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Hydrogen energy vector: Demonstration pilot plant with minimal peripheral equipment

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ABSTRACT

In this work we develop and build a demonstrative pilot plant of the hydrogen energy vector that includes: energy conversion by a photovoltaic panel, production of hydrogen by electrolysis of water, low pressure storage of gases and use of a stack of proton exchange membrane fuel cells. The system was designed without peripheral equipment in order to minimize energy losses. This improvement is achieved by means of suitable modification of the different elements involved. This demonstrative pilot plant appears to be useful for low and medium energy consumptions (for example, mountain huts and military shelters).

Introduction

The use of primary energy sources, particularly those of solar origin (photovoltaic, thermal, wind energy) is of great interest for a number of reasons, including the limited availability of fossil resources [1–3]. Among other advantages of no less importance is the greater energy efficiency which can be obtained by replacing conventional thermal machines [4] with electric devices. The growing world population and the increase in per capita demand for energy, the greenhouse effect, and pollution, have all contributed to an ever-growing awareness of the need to make a more rational use of the energy resources. Although a more rational use of energy is inevitable in the long run, it is however necessary to develop and disseminate more efficient and cleaner methods of energy conversion [1,5–10].

These primary forms of energy necessarily require a vector, i.e. a medium that allows the use of primary energy by transforming it into storable and usable forms as needed [10–13].

Among the energy carriers, the most appropriate and developed is hydrogen, capable of storing energy from primary sources in the H_2 molecule [14]. Two advantages of using hydrogen are its large energy capacity, and the fact that it can be produced inexpensively using simple methods which do

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not give off greenhouse gases. In this sense, Hydrogen is efficiently obtained by the electrolytic dissociation of water (O_2 is also produced) [15,16]. The stored energy can be recovered by the reaction of H_2 and O_2, producing only electricity and water [10,17].

Moreover, in Argentina it is necessary to find solutions that allow access to electricity and eventually to hot water supplies in areas far from urban centers (small populations, ranger checkpoints and armed forces outposts, most of them isolated from the electricity and gas networks in a sparsely populated territory). Because of the high insolation levels in large areas of Argentina, due to its geographical location, solar energy is a suitable option [18].

Finally, the introduction of new forms of energy will signify a paradigm shift not only in the engineering involved, but also in the everyday relationship between the individual and the energy resource. For this reason, there is a cultural aspect involved and which should be addressed through education, starting at the earliest stages of learning.

In this regard, although there are numerous European and U.S. commercial developments of educational equipment and devices for obtaining and converting Hydrogen from primary energy sources [19–26], these do not take into consideration the energy consumption of peripheral control systems, a fact which has been recognized as the main impediment to further development of renewable energy technologies [27,28]. Numerous studies are focused on determining the optimal configuration of a specific subsystem in order to optimize the use of energy (e.g. hydrogen generation from PV) [30–33].

In other cases, the work focuses on optimizing a single element, for example the use of the energy captured by photovoltaic device or converted in the process of electrolysis [34–40].

Some authors study the performance of complete systems by proper sizing of each of its elements (photovoltaic, electrolysis, storage and consumption stages); in these works adapters power devices are used between each stage, [28,41–44].

The main goal of this study is to develop and build a complete system using the hydrogen vector at pilot plant scale. In this sense, this paper presents the novelty of being the first to consider the possibility of using hydrogen vector with minimal use of peripherals. We also propose the use of low pressure hydrogen for storage in remote locations.

Local development of conversion devices taking into account these principles would allow their dissemination and use, both in education and in specific applications in remote areas.

Moreover, the use of domestic technology and know-how contribute to theoretical and practical progress of a highly specialized national industry, one of our laboratory's aims since 2003.

Proposed model

Developed demonstration equipment consists of five blocks, which are shown in Fig. 1:

A. photovoltaic solar energy device (PV),
B. Alkaline electrolyzer for H_2 production,
C. Hydrogen fuel cell,
D. Storage system for fuel (H_2) and oxidant (O_2),
E. Loads (one or more).

Fig. 1 shows the interconnection between each of these elements.

In the case of photovoltaic panels, the solar energy is converted into electrical energy with an efficiency of about 15%, typical of commercial devices [45]. This apparently low efficiency is nevertheless interesting for many technological purposes, especially for small to medium sized consumer applications. It is important to note that wind generation can be an independent or complementary alternative for this type of autonomous energy systems.

Experimental

Photovoltaic panel

Two types of commercial photovoltaic panels were used. These were provided by the firm Solartec, which manufactures them locally using high-efficiency polycrystalline silicon cells provided by Kyocera. The models used were modules KS12T and KS3T-6V whose specifications are shown in Table

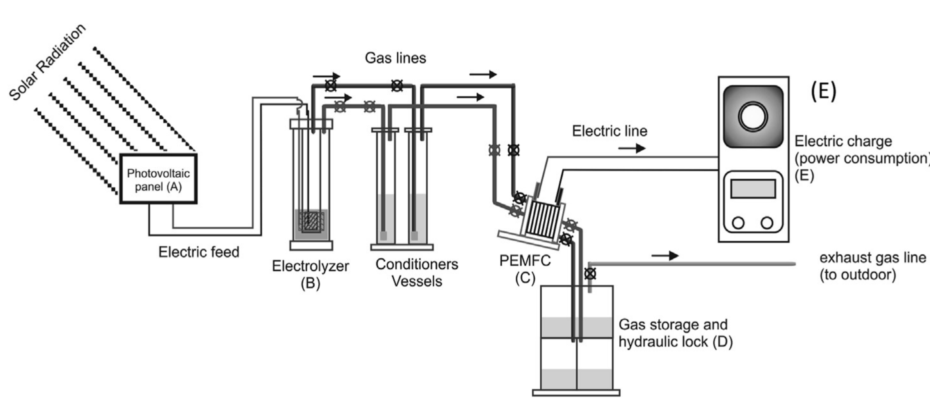

Fig. 1 – The solar energy captured by the solar panel (A) is used by the electrolyzer (B) to decompose water. The Hydrogen and Oxygen obtained are used, respectively, as fuel and oxidizer in the polymer electrolyte (PEM) fuel cell (C). The excess gases are stored (D) for later use (E).