Simulation and Optimization of a Wind Energy System in the Adrar Region

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Article Info

Article history:

Received, 15 August 2021
Revised, 23 October 2021
Accepted, 05 November 2021

Keywords:

Wind
Modeling
Turbine
Converter
Permanent magnet
Generator (PMSG)

ABSTRACT

The production of Electrical energy from so-called renewable sources in general and wind energy in particular, continues to increase and becomes more and more significant. Currently, the problem is not just how much energy is produced from an unpredictable source but how much can be improved and optimized. Each wind power system contains three main subsystems which can be modeled independently: Turbine (aerodynamic power), Generator side converter (active and reactive power) and the grid side converter (injected power). Our objective in this article is to contribute to the improvement and optimization of the quality of energy produced taking into consideration the real wind speed in the Adrar region**.** With the help of Simulink, we simulate this energy system and identify it more accurately and easily by monitoring the change in wind speed and its impact on the work of the system.

I. Introduction

Electrical energy is a very important and necessary component of life. The world has witnessed a huge increase in energy consumption and fossil fuels are being used in the production of this energy, which is extracted from the ground, which are the living remains formed in the earth's crust millions of years ago [1]. And since fossil fuels are a natural and permeable source, the world is resorting to their replacement by clean and renewable sources to generate energy, for example, find us hydroelectric power, solar power, energy nuclear, geothermal energy, the energy of the sea represented in the tides and wind energy, which is our subject, which is to convert wind energy into electrical energy, which has become competitive in the world thanks to its catalytic nature. there are problems with wind power conversion systems and wind speed instability [2].
Nowadays, there are two types of generators which are used in large scale wind turbines to transform wind power into electric power, such as: Asynchronous Dual Power Generators (DFIG) and Synchronous Magnet Generators permanent (PMSG) [2, 3].

Due to its ability to operate in all wind speed ranges and not requiring excitation current, the GSAP performs well in wind farms. As a result of the rapid development of wind power technology, the efficiency of the conversion device in the wind power generation system has become another thorny issue to improve the performance of the wind power generation system [3]. The increasingly demanding requirements of technology have made permanent magnet machines more and more used more particularly in industrial applications demanding in terms of size and power and also in the production of electrical energy. The performance of these structures can be enhanced by developing study models that represent their dynamic behavior as closely as possible. The work assigned to us in this thesis is the study and modeling of a permanent magnet synchronous machine. In order to order this system, it is necessary to give its mathematical model taking into account certain simplifying assumptions in order to obtain the simplest possible model of the synchronous generator with permanent magnets in the wind energy production chain. . In this paper we will study and present the modeling of a synchronous generator with permanent magnets and then the simulation of a wind power system with the MATLAB / Simulink software.

II. The potential of renewable energies in Adrar

The Adrar region is located in the central Sahara to the southwest of Algiers. It is about 1,543 km from the capital at an altitude of 279 m. This region covers an area of 427,971 km or 19.97% of the national territory. The Wilaya of Adrar is made up of 28 municipalities grouped into 11 dairates, Adrar, Fenoughil, Aoulef, Reggane, Timimoune, Zaouiet Kounta, Tsabit, Aougrout, Charouine, Tinerkouk, and Bordj Badji-Moukhtar. From a geographical point of view, this wilaya includes three main regions which are: Gourara, Touat and Tidikelt. “Often referred to as the“street of palm trees”, the Touat corresponds to the extension of the Saoura valley. It is located on the north-eastern edge of Adrar. Its appearance is that of a valley whose eastern slope affects the edge of the Tademaït plateau [12].

Their geographical framework located between the geographical coordinates:

- Longitudes between 00 ° 30 and 00 ° 30 in the West.
- Latitudes between 26 ° 03 and 28 ° 03 in the North. [13].

Being engaged in a new phase of exploitation of renewable energies, Algeria plans to reach by 2030 nearly 40% of the national production of electricity from renewable sources. Although the choice of solar energy is predominant, wind energy represents the second line of production for this program. Before studying the possibility of establishing a wind farm in a given region, it is necessary to make studies of the wind deposit for a precise knowledge of the wind meteorology.

II.1 Solar potential

Algeria is one of the world's largest solar energy producing fields, exceeding 5 billion megawatt hours / year with more than 2,500 hours of sunshine on average per year over a very large part of its territory. This duration can exceed 3,800 hours of sunshine in the highlands and the Sahara. The energy received daily on a horizontal surface of 1 East of the order of 5KW / h over most of the national territory, this potential is broken down as follows anordi, nearly 1700kwh / / year in the north and 2263 kWh / / year in the south of the country [9].

Table.1. Solar potential in Algeria

Regions	Coastal regions	Highlands	Sahara
Area (%)	4	10	86
Average sunshine duration (hours / year)	2650	3000	3500
Average energy received (kWh / year)	1700	1900	2650

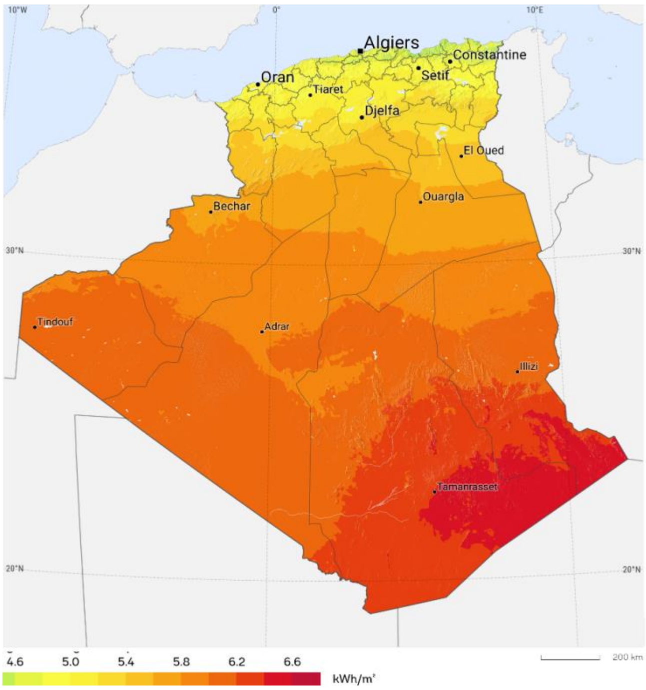


Fig 1: Solar irradiation of Algeria.

II.2 Wind Potentiel

The region of Adrar, in southern Algeria, has excellent wind potential as shown in the figure below. The average annual recoverable power density is very interesting for wind turbines. This makes it possible to supply isolated areas (Drilling, Kessour) with electrical energy, where connection to the electrical network is impossible or economically expensive.

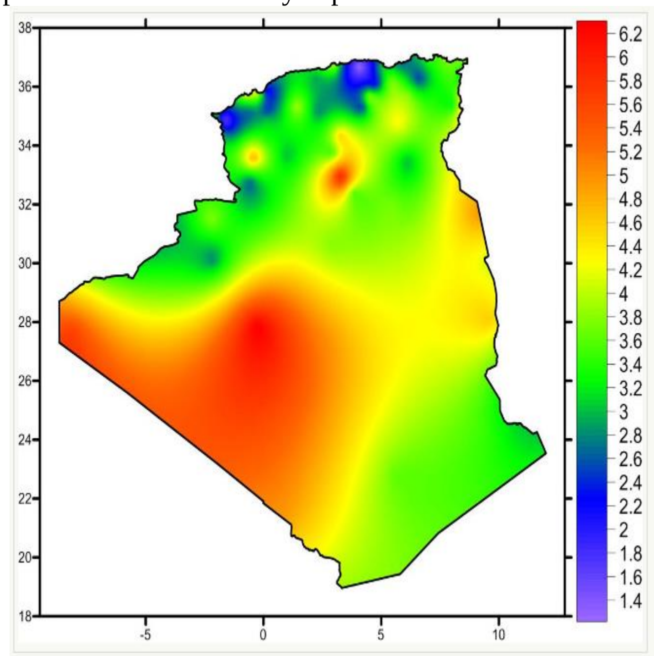


Fig 2 : Annual map of winds (m / s) at 10m.

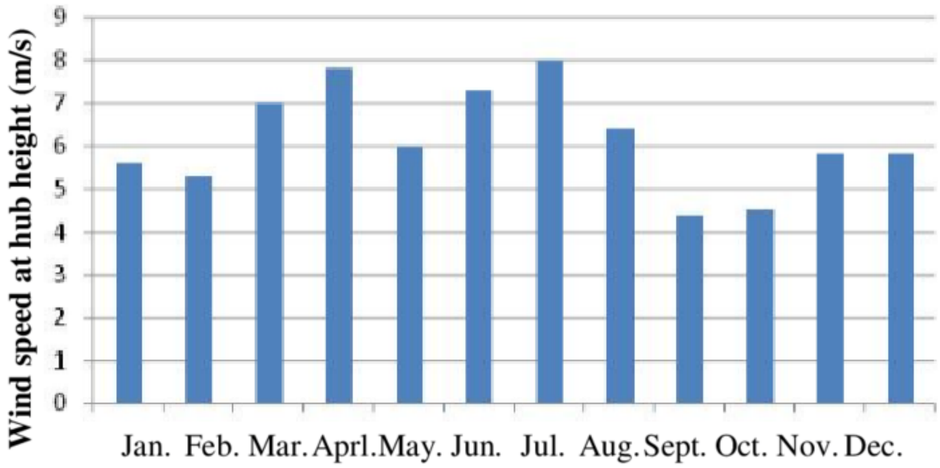


Fig.3: Average monthly wind speed in the Adrar region [5]

In this paper, we will focus more particularly on the modeling of the main components of a small wind turbine adapted to Saharan regions such as Adrar. The wind power conversion chain is schematized as follows in Figure 4.

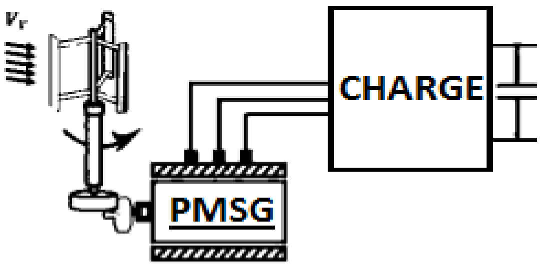


Fig.4: Diagram of the wind power conversion chain.

Figure 4 is a diagram of an aero generator associated with a wind turbine. The generator is of the synchronous type with permanent magnets and which outputs directly, through a three-phase diode bridge, to the DC bus and the electrochemical accumulator.

III. Modelling of wind system

The energy of the wind passes through the canopy which is directly coupled to the generator and allows the transformation of mechanical energy into electrical energy. Electrical components such as static converters and filter elements arranged downstream of the generator play an active role in adapting the characteristics of the electrical energy between the generator and the final load. This level is also responsible for controlling the assembly and obtaining the operating point at optimum power. The load, in the form of a battery pack. The diagram of the wind turbine studied in this work is schematized as shown in figure (4).

III.1 Turbine model

A wind turbine is a machine which, by definition, transforms wind energy into mechanical energy. To begin with, it is necessary to quantify the energy source available, that is to say the energy associated with the wind. If the wind has a certain speed "V" at a given moment and crosses a certain surface "A", the instantaneous power of the wind is given by the following relation:

$$P_m = 0.5.\ \rho.\ A.\ V^3 \tag{1}$$

Where ρ is the density of air, which is approximately 1.2 kg / m³. The surface "A" given by the following formula:

$$A = 2.R.\ H \tag{2}$$

where R represents the wing radius (m) and H its height (m). The turbine model is based on the steady state power characteristics of the turbine. The rigidity of the drive shaft is assumed to be infinite, the coefficient of friction and inertia of the turbine must be combined with those of the generator coupled to the turbine (figure 4). The output power is given by the following equation that we will normalize in pu:

$$P_m = 0.5.\ C_p(\lambda).\rho.\ \Pi.\ R^2.\ V^3 \tag{3}$$

The specific speed λ which is the ratio of the linear speed at the end of the turbine blades reduced to the wind speed, i.e:

$$\lambda = (R.\ \Omega)/\ V \tag{4}$$

With: Ω the angular speed of rotation of the blades.

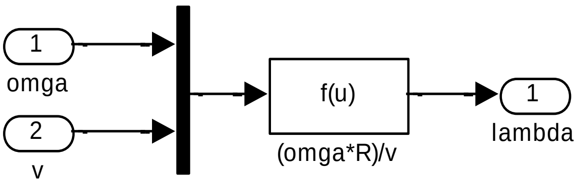


Fig.5: Calculation of the reduced speed (λ).

The wind torque C_e is obtained from equation (3) and using the expression (4) for the reduced speed:

$$C_e = (C_p(\lambda).\rho.\ R^2.\ H.\ V^2)\ /\ \lambda \tag{5}$$

In addition, the model of the wind torque calculator in the Simulink (fig.6):

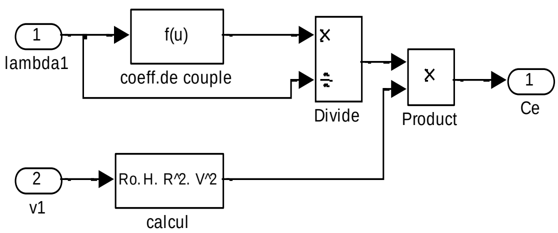


Fig.6: Wind power couple model in Simulink.

The evaluation of the power coefficient is specific to each wind turbine.

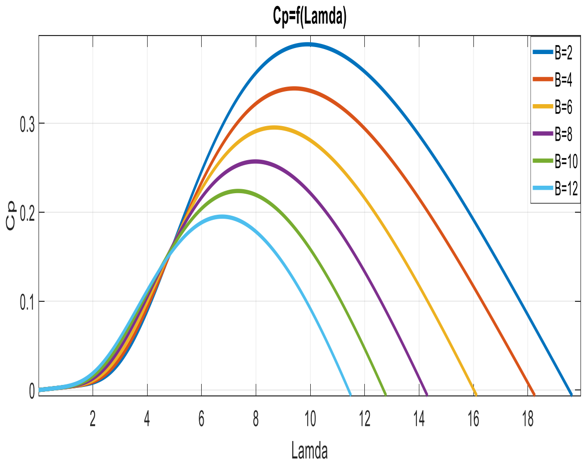


Fig.7: Characteristic curve selected for the tests [4].

Figure 7 shows the characteristics of power coefficient as a function of λ, Therefore, the higher the value of Bita, the lower the value of the power coefficient (Cp) and the more Lamda decreases with it ... that is i.e. there is an inverse relationship between Bita and Cp.

III.2 Wind speed

From the different approaches used in the literature for the generation of a synthetic series of wind, in our case, the realization under Simulink of the wind model is presented in figure 8.

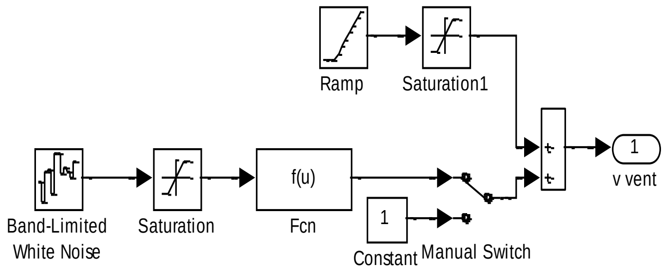


Fig.8: Wind model under Simulink.

Depending on the position of the manual switch shown in the diagram, the wind speed is considered either as variable in the form of step variations, or as a speed which has a turbulence component. This turbulence component is generated by filtering pseudo-random noise.

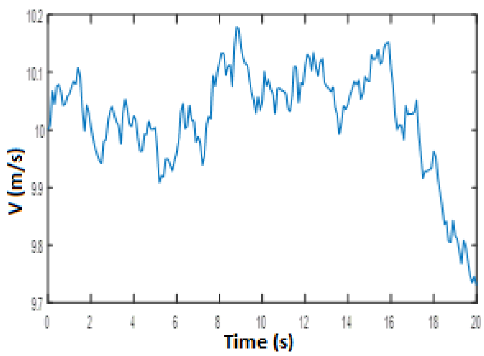


Fig. 9: Wind speed simulation

From the figure 9, we can say that the wind is unstable airwaves, which constantly change and cannot be controlled, but in the simulink program, we impose a system that is expressed roughly in order to simulate it.

III.3 PMSG Model

The equations are an exception to the prescribed specifications of this template. You will need to determine whether or not your equation should be typed using either the Times New Roman or the Symbol font (please no other font). To create multileveled equations, it may be necessary to treat the equation as a graphic and insert it into the text after your paper is styled.

The model of the PMSG is expressed at synchronous axes frame by [3, 10, 16]:

$$\begin{cases} v_d = R_s.I_d + L_d \dfrac{dI_d}{dt} - L_q \omega I_q \\ v_q = R_s.I_q + L_q \dfrac{dI_q}{dt} + L_q \omega I_d + \phi_f \omega \end{cases} \tag{6}$$

Where, v_{ds}, v_{qs} are the voltages of stator in (*d-q* axis), i_{ds} ,i_{qs} *are the* currents of stator in (*d-q* axis), L_d L_q *:are the* inductances in (*d-q* axis), R_s *:is the* stator resistance, ω *is the* electric pulsation and Φ_f *is the* magnetic flux of permanent magnet.

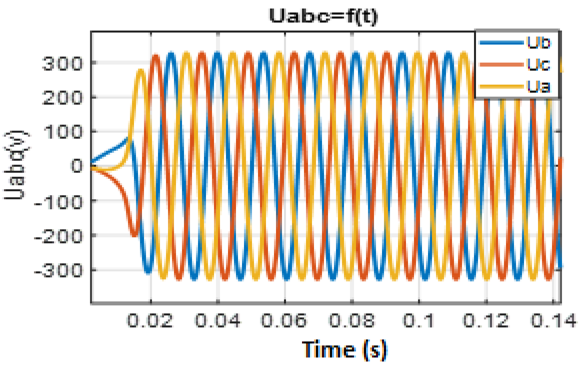
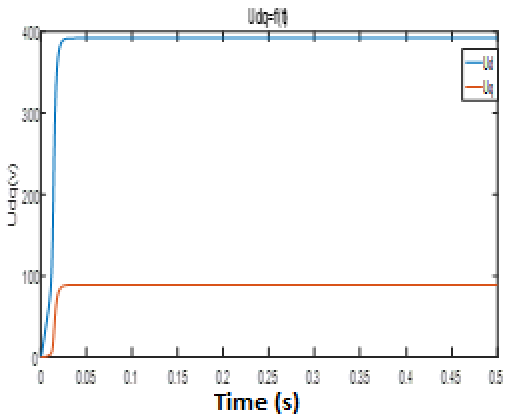


Fig.10: The Stator tensions voltages of PMSG after Simulation



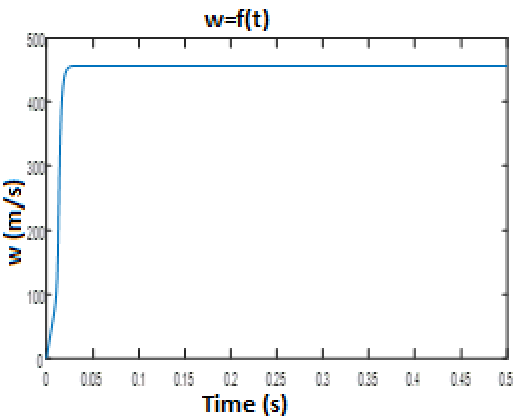


Fig.11: The Tension voltag Vd and Vq after Simulation

Fig.12: The angular speed variation after simulation

For the results of the generator simulation under load increased by almost twice the values of the simulation in vacuum, so that in figure (11) the largest value that the voltage curves (abc) reach is 300 volts. The same goes for figure (11), which represents the changes in voltage Vd and Vq so that there is a big difference between them. The voltage Vq is zero then increases by a small value to reach 80 volts and remains constant then, as for the voltage Vd, it reaches the highest value which is 390 volts and remains stable over time. Finally we have in figure (12) the changes of rotational speed where we notice that it increases by a large value until it reaches 450N.m and remains constant after that.

The electromagnetic torque is given by [3, 14, 15, 17, 18]:

$$T_{em} = \frac{3}{2} p \left[\left(L_q - L_d \right) i_{ds} i_{qs} + i_{qs} \varphi_f \right] \tag{7}$$

where, p is the number of pole pairs.

After applying Field Oriented Control (FOC), d-axis is aligned with the magnetic flux and the final form of equation of T_{em}, is obtained like the following equation:

$$T_{em} = \frac{3}{2} p.i_{qs} \varphi_f = K.i_{qs} \tag{8}$$

After, Eq.9 We can be used for the speed control of the q axis current component of the generator the q axis current component. The d-axis current is set to (0) zero [8].

The mechanical system can be described as by following relations, where T_t and T_a represent respectively the input wind torque and the torque respectively before the gearbox:

$$T_t - T_a = J_t \frac{Ld\Omega_t}{dt} + f_f \Omega_t \tag{9}$$

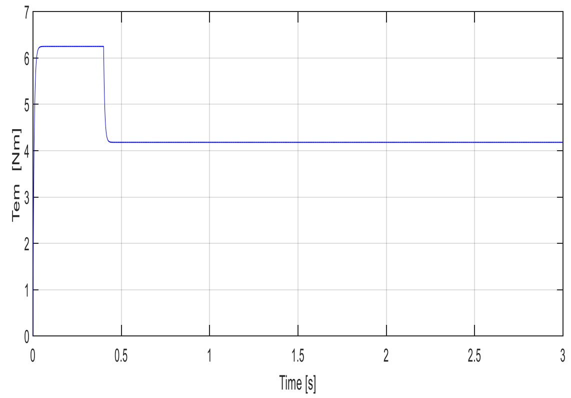


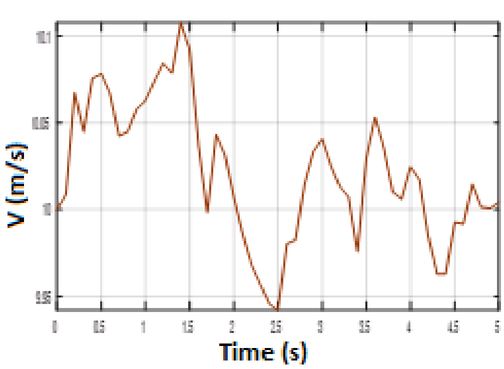
Fig.13: Simulated of electromagnetic torque T_{em} of PMSG generator.

Before the gearbox, the mechanical dynamic system can be described by Eq.10 in where T_b and Tg represent the torque after the gearbox and the generator torque produced respectively:

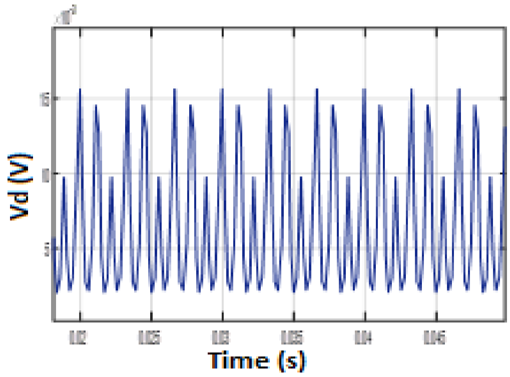
$$T_b - T_g = J_g \frac{Ld\Omega_g}{dt} + f_g \Omega_g \tag{10}$$

IV. Results and simulation

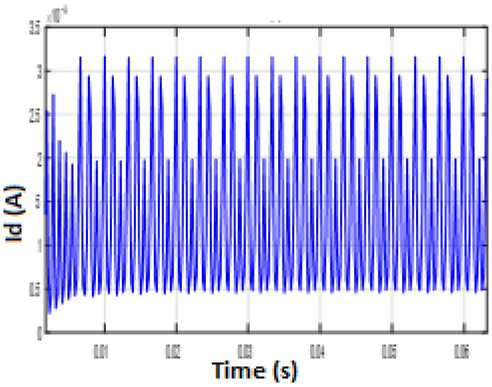
The simulation of our model on MATLAB is based on the application of all input system parameters such as wind speed. The wind speed in our case is already applied by several researchers which are the sums of the harmonic fluctuations generated as shown in the figure 14 (a).



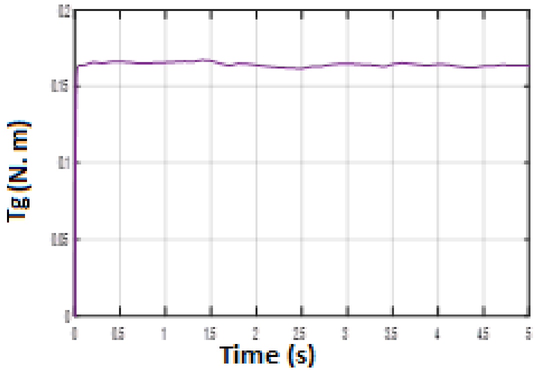
(a)



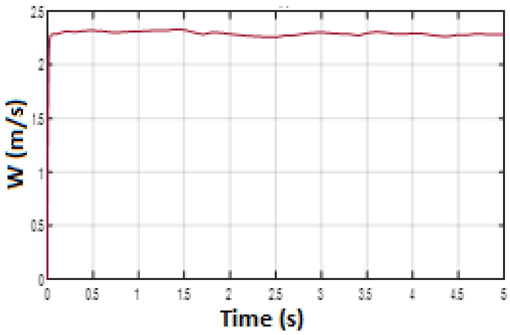
(b)



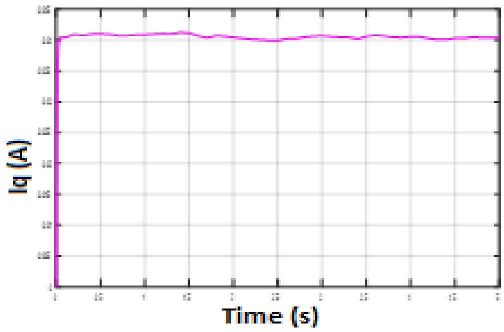
(c)



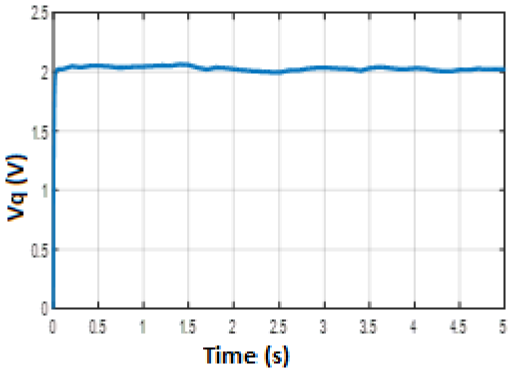
(d)



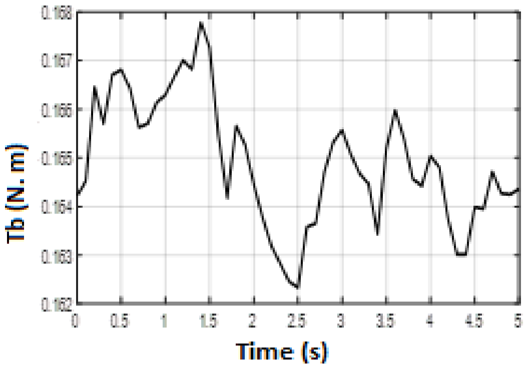
(e)



(f)



(g)



(h)

Fig. 14 : (a) Wind speed ; **(b)** Direct Statoric Voltage; **(c)** The variations of direct stator current; **(d)** the mechanical torque; **(e)** Vitesse de rotation ; **(f)** Courant quadratique ; **(g)** la tension quadratique ; **(h)** Le couple mécanique

After performing a simulation of the total wind system using the "Simulink" program, we obtained results which show us the evolution of several variables related to this system, and through them we note the following:

- In figure 14 (b), which shows us the changes of Direct Statoric Voltage in terms of time from the curve, we notice that the changes of Vd constantly change oscillating waves and the highest value recorded is 15.10 ^ -3 volts and the lowest value is 2.10 ^ -3 for a period of time (from 0 to 0.045sec)

- As for the variations of direct stator current (Id) represented in figure 14 (c), they evolve almost in the same way with Vd, and the highest value they reach is estimated at 3.10 ^ -4 amperes

- As for the mechanical torque curve shown in figure 14 (d), it takes the form of a wind speed change curve because it is related to the changes in wind and the movement of the wind turbine.

- The current curve (abc) in figure (23) is a sinusoidal curve and the largest value recorded by the current is 0.05 amperes

- For each of the curves Cem, Speed of Rotation, Vq and Iq, one notices that they take approximately the same evolutions so that they are null at the beginning and increase until reaching a value of reference for each variable and remain there constant.

V. Sizing by the HOMER PRO program

The objective of this part is the design of a mineral water production plant used for the exploitation needs of the latter in the Reggane region operating on wind energy (three types of wind turbines proposed). Reggane is a town in the wilaya of Adrar in Algeria, located north / desert of Tanezrouft. Associated with Sali.
Unconventional energy sources (wind and solar) can play a very important role in meeting global energy demand. The production of solar energy using PV/is very simple in construction, compact and can be installed in the country for the production of electricity [1-3]. Many authors have proven that network connectivity with a hybrid system is more efficient and reliable than a stand-alone system [4-

71A HOMER Pro is used for the optimization of the proposed hybrid orientation system, HOMER is used to analyze the physical behavior of the system.
Power plant and its life cycle cost, which includes its installation or capital cost and its operating cost over the lifetime of this power plant. life of the IS]Ae power plant system proposed includes an iniueral plant located in the Reggan region. We operate the plant using three different types of wind turbines. Lisine legally consumes approximately 2426.45 Wh of electrical energy in day
The following table shows the types used in this simulation

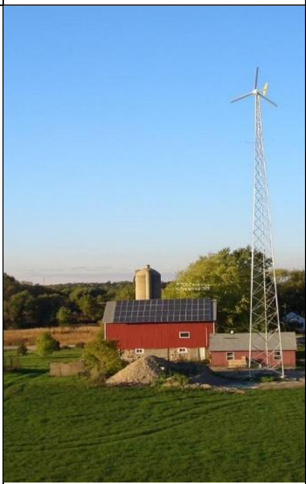
Wind turbine type	**Bergey Excel 10**	**XZERES 10kW**	**Gaia-Wind 133**
Capacity	10 KW	10 KW	11KW
Unit price	30720 USD	50000 USD	45000 USD
Photo of wind turbines			

Table 2: The three wind types used in our study.

We choose the month of peak load, in our case is the month July, then we find

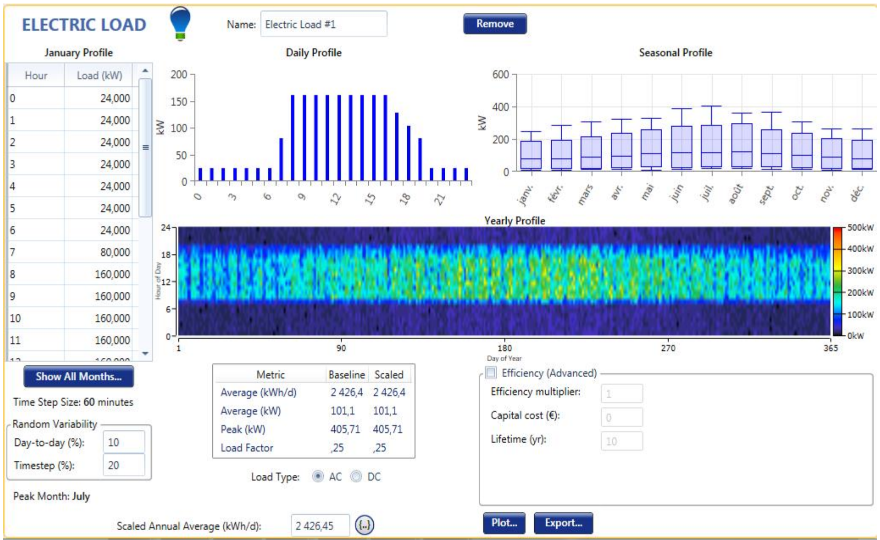


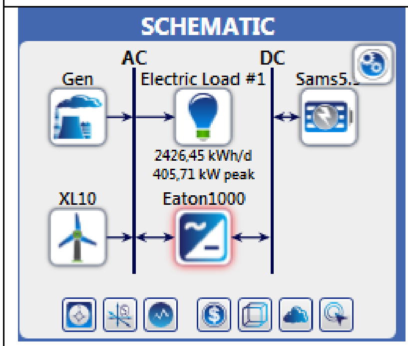
Fig. 15 : The daily consumption of our factory

a) Solar radiation:
As for the solar radiation, it is always high, especially during the months (May, June, July and August), so the radiation reaches maximum values and the temperatures are very high, reaching up to 50 degrees Celsius in summer.
b) Wind speed:
As for the wind speed, the region is also characterized by continuous monsoon winds sometimes, especially in the months (March, April, May). As we know, the state of Adrar and its cities have a climate characterized by great solar clarity and high temperature, as well as wind, which makes it an excellent area to invest in renewable energies, especially wind energyand solar

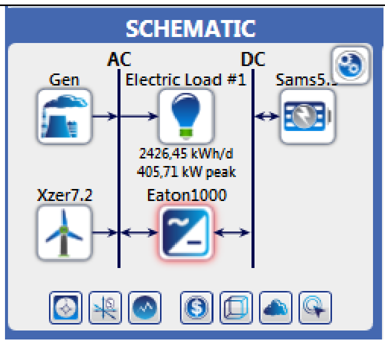
V.I Design diagram of system on the HOMER simulator

On the HOMER We have defined each element of our installation based on all the data and characteristics (design and installation system) and also we must know the coordinates of the site, the duration life of components and their costs. Thefollowing figures show the system data.

Bergey Excel 10



XZERES 10kW



Gaia-Wind 133

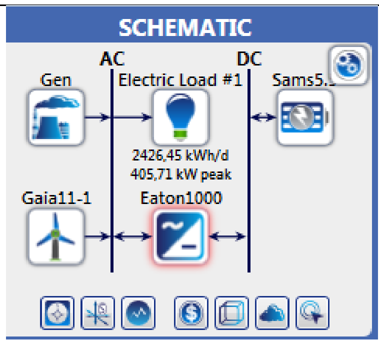


Fig. 16 : System diagram for each system.

V.II Results and discussion

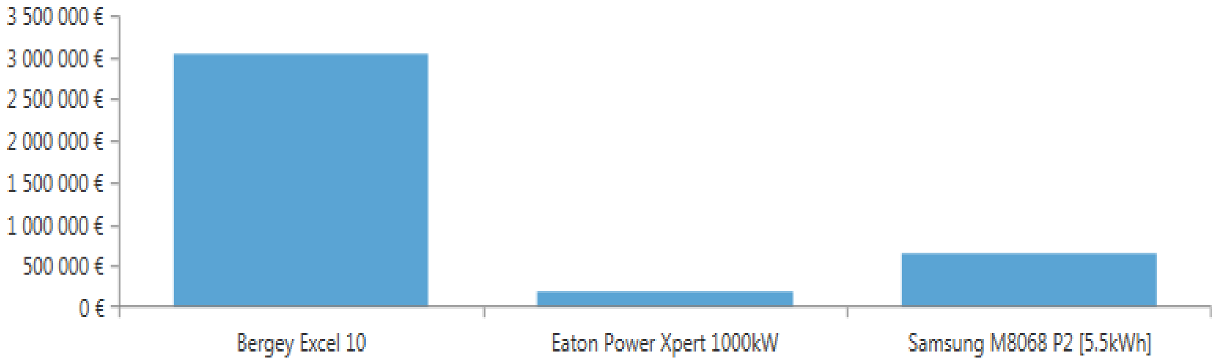
The simulation results by HOMER are given in the form of feasible combinations (technical and economic) of the elements defined in the installation. After the calculation is finished and without warning message, the results are classified according to the cost over the lifetime We can see the best solution by type of system, the following Table.1 presents the result of system simulation.

Bergey	81	2 527	727	CC	0,340 €	3,89 €M	108 052 €	2,49 €M
Fxzeres	111	1 587	599	CC	0,602 €	6,89 €M	103 447 €	5,55 €M
Gaia	55	2 134	754	CC	0,406 €	4,65 €M	104 516 €	3,30 €M

Table.3. Result of system simulation by HOMER.

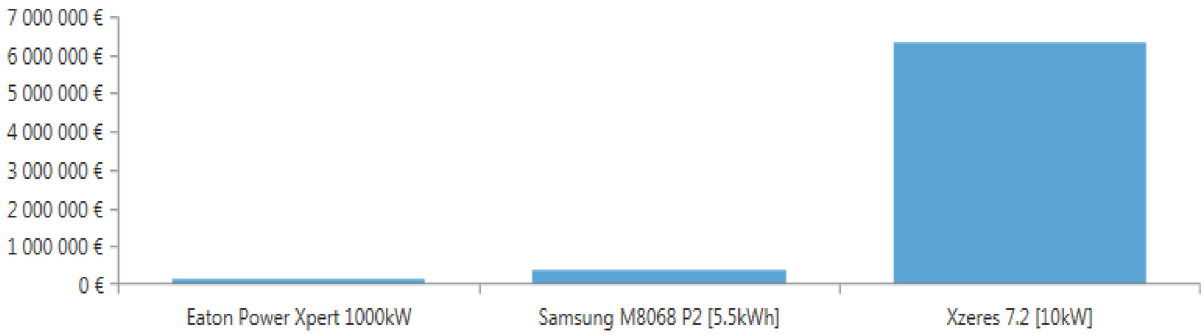
In this result can be seen several technical and economic details about each system configuration that

HOMER simulates. - The “Cost summary” tab categorized by type of component or by type of cost. It also allows access to the cost comparison window between the different solutions.



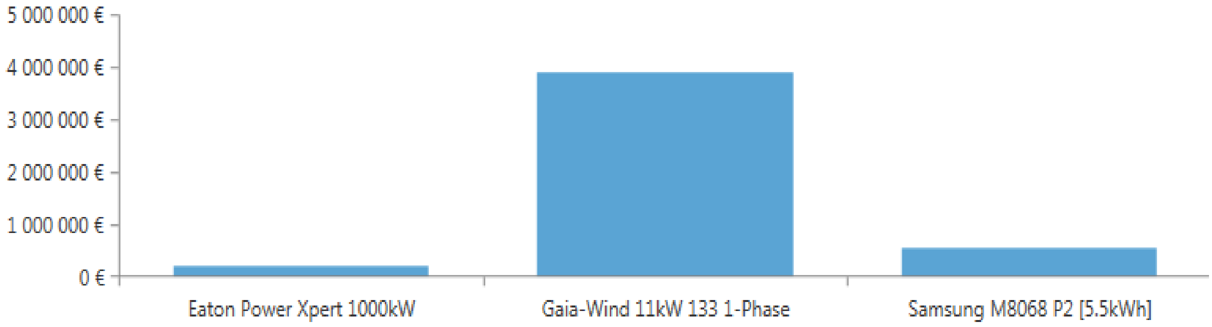
Component	Capital (€)	Replacement (€)	O&M (€)	Fuel (€)	Salvage (€)	Total (€)
Bergey Excel 10	2 488 320,00 €	793 294,71 €	209 425,77 €	0,00 €	-447 072,44 €	3 043 968,03 €
Eaton Power Xpert 1000kW	0,00 €	0,00 €	187 841,70 €	0,00 €	0,00 €	187 841,70 €
Samsung M8068 P2 [5.5kWh]	0,00 €	0,00 €	653 356,69 €	0,00 €	0,00 €	653 356,69 €
System	2 488 320,00 €	793 294,71 €	1 050 624,15 €	0,00 €	-447 072,44 €	3 885 166,41 €

(a) Bergey



Component	Capital (€)	Replacement (€)	O&M (€)	Fuel (€)	Salvage (€)	Total (€)
Eaton Power Xpert 1000kW	0,00 €	0,00 €	154 767,94 €	0,00 €	0,00 €	154 767,94 €
Samsung M8068 P2 [5.5kWh]	0,00 €	0,00 €	410 319,38 €	0,00 €	0,00 €	410 319,38 €
Xzeres 7.2 [10kW]	5 550 000,00 €	1 769 380,79 €	0,00 €	0,00 €	-997 159,55 €	6 322 221,24 €
System	5 550 000,00 €	1 769 380,79 €	565 087,31 €	0,00 €	-997 159,55 €	6 887 308,55 €

(b) XZERES

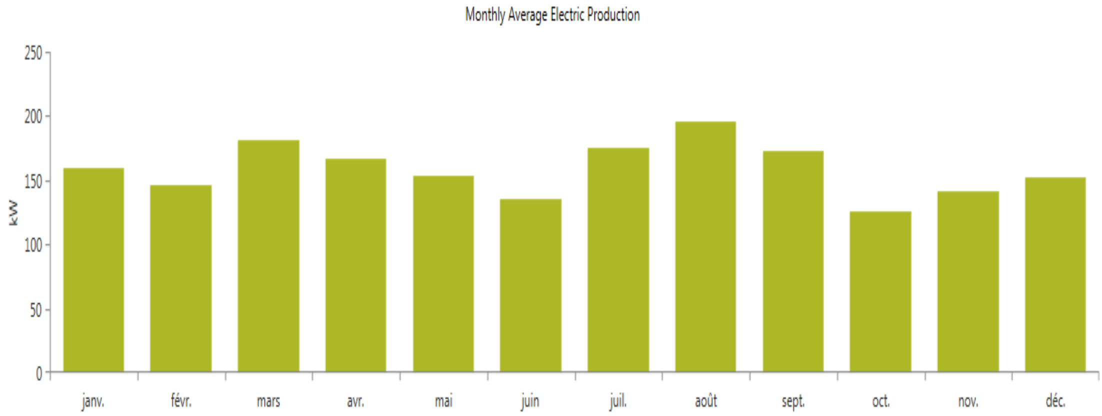


Component	Capital (€)	Replacement (€)	O&M (€)	Fuel (€)	Salvage (€)	Total (€)
Eaton Power Xpert 1000kW	0,00 €	0,00 €	195 028,22 €	0,00 €	0,00 €	195 028,22 €
Gaia-Wind 11kW 133 1-Phase	3 300 000,00 €	0,00 €	604 361,40 €	0,00 €	0,00 €	3 904 361,40 €
Samsung M8068 P2 [5.5kWh]	0,00 €	0,00 €	551 746,41 €	0,00 €	0,00 €	551 746,41 €
System	3 300 000,00 €	0,00 €	1 351 136,02 €	0,00 €	0,00 €	4 651 136,02 €

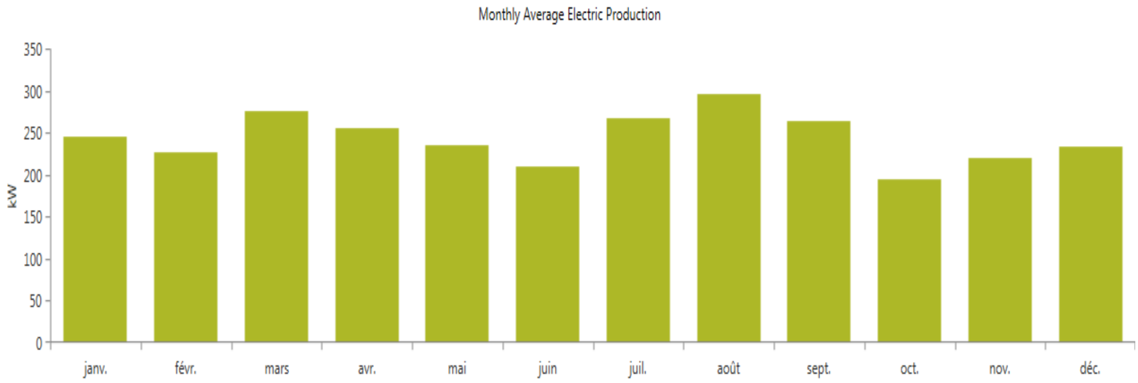
(a) Gaia

Fig. 17: Price of system generators

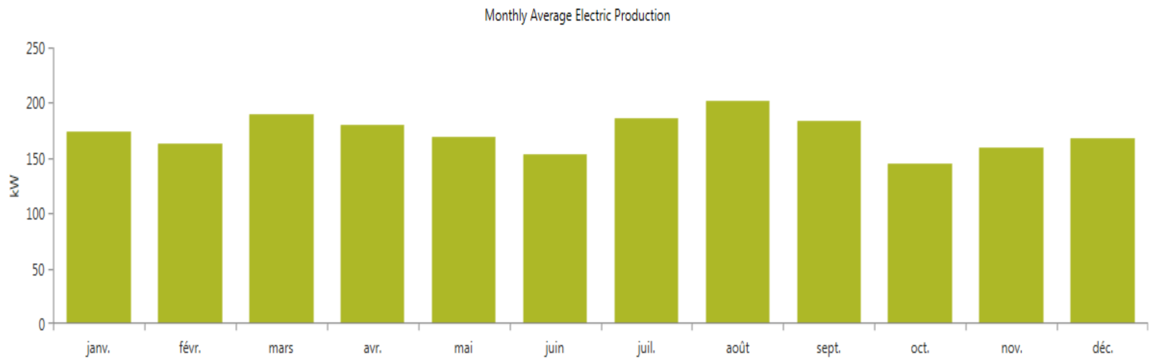
- The "Cash Flow" tab shows the graph of the cash flow corresponding to the system. Each bar in the graph represents either total expenses or total revenue for a year. The first bar, from year zero, shows the capital cost of the system. A negative value represents an expense, such as the cost of maintaining component replacement or operation and maintenance (O&M). A positive value represents revenue, which may be the sale of electricity or the resale of components when the system is dismantled at the end of the project's life. The energy produced from the optimal system is shown in the Figure below.



(a) Bergey



(b) XZERES



(c) Gaia

Fig. 18: average power profile produced by the wind.

We have the graphs of Figure 18, which represent the energy production for each type of wind turbine, from which we note: -The capacity that we obtain from the first type (Bergey) during the year varies between 130KW and 210KW, of, so that the highest value is recorded in August, which amounts to (210KW) -For the second type of wind turbine (XZERES), the amount of energy it product is between 200 kilowatts and 300 kilowatts, and the great values recorded by this type are during the months (March, July and August) its maximum value is in the month of August (320 kilowatts). -wind turbine type "Gaia" Produces energy ranging from 150 to 220 kilowatts per year. Therefore, we have noticed that for each of the types studied, they register large values in March, April and August. So that this region is characterized during these months.
Monsoon winds, so these are the best months of the year. For the good production of this energy.

The following table presents the production and the rate of electric energy for the wind:

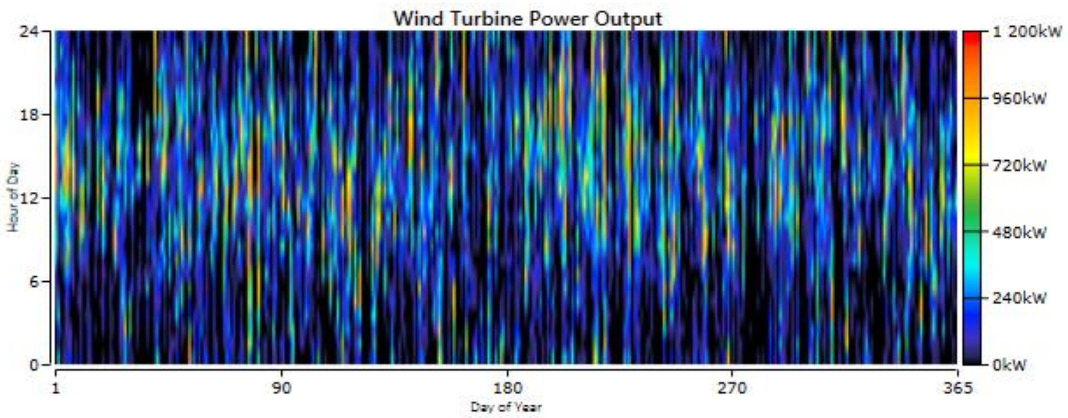
Type de système	Production	KWh/ année

Bergey	Wind flow 45-500	1 392 558
	Total	1 392 558
XZERES	Production	KWh/ année
	Wind flow 45-500	2 133 710
	Total	2 133 710
Gaia	Production	KWh/ année
	Wind flow 45-500	1 513 591
	Total	1 513 591

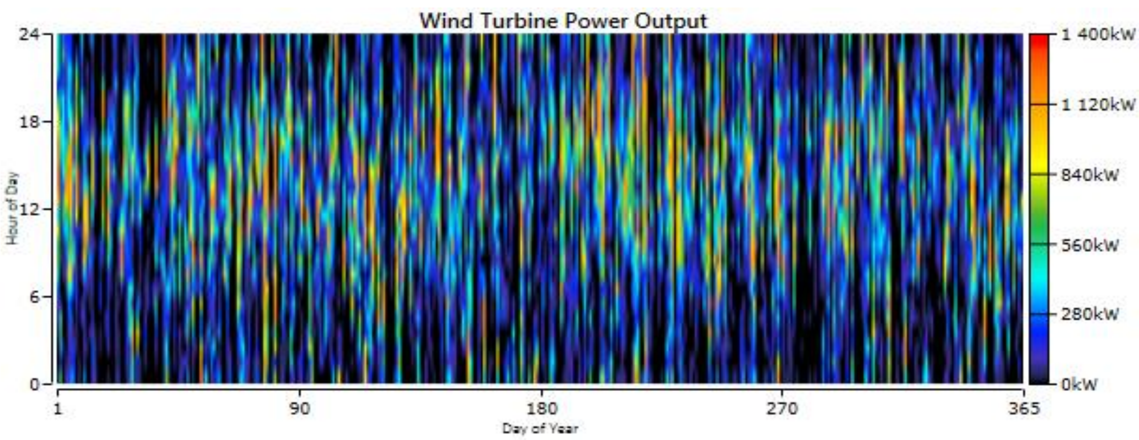
Table 4: Annual energy produced.

The previous table shows us the annual production of each type of wind turbine, through which we conclude that the best type among these three types that we have studied is eXZERES), so that its production during the year reaches 2133710KWH/ year, and then it is followed by the Gaia type wind turbine, which has a capacity of about 1513591KWH/year 44 So in terms of productivity and capacity, the best type is "XZERES."

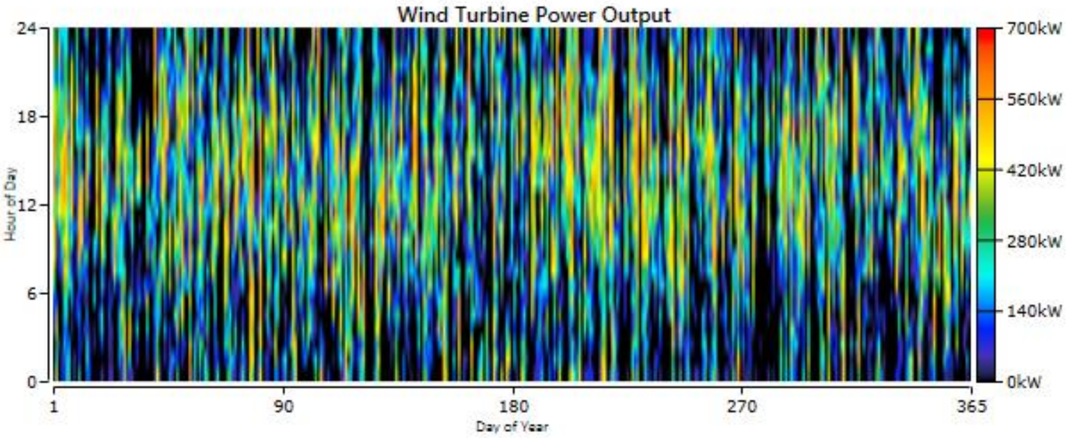
The wind generator presented in figure 19.



(a) Bergey



(b) XZERES



(c) Gaia

Fig. 19: wind energy production

. VIII.1. Interpretation of Results

Note in Figure 19 for wind generation for three types of wind systems. The first. Its level of energy production during the year noted up to 1200 kilowatts. We also see in the type b XZERES, the energy production reaches a maximum number estimated at 1400 kilowatts, which is the best and the best thanks to the last Gaia, which produces 700 kW. Type B is the best.

VI. CONCLUSION

In this paper, we focused on the simulation of the different components of a wind power system in Simulink and finally we made a block diagram for the generic wind power system consisting of a turbine, a generator and the load. This study is only a beginning for a development of renewable energy, one wishes to have more success in this economic field because the area is very rich in wind resources.

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