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Controllability analysis of decentralised linear controllers for polymeric fuel cells

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Abstract

This work deals with the control of polymeric fuel cells. It includes a linear analysis of the system at different operating points, the comparison and selection of different control structures, and the validation of the controlled system by simulation. The work is based on a complex non linear model which has been linearised at several operating points. The linear analysis tools used are the Morari resiliency index, the condition number, and the relative gain array. These techniques are employed to compare the controllability of the system with different control structures and at different operating conditions. According to the results, the most promising control structures are selected and their performance with PI based diagonal controllers is evaluated through simulations with the complete non linear model. The range of operability of the examined control structures is compared. Conclusions indicate good performance of several diagonal linear controllers. However, very few have a wide operability range.

Keywords: Polymeric fuel cell; Diagonal control; Linear control; PI controllers; Operating conditions; Linear analysis

1. Introduction

Proton exchange membrane fuel cells (PEMFC), also known as polymer electrolyte fuel cells, are being actively developed for use in cars, buses, as well as for a very wide range of portable applications, and also for combined heat and power systems [1,2]. They are regarded as ideally suited for transportation applications due to its high power density, compactness, lightweight, low-operating temperature which permits fast start-up, solid electrolyte, long cell and stack live, low corrosion, and higher efficiencies compared to heat engines [3,4].

A lot of works are dedicated to model polymeric fuel cells, as summarised by Yao et al. [5]. However, most of these models are static models. Some authors introduce electrochemical time constants in their models [6], but they do not model the flow dynamics of the whole system. With the aim to study the flow dynamics of polymeric fuel cells, Pukrushpan et al. [7] presented a control oriented model which includes the transient phenomena of the compressor, the manifold filling dynamics (both anode and cathode), reactant partial pressures, and membrane humidity. This model proposed by Pukrushpan et al. has been the base for the model used in this work although some modifications are introduced.

In 1998, Yang et al. [8] described the control challenges in fuel cell vehicle development. After that, some studies have addressed these challenges related to the control of polymeric fuel cells [4,9]. This literature has been considered to define the multiple objectives of the control problem addressed in this work.

PI based controllers are proposed by some authors but a complete study of the multiple input multiple output (MIMO) control problem is not done. In this work, different control structures are analysed and compared taking into account the interactions between loops and the directionality of the system.

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