Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 74 (2015) 308 – 319

Energy Procedia

International Conference on Technologies and Materials for Renewable Energy, Environment and Sustainability, TMREES15

Multi-stack fuel cells powering a vehicle

Mohamed Becherif[a]*, Frederic Claude[b], Thomas Hervier[c], Loïc Boulon[d]

[a]*FCLab FR CNRS 3539, Femto-ST UMR CNRS 6174, UTBM, France*
[b]*SEGULA MATRA Technologies,France*
[c]*ENSIAME, Valenciennes, France*
[d]*Institut de recherche sur l'hydrogène, Université du Québec à Trois-Rivières, Canada*

Abstract

Current issues concerning global warming and fossil fuel energy shortages impose to find alternatives in order to meet the growing planet's energy demand. The automotive sector is particularly concerned with these issues. The fuel cell seems to be a very promising technology. This article addresses a technological aspect of the integration of fuel cell on a vehicle. The chosen configuration is a multi-pack system favoring the use of several reduced power fuel cells. The energy management method is described along with the sizing and some simulation results.

Peer-review under responsibility of the Euro-Mediterranean Institute for Sustainable Development (EUMISD)

Keywords: Fuel cell; electrical vehicle; multi-stack; modelling.

1. Introduction

The global population growth and the increase in industrial activity are real issues with regard to global warming and power reserves. Fossil fuels tend to disappear and the use of new natural resources is more and more encouraged. Governments have the responsibility to initiate the energy transition. Measures have been taken and concerted effort concerning wind, solar, geothermal energy and biofuels are in progress all over the world. But, another resource seems very promising: hydrogen. Indeed, hydrogen has an energy density of 140 MJ/kg, which is 3 times higher than oil and 200 times higher than a lithium battery. The automotive sector, in particular, is one of the major contributors to the greenhouse effect. Indeed, there were already 1.015 billion cars in 2010 owing to Wardsauto [1]. However, new motor technologies emerge and reduce gas emissions.

* Corresponding author. Tel.: +33384583346; fax: +33384583636.
E-mail address: mohamed.becherif@utbm.fr

Peer-review under responsibility of the Euro-Mediterranean Institute for Sustainable Development (EUMISD)
doi:10.1016/j.egypro.2015.07.613

Hybrid technologies combining heat engine and electric engine are currently in use:

- In 1997, the Toyota Prius was the first mass-marketed hybrid vehicle.
- In 1999, the Honda insight was born.
- Then, in 2002 the Honda civic hybrid was marketed.

But, to make further progress, it is also possible to feed an electric motor only thanks to a fuel cell (FC). Gaseous hydrogen is used as fuel and air (oxygen) as combustive. The only byproduct are water and heat. This is a zero emissions technology. This FC can be reinforced with batteries and ultra-capacitors. Consequently, it is actually the source which is hybridized and not the engine.

Various types of FCs exist. The PEMFCs (Proton Exchange Membrane Fuel Cells) seem to be the most promising for transportation. This FC is composed of an electrolyte membrane allowing the passage of ions and preventing the passage of electrons. Around it are two porous electrodes containing hydrogen and oxygen: the anode and cathode. Electrons migrate from the anode through the electrical load to the cathode. Therefore, the electric current is created.

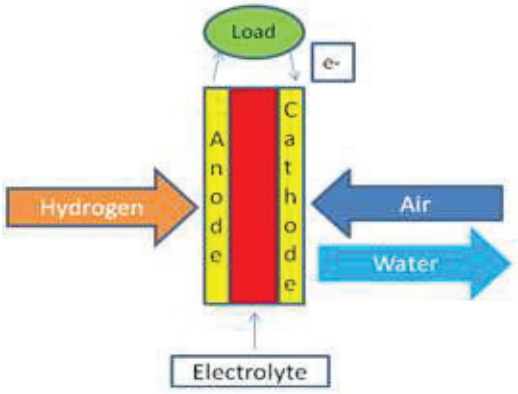

Figure 1 - Principle diagram of a cell

Two bipolar plates are present to feed the system in gaseous hydrogen and air, displace the water produced by the cathode, allow a cooling fluid to circulate, make the electrical connection between elementary cells of the FC and ensure the mechanical resistance of the entire system [2].

So, it's a basic oxide-reduction reaction which takes place within the FC. It is represented by the following chemical equation [3], [4], [5]:

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O + electricity + heat \quad (1)$$

The faster the rate of the reaction at the level of the electrodes is, the more the FC is effective. This is why, platinum is used as a catalyst material to form the surface of the electrodes. Three criteria can affect the efficiency of the reaction in a PEMFC (one can also add the air or oxygen pressure):

- The first is temperature, which must be between 60°C and 80°C.
- The second is the hydrogen intake pressure directly controlled by the current flowing the FC.
- The third is the suitable humidification of the polymeric membrane.

Actually, several auxiliaries take part in the operation of the FC. The package including the FC and the auxiliaries is called FC system [2], [6].

2. Description of the fuel cell model

The described modelling is of a multi-pack FC. It is an innovative concept in terms of architecture: FCs are