Generation and storage of green Hydrogen and its application for PEM Fuel Cells

SAN MARTÍN DÍAZ, José Javier[1], ROMERO GARCÍA, Eduardo[1]; ZUAZUA OJANGUREN, Jon[1]; ROMERO GARCÍA, David[1]; APERRIBAY MAIZTEGUI, Víctor[2]; SAN MARTÍN DIAZ, José Ignacio[1]; ARRIETA ALBIZU, José Mª [1]; MARTÍN AMUNDARAIN, Iñaki[1]

[1]Department of Electrical Engineering
[2]Department of Graphic Expression and Engineering Projects
EUITI Eibar (University of the Basque Country)
Av.Otaola 29, 20600 Eibar (Spain)
phone: 943033065, fax: 943033110, e-mail: iepsmdij@sb.ehu.es

1. Abstract

The object of this communication is to show to the application of a new tool learning multimedia in which it talks about the green Hydrogen generation, that is to say, the obtained one from renewable energies (in our case of photovoltaic origin) and to their storage, for its later use in the feeding of a standard fuel battery PEM.

The novel aspect that is tried to expose is that the knowledge acquired on the part of the user can be resisted by means of the accomplishment of the virtual practices available in the course, cradles by proving stand VENTUS Professional Science.

Key words: Fuel cells, Hydrogen, electrolysis, renewable energies.

2. Structure of the course

In this section is exposed and described the content of an interactive course with respect to the generation, storage and use of Hydrogen with Fuel Cells with solar cells.

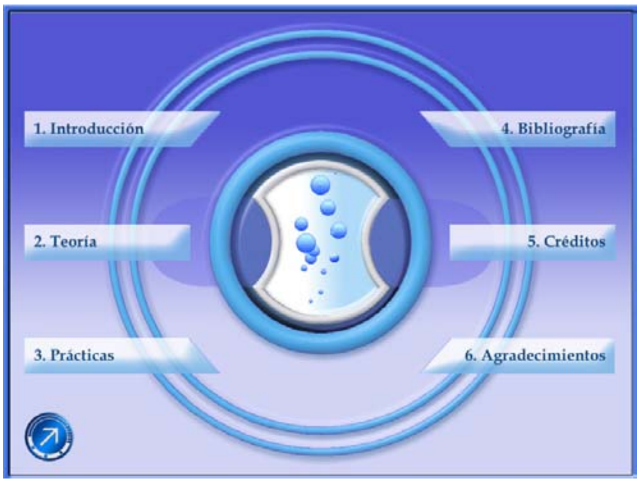

Fig. 1. Principal screen

A. Theoretical concepts

This virtual course presents, after an Introduction, a section whose purpose is that the user can arrange the referring theoretical knowledge to Hydrogen and Fuel Cells. The information available in this course deals with depth these subjects, but with the expectation of the assimilation, as much by a novice person, like by a person introduced in the world of Hydrogen and Fuel Cells.

This information is divided in different themes such as is organized in the following screen:

Fig. 2. Theme index screen

These treat from the process of generation of electrical energy by means of an solar cell for the production of hydrogen to the use of this feeding fuell cell of type PEM.

The theory contained in this tool counts so much of the demonstration of same by means of mathematical equations and the virtual animations.

B. Hydrogen obtaining by means of electrolysis

Electrolysis of the water is a trustworthy technology, with many years of accumulated experience in the industry, like technology of hydrogen obtaining, allows to obtain it with great purity. The cost depends on the electrical energy that is used. And in any case, it is important to remember that the global costs of hydrogen will be conditioned to the expenses of transport and storage, as well as the benefits of the intermediaries.

Between the existing electrolyzers, at the moment, we will emphasize on alkaline electrolyzers and PEM electrolyzers or polymeric membrane.

1) Alkaline electrolyzers

In them it starts of a watery solution of NaOH or KOH, so that there is a high ionic conductivity.

Reactions:

Cáthode: $2\ H_2O + 2e^- \rightarrow 2OH^- + H_2$
Anode: $2\ OH^- \rightarrow H_2O + ½\ O_2\ + 2e^-$
Global: $H_2O \rightarrow H_2 + ½\ O_2$

Reversible voltage = 1,229 V, is the smaller voltage necessary to produce the raised reactions. This is the theoretical voltage of decomposition of the water to 25 ºC. This voltage does not depend on means pH. It would imply that the system cools off.

Thermoneutral voltage = 1,481 V, is the corresponding to an ideal system that operates to constant temperature. It corresponds to the equivalence of which the amount of energy released by the one hydrogen mol combustion is 285,58 kJ to 25 ºC.

The voltage that will be necessary to apply in a real equipment will be of the order of the 1.7 V. It explains by the calls "overvoltages", that are:

Overvoltage of activation or kinetic. It is necessary so that the reaction takes place at a certain speed (it interests that "a small" equipment generates "much" hydrogen).

Overvoltage of concentration. In the anode $OH^–$ is consumed and, whatever takes place the reaction with high speed, the $OH^–$ begins to exhaust itself, because "it doesn´t flow" towards the electrode at the necessary speed.

Ohmic Overvoltage. Is the corresponding to all electrical component, of equal value to the intensity that circulates around the electrical resistance of the system.

These overvoltages depends, specially, of the material of the electrode, the traffic density (mA/cm2) and the temperature.

A cell with equal efficiency would ask 3.245 kWh of energy to produce 1 Nm^3 of hydrogen. The industrial electrolyzers work between 4.2 and 5 kWh for Nm^3 of hydrogen produced.

2) PEM electrolyzers or polymeric membrane

It contains a polymeric membrane that makes the functions of electrolyte. It is equivalent to an acid electrolyte (the conductive ion is H^+ instead of $OH^–$).

They are used widely in space applications and submarines, to obtain oxygen for breathing.

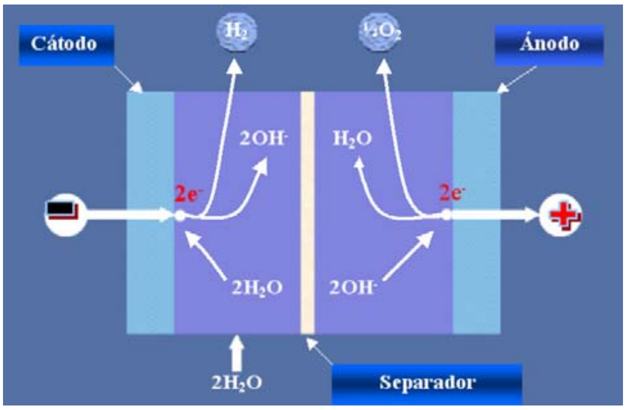

Fig. 3. PEM type electrolyzer

Chemical reaction:

Cáthode: $2H_2O + 2e \rightarrow H^+ + 2\ OH^-$
Anode: $2OH^- \rightarrow ½\ O_2 + 2e^- + H_2O$

In order to make profitable an electrolysis installation it is necessary to consider that oxygen is a valuable by-product, with applications such as aerobion residual water treatment, steel industry pollution investment and RSU combustion.

The hydrogen and oxygen generated in the electrolyzer are provided to the fuel cell to generate DC that will feed three load modules, as they are a ventilator, a incandescence lamp and a potentiometer.

As fact to review, hydrogen can be used in diverse applications such as clean combustion, catalytic combustion, internal combustion motors, gas/cycles combined turbines, etc, but the more "revolutionary" application are the fuel cells.

And the "revolution" of the fuel cells consists of escaping to "Carnot límit", applicable to the traditional systems of electrical generation based thermodynamic cycles with a cold spot to temperature Tf and a hot spot to temperature Tc. This limit temperature is the peak efficiency in the obtaining of electricity, and is worth

$$\eta_{máx} = 1 - Tf / Tc \ (T \text{ in Kelvin})$$

The fuel cells are static electrochemical devices that transform the chemical energy, stored in the H-H connection of the H_2 molecule, in electrical energy and water steam. In principle, a fuel cell works like a battery, but with the difference that is not exhausted, nor requires charge, producing electrical energy, while it is supplied fuel to him.

To similarity of other electric generator, the fuel cells have an intensity-voltage characteristic curve that determines its conditions of operation at every moment. The operation is determined by the electrical charge that it is connected (and, in fact, it is necessary to control this load to avoid "to request too much energy" to the cell, because we could destroy it).

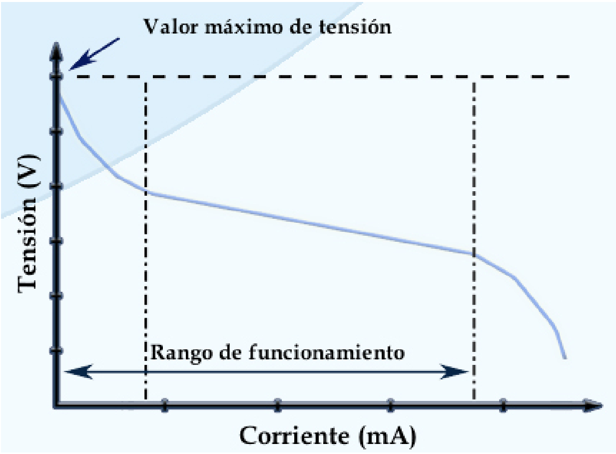

Fig. 4. PEM cell intensity-voltage characteristic curve

Between the advantages that present they are possible to detach the following ones:

High efficiency. Fuel cells transform directly chemical energy in electric energy, with higher efficiency than other energy generation system. This efficiency is approximately 50% in front of a 15% of the internal combustion motors. In SOFC fuel cells, for example, the temperature range is 750 - 1000 °C. Energy efficiencies around 80% are obtained if the use of thermal energy is included.

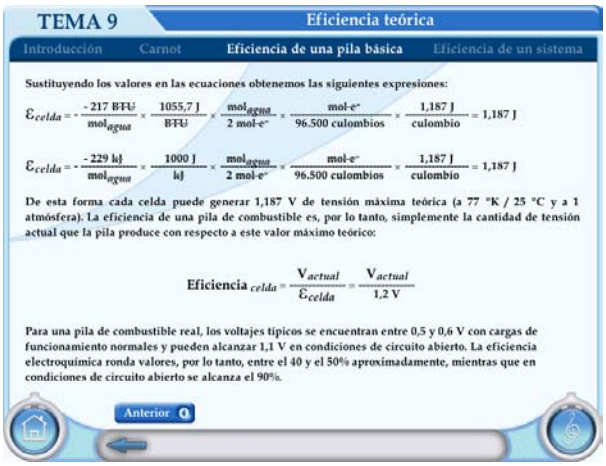

Fig. 5. Theory screen / Fuel cell efficiency

Silent operation. Because of the absence of mobile components, fuel cells don't produce noise.

They don't contaminate. One of the main advantages of using fuel cells is their low emission level, being it one of the main reasons to impel their research and development.

Long life. Although the fuel cell useful life is not still proved, recent studies based on fuel cells that have been working several years in an uninterrupted way indicate that fuel cells could keep on working during many years.

Modularity. It is possible increasing or decreasing the generated energy by a fuel cell in function of the number of heaped cells. This allow their use to feed low energy consumption systems (propulsion of vehicles), until systems capable of generating energy for big populations. Thanks to this characteristic, it is possible increasing (or decreasing) the energy of the systems in function of the change of the demand. Electric signal conditioner to be connected later to the network requires two electric and electronic devices that are being developed currently.

C. *Practical concepts*

Once acquired the necessary knowledge, this multimedia CD-ROM offers the possibility of contrasting this knowledge with several virtual practices.

The practices will carry out the simulation of the electric energy generation by means of photovoltaic cell whose energy will feed to a electrolyzer that will supply hydrogen and oxygen to the fuel cells connected in series or in parallel. The electric energy obtained from them will feed a load module that consists of a fan, a lamp and a potentiometer.

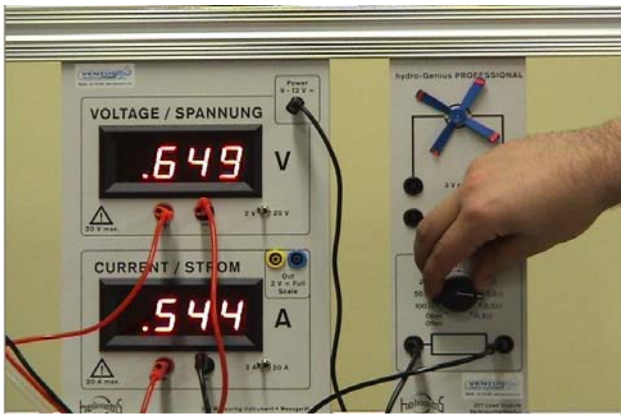

Fig. 6. Voltage real measurement on the potentiometer

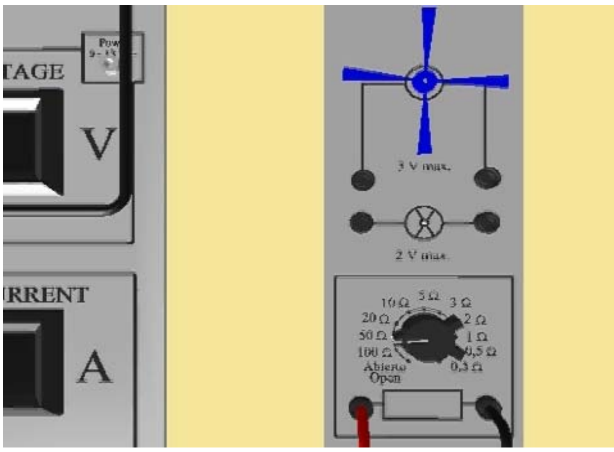

Fig. 7. Voltage virtual measurement on the potentiometer

3. Conclusions

Because the problems associated with the current energetic model, based in fossil fuels, such as atmospheric contamination and the prizes fluctuations in the market, it is necessary finding a new green energetic vector like hydrogen produced by means of renewable energies with no emissions.

In this paper is presented a new teaching tool whose objective is showing this new energetic source and its application in fuel cells. With it, it is sought to end up taking the first step to install hydrogen technology, and serving as understanding and acceptance on the part of the society of a clean and efficient energy way.

References

[1] A. Macdonald, M. Berry, Reseach Notes – Clean Energy for the Future, Berlin, 2003.

[2] S. Carlos, "Energías renovables: Solar Eólica", Ed. Díaz de Santos, Madrid, 2003.

[3] I Encuentro Científico del Hidrógeno y las Pilas de Combustible, Madrid, 2004.

[4] www. windpower.org

[5] www.ecoterra.org

[6] www.hynet.info

[7] www.aeh2.org

[8] www.ballard.com

[9] www.lanl.gov/mst/fuelcells

[10] www.ieahia.org

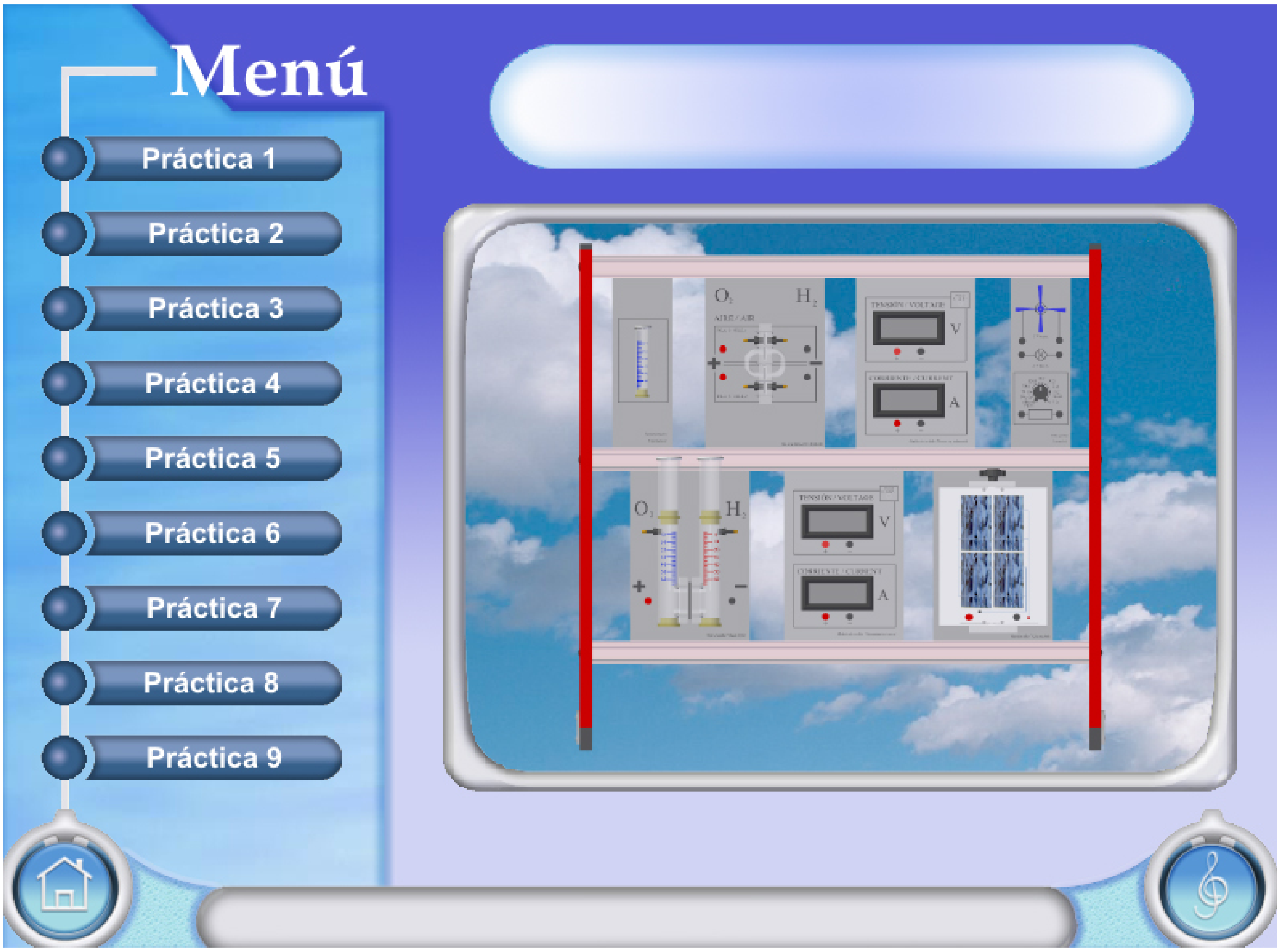

Fig. 8. Main menu practices screen