Small scale demonstration project for the production and use of hydrogen from renewable energy sources in the wine sector

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The energy demand in remote rural areas can be satisfied in a competitive manner with the use of renewable energy sources. In the present case, the energy required by Viñas del Vero S.A., a winery in Barbastro, Spain, will be supplied by the production from a photovoltaic panel array. However, the agricultural activities have a pronounced seasonal character, which, in turn, is reflected in energy demands that exhibit large variations with time. If the renewable production systems are designed to satisfy the energy peaks in periods with increased on-site activity, there will be an excess of energy for periods of lower work load. Only a limited amount of this energy can be accumulated in a battery system. This allows for balancing the power consumption on a daily basis or even in a several days range, but the associated costs are prohibitive when the exceeding energy has to be stored beyond this time frame. In the framework of the **EU LIFE+** program, this demonstration project proposes a feasible alternative for long period storage, using hydrogen as an energy vector. The overall idea is to hydrolyze on-site available water using the exceeding electrical energy, and to store the generated hydrogen in pressurized tanks. In this project, the end-user consists of a high-temperature PEM fuel cell system that re-converts the hydrogen to electric current. In particular, the project proposes its use in a commercial electric agricultural vehicle properly modified to be powered with a hybrid powertrain formed by the PEM fuel cell and gel-type batteries.

This work describes the design and initial testing of this fully operational small-scale demonstrator.

General Description of the Project

The hydrogen generation and refueling test-bed is the bespoken design, comprising mostly commercial components in order to minimize the overall capital costs and to ensure the reliability of the installation in the terms specified by the manufacturers. Basically, the system is composed by (see Figure1): 1) a compact purification system that produces ASTM Type II grade analytical water with tap water quality as input, 2) an electrolyser based on an Alkaline Solid Polymeric Membrane 3) a buffer tank at low pressure for the generated hydrogen, 4) a metal diaphragm compressor and 5) a storing rack of medium-to-high pressure cylinders to be used as refueling bank for the mobile tanks of a fuel-cell powered vehicle. Besides these components, power and control electronics panels have been also designed and built, together with the necessary inter-connections.

The basic functioning of the system can be resumed in the following steps: (1) the water, available on-site and previously conditioned, is fed to a compact demineralization device that combines reverse osmosis, deionization and nano-filtration in order to supply purified low conductivity water (< 5 μS/cm) to (2) an electrolyser with a combined PEM/alkaline technology. The chosen electrolyser combines the benefits of PEM electrolysis (functioning with 0%-100% power supply available, no hydrogen compression required, small footprint, no use of KOH), with the benefits of alkaline electrolysis (no need of noble metals, no need of ultra-pure water and low system cost). It is particularly suited to the on-site relatively small production needed in Viñas del Vero S. A., that is 0.5 Nl/h. The resulting oxygen is vented to the atmosphere and the produced hydrogen at low pressure (30 bar) is stored in a (3) buffer tank that supplies the gas to a (4) metal diaphragm compressor which raises the pressure up to 200 bar before being stored in a rack formed by 12 high-pressure bottles with a water volume of 50 l each (5). The rack serves as a refueling station for the on-board tanks of a fuel-cell powered electric vehicle (6). The variability in the electrical energy demanded by the system has not been taken into account. The main criteria is that the plant produces/stores hydrogen only when there is available electrical energy (which is produced by a hybrid off-grid photovoltaic panel array/batteries commercial system) and all the control and power electronics has been adjusted to this condition. The control system, which was also specifically designed for this purpose, guarantees the correct and safe functioning of the plant, specifying operating times and appropriate start-up and shut-down sequences.

The end-user in this project is a commercial ePath-7500 electric car suitably modified to be powered by a hybrid powertrain based on PEM fuel cell and batteries. This is an all-wheel drive (AWD) 4-seat vehicle designed to travel on bumpy and irregular terrain, ideal for agricultural or industrial work. Originally, the 7.5 kW 72 V electric motor of the car was powered by a set of 12 gel-type 225 A-h batteries, which provides a range of 100 km when moving at a constant velocity of 30 km/h. Several modifications were performed to adapt both the pure electric battery powertrain and its tilting rear load platform to include a 3 kW high-temperature PEM fuel cell stack (HT-PEMFC) designed and manufactured at LIFTEC experimental facilities.

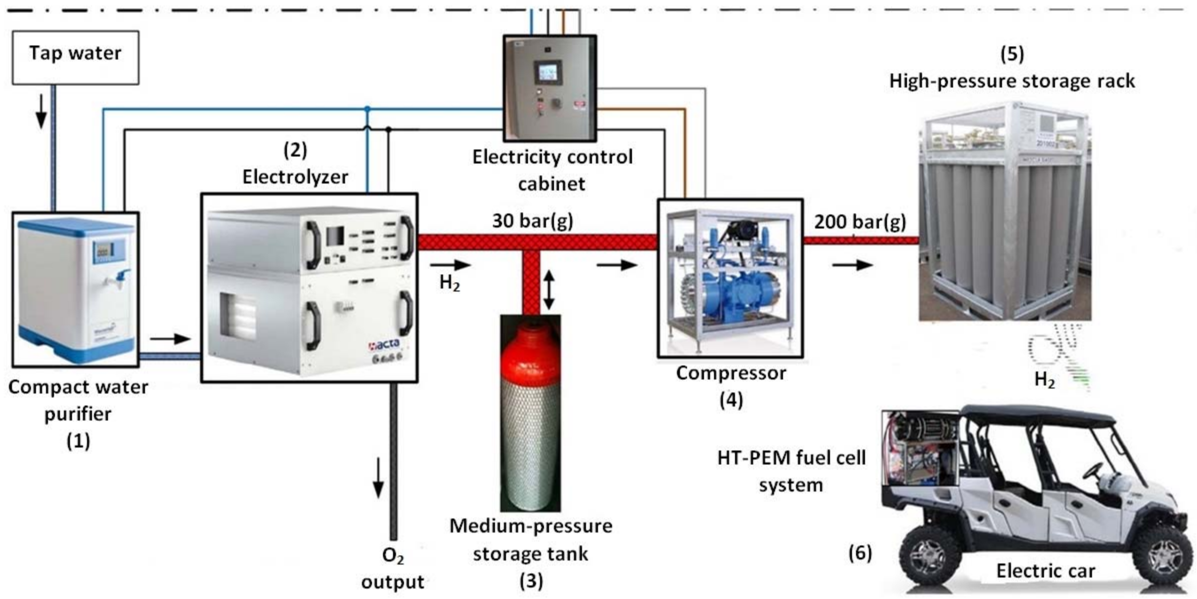

Figure 1. General scheme of the hydrogen production and storage plant together with the end-user commercial electric vehicle properly modified to be powered by a hybrid powertrain

The 30-cells air-cooled stack is formed by commercial Celtec P-1100 high-temperature MEAs with an active area of 605 cm², which allow operating at temperatures above 100°C. This feature simplifies some of the stack sub-systems compared with those required for the low-temperature PEM fuel cells. Operational tests performed at the test bench have allowed to obtain polarization curves, as well as to optimize the operating parameters. One of the polarization curves obtained for the optimal working parameters is shown in Fig. 2. It corresponds to a pressure of 0.5 bar in both cathodes and anodes, and a stoichiometry of 1.2 for H_2 and 2 for O_2. The operating point, indicated by the red lines, shows that the total stack voltage is 15 V and the current is 168 A (0.28 A/cm²), yielding a rated power of 2.53 kW. The maximum power reaches 3.1 kW. Considering the actual hydrogen consumption (61.5 Nl/min), and the gas storage capacity (7.08 Nm³), the range of the electric car will be enlarged by a 60% with the hybrid powertrain.

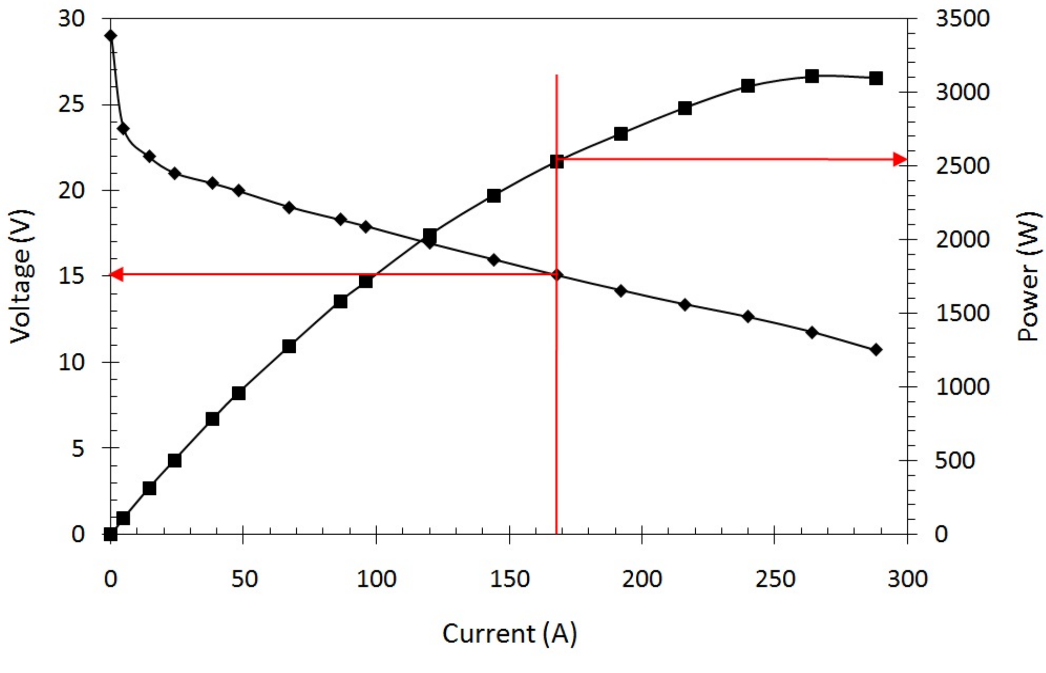

Figure 2. Polarization curve obtained for the 30-cells stack operating under optimal conditions

The different parts and elements of the projects are now being assembled, and preliminary tests are planned to be performed during January-February 2016.