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TAG DER FORSCHUNG

Thermodynamical and Electrical Model of a PEM Electrolyzer Plant in the Megawatt Range

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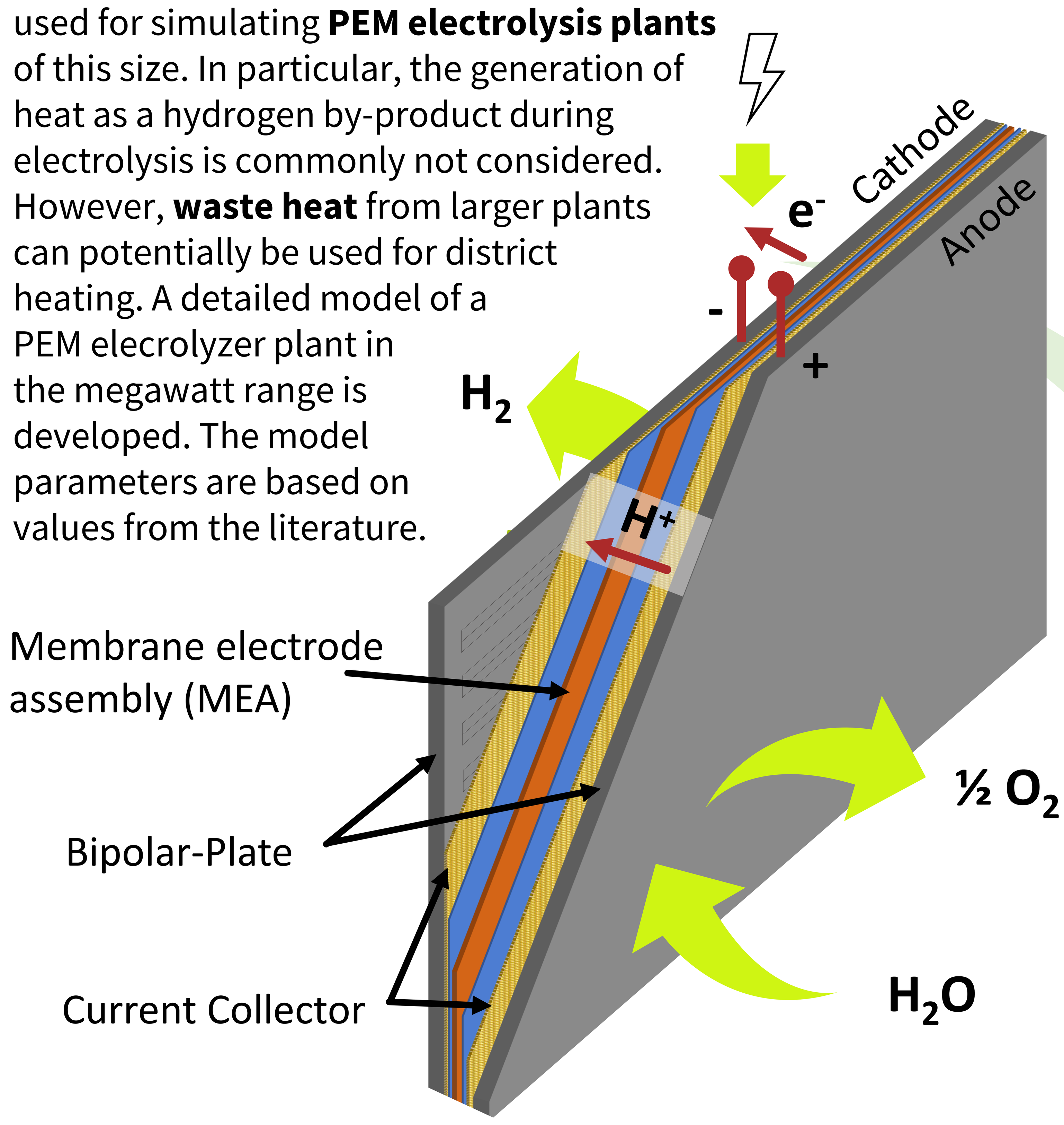
Introduction

During the next years, proton exchange membrane (PEM) electrolyzers with a capacity of several 100MW each, shall be built in the European Union. Currently, there are hardly any corresponding system models in the literature that can be used for simulating **PEM electrolysis plants** of this size. In particular, the generation of heat as a hydrogen by-product during electrolysis is commonly not considered. However, **waste heat** from larger plants can potentially be used for district heating. A detailed model of a PEM elecrolyzer plant in the megawatt range is developed. The model parameters are based on values from the literature.



$$H_2O \rightarrow 2H^+ + {}^1/_2\,O_2 + 2e^- \quad \text{Anode}$$
$$2H^+ + 2e^- \rightarrow H_2 \quad \text{Cathode}$$
$$H_2O \rightarrow H_2 + {}^1/_2\,O_2 \quad \text{Total reaction}$$

Fig. 1: Structure of a PEM cell with chemical formulas. Own work, based on [1]

Methods

The model equations are taken from the literature that describe the electrochemical properties of a cell. A cell is scaled linearly to a stack of 25 cells. The thermal model of a stack is solved by a first-order differential equation. The scaling from a stack to an electrolysis plant is **non-linear** due to thermal couplings between the stacks. The scaling up in the mega watt range is the focus of this research.

Non-Linear Scaling

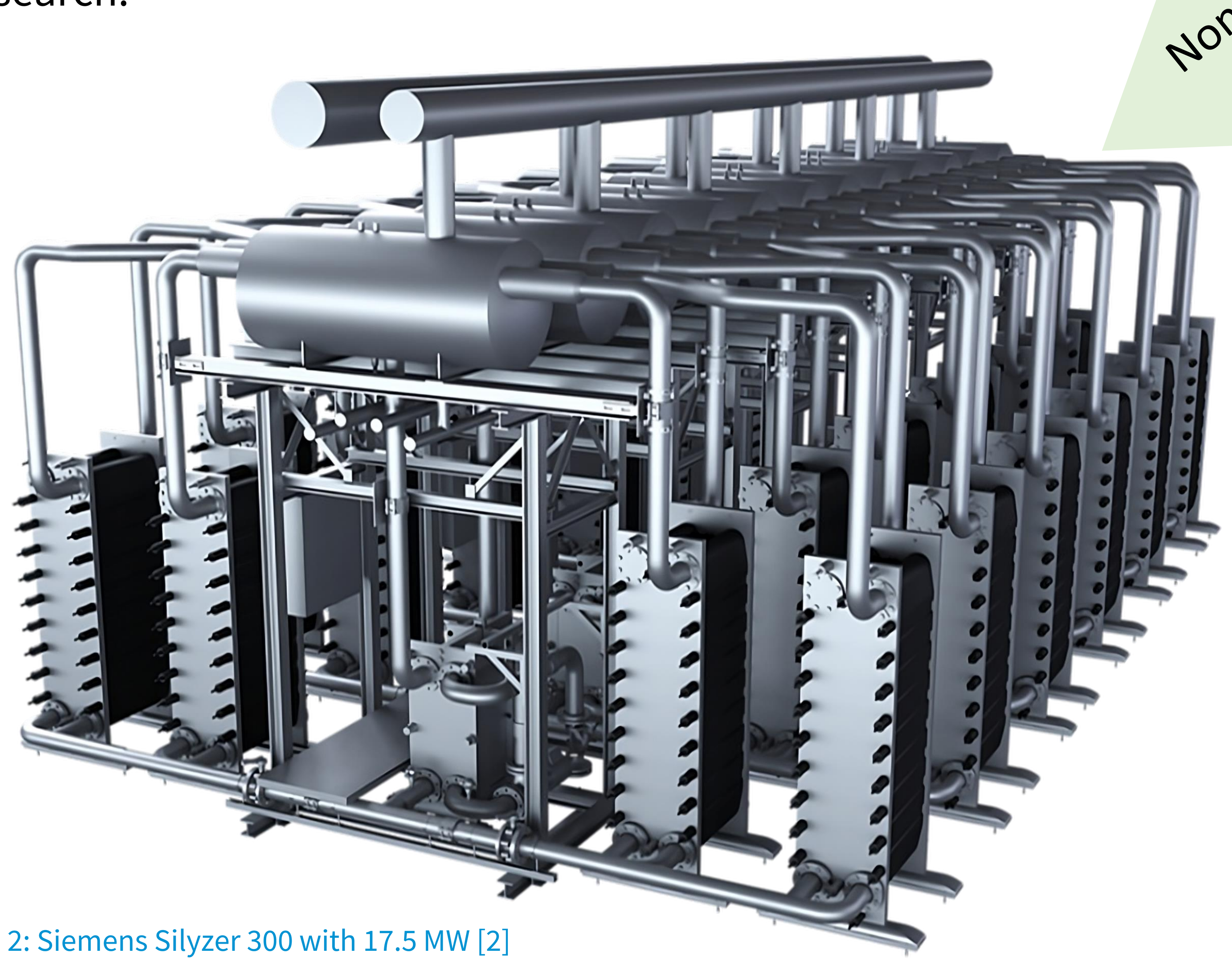
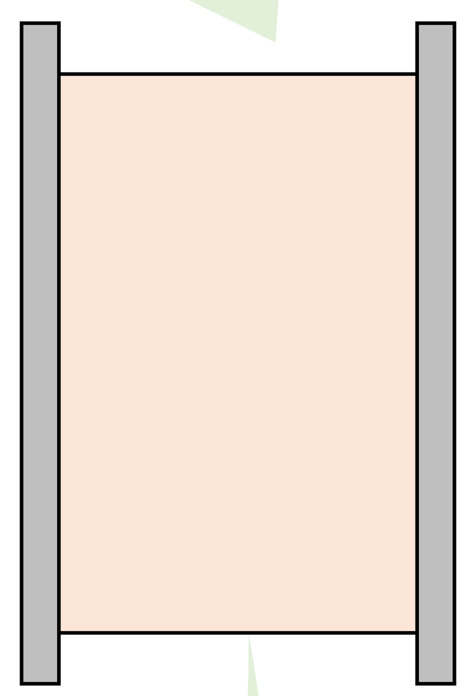


Fig. 2: Siemens Silyzer 300 with 17.5 MW [2]

Results

The analysis of the data shows that the electrochemical model can be well adapted to the real Siemens Silyzer 300 electrolysis plant. Parameters from literature and data sheets are used to parameterize the model. However, the parameters from literature have large **inconsistencies**. For example, the range of values for the exchange current density in the literature has a factor of 10^9. This leads to a large uncertainty in the parameters used. The thermal model can hardly be validated because there is no data of the thermal output of the Silyzer 300 available.
The first model results are calculated over a time for each stack (below in Figure 3).

Linear Scaling



Stack with 25 cells

Conclusion & Outlook

The model of the Silyzer 300 is a first approach. It is shown that initial results can be obtained that are comparable to those of a real plant. However, the values of the theoretical model cannot be validated due to missing information.

In the future, the model will be further developed, and each stack will be non-linearly scaled to a whole electrolyzer plant. Other components such as power converters and heat exchangers will be added to the model in the future.

Tbl. 1: Comparison of the model output with the real plant.

	Silyzer 300		Model	
	kg/h	$kmol/h$	kg/h	$kmol/h$
Hydrogen	330	163.70	330.11	163.68
Oxygen	2700	84.38	2619.97	81.84
Ratio		1.94:1		2:1
Thermal Output	value unknown			1.1496 MW_{th}/h

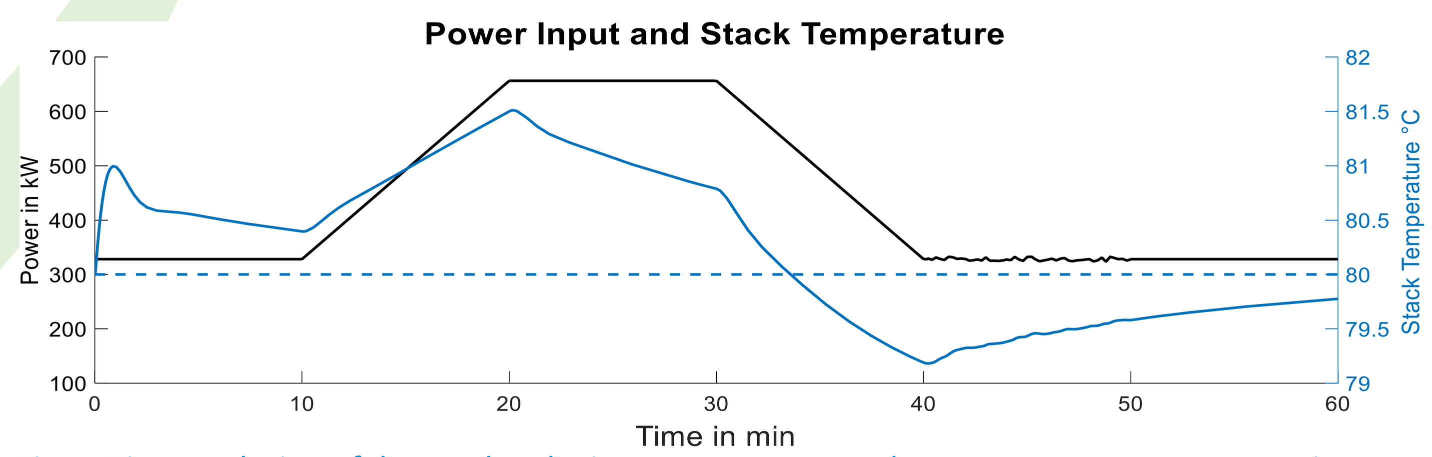


Fig. 3: Time evolution of the results, the input power causes the temperature to vary over time (Own work)

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[1] Carmo et al., A comprehensive review on PEM water electrolysis, 2013, doi: 10.1016/j.ijhydene.2013.01.151
[2] Siemens Energy, url: https://www.mobility.siemens.com/global/de/portfolio/schiene/storys/sector-coupling-with-green-hydrogen.html