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Design of an integrated power system using a proton exchange membrane fuel cell

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ABSTRACT

Integrated power systems could be a solution to provide energy to remote communities based on the use of renewable energies (such as wind or sun). This work proposed the design of one of those systems including alkaline water electrolysers, storage tanks and a proton exchange membrane fuel cell for generating of 53 kW (working at 60% of its maximum power). Electrode sizes and the quantity of unit cells proposed in this work were the same as those suggested in the research work by Yang et al., where a phosphoric acid fuel cell was built and studied. The results obtained in that research allowed comparing energy efficiency by scaling a laboratory prototype. The dimensions of the alkaline water electrolysers are the result of satisfying the necessity of fuel and oxidant. The energy consumption results from extrapolating laboratory devices. The integrated power system has a storage tank capacity of 16 h.

1. Introduction

Advances in the development of fuel cell and electrolyser technologies have allowed to define hydrogen position as a chemical energy storage medium. To confirm this fact a considerable number of production plants have been installed in different countries to investigate technical and commercial feasibility of the use of hydrogen as an energy carrier [1–8]. The majority of those plants are operated by universities and national energy agencies. With the purpose of offering a solution to the energy power supply to communities in remote areas, a lot of integrated renewable power systems were designed, built and studied [6–8]. Integrated power systems are based on the use of a primary renewable energy source such as wind and solar power through wind turbines or photovoltaic panels, respectively. As if it known, during the day the consumption of energy varies so in the periods when there is excess of primary energy, this could be stored in the form of hydrogen to be saved and later used when primary energy becomes insufficient. The most important equipment in those types of systems are: electrolysers, storage tanks and fuel cells. The electrolyser transforms excess of electric energy into chemical energy in the form of hydrogen. The fuel

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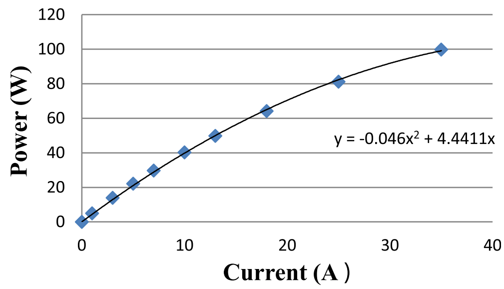

Fig. 1 – Graphic representation of power as a function of current for a laboratory PEM fuel cell with an active area of 100 cm^2.

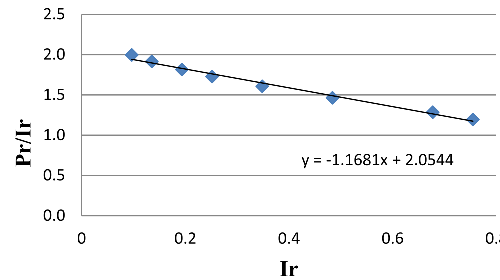

Fig. 3 – Graphic representation of the division between relative power and relative current density as a function of relative current density.

cell transforms chemical into electrical energy through a combustion reaction. [9]

The majority of the integrated power systems proposed, were based on commercially available equipment such as alkaline water electrolysers, proton exchange membrane (PEM), alkaline and phosphoric acid fuel cells and storage tanks.

In this work an integrated power system is proposed, scaling laboratory equipment capable of generating 53 kW, at 60 percent of PEM fuel cell maximum power. We assume the size of the electrodes and the number of unit cells to supply the necessity for fuel and oxidant flow. The main objective is to evaluate and compare these laboratory prototypes with commercial equipment or known prototypes and establish the design of the integrated power system.

2. Material and methods

2.1. Laboratory PEM fuel cell

A laboratory PEM fuel cell was tested in order to compare its energy efficiency with that proposed by Yang et al. [10], after scaling. This laboratory prototype has an active area of 100 cm^2 and it consists of a stack of six unit cells. One typical unit cell is comprised by a membrane electrode assembly, two bipolar plates and two seals. This stack has a membrane electrode assembly that consists of Nafion® 117 membrane, two dispersed catalyst layers that have a metal loading of 0.5 mg Pt/cm^2 as catalyst for both electrodes and two gas diffusion layers of carbon paper. The material for the bipolar plates is titanium with a protective coating layer of gold. Silicone is the material used for the seals. Fig. 1 shows power as a function of the current for this prototype at an operating room temperature. Hydrogen and oxygen obtained by alkaline water electrolysis are used as fuel and oxidant respectively.

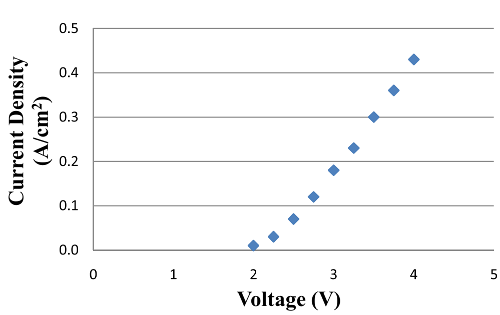

Fig. 2 – Graphic representation of the current density as a function of voltage for the water alkaline electrolyser.

2.2. Laboratory alkaline water electrolyser

The relevant components of an alkaline water electrolyser are the electrodes, the separator and the electrolytic solution. The laboratory prototype uses stainless steel 316L as electrode material, a Zirfon® membrane as separator and a high concentration solution of KOH (35% w/w) as electrolyte. To analyse the functioning of the electrolyser, it was connected to a power source Agilent N5743A System DC Power Supply (12.5 V/60 A, 750 W) once the device had been assembled. Current measurements were made at a certain potential between 0.0 and 4.0 V. The operational conditions are room temperature and atmospheric pressure. The monitor parameters are current and voltage. Fig. 2 shows the current density as a function of the voltage for the alkaline water electrolyser.

3. Results and discussion

3.1. Laboratory PEM fuel cell

To compare the energy efficiency between the phosphoric acid fuel cell by Yang et al. [10] and the laboratory PEM fuel

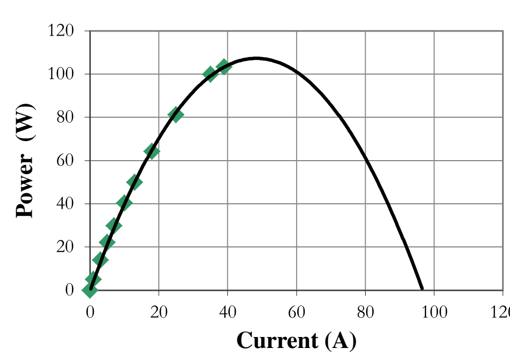

Fig. 4 – Behaviour representation of laboratory PEM fuel cell.