Parametrisation and validation of a tool for the electrical design of tubular redox flow stacks

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Introduction

All-vanadium flow batteries (VFB) with a tubular cell geometry offer advantages over the common planar design [1,2]:

- Improved stability
- Cost-saving potentials through production of the components by (co-) extrusion
- More flexible electric cell-setup, possibly reducing shunt currents

While a first generation of tubular substacks showed promising results [3], a design tool for the design of tubular substacks and stacks is necessary to reduce material usage. Existing models [4] aren't suited to the tubular geometry. In this work, we report on further development of the design tool [5] with a focus on the electrical side of the VFB.

Experimental

A first generation of tubular VFB substacks consisting of 5 tubular cells connected electrically in parallel was assembled and characterisation measurements were conducted:

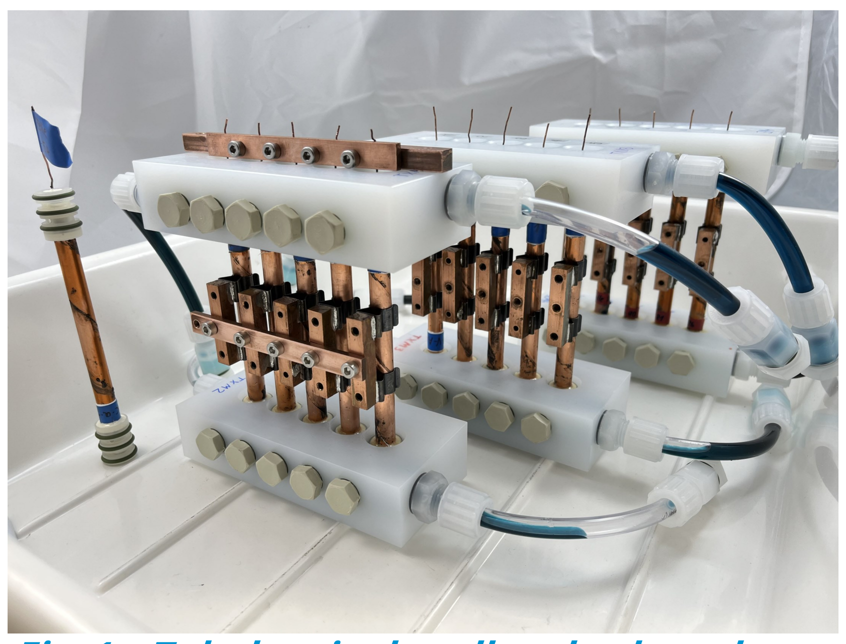

Fig. 1 – Tubular single cell and substacks.

- **Substack polarisation curves** at low (~20%), medium (~50%) and high (~100%) state of charge and different flow rates (32-120 ml min^{-1}).
- **Single cell polarisation curves** at medium (50%) state of charge and different flow rates (6.4-24 ml min^{-1}).
- **Substack charge/discharge cycles** at different constant current densities (30, 70 and 100 mA cm^{-2}).

Model expansion

- A **SoC-correction** for the activation and concentration overpotentials was implemented.
- To incorporate side reaction effects, a **current correction via coulomb efficiency** was implemented.
- The model was expanded to the **stack-level**, using existing structures.

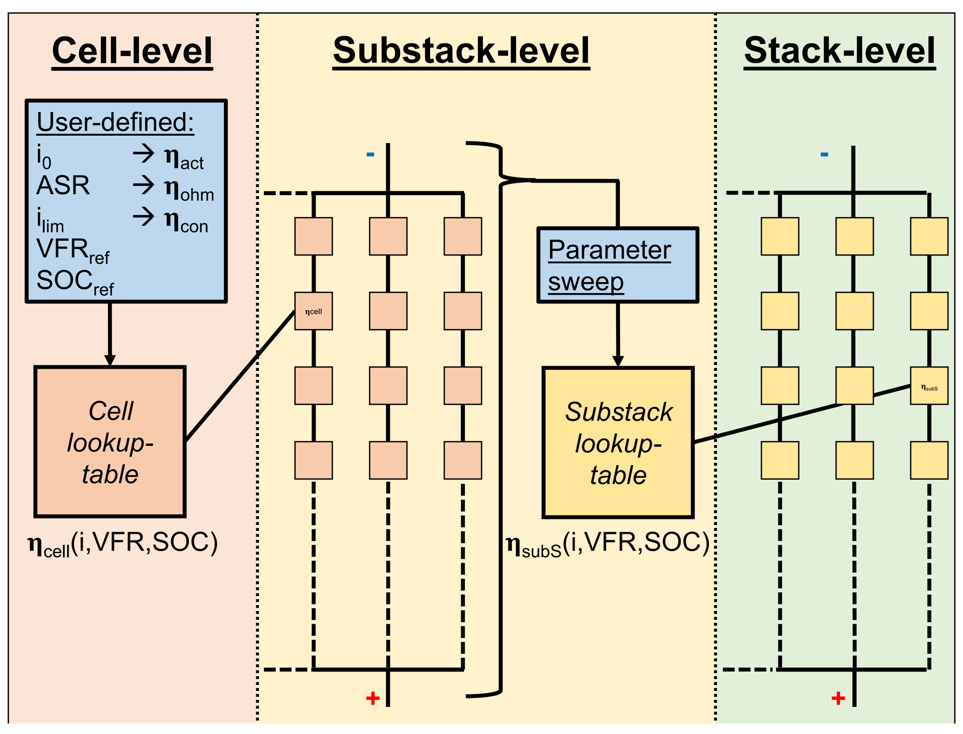

Fig. 2 - Structure of the design tool with the stack-level expansion.

Results

The model was parametrised and validated with experimental data from the first generation of tubular substacks:

Cell level:

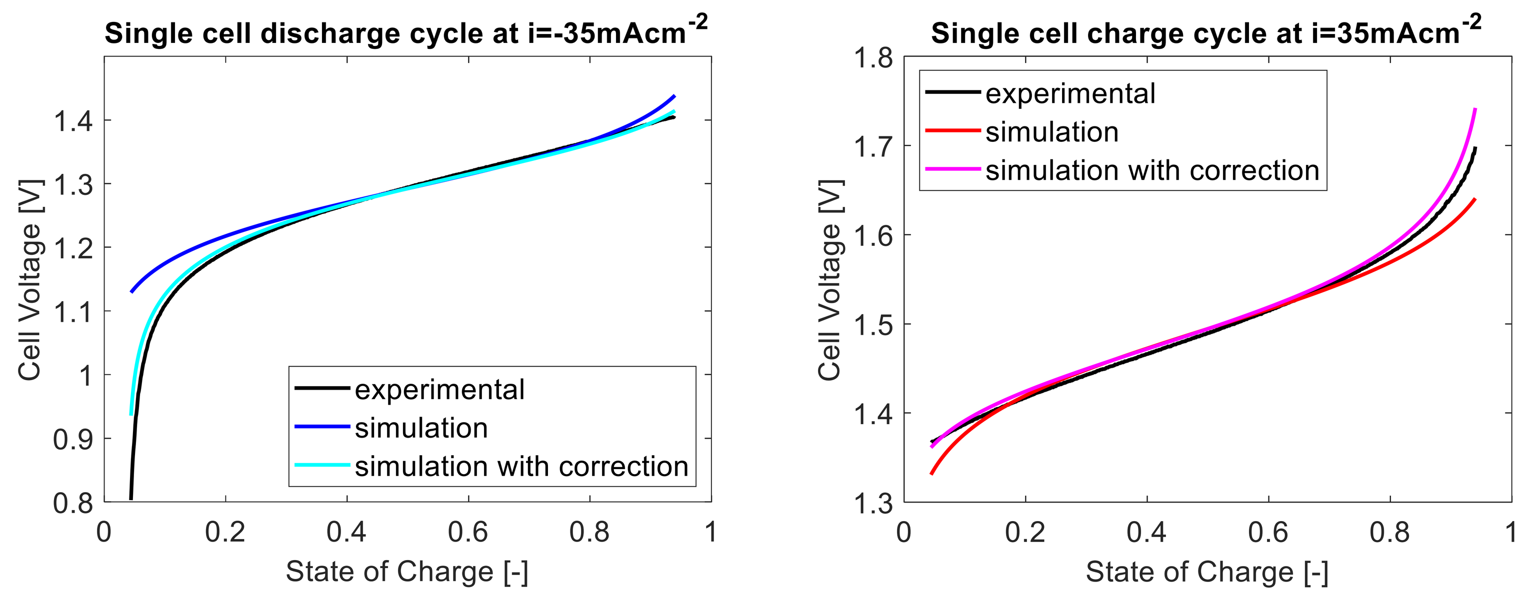

Fig. 3 - SoC-correction of a charge/discharge cycle of a single tubular cell.

Substack level:

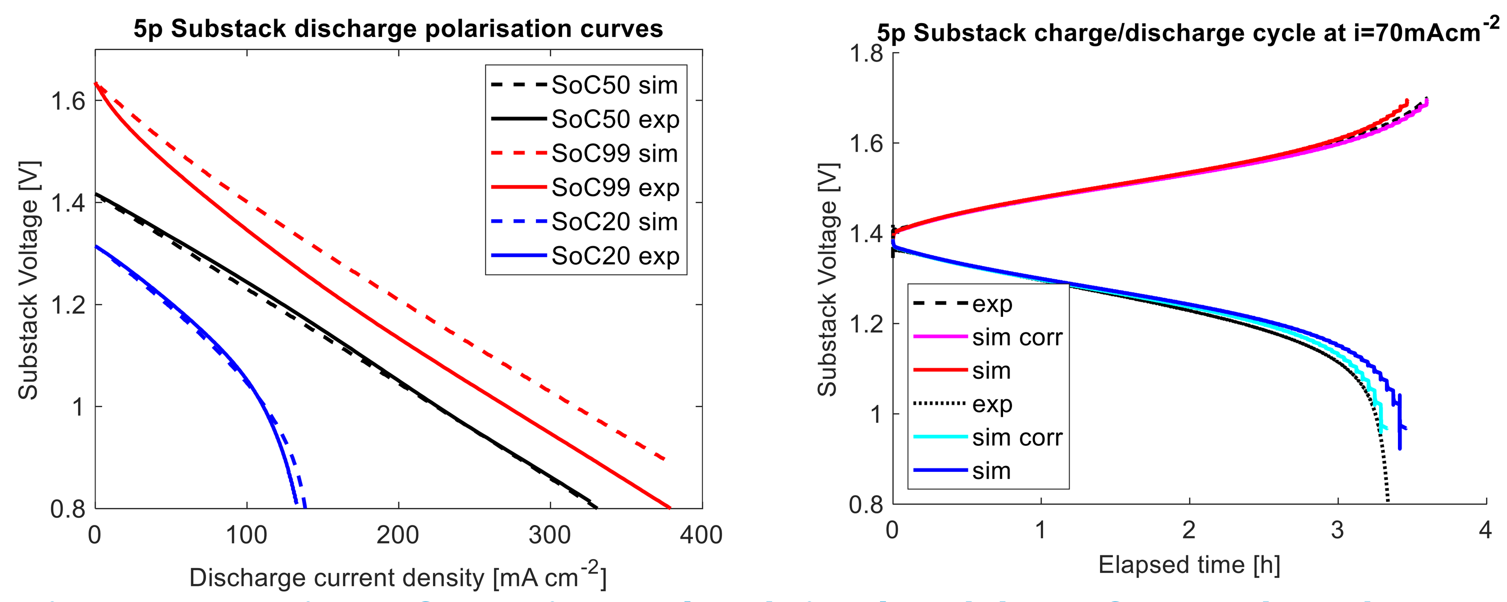

Fig. 4 - Comparison of experimental and simulated data of a 5p substack.

Stack level:

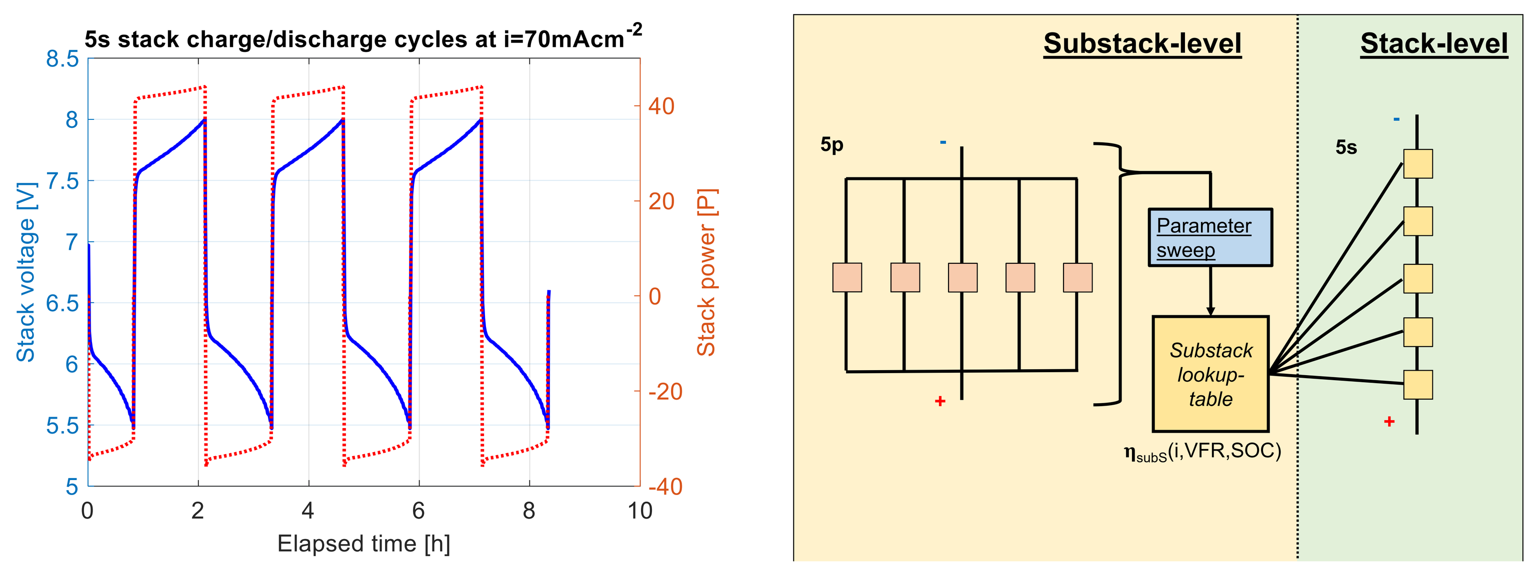

Fig. 5 - A simulated 5s stack consisting of 5p substacks.

Outlook

- Further parametrisation and validation with characterisation and long term measurement data from second-generation tubular substacks and stacks.
- Coupling with a microscopic multiphysics model for more accurate ASR and fluid flow simulation.
- Implementation of a crossover model.
- Model-based optimisation of the tubular substack and stack design.

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