The 23rd General Meeting and Singapore Forum
November 21–24, 2023

Electrolyzer Performance Modeling and Simulation

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Keywords: *Electrolyzer, Performance, Modeling, Simulation*

Abstract

Introduction

Hydrogen plays a vital role in the energy transition, offering a clean alternative to fossil fuels. Nevertheless, electrolyzer systems face some challenges. As a matter of fact, efficiencies still need to be optimized through design and relevant operational strategies. Besides, intermittent renewable sources introduce variability that needs to be deeply studied, impacting electrolyzer performance. In this sense, modeling offers a robust solution, simulating behavior under different conditions to optimize efficiency, predict the impacts of renewable energy sources intermittency, and test operational strategies. Presently, there are very few system-level models in the literature addressing these issues.

Methodology

A semi-empirical model has been developed to represent the entire electrolyzer system, including the stack and the balance of plant. This multiphysics model combines electrochemical, thermal, and mass balance models to incorporate all relevant phenomena, resulting in a representative simulation of a real electrolyzer behavior. Additionally, the model considers the decline in performance (degradation) of the stacks during operation. Finally, the model has been tailored for robustness in terms of computation time in order to perform the simulation of a whole year in couple of hours.

Results and discussion

To assess the performance of the model, an annual simulation using a combination of solar and wind intermittent load was conducted. **Figure 1** depicts a close-up view of a day from the intermittent load.

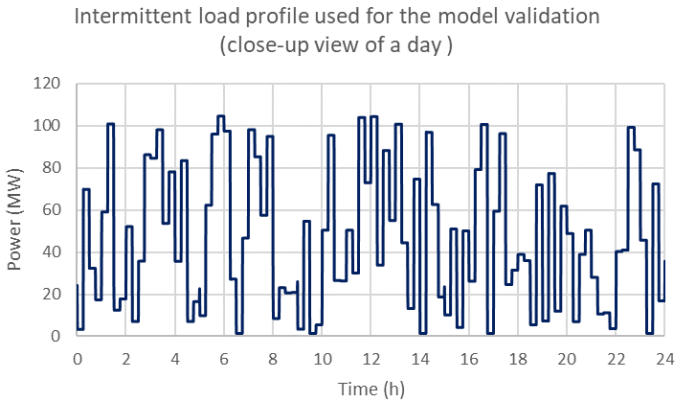

Figure 1 : Close-up view of a day of the intermittent load used for model calibration.

Upon gathering and analyzing the results of one year simulation, on a 10 second time step, various Key Performance Indicators (KPI) were calculated. **Table 1** showcases the computation results.

KPI	Unit	Value
Mean stack temperature	°C	74,9
Mean site-specific consumption	kWh/kgH_2	53,6
Site operating time	h	7774
Total H_2 production	ton	7892
Mean power consumption	MW	50,7

Table 1: KPI calculated for a year simulation.

The model has been developed to simulate a standard pressurized alkaline electrolyzer. The results obtained seem aligned with what was expected even if it is difficult to compare with previous works due to the lack of similar modelling approach. While the model still requires calibration, the results obtained are already highly insightful.

When considering future perspectives, the performance model can be applied to case studies beyond the one currently discussed. This would enable the creation of a database to analyze the impacts of intermittency on electrolyzer operation, to test advanced operational strategies, and assess the performance degradation during operation.