Lifetime Prediction Of PEM Fuel Cells In Maritime Applications

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Abstract

Maritime transport contributes to about 3% of global greenhouse gas emissions. Proton exchange membrane (PEM) fuel cells are considered among the most promising clean technologies for decarbonizing the maritime sector. Some of the main benefits of PEM fuel cells include highly efficient energy conversion, reduced air pollution, compatibility with renewable energy sources, good partial load performance, quiet operation, and low operating temperatures.

PEM fuel cell systems in marine vessels face stringent requirements for durability and cost-effectiveness. In this context, the broad implementation of fuel cells is still limited by challenges related to their durability and lifespan. Typical operating conditions of marine vessels, including startup-shutdown cycles, high-current operations, dynamic loads, steady-state loads, and idling or low-current operations, all contribute to fuel cell aging and lead to different types of degradation mechanisms. Therefore, developing models that can accurately predict fuel cell lifetime is essential. Such models are valuable for estimating remaining useful life and for enabling operational strategies that extend service life, for example, by optimizing component usage in fuel cell and battery hybrid propulsion systems.

This paper presents the development of a lifetime prediction model using COMSOL Multiphysics®, employing the Fuel Cell and Electrolyzer Module. The model builds upon existing examples from COMSOL's Application Libraries. The model developed is based on a semi-empirical approach. Experimental results from the literature are used to establish degradation relationships under various operating conditions. A parameter estimation study is conducted to estimate key fuel cell parameters and to tune the model's polarization curve with reference data.

The results show good agreement with both experimental data from the literature and the accelerated tests conducted in this study. The model shows reliable capabilities for estimating fuel cell lifetime. Simulations were performed using load profiles from various marine vessels, and the outcomes align with the general understanding of fuel cell aging. Some lifetime extension strategies are also highlighted: startup-shutdown cycles should be minimized; dynamic load operation (voltage cycling) should remain within the range of 0.60 to 0.85 V with minimal dwell time at higher voltages, and prolonged operation at open-circuit voltage should be avoided.

Figures used in the abstract

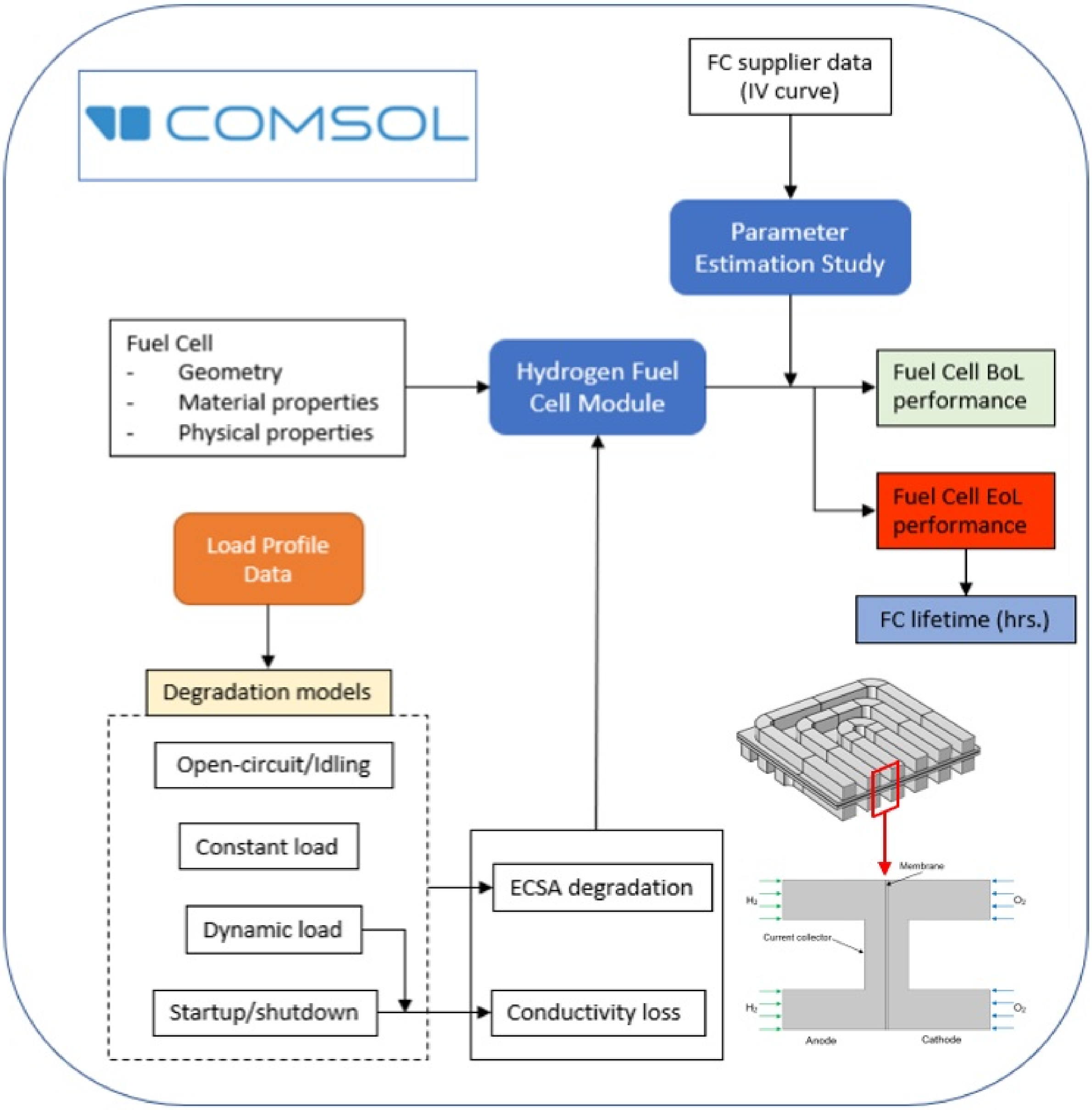

Figure 1 : Fuel cell lifetime prediction model