



New optimization algorithms for enhancing PEM fuel cell modeling accuracy

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ABSTRACT

Proton Exchange Membrane Fuel Cells (PEMFCs) represent a promising clean energy technology for electric vehicle (EV) applications due to their high efficiency and zero-emission operation. Precise parameter estimation is essential for effective simulation, optimal control, and performance evaluation of fuel cell systems. However, accurately determining the unknown parameters of PEMFC models from experimental voltage and current data presents a highly nonlinear and multimodal optimization challenge. Conventional deterministic methods often prove inadequate due to the problem's inherent complexity, while metaheuristic algorithms (MAs) offer superior solutions but require enhancements to avoid local optima trapping and accelerate convergence rates. Although advanced MAs have been recently developed to address these limitations, their application in fuel cell parameter identification remains relatively unexplored. Accordingly, this study aims to improve the accuracy and robustness of PEMFC parameter identification by evaluating two recently proposed MAs, namely the PID Search Algorithm (PSA) and Triangulation Topology Aggregation Optimizer (TTAO), for estimating the parameters of a semi-empirical electrochemical PEMFC model using experimental polarization curve data. These algorithms are assessed based on best fitness, average fitness, worst fitness, standard deviation (StD), average efficiency (Avg), and convergence characteristics. Results demonstrate that PSA achieves superior performance with significantly improved convergence stability and estimation accuracy. Specifically, PSA attains the lowest Sum of Squared Error (SSE) of 7.67426×10^{-3} with a standard deviation of 6.53764×10^{-4} for the Horizon 500W stack, and an SSE of 2.28813 with a standard deviation of 6.91510×10^{-4} for the NedStack PS6 stack, confirming its superior robustness and precision compared with competing optimizers.

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