314c Control Configuration Selection for Fuel Cell Stack Systems

Masoud Soroush and Yossef A. Elabd

This paper presents an evaluation of dynamic characteristics and available on-line measurements in different types of fuel cell stack systems, such as proton exchange (polymer electrolyte) membrane (60-100°C), molten carbonate (600-1000°C), alkaline (90-100°C), phosphoric acid (175-200°C), oxide (600-1000°C), and methanol (80-100°C) fuel cells. Systems properties, such as structural controllability and observability, are used to screen alternative control configurations and propose a control configuration for each type. For each cell type, the adequacy of each measurement is determined in terms of its sampling period, time delay, level of uncertainty, and contribution to observability of the system. Manipulated input candidates are evaluated and screened in terms of their contribution to state and output controllability, rejection of measured and unmeasured disturbances, and tracking load (set-point) changes.

For fuel cell vehicles to be commercialized, several design/control challenges have to be overcome. One of these is how to handle various load levels as well as sudden load changes during vehicle operation. To supply adequate power to an engine subjected to a changing load, a control system is required to maintain optimal temperature, membrane hydration, and partial pressure of reactants. The control system is to prevent detrimental degradation of the fuel cell voltage (efficiency reduction and fuel cell shortening). Reactant flow rate, total pressure, reactant partial pressure, temperature, and membrane humidity are the main variables that can be controlled to ensure (i) fast transient response, consistent warm-ups, and safe shutdowns and (ii) robustness and adaptation to a changing power demand. Notable studies on feedback control of fuel cells include model predictive control for starvation prevention [1], control of an air compressor motor in order to regulate (and replenish) oxygen [2], and fuel cell optimal control based disturbance accommodation [3].

Good control requires adequate high-quality measurements of process variables. In the case of proton exchange membrane (PEM) stack systems, reliable measurements of hydrogen partial pressure in the cell stacks are not available now [4]. Existing hydrogen sensors have slow responses, low accuracy, high cost, and/or high sensitivity to variations in gas composition. To overcome this measurement inadequacy, attempts have been made to estimate the partial pressure of hydrogen and membrane humidity, by using first-principle models [4]. Apart from the partial pressure measurement inadequacy, the regulation of hydrogen in a PEM system is among the most challenging control problems. Insufficient supply of hydrogen causes “starvation” of the cell, leading to shorter life of the cell, while excessive hydrogen output from PEM reduces the cell efficiency.

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