Li-Ion Myth-Buster

Poking holes into some common beliefs about Li-Ion cells and Li-Ion BMSs.

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As heard **this** morning:

"With few large format cells, each cell is monitored. With many small format cells, monitoring each cell is impractical."

Battery Power Conference 2010, 2,
The same BMS can work equally well with both formats.
Myths

A) Cells
B) Batteries
C) BMS
D) Balancing
Group A:
Myths about Li-Ion cells

- Cell capacity myths
- Cell swelling myths
Myth A1: "A cell puts out less charge than you put into it"

FALSE
Li-Ion charge efficiency = \textbf{100 \%}:

Every electron that goes in can come back out

(Though, energy efficiency is < 100 \%)
Charge efficiency

1 A in for 1 hour, 1 A out for 1 hour

SOC: 100 %, to 0 %, back to 100 %: charge efficiency is 100 %

Charge voltage is higher than OCV, lower during discharge

Charge power is more than discharge power

Energy doesn't go back down to 0: energy efficiency is < 100 %
Myth A2: "Cell capacity depends on rate of discharge"

FALSE
Yes, at high discharge a fixed cutout will stop discharge sooner
Capacity vs rate

But the rest is still there; you can still get it out, with a constant voltage load.
Capacity vs rate

But the rest is still there; you can still get it out, with a lower cutout

Cell voltage vs DOD (Depth of Discharge) at different rates (C rates): 0.1 C, 1 C, 10 C. As the rate increases, the cell voltage drops faster.
Myth A3:
"Cell capacity decreases with number of cycles"
Capacity vs cycles

Degradation = capacity loss

Higher resistance + fixed cutoffs = unused capacity
Group C:
"I don't need a BMS" myths

- Cutoff myth
- Small SOC range myth
- Extra cells myth
No BMS: I use a cutoff

C1: "I don't need a BMS my charger has a high voltage limit"

C2: "I don't need a BMS my load has a low voltage cut-off"

FALSE  FALSE
No BMS: I use a cutoff

There's no way of knowing the state of individual cells from the pack voltage.
No BMS: I use a cutoff

Top balancing won't help

<table>
<thead>
<tr>
<th>Fully charged, Top balanced</th>
<th>Discharged. All same capacity</th>
<th>Discharged. One has low capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.4 Vtot</td>
<td>11.2 Vtot = LV cutoff</td>
<td>11.2 Vtot = LV cutoff</td>
</tr>
<tr>
<td></td>
<td>3.6 V</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.6 V</td>
<td>2.8 V</td>
</tr>
<tr>
<td></td>
<td>3.6 V</td>
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<td></td>
</tr>
</tbody>
</table>

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No BMS: I use a cutoff

Yes: a CCCV will protect a top-balanced pack: when the pack voltage is at the max, all the cell voltages will be equally at the max.

However, when discharging without a BMS, the voltage of the least capacity cell will drop too far and be damaged.
## No BMS: I use a cutoff

### Bottom balancing won't help

<table>
<thead>
<tr>
<th>Fully discharged, Bottom balanced</th>
<th>Charged. All same capacity</th>
<th>Charged. 1 has low capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.0 Vtot</td>
<td>14.4 Vtot = Charger CV</td>
<td>14.4 Vtot = Charger CV</td>
</tr>
<tr>
<td>3.0 V</td>
<td>3.6 V</td>
<td>3.3 V</td>
</tr>
<tr>
<td>3.0 V</td>
<td>3.6 V</td>
<td>4.5 V</td>
</tr>
<tr>
<td>3.0 V</td>
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<td>3.6 V</td>
<td>3.3 V</td>
</tr>
</tbody>
</table>

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No BMS: I use a cutoff

Yes: a LV cutoff will protect a bottom-balanced pack: when the pack voltage is low, all the cell voltages will be equally low.

However, when charging without a BMS, the voltage of the least capacity cell will go too high.

And that's a fire danger!
No BMS: I mind the SOC

Myth #C3:
"I'll won't use the entire SOC range, so I don't need a BMS"

FALSE
Nice and easy: no BMS

The assumptions are that:
1) The pack SOC is known
2) All the cells are at that same SOC

Not so.

Without a BMS, the pack SOC is not known (and even a BMS doesn't always know the SOC)
More cells: no BMS

Myth #C4:
"Extra cells are cheaper than a BMS"

FALSE
More cells: no BMS

The assumption is that a pack without a BMS will simply slowly degrade. So, instead of buying a $1000 BMS, I'll buy 10 extra cells.

Not so.

A SINGLE overcharge or over-discharge event can kill a cell. And it will keep on happening after you replace that cell.
D: Balancing myths

Group D:
Myths about cell balancing

- Balance purpose myths
- Balance point myths
Balancing purpose

D1: "Balancing protects a battery"
D2: "Balancing compensates for variations in cell capacity"

FALSE   FALSE
Balancing purpose

The point of balancing is to maximize battery capacity.

Balancing brings all the cells to the same SOC at **ONE** point.

The SOC is balanced.
Bottom balancing

Myth D4: "Bottom balancing protects the cells"
Bottom balancing

No BMS & limited charge: bottom balance may work

Manually balance all cells at % SOC to stay away from overcharging

Stop charging at % SOC

Charge

Discharge

Turn off charger

Turn off load

SOC

Batt voltage

Cell voltage

Charge

Time

SOC

Manually balance all cells at % SOC to stay away from overcharging

Stop charging at % SOC

Turn off charger

Turn off load

SOC

Batt voltage

Cell voltage

Charge

Time

SOC

Manually balance all cells at % SOC to stay away from overcharging

Stop charging at % SOC

Turn off charger

Turn off load

SOC

Batt voltage

Cell voltage

Charge

Time

SOC

Manually balance all cells at % SOC to stay away from overcharging

Stop charging at % SOC

Turn off charger

Turn off load

SOC

Batt voltage

Cell voltage

Charge

Time

SOC

Manually balance all cells at % SOC to stay away from overcharging

Stop charging at % SOC

Turn off charger

Turn off load

SOC

Batt voltage

Cell voltage

Charge

Time

SOC

Manually balance all cells at % SOC to stay away from overcharging

Stop charging at % SOC

Turn off charger

Turn off load

SOC

Batt voltage

Cell voltage

Charge

Time

SOC

Manually balance all cells at % SOC to stay away from overcharging

Stop charging at % SOC

Turn off charger

Turn off load

SOC

Batt voltage

Cell voltage

Charge

Time

SOC

Manually balance all cells at % SOC to stay away from overcharging

Stop charging at % SOC

Turn off charger

Turn off load

SOC

Batt voltage

Cell voltage

Charge

Time

SOC

Manually balance all cells at % SOC to stay away from overcharging

Stop charging at % SOC

Turn off charger

Turn off load

SOC

Batt voltage

Cell voltage

Charge

Time

SOC

Manually balance all cells at % SOC to stay away from overcharging

Stop charging at % SOC

Turn off charger

Turn off load

SOC

Batt voltage

Cell voltage

Charge

Time

SOC

Manually balance all cells at % SOC to stay away from overcharging

Stop charging at % SOC

Turn off charger

Turn off load

SOC

Batt voltage

Cell voltage

Charge

Time

SOC

Manually balance all cells at % SOC to stay away from overcharging

Stop charging at % SOC

Turn off charger

Turn off load

SOC

Batt voltage

Cell voltage

Charge

Time

SOC
Bottom balancing

Otherwise, only top balance makes sense
Thank you

"Battery Management Systems for Large Lithium Ion Battery Packs"
Davide Andrea

book.LilonBMS.com

elithion.com