{Q_{max_bat}(t)} \end{cases}$$



Implementation



Simulation results – Behaviour of a battery composed of 3 cells Of 20Ah and with passive balancing

$$SOH_{cell_1} = 80\% \quad SOH_{cell_2} = SOH_{cell_3} = 100\%$$

