Efficient Fuel Cell Models for SOFC/GT Hybrid Power Plant System Simulations Designed to be Parameterized with Experimental Results

Institute of Engineering Thermodynamics

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Motivation

- Electrochemical reactor models are required for design and simulation of process systems with fuel cells or electrolysers
- An adaptable reactor model can use experimental stack test results to predict the performance in large process systems

Objectives

- Fast calculation time, good accuracy, wide operation range
- Physically meaningful parameters
- Adaptable to different reactor types by using experimental results or literature values

Experimental

Pressurized SOC test rig

- Pressure: 1 to 8 bar
- Temperature: up to 950 °C
- Analytic methods: – V(i) characteristics
  – Impedance spectroscopy (EIS)

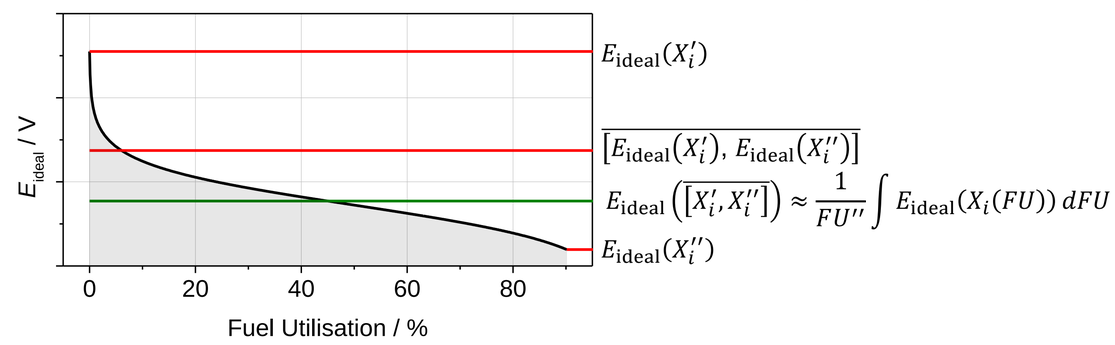
Stack

- 10 layer planar stack
- Electrolyte supported cells
- Open cathode
- 127.8 cm² active cell area

Modelling

Variance in ideal voltage E_{ideal} determination

- Calculated with the Nernst equation assuming ideal gases



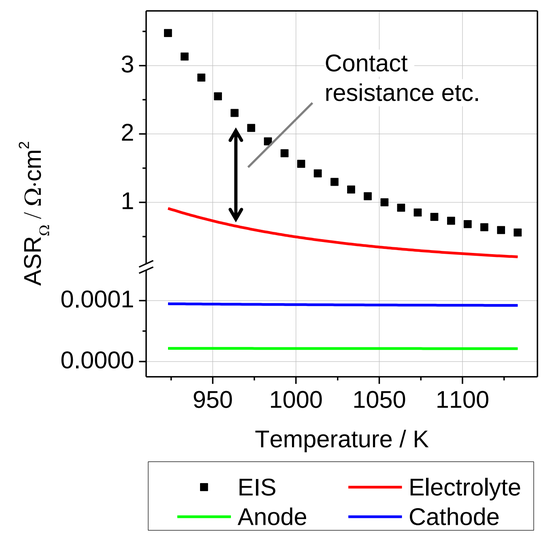
→ Therefore $E_{ideal}\left(\overline{[X_i', X_i'']}\right)$ is used for this model

Activation ΔE_{act} and concentration ΔE_{con} polarisation

- Butler-Volmer kinetics at anode and cathode
- Exchange current density depends on temperature, pressure and composition
- Knudsen and molecular diffusion are considered

Ohmic polarisation ΔE_{ohm}

- Parameters from literature are compared to EIS results
- Ohmic losses due to interconnects, contact resistance and other effects account for more than 50 %
- Literature values do not consider processing, production and differences in the material structure
- Therefore ohmic losses are taken from impedance spectroscopy



Cell voltage calculation

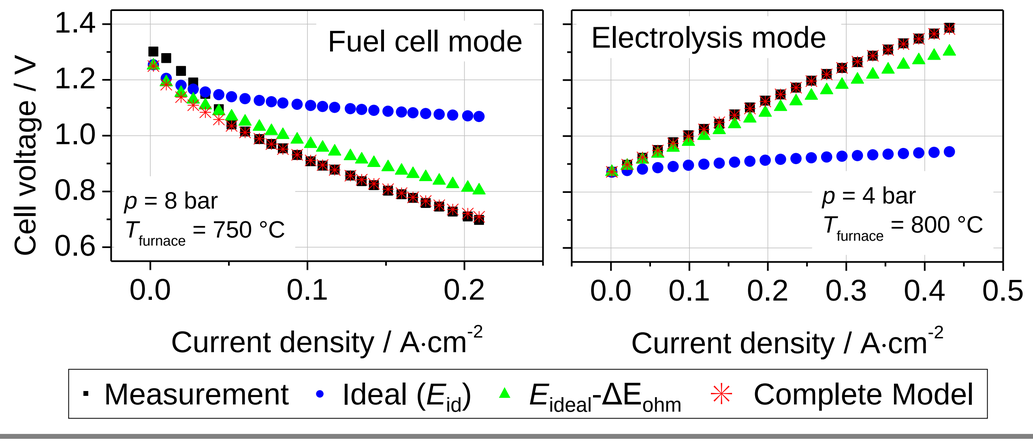
- $E = E_{ideal} - \Delta E_{ohm} - \Delta E_{act} - \Delta E_{con}$

Results

Parameterisation

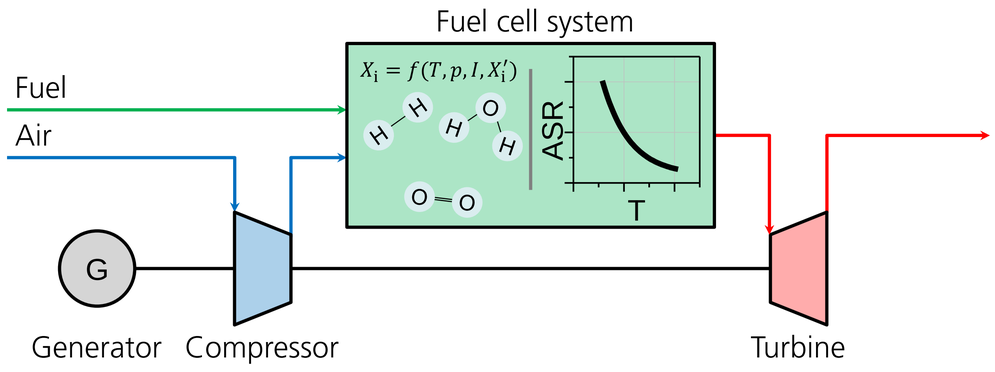
- Parameters (e. g. geometry, materials) can be taken from literature or experiments
- For this work material properties are taken from literature or are calculated from the experiments (e. g. activation energies)

Simulation results



Implementation into a Hybrid Power Plant model

- In addition simple model functions for the ASR have been developed (e. g. $ASR = a_1 + a_2 \exp(a_3\, T)$)
- In system models containing component models with high uncertainties the difference between the simple and the adaptable model can be neglected



Conclusion & Outlook

- The adaptable model matches experimental results
- Simple model functions are adequate in large process system simulations
- The adaptable model will be compared to other cells, especially anode supported cells
- Implementation of the adaptable model into an process system model
- Examination of the Impact of model simplifications on the calculation time

Knowledge for Tomorrow

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