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

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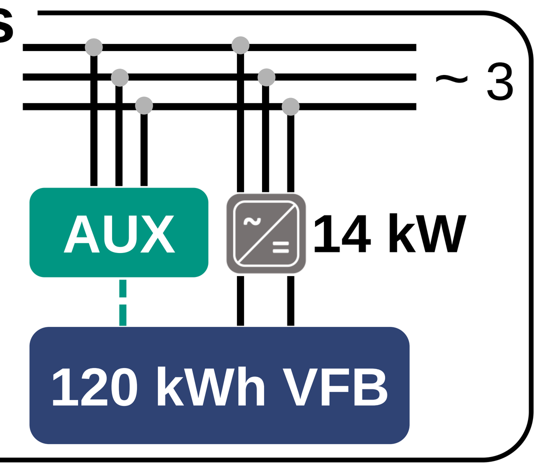
01 Motivation

- 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” in near future.
- Thermal vs electrical characteristics of the VFB are required in order to optimally drive this novel application.

02 Setup and data used for analysis

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



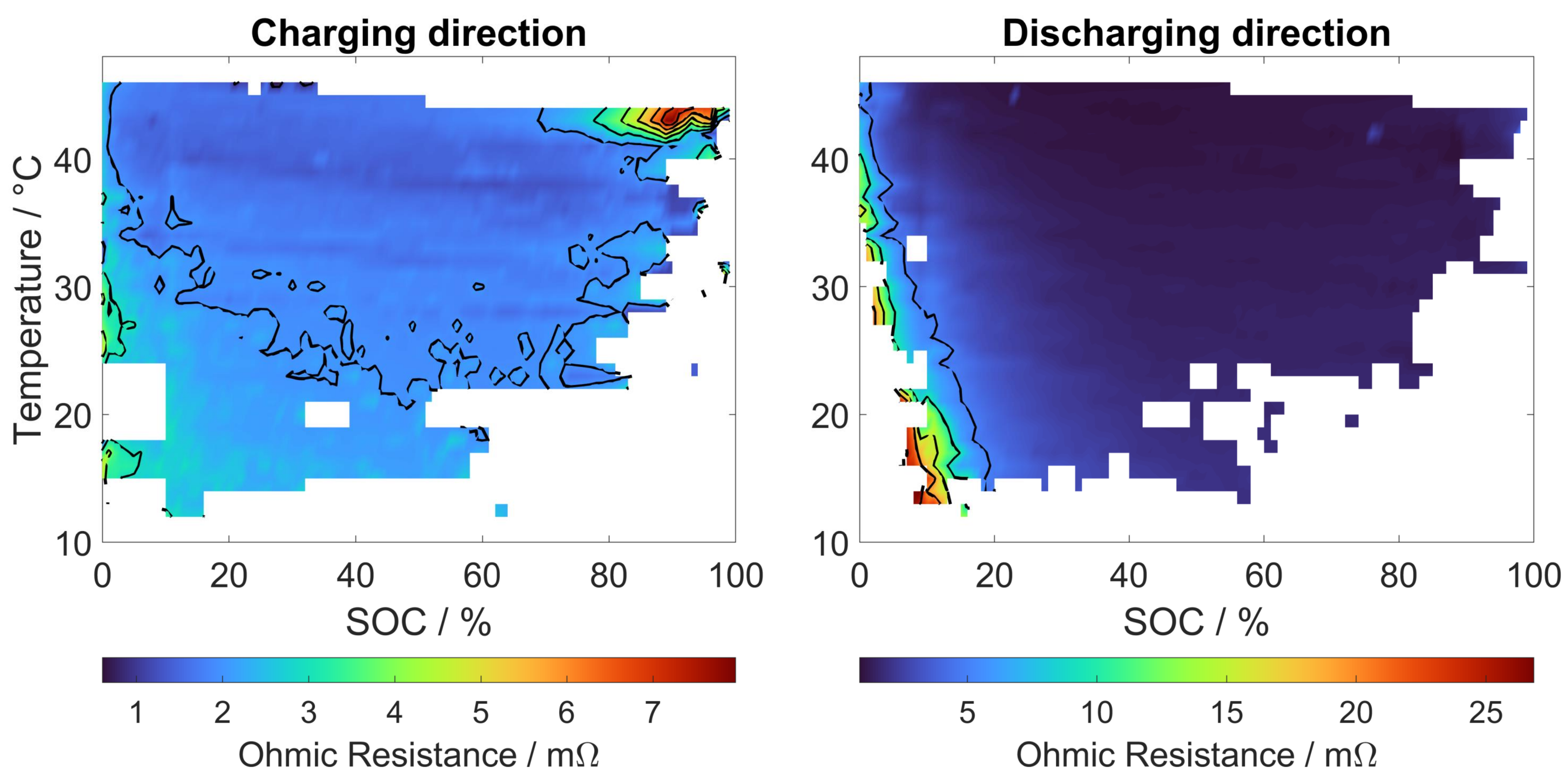


Fig 1. Cell level R_{Ohm} map measured during the operation. Resolution: 1°C by 1% SOC

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]:

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

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

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

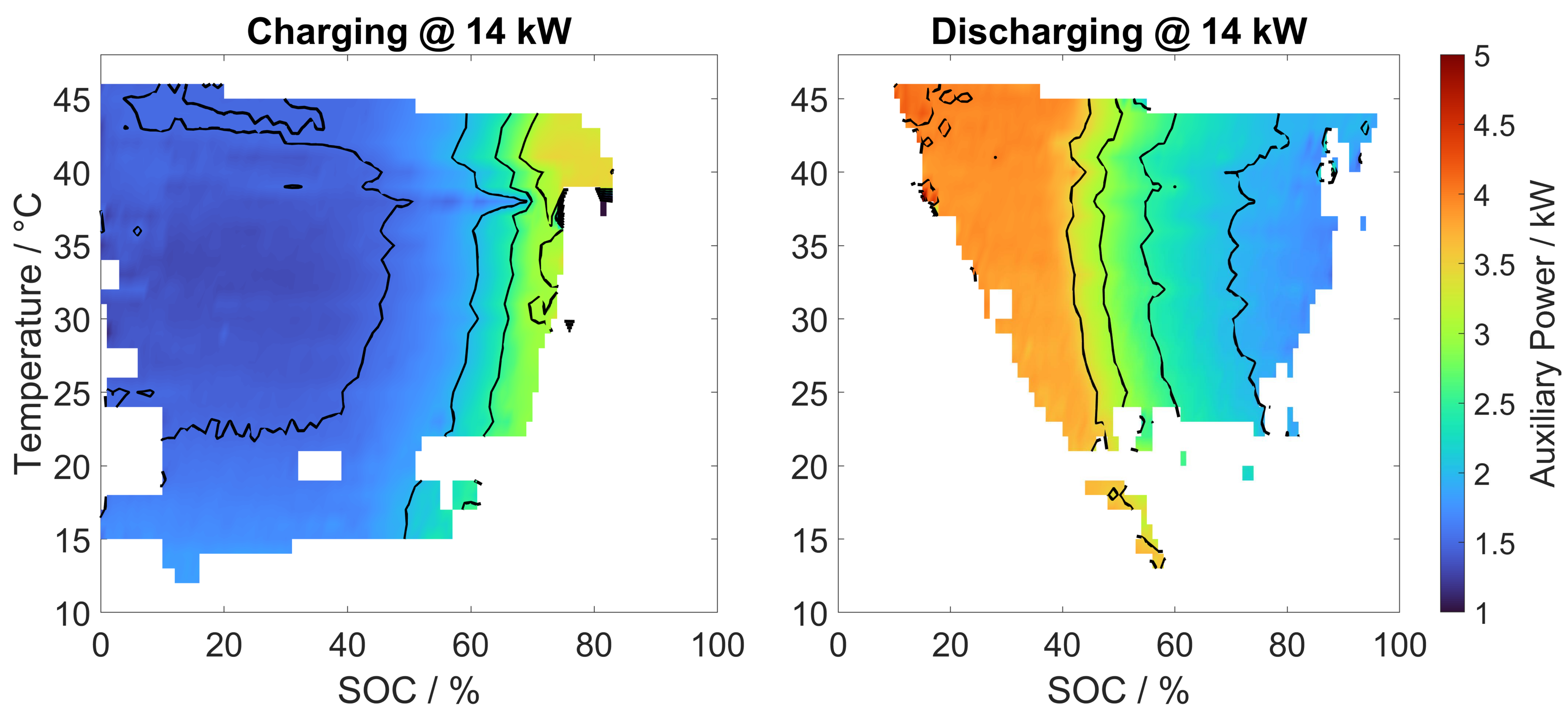


Fig 2. Total Auxiliary power requirement when operated at 14 kW. Resolution: 1°C by 1% SOC

04 Auxiliary requirement characterization

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

$$P_{Aux} \propto Electrolyte\ viscocity \propto SOC \text{ [2] } \propto 1/T_{Electrolyte} \text{ [2]}$$

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

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

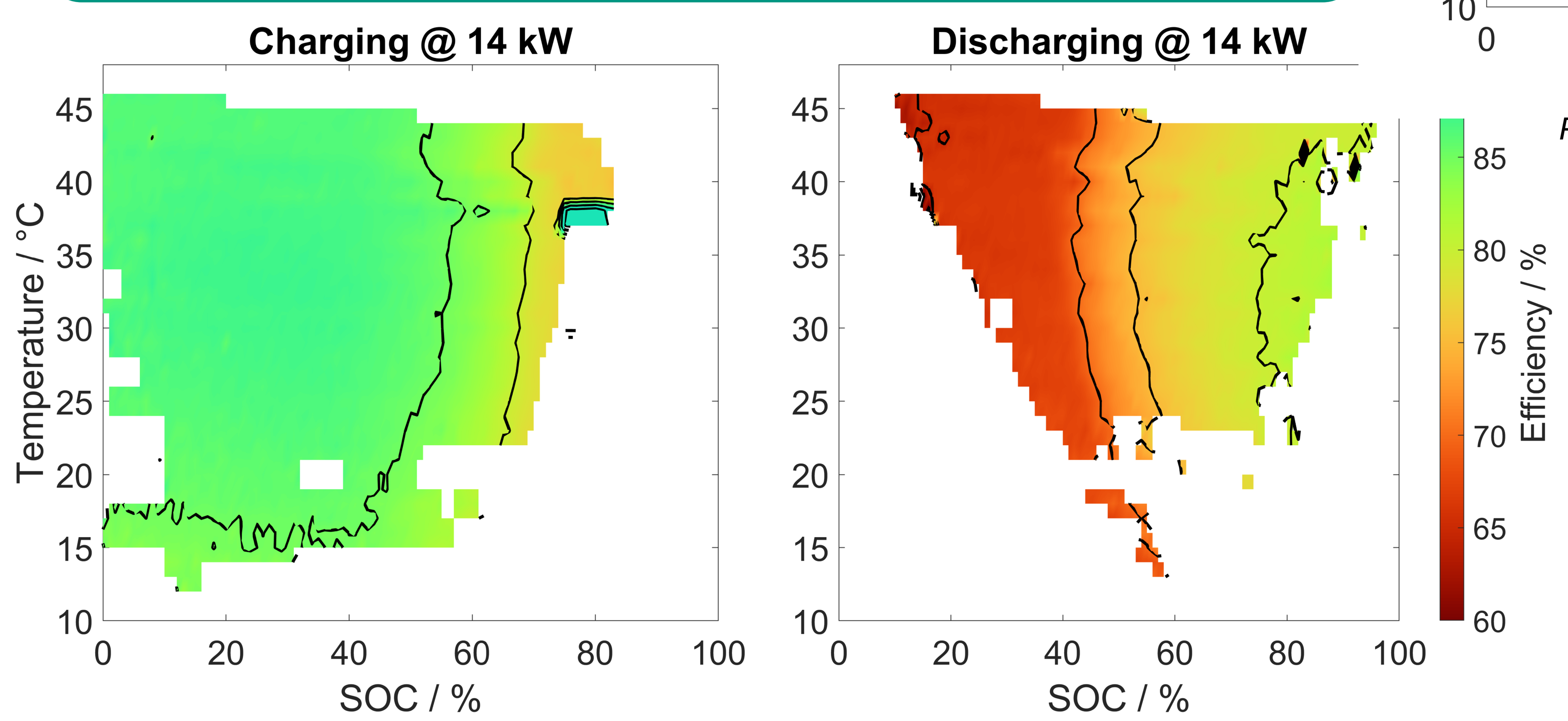


Fig 3. System level efficiency when operated at 14 kW. Resolution: 1°C by 1% SOC

05 System to electrolyte efficiency

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

Where η_{sys} = system level efficiency
P_{DC} = Power measured at stacks
$P_{R_{Ohm}}$ = Power losses at the stack
$P_{AC\ Bus}$ = Power measured at AC Bus (including Aux)

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

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

06 Conclusion and outlook

- In addition to electrical operational parameters, temperature has a significant impact on the η_{sys}.
- In general for better round-trip efficiency VFB could be operated at higher temperature.
- Dual usage of VFB as electrical and thermal storage can prove advantageous not only in economic perspective but also in operational perspective.
- With increased nominal power in future, η_{sys} would still increase as P_{Aux} would remain same.
- With the Thermal Coupling Module, the unknown temperature regions will be explored further in detail.

References

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BiFlow

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