Simulation of a stand-alone residential PEMFC power system with sodium borohydride as hydrogen source

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ABSTRACT

Catalytic hydrolysis of sodium borohydride (NaBH₄) has been investigated as a method to generate hydrogen for fuel cell applications. The high purity of the generated hydrogen makes this process a potential source of hydrogen for polymer electrolyte membrane fuel cells (PEMFCs). In this paper, a PEMFC power system employing a NaBH₄ hydrogen generator is designed to supply continuous power to residential power applications as stand-alone loads and simulated using Matlab/Simulink software package. The overall system is sized to meet a real end-use load, representative of standard European domestic medium electric energy consumption, over a 1-week period. Supervisory control strategies are proposed to manage the hydrogen generation and storage, and the power flow. Simulation results show that the proposed supervisory control strategies are effective and the NaBH₄–PEMFC power system is a technologically feasible solution for stand-alone residential applications.

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1. Introduction

Fuel cells are an attractive solution for residential self-generation needs because of their high efficiency, low thermal and noise signatures and modularity. Government and industry-led field demonstration programmes of residential fuel cell systems are already being conducted in different countries around the world [1]. Most of the installed systems are based on polymer electrolyte membrane fuel cell (PEMFC) technology and in most of the cases hydrogen is generated on-site via reforming of fossil fuels such as natural gas, LPG and kerosene [2,3]. The advantages of PEMFCs include the ability to provide high current densities at relatively low operating temperature, rapid start-up and good dynamic performance [4]. Fossil fuels' attraction is that a supply infrastructure already exists and that it is currently the least expensive source of hydrogen.

The most commonly used reforming processes generate poisons or impurities that negatively impact environment and PEMFC performance and durability [5–7]. Reduction of impurities to an acceptable minimum level renders these processes of hydrogen generation extremely complex and bulky. In addition, these processes are conducted at elevated temperatures (>500 °C [8]), which requires a rather complex system of heat management. Other

hydrogen generation routes are therefore desired for fueling PEMFCs.

The hydrolysis of chemical hydrides has been distinguished as a new route of generating hydrogen on-site for PEMFCs due to the relatively low reaction-initiating temperature and high purity of produced hydrogen. Among the chemical hydrides of interest, the hydrolysis reaction of sodium borohydride (NaBH₄) in alkaline solution is the most extensively studied owing to its combined advantages of theoretically high hydrogen storage capacity, satisfactory reaction controllability, safe fuel storability, and environmentally benign and recyclable reaction by-product [9]. In the presence of a suitable catalyst, a NaBH₄ solution with an alkaline stabilizer, sodium hydroxide (NaOH), reacts rapidly with water to generate hydrogen according to the hydrolysis reaction shown [9].

Kinetics studies of this reaction have been summarized in a recent review [10].

Although numerous studies exist on the NaBH₄ hydrolysis reaction for hydrogen supply, relatively few have reported results of the performance of PEMFC power systems with NaBH₄ as hydrogen source (NaBH₄–PEMFC). The NaBH₄–PEMFC power systems evaluated were developed for use in micro [11–12], portable [13–14] and vehicular [15–16] applications. The reported results are encouraging, but further improvements in system energy density and cost are still required with respect to these applications in order to be able to compete with the traditional power sources.

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