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Short communication

Design of control systems for portable PEM fuel cells☆

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Abstract

The current evolution in the design of fuel cell systems, together with the considerable development of integrated control techniques in microprocessor systems allows the development of portable fuel cell applications in which optimized control of the fuel cells performance is possible. Control, in the strict sense, implies a thorough knowledge of both the static and dynamic behaviour of the system comprising the stack, manifold and the compressor that enables oxygen supply. The objective of this control, far from being simply to maintain the stack free from oxygen and hydrogen shortages, is to achieve the necessary values of these gases, minimizing compressor consumption, which is the cause of the greatest inefficiency of fuel cells. This objective is essential when fuel cell systems are involved in situations where the net power of the stack is reduced and any unnecessary consumption lowers the total power available to the user. The design of an efficient control system requires the following steps: (1) modeling of the stack, compressor and other pneumatic elements involved in the system. (2) Calculation of the control equations and simulation of the entire system (including control). (3) Emulation of the stack and other pneumatic elements and simulation utilizing the designed control system. (4) Physical realization of the control system and testing within the fuel cell system. The design of a control system for fuel cell systems is introduced to manage PEMFC stacks. The control system will guarantee the correct performance of the stack around its optimal operation point, in which the net power is maximized. This means that both, the air flow and the stack temperature are controlled to a correct value.

Keywords: PEMFC; Control; Fuel cell; Oxygen excess ratio

1. Introduction

The automatic control of PEM fuel cells is a process where the actuation on at least two families of variables: hydraulic (gas flows) and electric (electron flow). The main task that a control strategy must fulfill is to maintain the chemical kinetic of the redox reaction [1]:

$$\begin{aligned}\text{Cathode}: &\ \tfrac{1}{2}O_2\,(g) + H_2O + 2e^- \rightarrow 2OH^-\,(aq)\\ \text{Anode}: &\ H_2\,(g) + 2OH^-\,(aq) \rightarrow 2H_2O + 2e^-\end{aligned} \qquad (1)$$

The load or electric impedance that is connected to the stack unbalances the electron equilibrium thus forcing the control systems to dynamically adapt the reactants quantities (oxygen and hydrogen). It is also necessary the use of ambient controller in order to ensure the optimum reaction conditions.

2. Control systems

The work that is presented implements an electronic controller that handles the entire system (Fig. 5). The controller system includes three control loops assigned to the control of oxygen flow, hydrogen flow and environment control (temperature). The oxygen flow is modified actuating on the air flow entering the cathode of the fuel cell stack (FCS). The hydrogen flow is also controlled through the hydrogen output. Finally, the temperature is kept within the limits that guarantee an optimum reaction performance actuating on a fan. In the case of hydrogen flow control, proportional regulation valves are used. These valves ensure a flow that is proportional to the pressure difference between the hydrogen storage unit and the stack anode input. This automatically solves the problem of the control of hydrogen flow ($W_{\text{anode, in}}$) when using a stack with closed anode

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