Technical University of Munich

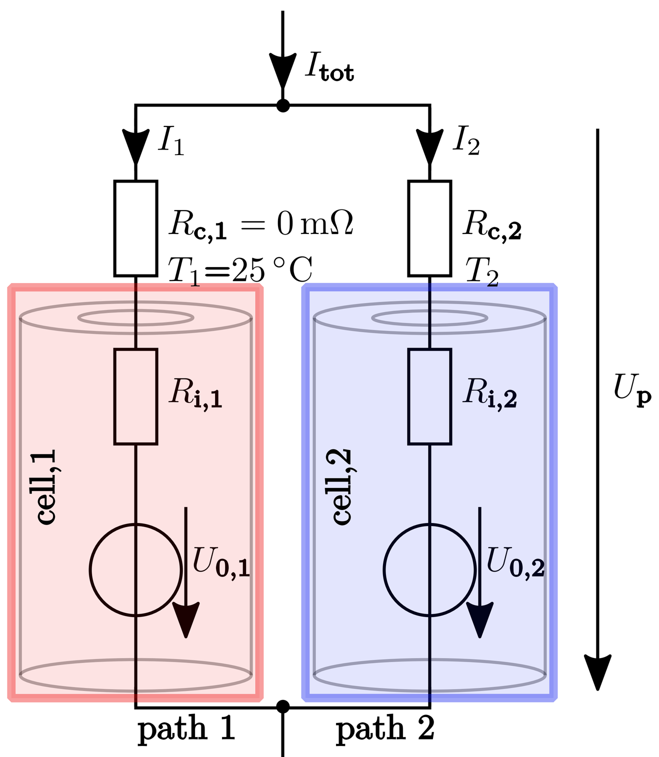
Strength and Challenges of Sodium-Ion and Lithium-Ion Technology regarding Scaling from Cell to System * *Under review

P. Jocher, F. Roehrer, M. Rehm, T. Idrizi, A.V. Himmelreich, A. Jossen

Technical University of Munich (TUM), TUM School of Engineering and Design, Chair of Electrical Energy Storage Technology, Arcisstr. 21, 80333 Munich, Germany

Scope of Study

- What are the challenges and strengths of different cell technologies (LIB_{NCA}, LIB_{LFP} and SIB) for scaling from a cell to a parallel system?
- How sensitive are LIB_{NCA}, LIB_{LFP} and SIB against inhomogeneous path resistance and temperature?
    - What is the resulting current difference?
    - What is the resulting SoC difference?
- What are the consequences for the application?



Simplified ECM of a two parallel battery connection. The voltage sources $U_{0,1}$ and $U_{0,2}$, and the internal resistances $R_{i,1}$ and $R_{i,2}$ represent the cells. T_1 and T_2 represent possible temperature inhomogeneities between the two cells. Additionally, the path resistances, $R_{c,1}$,1 and $R_{c,2}$, stand for any additional potential drop.

Design of Experiment

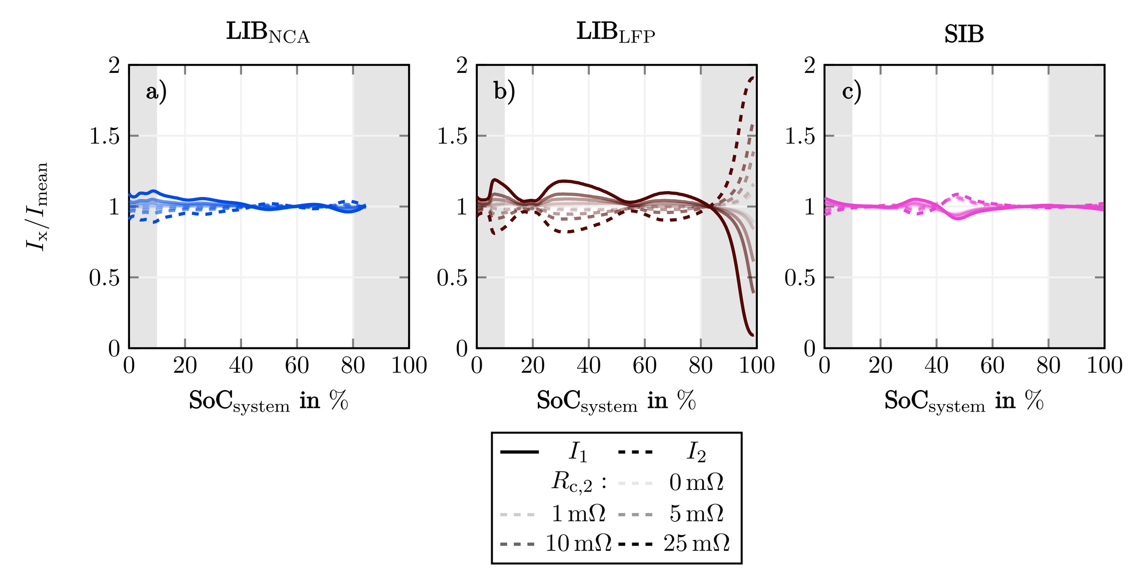
Testbench: Virtual Parallel Connection [1]

Resistance: $R_{c,1} = 0\ \mathrm{m\Omega}$ and $R_{c,2} = 0\ \ldots\ 25\ \mathrm{m\Omega}$

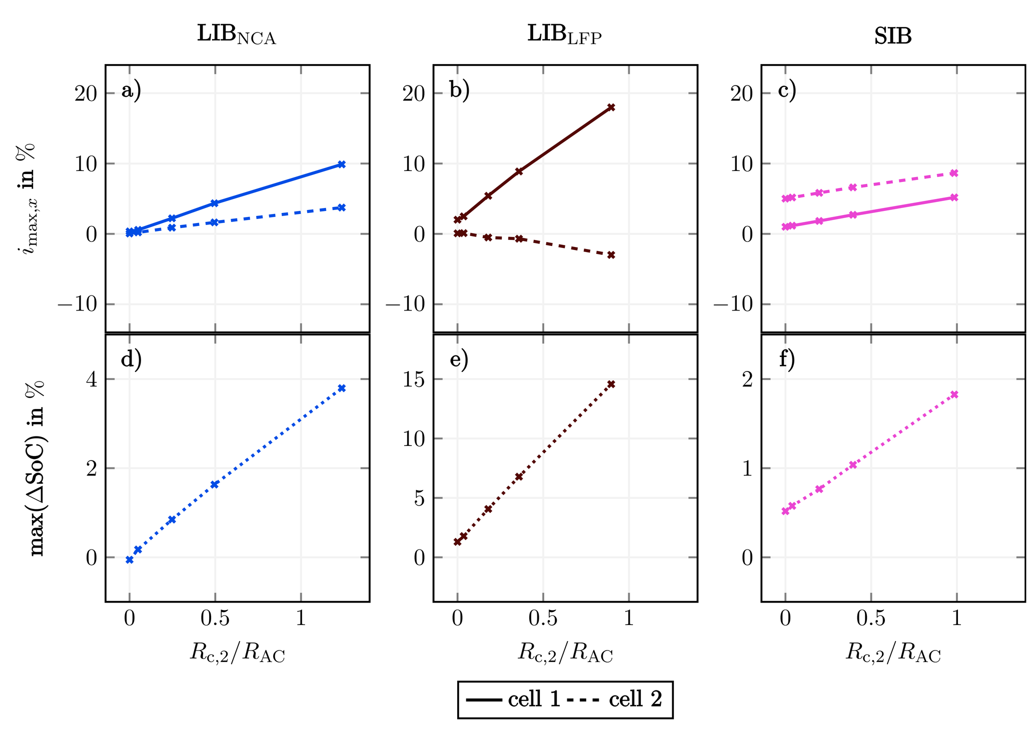
Temperature: $T_1 = 25\ °C$ and $T_2 = 15\ °C\ \ldots\ 35\ °C$

Parameter	LIB_{NCA}	LIB_{LFP}	SIB
Identifier	NR18650-35E	HDCF18650-1800	NA18650-1250
Manufacturer	Samsung SDI	HAIDI Energy Group	Shenzhen Mushang
Capacity in Ah	3.35	1.8	1.25
Lower voltage in V	2.65	2	1.5
Upper voltage in V	4.2	3.65	3.8
$Z_{AC,Zlm=0}$ in mΩ	20.2 ± 0.1	27.9 ± 0.2	25.4 ± 0.3
$R_{DC,10\,s}$ in mΩ	37.12 ± 0.05	58.4 ± 1.0	84.99 ± 0.01

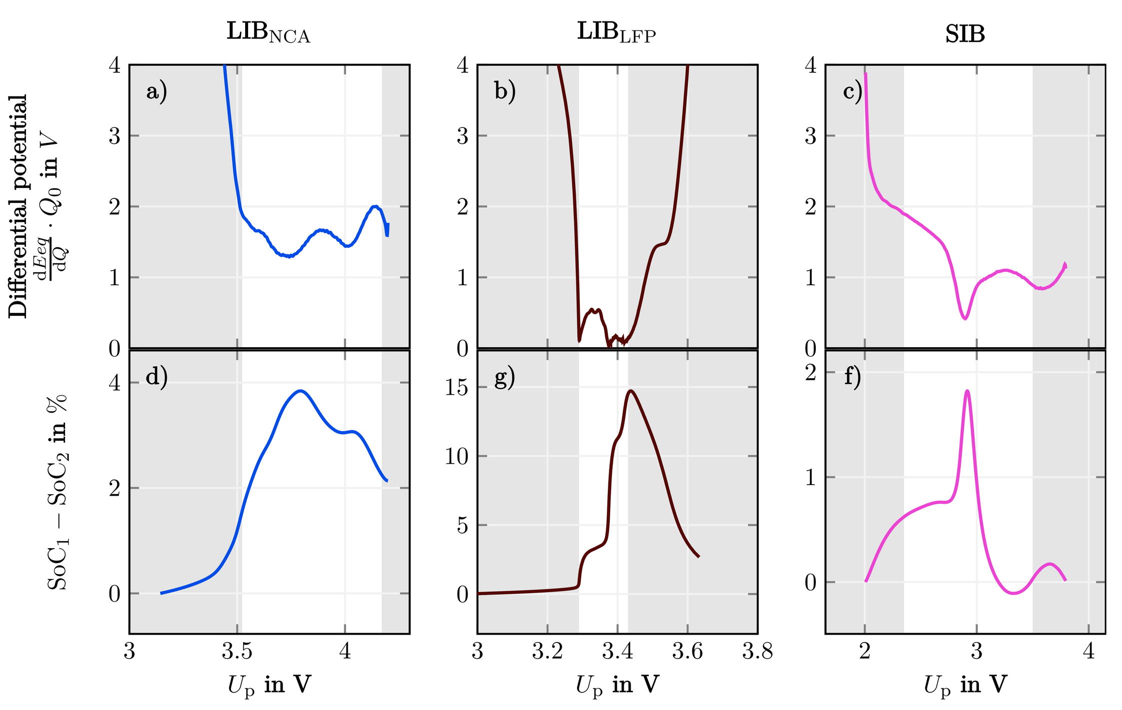
Results



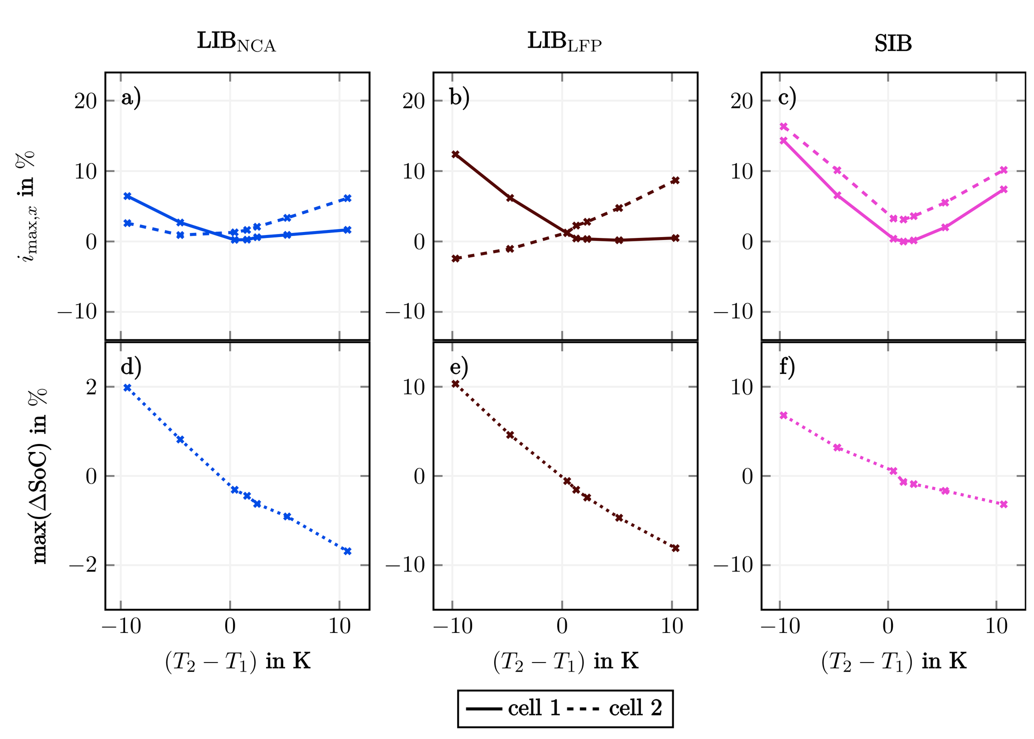
Current distribution between 2p connected cells during CC charging with 0.5 C regarding inhomogeneous contact resistance. The resistance, $R_{c,2}$, was varied from 0 to 25 mΩ.



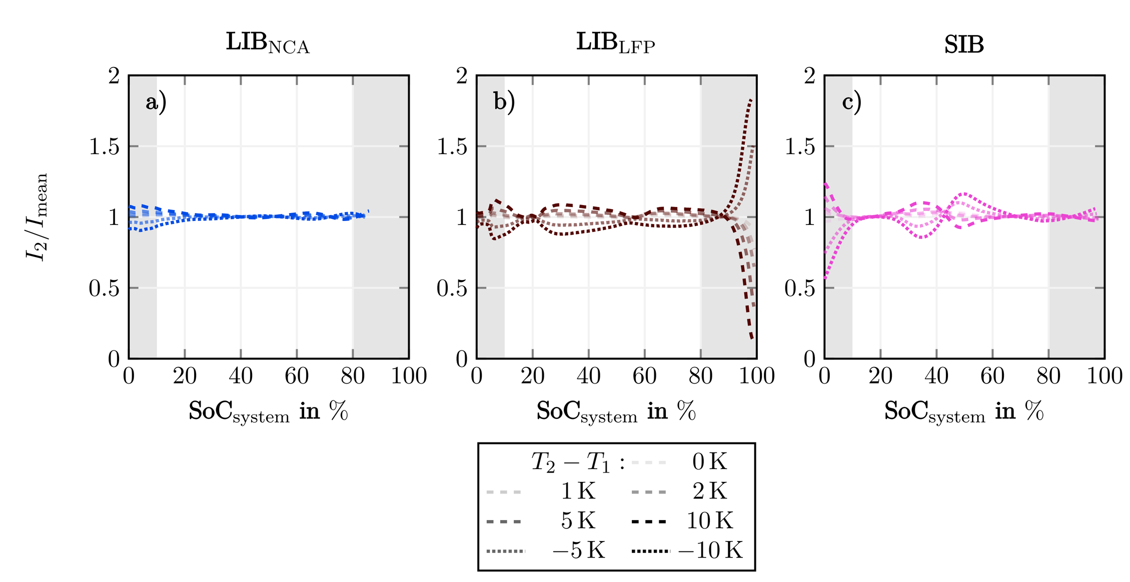
Maxima of the current distribution regarding inhomogeneous contact resistance between 10 to 80 % SoC_{system}. Please be aware that the y-axis of Subfigure d), e) and f) is different.



Differential Voltage Analysis a-c) during CC charge with 0.5 C. Subfigures d), e) and f) correspond to the SoC cell to cell difference regarding the additional contact resistance $R_{c,2} = 25\ \mathrm{m\Omega}$. A large SoC difference between the cells can be traced back to a small slope of the OCV. The gray areas represent low SoC_{system} < 10 % and high SoC_{system} > 80 %.



Maxima of the current distribution regarding inhomogeneous path temperature between 10 to 80 % SoC_{system}. Subfigures a), b) and c) represents the maximum current and d), e) and f) the maximum SoC differences between both cells, x ∈ 1, 2. Please be aware that the y-axis of Subfigures d), e) and f) is different.

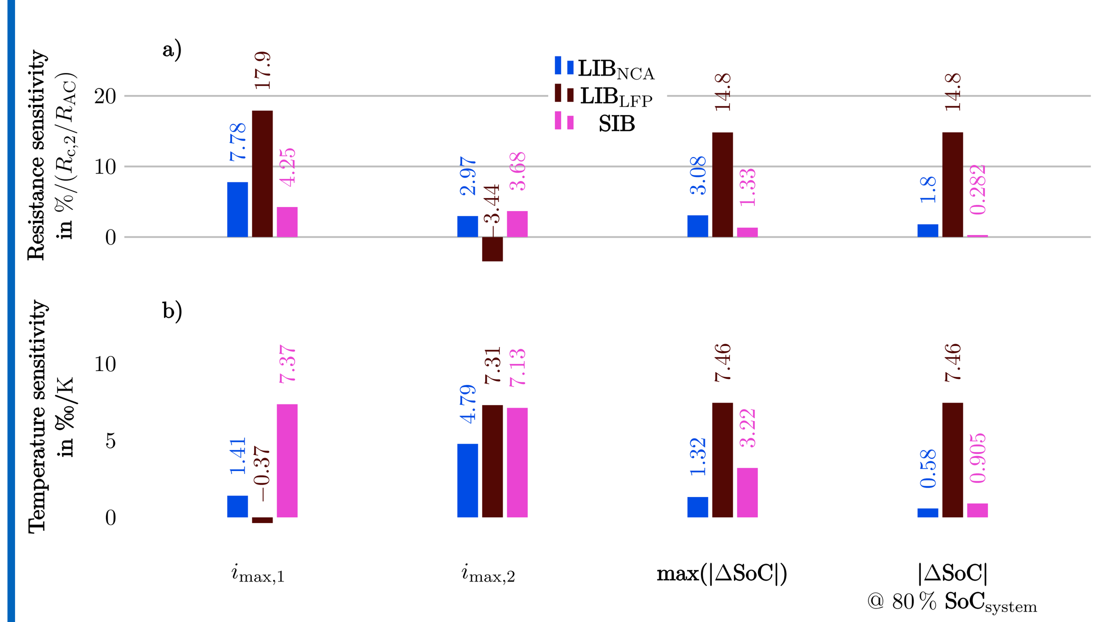


Current distribution between 2p connected cells during CC charging with 0.5 C regarding inhomogeneous path temperature. The temperature T_2 was varied from 15 °C to 35 °C, T_1 was kept to 25 °C.

- Maximum values are dependent linearly
- Slope can be calculated to quantify inhomogeneity

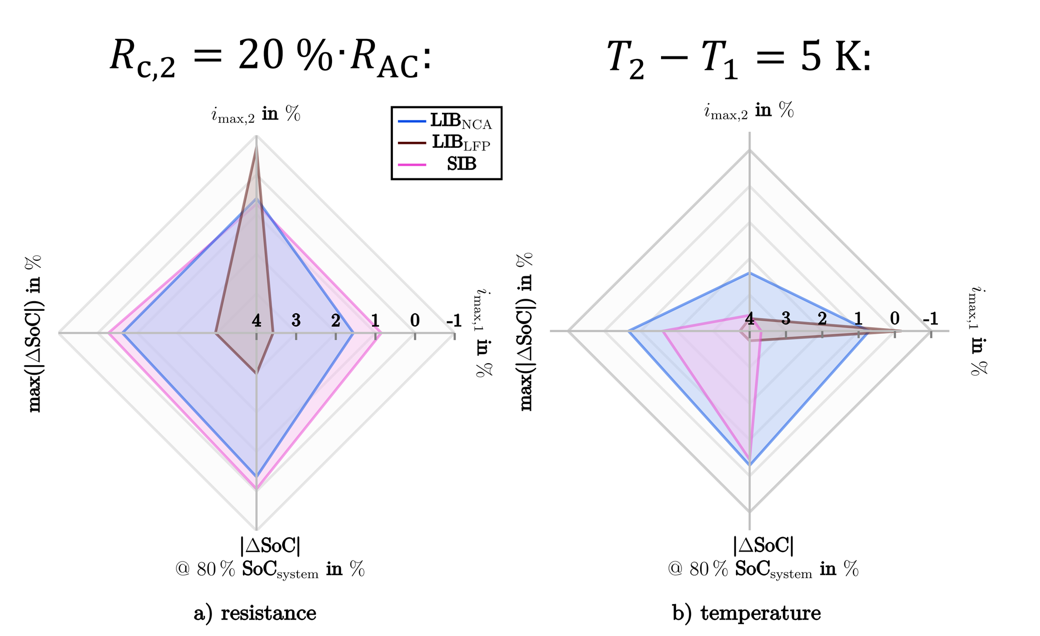
➡ Sensitivity factor to quantify inhomogeneity

Conclusion



Sensitivity factor regarding inhomogeneous contact resistance and path temperature between 10 and 80 % SoC_{system}. Quantitative comparison between the investigated sensitivity factors, $i_{max,x}$, maximum and at SoC_{system}=80 % SoC difference between the cells for a)resistance and b) temperature.

- LIB_{LFP} shows strong influence for both, inhomogeneous path resistance and temperature
- SIB exhibit strongest dependence of inhomogeneous path temperature
- LIB_{NMC} cell demonstrates comparatively low sensitivity to both investigated inhomogeneities compared to the other cells



Comparison between the sensitivity factors, $i_{max,x}$, max(|ΔSoC|) and |ΔSoC| @ SoC_{system}=80 %. Subfigure a) represents an inhomogeneous contact resistance in the order of $R_{c,2} = 20\ \% \cdot R_{AC}$ and b) a temperature difference, $T_2 - T_1$, of 5 K. The numbers represent the inhomogeneity of each sensitivity factor in %. Consequently, a large area corresponds toa small sensitivity. The SoC range between 10 to 80 % is considered.

Technical University of Munich
TUM School of Engineering and Design
Chair of Electrical Energy Storage Technology

References
[1] P. Jocher, M. Steinhardt, S. Ludwig, M. Schindler, J. Martin, A. Jossen, A novel measurement technique for parallel-connected lithium-ion cells with controllable interconnection resistance, Journal of Power Sources 503 (2021) 230030. doi:10.1016/j.jpowsour.2021.230030.

Acknowledgements
This research is funded by the German Federal Ministry of Education and Research (BMBF) via the OSLiB research project (grant number 03X90330 A).

BattNutzung OSLiB

SPONSORED BY THE Federal Ministry of Education and Research