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PEM fuel cell low flow FDI

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ABSTRACT

In this work, a signal-based diagnostic methodology that can isolate PEM fuel cell low anode and cathode flow rates is introduced. The methodology is based on calculating symptoms of the faults, and comparing them versus thresholds that are calibrated *a priori* of real time operation. The novelty with the methodology is in using cell voltage oscillations, imposed by a small signal oscillation on the cathode output pressure, to isolate cathode flooding. Furthermore, it is shown in this work that the fixed reference cathode stoichiometry commonly used in the literature for isolating cathode starvation is not reliable and results in false alarms, and an adaptive scheme is proposed. It is also shown that a fixed stoichiometry scheme can be used to reliably isolate anode starvation. These measures are then used to design a signal-based diagnostic algorithm to isolate cathode flooding, cathode starvation, and anode starvation in real time. Finally, the robustness of the algorithm to changes in current, pressure, temperature, and humidity operating conditions is examined.

1. Introduction

Polymer electrolyte membrane (PEM) fuel cells are electrochemical cells that combine hydrogen and oxygen and produce electricity, heat, and water. The power delivered by the fuel cell is proportional to the catalyst active area, while the total deliverable energy is determined by the size of its fuel container. Therefore, it is possible to scale the power and energy of fuel cells independently. This allows them to satisfy power and energy requirements of a wide range of applications; from portable electronics to transportation. Their commercialization, however, has been hindered by their high cost, limited durability, and limited reliability, compared to their mature rival technologies, i.e., batteries and Internal Combustion Engines (ICEs).

One way to improve the performance, reliability, and durability of PEM fuel cells is by preventing them from entering faulty modes. These faulty modes include drying, starvation, flooding, CO poisoning, etc. [1]. The operating conditions as well as cell design determines the boundary conditions for these faults. In this work, we focus on detecting and isolating PEM fuel cell faults caused by low anode and cathode flow rates, i.e., flooding and starvation.

Model based Fault Detection & Isolation (FDI) algorithms work based on creating a redundancy in the system, and use that redundancy to make a decision regarding possible faults in the system. They can be classified based on the model they use to create the redundancy [2]:

1. *Quantitative methods*: In this approach, a quantitative model of the system is built using first principles. The quantitative model is used to build output observers or Kalman filters that create analytical redundancy required for fault detection.
2. *Qualitative methods*: In this approach, symptoms of the process faults are reconstructed using qualitative models. These symptoms could be measures such as magnitude, phase, mean, or variance of the output signal. The qualitative models are used to create knowledge redundancy for fault detection.

Authors in [3–6] used first principle models to create analytical redundancy for detection and isolation of PEM fuel cell faults. The problem with this approach for PEM fuel cell fault detection is the high degree of uncertainty and simplification incorporated to model fuel cell dynamics. This is partly due to the fact that transport phenomena in the polymer membrane is still not well understood to be modeled. In addition, the two phase flow of water in liquid and vapor phases is very challenging to model. Adding to this the wide range of time and length scales, coupled dynamical parameters, as well as non-linearities and hysteresis in their dynamical response makes PEM fuel cell modeling very challenging. Therefore, dynamical models introduced in the literature for fault detection typically capture the dynamical response of the control system components, rather than the PEM fuel cell itself. As a result, the diagnostic algorithms that use these models are more effective in diagnosing faults

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