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Design and Analysis of Aluminum/Air Fuel Cell model for portable devices.

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ABSTRACT

This extended abstract presents the concepts of Aluminum Air Fuel cells, specifically, focus on the modelling alternatives of this technology. Different model tools are assessed in order to be implemented. It also reviews potential applications of such technology and develops an actual model using as a main tool for it Matlab/Simulink. Test and results of this research will also be shown and analized as part of the final report.

1. INTRODUCTION

Fuel cells are electrochemical devices that convert the chemical energy of a fuel directly into electricity. This process is proven friendly environment as the waste byproduts of this transformation can be as harmless as water, oxygen and heat. Different types of fuel cells are currently being assessed as a potential stationary and mobile power source[1].

Different materials can be used as fuel independent of the fuel cell performance exclusively from the supply of fossil fuels. Different kind of fuel cells can be developed and named after the different fuels uses in the process or the different kind of membranes materials between anode and cathode: Proton Exchange Membrane Fuel Cell(PEMFC), Solid Oxide Fuel Cell(SOFC), Direct Methanol Fuel Cell(DMFC), are among the most known and developed Fuel cells[6]. In majority of applications, Hydrogen(which can be obtained from air or water) or hydrocarbons such as Methanol or natural gas are used. The byproducts of the system often are water and oxygen which brands the system as a convenient friendly environment product[2]. There are several developed models available for the above types fuel cells which can provide the designer with more convenient approach for system analysis and design. In the other hand, for portable devices, there is a concern pertains to fuels such as Hydrogen or Hydrocarbons. Aluminum-Air Fuel Cell (Al/Air FC) has recently emerged as an excellent choice for the development of these types of applications. It has the flexibility to mechanically recharge the system by inserting a new stick of aluminum. In addition, there are other favorable characteristics for the Al/Air FC) such as: high theoretical limit of internal energy of Aluminum, the safe storage(non Flammable) and the fully recyclability of the material. These characteristics constitutes this type of FC as an excellent choice to be developed, for portable devices as well as other potential applications[3]. Most of current portable devices are capable of providing the needed power, but suffer the lack of autonomy pertaining to fuel charging in a timely fashion. In this paper, the modeling of the Al/Air FC has been developed for the analysis, design and implementation of the fuel cell. In addition, the simulation experiments will be carried out to demostrate the effectiveness of the development models.

2. ALUMINUM-AIR FUEL CELLS (AL/AIR FC)

Since the early 1960's, the use of Aluminum as an anode has atracted many potential applications. During 1980´s Aluminum-Air systems have reached safeness and realiability as systems capable to achieve 300-500 Wh/kg and specific power up to 22.6W/kg[3]. Al/Air FC are devices which converts chemical energy of the reaction between oxygen present in the air with Aluminum as fuel in order to obtain electricity. The fuel cell has an aluminum anode with a a gas diffusion electrode/cathode, the oxidation of Aluminum by Oxygen from air generates a power suply. The chemical reactions are shown as follows:

$$4\,Al + 3\,O2 + 6\,H2O \rightarrow 4\,Al\,(OH)3 + E\uparrow + H\uparrow$$

Figure 1: Al/Air FC chemical reaction

Where E and H represent Energy and Heat respectively. Aluminum plates conforms the anode, a gas diffusion electrode supplies the oxygen extracted from the air, and additives such a water cartridge are added to obtain the reaction.[4] In this chemical reaction there is an aluminum component as byproduct waste result mixed with oxygen and hydrogen which can be recovered thru a recycle process and used again as many times as needed. The Al/Air FC has a theoretical voltage and high theoretical energy density due to the the high aluminum enthalpy along with other advantages as this is an abundant material on earth crust, light, cheap and fully recyclable. The enthalpy of Aluminum chemical reaction with oxygen has reached 10.176 kWh/kg.[4] In the down side impurities found in its natural form on earth or added thru the extraction process of aluminum have a high impact in the material efficiency and behavior as fuel for FC systems. Therefore this is a concern that has to be properly reflected in the Fuel Cell Model.[5]. Also some Aluminum alloys have been extensively used to improve its inherent characteristics and behavior in fuel cell systems which also should be considered in the system model.

3. Model analysis and implementation

Fuel cell systems development involve many technical variables and problems which make the FC system a complex system. In order to optimize the efficiency inputs such as feed, proper flow, pressure regulation, heat management, etc. have to be taken care of in the system analysis. The critical fuel cell parameters can be controlled by a series of actuators. A model facilitate a better understanding of all variables and parameters which can affect the performance of the fuel cell or the fuel cell systems, allowing the developer to design, test and optimize the fuel cell or the FC system. Different approaches of modelling are consider in order to get the final model to test and obtain results. Important features as model approach, state, system boundary, spatial dimensions, accuracy flexibility among other characteristics are taken in count and optimized in order to get the best alternative. The following table shows the state of art of many models current available either theoretical or comercially.[6]

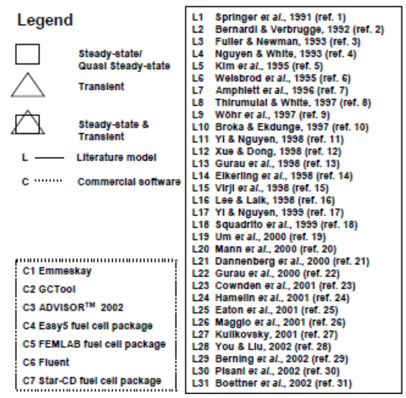

Figure 2: An Overview of Fuel Cell models available in literature and commercially [6]

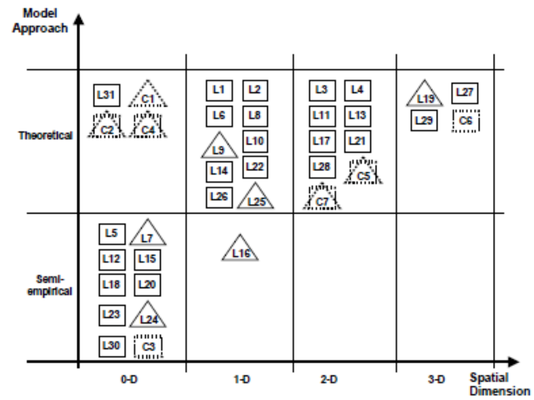

Figure 3: Classification of Fuel Cell models available in literature and commercially [6]

The construction of the model will be primary based in Matlab/Simulink™ along with other libraries toolbox which enhanced the evaluation capabilities of the system in terms of thermodynamics, electrochemics, actuators availability and system analysis approach point of view. Other software tools comercially available may also be evaluated to measure the potential contribution to the final model.

References

[1] Pukrushpan, J., Stefanopoulou, A., Peng, Huei. (2010). "Control of Fuel Cell Power Systems". Springer-Verlag London Limited 2004.

[2] Baccaletti, C., Duni, G., Fabbri, G., Santini, E., (2006) "Simulation models of fuel cell systems" Department of Electrical Engineering, University of rome "*La Sapienza*". Italy.

[3] Dougherty, T., Karpinski, A. (Alupower Inc) Stannard, J., Halliop, W.,(Fuel Cell Technologies Ltd) Warner, S., (Alupower-Chloride Ltd) (1996). "Aluminum-Air Status of Technology and applications. IEEE

[4] Kulakov, E., Ross, A., (2007). "Aluminum Energy for Fuel Cells". *Altek Fuel Group, Inc,* USA.
[5] Yang, S., Knickle, H., (2002). "Design and Analysis of Aluminum/Air battery system for electrical vehicles". *Journal of power sources, 112,* pp. 162-173
[6] Haraldsson, K., Wipke, K., (2003) "Evaluating PEM fuel cell system models". National Renewable Energy Laboratory (NREL), Golden, Colorado, USA. p 6.

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