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Performance improvement of a PEMFC system controlling the cathode outlet air flow☆

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Abstract

This paper presents a stationary and dynamic study of the advantages of using a regulating valve for the cathode outlet flow in combination with the compressor motor voltage as manipulated variables in a fuel cell system. At a given load current, the cathode input and output flowrate determine the cathode pressure and stoichiometry, and consequently determine the oxygen partial pressure, the generated voltage and the compressor power consumption. In order to maintain a high efficiency during operation, the cathode output regulating valve has to be adjusted to the operating conditions, specially marked by the current drawn from the stack. Besides, the appropriate valve manipulation produces an improvement in the transient response of the system. The influence of this input variable is exploited by implementing a predictive control strategy based on dynamic matrix control (DMC), using the compressor voltage and the cathode output regulating valve as manipulated variables. The objectives of this control strategy are to regulate both the fuel cell voltage and oxygen excess ratio in the cathode, and thus, to improve the system performance. All the simulation results have been obtained using the MATLAB-Simulink environment.

Keywords: PEMFC; Multivariable control; Predictive control; Dynamic matrix control; Performance improvement

1. Introduction

Polymer electrolyte membrane (PEM) fuel cell systems are efficient devices which allow the transformation of chemical energy stored in hydrogen to electric energy. In order to obtain this transformation efficiently the global system, which includes several subsystems, must be considered. The air supply is one of these subsystems, which has a great influence in the system efficiency. At the same time, one of the most important challenges in fuel cell control is to assure sufficient amount of oxygen in the cathode when current is drawn abruptly from the fuel cell stack. In this study, the air supply subsystem is composed by an air compressor, while the fuel supply subsystem relies on a pressurized hydrogen tank. The hydrogen inlet flow rate is regulated by an independent control loop to maintain the working pressure in the anode close to the pressure in the cathode. A schematic diagram of the system is showed in Fig. 1.

The PEM fuel cell system without a proper controller will not be able to withstand the load fluctuations [1]. When an electric load is connected to the fuel cell, the control system must maintain the optimal temperature, the membrane hydration and the partial pressure of the gases at both sides of the membrane in order to avoid voltage degradation and fuel cell life shortening [2]. In particular, the air supply results critical in the system performance because the oxygen reacts instantly as current is drawn, whereas the oxygen supply is limited by the dynamics of the inlet manifold and the air compressor [3]. The operating air pressure and the air stoichiometric ratio provided to the stack by the air supply subsystem, control the oxygen partial pressure at the cathode catalyst layer. This partial pressure has major influence in the cathode polarization and thus, in the conversion efficiency [4].

In several publications, the control of air supply has been approached. In Ref. [5], it is demonstrated the convenience of regulating the oxygen excess ratio in the cathode to maximize the system net power. The oxygen excess ratio or stoichiometric ratio is defined as the ratio of inlet oxygen flow to reacted oxygen flow in the cathode. In Refs. [2,5,6,7], the control of oxygen excess ratio is approached through the manipulation of the compressor motor voltage. In Refs. [2,5], feedforward

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