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"LIFE+ Zero Hytechpark: toward a sustainable building with thermal, photovoltaic and hydrogen technology"

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Abstract. The use of renewable energy to produce hydrogen as an energy vector can contribute to increase energy efficiency and buildings sustainability. Besides, it may contribute to develop new mobility models which are more respectful to the environment. Therefore, this is the main objective of the LIFE+ Zero-HyTechPark in order to get more sustainable Technology Parks.

On FHa building a real isolated hybrid (photovoltaic/micro-wind / hydrogen tech) renewable plant has been installed and also simulated with a specific own software developed. The hydrogen is used for two purposes, as long time energy electrical storage, and for mobile application, such as bike fleet. Also it has been installed a thermal solar panel roof plant to cover a percentage of thermal energy consumptions of the building.

This project has the capacity to behave as a referent in sustainable architecture for research centres and as the first step in real sustainable urban projects. In small-scope, the experience will be extrapolated to other Technology Parks and industrial areas effectively reducing local emissions in short and medium term.

The prototypes developed in this project present sustainable alternatives for common applications that are using fossil fuel. The use of hydrogen will reduce the CO_2 for the future.

Key words

Simulation model, photovoltaic, solar thermal energy, wind energy, sustainable building.

1. Introduction

The main objective of the LIFE + Zero – HyTechPark project, coordinated by the Foundation for the Development of New Hydrogen Technologies in Aragon (FHa) and with the participation of Huesca, Andalusia and Vizcaya Technology Parks, is to implement the capacity of full-sustainability in Technology Parks with an optimal management of energy by means of a green-hydrogen system.

The main actions that are going to be carried out during this four years' duration project consist of designing, simulating and implementing energy solutions based on hydrogen technologies and renewable energies in the building of the FHa located at Walqa Technology Park (Huesca) and extrapolating these results to other buildings of this one or other Technology Parks. The expected results of this project are based on having a building with practically zero CO_2 emissions, promoting sustainable mobility through the development, starting up and monitoring of a hydrogen vehicle fleet and disseminating the developed technologies through people in general and through interested technological sectors in particular.

Fig. 1 FHa building

2. Isolated photovoltaic system

One of the main parts of the project is to develop an isolated system in order to cover the electrical consumptions of the FHA office.

First of all a Matlab/Simulink model was developed in order to study the topologies and possibilities about the system. This model includes also de hydrogen equipment like electrolyzer and fuel cell.

The model can simulate the amount of energy that the isolated hybrid system would have been able to obtain in case of having enough electrical loads to feed; it is to say meeting the Office demand or storing extra energy in batteries or metal hydride systems. That is useful because, in the real system, the inverters only produce electricity when it can be supplied to loads or when any storing system is available.

Photovoltaic solar production is simulated by using a mathematical model, which has been referenced in several previous articles [4, 5], where the equations of the model are detailed.

$$I_{pv} = I_{sc}\left\{1 - C_1\left[\exp\left(\frac{V_{mp}}{C_2 V_{oc}}\right) - 1\right]\right\} + \left(\frac{E_{tt}}{E_{st}}\right)\left[\alpha(T_a + 0.02E_{tt}) + I_{sc}\right] - I_{sc} \quad (1)$$

$$V_{pv} = V_{mp}\left[1 + 0.0539\log\left(\frac{E_{tt}}{E_{st}}\right)\right] - \beta(T_a + 0.02E_{tt}) \quad (2)$$

$$C_1 = \left(1 - \frac{I_{mp}}{I_{sc}}\right)\exp\left[\frac{-V_{mp}}{C_2 V_{oc}}\right] \quad (3)$$

$$C_2 = \frac{V_{mp}/V_{oc} - 1}{\ln(1 - I_{mp}/I_{sc})} \quad (4)$$

Where (I_{pv}, V_{vp}) is the maximum power point, which is calculated in the equations (1) and (2) by using (3) and (4), I_{sc} is the short-circuit current of the module, V_{oc} is the open-circuit voltage of the module, I_{mp} is the maximum-power current of the module, V_{mp} is the maximum-power voltage of the module, E_{tt} is total solar radiation on titled panel, E_{st} is standard solar radiation (1000 W/m^2), T_a is ambient temperature at arbitrary conditions and α, β are coefficients which include operation variation of the module when varying temperature, α is known as current temperature coefficient and β is the voltage temperature coefficient of the module.

The model above has been implemented for each type of PV solar technology of the isolated system.

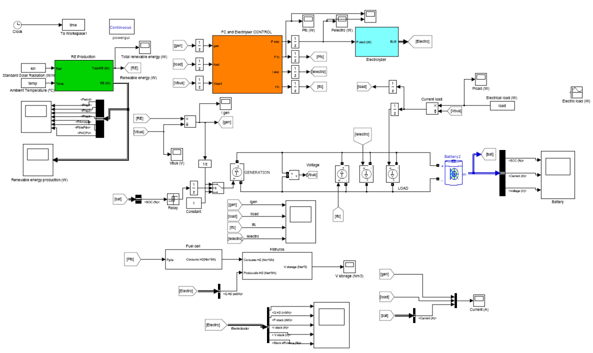

Fig. 2 Matlab model

Furthermore, the rest of the equipment has been simulated by its performance equations and integrated in the complete model showed in Fig. 2.

After analyses de best option, the system was build and test to verify the correct function.

2.1 System description

The hybrid isolated system is divided in three main parts: generation, loads and hydrogen equipment. In Table 1 and 2, it can be observed the different generation and consumption equipments installed in the facilities and their nominal power.

Table 1. Generation equiptments.

nº	Equipment	Technology	Power
1	Fixed Solar Panel	Si Amorph	1,08 kW
2	Fixed Solar Panel	CdTe	0,7 kW
3	Solar Follower	High Concentration	0.8kW
4	Fixed Solar Panel	High Efficiency HIP	7,8 kW
5	Micro Wind Turbine	-	0,6 kW

Fig. 3 Isolated photovoltaic system on the FHa roof

Table 2. Electric loads.

nº	Equipment	Power
1	Programmable load generator	3 kW
2	Office FHa	4 kW
3	Graduable loads	4 kW

All the equipments of the isolated hybrid system are totally autonomous, allowing configuring different types of performance tests. It is necessary to point out that high efficient PV solar panels, Table 1 (line 4), are connected in three independent arrays, being possible to select three additional generation levels.

Furthermore, the hybrid isolated system includes hydrogen equipment to store energy excess in a metal hydride storage system (Table 3). First, electricity from renewable sources is converted to hydrogen in the electrolyser and then, when more electricity is necessary to meet the demand, hydrogen turns into electrical energy by means of fuel cells.

Table 3. Hydrogen Equipment.

nº	Equipment	Technology	Power
1	Fuel Cell	PEM	1,2 kW
2	Fuel Cell	PEM	5 kW
3	Electrolyser	PEM	7kVA
4	Storage	Metal hydride	21.000liters H2

Fig. 4. 5kW fuel cell

In Figure 5, it can be seen the complete isolated hybrid system developed. The integration of all the equipments takes place in a 48V DC Bus in combination with a small Lead-acid battery storage system, which have a total capacity of 20kWh (C100). The objective of the battery system is to balance differences between energy generation and consumption in the range of minutes and hours.

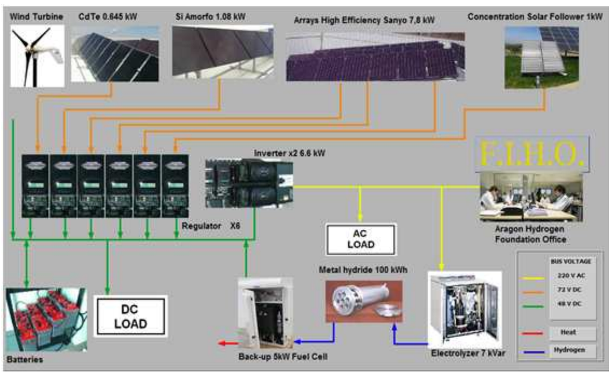

Fig. 5 The complete Isolated Hybrid System of FIHO Project

Next, one of the measurement panels is shown in Figure6. The monitoring application has been developed in Labview software. This program is used to keep data and realize tests under different conditions. Figure 6 shows all the electrical signals of the system including demand and generation, and making possible to adapt production to electricity demand in each moment [3].

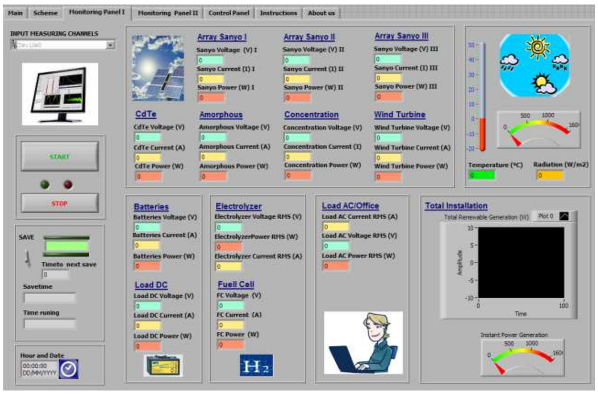

Fig. 6 Measurement panel

3.   Solar Thermal System

A solar thermal system has been installed on the roof of the FHa building. This system takes advantage of solar radiation to preheat the water of the heating system. The performance of the solar thermal systems was simulated previously in order to calculate the feasibility of install it. A simulation model was developed by means of physical equations of the components. The main algorithm is shown in equations 5-8.

For i=1to 5:

$$\eta_i = 0.75 - 2.9\left(\frac{Te_i - Ta}{I}\right) \quad (5)$$

$$Q_i = \eta_i \cdot I \cdot S_c \quad (6)$$

$$Q_i = m \cdot C_p \left(Ts_i - Te_i\right) \quad (7)$$

$$Te_i = Ts_{i-1} \quad (8)$$

Where:

- η_i : Collector *i* efficiency
- Te_i : Fluid temperature entering the collector *i*
- Ta : Outside temperature
- Ts_i : Fluid temperature leaving the collector *i*
- I : Global solar radiation (W/m^2)
- Q_i : Solar heat produced (W)
- m : Flow circulating inside the collector
- S_c : Collector surface (m^2)

Each raw of solar collectors produces the same amount of heat. Thus, the total solar heat recovered by the system is:

$$Q = rows \cdot (Q_1 + Q_2 + Q_3 + Q_4 + Q_5) \quad (9)$$

Heat from solar thermal collectors is transferred to the storage systems, which is composed of three storage tanks with a total volume of 3.000 liters of water. The solar field consists of 25 flat plane solar thermal collectors with high efficiency. The total thermal power installed is around 45 kW, depending on solar radiation and external temperature.

Fig. 7 Solar thermal system on the roof of the FHa building.

The connection of panels has been realized in series-parallel to get higher temperatures in the storage system because the aim of the solar system is to preheat some degrees,the return water from the heating system in the building. The heating system is composed of two different boilers, with a thermal power installed of 145 kW. Recently, one of the old boilers has been replaced by a gas fired condensing boiler which has higher efficiency in heat production, reducing propane consumption significantly.

Fig. 8 Heating boilers and its integration with the solar thermal system inside the boilers room.

In this way, it is possible to preheat cold water which comes back to the boilers before entering in them, reducing the amount of heat that needs to be supplied by the boilers. Gas consumption is expected to be reduced 20% due to solar thermal contribution and CO_2 emission will be reduced in 100 tons during the lifetime of the system. The best solar system performance takes place during spring and autumn because of suitable weather conditions and lower heating demand.

Apart from this, the heating system efficiency is expected to increase because of the new condensing boiler. All the parameters of the system are measured and monitored in order to control them and try to optimize the global system operation to reduce energy consumption. Some of the measured and controlled parameters are: temperatures in the solar field, external temperature, solar radiation, system pressure, storage system temperature, solar energy production and heat produced by the boilers.

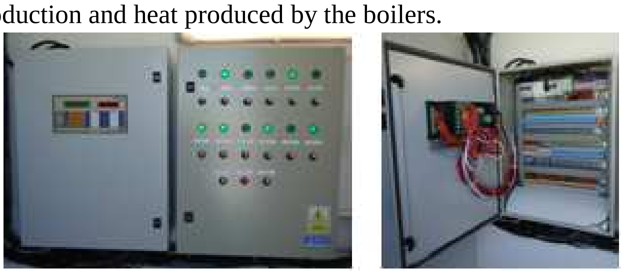

Fig. 9 Electrical panel and programmable automaton

Furthermore, a web application has been developed in order to do an on-line control. It is possible to observe the measured values in real time and to check if the system is operating properly. In the application, there are different panels showing the system performance and some tabs allow you to change the system control parameters.

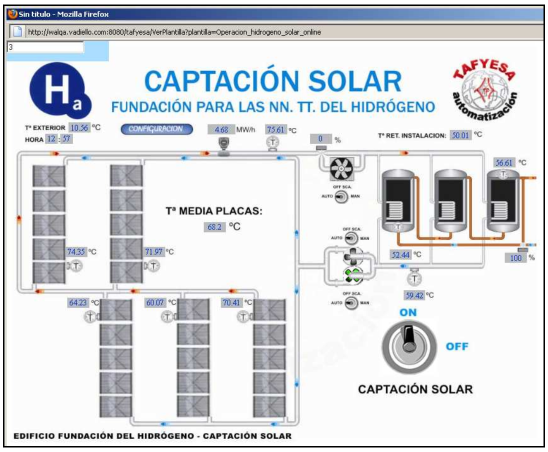

Fig. 10 Solar thermal system on-line control.

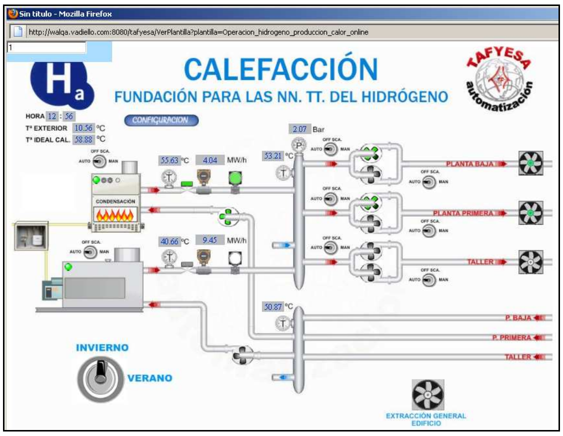

Fig. 11 Gas fired boiler on-line control.

The designed solar thermal system is technically feasible but cost-effectiveness is restricted to economic helps from the Spanish Government. The Pay back of this inversion is 14 years considering that 36% of the total cost has been subsidized. Therefore, solar energy supplies 20% of the heating demand representing 1.400 € of annual savings.

4. Results of electrical isolated system

The isolated photovoltaic system is presently in test phase together with data and results processing. Following, one of the first tests carried out, particularly energy consumption of the FHa Office during year 2010 is shown. At that moment, the Office energy demand is supplied by the isolated system exclusively.

The electrical demand of the FHa office is around 9.700 kWh/year. By using the solar system will be possible to avoid almost 100% electricity grid consumption. The total amount of electricity produced by the installed solar system is estimated to achieve 16.620 kWh/year, and real data measured in 2010 correspond to 16.000kWh.

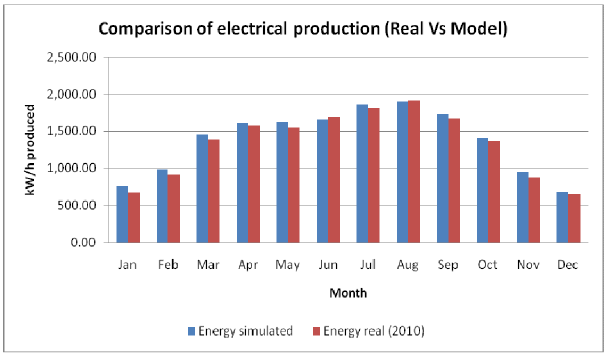

Fig. 12 Electrical production

The total amount of additional energy that the system would have been able to produce during the tested period has been used to produce hydrogen. This extra electricity would be stored in way of hydrogen to be used in those moments with low renewable energy production. The installed PEM electrolyser has been able to generate about 125Nm^3 of hydrogen in the analyzed year. When the photovoltaic system cannot meet the Office demand, the hydrogen stored in the metal hydride system would be reconverted into electricity by means of fuel cells.

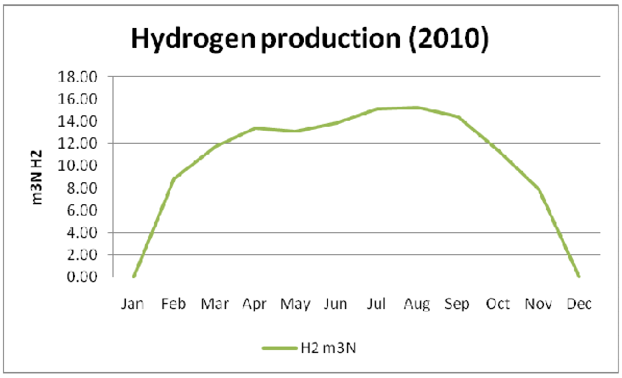

Fig. 13 Hydrogen production

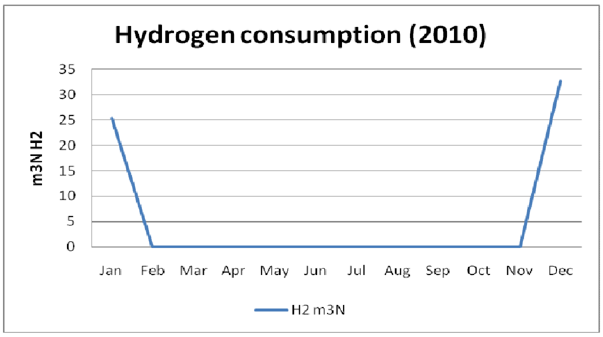

Fig. 14 Hydrogen consumption

Figure 14 shows hydrogen consumption on the fuel cell, to supply energy on periods of lack of sun. After using the stored hydrogen in the fuel cell hydrogen, is used in others facilities such us hydrogen bikes, toys or other fuel cell installed in Fha.

5. Results of the solar thermal system

The heating demand of the FHa building is around 104.700 kWh/year. By using the solar system will be possible 20% oil consumption reduction. The total amount of heat produced by the installed solar system is estimated to achieve **22.029 kWh/year**.

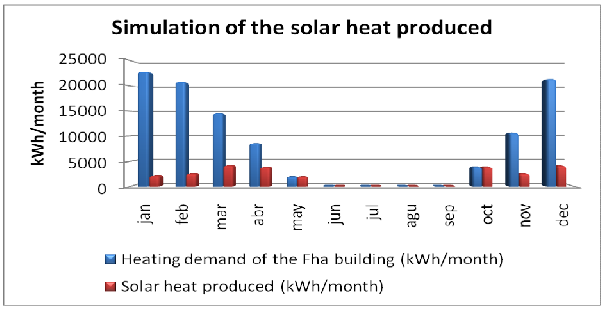

Fig. 15 Simulation of solar heat produced versus total heating demand.

The solar system is expected to get the best results during the spring and the autumn. The rest of the year a lower contribution of solar heat is expected. However, a total reduction per year of 20% oil consumption is quite significant to invest in this type of sustainable systems in order to demonstrate its results in a real system. This experience is being transferred to other Technological Parks ant it contributes to the sector development.

The solar system efficiency has been simulated with the model developed. The results are shown in Fig. 15.

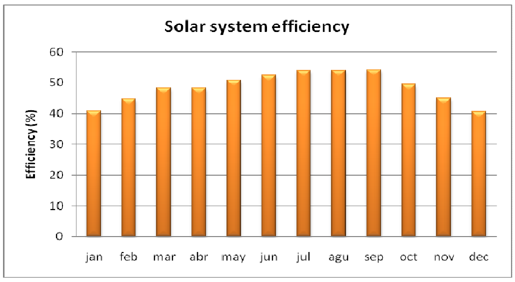

Fig. 16: Solar system efficiency around the year.

The higher efficiency is expected during the summer. Nevertheless, there is no need of heat during this period and the solar fluid will be fully emptied out to avoid heat generation. In future, the option of install an absorption machine will be analyzed to meet a part of the cooling demand, but firstly it is necessary to check the real performance of the solar system.

Currently, the first results of the sensors measures have been obtained and comparisons between simulation and real solar contribution are reliable. (Fig. 16.)

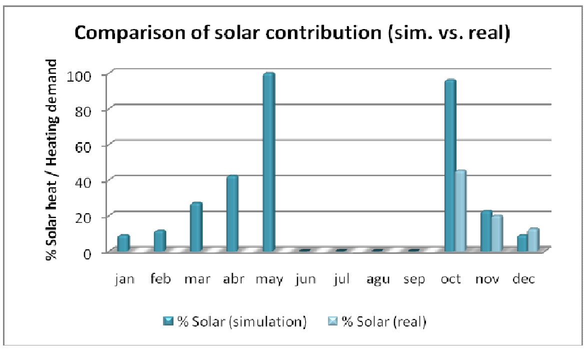

Fig. 17 Comparison between solar heat simulated and real production.

Finally, the contribution of the different sources of heat to the heating system can be seen in Fig. 17. The condensig boiler is working during more hours than the low tempeature boiler, however, the consumption of old bolier is is much higher. For that reason, it is necessary to reduce the operating hours of the old boiler to increase global system efficiency.

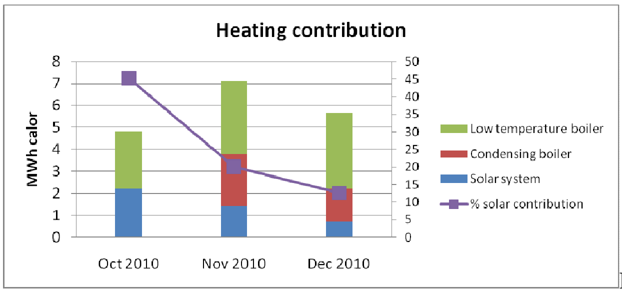

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Fig. 18 Contribution of heat sources to meet the heating demand

6. Conclusions

This project has the capacity to behave a referent in sustainable architecture for research centres and the first step in real sustainable urban projects. In small-scope, the experience is extrapolated to other Technology Parks and industrial areas. Walqa Technology Park is carrying out a study of energy demands in all the building and it will be possible to quantify our carbon footprint reduction and costs to do it and the relative improvement respect our neighbours, making nearest community aware of the practical solutions implemented with the project, what would strengthen the adhesion to new frames of energy management, effectively reducing local emissions in short and medium term.

The systems developed in this project present sustainable alternatives for common applications that are using fossil fuel. The use of hydrogen will reduce the CO_2 emissions. The amount of $C0_2$ emissions avoided by the two utilities presented in this project is 5,2 tones during 2010. [6]

The ZERO-HYTECHPARK project is not only a combination of existing technologies due to the integration of new technologies (fuel cells, electrolyzers, hydrogen storage) in existing devices and applications. There are some difficulties on energy management, on balance of plant and on homologation and certification as well. The project will be developed exclusively in the Foundation building to integrate, test and evaluate all the technologies and their contribution to reduce CO_2 emissions (monitoring). Walqa Technology Park uses propane or diesel in the buildings (heating system) nowadays and electricity from the grid, so that the project results will be used to spread the knowledge and eventually be implemented in the other buildings, in a second phase. The project will develop manuals to facilitate the technology implementation in other Technology Parks, Companies, and Institutes and so on, that will be disseminated also by the technology parks partners.

7. Acknowledgement

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