Battery Cells, SerialParallel, Balancing

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One LiFePO battery cell used by Lishen has nominal voltage $U = 3.0V$ and charge capacity $Q = 16.6Ah$ (also often used C).
If two cells are connected in serial we have $U = 6.0V$ and charge capacity $Q = 16.66Ah$
If two cells are connected in parallel we have $U = 3.0V$ and charge capacity $Q = 32.33Ah$.
The two parallel cells will automatically equalize in voltage by balancing.
If we connect m cells in parallel to supercells and then n such supercells in serial we get a (nS, mP) battery pack. Nomenclature is not unique in the literature.
In the LiShen standard Module M48A there is a 16S6P battery pack connection leading to

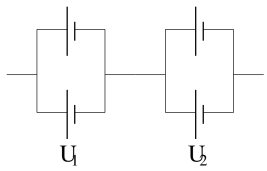

Figure 1: (2S2P) serial of parallel

$U = 16 * 3.0V = 48.0V$ nominal voltage and charge capacity $Q = 6 * 16.6Ah = 100Ah$ together with a Local Monitor Unit (LMU). The LMU consists of a Printed Circuit Board (PCB) with

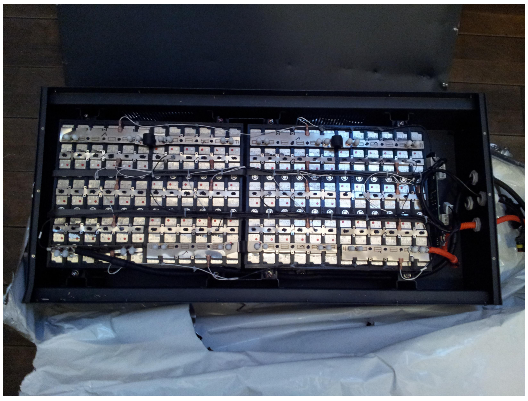

Figure 2: M48 battery unit

connections for the temperature sensors and the individual cell voltages for equalizing. Further there is CAN-Bus connection to the BMS and the other M48 modules.

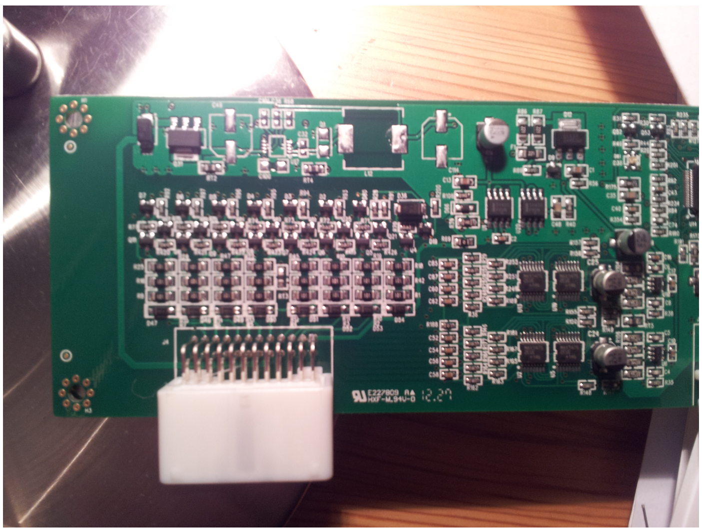

Figure 3: PCB of LMU for cell equalizer

0.1 Cell equalizing - Active vs. Passive

If two serial cells are discharged starting from equal voltage there is no mechanism guaranteeing equal voltage after partial discharge.
So with the total pack voltage alone it is not possible to protect each cell from deep-undercharging.
Similarly if we charge serial cells one could run into overcharging of one cell while the others are not full yet.
In case of LiIon cells that is a common issue and one has to use a cell equalizer which balances the cells until all have the same voltage due to safety reasons.
A cell equalizer works similar in a (nS,mP) serialParallelBack where it has to balance the

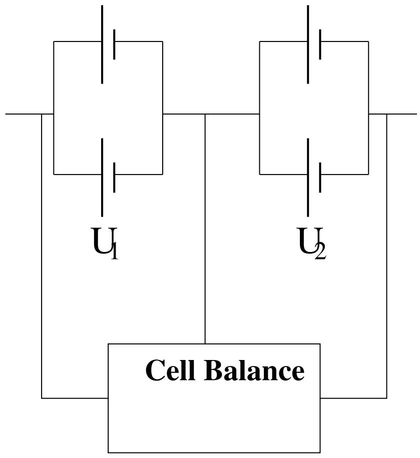

Figure 4: SerialParallel with Balance

n serial supercells, which in the Lishen case (16S6P) means that the LMU-equalizer needs to monitor the 16 serial voltages of the 6P supercells to be equal.
While the necessity to equalize the cell voltages is unchallenged, there is no agreement which method to use!
Roughly speaking they can be divided into passive (dissipating) and active (non-dissipative, energy transferring) methods

0.1.1 Passive, dissipative equalizing

In a passive, dissipating method the cell voltages are continously measured and during charging the cells with a voltage some threshold above (some mV) the lowest cell voltage are discharged over an auxiliary resistor network.
Because that discharging is often under control of a dedicated microcontroller, it is sometimes and misleadingly called active cell balancing.
That is done by the Lishen LMU and contributes to energy losses during charging/discharging cycles.
If the individual cell characteristics are very homogenous the energy dissipation in the resistor network is minimal and there is no need for more sophisticated active solutions.

0.1.2 Active,non-dissipative equalizing

The basic idea of an active non-dissipating method is that high-voltage cells are discharged to low-voltage cells and ideally no energy is dissipated.
These methods were popularized in satellite-powering applications and can be realized for example with a bus-topology on which the cells are periodically connected.
This increased complexity, e.g. some more $DC \rightarrow DC$ converters are necessary, can buy some extra run-time but the cost of equalization mainly pays-off if the individual cells show marked differences from each other.