HYBRID ELECTRIC VEHICLE (NAYAA)
BATTERIES – FUEL CELL

A. Rodríguez-Castellanos, S. Citalán-Cigarroa, J. L. Díaz-Bernabe, O. Solorza-Feria
Depto. Química, Centro de Investigación y de Estudios Avanzadosdel IPN,
A. Postal 07360, México D.F., México.
Tel: 57473800 ext. 4473, Fax 57473389, acastella@cinvestav.mx

ABSTRACT

Worldwide, the automobile sector emits 25 %of CO_2 .This will be increase up to 50% in 2030 and more than 80% in 2050, according to the International Energy Agency (IEA, info. 2009).

The use of hybrid vehicles can significantly reduce the amount of polluting gases in the atmosphere. A hybrid electric vehicle (HEV) has two or more power sources on board and depending on system configuration; two or more sources of energy are used to drive the vehicle. The interest of our research is to reduce the automobile emission of pollutants gases in the atmosphere. This has created the need to develop and build a wide variety of systems and devices.

Our experimental work presents the design, construction and performance evaluation of a hybrid electric vehicle (Nayaa), powered by a generator with PEM fuel cells and / or rechargeable batteries. The generator design was done using AutoCAD software. Construction of fuel cells was carried out by CNC router and CNC laser cutter.

The fuel cells characterization was performed by potentiostatic polarization tests. The operation conditions of generator with fuel cells were: feeding the fuel (H2) and oxidant (air) at room temperature and a pressure of 0.1 atm (1.5psi), operating temperature varied from 20 ºC to 70 ºC. This experimental work presents the commissioning of the hybrid electric vehicle, which weighs was 80 kg, made of aluminum.

1. INTRODUCTION.

At present the use of fossil fuels in automobiles, produce large amounts of emissions, it is directly affects the climate change and leads to global warming finally deteriorating the health of living beings. In worldwide many laboratories and institutions have been developing prototypes and marketing, based on different technologies, such as hybrid vehicles (ie., different motor carriers), this will help to reduce energy dependence on fossil fuels and significantly reduce the amount of greenhouse gas emissions to the atmosphere.

A hybrid electric vehicle can has two or more power sources are used to drive the vehicle depending on system configuration, in this case, two sources of electrical energy are used, one is rechargeable batteries and another is proton exchange membrane (PEM) fuel cell (FC), coalesce called as Nayaa.

PEM fuel cells are devices that produce direct current (D.C.) when fed with hydrogen (fuel) and oxygen (oxidant) through an electrochemical reaction. The end product of this reaction is water and heat; therefore, it does not produce any green house gases [1].

2. EXPERIMENTAL CONDITIONS.

2.1. Electricity generator by PEM-FC.

The power generator consists of three PEM fuel cells stack with their respective systems of fuel supply and power electronics.

The power generator provides the electrical energy through the unregulated D.C. Cell # 2 and # 3 connected in parallel. The weight of the system is 30 kg.

The design of the three fuel cells stack were carried out by AutoCAD software, taking into account the different designs proposed in the literature [2-3-4-5]. The construction of the monopolar, bipolar and end plates were carried out by milling machine through CNC controller. Gaskets, membranes and acrylic pieces were cut by a laser cutter.

Fuel cells are constituted by plates of high density carbon with a thickness of 5mm, 100mm wide and 100mm long. The field flow design of gas to the anode and cathode is shaped cross straight channels. Sheets brass were act as current collector and acrylic plates act as channel input and output for hydrogen and air.

Aluminum end plates, silicone gaskets and stainless steel studs were used. Between each current collector plate there is a membrane-electrode assembly (MEA), which is formed by Nafion membrane ® (NRE-212) and carbon cloth diffusers with catalyst loading of 20 wt% Pt / C loading of 0.5 mg / cm^2 in both the anode and cathode. The performance of fuel cells was determined by potentiostatic polarization in a test module.
Figure 1 shows a photo of the generator, contains the PEM-FC, and peripheral system.

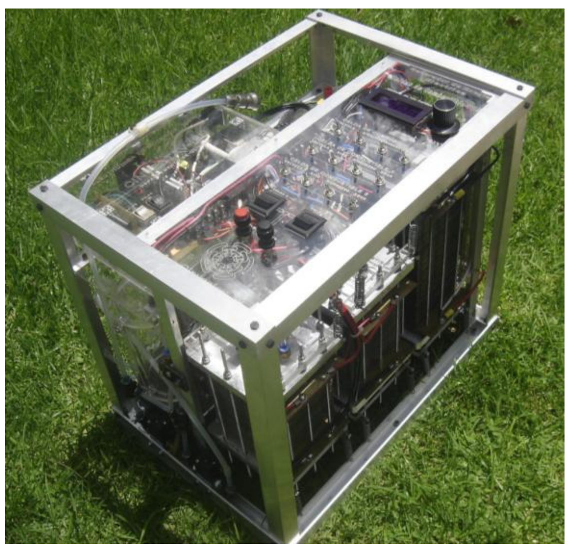

Figure 1. Power generator

2.2. Rechargeable batteries.

Two rechargeable lead-acid batteries with an electrical capacity of 12V, 7.0 Ah (Genesis NP7-12) were used. They are connected in series in order to obtain a total voltage of 24 V.

The following table describes some of the specifications of the battery and the figure shows the component parts.

Table 1. General Specifications.

Type	FR Type*	Volts	Nominal Capacity (20hr rate-Ah)	Length (mm)	Width (mm)	Overall Height incl. Terminals (mm)	Weight (kg)	Layout	Terminal Illustration
NP7-12	NP7-12FR	12	7.0	151	65	100	2.59	4	A/C

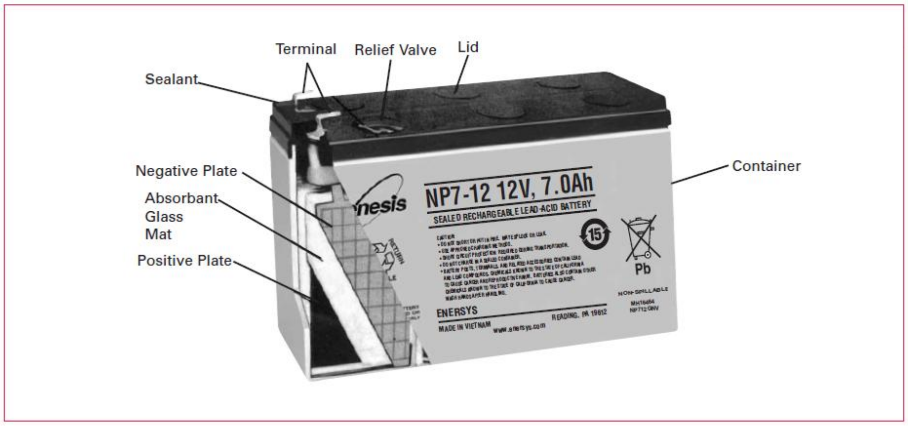

Figure 2. Genesis NP Battery.

2.3. Power electronics.

2.3.1. Power Electronics 100 watt generator.

The 100W power electronics was designed and built in order to regulate the electricity, which is composed of DC / DC converter based on a microprocessor that is coupled to the fuel cell # 1 and take advantage of the full power in the fuel cell. The converter can operate with input voltages from 6V to 15V and produce an output voltage of 13.8V with a variation of ± 0.5Volts. A 100W inverter converter was coupled, which operates with an input voltage of 13.8V at 8A and produces an output voltage of 115V AC, 60Hz. Figure 3 shows a picture of the power electronics, DC / DC converter - DC / AC 100W.

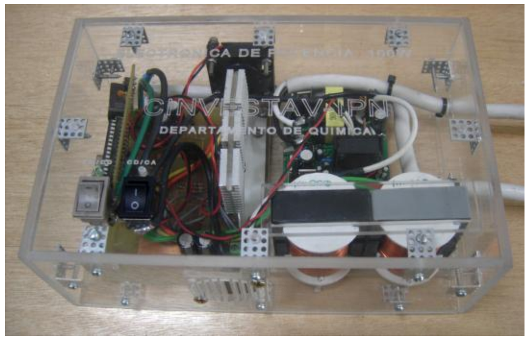

Figure 3. Power Electronics of 100W DC / DC converter and inverter DC / AC.

.

2.3.2. Power Electronics 500W - 24V.

A 500W power converter was designed and built for conditioning the electrical energy generator from PEM-FC. The DC-DC converter uses a digital control to adjust the output voltage. The output voltage level is governed by the position of a switch on the front panel. The range of the input voltage is 9 to 18 volts. The output voltage varies between 15 and 24 volts. Moments after disconnecting the starter battery and connect with fuel cell, on that time the output voltage is adjusted to maintain torque and vehicle speed. About a minute after the voltage is increased to 18 Volts. On flat surface we can see the speed change. The operator can change the power switch, until the output voltage attains the maximum energy level.

Figure 4. Power Electronics 500W DC / DC converter.

2.4.- Diagrams of energy systems.

2.4.1.- Diagram of the fuel cell generator.

Figure 5 shows the block diagram of the components that make up the autonomous system: pressurized tank with hydrogen at 4 atm, auxiliary systems recirculation of hydrogen pressurized to 0.1 atm with humidification [6], fans for cooling the cell # 1 and feeding of the oxidant (atmospheric oxygen), fuel cells, DC / DC converter and inverter DC / AC. The lines show the flow of the different states of electricity and fuel.

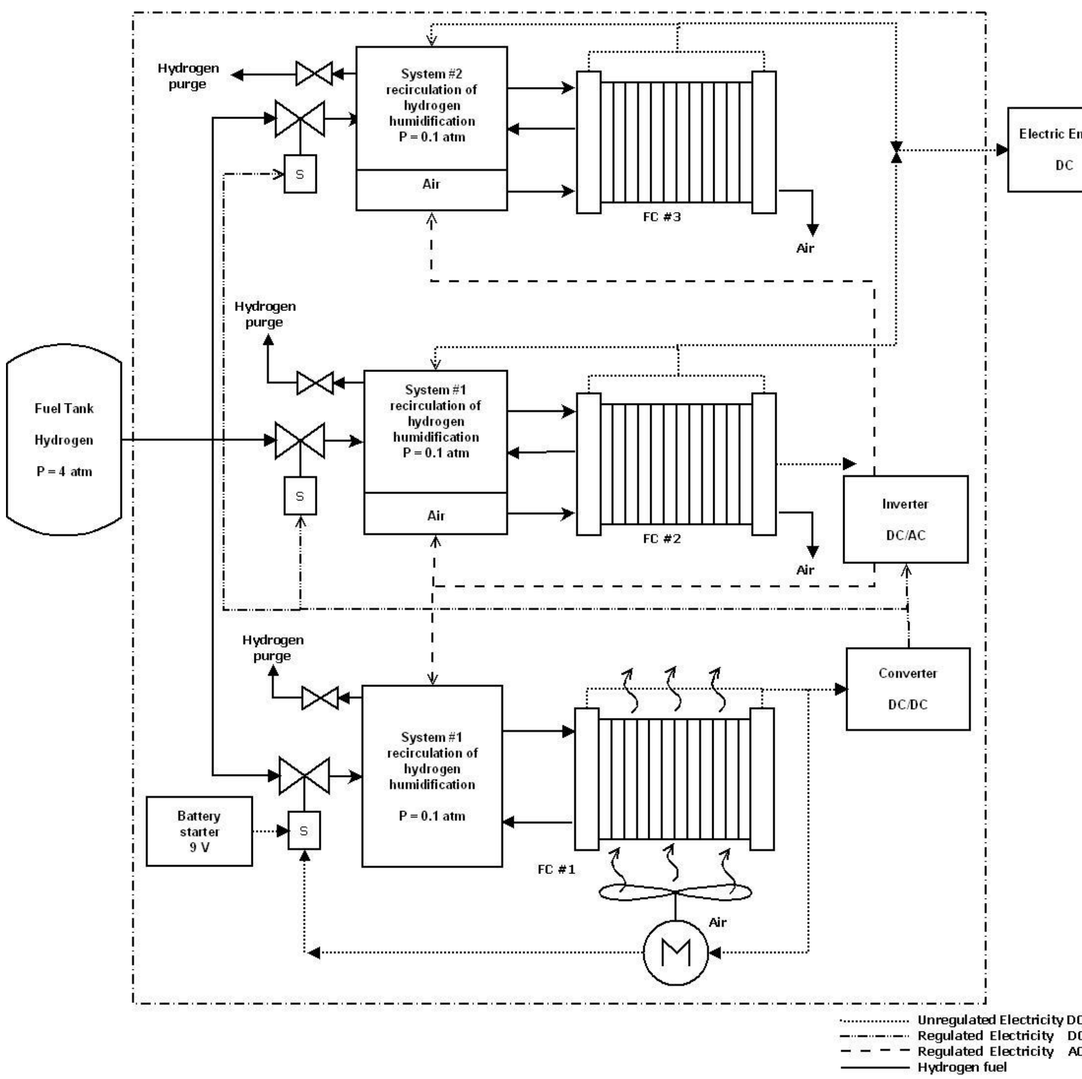

Figure 5. Block diagram of the autonomous system based on fuel cells.

2.4.2. Block diagram of the installation of energy sources.

Figure 6 shows the two main power sources, while on board the vehicle and also the main components that make up its operation.

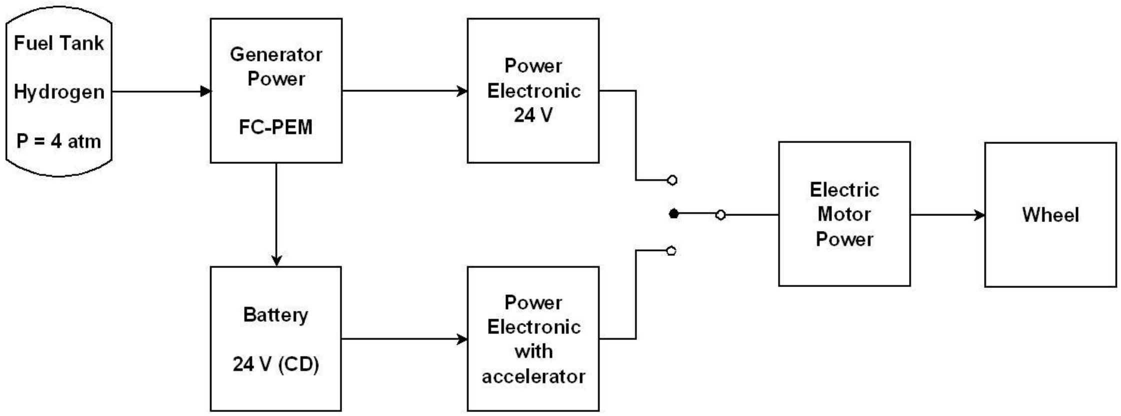

Figure 6. Block diagram of energy sources (B*attery, PEM-FC).*

2.5. Hybrid Electric Vehicle.

The hybrid electric vehicle (HEV) has two power sources for on board and propulsion [6]. It consists of three wheels; a rear-wheel drive for progress and two fronts for steering, angles were used. Sills, tees and channels of aluminum was used for the chassis, which has a total weight of 80kg with all systems.

The displacement front is provided by an electric motor with maximum power of 240W at 24V and 10A, sprockets and chains attached by the rear wheel on the wheel itself is also urging the braking system.

Figure 7 shows the photo of HEV (Nayaa), powered by rechargeable batteries and PEM-FC and all peripheral systems.

Figure 7. Hybrid electric vehicle (Nayaa).

3. RESULTS AND DISCUSSION.

3.1. Performance of power generator PEM-FC.

The pressurized hydrogen (4atm) is stored in tanks and fed to the PEM-FC by three auxiliary recirculation systems and humidification of hydrogen at 0.1atm, using 12 diaphragm pumps. Cell # 1 supplies electric power to three fans for cooling and air supply of oxygen and also it turns on the recirculation pump hydrogen cell # 1 and air cells 2 and 3 using the 100W power electronics, each of the cells (2.3) driven feed pumps for their water with hydrogen and electricity unregulated doing this a self-contained system for full operation.

The hydrogen consumption rate is varies and all the times load demand will range cells, whereas the three cells operating at its maximum power consumption of total hydrogen is approximately 7.5l / min.

Figure 8 shows the voltage-current response of the two-power fuel cells connected in parallel.

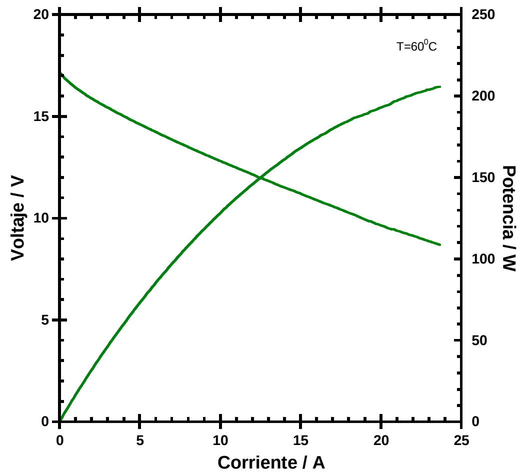

Figure 8. Generator Performance.

3.2. Performance of Rechargeable Lead-Acid battery.

This battery is typically used for UPS that provides constant power for 30 minutes. Figure 9 shows the typical behavior of discharge at the ambient temperature of 25 ° C.

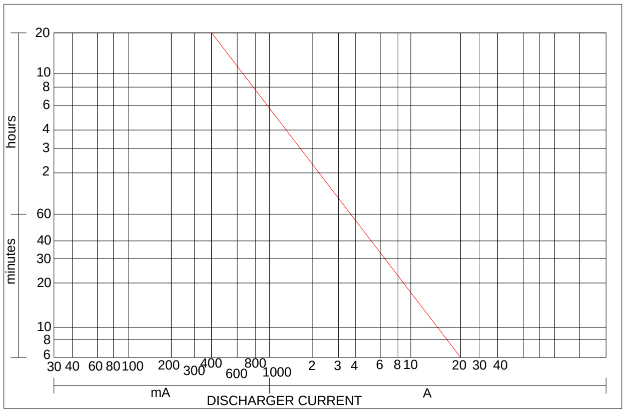

Figure 9. Discharge curve.

3.3. Strategy and distribution of energy to the vehicle.

In initial the vehicle progress is achieved with batteries and power electronics using an accelerator, as shown in Figure 10, later suspends the battery power and feeds electricity to the generator when the accelerator pedal in the lower position as shown in figure 11, the change in energy is achieved by means of switches that are coupled to the accelerator pedal.

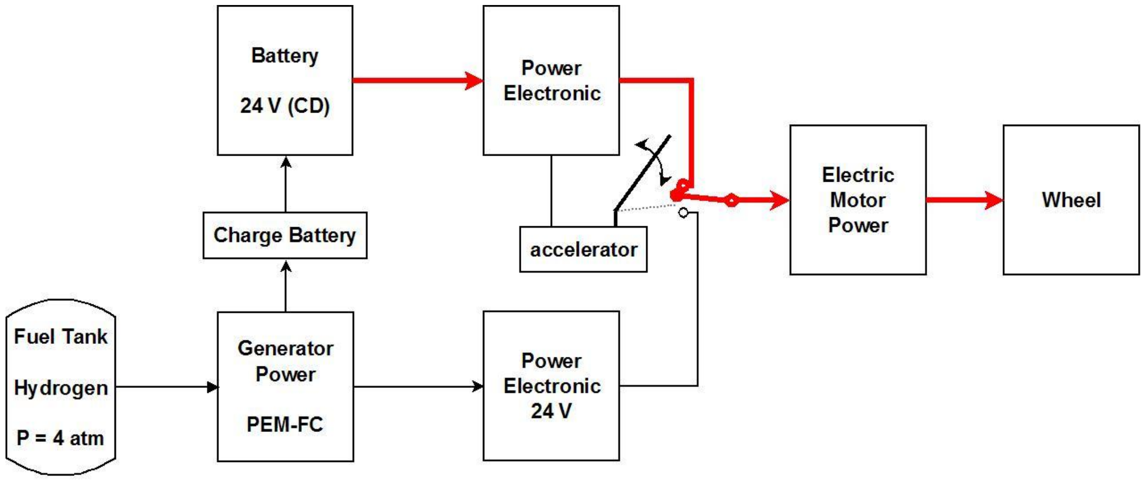

Figure 10. Initial progress of the vehicle with batteries.

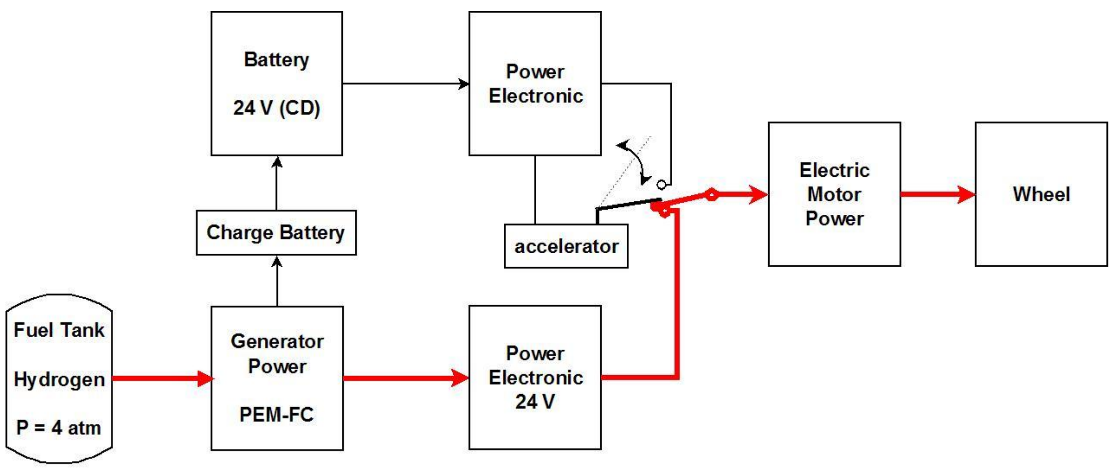

Figure 11. Power generating electricity with PEM-FC.

When the vehicle is not moving the lead-acid batteries are recharged using the PEM-FC generator and power electronics as shown in Figure 12.

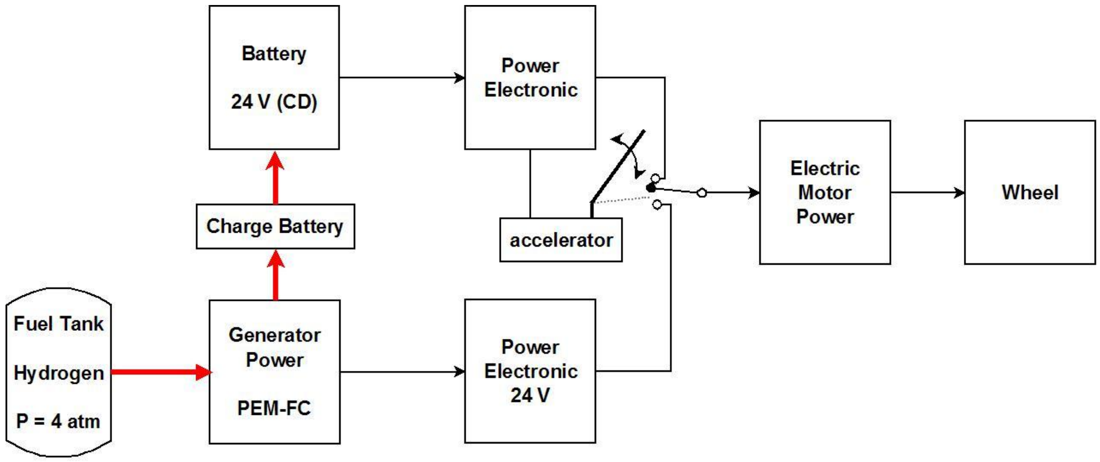

Figure 12. Charging the battery with the generator PEM-FC.

4. CONCLUSIONS.

This hybrid solution (battery and PEM-FC) for vehicle is inexpensive, profitable and eco friendly.

The battery is used for starting and heavy displacement, PEM-FC generator for smooth ride and charges the batteries.

Generator power PEM-FC provides maximum power of 23.5 V in 210W at 9.0 A with a maximum consumption of hydrogen at 7.5l / min.

The rechargeable lead-acid provides a maximum power of 168 W in 24 V and 7A. It provides constant electricity for 30 minutes.

In our laboratory was achieved to build a hybrid electric vehicle and to analyze the possibility towards the automobiles application.

5. ACKNOWLEDGEMENTS.

The authors thank CINVESTAV for the facilities.

The authors thank for the financial support provided by the project ICyTDF PICCO10-3 CONVENIO 64/2011.

The company INFRA S.A. de C.V. for hydrogen provided for this project.

6. REFERENCES.

[1] Barriers, and R&D Needs, *The Hydrogen Economy: Opportunities, Cost*, The National Academies Press, Washington DC, 2004.

[2] A. Rodríguez Castellanos, E. López Torres, O. Solorza Feria, *J. Mex. Chem. Soc.*, 50(4), 97, (2007).

[3] F. Urbani, G. Squadrito, O. Barbera, G. Giacoppo, E. Passalacqua, O. Zerbinati, *Journal of Power Sources*, 169, 334, (2007).

[4] Xianguo Li, Imran Sabir, *International Journal of Hydrogen Energy*, 30, 359, (2005).

[5] Frano Barbir, *PEM Fuel Cells: Theory and Practice*, 147, Ed. Elsevier Academic Press, USA, (2005).

[6] Frano Barbir, Haluk Görgün, *Journal of Applied Electrochemistry*, 360, (2007).

[7] Ali Emadi, *Handbook of Automotive Power Electronics and Motor Drives*, Ed. CRC Press, USA, (2005).