



THE NEXT LEVEL: Lithium battery systems with a much increased lifespan



BMS with Q-Leveling

In a BMS with Q-Leveling, the battery assessment process is not based exclusively on information from the voltage curves of the cells during charging. The system also uses a dynamic cell-specific “capacity matrix” containing information about minor differences in capacity between the cells.

- All cells can be assigned an individual charging or discharging current.
- The weakest cells no longer determine the performance of the entire battery system.
- Ageing is slowed, so there is less variation in the rate of capacity loss for the different cells.
- Impacts of ageing are largely offset.

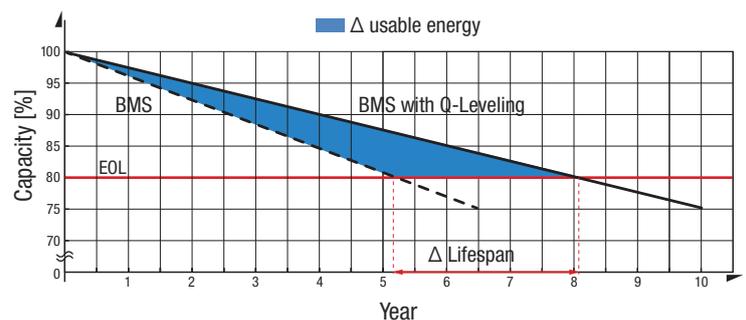
The challenge: As a battery system goes through more and more cycles, each cell experiences different rates of age-related capacity loss. This results in differences between the cells, which usually become very pronounced over time.

The technology & the solution: Q-Leveling uses sophisticated measurement and control algorithms to identify the specific state of charge and age-related capacity loss of each individual cell.

The result – longer lifespan: Q-Leveling eliminates the traditional reliance on all cells connected in series always being supplied with identical currents – thus solving the problem of the weakest cell connected in series determining the performance of the entire system.

Lifespan comparison

(Standard BMS vs. BMS with Q-Leveling)



- This lifespan comparison for a lithium-ion battery shows the impact that energy loss in one cell has on the whole system. This energy loss is much reduced when using a BMS with Q-Leveling.

Over the lifetime of a battery, Q-Leveling reduces variation in the rate of age-related capacity loss for the different cells connected in series and offsets the negative impacts of this.

Scientific study

A scientific evaluation of the Q-Leveling process was carried out by Offenburg University of Applied Sciences. The aim of the study was to analyse the process and how it works.

Methodology and verification of results

The study monitored a battery system for four days under test conditions. During this time, the system was put through several dynamic and abuse scenarios, and voltage, current and power measurements were taken at various measuring points.

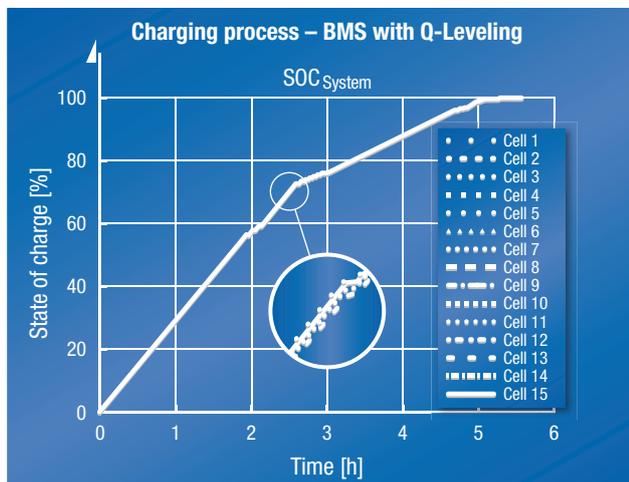
Fifteen cells, each with different capacities, were connected in series and managed using Q-Leveling. The maximum difference in capacity between the individual cells in the battery block was 96% (see table).

No.	Cell type	Product ref.	Nominal capacity	Actual capacity
1	LFP	Sinopoly, SP-LFP40AHA	40 Ah	39.3 Ah
2	LFP	InnoPower, LFP40 AH	40 Ah	38.5 Ah
3	LFP	Winston, WB-LYP60AHA	60 Ah	74.0 Ah
4	LFP	Sinopoly, SP-LFP40AHA	40 Ah	38.8 Ah
5	LFP	Sinopoly, SP-LFP40AHA	40 Ah	39.0 Ah
6	LFP	HiPower, HP-PW-60AH	60 Ah	52.9 Ah
7	LFP	Winston, WB-LYP40AHA	40 Ah	42.8 Ah
8	LFP	Winston, WB-LYP40AHA	40 Ah	44.2 Ah
9	LFP	Winston, WB-LYP40AHA	40 Ah	42.0 Ah
10	LFP	Winston, WB-LYP40AHA	40 Ah	44.6 Ah
11	LFP	Winston, WB-LYP60AHA	60 Ah	75.5 Ah
12	LFP	Sinopoly, SP-LFP40AHA	40 Ah	39.2 Ah
13	LFP	Sinopoly, SP-LFP40AHA	40 Ah	39.1 Ah
14	LFP	Winston, WB-LYP60AHA	60 Ah	76.0 Ah
15	LFP	Sinopoly, SP-LFP40AHA	40 Ah	39.5 Ah

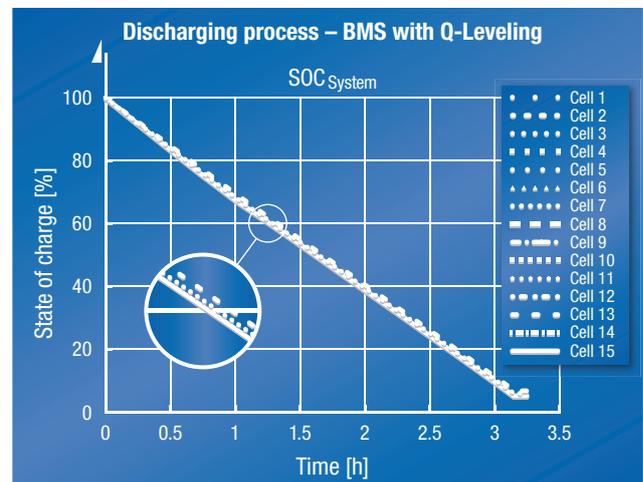
The nominal capacity was taken from the manufacturer's specifications. The actual capacity (i.e. usable capacity) was measured using Q-Leveling.

All the cells in the battery system were subsequently analysed under laboratory conditions, primarily to verify the capacity measurements generated by Q-Leveling for each individual cell.

SoC curve for the whole battery system

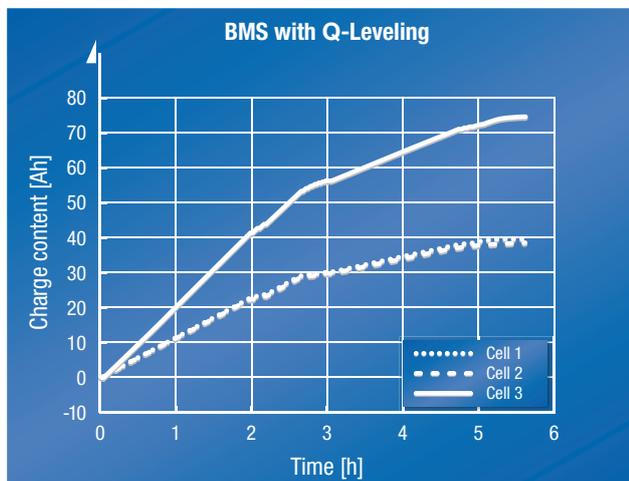


- Despite the significant differences in capacity within the battery system, the state of charge (SoC) curves for the individual cells are almost identical.

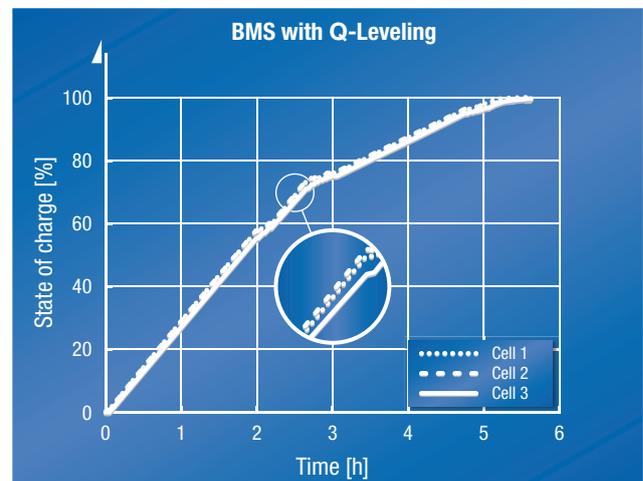


- The SoC for each individual cell aligns with the SoC for the whole system at all times.

Detailed view of the SoC curve for three sample cells from the battery system



- For all cells to maintain the same SoC, each cell must be supplied with its own individual charging current during charging and discharging. This ensures that, despite their different capacities,



- the individual cells maintain almost the same SoC (based on their individual capacities).



The study found that the innovative circuit concept, which combines a series current with parallel currents for individual cells, performed well under test conditions.

The capacity management system (CMS) therefore proved itself effective.” (Quote from Offenburg University of Applied Sciences)

Note: CMS is the original name for the process now called Q-Leveling.

Summary of the facts

Option to combine cells from different manufacturers

- Q-Leveling works well with Lithium-ion batteries connected in series from different manufacturers, including where their capacities differ by almost 100% and for use cases with dynamic load profiles.

Comprehensive data source

- Q-Leveling can generate relevant information whenever required about the current charge level, overall capacity, current SoC, temperature, voltage and charging/discharging current.

Almost identical state of charge (SoC) across all cells

- In addition to the current from the primary circuit, each cell is supplied with its own dynamic charging and discharging current from a secondary circuit. This ensures that, despite their significantly different capacities, all cells maintain approximately the same state of charge (SoC) at all times.

Benefits of a BMS with Q-Leveling

- ✓ Longer battery lifespan
- ✓ Possible to have significant variation between cells within a system
- ✓ Greater system energy turnover thanks to improved lifespan
- ✓ Cells are well preserved, slowing the ageing process of the individual cells
- ✓ Information about individual cells available at any time
- ✓ Defective cells can be easily replaced when needed
- ✓ Cost reduction through reliable lifespan planning (ROI)
- ✓ Cost reduction thanks to less necessary servicing and easier maintenance
- ✓ Shorter charging times
- ✓ More uniform ageing times of a system's individual cells
- ✓ Ageing mechanisms are inhibited owing to higher cell voltages

Q-Leveling is ideal for:

- ✓ Battery systems
 - with large capacities
 - with significant differences in capacity between cells
 - that comprise cells from different manufacturers
- ✓ For retrofitting existing batteries with common BMS systems

Opportunities for collaboration

There are many ways in which you can use the processes we have developed. For instance:

Licensed use

If you would like to rely on your own development resources, we would be happy to support and advise you during your development phase. We offer support for specific elements of individual phases of implementing the processes or for the entire development period in the form of regular workshops. The process-oriented algorithms can then be used on the basis of a licencing contract.

Development contract

Would you like to commission us to develop a battery management system for you? We would be happy to make you an offer for the development of a customised BMS including Q-Leveling.

From initial designs to the development of the electronic components to the certification of the final product, we attend to all of the necessary tasks for you, including functional safety tasks.

Upon request, we will even take care of series production of the electronics afterwards. In this case, a use licence for the process can be precalculated into the price.

Make your ideas a reality

Do you have ideas about how you can benefit from the potential our processes offer? Let us know – whether you are looking to develop a completely new product or if you would like to secure the exclusive rights for use in a specific industry.

As you can see, there are many ways for us to collaborate to reach your goals. But they all have one thing in common: Through existing patent protection, you can ensure exclusive benefits and a leading technological edge over your competitors that are yours to keep.



Founded in 2017, BENNING CMS Technology GmbH is a company which specialises in the new development of battery management systems (BMS) and their technical implementation for lithium battery systems.

We have since patented two revolutionary processes for lithium battery system operation which are more efficient and economical, and which better preserve the battery system. We have also applied for patents for even more ideas.

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