Institute of Electrical Engineering (ETI)
Battery Technology Center
Hermann-von-Helmholtz-Platz 1, Bldg. 420
76344 Eggenstein-Leopoldshafen, Germany
www.batterietechnikum.kit.edu

Advanced Characterization of a Commercial Scale Vanadium Redox Flow Battery at Controlled Temperature Levels

Felix Schofer[1], Lakshimi Narayanan Palaniswamy[1], Nina Munzke[1], Christian Kupper[1], Marc Hiller[1], Frank Säuberlich[2]
[1]Karlsruhe Institute of Technology, [2]1st Flow Energy Solutions GmbH

01 Motivation

- In the BiFlow project, a newly developed Thermal Coupling Module (TCM) [1] allows heating up or cooling down the electrolyte of a 21 kW / 120 kWh Vanadium Redox Flow Battery (VFB) [2]
- The VFB is specifically adapted to operate at temperatures from 10 to 50 °C, and can thus be used as thermal storage, or operated in an optimized temperature range

Fig 1. Installation in Bruchsal, Germany with the VFB (left) and TCM (right)

02 Characterization Methods

- Stack resistance R_{Stack} is determined by executing a step profile for the AC-power (Fig. 2)
- Measurements are performed with all permutations of three factors
  - Nominal power: -21 kW / 21 kW
  - SoC Range: 10 % intervals from 0 to 100 % (e.g. 30-40 %)
  - Temperature: 15-20 °C (cold), 30-35 °C (warm), 45-50 °C (hot)

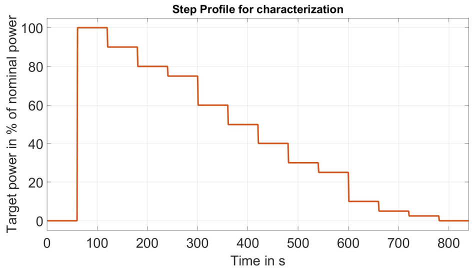

Fig 2. Step profile used to determine internal resistance of the VFB

03 Cell internal resistance

- The characterization allows the determination of the internal resistance of the three stacks at different values of AC power, SoC and temperature
- Stack resistance is calculated using:

$$R_{\text{Stack}} = (U_{\text{Stack}} - OCV\ x\ n_{\text{Cells}})\ /\ I_{\text{Stack}}$$

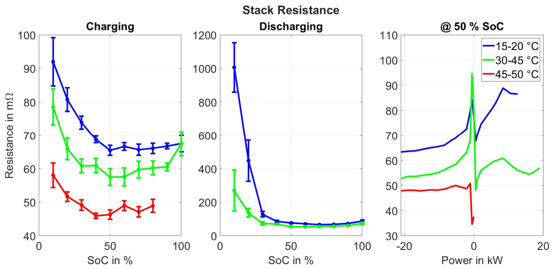

Fig 3. Stack resistances measured at different SoC intervals and AC powers. Left and middle plot include error bars to show standard deviation of the measurements.

04 Round trip analyses

- To determine system efficiency, the VFB was subjected to round trips from 0 to 100 % SoC at 7, 14 and 21 kW target power and the aforementioned temperature levels
- System is characterized using different efficiencies [3]:
  - Coulomb efficiency (CE): $\frac{\int I_{\text{Stacks,discharge}}}{\int I_{\text{Stacks,charge}}}$
  - DC Energy Efficiency (DE): $\frac{\int P_{\text{DC,discharge}}}{\int P_{\text{DC,charge}}}$
  - Voltage Efficiency (VE): DE/CE
  - System Efficiency (SE): $\frac{\int P_{\text{AC,discharge}}}{\int P_{\text{AC,charge}} + P_{\text{Aux,charge}} + P_{\text{Aux,discharge}}}$
- CE lowers with temperature while VE increases, both possibly due to an increased reactivity of the electrolyte
- SE increases significantly with temperature, due to a decrease in pump losses at high temperatures

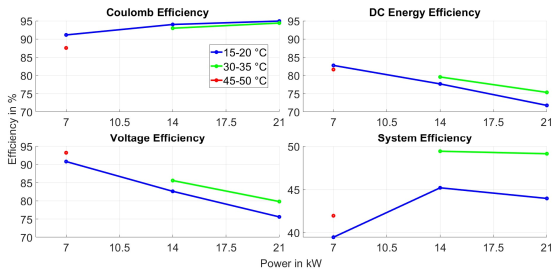

Fig 4. Efficiencies of the VFB system measured at different temperatures and round-trip powers

05 Auxiliary power consumption

- System efficiency is influenced by the auxiliary power consumption of the VFB
- Electrolyte pumps require the largest part of auxiliary power
- Higher pump power is required at higher electrical powers
- Higher temperatures reduce required pump power

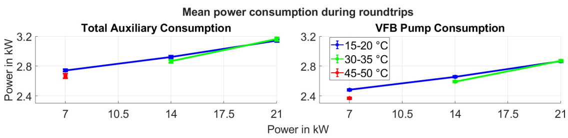

Fig 5. Auxiliary power consumptions of the VFB during roundtrips including error bars to account for sensor errors

06 Conclusion and outlook

- Temperature of electrolyte impacts the system efficiency by:
  - Increasing Voltage Efficiency
  - Decreasing Coulomb Efficiency
  - Lowering pump power consumption
- Controlling the temperature might allow minimizing losses in the VFB

Outlook:

- System efficiency of the VFB will be improved using the TCM
- The effects of high temperature operation on the electrolyte will be analysed
- The TCM will be integrated in an energy management to optimize combined operation with the VFB

References

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Contact: Felix Schofer, felix.schofer@kit.edu

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