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# Integration of commercial alkaline water electrolysers with renewable energies: Limitations and improvements

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ABSTRACT

Hydrogen can be stored, transported and used in a large number of applications in which fossil fuels are currently used. From a sustainable point of view, the synergy existing between hydrogen and renewable energy sources shows great potential. In this respect, hydrogen can be produced from water electrolysis using the electricity generated by renewable systems. This paper studies the integration of a 1 $Nm^3 h^{-1}$ alkaline water electrolyser with photovoltaic solar energy (PVE) and wind energy (WE) in a stand-alone system. In particular, a one year energy balance of the conventional integration of the electrolyser with PVE and WE is carried out. To do so, actual weather data are used for irradiance, ambient temperature and wind speed, in addition to the technical specifications and characteristics of a 6.8 kWp PV generator and a 6 kW wind turbine. This energy evaluation reveals the main limitations of commercial electrolysers, such as the lower operating limit and the number of stops permitted by manufacturers. Two strategies are therefore proposed to improve the integration of conventional electrolysers, namely to allow the electrolyser to operate for a period of 10 min under the lower operating limit and to integrate a battery bank. Both strategies achieve successful results, with a reduction in the number of stops by up to 62.1% for the PVE integration and 63.1% for the WE, which should increase the electrolyser service life, and an increase in energy efficiency by up to 6.3% for the PVE integration and 7.6% for the WE.



## Introduction

Despite the present day insecurity and uncertainty shown by the financial markets, primarily in Europe and the United States, there is still considerable global investment in renewable energies, focussed on reducing the mass utilization of fossil and nuclear fuels, improving the energy efficiency and increasing the electricity from the renewable resources. Over the last few years, the development of renewable energies has been spectacular. At the end of 2014, the worldwide installed power capacity reached 1712 GW, representing an increase of 8.5% in the total renewable power

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installed over 2013 and supplying 22.8% of the overall electricity production [1]. Of all the renewable energies, the wind power sector installed the most power in 2014, namely 51 GW to reach 370 GW, representing a 16% increase over 2013. Whilst, the installed capacity for photovoltaic (PV) systems increased by 39 GWp in 2014 to reach 177 GWp, representing an increase of 28.3% over the installed power capacity in 2013.

From a sustainable point of view, the synergy between hydrogen and renewable energy sources is of particular interest. Hydrogen can be stored, transported and used in a large number of applications in which fossil fuels are currently used [2–10]. However, as hydrogen cannot be found in a natural free state, this energy vector must be obtained by industrial and technological methods. Amongst the numerous methods available, water electrolysis is the cleanest and most sustainable way to obtain hydrogen, based on the electricity generated by wind power and PV systems in a number of configurations, for stand-alone and grid-connected systems alike [11–16].

Fig. 1 shows the two main configurations for a scenario in which the electrolysers and renewable systems are not connected to the electricity grid. In the first off-grid configuration, named OG1 (see the solid arrows in Fig. 1), the wind power and PV systems are connected to the electrolysers for the production of hydrogen [17–29]. In this configuration, there are considerable fluctuations in the electrolyser operating conditions given the fact that these are governed by the variability of the wind power and PV resources. The connection between the renewable systems and the electrolysers can be made through dc–dc power conversion stages for the PV generators and ac–dc for the wind power systems. These conversion stages make it possible to condition the currents and voltages generated by the renewable systems to some suitable values for the electrolysers and, furthermore, to harness the maximum power from these systems at all times. A direct connection between the renewable systems and electrolysers with no conversion stage could also be considered for PV applications [30–33]. This connection involves designing the PV generator to ensure that its characteristic current–voltage curves are adapted to suit those of the electrolyser.

The second possible configuration in stand-alone systems is named OG2 (see the dotted arrows in Fig. 1) and is based on the use of electrolysers together with the storage of hydrogen and fuel cells [34–42]. This configuration is primarily directed at the supply of energy to remote areas with no connection to an electricity grid. For this reason, two energy storage stages are generally considered: one for short-term storage based on batteries, supercapacitors or flywheels and the other for long-term storage based on hydrogen. Generally, this configuration comprises a combination of wind power and PV generators, given the fact that their complementary nature makes it possible to considerably increase the electricity generation capacity factor.

Despite the theoretical studies and demonstration projects, there is still little knowledge about the integration of the electrolytic hydrogen production systems with renewable energies. Although water electrolysis is currently considered to be a mature technology, the electrolysers available on the market are designed to operate in stable operating systems, connected to the electricity grid. For this reason, the manufacturers of these devices are starting to show an interest in the development of electrolysis units capable of being integrated with renewable power sources, and are now trying to acquire the experience that will enable them to adapt their electrolysers to this type of operation.

In this context, this paper is directed at analysing and improving the integration of a 1 $Nm^3 h^{-1}$ commercial alkaline water electrolyser with PV and wind power energy in a stand-alone system. To do so, a one year energy study of the conventional integration of the electrolyser with a PV generator and wind turbine is carried out. This study evaluates the electrolyser energy losses, power limitations and additional consumption. We subsequently analyse the critical factors and limitations detected for the conventional integration. We conclude by proposing two strategies to improve the electrolyser integration with renewable energies, which have successfully reduced the number of stops and energy lost due to power limitations while increasing the electrolyser equivalent operating hours.

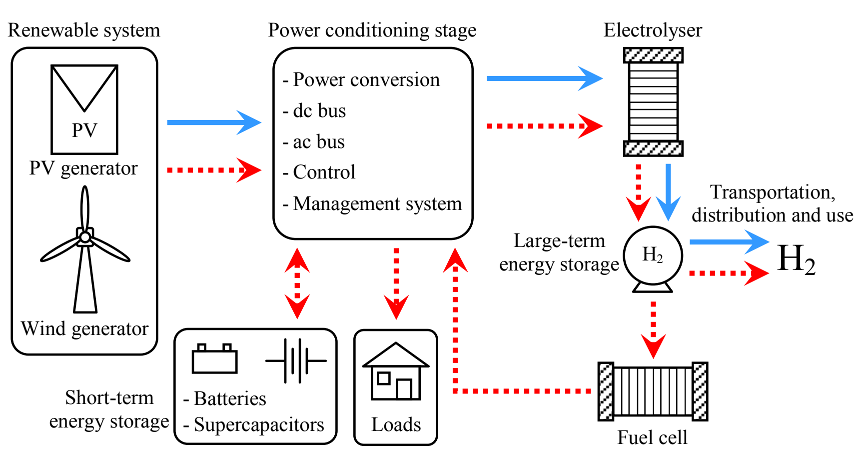


**Fig. 1 – Configurations for the integration of electrolysers with renewable energies in stand-alone systems: OG1 (solid arrows) and OG2 (dotted arrows).**