Abstract

A control system design for a proton exchange membrane fuel cell (PEMFC) is presented. A simple model of the PEMFC is used in the design, holding the hydrogen and oxygen input gas flows constant. The model assumes constant temperature to simplify control system design. The control system demonstrates its effectiveness at maintaining hydrogen and oxygen partial pressures at the same steady state values to prevent membrane damage, as well as mitigating disturbances due to changes in residential power consumption.

Methodology

The use of a PI (proportional-integral) controller has been employed to handle the constant disturbance brought on by current. The outputs of both hydrogen and oxygen are connected to their respective inputs through the use of feedback loops. The gain in the feedback loops rectify present error values while the integrator accounts for past error values. Typically hydrogen dioxide is controlled in a similar manner but was assumed to be constant for the purposes of this project.

Calculations

The following equations are the transfer functions for $H_2$, $O_2$, and $H_2O$ from which the gain values are derived.

$$H_{O_2}(s) = \frac{1}{1 + \tau_{O_2}s}$$

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$$H_{H_2O}(s) = \frac{1}{1 + \tau_{H_2O}s}$$

Results

The model of the PEMFC used in the design functions properly, as shown above in fig. 3. The output voltage produced by the model are reasonable values that can be expected from a stack of 88 fuel cells. The partial pressures of hydrogen and oxygen shown in fig. 4 are simulated with only gains in the feedback loops. Observe that at $t = 15$ seconds, a disturbance in the current causes a slight change in the steady state values of hydrogen and oxygen. While the partial pressures of hydrogen and oxygen remain quite close, the slight change in their steady state values is undesirable. With the addition of integrators in the feedback loops, there should be a slight oscillation at the moment of disturbance, but the pressures should quickly return to the desired steady state value. Unfortunately, our design was unsuccessful in implementing these integrators.

Objectives/Challenges

- Achieving stable steady state values for the partial pressures of hydrogen and oxygen under the effects of a constant disturbance (expressed through current)
- Ensuring that the partial pressures of hydrogen and oxygen are equal to prevent damage to the electrolyte membrane
- Achieving acceptable and stable steady state values for the output voltage of the PEMFC

Acknowledgement

We would like to thank Professor Gajic for his valuable guidance.

Background

A PEMFC consists of four basic components, an anode, a cathode, an electrolyte membrane, and a resistive load. Hydrogen is pumped into the anode and broken into hydrogen ions and electrons by a catalyst. The electrons pass through a load and the hydrogen ions flow through the electrolyte membrane into the cathode. Oxygen is supplied to the cathode where it combines with the electrons and hydrogen ions to form water vapor as the only waste product. The development of PEMFCs is highly motivated by its wide range of applications as a clean alternative energy source. Some applications of PEMFCs today include residential power, portable power, transportation, military uses, etc.

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