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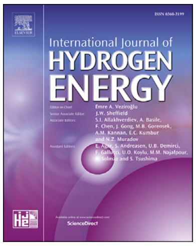

A wind energy conversion system for hydrogen production by water electrolysis in the region of Hassi R'mel (Algeria)

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ABSTRACT

The present paper describes a model of wind energy conversion system (WECS) for hydrogen production by water electrolysis in the region of Hassi R'mel (South of Algeria), developed under Simulink environment, The amounts of hydrogen produced using a WECS were considered as a case study for the three different sites of Hassi R'mel, Telghemt, and Delaa located in the region of Hassi R'mel. The results showed that Telghemt and Hassi Delaa sites have significant wind potential with average wind speeds exceeding 9 m/s at 25 m height. The dominant hydrogen production is occurred for the site of Telghemt, approximately 49286 Nm^3 during favorable month (April).

Introduction

Algeria is blessed with an important renewable energy potential, more particularly solar and wind [1]. This offers the opportunity not only to increase, but also to diversify its energy resources. It also opens for it undeniable perspectives to develop its remote regions, and to meet its domestic energy needs that are becoming increasingly important.

One of the most important renewable sources is wind energy. As reported by Chellali et al. [2] Algeria is generally quite windy. At 10 m above ground level, 78% of the country area is characterized by wind speeds exceeding 3 m/s, with about 40% of these speeds above 5 m/s. Chellali et al. [3] proposed a method of wind potential assessment using descriptive statistics and time–frequency analysis. They found that the windiest regions are located in the southern part of the country with annual mean speed varying between 5 and 6 m/s at 10 m above ground level. This important wind potential is considerable and is more than sufficient for providing energy to these isolated area where the extension of the national grid is prohibitively expensive. However, because of the intermittent nature of wind energy and mismatch between offer and demand, there is then the need for its storage. Hydrogen, as a storage medium has been widely

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considered. In this case, wind provides the energy needed and the excess of wind energy is used to generate hydrogen. The generated hydrogen is then stored to be converted into electricity using a fuel cell in the case where wind energy is not sufficient to provide the required energy needs.

Several methods have been developed for hydrogen production from renewable energy sources [4]. The coupling of a wind generator and an electrolyzer is one of the most promising options for obtaining hydrogen from a clean renewable energy source; it consists of supplying the excess electrical power produced by wind generator to an electrolyzer to produce hydrogen.

Literature review shows that the technique of hydrogen production by water electrolysis using wind energy has already been considered. Sopian [5], presented the performance of an integrated PV–wind-hydrogen energy production system. This system has been capable of producing 130–140 ml/min of hydrogen, for an average global solar radiation and wind speed at 10 m above ground level ranging between 200 and 800 W/m^2 and 2.0–5.0 m/s, respectively. Khan et al. [6], presented a detailed modeling, simulation, and analysis of an isolated wind-hydrogen hybrid energy system. Dynamic nonlinear models of all the major subsystems are developed based on sets of empirical and physical relationships. As results, economics of stand-alone energy systems, with hydrogen storage and generation is not favorable for mass deployment. However, research and advancements in this field are quite dynamic and cost-competitiveness of wind-hydrogen systems may improve in future. Bechrakis [7], 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 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. Korpa et al. [8], have shown different possibilities of combining wind and hydrogen in low production networks. They examined the benefits, hydrogen storage limits and its various applications, and presented a logistic simulation model for evaluating the performance of wind-hydrogen plants. The results illustrate the benefits of storing hydrogen and its use for electricity production in periods when the wind speed is low. Battista et al. [9], proposed a control for wind-electrolysis system which match the wind power output to the electrolyzer power requirements, thus gaining in system performance. Mantz and Battista [10] investigated the production of hydrogen via excess energy from wind turbines. They analyzed the system configuration and developed a control strategy for the system. Ulleberg et al. [11] studied hydrogen production efficiency in an autonomous wind-hydrogen system which located at Utsira, Norway. This system provided all of the energy demand of 10 houses on the island. It is found that it is possible to supply remote area communities with wind power using hydrogen as the energy storage medium. However, further technical improvements and cost reductions need to be made before wind/hydrogen systems can compete with wind/diesel hybrid power systems. Olatejuet al [12] made an assessment of hydrogen production from wind energy in Western Canada by considering 1.8 MW wind turbine and electrolyzers that have different nominal powers (240 KW, 360 KW) proved to be the optimal sizes for constant and variable flow rate electrolysers. The minimum hydrogen delivery cost has been found to be \$4.96/kg H_2. The life cycle of CO_2 emissions is 6.35 kg CO_2/kg H_2. Rodriguez et al. [13] investigated hydrogen production potential from wind energy and the use of the produced hydrogen as a fuel in the transport sector. They concluded that produced electricity met the annual energy demand of the transport sector. Gamze Genc et al. [14] considered the case of hydrogen production in Pınarbası Kayseri using a wind/electrolysis system. They estimated the potential and cost of hydrogen production for different hub heights, i.e., 50 m, 80 m and 100 m. Electrolyzers with different rated power, namely 40 kW and 120 kW, were considered in this study. The maximum hydrogen production potential found was 14192 kgH_2/year; while the minimum hydrogen cost of 8.5 \$/kgH_2 was obtained for a wind energy conversion system with 100 m hub height. Nouni et al. [15], presented a techno-economic evaluation of small wind electric generator (SWEG) project for providing decentralized power supply in remote locations in India. The capital costs of this project and sub-systems have been analyzed, the levelised unit cost of electricity has been estimated for 19 select sites located in different geographical regions of the country. Genc et al. [16] have proposed a review for the investigation of hydrogen production from wind energy and hydrogen production costs in Turkey. The costs and production quantities of hydrogen using a wind energy conversion system for 50 m, 80 m and 100 m hub heights were considered for five different locations in Turkey. The results show that hydrogen production using a wind–electrolyzer energy system is considerable as the sites of Pinarbasi and Sinop have remarkable wind potential. Gökçek et al. [17] established a preliminary study on wind energy cost in Central Anatolian-Turkey, the economic evaluation of wind energy conversion systems ranging from 2.5 to 150 kW power sizes using the levelised cost of electricity method and wind energy production using time-series approach for the seven different locations, in Central Turkey were made. It has been found that the levelised cost of electricity varies between 0.29 and 30.0 \$/kWh in all cases. Khalilnejad [18], dealt with the design and modeling of hybrid wind–photovoltaic system for hydrogen production through water electrolysis. This system is analyzed in three different conditions of using just wind turbine (WT), photovoltaic (PV) array, and combination of them as power source, it is found that the Wind turbine is more effective in term of production. Recently Al-Sharafi et al. [19], investigated the potentials of power generation and hydrogen production via solar and wind energy resources at different locations in the Kingdom of Saudi Arabia. At each location, different renewable off-grid power generation systems are considered to cover a load demand of a typical house. Simulations and optimizations studies are carried out to identify the cost effective of different configurations those lead to the minimum levelised cost of energy produced.

In Algeria, the potentialities of hydrogen production, particularly sustainable hydrogen from renewable energy,

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were estimated by Boudries et al. [20–22]. In these studies, the overall energy situation in Algeria has been reviewed and the perspective of using hydrogen in the national energy mix discussed. The results of these studies indicated that the shift to hydrogen economy shows a promising prospect. L. Aîche-Hamane et al. [23], presented the feasibility study of hydrogen production from wind power in the region of Ghardaia. This study is based on the estimation of the hydrogen rate produced by a 5 kW electrolyzer fed by the electricity provided by a 10 kW wind turbine. The results show that it is possible to improve the system output by increasing the height of the wind turbine tower. Indeed, it has been obtained 3200 Nm^3 of hydrogen production for a 30 m wind turbine height and 4200 Nm^3 at 60 m. The production has reached a maximum of 395 Nm^3 in May and a minimum of 187 Nm^3 during November and October. Recently, Meziane et al. [24], developed a dynamic model of Wind-Electrolyzer-fuel cell hybrid system using Simulink to meet the energy needs of an isolated site in the south of Algeria. The optimization task has been carried using HOMER software. The optimal system is composed of a wind turbine ENERCON E33 with rated power of 330 KW, an electrolyzer of 6 kW, and a Fuel cell with 8 kW rated power. The electricity delivery cost has been found to be 2.456 $/KWh.

In the present study, we consider the case of providing electricity to the isolated zone of Hassi R'mel. As wind is the most important renewable energy source in the area, electricity is generated using a wind energy conversion system (WECSs) and hydrogen as the storage medium. First the energy potential in the region is estimated. Then a model of WECS-electrolyzer system has been developed under Simulink environment. The main components in the developed system are a wind turbine to produce electricity from wind energy, an electrolyzer unit to produce hydrogen from the produced electricity by electrolysis technique, and a tank for hydrogen storage as shown in Fig. 1.

Characterization of Hassi R'mel region

Geographical situation

The region of Hassi R'mel, as shown in Fig. 2, is located in the northern Sahara of Algeria. With an area of 40 × 60 km^2, it is bounded by a longitude ranging from 3.1° to 3.6° East and latitude varying between 32.9° and 33.5° north. This region is characterized by a hilly topography, and the average altitude is about 750 m above sea level. In Arabic terminology, the name Hassi-R'mel means the source of sand. The nomads of the region have given this name to this region because it is characterized by heavy sand storms. Located between the region of the continental climates and the Saharan climate region, it is considered to have a desert climate. This climate is characterized by low rainfall 140 mm/year, and an average humidity of 19% in summer and 34% in winter. The region is poorly developed and the majority of the dwellings in the region are considered as isolated sites. Indeed, scattered over a large area, the dwellings suffer from very poor communication means and very limited connection to the national electricity grid. The region of Hassi-R'mel has though a significant solar and more particularly wind potential. With average wind speed around 6 m/s, the region is well suited for the installation of wind energy conversion systems. This situation could help meet the energy needs of the region and develop it. The wind potential in this region has though been underestimated due the fact that it is located between two less windy regions, namely the region of Ghardaia and the region of Laghouat [2]. All this has lead us to think to provide autonomous energy production to meet its energy needs.

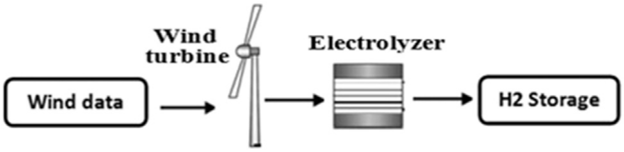

Fig. 1 – Schematic diagram.

Wind potential

To evaluate the wind potential at Hassi R'mel (longitude:3.3°N; Latitude:33.18°E; Altitude:718 m), the monthly average wind speeds data measured at 10 m above the ground, from February 2004 to December 2009 are provided by Algeria's Office of Meteorology.

To better understand the wind distribution, as well as to identify favorable site for hydrogen production by electrolysis using wind energy, three measurement stations have been installed in three different sites of Hassi R'mel. As shown in Fig. 2, these sites are Hassi R'mel, Telghemt and Hassi Delaa. The geographical coordinates of the three considered measurement sites are reported in Table 1.

Wind analysis model

The Weibull function is used to characterize the frequency distribution of wind speeds over time [23]. It is defined by the following equation:

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} exp\left[-\left(\frac{v}{c}\right)^{k}\right] \tag{1}$$

where f (v), is the probability of observing wind speed v, k is the dimensionless Weibull shape parameter, and C is the Weibull scale parameter (m/s).

The average wind speed can be calculated on the basis of the Weibull parameters as given below [23]:

$$\overline{v} = c \times \Gamma\left(1 + \frac{1}{k}\right) \tag{2}$$

where Γ is the Gamma function defined by the relation:

$$\Gamma(x) = \int_0^{\infty} \exp(-t)\, t^{x-1} dt \tag{3}$$

With $x > 0$.

The power density of the wind that flows at speed v through a blade sweep area S (m^2) as the cubic of its velocity and is given by Ref. [23]:

$$P(v) = \frac{1}{2} \times \rho \times \overline{v}^3 \tag{4}$$

ρ: is the air density (kg/m^3).

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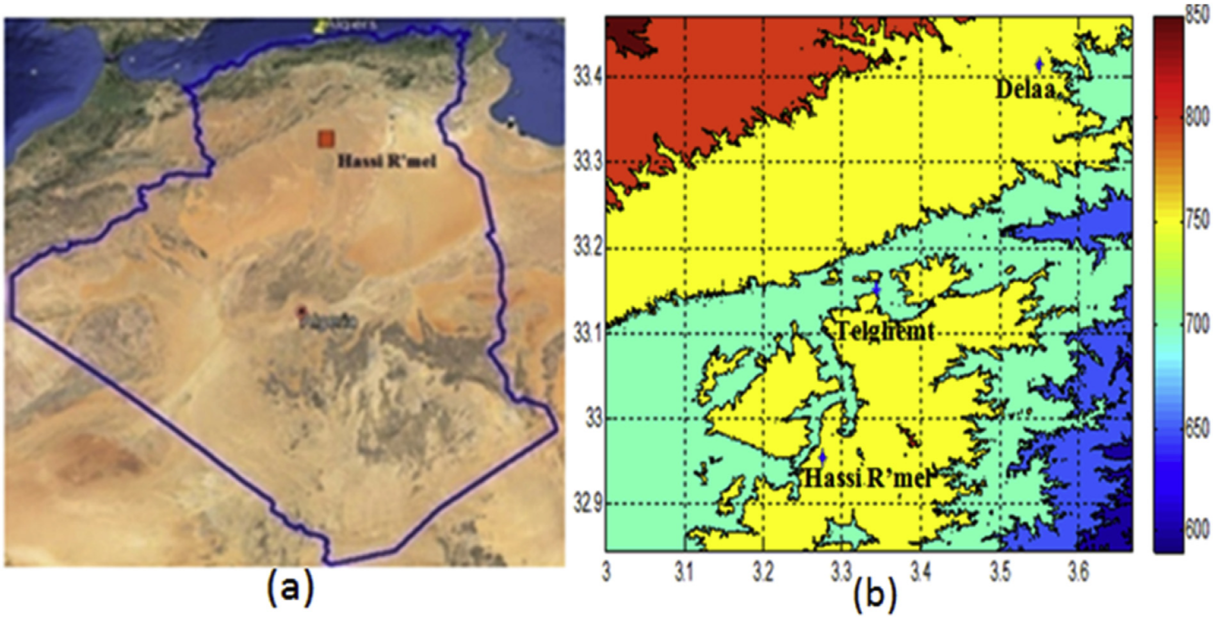

Fig. 2 – a) Map of Algeria (studied region in the red square); b) sites of interest in Hassi R'mel. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The power density as a function of the Weibull parameters can be calculated as follows:

$$P(v) = \frac{1}{2}\times\rho\times c^{3}\times\Gamma\left(1+\frac{3}{k}\right) \qquad (5)$$

System description

The standalone wind energy conversion system (WECS) considered here, is a wind-hydrogen based system developed under MATLAB Simulink environment. Such system is used to estimate the amount of hydrogen that can be produced by water electrolysis using the electricity generated by the wind turbine at the three different sites of the region of Hassi R'mel. The full system bloc diagram is shown in Fig. 3.

The main components of the considered system are; a wind turbine ENERCON E33, an alkaline electrolyzer, and a tank for hydrogen storage. Description of these components is given in the following sections.

Wind turbine

Considering the socio-geographical features, the wind potential of the region of Hassi R'mel, and looking for machines with good performance, The ENERCON E33 wind turbine from different manufacturers has been chosen. The different characteristics of this wind turbine are summarized in Table 3.

Table 1 – Sites geographical coordinates.

Site	Hassi R'mel	Telghemt	Hassi Delaa
Latitude	32.93° N	33.12° N	33.42° N
Longitude	03.26° E	03.33° E	03.54° E
Altitude	682 m	758	757

The ENERCON E 33 wind turbine is characterized by a “cut-in wind speed” of 2.5 m/s that is inferior to the mean wind speed observed in Hassi R'mel (i.e.; 6 m/s). The rated speed of 12 m/s, and the corresponding rated power of 330 kW for winds attaining the speed of 12 m/s are considered as others criterions added to the raison of our choice. The power output of this machine was evaluated at different hub heights. This evaluation confirms that this wind turbine can be used to supply remote regions with more important electricity demand without conjunction with other energy resources (solar and/or diesel) in order to compensate wind energy output fluctuations. The wind power curve of the ENERCON E33 wind turbine is given in Fig. 4.

The Simulink model of this wind turbine is shown in Fig. 5.

The wind turbine block is composed of an input where the wind speeds are stored; this data will be injected into the block representing the characteristic curve of this wind turbine to obtain a power supplied by the wind turbine. This power is transmitted to the transfer function block for its regulation, and finally the final output power produced by the wind turbine is obtained.

Table 2 – Characteristics of ENERCON E 33 wind turbine.

ENERCON E 33	
Rated power	330 kW
Rated speed	12 m/s
Cut-in wind speed	2.5 m/s
Cut-off wind speed	28–34 m/s
Diameter	33.4 m
Hub height	34-50 m
Number of blades	3
Generator	Synchronous

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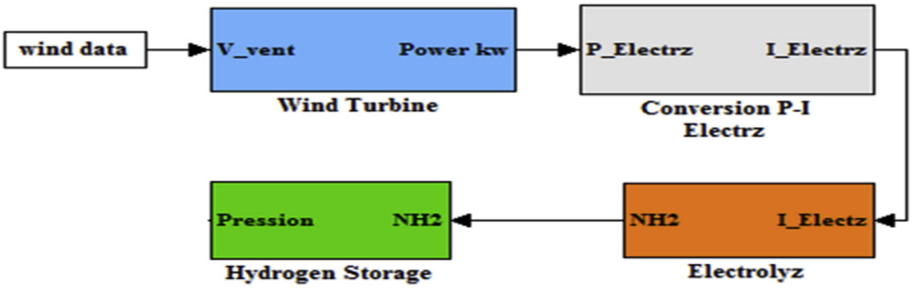

Fig. 3 – System components and flow chart.

Table 3 – Characteristics of the considered sites at 25 m.

Site	V_{mean} (m/s)	C (m/s)	K	Wind power (w/m^2)
H-R'mel	8.00	9.1	1.90	626
Telghemt	10.90	12.3	2.30	1331
Delaa	09.08	10.3	2 .27	795

Electrolyzer model

The decomposition of water into hydrogen and oxygen can be achieved by passing an electric current between two electrodes separated by an aqueous electrolyte [25,26]. The electrochemical reaction of water electrolysis is given by:

$$H_2O\ (l) + electrical\ energy \Rightarrow H_2(g) + \frac{1}{2}O_2(g) \tag{6}$$

According to Faraday's law [25], the production rate of hydrogen in an electrolyzer cell is directly proportional to the transfer rate of electrons at the electrodes, i.e., the current flowing through the electrodes.

$$n_{H2} = \frac{\eta_F \cdot n_C \cdot i_e}{2 \cdot F} \tag{7}$$

where:

F: Faraday constant [C kmol^{-1}]
i_e: Electrolyzer current [A]
n_c: number of Electrolyzer cells in series.
η_F: Faraday efficiency.
n_{H2}: produced hydrogen moles per second [mol.s^{-1}].

Because of charge losses, the actual amount of produced hydrogen is smaller than the theoretical amount of produced hydrogen. The ratio between the actual and the theoretical maximum amount of hydrogen produced in the electrolyzer is known as Faraday efficiency. Assuming that the working temperature of the electrolyzer is 40 °C, Faraday efficiency is given by Refs. [25,26].

$$\eta_F = 96.5{*}\exp\left(\frac{0.09}{i_e} - \frac{75.5}{i_e^2}\right) \tag{8}$$

According to Eqs (7) and (8) a simple electrolyzer model is developed using Simulink, which is illustrated in Fig. 6.

This block has the electrolyzer current as input; this current is used to calculate the Faraday efficient using equation (3), the obtained result is used to calculate the hydrogen flow using equation (2).

Hydrogen storage subsystem

One of the hydrogen storage techniques is physical hydrogen storage, which involves using tanks to store either compressed hydrogen gas or liquid hydrogen. The hydrogen storage model is based on Eq. (9) and it directly calculates the tank pressure using the ratio of hydrogen flow to the tank. The produced hydrogen is stored in the tank, whose system dynamics can be expressed as follow [27]:

$$(\widehat{P_b - P_{bi}}) = y\frac{N_{H2}RT_b}{M_{H2}V_b} \tag{9}$$

M_{H2}: molar mass of hydrogen [kg kmol^{-1}]

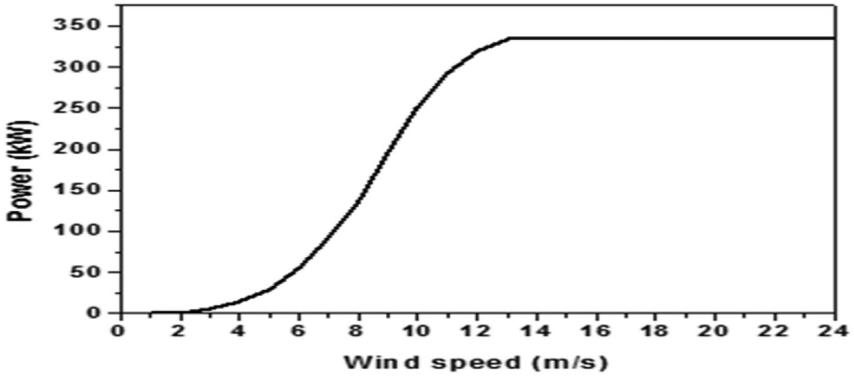

Fig. 4 – Enercon E33 wind turbine power curve.

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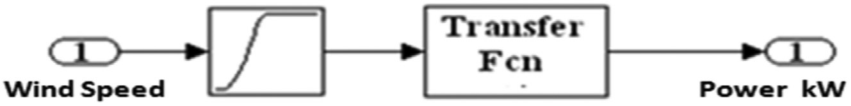

Fig. 5 – **Wind turbine Simulink model.**

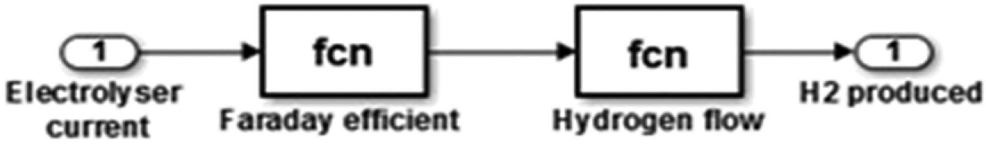

Fig. 6 – **Electrolyzer model as developed in Simulink.**

N_{H2}: hydrogen moles per second delivered to the storage tank [$kmol.s^{-1}$]
P_b: pressure of tank [Pa]
P_{bi}: initial pressure of the storage tank [Pa]
R: universal gas constant [J (kmol. °k)$^{-1}$]
T_b: operating temperature [°k]
V_b: volume of tank [m^3]
y: compressibility factor as a function of pressure.

The Simulink version of the hydrogen storage model is depicted in Fig. 7.

In this block, the main inputs data are: hydrogen flow rate, tank volume, and compression factor. It consists of calculating the reservoir pressure from the flow of hydrogen and calculates the difference of pressure compared to the initial tank pressure, giving the final tank pressure of the tank.

Results and discussions

Wind potential

The statistical analysis of the wind data measured at 10 m, provided by the National Office of Meteorology; allow the estimation of the wind potential at Hassi R'mel, as shown in Figs. 8 and 9.

From Figs. 8 and 9, we can note that the monthly mean speed for the investigated site varies between 4.5 and 8 m/s and the average power density is 156 W/m^2. The windy months are undeniable those of March ($\upsilon \approx 7.6$ m/s), April ($\upsilon \approx 8$ m/s), and May ($v \approx 7.8$ m/s). We also note that spring is the windiest season with ($\upsilon \approx 8.1$ m/s), and significant wind potential ($P \approx 300$ W/m^2) compared to others seasons.

Statistical analysis of the collected data using cup anemometers (Lacrosse technology WS2-550) installed in Algeria TELECOM pylons at 25 m above ground level (a. g.l), with 10 min of interval during the month of April is summarized in Table 2.

The analysis of the results reported in Table 3, indicates that the three regions have average wind speeds large enough for wind energy viable exploitation with wind farms installation. The site of Telghemt is the windiest. Indeed, the maximum value of wind speed at 25 m above ground level occurs at the site of Telghemt with a wind speed of 10.90 m/s, the site of Delaa ranks in the second position with a wind speed of 9.08 m/s. For the power density, a potential of 1331 W/m^2 is available at the site of Telghemt representing the maximum value, while the lowest value is found at Hassi R'mel site with 626 W/m^2.

The analysis of Weibull parameters gives the greatest shape parameter k for Telghemt and Delaa sites with respectively 2.30 and 2.27; the worst value for Hassi R'mel site with 1.90. The analysis gives also a good scale parameter C for

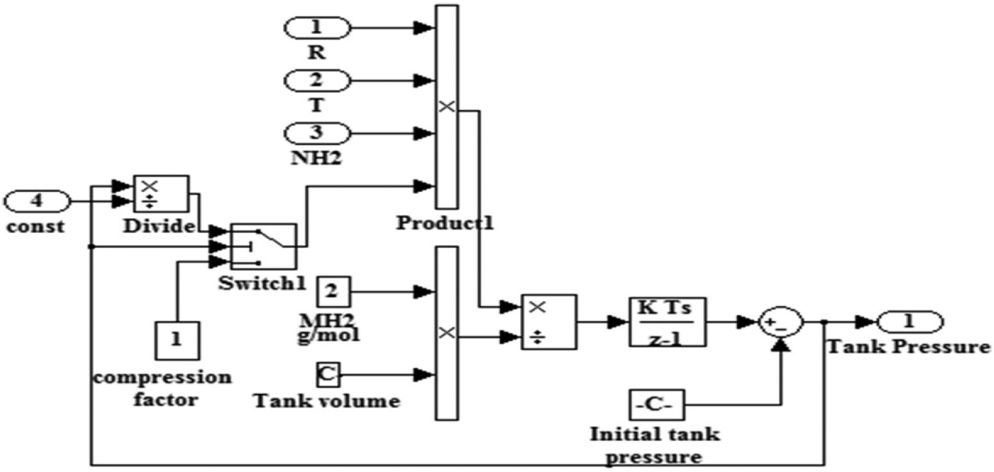

Fig. 7 – **The Simulink model of the hydrogen storage system.**

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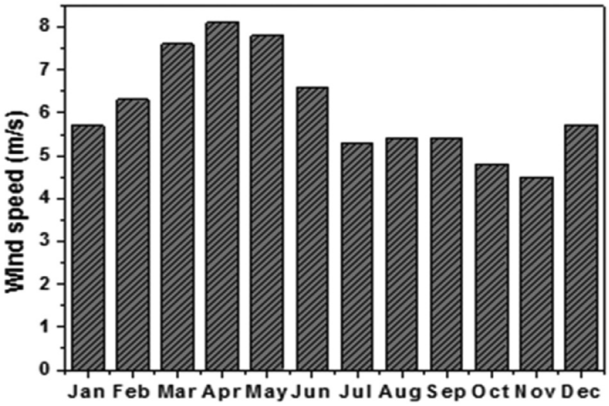

Fig. 8 – **Monthly Wind Speed at 10 m.**

the site of Telghemt with a greatest value equal to 12.3 m/s. The results indicate that the wind is more stable for the studied sites.

Hydrogen production

Hydrogen production rate in Hassi R'mel

The monthly hydrogen production at 10 m hub height presented in Fig. 10, shows an important monthly variation since the production is minimal during November and October 7000 Nm^3, 8000 Nm^3 respectively and increases to reach a maximal value of 21000 Nm^3 in April.

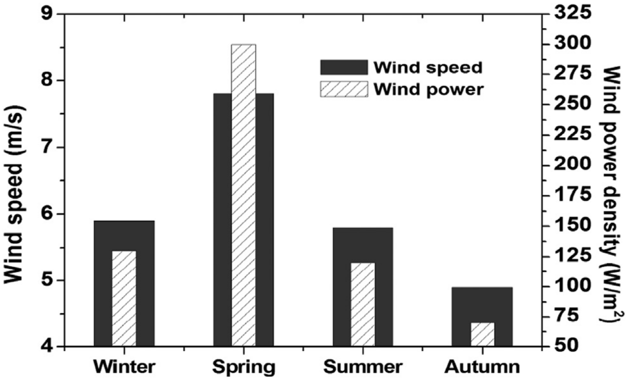

Fig. 9 – **Seasonal Wind Power at 10 m.**

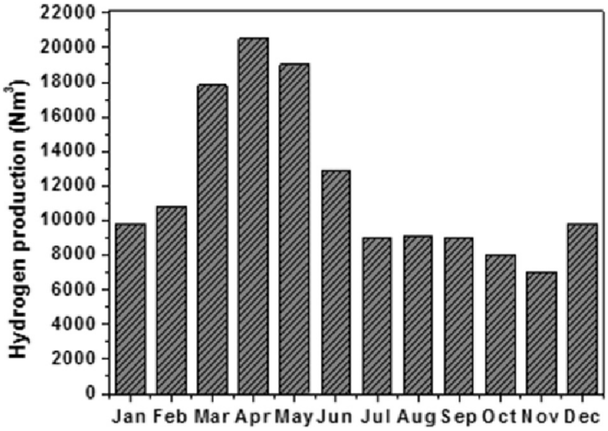

Fig. 10 – **Monthly hydrogen production at 10 m.**

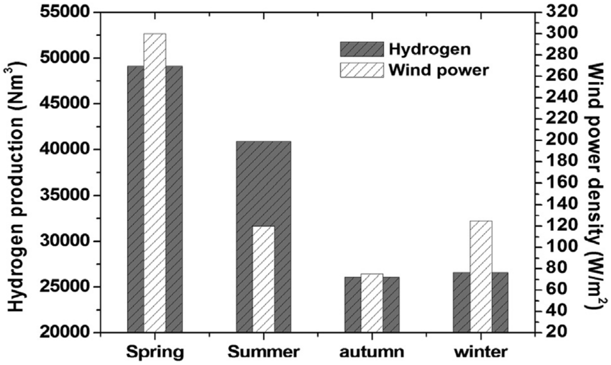

Fig. 11 – **Seasonal hydrogen production at 10 m.**

Moreover, as reported on Fig. 11, it is noticed a seasonal variation of the hydrogen production. Indeed, the production is minimal in autumn and winter approximately 27000 Nm^3. It increases gradually in summer to reach a maximum in spring 490000 Nm^3.

The annual hydrogen rate production is shown in Fig. 12 for hub heights ranging from 10 m to 100 m per step of 10 m. From this figure, it appears that the annual production of hydrogen increases when the height increases. This increase is significant between 10 m and 30 m. It goes from 140000 Nm^3 at 10 m to 158000 Nm^3 at 30 m hub height.

Fig. 13, indicates that the amount of hydrogen produced between 10 and 100 m is approximately 93000 Nm^3; the rate of hydrogen production is significant between 10 m and 30 m height about 45% of the total quantity produced between 10 and 100 m. However, this rate decreases with height until reaching a minimum of 12% between 70 and 90 m, and finally 5% between 90 m and 100 m.

The hydrogen production can be optimized by choosing the hub height. The appropriate altitude for improved hydrogen production is between 10 and 30 m at the site of Hassi R'mel, this rate is not relevant for heights exceeding 100 m.

Storage tank pressure

The hydrogen storage tank pressure variation corresponding to the amount of hydrogen delivered to the storage tank is shown in Fig. 14. For 10 m^3 tank volume with compression

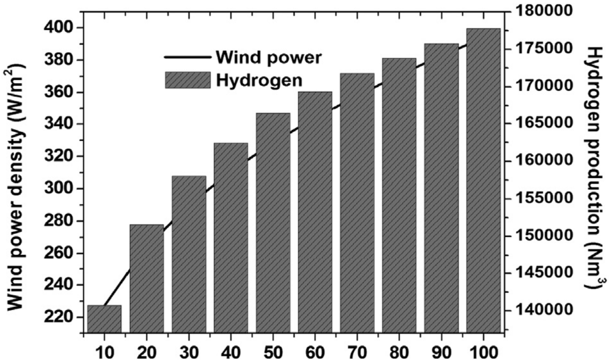

Fig. 12 – **Hydrogen rate production with Heights.**

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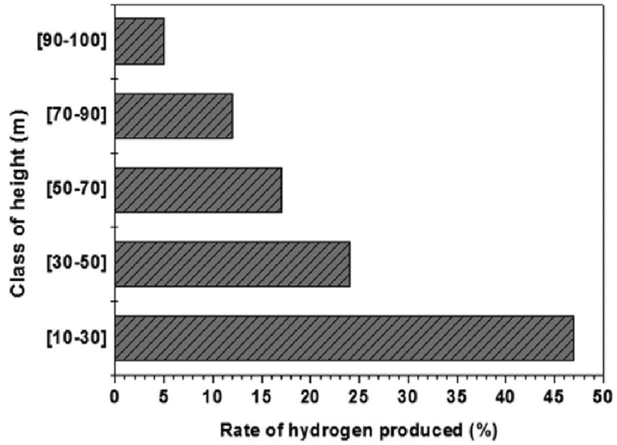

Fig. 13 – **Hydrogen rate production by class.**

Fig. 14 – **Hydrogen Tank pressure.**

ratio of 5, the hydrogen storage tank pressure increases with time (it varies from 0.75 bars for January to reaching 3 bars in December) as more and more hydrogen moles delivered to the tank.

Fig. 14 also demonstrates that the slope of the pressure is proportional to the amount of hydrogen delivered to the storage tank. In this section we were interested to the variation of the pressure in the storage tank; the case of hydrogen consumption is not taken into consideration.

Hydrogen potential

From Figs. 10 and 11, it can be found that the hydrogen production for the region of Hassi R'mel is significant; the higher value is reached during spring season, particularly, in April. Therefore, this month can be considered as a typical month to estimate the productivity of hydrogen in this region.

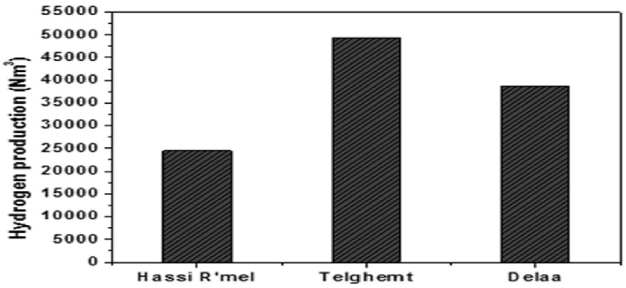

Fig. 15 – **Hydrogen production during April.**

The statistical analysis of the data collected during the month of April at 25 m above ground level, for the considered sites allows us to estimate the amount of hydrogen which can be produced in each of the studied sites as shown in Fig. 15.

As can be seen from this figure, the maximum value of the hydrogen production occurs for the site of Telghemt with 49000 Nm^3, then the site of Hassi Delaa with 38000 Nm^3. The minimum cumulative monthly hydrogen production value of 25000 Nm^3 is occurred for the site of Hassi R'mel.

These results indicate that the higher hydrogen amount production can be obtained by choosing sites with high wind speed.

Conclusion

This study relates to hydrogen production from wind energy, it is important to mention that this work was conducted as part of work for estimating the hydrogen production from wind source in the region of Hassi R'mel. However, it can be considered as preliminary results to estimate the amount of hydrogen that can be generated from wind energy in this region.

For this purpose, a model of wind energy conversion system for hydrogen production through electrolysis in the region of Hassi R'mel has been developed under Simulink environment.

In order to estimate the amount of hydrogen produced, the full electric energy produced from wind energy is converted into hydrogen by electrolysis methods.

An overview of the potentiality of hydrogen production from wind power in the region of Hassi R'mel (Algeria) has been given; an example of simulation was applied to three sites (Hassi R'mel, Telghemt, and Hassi Delaa) where the meteorological data are available. It can be noted that hydrogen production depends on the wind speed, its frequency distribution and the size of the wind turbine. The results showed that the hydrogen production using a wind energy conversion system with 330 kW rated power is reaching the range of 261362 Nm^3/year at 25 m above ground level.

In order to improve the system efficiency, it is recommended to choose a suitable system for the exploitation of the energy available and a well windy site.

To evaluate the hydrogen production from wind energy systems, it is important to make an accurate wind energy resource assessment. The predicted annual hydrogen flow rates are strongly affected by the climatic conditions of wind speed.

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