Presenting the Modular Multilevel Battery (M2B): A new Generation of Battery Storage Systems

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Abstract

The dependency of energy systems on battery storage systems is constantly increasing, but there are still several unsolved problems. Current battery systems are inflexible: only cells with the same electrical parameters can be combined, and cell defects cause a high reduction of the overall battery lifetime or even a system black out. In addition, the maximum usable capacity and the maximum charging current are limited by the weakest cell in the system.

Current Battery Management Systems (BMS) solve some of these problems, but simultaneously raise other disadvantages. With the M2B, a very flexible, fault tolerant, and cost-efficient battery storage system can be implemented. With this system, it is possible to establish either serial or parallel connections between neighboring modules or to bypass a module. Moreover, a dedicated converter, linking the batteries (DC) to the grid (AC) is no longer needed as BMS and power electronics are merged into one single system.

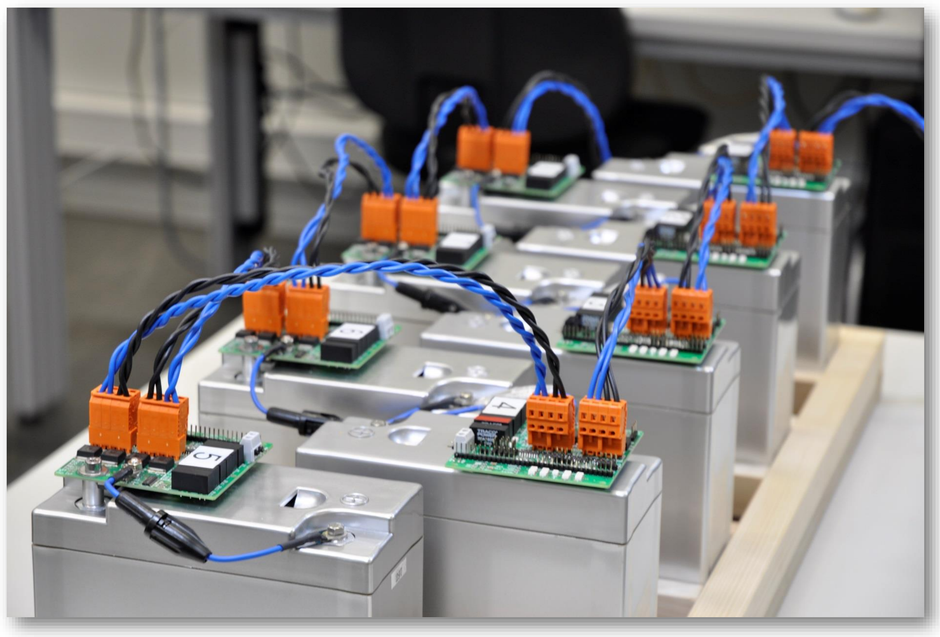

Fig 1: Laboratory prototype of proposed battery storage system with 8 modules 2 kWh capacity (LFP cells) and rated power of 4 kW (single phase) featuring a very high efficiency and dynamic, SOC-based cell balancing.

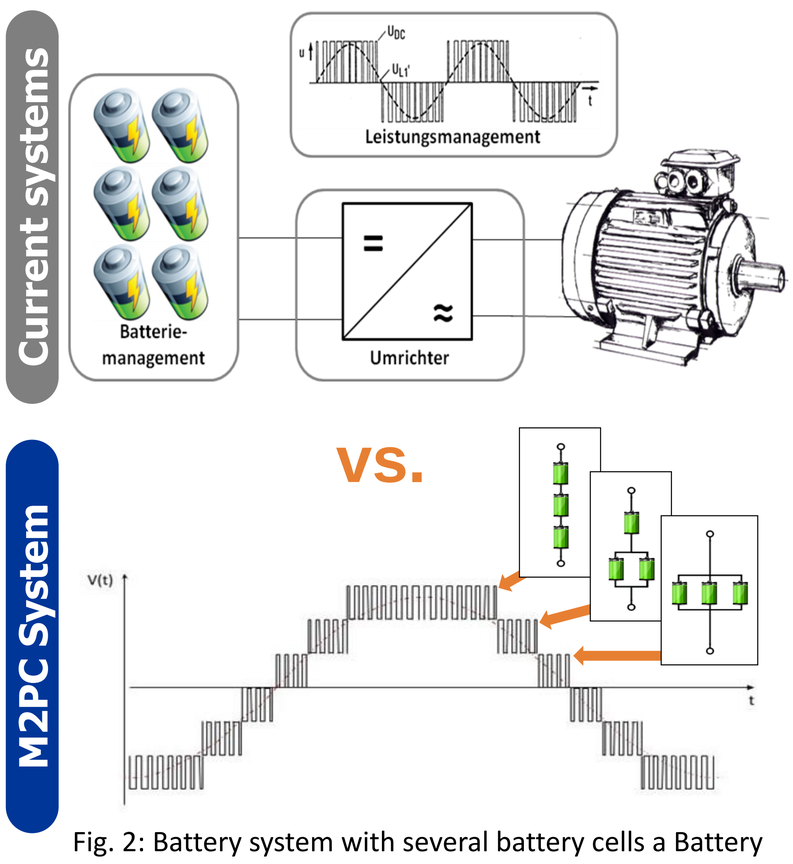

Fig. 2: Battery system with several battery cells a Battery Management System (BMS) and an inverter vs. novel M2PC implementation

Comparison

With our Modular Multi-Level Parallel Converter based Split Battery System (M2B) [4] a fundamentally new approach to directly integrate power electronics on battery cells or packs is presented. As BMS and bidirectional converter become a unity, several advantages to the state-of-the-art systems arise:

Current battery storage systems [1-3]

Static series – parallel connection of cells

- Cell failure = System failure
- Only identical cells usable
- Complex cell balancing system needed
- Dangerous high voltage DC, even if the system is shut down
- Converter switching full voltage at fixed PWM frequency
- Low efficiency especially at partial load

M2B System

Dynamical connection of cells: Serial – Parallel – Bypass

- Cell failure ≠ System failure
- Unequal cells can be combined
- Separate cell balancing can be omitted because it is inherently incorporated
- No dangerous high voltage DC, even if the system is shut down
- Arbitrary output voltage without need of dedicated converter

Basic Idea – M2B Topology

The M2B establishes flexible interconnections between its modules for optimum utilization and efficiency of the battery pack, while eliminating special need for cell/pack balancing. Thus the cells can be operated according to their needs and their state of charge (SOC). Separate balancing methods for balancing the SOCs however, become obsolete.

Individual modules can be bypassed, if they are full or defective, and rearranged in series and in parallel to adjust their charge or discharge rate. Using these switching configurations arbitrary output functions can be created by approximating them with voltage steps as depicted in Fig. 2 for a sine wave. This principle leads to higher efficiency and massively decreased voltage and current harmonics, making it possible to reduce system size and volume due to smaller output filters and less need for cooling.

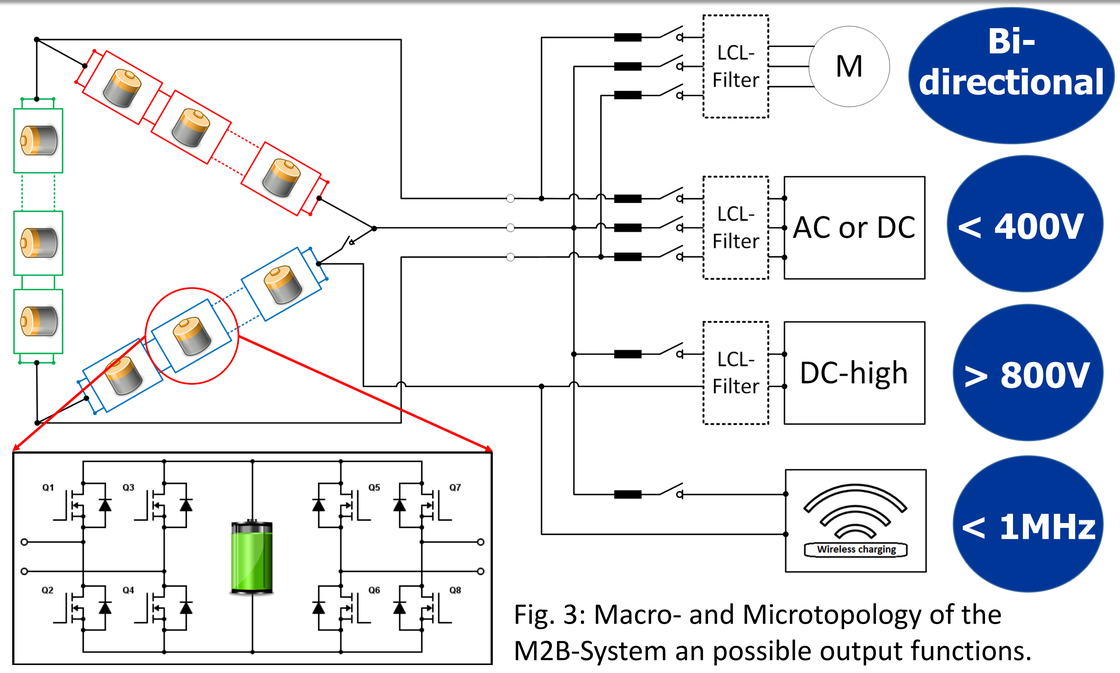

Fig. 3: Macro- and Microtopology of the M2B-System an possible output functions.

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Next step: eXIST Existenzgründungen aus der Wissenschaft

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Conclusion

- Battery is no longer an inflexible static component
- Cell balancing is an inherent function of the circuit
- More extensive use of the chemically available capacity
- Option to combine cells with different electrical properties:
  - Combination of the advantages of different cell types
  - Compensation of the shortcomings of different cell types
- Option to use Second-Life-Cells
- Increased fault tolerance (Bypass of defective cells)
- Flexibly expandable: Additional Submodules (SMs) can just be plugged in
  - without redesigning the system and
  - without accurate matching of the cell parameters.
- Battery system is no longer a dangerous high-voltage DC system; maximum the voltage level of one cell is applied to any point in the system, if the M2B is shut down.
- Very high efficiency, even at low load conditions

[1] J. Cao, N. Schofield, and A. Emadi, "Battery balancing methods: A comprehensive review," Vehicle Power and Propulsion Conference, 2008. VPPC '08. IEEE, pp. 1-6, 3-5 Sept. 2008.
[2] M. Uno and K. Tanaka, "Influence of High-Frequency Charge-Discharge Cycling Induced by Cell Voltage Equalizers on the Life Performance of Lithium-Ion Cells," Vehicular Technology, IEEE Transactions on, vol. 60, pp. 1505-1515, 2011.
[3] R. F. Nelson and M. A. Kepros, "AC ripple effects on VRLA batteries in float applications," Battery Conference on Applications and Advances, 1999. The Fourteenth Annual, pp. 281-289, 1999
[4] A. Singer, F. Helling, T. Weyh, H.-J. Pfisterer, and U. Bürger, “Ein disruptiver Ansatz: Hocheffiziente, modulare Energiespeicher durch den verstärkten Einsatz von Software und offener Hardware,” VDE-Kongress 2016