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Metal hydride-based hydrogen production and storage system for stationary applications powered by renewable sources

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The development of systems for production and storage of hydrogen as an energy vector for various applications, has gained much relevance in recent years as it is considered critical in the increase of renewable energies in the energy mix. Presently, most part of the hydrogen production using renewable energy sources is based on electrolysis systems that use water to obtain green hydrogen, that can be stored and later used or converted to electrical energy using fuel cells.

New laboratory reactor systems for the production and storage of hydrogen using metal hydrides have been demonstrated in recent years, making these kind of reversible electrochemical systems alternative future options for the production and storage of hydrogen.

In this paper a compact electrochemical laboratory system prototype for the production and storage of hydrogen, based on metallic hydrides, with high reversibility in the charge/discharge process is demonstrated, using renewable energies as power source. This laboratory reactor prototype is a 316 L stainless steel vessel with a capacity up to 15 bar of internal pressure. It includes working electrodes of alloy $LaNi_{4.3}Co_{0.4}Al_{0.3}$ and counter-electrodes of Ni foam in an electrolyte solution of 35% KOH that can be configured using unicellular or multicellular arrangements. The replacement of Ni for small amounts of Al and Co in $LaNi_5$ alloys, brought improvements in the thermodynamic properties of the alloy that will be described.

The production and storage of H_2 uses external electrical energy to induce its absorption by the metal lattice, in the charge cycle, with the production of O_2, which must be completely released from the reactor's interior at the end of the cycle. This production/storage stage continues until the maximum H_2 absorption capacity of metal hydride has been reached, which can be detected by the presence of gaseous hydrogen in the interior of the reactor.

During the discharge stage, the stored hydrogen is released by applying again an auxiliary source of electrical energy, and has a high purity, eventually with some water vapour, being easily conditioned to comply with specifications to supply directly to PEM fuel cells.

The metal hydrides show a high energy density by volume unit (higher than liquid hydrogen) under ambient temperature and pressure. In opposition show low energy density by mass unit. Nevertheless, the metal hydrides can be a useful way of storing several MWh of energy using hydrogen as a carrier, especially for stationary applications, being its feasibility still under study and development.

Experimental results using a reactor unicellular configuration directly coupled to DC Power supply and to a photovoltaic panel are presented, in order to evaluate the reactor performance and to establish and quantify criteria to identify the states of full charge and discharge of hydrogen.
Results show excellent linearity, reversibility, and stability under cycling at room temperature and pressure, demonstrated either when powered by the grid or by off-grid renewable energy. The overall capacity of this system can be extended by increasing the number of working electrodes, connected in parallel, resulting in a high modular system.
The generator includes an electronic specific system for monitoring and control being developed in-house, in order to optimize the performance and energy efficiency of the global process of production/storage and discharge of hydrogen, when using renewable energy sources, namely solar energy (Fig. 1).

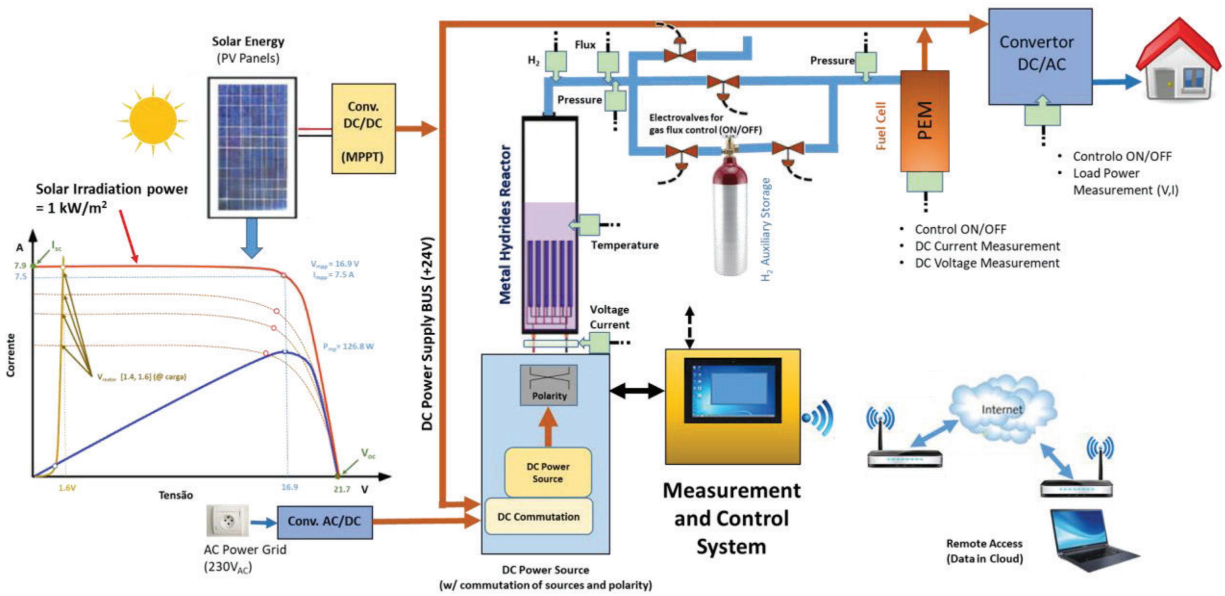

Figure 1: Global architecture of the metal hydrides reactor for H_2 charge/discharge using solar energy as main DC power source, integrating a custom monitoring and control system to automate the full process.

The electronic system includes the capability of acquisition and processing of local sensor data from electrochemical, physical and electrical process variables, allowing the automated control of the reactor, in order to optimize its performance and energy efficiency, accordingly to the expected conditions of electrical energy supply and demand.
Results from the global reactor system will be presented, having in mind the possibility to integrate this type of compact electrochemical systems for production/storage of hydrogen within electrical stationary power systems using renewable energy sources. These reactors could be used, for instance, as an energy storage buffer, using the stored hydrogen as an energy carrier, considering the moderate cost and better efficiency of these reactors, when compared with the more traditional electrolysers.

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