Hydrogen production by a PEM electrolyser

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Abstract. A PEM electrolyser for hydrogen production was evaluated. It was fed with water and a 400 mA, 3.5 V cc electrical power source. The electrolyser was built with two acrylic plates to form the anode and the cathode, two meshes to distribute the current, two seals, two gas diffusers and an assembly membrane-electrode. A small commercial neoprene sheet 1.7 mm thin was used to provide for the water deposit in order to avoid the machining of the structure. For the assembly of the proton interchange membrane a thin square 50 mm layer of Nafion 115 was used.

1. Introduction

The ever increasing world population demands more goods and services, and as a consequence an incremented necessity for energy supply. To find alternative sources of energy for fossil fuels, in order to diminishing the combustion gasses discharged to the atmosphere and the global warming that they generate, is the world most pressing problem. At present, one of the cleanest fuels is hydrogen and one with the highest probability to become the most used in a near future. Its versatility, low contamination and their quality of being renewable [1] made it very attractive for generalised use, in combination with fuel cells.

One of the most promising methods for the generation of hydrogen is water hydrolysis. This was achieved for the first time by William Nicholson and Sir Anthony Carlisle in 1800 [2]. In this process a water molecule is dissociated by the effect of an electrical current. That is, the action of an electrical current produces the gain or loss of electrons in direct proportion to the intensity of the current; which in time generates an oxidation-reduction reaction [3].

An electrolyser, the device that generates hydrogen, is an electrolytic cell that is fed by an electrical current from an external source to produce the electrochemical oxidation-reduction reaction [4-5]. The key aspects in the use of electrolysers are that it could be coupled with a renewable source of energy and thus diminish the emission of atmospheric contaminants [5].

The first electrolysers developed by the General Electric Co in 1966, were of the “Proton Exchange Membrane” (PEM) type; they used a solid polymer electrolyte [6]. When a potential difference is applied between the electrolyser’s electrodes an oxidation reaction is produced. In the anode appear oxygen atoms, protons and electrons; whereas in the cathode a reduction reaction takes place, where the protons (H+) together with the electrons form molecules of gaseous hydrogen.

The parts that constitute an electrolyser are: two plates that function as the anode and the cathode; two meshes that distribute the electrical current; two gas diffusers and the arrangement membrane electrodes (MEA) that is, the electrolyser main structure. The hydrogen produced in this electrolysers has great purity and therefore suitable for use in fuel cells.

A fuel cell is an electrochemical energy converter that transforms directly the chemical energy of a fuel into electric energy. The most important aspect of these devises is that generates clean direct current by the electro-oxidation of hydrogen (H_2) and the electro-reduction of oxygen (O_2) and only generates by products no contaminants (steam and heat).

2. Methodology

An electrolyser was built with two acrylic plates that serve as its supporting structure, the acrylic was chosen because is a light material, corrosion resistant an ease to machine. The plates were squares with 65 mm by side and a 10 mm thickness. These plates were provided with an exit for the gas and an admission for the water. To avoid the machining of the acrylic plates, the water reservoir was made with a sheet of commercial neoprene, 1.7 mm thick; Figure 1. The electrodes (anode and cathode) were built with an active area of 9.62 cm^2.

The current distribution meshes were built with stainless steel 1 mm thick and holes 0.5 mm diam. They have the function of holding the electrodes and to distribute the electrons over all the surface of the catalyser. The sealing is made of silicon 0.25 mm thick, avoiding the leaking and providing isolation between the anode and cathode plates. Both seals have a central recess, 9.62 sq cm. The gas diffusers are made with carbon fabric and are Teflon coated, their purpose is to improve the contact between the current distributing meshes and the catalytic surface. Both were cut as circles, 9.62 cm^2.

The core of the electrolyser is the Membrane Electrode Assembly (MEA). MEA is a set of 5 layers; at its centre the proton interchange membrane, which acts as the electrolyte, is located. The PEM separates the anode from the cathode structures and avoids the mixture of gases. Each electrode has a gas diffuser with a layer of electro catalyser located between the membrane and the diffuser.

Figure 1. PEM electrolyser construction

As the electrolyte a 50mm square membrane made with Nafion 115 and 127 µm thick was used. The membrane allows the passing of the ions of hydrogen that form in the anode to the cathode and thus generate the molecular hydrogen. To activate the membrane several baths of chemical solutions at 60°C were used. The preparation of the catalytic inks took as reference the reactive area of the electrolyser, 9.62 cm^2. The catalytic ink for the anode was made with 7.81 gr of IrO_2, 23.44 mg of RuO_2, 120 µl of liquid Nafion, 900 µl of ethylic alcohol and 200 µl of water. The catalytic ink for the cathode was prepared with 5 mg of Pt-Etek at 20% in weight, 100 µl of liquid Nafion, 700 µl of ethylic alcohol and 200 µl of water. To impregnate the inks over the Nafion membrane a sprayer technique with an aerograph was used. The sprayed area was the 9.62 cm^2 circle, previously marked.

The assembly of the MEA was made in a hydraulic press using the process of heat pressing. At the centre, the sprayed Nafion membrane with a gas diffuser was located and a 5 Ton/cm^2 pressure was applied at 120°C for 5 s; afterwards the pressure was reduced to 0.25 Ton/cm^2 , keeping it for 2 min to achieve a good integration. The machining of the acrylic plates was made in a vertical milling machine; on the exterior surfaces of the arrangement, four fast coupling stainless steel connectors where located to provide for the water and gasses admission and discharge; Figure 2.

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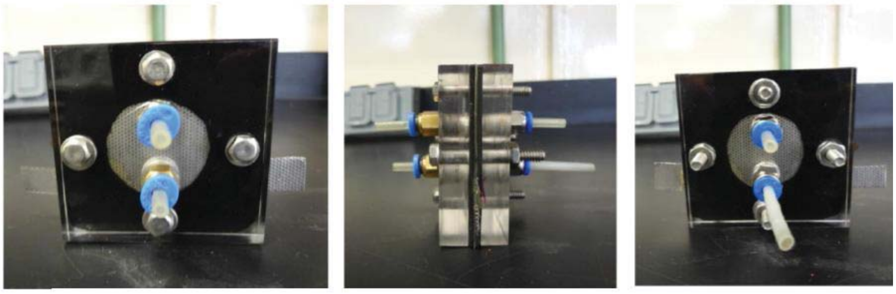

Figure 2. PEM Electrolyser final assembly**.**

3. Results and discussion

In order to correctly coupling of the electrolyser with the photovoltaic cells, the characteristic curve of each device is necessary. Then, the optimal performance point is determined so that the photovoltaic cell generate enough energy and the electrolyser can initiate the water electrolysis, and thus produce gaseous H_2 and O_2.

To characterise the photovoltaic panels three 250 W halogen lamps were located at 20 cm apart from then, so that solar radiation could be simulated. The system was connected to an arrangement of resistances where the open circuit voltage (VCA) and the short circuit current (CCC) theoretical values were adjusted. To obtain the panels real curve performance, resistances from 1 Ω to 200 Ω were applied. With this data graphs of voltage vs current were obtained.

The PEM electrolyser characteristic curve is obtained connecting it to an electrical power source, in this case the photovoltaic panels. The first test was made with an arrangement of three photovoltaic panels, serial connected, so that, a constant 100 mA (CCC) and 13.5 V (VCA) were obtained. A second test was made with the panels connected in parallel. In this case, 4.5 V (VCA) and 300 mA (CCC) were obtained. Both results were compared with the electrolyser characteristic curve; Figure 3.

The PEM electrolyser characteristic curve does not pass by any of the maximum power curve bends obtained from the photovoltaic modules. That is, the photovoltaic modules arrangement serial or parallel connections do not satisfy the electrolyser optimal energetic performance requirement. Therefore, the modules connection was modified to a serial-parallel arrangement. First, four arrangements were prepared, each one with two modules serial connected; then, these four arrangements were parallel connected, so that, 400 mA (CCC) and 3.5 V (VCA) were obtained.

In figure 4, the coupling of the photovoltaic serial-parallel system curve with the electrolyser performance curve is shown. In this new arrangement the electrolyser performance curve goes through the photovoltaic system maximum power curve bend.

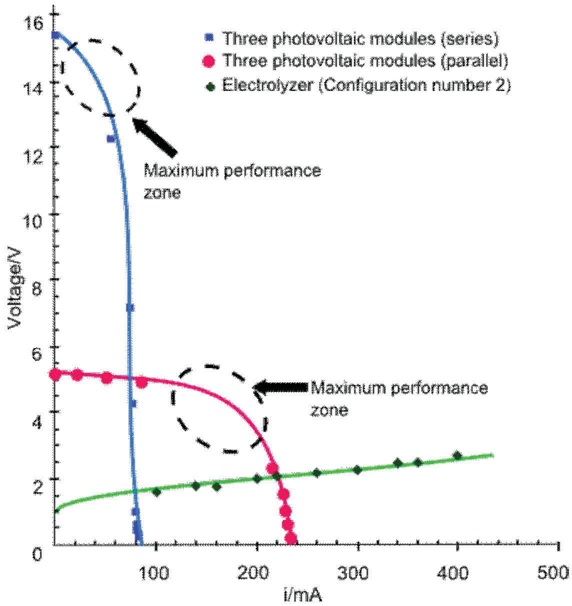

Figure 3. Photovoltaic modules, series and parallel, coupled with the stainless steel mesh electrolyser.

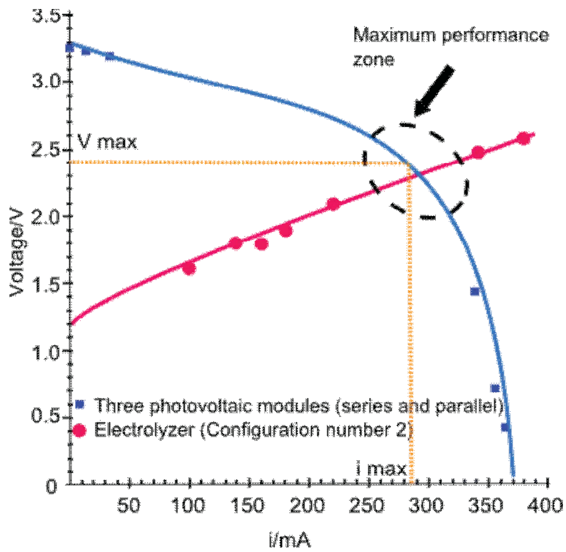

Figure 4. Photovoltaic serial-parallel system coupling with the PEM electrolyser performance curve.

4. Conclusion

The electrolyser design and the MEA assembly with the sprayed Nafion membrane gave satisfactory results in the hydrogen production, as well as to feed a low power fuel cell; all obtained from the electrical power of a photovoltaic system.

The use of a commercial neoprene sheet, in order, to form the water reservoir was successful and this in turn avoided the machining of the acrylic plates. The use of the acrylic plates to form the structure of the electrolyser was simple and at low cost.

The performance of photovoltaic cells alone and connected in serial and parallel arrays were obtained. It was found that a serial-parallel arrangement, giving a 400 mA short circuit current and a 3.5V open circuit voltage was satisfactory for the PEM electrolyser energy requirement.

5. References

[1] Aguado Alonso M, Alzueta Ibañez B, Garde Aranguren R. 2004 Altener.
[2] Chen J P., Chang S Y, Hung Y T 2007 *Physicochemical Treatment Processos, Handbook of Environmental Engineering* **5**
Lawrence K. Wang Yung-Tse Hung, Nazih K. Shammas *Handbook of Environmental Engineering* ISBN: 978-1-58829-860-7
[3] Yunez Cano A. 2013, Tesis, IPN-ESIQIE.
[4] Domínguez Reza M. A. 2010, Tesis, IPN-ESIQIE,
[5] Santillán Aragón G. 2012, Tesis, IPN-ESIQIE, p 8-18.
[6] Carmo M., Fritz D. L., Mergel J., Stolten D. 2013, *Int. J. Hydrogen Energy*, **38**, 4901-4934.
[7] Höök M, Tang X 2013 Depletion of fossil fuels and anthropogenic climate change, *Energ. And Police* **52** 797-809.