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Energy Storage in Islands - Modelling Porto Santo's Hydrogen System

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Most islands depend mainly on the importation of fossil fuels for energy production. This causes economic and environmental problems. But generally, islands present a considerable potential in renewable energies.
Islands that have energy sources such as hydro or geothermal energy, can easily integrate them into the power system, but those with mainly intermittent renewable energy sources (wind, solar) have to tackle the need of energy storage. In these cases, advanced energy planning should be used,
The present paper intends to demonstrate the urging need of planning energy storage systems for small islands and the results of a case-study carried out in a Portuguese island. The need to store intermittent energy is an important issue in the island of Porto Santo, since it is a small and isolated network. H2RES was used to model the energy storage scenarios for this island. One scenario was chosen to evaluate the potential of hydrogen as an energy storage vector and a pilot system of two 5kW fuel cells, one electrolyser of 13 kW, and a 55 m^3 storage tank was built.
The main objective of this system is to produce hydrogen from electricity from wind mills that otherwise would be wasted, and to use this hydrogen for electricity during peak time.

1. Introduction

With respect to energy production, in the two islands from Madeira archipelago depend on importation, mainly of heavy fuel-oil and Diesel. The electrical grid in these islands is isolated and even in the case of other islands close to mainland the grid connections are weak.. In some cases, it is nearly impossible to link the islands to continental European energy networks, making it difficult to implement the solutions to reduce environmental costs, and increasing the security of supply to the level necessary to maintain the quality of life and competitiveness of island economies. Due to high energy costs, the islands are proving to be excellent test beds for the introduction of new technologies, and some islands are trying to become so-called renewable islands to satisfy their energy demand mainly or entirely from indigenous and renewable sources,

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thus increasing the security of supply and employment opportunities without necessarily increasing the costs (Duic´ et al, 2003). Islands that have energy sources like hydro or geothermal can easily integrate them into the power system, but those with mainly intermittent renewable energy sources (RES) are confronted with the necessity of energy storage.

Possibility for using hydrogen as an energy vector in the islands' energy supply is not a novel idea. Vujcic´ et al, in 1994 and 1998 calculated the size of necessary hydrogen equipment for the energy supply of the Island of Lastovo in the Adriatic Sea. The authors also made the optimization of hydrogen storage and tackled the problem of energy storage, which is necessary to use in combination with intermittent renewable sources to make their better integration in energy systems and achieve security of supply. The integration of intermittent sources might be a complex problem but with a proper planning of energy systems it could be solved or minimized.

1.1 Porto Santo Island

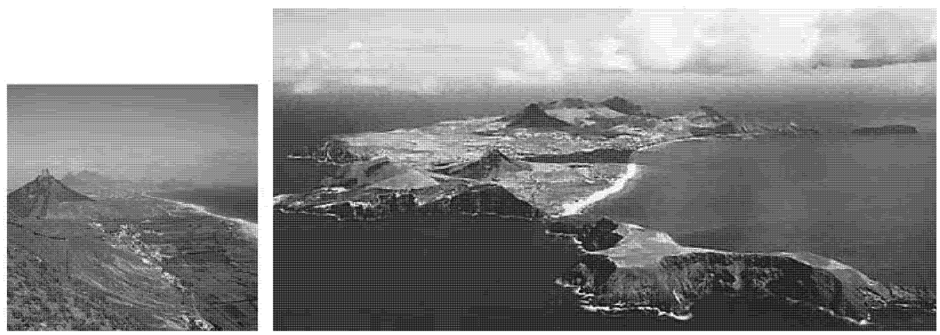

Fig 1: Porto Santo Island

Porto Santo (see Fig. 1) is inhabited by 5000 year long residents, most of them living in the capital, Vila Baleira, but the number increases significantly during summer months. The number of tourists and part time second house residents fluctuates between 500 in the wintertime and reaches up to 15,000 in the summertime. Tourism has given Porto Santo an economic dynamism that has been growing year by year. The construction of its airport in 1960, further expanded in 1973, was an important factor that contributed decisively to the island's economic and tourist expansion (Duic´and Carvalho, 2004).

1.2 Porto Santo Energy System

The power system of Porto Santo Island is basically composed of a thermoelectric power station and two wind farms. The total installed power is 24.07 MW, of which 22.96 MW (95.4%) are the diesel engines from the thermoelectric station and the remaining 1.1 MW (4.6%) are from the wind farms.

The electricity supply for Porto Santo's grid, in 2006, was 36,32 GWh, 95,2% (34,58 GWh) came from diesel engines and the other 1,74 GWh (4,8%) came from the wind farms (EDEN, 2008).

The main limitations of wind power in Porto Santo, are primarily concerned with the ability to use the electricity from wind turbines during periods of base load, except during the Summer, where demand for energy in 2006 did not went lower than 3,3 MW. Additionally, for reasons of criteria N-1, the thermal power plant is operated at least with two thermal engines, not fulfilling the minimum conditions (1,705 kW per engine - 50% of its rated power),, during a few hours per year, even without wind production. In these conditions the production of wind energy is limited, in base load periods, with direct consequences on the profitability of the wind farms.
The lack of other technical solutions will limit the integration of wind power in Porto Santo in the base load periods. One possibility for excess production is the use of energy storage, through production of hydrogen and/or batteries, or a reversible hydroelectric system. In these situations the energy stored in the periods of base load, could be sent to the grid during peak time periods.
Based on expected trends for the loads during periods of base load, it is estimated that only in 2012 there will be an ability to integrate additional wind power to about 40% of the capacity currently installed.
These were the problems that encouraged a consortium to develop this hydrogen production and storage demonstration project in Porto Santo.

2. H2RES Model

The H2RES model (Fig. 2) (Busuttil A, et al in 2008) is designed to balance in hourly time basis with the demands of water, electricity, heat and hydrogen supply from available sources (wind, solar, hydro, geothermal, biomass, fossil fuels or grid). The excess of renewable electricity is stored either as hydrogen, pumped water or electricity in batteries, or for some non-time critical use. The main purpose of the model is energy planning of islands and isolated regions which operate as stand-alone systems, but it can also serve as a planning tool for single wind, hydro or solar power producers connected to bigger power systems. Wind velocity, solar radiation and precipitation data obtained from the nearest meteorological station are used in the H2RES model.
The energy that is stored can be retrieved later and supplied to the system as electricity or hydrogen for transport purpose. If there is still unsatisfied electricity load, it is covered by fossil fuel blocks or by the mainland grid where such connection exists. The order of sources in supplying of demand could be easily set up according to criteria. Currently, the model does not support the automatic choice of sources according to minimal cost of electricity or according to minimal environmental pollution. There are two abilities of H2RES that make it specifically suited for islands: it can manage the water supply and consider hydrogen load for other than power supply (Martins, et al 2007).

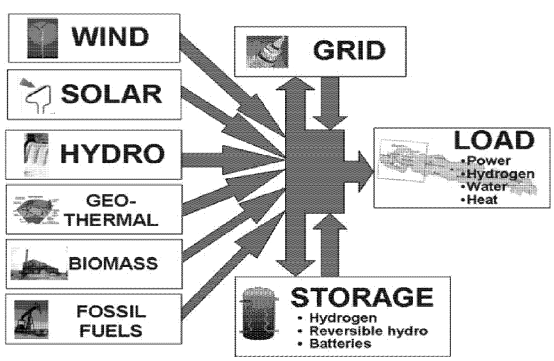

Fig 2: H2RES Scheme

2.1 Data Collection

In order to build scenarios and to model those using H2RES, electricity demand data was collected for a period of 5 years, wind velocities from one measuring station for a period of 1 year and wind turbines characteristics data were also collected.

Regarding the main objective of this project, to build a renewable hydrogen production site and use the hydrogen in a fuel cell to produce electricity in peak periods, data for all these equipments was also gathered and used in modeling scenarios.

2.2 Scenarios

The analysis of a scenario with the installation of more wind power capacity (2.5 MW) was preformed by Duic´and Carvalho in 2004 for peak shaving. In these conditions it was calculated that there was potential for the installation of 500 kW of FC. The hydrogen storage was estimated as 8000 Nm^3 and the electrolyzer capacity of 200 Nm^3/h. The wind power capacity was not yet increased but a project was set up to gain experience and demonstrate the use of a hydrogen based storage station. Based on initial cost estimates the demonstration was planned for a 7.5 kW FC.

Considering the main objectives of the project and the power of the fuel cell, and that it should work during peak time (5 hours per day from 19h to 00h), two scenarios where proposed. These two scenarios where different only in the use for electricity produced by the fuel cell, the first scenario pointed for grid injection, and the second for public lightning in a specific area to ensure the project visibility.

In both scenarios was considered that electricity was available for the electrolyzer whenever the wind park was producing. Also the storage was optimized in order that the fuel cell would stop a maximum of 50 hours of its 1825 annual working hours and that a minimum pressure was assured in the storage tank allowing the fuel cell to run.

2.3 Results

Fuel cell systems typically have a decrease in their efficiency increasing their load. FC suppliers announce their efficiencies at different conditions from negligible to maximum load, and the efficiency was estimated from 35 to 55%. Therefore a parametric study was preformed using H2RES to determine the capacity of electrolyzer and of the storage tank.

Taking in account the chosen scenario, three different configurations of it where modeled in H2RES, according to technology efficiency and storage capacity as showed in table1.

Table 1 Scenaria Results Resume

Fuel Cell Efficiency	35%	45%	55%
Electrolyzer Power	15 kW	10 kW	7,5 kW
Electrolyzer working hours	4613	5544	6230
Storage capacity	55 Nm^3	50 Nm^3	45 Nm^3
Fuel Cell Working Hours	1775	1789	1798
Electricity Produced by the Fuel Cell	13313	13418	13485

The influence of the FC efficiency has impact on the required capacity of the electrolyzer and the storage tank. From the results in the table it is clear that this influence is relatively small and the FC should work close to their maximum load. This has the consequence of increasing the capacity of the electrolyzer that has a significant cost, while the cost of storage is much smaller. So the scenario of 55% of FC efficiency was chosen to be the one that would be built in Porto Santo Island. And once this is was to be installed in outdoor environment and to be exposed to meteorological conditions the safer choice was proven and tested technologies.

3. Site Construction

During the process of consulting companies for acquiring the fuel cell it was noticed that there was no 7,5 kW FC available on the market, so the chosen proposal for this equipment were two 5 kW FC working with three 2,5 kW inverters.
Were also acquired an electrolyzer with the capacity to produce 2 Nm^3/h of hydrogen, a storage tank with capacity for 55 Nm3 of H_2 at 30 bar, a water deionizer system and reservoir and a monitoring and control system.
Site construction began in May 2008 with the concrete platform and a safety wall being built. In June 2008 were installed both FC and the hydrogen storage tank. During July all the other equipments were installed and the operation testing began in September.

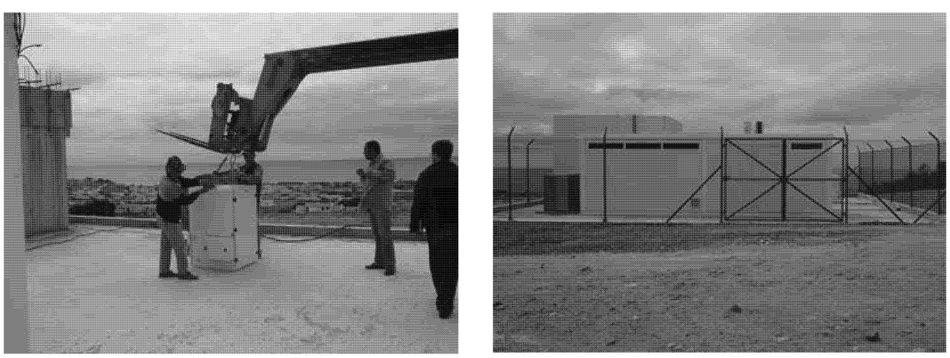

Fig 4: Fuel Cell installation and front view of the site.

The whole installation is working since November 2008 and is serving for public lightning of 2 streets near by the operation site. It can be visited by general public, institutions, researchers and schools.

4. Conclusions

This work shows the urging need that most islands have in energy storage systems.
It is demonstrated that hydrogen can be a solution to store energy in places where there is no possibility to build dams and large water reservoirs to do so. This project also shows that energy produced by renewables can be stored when there is no demand on the grid to dispatch this energy.
Currently, H2RES program does not support economic and environmental evaluation of calculated scenarios and even if it is simple to calculate price of electricity or reduction of emissions from H2RES results, it will be very valuable to expand the model with economy and environment modules in order to have other parameters for the optimization as it was stated by Krajacic´, et al in 2008.
Analyzing all the operation data from the equipments and compare it with the modeled scenarios, in order to sharp the capacities of H2RES model will be the next step of this project.

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