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

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ABSTRACT

In this work, a compact and low-cost electrochemical laboratory prototype for the storage and production of hydrogen, based on metallic hydrides, with high reversibility in the charge/discharge process is demonstrated, using electricity either from the grid or by direct coupling to renewable energies as power source. The reactor is a 316 L stainless steel vessel with a capacity up to 15 bar 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. The reactor uses unicellular/multicellular configurations, so that the overall capacity of the system can be extended by increasing the number of working electrodes, resulting in a highly modular system. 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. Furthermore, criteria were established for the quantification of the state of full charge and full discharge. The system was integrated with a custom electronic system, developed in-house for monitoring and control the reactor and to optimize the performance and energy efficiency of the hydrogen storage and discharge processes.

## 1. Introduction

Hydrogen has emerged in recent years as an energy vector of increasing relevance in the vision of an energy-sustainable future. The favorable evolution of hydrogen production costs and of electricity from renewable sources, together with the urgency of reducing greenhouse gas emissions, has given hydrogen a new window of opportunity within a global unprecedented momentum.

Presently, most part of the green hydrogen production using renewable energy sources is based on water electrolysis processes which is expected to fully scale-up in the coming years, enabling the growth of the renewable electricity market and an increase in the penetration of more sustainable solutions, fostering progress in the research and implementation of energy storage and generation systems using hydrogen [1,2].

Selecting the most suitable hydrogen storage type for a given application is a function not only of the amount of storage required, cost, efficiency and constrains regarding volume and weight, but also of the desired cycle rate [3,4]. Compressed hydrogen allows small to medium-scale applications that require high cycle rates being more efficient than liquid hydrogen, although it provides a higher density of energy per unit of volume. It should be noted that investment in cryogenic installations and in the intensive use of energy in liquefaction, with 30% of the energy lost [5], have limited the use of this technology. In comparison, metal hydrides have the potential to store hydrogen at much higher volumetric densities than compressed and liquefied hydrogen, while minimizing the safety risk associated with the use of high-pressure hydrogen [6,7]. However, metallic hydrides have very low energy densities per unit mass, which excludes their use in important applications, such as on-board fueling vehicles. Their actual storage capacity is not sufficiently high for PEM fuel cells to achieve the objectives proposed, with major improvements being necessary [8,9]. Notwithstanding, efforts in the design of new materials with improved properties (capacity, absorption-desorption kinetics, thermal properties, cyclability and cost), have prompted developments for applications as diverse as air conditioners, heat pumps, Ni-MH batteries and many other devices [10–12].

Metal hydrides can be a useful way to store dozens of MWh for systems with medium cycle rates, but it is still necessary to demonstrate their technical and economic viability. Costs of hydrogen storage using metal hydrides are difficult to estimate, given the state of maturity of the technology.

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