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A new dynamic model for predicting transient phenomena in a PEM fuel cell system

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Abstract

In this paper, a mathematical model is developed to simulate the transient phenomena in a polymer electrolyte membrane fuel cell (PEMFC) system. At present many electrochemical models are available to the fuel cell designers to capture steady state behavior by estimating the equilibrium voltage for a particular set of operating conditions, but models capable of describing transient phenomena are scanty. In practical applications such as powertrains of land-based vehicles or submarines, the output power from the fuel cell system undergoes large variations especially during acceleration and deceleration. During such processes, many transient dynamic mechanisms become significant, while simple empirical models are unable to represent the transient dynamics caused by such as diffusion effect and double layer capacitance at the interface between the electrodes and the electrolyte. Hence, a novel dynamic fuel cell model is developed in this paper which incorporates the effects of charge double layer capacitance, the dynamics of flow and pressure in the anode and cathode channels and mass/heat transfer transient features in the fuel cell body. This dynamic model can predict the transient response of cell voltage, temperature of the cell, hydrogen/oxygen out flow rates and cathode and anode channel temperatures/pressures under sudden change in load current. The proposed model is implemented in SIMULINK environment. The simulation results are analyzed and compared to benchmark results. Lab tests are carried out at Connecticut Global Fuel Cell Center and a good agreement is found between tests and simulations. This model will be very useful for the optimal design and real-time control of PEM fuel cell systems.

Keywords: PEM fuel cell; Transient phenomena; System level dynamics; Charge double layer capacitance; Anode/cathode channel dynamic modeling and simulation