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Operational Performance Characterization of Commercial Scale VFB at Various Electrical and Thermal States

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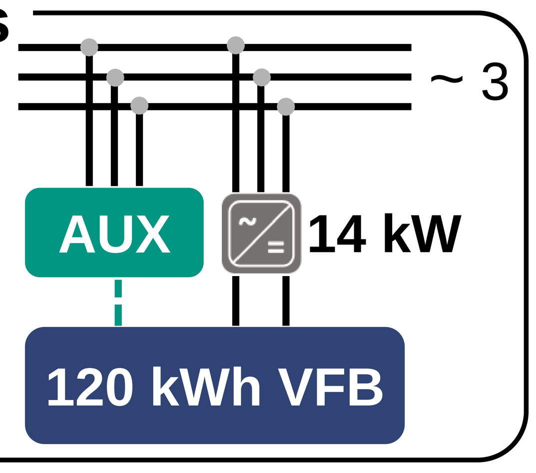
01 Motivation

- With project „BiFlow“ in KIT, a Vanadium Flow Battery (VFB) is used as an electrical as well as thermal storage.
- The VFB could be artificially cooled or heated through a Thermal Coupling Module (TCM) in near future.
- Thermal vs electrical characteristics of the VFB are required in order to optimally control this novel application.

02 Setup and data used for analysis

- VFB is used for self-sufficiency improvement of a student residence in Bruchsal, Germany.
- Operated since April 2022 at max 14 kW and between 12 – 47 °C.
- Runs from 0 – 100 % SOC_{BMS} almost daily.
- Can be operated till 20 kW in near future.



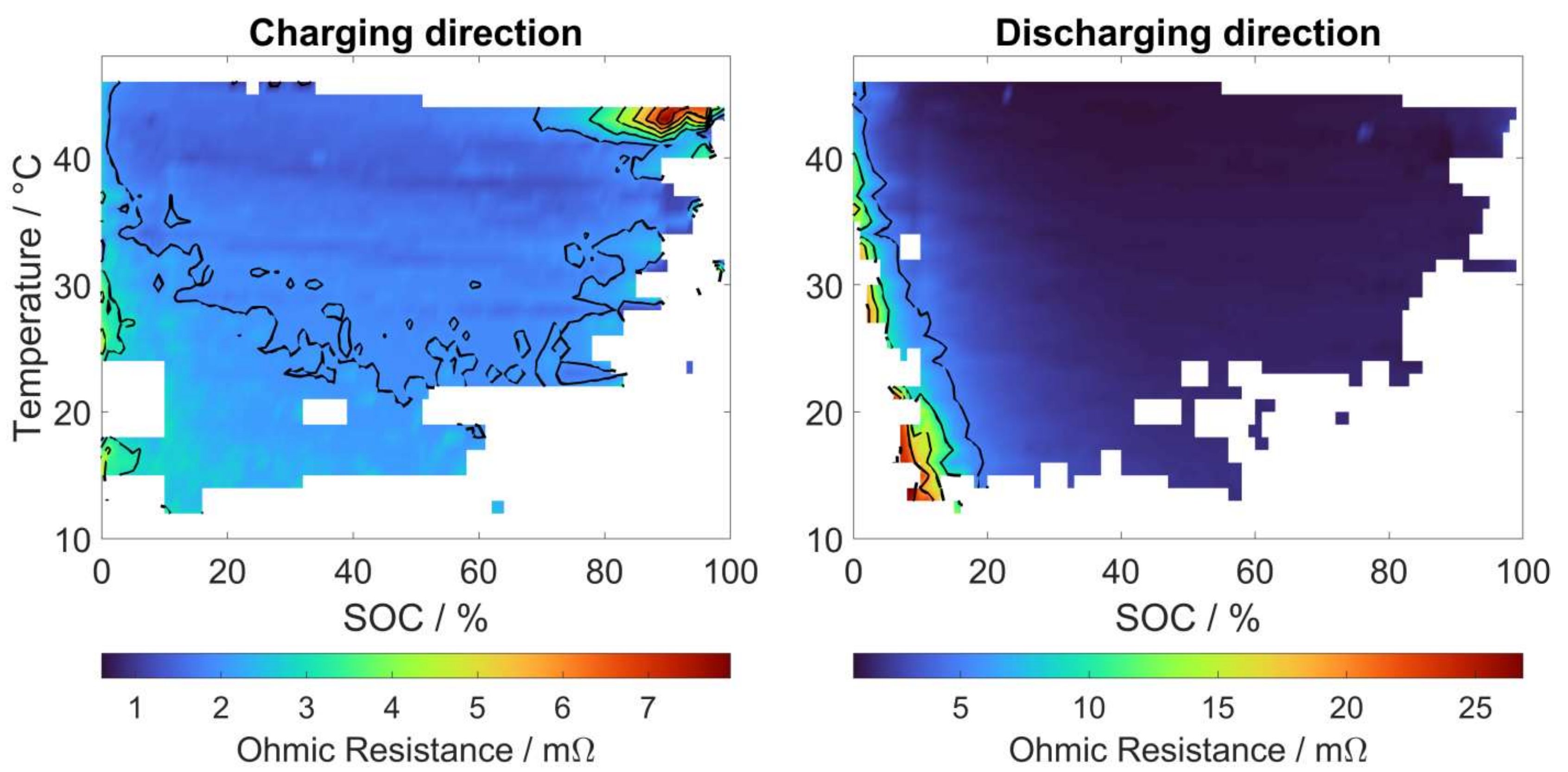


Fig 1. Cell level R_{Ohm} map measured during the operation. Resolution: 1 °C by 1 % SOC

03 Cell internal resistance characterization

- Based on 1 year live measurements of stack voltage, current and OCV (from reference cell), internal resistance is estimated as [1]:

$$R_{\mathrm{Ohm}} = ((U_{\mathrm{stack}}/n_{\mathrm{cell}}) - OCV)/I_{\mathrm{stack}}$$

	Charging direction									Discharging direction								
Temperature	↑			–			↓			↑			–			↓		
SOC	↑	–	↓	↑	–	↓	↑	–	↓	↑	–	↓	↑	–	↓	↑	–	↓
Cell R_{Ohm}	↑	↓	↓	?	↓	–	?	–	–	↓	↓	↓	↓	↓	↑	?	↓	↑

Legend = ↑ : High, – : Medium, ↓ : Low, ? : Unknown

04 Auxiliary requirement characterization

- Pumps power requirement = 70 – 90 % of auxiliary load (P_{Aux})

$$P_{\mathrm{Aux}} \propto Electrolyte\ viscocity \propto \begin{cases} SOC\ [2] \\ 1/T_{\mathrm{Electrolyte}}\ [2] \end{cases}$$

- Additionally, VFB actively regulates the pump speed according to the electrical output requested by the EMS ($P_{\mathrm{EMS,Target}}$) ⇒

$$P_{\mathrm{Aux}} = f(SOC, Temp, P_{\mathrm{EMS,Target}})$$

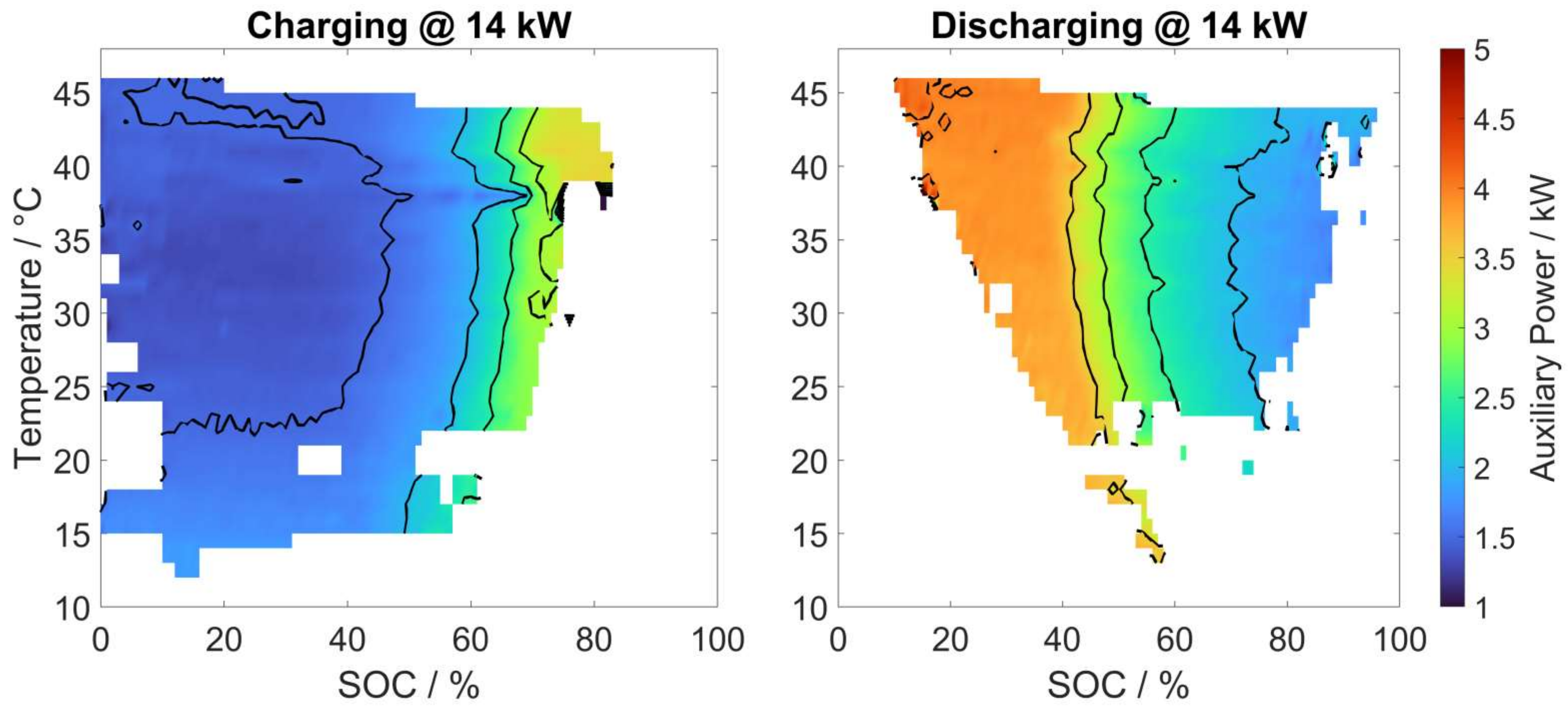


Fig 2. Total Auxiliary power requirement when operated at 14 kW. Resolution: 1 °C by 1 % SOC

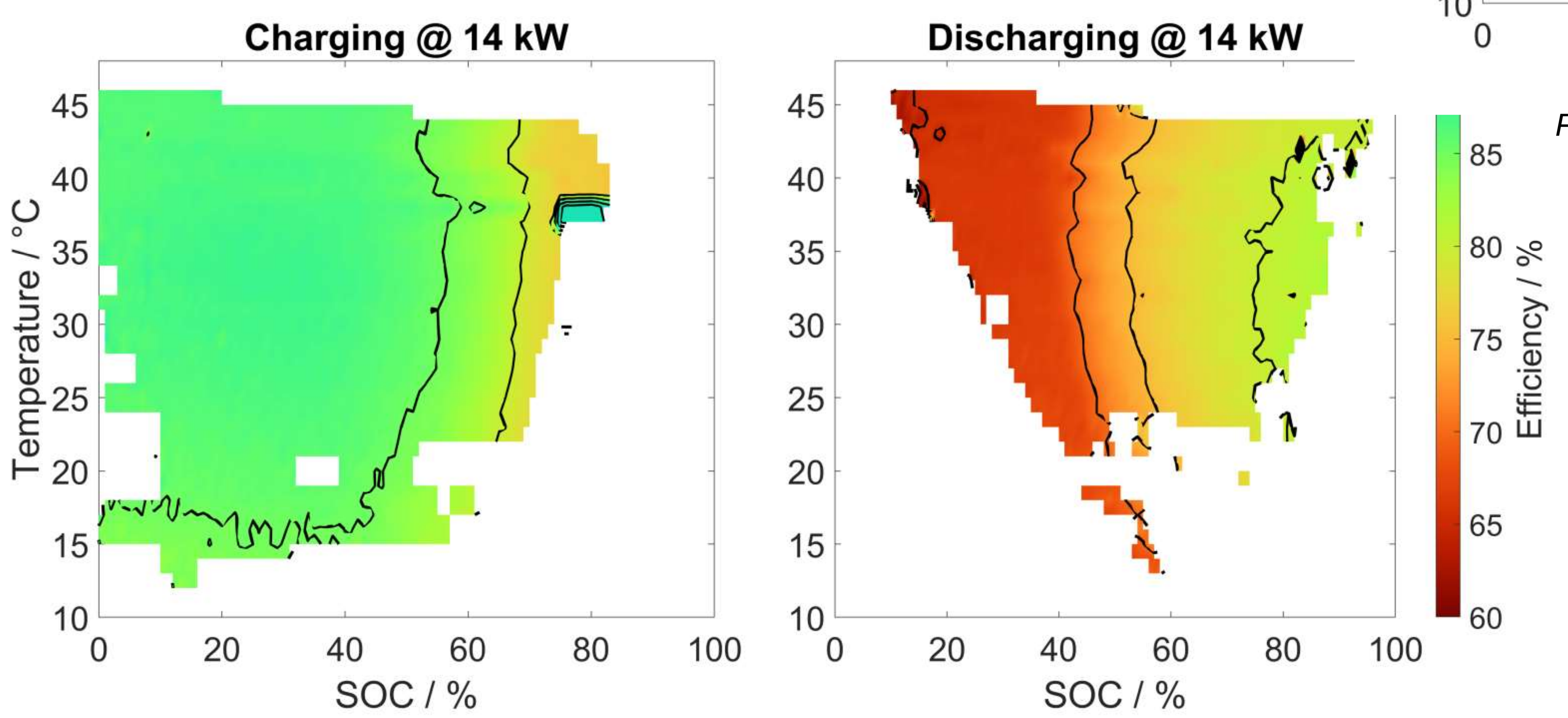


Fig 3. System level efficiency when operated at 14 kW. Resolution: 1 °C by 1 % SOC

05 System to electrolyte efficiency

$$\eta_{\mathrm{sys,charging}} = \frac{P_{\mathrm{DC}} - P_{\mathrm{R_{Ohm}}}}{P_{\mathrm{AC\ Bus}}} \quad \Big| \quad \eta_{\mathrm{sys,discharging}} = \frac{P_{\mathrm{AC\ Bus}}}{P_{\mathrm{DC}} + P_{\mathrm{R_{Ohm}}}}$$

where
η_{sys} = System efficiency between electrolyte and AC Bus
P_{DC} = Power measured at stacks
$P_{\mathrm{R_{Ohm}}}$ = Power losses at the stack
$P_{\mathrm{AC\ Bus}}$ Power measured at AC Bus (including Aux)

Based on 03 and 04 system level efficiency has to be represented as a three dimensional function

$$\eta_{sys} = f(SOC, Temp, P_{\mathrm{EMS,Target}})$$

06 Conclusion and outlook

Temperature of electrolyte:

- has a significant impact on the η_{sys}
- when higher, could improve round-trip efficiency of VFB

Dual usage of VFB as electrical and thermal storage can prove advantageous not only in economical but also in operational perspective.

In future:

- with increased nominal power, η_{sys} would still increase as P_{Aux} would remain same.
- with TCM the unknown temperature regions will be explored further.

References

[1] F. Holger, "Untersuchung von Verlustmechanismen in Vanadium-Flussbatterien", dissertation, Technische Universität München, 2019

[2] X.Li, J. Xiong, A.Tang, Y.Qin, J.Liu, C.Yan, "Investigation of the use of electrolyte viscosity for online state-of-charge monitoring design in vanadium redox flow battery", Applied Energy, vol. 211, pp. 1050-1059, 2018

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