Renewable Energy and Power Quality Journal (RE&PQJ), ISSN 2172-038 X, No.9, 12th May 2011, Reference Paper: 419

Model Based Controller Design for Hydrogen Fuel Cell Systems

K.K.T. Thanapalan#, G.C. Premier, A.J. Guwy

Sustainable Environment Research Centre (SERC),
Renewable Hydrogen Research & Demonstration Centre, University of Glamorgan,
Baglan Energy Park, Baglan, Port Talbot, SA12 7AX, UK
Phone/Fax number: +44(0)1639 814510, e-mail: kthanapa@glam.ac.uk

Abstract

In this paper, fuel cell system modelling alongside controller development for performance improvements, are investigated. Essentially and in general terms there are two approaches to modelling; black box modelling and detailed dynamic modelling. This work addresses both modelling approaches. These models are then used for hydrogen fuel cell (FC) controller development for improved system performance. A fuzzy-PID hybrid controller has been designed and tested and the results indicate that the fuzzy-PID hybrid control strategy can improve the system's performance significantly.

Key words

Modelling, Hybrid control, Fuel cell, Controller Design

1. Introduction

Fuel cell technologies have been identified as an area of significance in providing solutions to the problems of meeting increasing renewable energy demands. Mitigation of environmental pollution and providing energy shortage routes has led to fuel cells being considered as elements of alternative energy systems; capitalizing on high efficiencies and low emissions. A fuel cell is an electrochemical energy conversion device which may convert hydrogen and oxygen into water and in the process produces electricity. Fuel cells are able to provide large amounts of current and hence power, with the thermodynamic requirement being the appropriate flow of reactants. It is this supply of reactants which presents one of the several challenges encountered by fuel cell system investigators [1]. There are several types of fuel cells, each using a different chemistry. The Polymer Electrolyte membrane (PEM) fuel cell is commonly used to power vehicles.

The performance of fuel cells and the vehicle applications they are embedded into depends on a delicate balance of the correct temperature, humidity, reactant pressure, purity and flow rate. Thus, it is clear that good performance of the fuel cell system is closely related to the efficacy of the control used. For practical applications, accurate fuel cell models play a key role in controller design and power management, so the study of control oriented models is a critical first step for the understanding of system behaviour, and for subsequent design and analysis of model based control systems [2].

This paper investigates fuel cell system modelling alongside controller development for performance improvements. A variety of literature has been published concerning various aspects of fuel cell system modelling, dynamics and operation. Broader details of the subject can be found in various reports, which summarise the modelling aspects and the problems experienced with fuel cells. These reports also suggest some technical solutions and analysis methods for some of the problems [3]. However, in general there are two types of models which have been proposed to investigate fuel cell technology via simulation. The approaches of these models are: detailed lumped parameter dynamic models; and black-box models based on system identification. The latter commonly expresses as NARX (Nonlinear Auto Regressive with eXogenous input) or ARMAX (Auto Regressive Moving Average with eXogenous input) equations. This work addresses both modelling approaches by presenting an ARMAX model for the black-box modelling approach and a detailed mechanistic model for the dynamic modelling approach.

2. Fuel Cell System ARMAX Model

In order to develop control strategies for fuel cell reactant flows, it is necessary to have a model for the fuel cell systems. From a system viewpoint, hydrogen is an input variable and is fed at an adjustable flow rate N_H. Oxygen is also an input and can be represented by N_A where a fuel cell uses the oxygen content of air. Voltage and current are then considered the system outputs. Franklin et al [4] represent this as a standardised MIMO system. Taking this view into consideration in this paper, a cross coupled block representation of the relationship has been formulated as shown in Figure 1, with blocks G_i where, $i = 1...4$ describing the relationship between the outputs I_c and V_c, and inputs N_A and N_H, where R represents the internal cell resistance. The overall stack model can be expressed as follows:

$$V_C = G_2 N_A + G_4 N_H + RI_C \qquad (1)$$

$$I_C = G_1 N_A + G_3 N_H \qquad (2)$$

Equations (1) and (2) will now form the basis for the proceeding system identification methodology and design of controllers.