Experimental Analysis of a Photovoltaic Power Plant in a Desert Environment– Adrar area –

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ABSTRACT

Algeria has one of the highest solar deposits in the world, the average duration of sunshine in the Algerian Sahara is 3500 hours, and this potential can be an important factor for sustainable development in this region, if it is exploited economical way. In this context, it should be noted that the city of Adrar is located in the region of the "solar belt", which enjoys abundant sunshine of more than 3000 hours of sunshine per year, based on data from Overall hourly irradiation on a horizontal surface, the Adrar region is distinguished by a higher average daily irradiation of up to 5.7 kWh/m^2/day. In the present work, an operational performance analysis of a polycrystalline silicon photovoltaic system for one year is performed. The installed capacity of this system is 20 MW, and it is exposed in an arid climate in Adrar of southern Algeria.

I. Introduction

Algeria has an excellent solar deposit, which places it in a good position for the exploitation of a clean and sustainable source of energy such as solar photovoltaic. Indeed, the great Algerian south is located in sectors where the average density of solar radiation is very high. So the photovoltaic is called to play a more important role in the market of the production of electricity in the great south. The question of the cost and profitability of photovoltaic energy therefore becomes capital, practical applications, tests and important research are launched in Algeria to improve and increase the performance of these PV installations in Saharan sites and far away.

Grid-connected PV systems were used in the early 1990s and quickly spread to developed countries, mostly bolstered by broad government incentives. The main advantage of this configuration, in addition to reducing costs due to the absence of batteries, is that each surplus of energy generation compared to the consumption of the load is directly fed into the distribution network. The latter will provide the back-up in the opposite case (low energy generation). Thus, the integration of PV systems into the distribution network is an important and strategic issue in the future energy policies of southern countries.

The government aims to produce 27% of its energy from renewable energies by 2030 and has already commissioned six grid-connected solar power plants with a capacity of 48 MW in the city of Adrar. A 20 MW solar power plant near the city of Adrar, and three other power plants in the southern part, one of (6 MW) and two of (5 MW) in the communes of ZaouietKounta, Reggane and Aoulef respectively. Two other solar power plants of (9 MW) and (3 MW) were also commissioned in the communes of Timimoune and Tsabit (Kaberten) respectively [1].

The region of Adrar is characterized by a hot and very arid Saharan climate, cold nights in winter, very low precipitation and seasonal sandstorms [2-4]. July is the hottest month with an average minimum temperature of 26.8 °C and an average maximum temperature of 44.9 °C. In contrast, the coldest month is January, during which the minimum temperatures and average maximums respectively reach 4.5 °C and 20.3 °C [5-7].

Due to the increase in photovoltaic capacity observed in most of the countries of the world, research on the performance of photovoltaic installations under real outdoor conditions has become an important issue [8-10].

Evaluating the performance of PV systems is the best way to determine the potential for PV power generation at a site. Usually, the performance of photovoltaic modules refers to the conditions of standard tests (STC) which is not always representative of the actual operation of the modules. Different studies have been carried out on the performance parameters of photovoltaic power plants installed in different geographical locations and different climatic conditions [11-20].

The performance and reliability of photovoltaic systems are strongly influenced by environmental conditions. Therefore, the performance of the PV module degrades due to prolonged exposure to outdoor conditions [21-24].

In order to make PV technology profitable and commercially viable, it is important to study the technology, behavior and characteristics of PV systems outdoors.

The main objective of this article, an analysis of the operational performance of field-exposed polycrystalline silicon photovoltaic system is carried out on the basis of the monitored data of a PV plant of installed capacity is 20 MW, and it is exposed to arid climates in the Adrar site (southern Algeria).

II. Measurement site

The Adrar photovoltaic power plant is part of the national renewable energy development program set up by the responsible ministry.

It is a power plant under the southern production unit, an entity of the subsidiary of SKTM (Sharikat Kahrabawa Taket Moutadjadida, electricity production company) commissioned on 12/10/2015. The SKTM photovoltaic plant covers an area of 40 hectares. It is located 10 km from the center of city of Adrar (figure 1).

The Adrar PV plant contains 20 Subfields; each subfield produces 1 MWp. 93 Matrices, each matrix made up of 44 panels devised in 2 strings, each string is made up of 22 panels connected in series. The total number of panels is 81840. Each 8 string (4 matrices) are connected to a junction box, each three junction boxes are connected to a parallel box and each 4 parallel boxes are connected to a general box located in a shelter . A shelter contains 2 general boxes and 2 inverters. The general box is connected to the inverter (CC / AC) which is connected to the transformer (315 V/30 KV step-up) and then to the inlets which inject to the busbar from which it is injected into the electrical network.

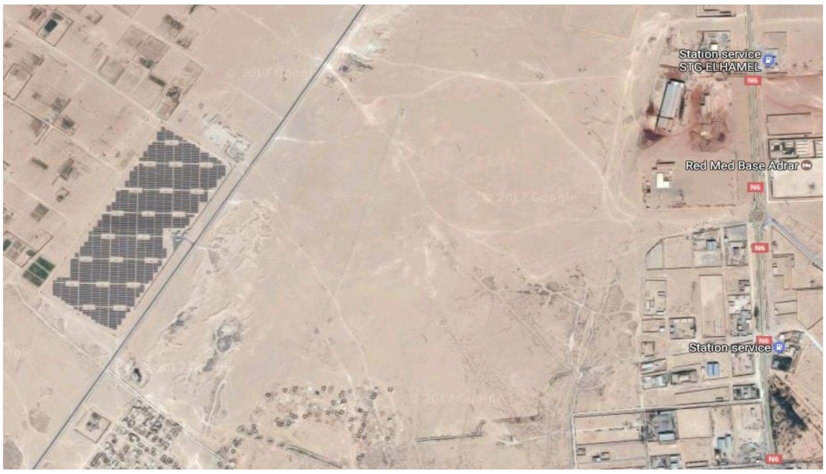


Figure1.Adrar solar power plant seen by Google Map.

The panels are polycrystalline silicon, facing south at an inclination of 27˚. It is measured at an AM1.5G solar spectrum, an irradiation of 1000 W/m^2 and a cell temperature of 25˚C (standard conditions) (Table 1).

Table .1Electrical characteristics of polycrystalline silicon panels

Parameters	Specification
Mark	YINGLI SOLAR
Type of module	YL245P-29b
Application class	A
Measured power (W)	245
Measured voltage (V)	29,6
Measured current (A)	8,28
Max series fuse (A)	15
Open circuit voltage (V)	37,5
Short circuit current (A)	8,83
Max system voltage (V)	1000
Number of cells	60
Module dimensions (mm)	1640*990*35

III. Environnemental conditions of the PV installation

To analyze the environmental conditions of the site, in this part we interpret the data from the various sensors (pyranometer, thermometer, anemometer and wind vane (figure 2)).

Figure2.Meteorological station of Adrar solar power plant.

III.1. Solarirradiation on site

In order to understand the environment in which the photovoltaic solar installation operates, we have illustrated in figure 3 the monthly global solar radiation in terms of the modules during the hours of sunshine during the year 2019 of operation of the plant.

Figure.3 shows the average monthly solar irradiation measured over the entire months of the year 2019. As shown, during the summer months, the maximum solar irradiation is recorded in June (1039.853 W/m^2); however, the minimum value was in January (939.683 W/m^2).

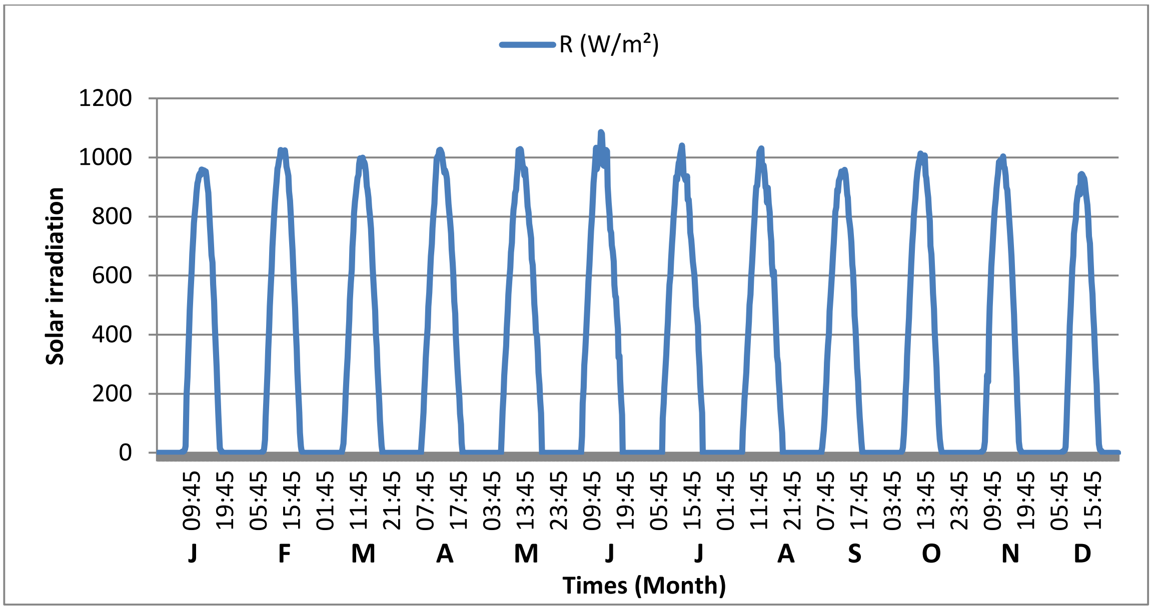


Figure3. Average solar irradiation measured for each month for a year at the site.

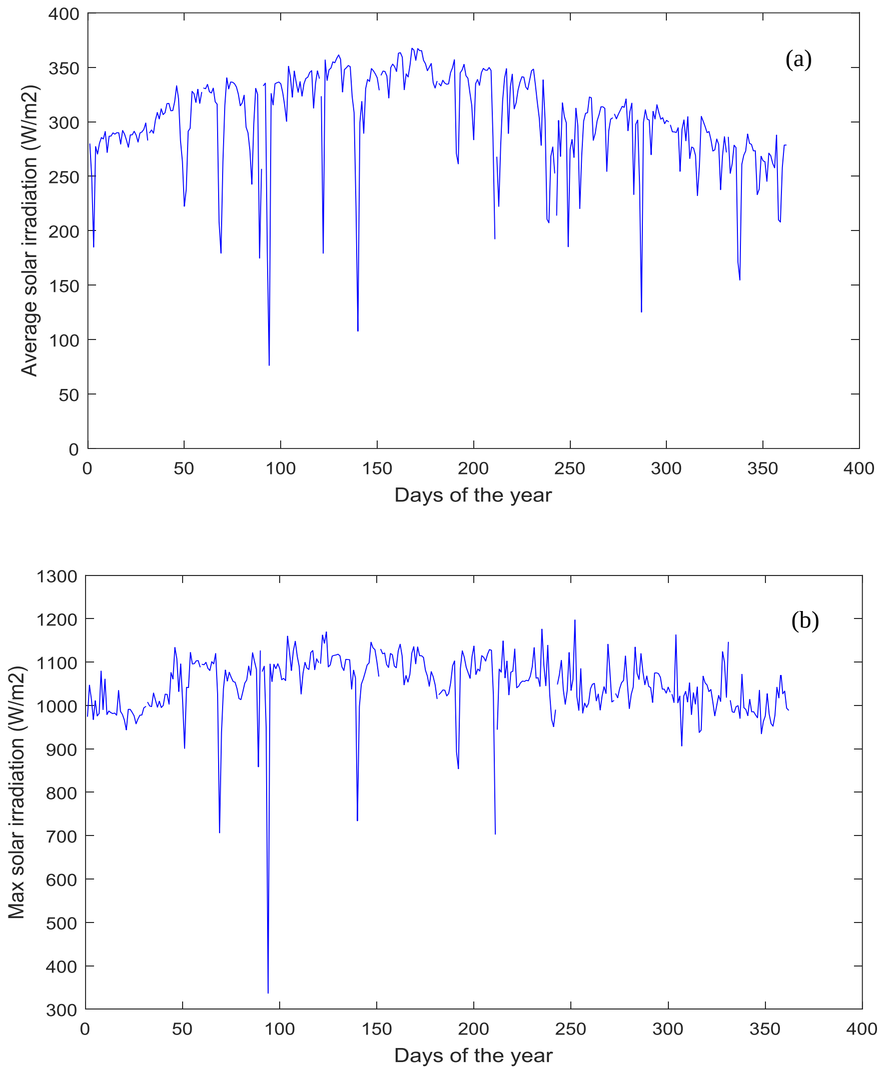


Figure4.Daily evolution of the average (a) and maximum (b) irradiation during the year 2019.

According to the graph analysis (figure 4) of the annual evolution of the average and maximum daily irradiation during the year 2019, we can notice that the maximum value of the irradiation varies according to the season of a PV plant where it is optimal for the summer. On the other hand, the lowest value of the radiation was recorded in the month of April due to the clouds.

III.2. Ambient temperature and wind speed of the site:

In order to understand the environment in which the solar photovoltaic installation operates, we have illustrated in figure 5 the ambient temperature (Ta) and the wind speed recorded during one year (2019) of operation of the plant.

Figure 5 (a) shows that the hottest month is July, characterized by a maximum average value (Tmax) equal to 46.61 °C; while the minimum average value (Tmin) is equal to 4.8 °C in January. However, the wind speed (figure 5 (b)) is an important parameter to estimate the productivity of the PV system, over a year, the wind speeds vary from 0 m/s to 17 m/s. The average maximum daily wind speed of 10 m/s occurs around April 4, decreasing very slowly during the months of September to December and its average monthly maximum range varies from 3.5 m/s (in January) to 5, 2 m/s (in August) (Table 2).

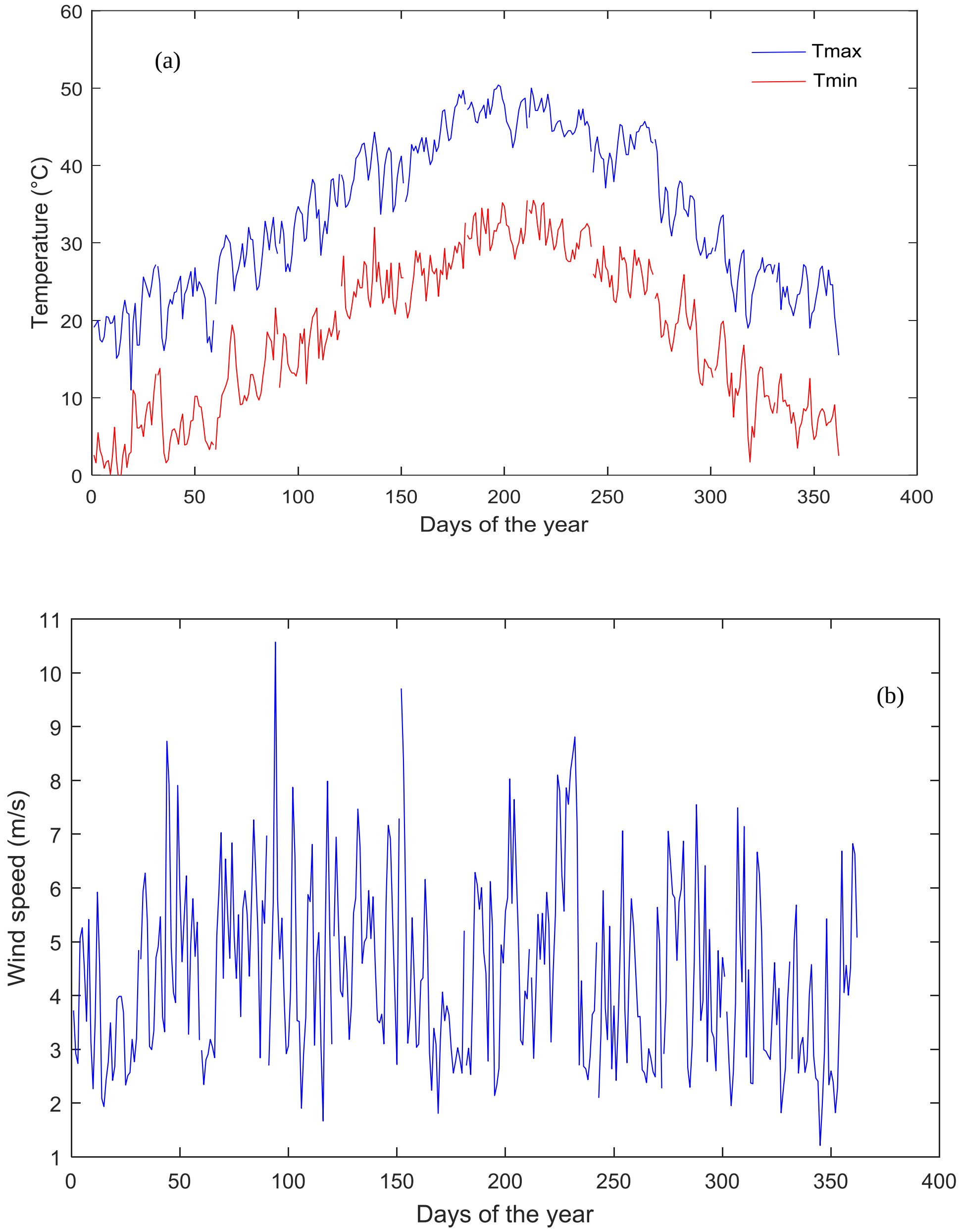


Figure5.Daily variation in ambient temperature (a) and Average wind speed (b).

Table2.Climatic data of measurement site (2019)

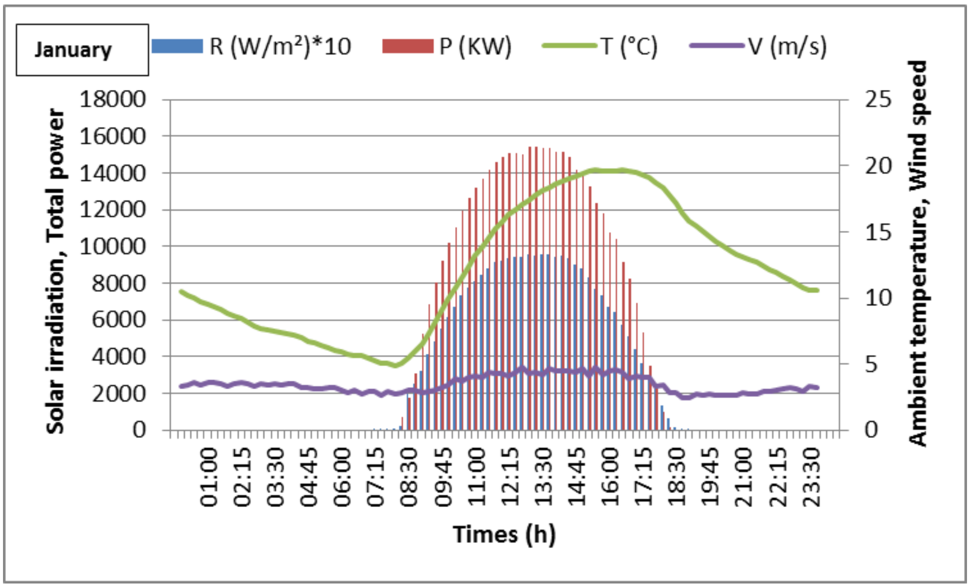
	Wind speed (V avg)	Temperature (T max)	Temperature (T min)
January	3,4645	19,7032	4,8871
February	5,0221	22,1393	6,5500
March	4,8748	28,0468	13,3064
April	4,6952	32,3866	17,2466
May	5,0591	38,6871	25,2806
June	3,9994	43,1266	27,1900
July	4,6577	46,6100	32,2033
August	5,2130	45,4742	31,8903
September	3,7565	41,8333	26,6448
October	4,6422	33,3241	18,7965
November	3,8728	26,2133	11,8867
December	3,6515	22,9709	8,10645

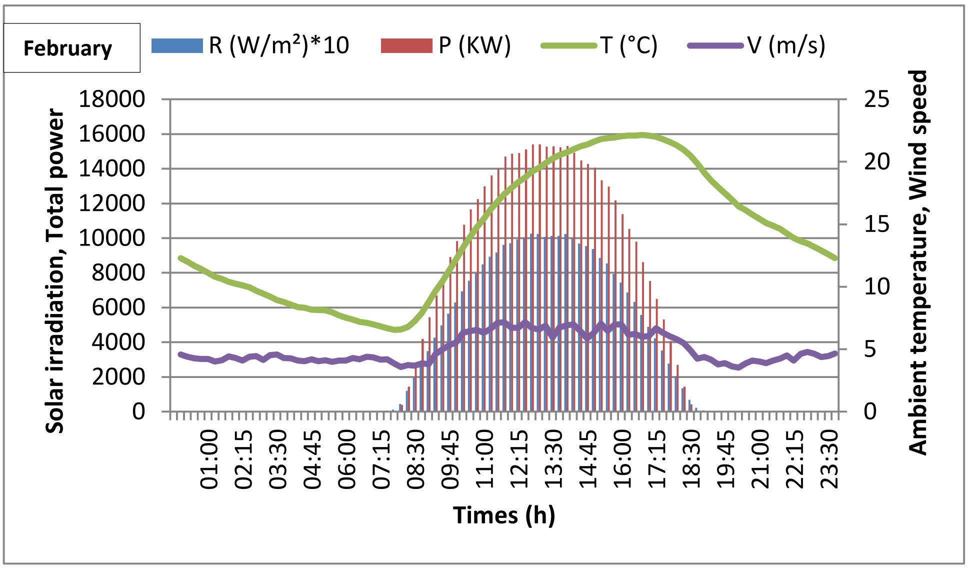
IV. The production of the Adrar solar power plant

After the study we made on the characteristics of the sites, we will analyze the influence of temperature, radiation intensity and wind speed on the power delivered from the plant.

Figure 6 shows the variation in maximum annual power with the corresponding variation in temperature and irradiation. This figure confirms the influence of the power delivered by the irradiation which is related to each other in a proportional relationship. On the other hand, the high temperature values considerably hampered production. Normally the trajectory of the power follows the trajectory of the radiation at each point but on the other hand we notice that the trajectory of power does not follow the trajectory of the radiation in this case we can say that the temperature is a parameter which disturbs the evolution of the power and this is evident in summer.

In addition, the increased wind speed promotes heat dissipation from the PV panel, which can improve electrical and thermal performance somewhat. But according to the nature of the soils of the sites; the high wind speed causes the dust to move and this can negatively affect the performance of the PV module




February
R (W/m²)*10
P (KW)
T (°C)
V (m/s)
Solar irradiation, Total power
Ambient temperature, Wind speed
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
25
20
15
10
5
0
01:00
02:15
03:30
04:45
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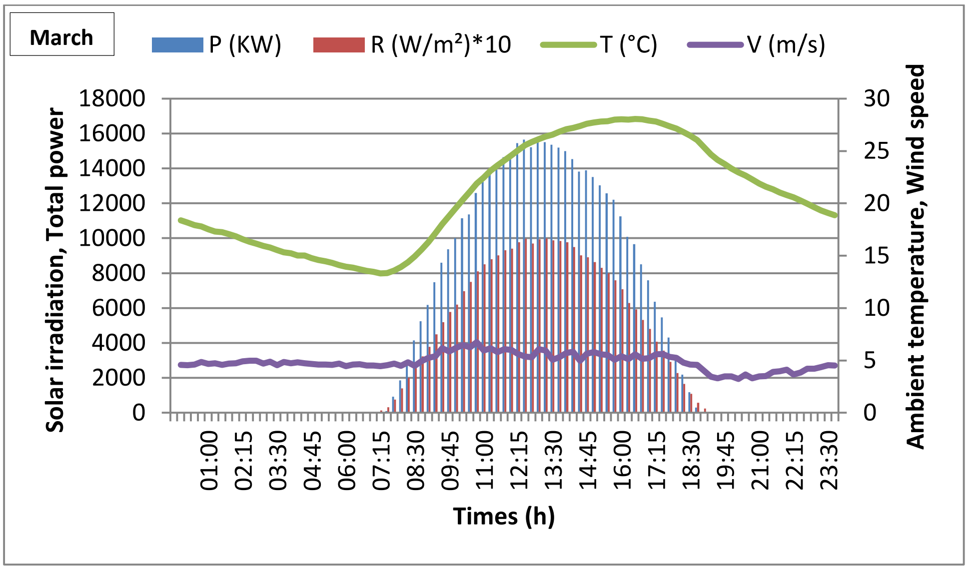
Times (h)


March
P (KW)
R (W/m²)*10
T (°C)
V (m/s)
Solar irradiation, Total power
Ambient temperature, Wind speed
18000
16000
14000
12000
10000
8000
6000
4000
2000
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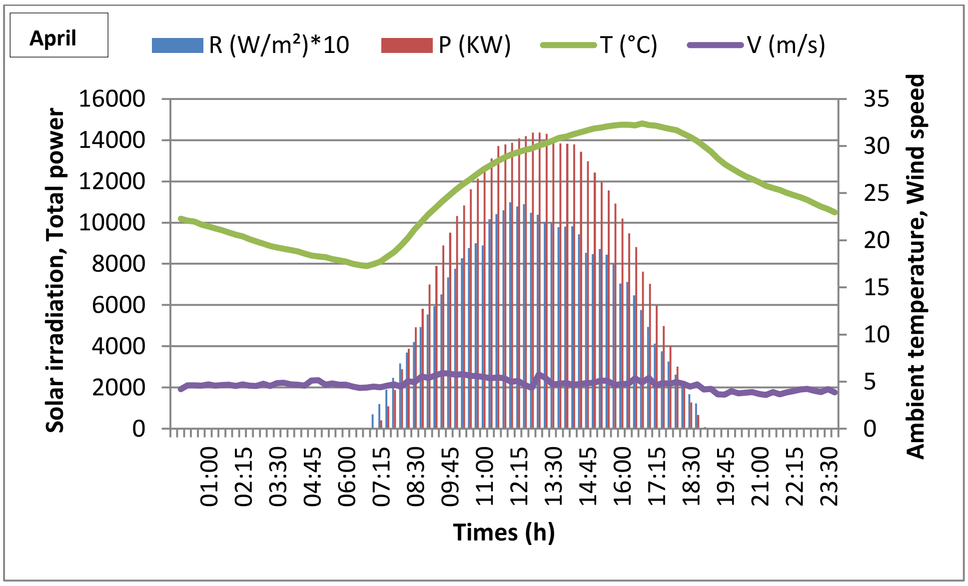
Times (h)


April
R (W/m²)*10
P (KW)
T (°C)
V (m/s)
Solar irradiation, Total power
Ambient temperature, Wind speed
16000
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12000
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8000
6000
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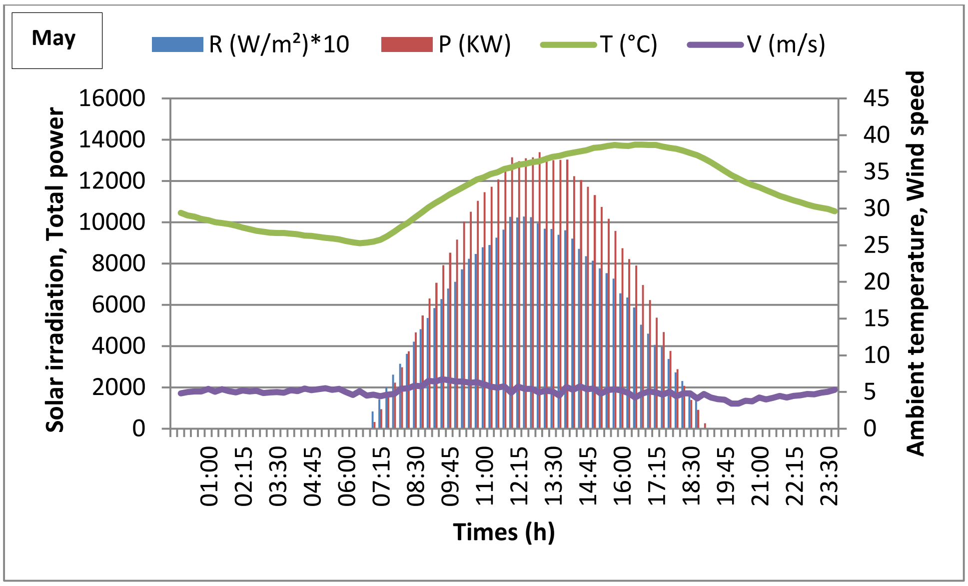
May
R (W/m²)*10
P (KW)
T (°C)
V (m/s)
Solar irradiation, Total power
Ambient temperature, Wind speed
16000
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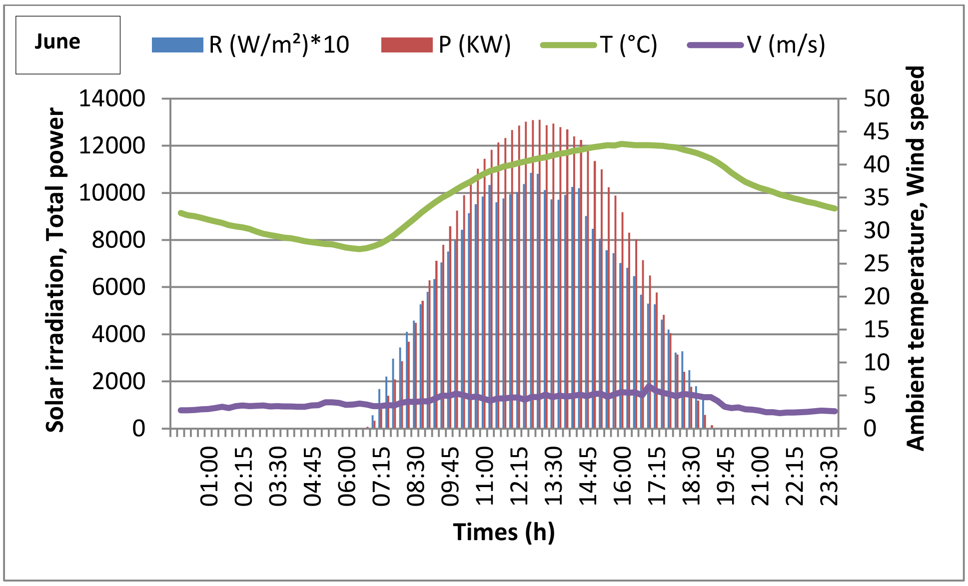
June
R (W/m²)*10
P (KW)
T (°C)
V (m/s)
Solar irradiation, Total power
Ambient temperature, Wind speed
14000
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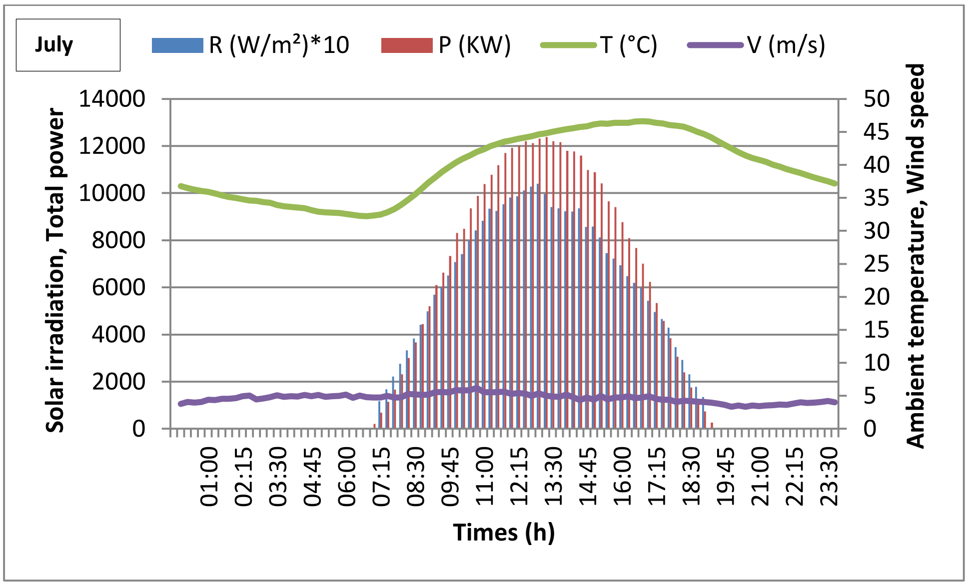
July
R (W/m²)*10
P (KW)
T (°C)
V (m/s)
Solar irradiation, Total power
Ambient temperature, Wind speed
14000
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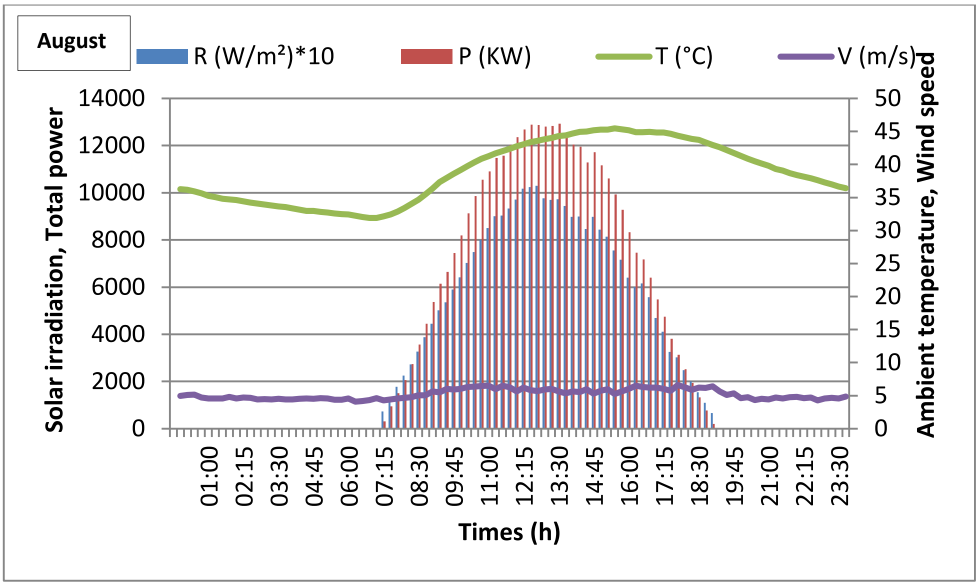
August
R (W/m²)*10
P (KW)
T (°C)
V (m/s)
Solar irradiation, Total power
Ambient temperature, Wind speed
14000
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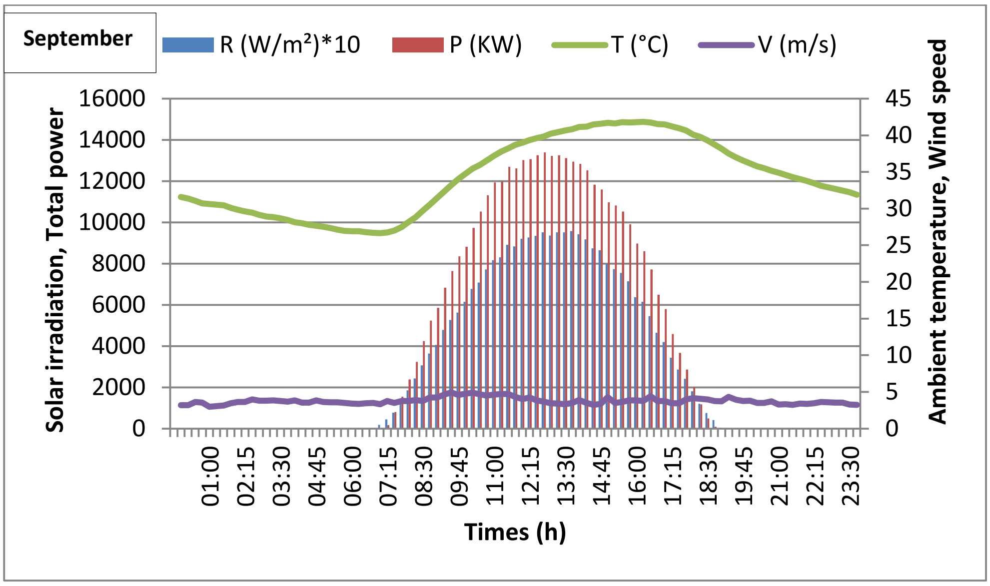
September
R (W/m²)*10
P (KW)
T (°C)
V (m/s)
Solar irradiation, Total power
Ambient temperature, Wind speed
16000
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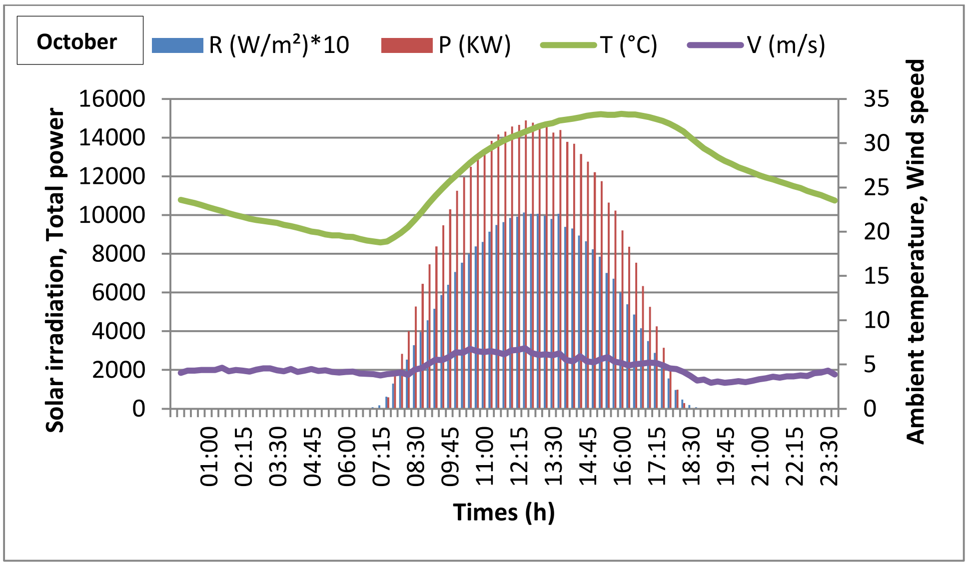
October
R (W/m²)*10
P (KW)
T (°C)
V (m/s)
Solar irradiation, Total power
Ambient temperature, Wind speed
16000
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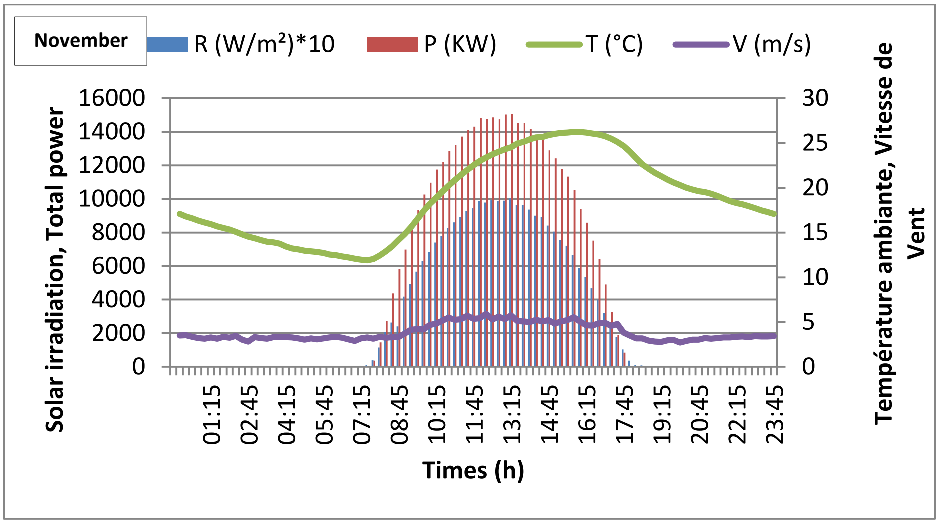

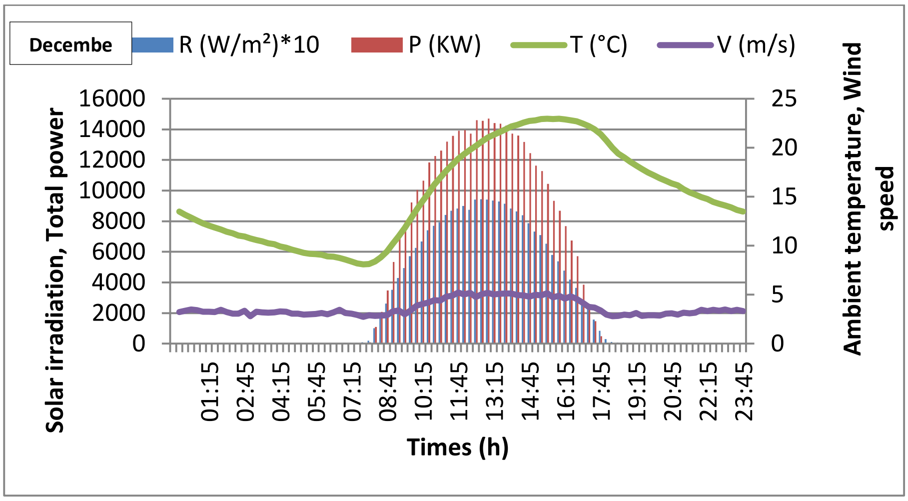

Figure6. The annual power variation with temperature, irradiation and wind speed for one year.

V. PV system performance evaluation and analysis

The expected energy outputs on the side of the photovoltaic generator show a decrease in a few months (generally from May to September) and this is due to the influence of meteorological parameters, in particular the temperatures of the modules and other components of the system. To understand the performance in more detail, the efficiency of the PV system is estimated and shown in Figure.7 The efficiency (η) of the system is estimated between 8.92% (in June) and 11.93% (in January). The minimum value of matrix efficiency is expected in June, and this is due to the high temperature observed during this particular season (summer). Most of the time, the efficiency of the generator in the roof integrated PV system is affected by the temperature in summer season. This is due to the long exposure to solar irradiance which directly leads to an increase in the temperature of the cell. Apart from that, few other factors also influence the performance of the arrays such as module quality, mismatch, dust, degradation, ohmic losses, etc. Therefore, the efficiency does not seem to be an appropriate parameter that defines the performance, hence the new parameter, namely the performance ratio (PR), has been introduced to define the performance quality of the PV system. The performance ratio indicates the overall effect of the losses on the energy production of the rows of a PV system. PR values indicate how close a PV system approaches ideal performance under real operating conditions. The PR is reasonably maintained at a constant average measurement value of 70.72% over one year, varying between a minimum of 59.13% (in June) and a maximum of 79.05% (in January). The predicted PR of the currently studied system has declined within a few months (usually May to August) and this is due to the influence of meteorological parameters, in particular the high temperatures of the modules which cause an overall energy loss.

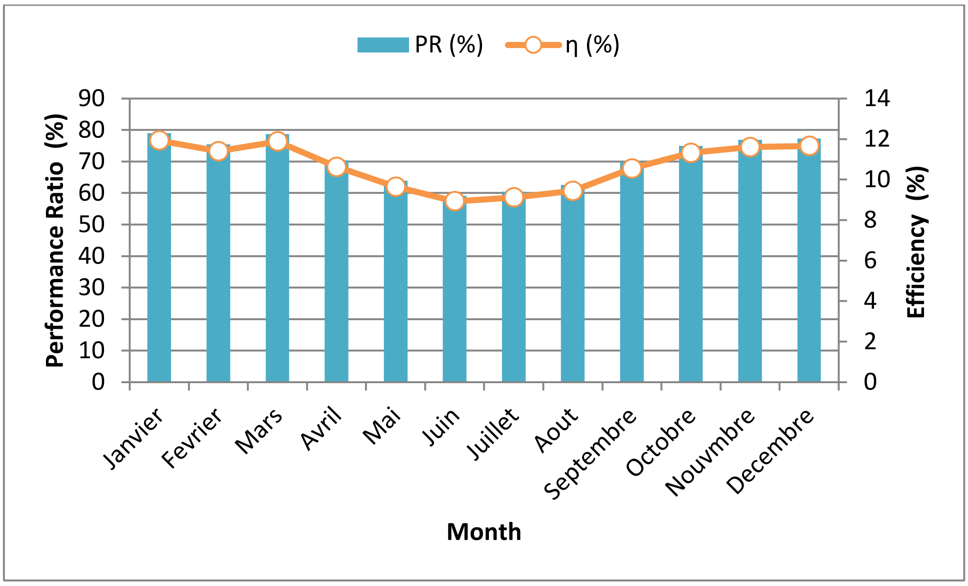

Figure7. Performance ratio and efficiency of the PV system for one year.

VI. Conclusion

In this work, a performance analysis study of a 20 MW PV system located in Adrar (southern Algeria) over the study period according to the actual climatic conditions of the site. The study provides a detailed analysis of the energy and electrical parameters of the PV system in a desert climate.

The solar radiation is varied during the day, reaching its maximum at 12 noon (12:00h) approximately 1000 W/m^2, its values are lower in the sunrise and sunset due to the decrease in the values of the height of the solar, with an increase in the hot months and a reduction in the cold months.On the other hand, we deduce that the performance and efficiency of the PV system are good for the winter season although the sunshine is less due to the temperature drops in winter by about 20°C while for the summer it exceeds 45°C. Increasing the temperature of the module further results in an increase in thermal energy destruction, thus reducing the performance of the module. In which the deviation of the overall annual average energy efficiency between winter and summer is about 3%, while the deviation of performance ratio with the real operating conditions of the photovoltaic system is around 9% between winter and summer. As can be seen, reduced energy efficiency occurs due to the generation of high thermal losses which depend on temperature and dust accumulation. Heat loss can be minimized by reducing the band gap between the p-layer and the n-layer of solar cells during manufacture or by controlling the temperature of the module which is done by bottom surface cooling.

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