Assessment performance parameters correlation of a grid-connected PV system

Salem Chabachi[1], Ammar Necaibia[2], Othmane Abdelkhalek[3], Ahmed Bouraiou[2]

[1]*Laboratoire de Développement Durable et Informatique LDDI, Faculté des Sciences et de la Technologie Université Ahmed Draia Adrar Algeria*

[2] *Unité de Recherche en Energies Renouvelables en Milieu Saharien (URERMS), (CDER), 01000, Adrar, Algeria*

[3]*Smart Grid and Renewable Energy Laboratory SGREL, Department of Electrical Engineering, University of Tahri Mohamed, Bechar, Algeria*

slm.chabachi@univ-adrar.edu.dz

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ABSTRACT

The primary objective of this examination is to show the impact of climate conditions on grid-connected photovoltaic (PV) framework execution introduced in the Saharan territory of south Algeria (Adrar). This area is described by high surrounding temperature in the late spring, solid sun-based insolation potential and low moistness rate. The information estimation was done in Zaouiet Kounta in different day by day climatic conditions (clear, shady and Dust storm day). The presentation assessment dependent on the checking of execution parameters, for example, last yield, reference yield, execution proportion and Framework proficiency. The got outcomes demonstrate that the framework execution predominantly influenced by the natural changes.

I. Introduction

Energy is one of major foundation of modern civilization prosperity and economic development, but as the world is growing in population, the demand for energy has increased significantly; the renewable energies have become an alternative solution to contribute in this development [1]. There are various forms of Renewable energies such as, solar, wind, hydro, tidal, biomass, geothermal, etc. Solar energy is one of the most prominent of these energies due to numerous reasons: abundance, pollution free and renewability for this it's considered as one of the most emerging technologies in field [2], [3] .

Many countries are nowadays changing their national energy policies to a green one, especially those who are heavily dependent on fossil energy and their economies are vulnerable to the impacts of fluctuating of oil price in the global market. Regardless of environmental benefits, there are many other advantages of renewable energy sources, such as the improvement of the social and economic level of sub developing countries.

The diverse availability of renewable sources has permitted various countries to pursue the most suitable type of renewable energy according to their potentials and energy sources sufficiency/wealth [4], [5].

In Algeria, solar energy is considered as a profuse source of renewable energy due to its geographical location and surface area which is the largest one in Africa in addition to the massive solar irradiation throughout the year especially in the south [6]–[8].

The main objective of this article is to exhibit and evaluate one-year performance of a 6 MWp grid connected photovoltaic system installed at the Zaouiet Kounta in the city of Adrar - Algeria without overestimating or underestimating. The meteorological conditions have a direct impact on the performance indices (Efficiency (PV array ηPV, Inverter ηinv and system ηsys). – Yield (PV array YA, reference YR and final YF). – Energy Losses (Array capture LC, system LS). – Performance Rate (PR),).

These performance indices, allow us to analyze and assess the behavior of the photovoltaic system (PVs). This assessment is used to support the increased level of propagation of grid-tied photovoltaic (PV) systems in the middle of Sahara south of Algeria.

II. Performance evaluation

To obtain an accurate and consistent assessment of grid-tied photovoltaic (PV) systems the International Electro Technical Commission (IEC) published the International standard **IEC standard 61724 [1]** performance parameters may be used to define the overall system performance with respect to the energy production, solar resource, and overall effect of system losses [2]. To analyze the performance of the grid connected PV system, the most appropriate and relevant performance parameters that define the whole system performances are efficiency (PV array $\boldsymbol{\eta_{PV}}$, Inverter $\boldsymbol{\eta_{inv}}$ and system $\boldsymbol{\eta_{sys}}$). – Yield (PV array **YA**, reference $\mathbf{Y_R}$ and final $\mathbf{Y_F}$). – Energy Losses (Array capture $\mathbf{L_C}$, system $\mathbf{L_S}$). – Performance Rate (**PR**) and capacity factor (**CF**)[3], [4]. The collected data during the assessment period of 12 months from January to December 2018.

<u>Energy output</u>

The total monthly AC energy output (kW h) $E_{AC,m}$ and monthly average daily total DC output (kW h) $E_{DC,m}$, delivered by the PV system are defined as [5], [6]:

$$E_{AC,m} = \sum_{d=1}^{n} E_{AC,d} \quad and \quad E_{DC,m} = \sum_{d=1}^{n} E_{DC,d} \qquad (1)$$

Where **n** is the number of days in the month.

<u>Yields Array, Reference and Final (Y_A, Y_R, Y_F)</u>

The expressions of Y_A,Y_R, Y_F are presented as below [7]:

$$Y_A = \frac{E_{DC}}{P_{PV.rate}} \qquad (2)$$

$$Y_R = \frac{H_t}{G_{STC}} \qquad (3)$$

$$Y_F = \frac{E_{AC}}{P_{PV.rate}} \qquad (4)$$

<u>PV array, Inverter and System efficiency</u> (η_{PV}, η_{inv}, η_{sys}) (%)

The PV system efficiencies are presents as well [8], [9]: PV array efficiency, inverter efficiency and system efficiency.

The monthly PV array conversion efficiency is defining as:

$$\eta_{PV} = \left(\frac{E_{DC}}{H_t A}\right) \times 100\% \quad (5)$$

The DC/AC inverter conversion efficiency is defining as:

$$\eta_{inv} = \left(\frac{E_{AC}}{E_{Dc}}\right) \times 100\% \quad (6)$$

The whole system efficiency is defining as:

$$\eta_{sys} = \left(\frac{E_{AC}}{H_t A}\right) \times 100\% \quad (7)$$

Performance Rate (PR) and Capacitor Factor CF (%)

$$PR = \frac{Y_F}{Y_R} \quad (8)$$

The capacity factor (CF) is defined as the ratio of the actual annual energy output to the amount of energy the PV system would generate if it operated at full rated power ($P_{PV,rated}$) for 24 h per day for a year and is given as [7],[10]:

$$CF = \frac{Y_{F,a}}{24*365} = \frac{E_{AC,a}}{P_{PV,rated}*8760} = \frac{H_t*PR}{P_{PV,rated}*8760} \quad (9)$$

Array capture, System and Temperature Losses (L_C, L_S, L_T) (h/d)

Array capture losses (L_C) are due to the PV array losses and are expressed as [11]:

$$L_C = Y_R - Y_A \quad (10)$$

System losses (L_S, L_T) generated by the inverter and are defined as:

$$L_S = Y_A - Y_F \quad (11)$$

$$L_T = Y_A\left(\frac{1}{\eta_{tem}} - 1\right) \quad (12)$$

and $\eta_{tem} = 1 - \beta(T_c - 25)$

Where

- $E_{DC,d}$: DC energy output (daily) of PV array (kW h).
- $P_{PV.rate}$: PV rate power (kW_p).
- $E_{AC,d}$: AC energy output (daily) of inverter (kW h).
- H_t : Total in-plane solar irradiation (kWh/m^2).
- G_{STC} : Total solar radiation under standard test condition (1 kW/m^2).
- A : Area of PV array (m^2).
- η_{tem} : The temperature loss coefficient
- Tc : The PV cell temperature and β is the temperature factor of the PV module.

III. Assessment and discussion

The performances of the 6MWp PV grid-connected system have been monitored over the entire year 2018. The solar irradiance and the PV module temperature are the most important parameters that directly control the amount of the output power as well as the generated energy. The total average monthly AC, DC energy generated by the inverter and array systems as well as the PV module temperature during all the months

Figure 1 shows the monthly average daily reference, array, and final yield of the Grid-connected system. The final yields and reference yields in March exceeded the ones all the months, which coincide between the wet and dry season in Adrar.

The highest values of the final and reference yields, which reached 5.74 kWh/kWp/day and 7.68 kWh/kWp/day, respectively, were observed in March. The lowest ones were observed in September (final yield 5.79 kWh/kWp/day and reference yield 3.98 kWh/kWp/day).

Table 1 shows monthly average of the weather parameters of solar radiation, average ambient air temperature, PV module temperature, wind speed and relative humidity between January and December 2015

Table 1. Monthly average daily weather parameters (2018)

	Solar radiance (KWH/m2)	Ambien temperature (C°)	Wind speed (m/s)	Relative humidity (%)
January	5.43	15.34	3.00	30.77
February	6.78	19.56	3.67	25.78
March	7.76	23.59	3.78	18.65
April	7.87	30.90	3.30	11.45
May	6.78	36.21	3.90	10.02
Jun	7.67	37.98	3.78	12.82
July	7.89	39.12	3.78	11.56
August	6.21	38.02	3.82	18.56
September	5.37	36.66	2.87	24.06
October	5.44	33.00	2.66	25.97
November	6.59	29.44	3.78	35.06
December	5.45	17.60	3.52	38.08

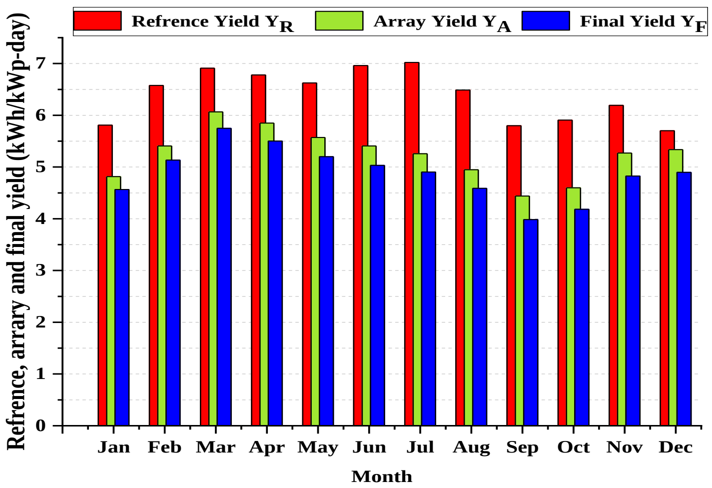

Fig. 1. Monthly daily average reference yield, array yield and final yield.

From figure 4 and 5 the energy generated (EAC) is strongly related to YF. On the other hand, the same figures show that the variation of the PV module temperature affect both EAC and YF, where it can clearly be seen that the variations of YR do not influenced by the PV module temperature variations, it's depended only by solar radiation [7], [12].

For a long-term forecast, the inverter efficiency system and its fitted curve are plotted as a function of the solar radiation, as shown in figure 2. The variations in inverter efficiency versus solar radiation for several months are exhibited as shown in the figure below when the inverter operates with a constant average efficiency 94.8% for a solar radiation is around 200 W/m2, otherwise the efficiency of the inverter decreases dramatically due to the drop in the density of solar radiation.

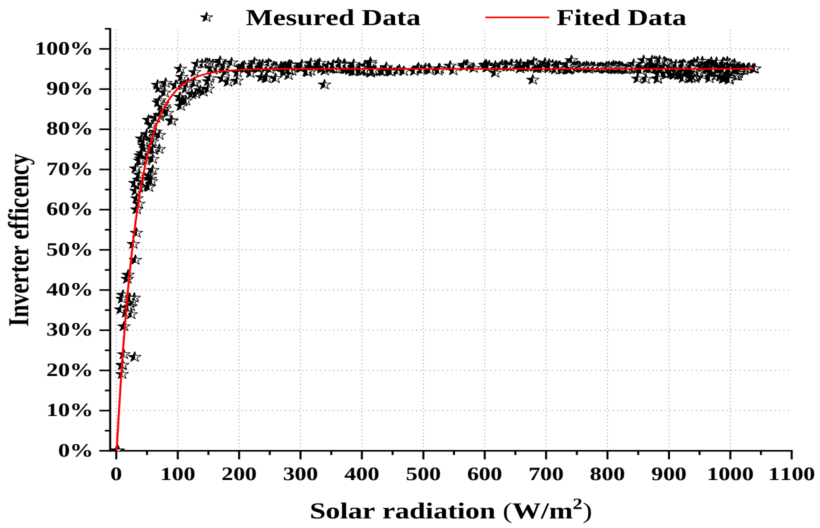

Fig. 2. Inverter efficiency versus solar radiation

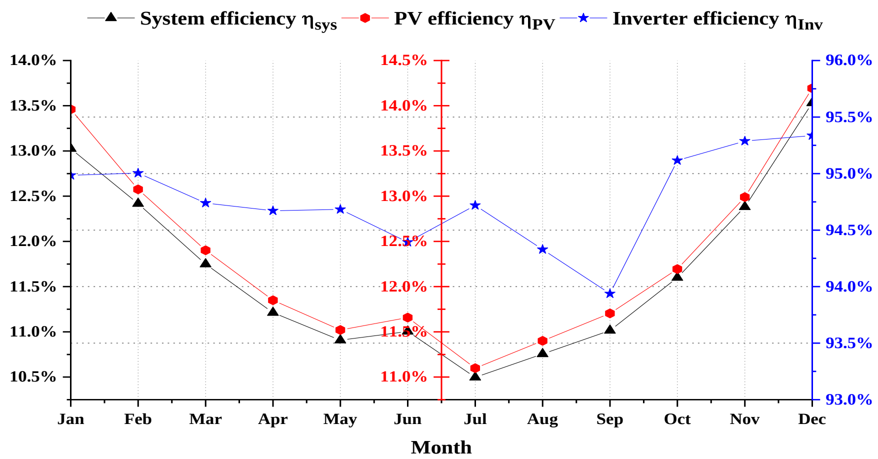

Fig. 3. Monthly average daily PV array, system and inverter sufficiency over a monitoring period.

Figure 3 shows the change in the efficiency of the PV array, inverter and the system within a full year. The results showed that the PV array and the system efficiency reached its maximum values in December, where they were 13% and 13.4% respectively, due to the availability of a significant radiation and low ambient temperature, which increased the performance of the system and the PV array.

The PV array and system efficiency reached the lowest values in July, where they were 11% and 11.2, respectively due to the high PV module temperature 49C°. As for the inverter efficiency is rarely affected by the ambient temperature but is directly related to the instability of solar radiation, which may be caused by the sandstorms [3]

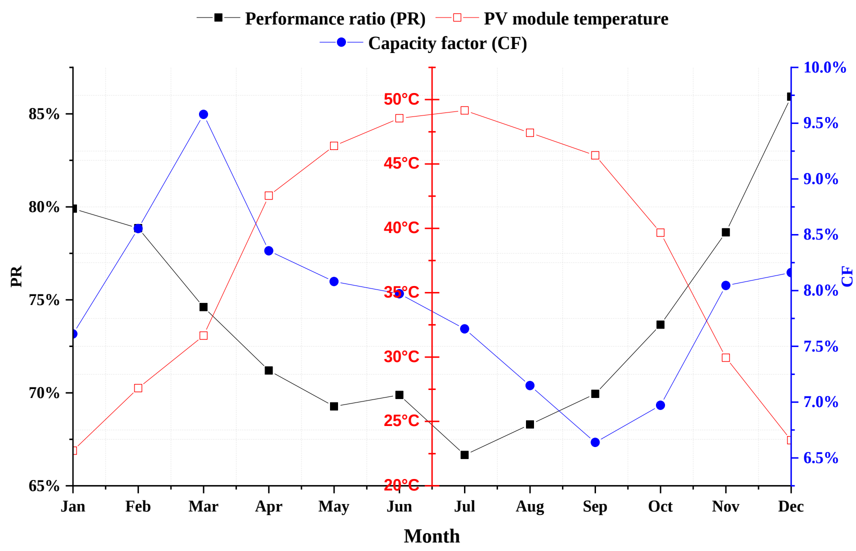

Fig. 4. Monthly average daily performance ration, capacity factor and the PV module temperature.

Figure 4 shows the results of monthly average daily performance ratio (PR), capacity factor (CF) and PV module temperature. The results indicated that the PR wide-ranging between 66.66% in July and 85.93% in December and the annual average value reach 73.82%. Meanwhile, the CF varied between 6.64% in September and 9.58% in March with an annual average value of 7.90% and these variations is inversely proportional to the PV module temperature [13].

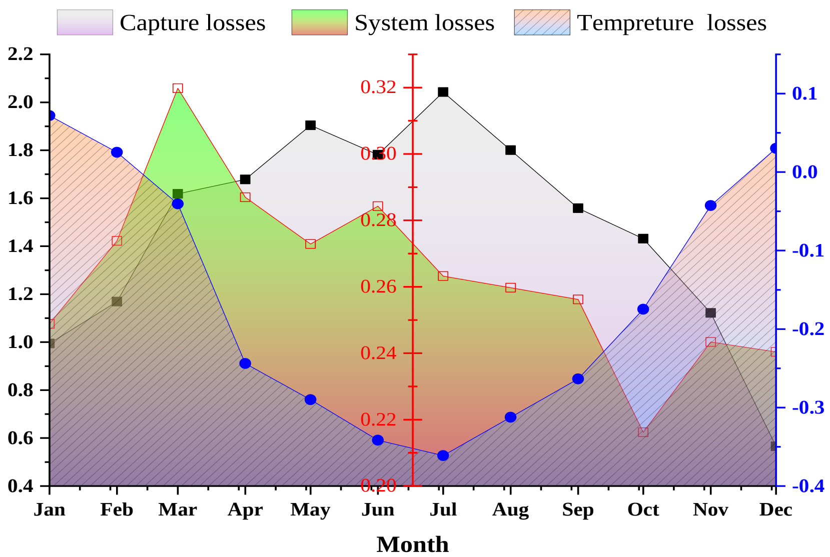

Fig. 5. Monthly daily average capture, system and temperature losses.

The monthly average daily capture, system and the temperature coefficients losses over the monitored period as shown in Fig. 5. The capture losses reached its maximum and minimum values 2 h/day, 0.56 h/day in n the month of July and December respectively. On the other hand, the temperature losses reached a minimum of -0.45 h/day in July and were the highest value in December and January [3], [14]
The climate in ADRAR is characterized by hot and dry seasons. The collected Data for one year are classed by seasons to facilitate the evaluation the performance of PV Grid-connected system installed in this region [9], [10].

The results in Table 2 allow us to understand better the relationship between some performance indices such as harvested energy and the final yield, which is a well correlated between them. Where there is a large production of energy in the spring season due to the large value of the final yield. On the contrary, the worst value was in the summer due to the high temperature, which was the cause of the performance deterioration of both solar panels and the system.

Table 2. Seasonally, average monthly energy generated, reference yield, array yield and final yield.

Months	Energy generated (kW h/kWp))	Reference yield (kW h/kW$_p$/day)	Array yield (kWh/kW$_p$/day)	Final yield (kWh/kW$_p$/day)
Winter	375.75	6.13	5.65	4.84
spring	420.55	6.53	5.99	5.23
summer	377.06	6.91	5.65	4.78
autumn	308.67	6.08	4.90	4.43

Table 2 shows the monthly, average daily variation in-plane solar insolation, ambient temperature, wind speed module temperature, PV module efficiency, system efficiency and inverter during four seasons. Low irradiation and ambient temperature in winter, a considerable radiation and ambient temperature in springer, a huge amount of solar radiation and maximum ambient temperature characterize these seasons in summer and unstable radiation and ambient temperature with an intermittent sandstorm in autumn [11], [12].

IV. Conclusion

The 6 MWp grid-connected PV system installed in the field of Zaouiet Kounta, in southern-west of Algeria (Adrar) was monitored in three days with different climatic condition (clear, cloudy and sandstorm). The performance parameters of the grid-connected PV system analyzed form the measured data, and the experimental results prove that the PV array, reference and final yield are proportional with the level of solar irradiance (increase/decrease). Based on the experimental results, the impact of these parameters on the performance of the grid connected PV system is discussed. A direct correlative relationship was found between energy production environmental parameters, where it is clear that the summer season did not have a large amount of energy, with a huge availability of solar radiation, compared to other seasons, and this is directly related to losses caused by the high temperature. The highest and worst values of annual average daily-generated energy was in spring and summer seasons respectively. Low values of temperatures and high levels of solar insolation during springer resulted in high final yield and efficiency system.

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