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Simulation and operational assessment for a small autonomous wind–hydrogen energy system

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Abstract

A case study with respect to the current trends in hydrogen technology and market developments is presented in this paper. The main goal is to design an autonomous, environmentally sustainable and zero emission power system using commercially available equipment. In order to achieve the optimum cost effective solution, its limitations are defined by simulating its performance over a year. A scenario is chosen which is representative of an area with significant wind potential, where the grid connection is relatively long or the construction of the line itself would irretrievably harm the environment. This study simulated the operation of a small, remote hotel primarily powered by a wind turbine and supported by a hydrogen energy system incorporating a medium pressure electrolyzer, a compressed hydrogen gas storage unit and a PEM fuel cell stack. The simulated load is biased towards a particular season as in the case of a small hotel for summer holidays. This arrangement takes advantage of the long period of low load during the "off peak" season, which enables the production of reserves of hydrogen to supplement the wind generated electricity during the "peak" season, avoiding the use of a large electrolyzer system, which is the most expensive and vulnerable component. The simulation results showed that for this particular system, a wind turbine rated at four times the peak load power associated with the optimum combination of an electrolyzer and a hydrogen storage unit would meet the electrical energy needs of a 10 bedroom, non-luxury hotel under the supervision of a load management controller.

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1. Introduction

The concept of using renewable energy sources for electrolysis for hydrogen production has been studied widely in the past decade, but the optimistic predictions for the future development of large scale systems have not been realized. The delay in the establishment of the hydrogen economy is due mainly to the lack of commercially available technology associated with unattractive economic figures [1,2]. It is likely, however, that mass production of the system components will lead to more favorable economics in the future [3].

The majority of renewable energy systems for hydrogen production use photovoltaic arrays (PVs) as a power source for water electrolysis [1,4,5]. The DC power generated by PV's can be easily integrated with an electrolyzing system. Another advantage of PVs is that they do not require frequent maintenance, as do other forms of stand alone power sources. The main disadvantages with PV systems, apart from the large surface area required by the PV panels, is the low efficiency in regions of low solar radiation levels and the high cost of energy production compared to other sustainable systems.

Although wind energy is generally recognized as the fastest growing electricity generating technology, which has yet to reach its peak [6], the small and medium size wind turbine sales do not show the same high growth rates as the large units. On the other hand, for stand alone domestic applications, the combination of a wind turbine and a battery bank energy storage system has been successful and economically viable for more than 20 years [7]. Many technical features of these wind turbines have been improved, following the evolution of the large wind machine technology.

The operation of an autonomous, wind–hydrogen, hybrid power production system for a hypothetical remote hotel unit is simulated and analyzed in this paper. A scenario is chosen that is representative of an area where the grid connection is relatively long or the construction of the line itself would irretrievably harm the environment. Furthermore, the study deals with a realistic load that is biased towards a particular season as in the case of a small hotel for summer holidays or a ski lodge. The main power unit of this renewable energy supply is the wind energy converter, which is supported by a hydrogen energy system incorporating a medium pressure electrolyzer, a compressed hydrogen storage unit and a PEM fuel cell stack, assuming that the wind energy potential is adequate for the total energy requirements. This arrangement takes advantage of the long period of low load during the "off peak" season, which enables the production of reserves of hydrogen to supplement the wind generated electricity during the "peak" season. The goal is to achieve an autonomous, environmentally sustainable, zero emission electricity supply while, at the same time, remaining economically viable and competitive with respect to more conventional systems.

The location selected for the simulation is on Samothrace (Samothraki), an island in northeastern Greece (Fig. 1) and is within a "Natura" region. The hotel is considered to be open for business during the summer period from May to September, which is the high season for tourism on the island.[1] The "Natura" commitment protects more than 60% of its territory from works that

[1] Many hotels of this category in this island are closed during the off peak season.