SIMULATION AND DESIGN OF AN ENERGY ACCUMULATOR AROUND THE HYDROGEN ENERGY VECTOR

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Highlight
Reduction of greenhouse gases thanks to an energy generator using green hydrogen.

Abstract
This work demonstrates the study of the numerical modelling and a design of a compact energy generator based on green hydrogen. This generator aims allowing the energy storage, electricity, cold and heat productions as well as a supply the energy for the production of the sanitary hot water. The generator is considered to be powered by 30 solar cells panels and will mainly consist of a Proton Exchange Membrane (PEM) electrolyzer compiled with a Metal Hydride (MH) tank, a PEM fuel cell, and a system of heat exchangers sized to recover the heat from the electrolyzer, PEM fuel cell and MH tank. Furthermore, the generator will contain an adsorber to manage air conditioning (cooling and heating) and a production of the sanitary hot water. A converter block is included in the generator, in particular, a Buck-booster to raise the voltage of the solar panels and the DC-AC converter for the electricity consumption in the household. The desorption of the hydrogen contained in the tank MH will take place using the heating resistance. In overall, the designed generator is foreseen to have a dimension of 1800 × 1000 × 500 mm and its role is to allow integration of the hydrogen energy for the tertiary and residential sectors. As such it is a suitable choice of components for the cost reduction and high yield hydrogen production, storage, and consumption.

Keywords
energy storage; thermal energy; green hydrogen; trigeneration; energy transition.

Introduction

Facing the challenges to act against global warming, reducing the world's energy consumption is one of the big challenges. Sustainable development is the main action that will enable our planet to address the challenges of global warming. Considering the World population increase, and the climate changes observed in the World [1], indeed a paradigm shifts in the energy sector is essential for the future of humanity. The circular economy,

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renewable energy, and energy efficiency are key aspects of current economies and allows changing the way the World consumes the energy. To address all these challenges, the production and storage of energy play a key role. Therefore, the number of power plants producing electricity from renewable energy is growing considerably around the World. However, with an increase in the renewable energy production, there is proportional growth in energy storage systems (ESS). ESS occupies an equally important place in the energy transition because electricity from renewable energies such as solar energy and wind energy is unstable over time due to the intermittency of these energy sources. Hence, it is important to store this energy for consumption corresponding to the actual needs of the humankind. There are several types of energy storage systems [2,3]. The effects of the global warming observed and those planned require the use of a so-called clean ESS. To meet this need, the strategy for ESS, especially for the energy produced from renewable sources, in particular solar and wind power, relies in the hydrogen production and storage [4]. The use of hydrogen continues to increase and today, several countries have allocated a considerable percentage of their GDP in the R&D on the hydrogen area [5]. On the other hand, the hydrogen can find its application in all scales, ranging from the tertiary sector to industry including transport [6,7]. Nowadays, the main obstacle in the use of green hydrogen as an energy storage is its production cost. The solution to improve the economic analysis of the hydrogen production is to consider the recovery of thermal energy, resulting from the production of hydrogen. Several studies demonstrated integrated cogeneration and trigeneration as an approach to increase in the energy efficiency and to reduce the cost of ESS of green hydrogen [8–11]. Other technical and economic studies [9,11] highlighted a possible cost reduction of the hydrogen production by recovery of the generate heat. It should be noted that one of the energy-intensive sectors in terms of demand for thermal energy, especially for air conditioning and for the sanitary hot water, is the tertiary sector. Hence, this work aims to demonstrate the integration of green hydrogen production in the households. For this purpose, this work proposes the study on a modelling and a design of an energy generator based on hydrogen storage for use at the medium and small scales. This work is an advance in comparison to already existing batteries, such as the first hydrogen fuel cell for domestic use [12], which mark the importance of the use of hydrogen in the tertiary sector.

Methods

The results presented in this study rely on the conceptual modelling of the hydrogen generator. This considers the bibliographic data and implementation of them in the numerical modelling of the entire designed system. The modelling was performed using MATLAB® Simulink R2013a. The heart of MATLAB is the MATLAB language, a matrix-based language allowing the most natural expression of computational mathematics. The modelling was performed until the coherent iteration all of elements was satisfactory and obtained results were consistent. PVsyst 6.8.1 software was used to perform the calculations regarding the energy production by the photovoltaic systems. PVsyst is a PC software package for the study, sizing and data analysis of complete PV systems. It deals with grid-connected, stand-alone, pumping and DC-grid (public transportation) PV systems, and includes extensive meteorological and PV systems components databases, as well as general solar energy tools.

Results and discussion

Energy conception profile

To properly model and design the generator, the energy consumption profile of a standard household was considered. The simulation of energy consumption was established on the basis of PVsyst software. This simulation allowed evaluating the energy to be produced by the generator and the number of photovoltaic panels needed to power it. The study of household energy consumption was done over three intervals, the day (6 a.m. - 6 p.m.), the evening (6 p.m. - 12 a.m.), and the night (12 a.m. - 6 a.m.).

Table 1. The consumption behaviour between 6 a.m. and 6 p.m. *Source: Author.*

Number	Appliance	Power (W)	Daily use (h/day)	Daily energy (Wh)
8	Lamps	20	1	160
2	Fridge	110	12	2640
1	Washing machine	600	0.5	300
1	TV	150	6	900

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Table 2. The consumption behaviour between 6 p.m. and midnight. *Source: Author.*

Number	Appliance	Power (W)	Daily use (h/day)	Daily energy (Wh)
8	Lamps	20	7	1120
2	Fridge	110	6	1320
1	Washing machine	600	0.5	300
4	Lamps exterior	36	6	864
1	TV	150	6	900
1	Stand-by consumer	24	1	24

Table 3. The consumption behaviour between midnight and 6 a.m. *Source: Author.*

Number	Appliance	Power (W)	Daily use (h/day)	Daily energy (Wh)
8	Lamps	20	1.5	240
2	Fridge	110	6	1320
4	Lamps exterior	36	6	864
1	TV	150	1	150
1	Stand-by consumer	24	1	24

Tables 1-3 give us an overview of the profile standard consumption evaluated on PVsyst. The estimated power consumed was 980W without heating and air conditioning. The simulation of the number of solar panels presented in Figure 1 shows the need for 24 solar panels to satisfy the expected consumption.

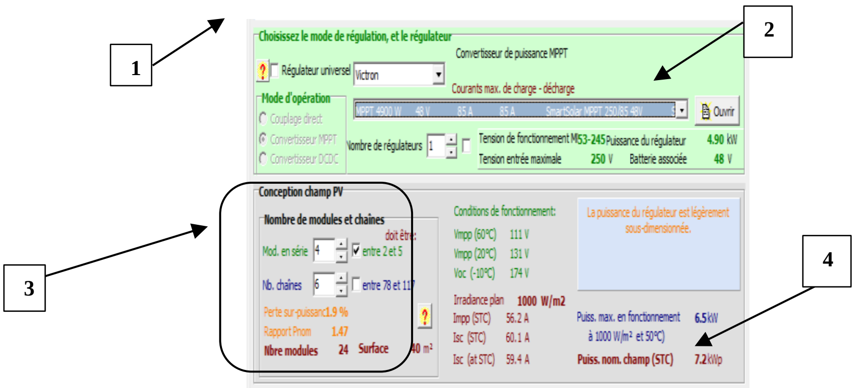

Figure 1. PVsyst simulation of solar panels needed to support the household energy consumption: 1 type of the regulation mode and the regulator; 2 - the power of the inverter sized for the total consumption; 3 - the number of solar panels to be put in series, i.e., 4 and in parallel, i.e., 6; 4 - the total power supplied by the 24 solar panels. *Source: Author.*

The proposed generator is expected to cover the previously defined consumption. Furthermore, the proposed generator uses components such as electrolyzer, MH storage tank, fuel cell, and converter from different manufacturers presented below. The manufacturers were selected taking into consideration the expected dimensions and in terms of technical characteristics corresponding to the defined design.

<u>Selection of the PEM fuel cell (PEMFC)</u> [13,14].

The selected generator can deliver 1000 W, which is necessary to cover the demand of 980 W observed in this case study.

The maximum useful power provided by the battery fuel is:

$$P_{u_{fc}} = \eta_{fc} \times P_{abs\_fc} \quad (1)$$

where $P_{u_{fc}}$ - the utile power; η_{fc} - the fuel cell efficient, P_{abs_fc} - the power absorbed, Q_{max} (L/min) – the maximum volume flow; Pc - the power consumed; Qch - the hydrogen volume flow generated; tc – the production or consumption time; Ec - the energy consumed; h2l - the quantity of hydrogen produced in litters. As presented above, the consumption profile is divided into 3 parts. For a maximum power of 1000 W, the maximum flow rate is 23.4 L/min, therefore, to produce 335.33 W required to supply the household between 6 a.m. and 6 p.m., the flow rate should be reduced for a proper management of the hydrogen stock in the generator. The power production is needed to be adjusted according to the power demand as given in Tables 4, 5 and 6 in the corresponding consumption periods using the following formula.

(2)
$$Q_i = P_i \times \frac{Q_{max}}{1000}$$

Table 4. The fuel cell behaviour between 6 a.m. and 6 p.m. *Source: Author.*

Components	**Rating values**
P_{abs_fc} (W)	2000
Q_{max} (L/min)	23.4
Production time (h)	12
Pc (W)	335.33
Qhc (L/min)	7.84
tc (h)	12
Ec (Wh)	4024
h2l (L)	5649.69

Table 5**.** The fuel cell behaviour between 6 p.m. and midnight. *Source: Author.*

Components	**Rating values**
Qhc (L/min)	16.49
Ec (Wh)	4229
Pc (W)	704.83
h2l (L)	5937.52
tc (h)	6
h2l	12.56

Table 6. The fuel cell behaviour between midnight and 6 a.m. *Source: Author.*

Components	**Rating values**
Qhc (L/min)	10.13
Ec (Wh)	2598
Pc (W)	433
tc (h)	6
h2l (L)	3647.59

Data given in Tables 4-6 allows estimating the quantity of hydrogen to be stored. Table 4 shows that for the estimated consumption between 6 a.m. and 6 p.m., i.e., 4024 kWh, the fuel cell consumes 5650 L of hydrogen. For other periods, i.e., from 6 p.m. until midnight and from midnight until 6 a.m., the consumptions are of 5937 L and 3647 L, respectively. In total, as much as 15235 L of hydrogen is needed.

Selection of the PEM electrolyser [15].
The hydrogen production in the electrolyser is done mainly due to the photovoltaic energy, which is only available during day. Therefore, a key to cover the energy demand during the night is a choice of the proper electrolyser (Table 7) able to ensure the adequate hydrogen flow rate also to obtain the desired quantity of hydrogen to be stored. The average sunshine time is estimated at 8 hours as given by PVgist.

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Table 7. The electrolyser production performance for 8 hours. *Source: Author.*

Components	Rating values
Q_{elh}	1.57
η_{el}	75
Nominal power (kW)	5
tc (h)	8
h2f (Nm^3)	12.56
m_{h2}	1.11
h2s (L)	15737.196

The estimated quantity of hydrogen stored in 8 hours can be calculated using the following equations:

(3) $$V_{h2} = Q_{elh} \times t$$

where V_{h2}(Nm^3) is the volume of hydrogen produced during 8h, Q_{elh}(Nm^3/h) is the maximum flow rate of hydrogen in the electrolyser, and tc represents the total production time in hours.

(4) $$m_{h2} = 0.044 \times M_h \times V_{h2}$$

where m_{h2} is the total mass of hydrogen produced in kg.

Therefore, the total volume of hydrogen produced in litters can be calculated using the following formula:

(5) $$V_h = 14128 \times m_{h2}$$

where 14128 represents the volume of 1 kg of hydrogen expressed in litters.

The volume of hydrogen produced by the selected electrolyzed corresponds to 15737.2 litters, which is superior to expected consumption of the PEM fuel cell, which is 15235 litters as given in Table 7. It is fundamental to note that the selected fuel cell provides an output voltage between 24 – 40 Vdc and will provide a maximum current of 80 A.

Thus, this voltage range is suitable for a 24 Vdc-220 Vac/2000 VA [16] inverter intended for the supply of undulating current. In addition, a buck-booster [17] is integrated into the generator to raise the voltage of the photovoltaic field to 125 Vdc nominal voltage of the electrolyser.

Selection of MH tank

Evaluation of storage characteristics in a MH tank according to the electrolyser productivity is given in Table 8.

Table 8. Electrolyser productivity. *Source: Author.*

Components	Rating values
h2f (L)	15737.196
h2f (Nm^3)	13.29
h2f (m^3)	5

Several types of MH tanks for hydrogen storage are available in the industry. Hence, exist a vast number of the research studies on MH tanks [18–23]. For the purpose of this work, a model given in Figure 2 was selected according to its storage capacity, its weight, the size, and the thermal energy dissipated. To address the demand for the hydrogen storage capacity, i.e., 1.11 kg, as many as 24 MH tanks are need.

Figure 2. MH tube [22].

Table 9. Fundamental characteristics of the MH tank given in Figure 2. *Source: Author.*

Components	**Rating values**
Diameter (m)	0.0508
Storage capacity (g)	50
Height (m)	0.64
weight (kg)	4.4
Number	24
Clutter (m)	0.6096 × 0.116 × 0.64
Weight (kg)	101.2

Selection of an adsorber

In the design of the generator intended to provide electricity, heating, air conditioning, and sanitary hot water, besides the heat loss management system, one of the most important elements is the absorber. The adsorber must be sized to provide the air conditioning and heating power required for a standard household adapted in this study. According to Fernandez et al. [24] it can be estimate that an average annual consumption of 125.54 kWh/m², 22.24 kWh/m², and 13.025 kWh/m² for heating, air conditioning, and the sanitary hot water, respectively is needed. In the case of the tropical regions of Africa, the consumption related to air conditioning is at 200 kWh/m² [25]. Therefore, in this study, an adsorber capable of producing 12500 kWh/year, 2200 kWh/year, and 1300 kWh/year for heating, air conditioning, and the sanitary hot water, respectively should be considered. This data is given in Table 10.

Table 10. Heating Ventilation and Air Conditioning (HVAC) consumption. *Source: Author.*

Heating	**Air conditioning**	**Sanitary hot water**
12500 kWh/year	2200 kWh/year	1300 kWh/year
32.24 kWh/day	6.027 kWh/day	3.56 kWh/day

The adsorber selected in this system is based on the models presented in the literature [26–31]. Table 11 presents the characteristics of the main component of the adsorber.

Where m is the mass of the adsorbent or the refrigerant, respectively in the adsorption/desorption chambers and the condenser and the evaporator (kg), Cp is the heat capacity (J/(kg·K)), U heat transfer coefficient (W/(m²·K)), A is exchange area (m²), q is the amount of water vapour uptake (kg/kg), t is the fluid circulation time (s).

Through the numerical simulation and the dimensions of the internal components of the adsorber defined in Table 11, the total dimension of the absorber can be estimated using the following equation:

$$A_{ad} = 2 \times (\sum_{i=1}^{4} A_i) \quad (6)$$

where A_i is the surfaces of the adsorption/desorption chambers, condenser, and evaporator.

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Table 11. Characteristic of the adsorber. *Source: Author.*

Units	Adsorber	Desorber	Evaporator	Condenser
m (kg)	50	50	20	25
Q (l/min)	0.35	0.35		
Cp (J/(kg·K)	20	20	15	20
UA (w/k)	85.45	90.47	257.05	475.73
Cp.m (J/K)	347.37	231.58	744.91	935.16
t cycle(s)	120	120	120	120
U (W/(m²·K))	1700	1800	2557	4115
A (m²)	0.050	0.050	0.1005	0.1156
Cp (Cu)	386	386	386	386
Cp (H_2O)	4185	4185	4185	4185

Selection of the heat exchanger management system

As mentioned above, one of the characteristics of the proposed generator is its heat recovery system. The electrolyser, the fuel cell, and the MH hydrogen storage tanks emit a considerable amount of heat, which is generally lost. In the proposed energy generator, two flat tubes heat exchangers are designed to recover the heat losses. In addition, the MH tank is contained in a heat exchanger similar to a Shell- and tube exchanger (Figure 3).

Table 12**.** Exchanger characteristics. *Source: Author.*

Air to water exchanger	Exchanger in electrolyser	Exchanger in fuel cell	Exchanger MH
Q min (kg/s)	0.0017	0.0017	
Q max (kg/s)	0.0588	0.0588	
Dc (mm)	15	15	508.8
L (m)	1.42	2.48	0.64
Material	Coil	Coil	Coil
Dimensions (mm)	230x110x50	260x150x50	370x240x660
Tube number	6	8	23
Fins number	20	24	
Thickness (mm)	3	3	5

Using data given in Table 12, the various flow rates and the approximate stored quantities of water can be calculated using the following equations:

(7)
$$S_{inx}.v_{inx} = S_{ox}.v_{ox}$$

(8)
$$t_D = \frac{V}{v.S}$$

where S_{inx} (m²) is the section of the vein of the entering fluid, v_{inx} (m/s) is the flow velocity of the entering fluid respectively, S_{ox} is the section of the outgoing fluid pipe, v_{ox} is the outgoing fluid velocity, $t_D(s)$ is a duration of the water course in the MH exchanger and *Dc* is the intern diameter. Therefore, after defining all the devices necessary for the generator, they are installed in the most suitable ergonomics according to the dimensions obtained in the design study as shown in Figure 4. A medium-sized generator obtained is of 1800 × 1000 × 500 mm size.

Such proposed energy generator allowed obtaining different profiles of variation of the energy flows. To validate its adequacy the modelling of the system in the real environment was modelled. As such Figure 5 presents the solar irradiation over 24 hours. During the experiment, the simulation of the entire system lasted 50 min in real time for implementation of 5 s on MATLAB Simulink.

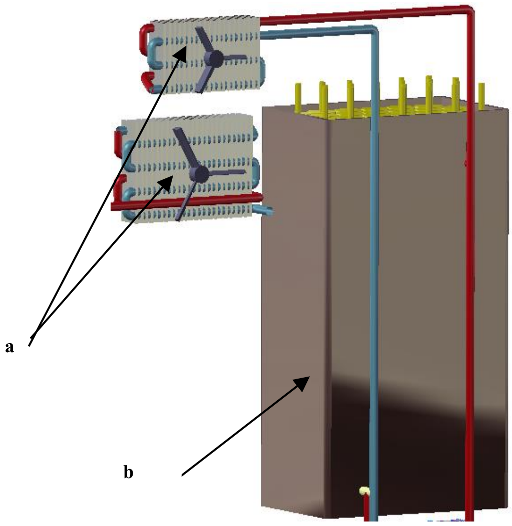

Figure 3. Heat exchanger system: (a) two flat tubes heat exchangers; (b) Shell- and tube exchanger. *Source: Author.*

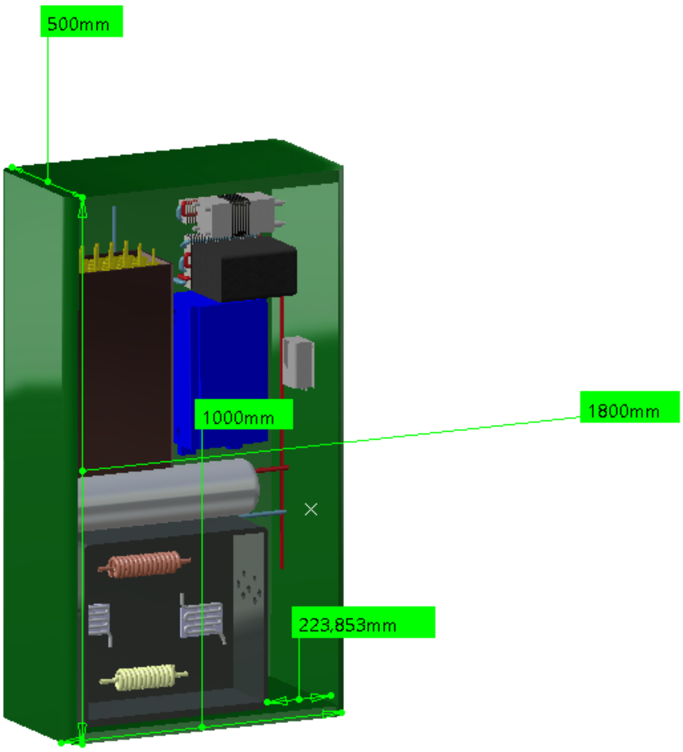

Figure 4. Internal view of the energy generator by hydrogen storage. *Source: Author.*

Thus, it was note that the solar irradiation increases between 1 s-2.5 s, i.e., between 6 a.m. and 1 p.m., then decreases between 1 p.m. and 7 p.m. The results presented below are basis of this solar radiation profile.

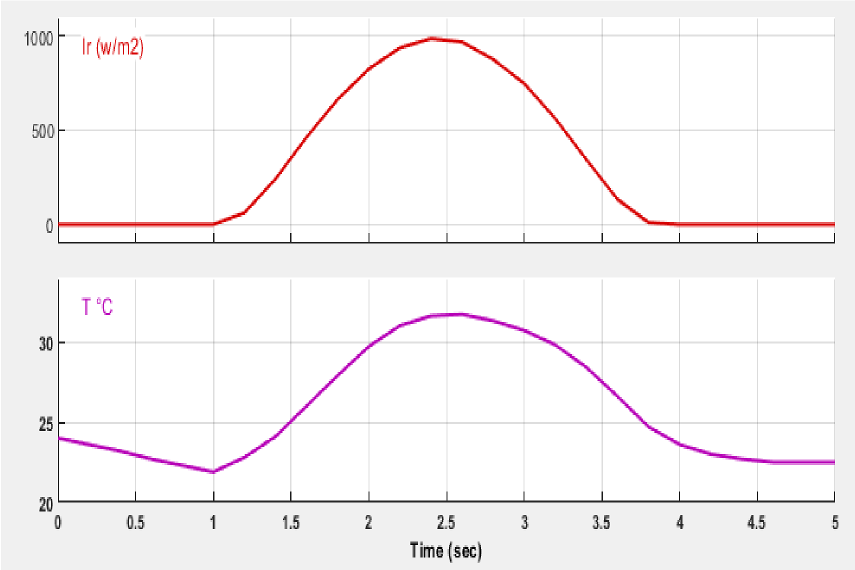

Figure 5. Solar irradiation in Morocco between 1 a.m. and 12 a.m. *Source: Author.*

Figure 6 presents the characteristics of the variations of the thermal flows according to the time of operation of the electrolyser.

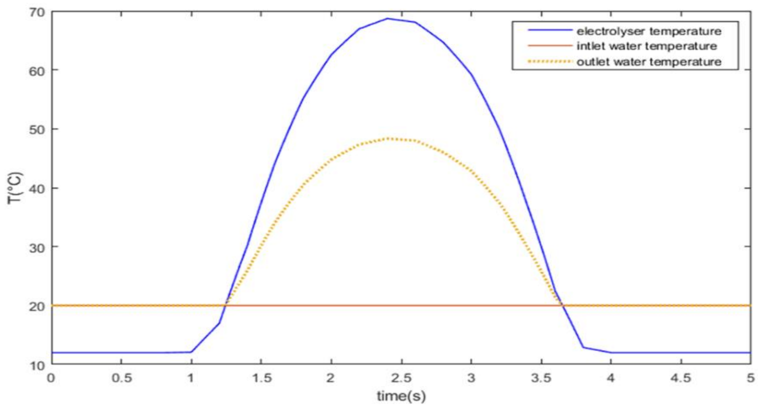

Figure 6. Electrolyser-exchanger heat flux curve. *Source: Author.*

The photovoltaic field produces useful energy in the time interval of 1.25-3.25 s, i.e., between 9 a.m. and 5 p.m., which corresponds to approximately 8 h. It can be noticed that during this time, the temperature in the electrolyser increased and reached 68°C. Thus, the cold water that enters the exchanger at a temperature of 22 °C can be heated up to 49 °C. During the heating period, which lasts about 6 hours, from 9 a.m. to 3:30 p.m. the quantity of hot water stored is approximately 38 litters. Figure 7 shows the heat flow characteristics in MH tanks responsible for hydrogen storage. As it can be observed, the variation of heat in the heat exchanger occurs and a temperature in the MH increases rapidly until it reaches maximum during the exothermic period, i.e., 130°C. During this time, the cold water, which enters at 25°C can increase its temperature from 80°C to 100°C. This increase in heat is observed between 9 a.m. to 3:30 p.m.

Following results given in Figure 7, the evolution of the temperature in the fuel cell during its operation can also be noticed as given in Figure 8. The heat generated by the PEM cell reaches 80°C and it allows heating up the cold water, which enters the exchanger at a temperature of 25°C, to temperature of 68°C. In this experiment, the adsorber is fed by hot water coming from the storage tank coming from the heat exchanger of the electrolyser, the MH tank, and the fuel cell combustion. The energy of hot water stored in the storage tank can be calculated using the following equation:

$$\varphi = m_{T1}C_{p1}(T_1 - T_f) = m_{T2}C_{p2}(T_f - T_{T2}) \quad (9)$$

where Cp is the specific heat capacity and m_{T2} is the mass.

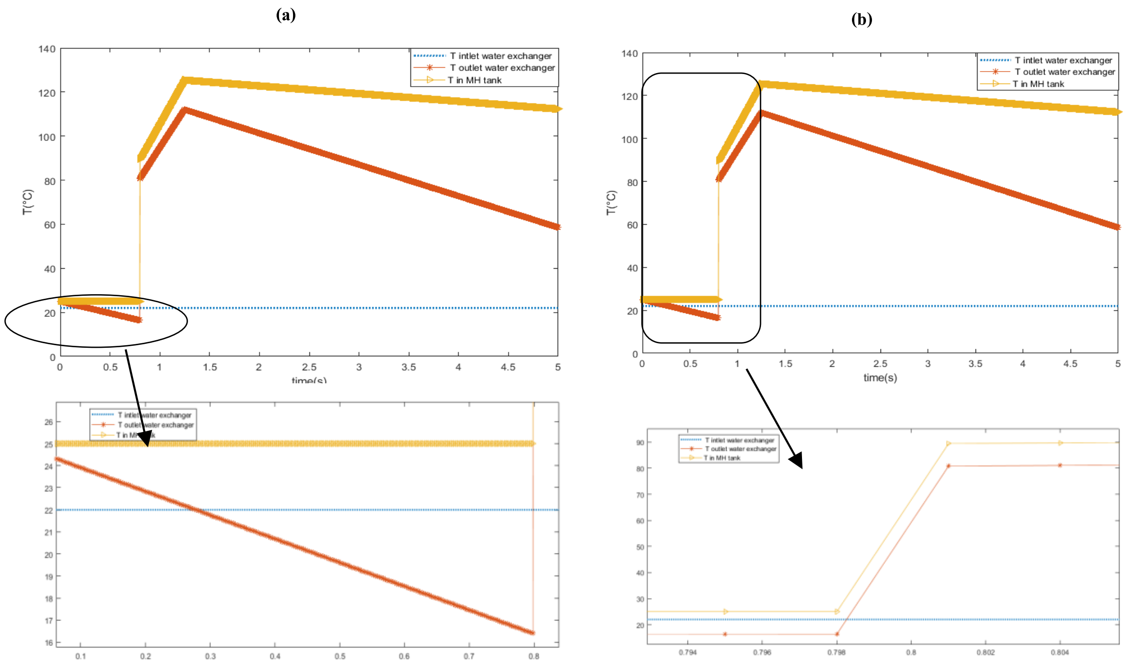

Figure 7. Characteristic of the heat exchange of the system MH-exchanger with enlarged views: a – up to 0.8 s, and b – from 0.793 to 0.805 s. *Source: Author.*

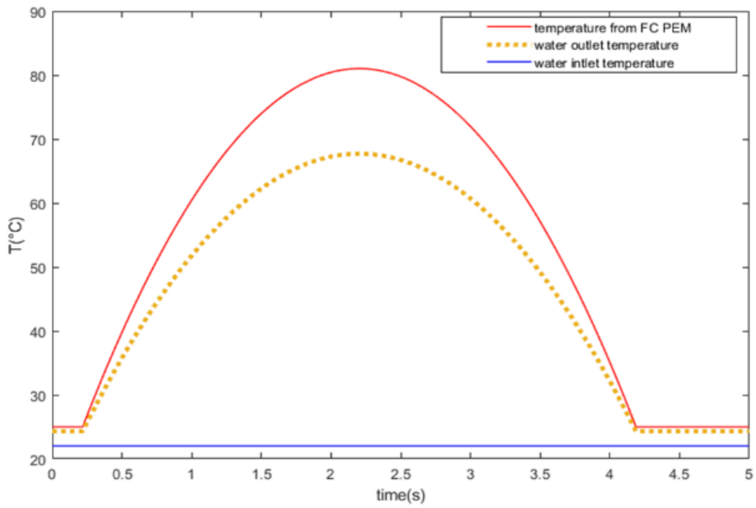

Figure 8. Heat variation in the fuel cell and its heat exchanger. *Source: Author.*

Figure 9 demonstrates the changes in the hot water temperature. The water stored in the tank reaches 85°C and the evolution of the temperature of the water stored in the tank occurs between 9 a.m. and 3 p.m. for the hot water coming from the MH and the one coming from the electrolyser. The total quantity of water stored is approximately 949 litters. The data3 curve represents the variation of data1 and data2 temperature curves mixed. The water stored in the container allows the supply of the absorber, which provides the air conditioning and heating of the building and the supply of hot water to the MH tank for the desorption of the stored hydrogen and to cover the needs for the sanitary hot water. During the period from sunshine on, the storage and the adsorber is supplied with hot water from the mixture as given in Figure 9. Figure 10 demonstrates the thermal and cooling production power where the productivity of the adsorber is fed by the hot water mixture MH-electrolyser and MH-electrolyzer- fuel cell.

Note that the desorption of hydrogen in the MH is carried out by the hot water stored in the balloon, and to accelerate the desorption this water is superheated by resistors, which raise the temperature from 80 to 120°C. The resistors integrated in the exchanger are powered by a 2v/100Ah battery allowing overheating for more than 12 hours. Table 13 demonstrates basic characteristics resulting from the sizing justifying the choice of a 2V/100Ah battery. The following equations allows obtaining the characteristics of resistant present in Table 13.

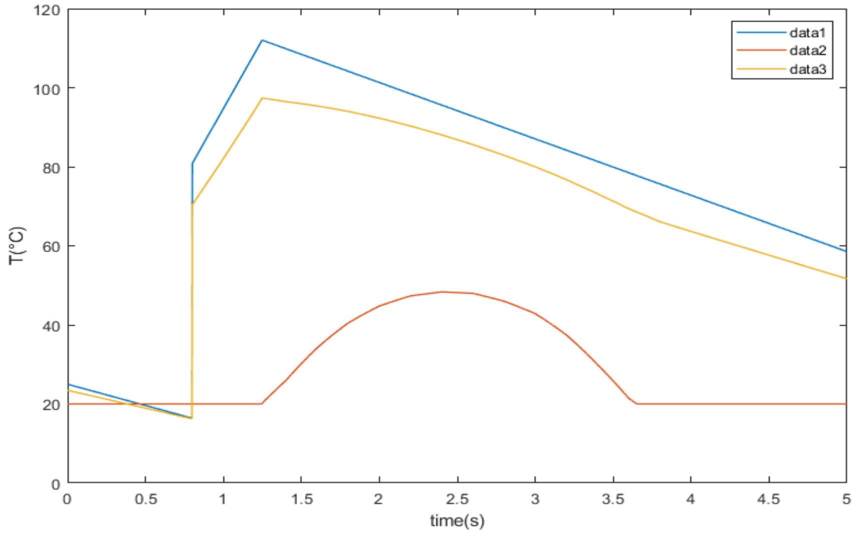

Figure 9. Hot water temperature in the storage tank (data1 and data2 represent the hot water Coming from the MH exchanger and the electrolyser exchanger, respectively. Data3 represents the variation of data1 and data2 mixed). *Source: Author.*

(10) $$R = \rho \frac{L}{S} = m_{T2} C_{p2}$$

(11) $$(T_f - T_{T2})$$

(12) $$R_{45} = R[1 + (\Delta\theta \alpha_{cu})]$$

(13) $$R_{120} = R_{80}[1 + (\Delta\theta \alpha_{cu})]$$

(14) $$U = RI$$

Where R, R_{45}, R_{120} are the resistances of the heating rods at 0 °C, 45 °C et 120 °C, ρ is the resistance of copper (Ω·m), α_{cu} (K) is the temperature coefficient, $\Delta\theta$ (K) is temperature, L (m) is the rod length, S(m²) is the rod section, U(V) is the voltage and I (A) is the current sent to the heating resistor, C is the battery capacity (Ah).

Table 13. Characteristics of the 24 heating resistors integrated into the MH heat exchanger. *Source: Author.*

Components	**Rating values**
S (m^2)	0.000020568
L (m)	0.64
ρ (Ω·m)	$1.725 \cdot 10^{-8}$
α_{cu} (K)	0.00393
R (Ω)	0.000536
R_{120} (Ω·m)	0.471
U (V)	2
I (A)	4.245
C (Ah)	76.4180

As presented in the section related to the adsorber selection, thermal and cooling consumption is on average 125.54 kWh/m², 22.24 kWh/m², and 13.025 kWh/m² for heating, air conditioning, and the sanitary hot water, respectively. The proposed absorber produces as much as 13.42 kW as cooling power and 33.29 kW as thermal power during the 50 min, which represents a day according to the performed simulation. Thus, to compare this data to this given in Table 10 it can be concluded that the proposed solution satisfies the estimated needs.

Thus, the evolution of the heating and cooling powers from the adsorber is shown in Figure 10.

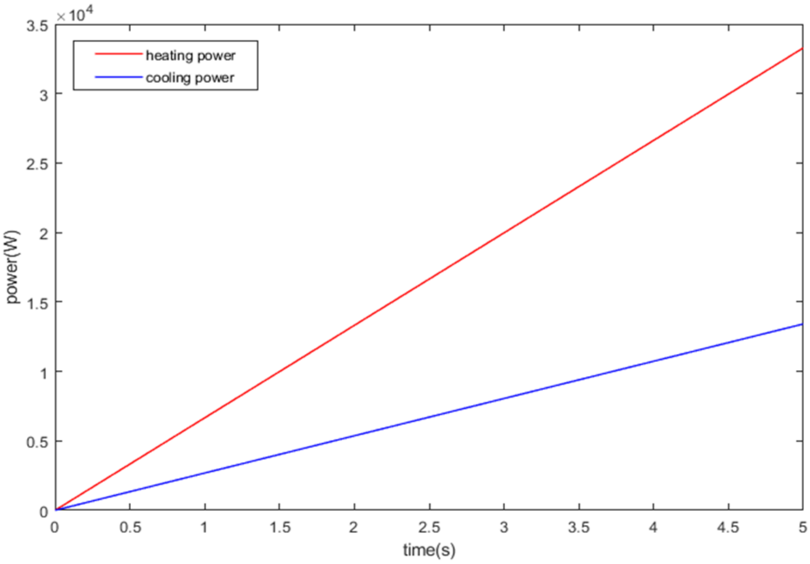

Figure 10. Characteristics of the heating and cooling capacities of the absorber. *Source: Author.*

Impact

This work contributes to the area of green hydrogen production and use. In more general term, this work helps to create solutions for more renewable energy use and contributes to the general changes against the global warming. This work depicts the role and importance of an energy storage based on technologies relied on hydrogen. Through this article, it can be seen that an energy storage based on green hydrogen will have a considerable impact especially when integrated with co- and trigeneration approaches combined with the process of production and storage of hydrogen for further electricity production. The real impact of this research is the innovative design of an all-in-one energy generator, based on the use of green hydrogen. This model shows that a generator is capable to store energy by means of green hydrogen, providing electricity, the sanitary hot water, cold and heating. Consequently, it contributes to the reduction of green hydrogen cost and in parallel impact the fight against global warning provoked by the energy production. Knowing that the electricity production sector generates approximately 40% of global pollution [32] and that the tertiary sector is among the largest energy consumers (electricity, the sanitary hot water, heating and cooling), the design and marketing of such an energy generator will contribute to the reduction of the CO_2 emissions resulting from the use of electricity in this sector. The particularity of this article is that it presents a novel technical energy efficiency solution allowing obtaining a favourable economic performance. It is possible to achieve by the green hydrogen production via electrolysis of water and the hydrogen storage in MH to be later used for electricity production by a PEM fuel cell. The process is completed by a thermal energy recovery system. This in turn, makes possible to demand for the sanitary hot water and heating. In addition, due to the use of absorber the needs for cold is ensured too. Ultimately this article demonstrates energy innovation approach by showing that even at household size an energy storage can be efficient and can play an important role for the tertiary sector.

Conclusion

This work showed the design of an energy generator as an energy storage system, the production of hydrogen by electrolysis of water via a PEM electrolyser through photovoltaic energy. The proposed energy efficiency generator allows for a maximum heat recovery from production, storage, and electricity generation obtained from green hydrogen. All the main components were dimensioned so that the size of the generator is suitable for a common use in the residential - tertiary and industrial sectors. It is mainly composed of a 5kW PEM

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electrolyser, a 2 kW PEM fuel cell, 24 MH tubes with a capacity of 50 g each, an absorber, heating resistors, a 2V/100Ah battery, an oxygen storage tank, a DC-AC converter, a boost DC-AC converter, and several heat exchangers. The overall dimension of the generator block is 1800 × 1000 × 500 mm. Through modelling, component sizing, and simulation, it was possible to confirm that the proposed solution can store up to 949 litters of hot water in the temperature range from 49 to 85°C and ensure the storage of 1.11 kg of hydrogen for the energy consumption of 6.9 kWh from 6 p.m. to 6 a.m. In addition, the absorber integrated into the generator makes it possible to produce 33.29 kW of heating power with 13.42 kW of cooling power per day. This study allowed to demonstrate that the PEM electrolyser - PEM fuel cell - MH tank combination provides significant thermal power that can be used to cover heating, the sanitary hot water, and air conditioning needs. Thermal and cooling consumption is of 125.54 kWh/m², 22.24 kWh/m², and 13.025 kWh/m² for heating, air conditioning, and the sanitary hot water, respectively. It can be also noted that absorber produces 13.42 kW as cooling power and 33.29 kW as thermal power during the period equivalent to full day of simulation. The results obtained in this study confirm that an energy generator coupled to the hydrogen storage can have an optimal yield due to high energy efficiency and thus make it possible to obtain a cost of integration of hydrogen for very competitive small and medium scale use.

Conflict of interest
There are no conflicts to declare.

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