HYDROGEN AS ENERGY STORAGE FOR WIND ENERGY

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Abstract

Nowadays, problems associated with greenhouse gases emission and fuel ending, makes that renewable energy sources and hydrogen technology have high interest for governments and researchers, and become an option for an environmentaly sustainable world.

Renewable energy sources, like solar energy and wind energy, have been used for the last three decades to produce electricity. Researchers and companies have improved the efficiency of this kind of systems, but they have a problem due to energy source temporality that does a fluctuation in systems power output. This fluctuation makes sometimes energy demand is higher than energy produced by the system and vice versa. Hydrogen Technology, actuating as energy storage, may solve this problem.

In this paper, a wind-hydrogen installation will be described. Also, its behavior in relation to different electric demand will be analysed.

Key-words

Wind-Hydrogen, model, simulation, energy storage.

Introduction

Worldwide, the theoretical potential of wind energy is more than twice forecast electricity need in 2020. This potential, and its steadily improving competitive position as a result of technological advances, makes wind energy an essential replacement for fossil fuels.

Over the last few decades, installed generation capacity using wind energy has increased spectacularly. The capacity of commercial turbines has grown from 10kW to more than 4,5MW. Over the last eight years, installed generation capacity using wind energy has grown at an annual rate of more than 30%. According to projections by the European Wind Energy Association (EWEA), total wind energy capacity will be sufficient in 2020 to cover 12% of electricity needs. This implies an increase in wind energy capacity from 31GW at the end of 2002 to 1260GW in 2020, growth of 23% per year [1].

The development of wind energy has advantages from a several points of view:

a) Environmental Policy: wind energy is a clean form of energy without emission of CO_2 or other pollutants.
b) Social Policy: Wind energy contributes to employment. The estimation in wind energy companies is 20 jobs per megawatt of installed capacity.
c) Regional Policy: Due to support schemes, wind energy develops into large, centralised wind energy farms. Because of their profits, they are very attractive for investors.

The steadily improve of wind energy in all the countries, are creating problems to the electrical grid operators and electric market operators. The principal problem is the fluctuation and random of wind, which produces difficulties in the integration of wind energy in the electric market.

Developers and investigators consider that wind energy requires energy storage in order to improve the integration of wind energy. Actually, there are different kinds of energy storage: waterfalls, batteries, flywheel's, hydrogen technology,…

International Energy Agency has a work group (Task 24) inside the Hydrogen Implementing Agreement that analyzed integration between wind energy and hydrogen technology [2]

In this paper, a wind-hydrogen installation will be described. An example of this kind of system will be analysed using different electrical grid demand profiles.

Wind-Hydrogen System

A wind-hydrogen system is composed using next units: Wind-turbine, electrolyzer, hydrogen storage (low and high pressure), hydrogen compressor, Fuel Cell and system control elements. See Figure 1.

Next, system operation is described:

a) Wind energy is transformed into electrical energy, via a wind-turbine.
b) A control system may control if energy produced is higher or lower than grid demand. There are three possibilities:

1) Energy produced is higher than energy requirements. In this case, remaining energy is used to produce hydrogen using an electrolyzer.

2) Energy produced is lower than energy requirements. The energy necessary to satisfy all the demand is ‘taken’ from the hydrogen storage, via a fuel-cell.

3) Energy produced is equal to energy requirements. In this case, hydrogen storage doesn’t work.

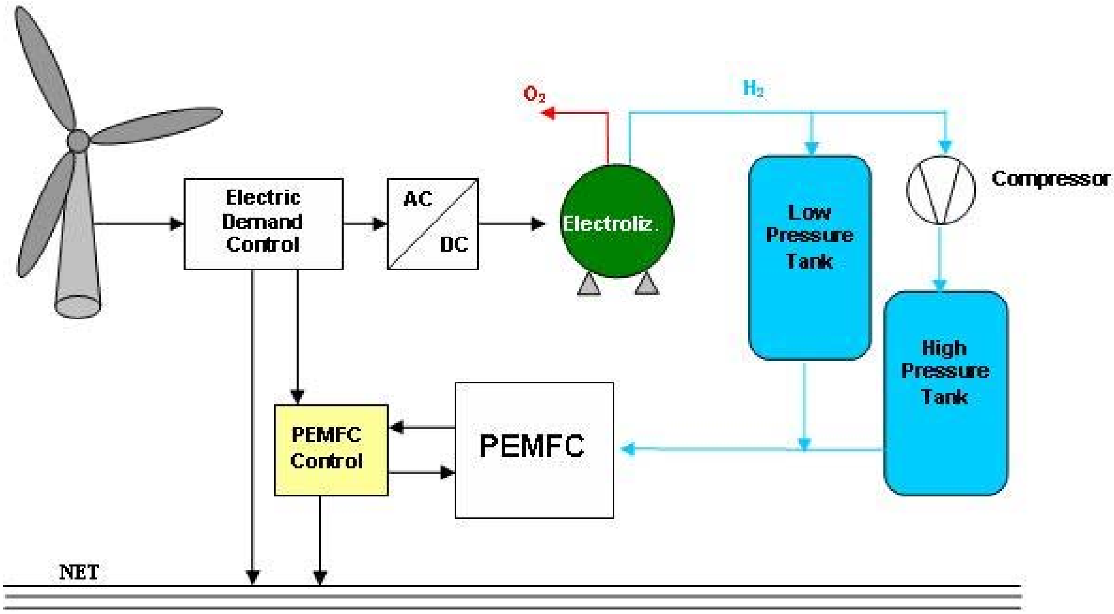

Figure 1. Wind-Hydrogen system.

c) Hydrogen is produced, by means of an electrolysis process, in an electrolyzer. Hydrogen output pressure is the same as the pressure of the water inlet.

d) Produced hydrogen must be stored. In the installation studied, hydrogen is stored in two pressure tanks. One of them, low-pressure tank where hydrogen is stored at output electrolyzer pressure; the other, high-pressure tank where hydrogen is stored at 200 bar using a hydrogen compressor.

e) Electric energy is produced, via PEM Fuel Cell, using Hydrogen as an energy source. Hydrogen is transformed into electrical energy by means of electrochemistry process.

In this installation, a PEMFC is selected due to its quick start-up and quick response to the electrical demand.

Low-pressure tank is the first vessel that will be filled with hydrogen. When it is full, the high-pressure tank will be started to be filled. This is the best energetic option due to hydrogen compressor electric consumption.

Wind-Hydrogen system operation modes

Wind-Hydrogen system can be operated using different ways, depending objective pursuits. Most important operation modes are: Tracking demand profile and pumping. Both are explained below.

a) TRACKING DEMAND PROFILE. Wind farm electric power output is equal to the power demanded at any time. In this case, the wind-turbine is the first electrical energy source. There are three possibilities:

   1) Energy produced is higher than energy requirements. In this case, the remaining energy is used to produce hydrogen using an electrolyzer.
   2) Energy produced is lower than energy requirements. The energy necessary to satisfy all the demand is ‘taken’ from the hydrogen storage, via a fuel-cell.
   3) Energy produced is equal to energy requirements. In this case, hydrogen storage doesn’t work.

b) PUMPING ENERGY. In this procedure, during the hours where electrical energy benefits are lower, known as valley hours, electricity produced by wind-turbine is used to produce hydrogen. When electrical energy benefits are higher, known as peak hours, PEMFC is used, consuming hydrogen. Here, benefits optimization is necessary.

In this article, wind-hydrogen system operation is going to be simulated, using different kinds of electric demand: constant, randomized and pumping energy.

Wind-Hydrogen system simulation

Components specifications of wind-hydrogen installation simulated are showed in . Simulations are realized using Matlab® Simulink® software.

	Specifications
Wind-turbine	850 kW
Electrolyzer	200 kW
Fuel Cell	150 kW
LP Hydrogen Storage	1000 Nm3
	20 bar
HP Hydrogen Storage	1000 Nm3
	200 bar

Table 1. Components of Wind-Hydrogen system

Installation has been simulated using typical wind profile of Huelva (Spain). Average wind speed is shown in Figure 2.

Three different demand profiles, Figure 3, are implemented in the software. Simulations have been done using this profiles, and wind conditions during a year. Considering all possible simulation results, only one week electric behaviour of demand, wind-turbine and fuel cell (Figure 4); and energy stored in tanks as hydrogen (Figure 5) have been estimated as more important results and they are showed in this article.

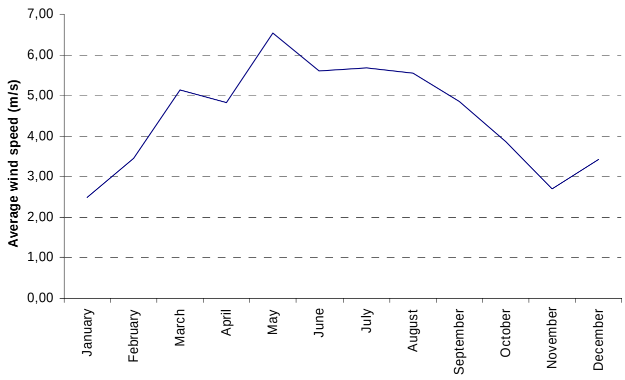

Figure 2. Average wind speed profile used in simulations.

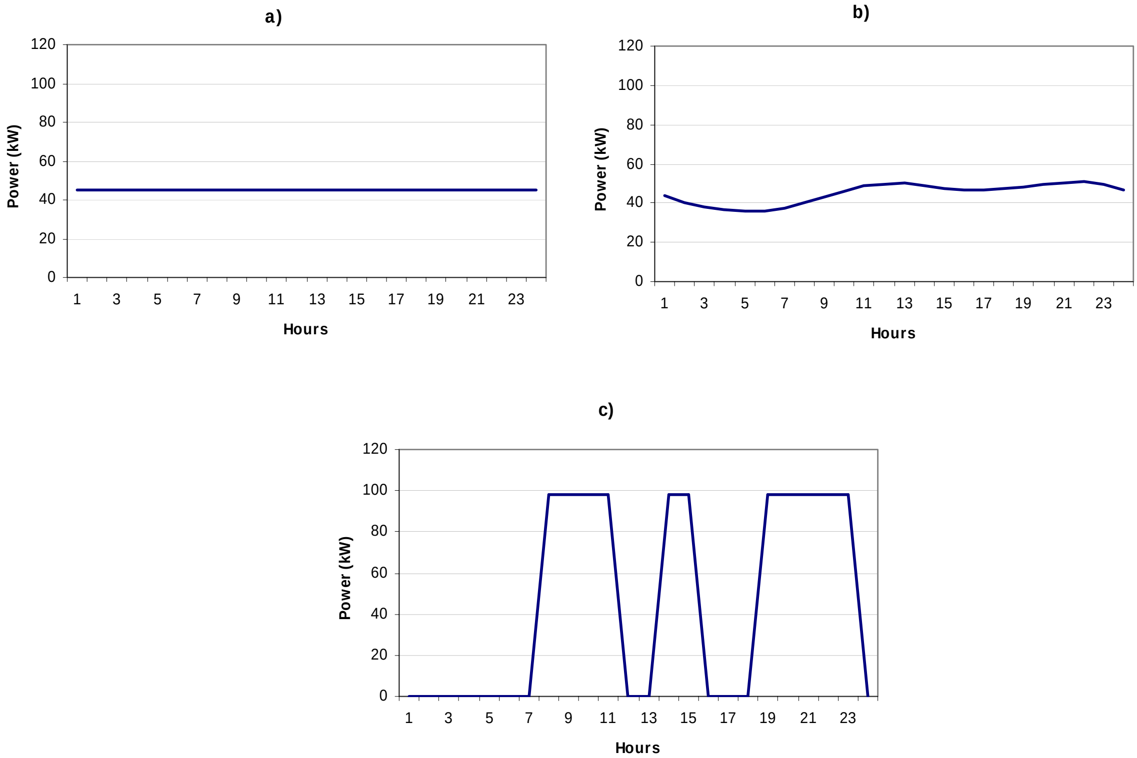

Figure 3. Electric demand profiles. a) Constant demand, b) Variable demand, c) Pumping energy demand.

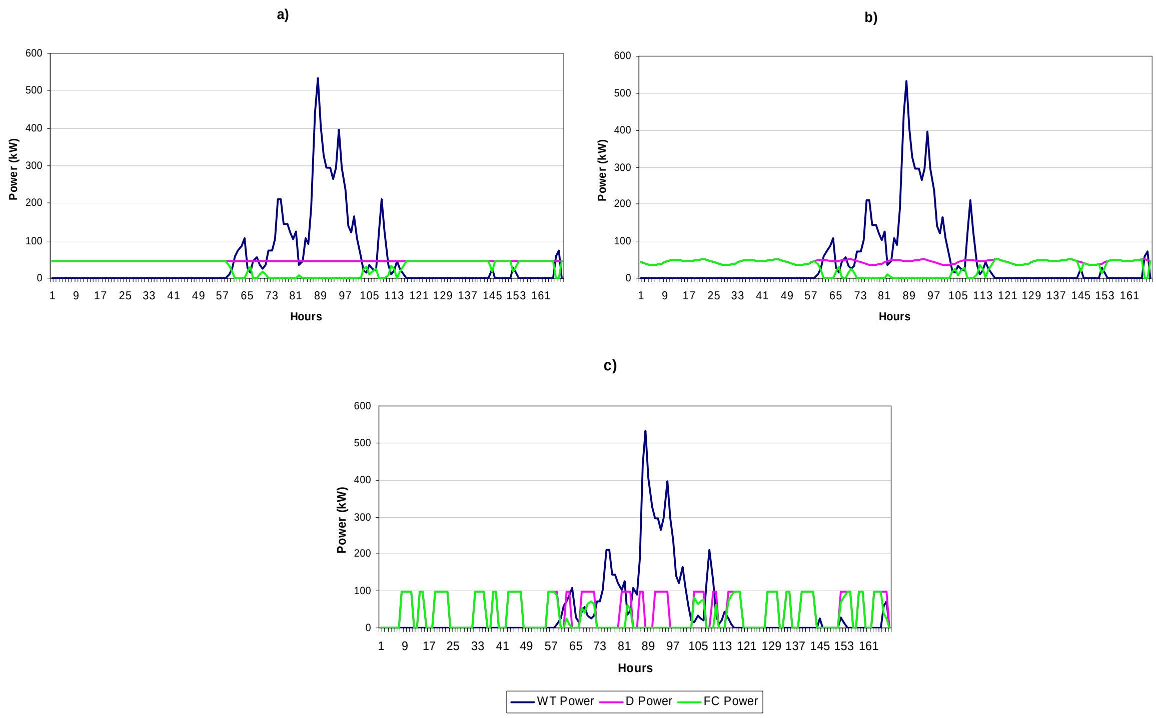

Figure 4. Wind-hydrogen power behaviour. a) Constant demand, b) Variable demand, c) Pumping energy demand. WT (Wind-Turbine), D (Demand), FC (Fuel Cell).

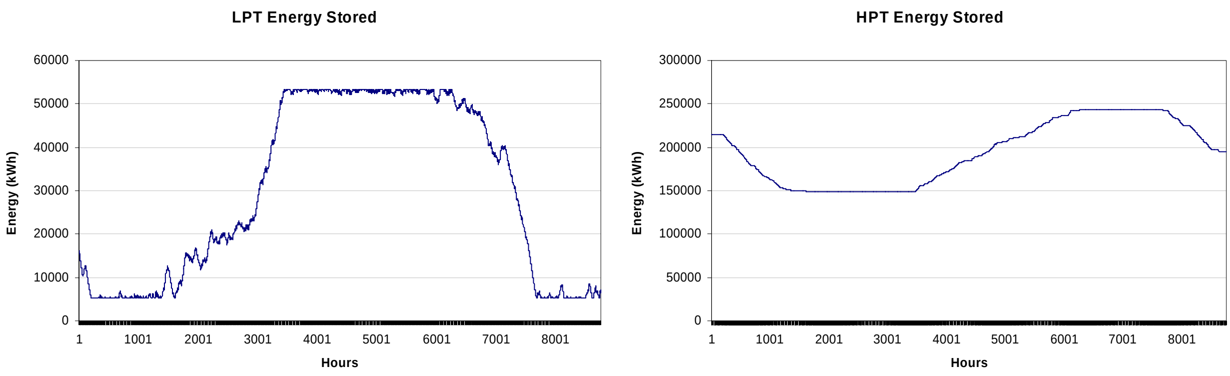

Figure 5. Energy stored in tanks. LPT (Low pressure tank). HPT (High pressure tank).

In Figure 5, only are shown energy changes using constant power demand because the three electric demands have a similar behavior.

Conclusions

A wind-hydrogen installation is presented and simulated in this article. Most important conclusions are showed below:

- Wind profile is a key for wind-hydrogen installation components design.
- Installation behaviour is correct with different demands profiles. The only requisite for all electrical demand is that electric energy consumed daily has to be the same.
- Other storage elements, like batteries or super-condenser, are needed in order to take advantage of all energy generated by wind-turbine in transient times.

References

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