Comparative analysis of PVsyst and RETScreen simulations for a grid-connected photovoltaic system

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ABSTRACT

The use of solar energy in sunny countries is a promising way of compensating for the energy deficit. The benefits of this type of energy are not just economic, but also environmental, since it emits few greenhouse gases. NIGER, a vast landlocked country in the Sahel, has an average level of sunshine estimated at around 5 to 7 kW/m2/d for an average duration of 8.5 hours per day. However, the rate of access to electricity in Niger remains very low. As part of its policy to reduce the energy deficit, the State of Niger has built a 7MW photovoltaic solar power plant in the town of MALBAZA (TAHOUA). The aim of this study was to evaluate the effectiveness of the PVsyst and RETScreen software packages, which are widely used in the solar energy sector. The results of the various simulations were compared with the average of the experimental measurements collected over three years: 2019, 2020 and 2021. These results mainly concern parameters such as the capacity factor (CF), the performance ratio (PR) and the final yield Yf. Error matrices (MBE and NMBE) were used for validation. The plant supplied an average of 11995.94 MWh of energy to the grid during the monitoring period. We obtained a mean bias error (MBE) of 5.81% (PVsyst), and 0.14% (RETSceen) and a normalised mean bias error (NMBE) of 3.81% (PVsyst), and 0.27% (RETScreen).

Keywords: Simulation, Final yield, Capacity factor, Performance ratio, Statistical parameters.

1. INTRODUCTION

Energy is a fundamental element of human existence [1]. Global demand is growing rapidly. This is due to a galloping population and a lifestyle based on unbridled consumption [2], [3], [4]. Among energy sources, fossil fuels are the main source of electricity [5]. Not only do these so-called conventional energy sources have limited resources, but their exploitation and use are also the main causes of pollution on the planet. Faced with the programmed depletion of fossil fuels and their negative impact on the environment, renewable energies are emerging as the solution of the future for sustainably meeting the world's energy needs. [6], [7], [8]. Niger has a high level of sunshine throughout its territory, with peaks in the northern part.

Sunshine is fairly regular except in August, due to heavy rainfall. The average monthly values observed vary from 5 to 7 kWh/m² per day, and the average duration of sunshine is 8.5 hours per day [9], [10], [11], [12]. This represents significant potential for the development of solar energy in Niger. According to the SNAE (Stratégie Nationale d'Accès à l'Electricité), by 2020, access to electricity in Niger will be among the lowest in the sub-region, with an average rate of almost 16%, and most of this electricity will be imported from neighbouring Nigeria [13], [14]. To alleviate this problem, the State of Niger has built a 7MW solar photovoltaic power plant in the town of MALBAZA. In the study of photovoltaic systems, there are several simulation software packages widely used in their design, modelling or even in the prediction of energy production. This study therefore focuses on a comparative analysis of the efficiency of two prediction software packages, PVsysyt and RETScreen. The results obtained will then be compared with data measured on site using MBE and NMBE [15], [16], [17], [18].

2. MATERIAL AND METHODS

This study is based on measurements taken at the 7MW solar PV power plant located in MALBAZA, in the TAHOUA region of Niger (13°58'.54 N and 13°58'.54 E). Data were collected over a three-year period, from 2019 to 2021. Tables 1 and Tables 2 show the characteristics of the plant and its components. The data is recorded from an integrated data acquisition system, which monitors the main parameters of the PV system. Two PV system simulation software packages were evaluated in this work: PVSyst and RETScreen. The simulation results for solar irradiation and energy production from each of the software packages were compared with the average of the actual data collected. To simulate the performance of the photovoltaic installation using these different tools, specific data is required. Both software packages require similar data for the simulation. We therefore used data such as: the peak power to be installed (7MWp), the installation configuration parameters and the type of PV technology (monocrystalline). The procedure adopted is as follows:

- Enter the latitude and longitude of the selected site.
- The electrical characteristics of the PV system components and the technical specifications of the PV module installation are entered: tilt angle and azimuth, PV technology, PV power and system losses in percentage (%).
- The monthly energy production of the solar photovoltaic plant is directly estimated using these software tools.
- The following electrical parameters: final yield, capacity factor and performance ratio were calculated using Excel software.
- From the measured and estimated values, the mean bias error (MBE in %) and the normalised mean bias error (NMBE in %) were calculated.
- Charts comparing the various results obtained by the simulation and the measured monthly averages for the three years of data collection were plotted using Excel software.
- The statistical parameters MBE and MNBE were introduced for validation.

Table 1. Characteristics of the inverters and PV panels used.

Inverter specification	Value	PV Module Specifications	Value
Max Power DC	1200 kW	Rated power at STC	330 Wp
Max Input Voltage	1100 V	Module efficiency	17.07 %
MPP voltage range	600–850V	Max voltage (Vmpp)	36 V
Max Input Current	1710 A	Max current (Impp)	9.17 A
AC Power Range	1000 kW	Open circuit voltage (Voc)	45.6 V
Rated AC voltage range	160–280 V	Open circuit current (Isc)	9.65 A
Frequency	50 HZ	NOCT	46 ±◦C
Max output current	1445 A	Temperature coefficient at Pmax	−0.3845 %/◦C
Max. efficiency	98.30%	Temperature coefficient at Voc	−0.2941 %/◦C
Weight	61 kg	Temperature coefficient at Isc	0.0681 %/◦C

Table 2. Characteristics of the MALBAZA PV plant.

N°	Parameter	Value
1	Rated power at STC	7MW
2	Number of PV modules	21231
3	Number of inverters	7
4	Number of modules in series/strings	42
5	Number of strings	1011
6	Number of strings/inverters	144
7	Output voltage	3 phases 415V AC

2.1 Final energy yield Yf, capacity factor FC and performance ratio PR

The final energy yield Yf : this is the ratio of the net energy produced by the power plant to the nominal power of the solar PV array. It represents the total time during which the PV array would have to operate at its rated power in order to supply the same energy. It is expressed in kWh/kWp or in hours. Its expression is given by equation (1) [11], [19].

$$Y_f = \frac{Eac}{Po} \quad (1)$$

Eac: the total energy produced (MWh) and Po, the installed peak power (MW), considered equal to 7MW in this case.

The capacity factor (CF) : this represents the ratio between the actual production of electrical energy over a given period and the maximum electrical energy that can be produced over this period. It is expressed as a percentage (%) and is calculated from the following relationship (2) [20], [21], [22] :

$$\mathrm{FC} = \frac{Y_f}{operatingtime} \quad (\%) \quad (2)$$

Performance ratio (PR) : this is the parameter that illustrates the long-term effect of losses on solar energy production. It is calculated monthly or annually and depends on the temperature of the PV modules. Its value varies from one season to another depending on solar irradiation. The PR is calculated by equation (3) [11], [22], [19] :

$$PR = \frac{Y_f}{I_{po} * A} \quad (3)$$

Where :

PR is the value of the performance ratio expressed as a percentage (%), Yf, the final yield, Ipo, the value of the irradiation measured on the plane of the panels and A, the total area of the PV fields, considered equal to 41177m².

2.2 Mean bias error (MBE) and normalised normal bias error (MNBE)

To assess the difference between the simulation results obtained and the results of the actual measurements, the mean bias error (MBE) and the normalised mean bias error (MNBE) were calculated.

The mean bias error indicates the difference between the measured values and the theoretical values estimated by the tools. The normalised mean bias error indicates whether the frame is overestimated or underestimated. Both parameters are calculated using equations (4) and (5) [20], [9].

$$MBE = \frac{\text{Estimated value} - \text{measured value}}{\text{Measured value}} \quad (\%) \quad (4)$$

$$MNBE = \frac{\text{Estimated value} - \text{measured valueé } e}{\text{Maximum measured value}} (\%) \quad (5)$$

3. RESULTS AND DISCUSSION

Many studies have already shown that the meteorological parameters of the site are important parameters that greatly influence the operation of the system. Solar irradiation is the main one [23], [24]. In this study, a simulation of the grid-connected 7 MWp solar PV plant installed in MALBAZA is carried out using the PVsyst and RETScreen tools. The results are then compared with actual measurement data from the plant. Figure 1 shows the evolution of the monthly average for the years 2019, 2020 and 2021 of solar irradiation at the site and the values predicted by the software. It has been calculated that October is the month in which the data from PVsyst, RETScreen and the power plant are closest to each other, and the difference in irradiation values is around 5 kWh/m² between the data. Apart from this, there is a better approximation between the two software packages.

Results should be clearly described in a concise manner. Results for different parameters should be described under subheadings or in separate paragraph. Table or figure numbers should be mentioned in parentheses for better understanding.

The discussion should not repeat the results, but provide detailed interpretation of data. This should interpret the significance of the findings of the work. Citations should be given in support of the findings. The results and discussion part can also be described as separate, if appropriate.

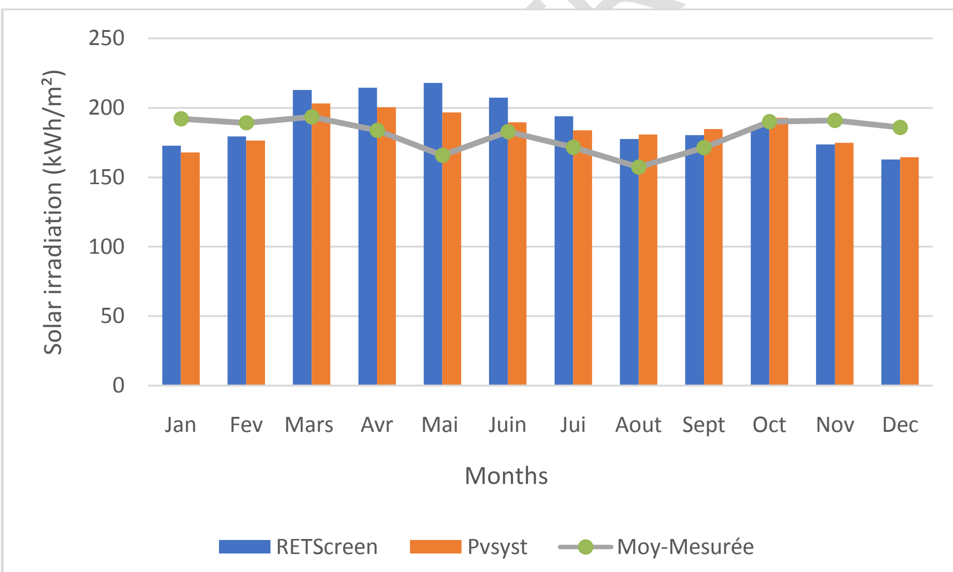

Fig. 1 : Simulated monthly irradiance and average irradiance measured from 2019 to 2021.

The monthly and annual electricity production values obtained from the simulations using the PVsyst and RETScreen programs were compared with the actual power plant values on a monthly and annual basis. The comparison of electricity production data from PVsyst, RETScreen and the power plant is presented in Table 3.

Table 3: Annual energy measured during the years 2019, 2020 and 2021 and the energy predicted by the different software.

Mois	Measured energy (MWh)	Simulated energy (MWh)

	2019	2020	2021	Moyenne	RETScreen	PVsyst
January	1101,7	1 041	1169,35	1104,02	993,77	1067,00
February	1064,4	1 111	984,20	1053,20	999,41	1071,00
March	993,6	1 144	1078,40	1072,00	1117,19	1163,00
April	998	943,2	975,15	972,12	1068,63	1089,00
May	888,1	949,8	975,15	937,68	1057,15	1038,00
Jun	1007,7	949,6	992,50	983,27	1001,87	1001,00
July	987,9	928,7	1048,60	988,40	965,66	987,00
August	861,7	869,3	976,59	902,53	915,51	1003,00
September	1011,1	915	1037,83	987,98	947,33	1053,00
October	1015,2	1 075,80	1028,64	1039,88	1014,18	1136,00
November	1081	1039,7	958,46	1026,39	991,09	1085,00
Décember	989	1041,25	756,00	928,75	960,47	1051,00
Annual	11998,8	12 008,15	11980,88	11995,94	12032,26	12746,00

It has been calculated that July is the month in which the PVsyst and power plant data are closest to each other, and that there is a difference in electricity production of approximately 1.4 kWh between the two data. The month for which the greatest difference between the two data was observed was December. The difference between the two data for this month is 122.25 kWh. It was observed that the measurement data are closer to the production data obtained from the RETScreen software. The difference in electricity production value between the two data is approximately 119.47 kWh. This difference, the most significant between the data, occurred in the month of May, and is followed by that of January, which is approximately 110.25 kWh. Generally speaking, the electricity production values obtained from the PVsyst and RETScreen software are very close to each other. The most significant difference in electricity production is observed during the months of September and October. Apart from these observations, there is good agreement between the experimental measurements and the theoretical values. The comparison of electricity production data from PVsyst, RETScreen and the power plants is presented graphically in Figure 3.

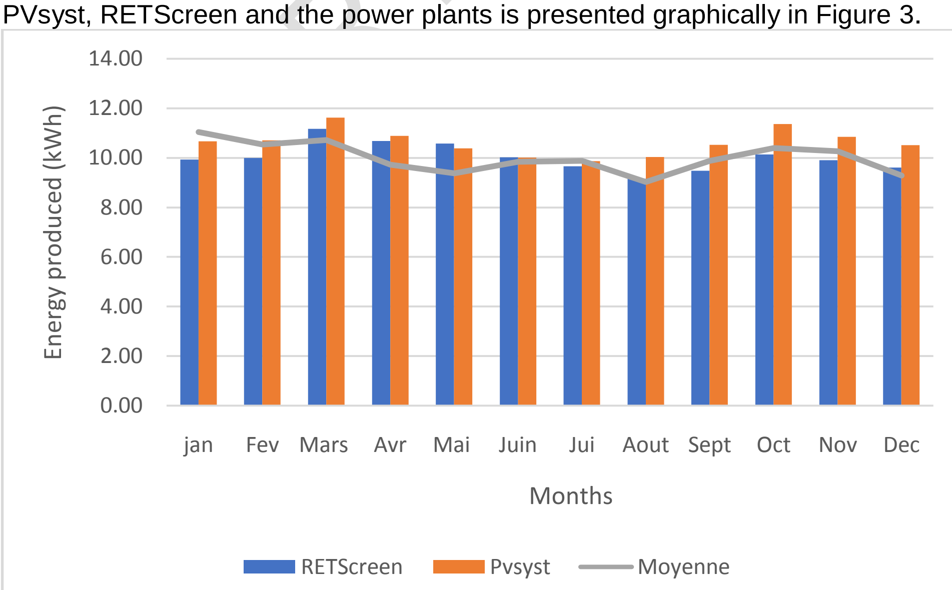

Fig. 2: Simulated monthly energy and average energy measured from 2019 to 2021.

Over the three years, the plant produced an average energy of 11995.94 MWh, with the PVsyst and RETScreen software providing annual values of 12746.00 MWh and 12032.26 MWh respectively.

In order to assess the differences between the measured values and the estimated values, mean bias errors (MBE) and standardised mean bias errors (MNBE) were introduced. These values are shown in Table 4. Negative MBE and NMBE values indicate periods when the software underestimated the energy produced. The lower these values are, the better the agreement between them. The annual average MBE is 5.81% (PVsyst) and 0.14% (RETScreen). Similarly, the annual average NMBE is 5.64% (PVsyst) and 0.27% (RETScreen). It can be seen that the MBE and MNBE values of the PVsyst tool are higher in December and negative in January and July. For the RETScreen, the highest MBE and MNBE values are observed in May and the lowest values in January.

Table 4: MBE and MNBE values calculated.

	RETSceen		Pvsyst	
Mois	MBE	NMBE	MBE	NMBE
January	-11,09	-9,99	-3,47	-3,35
February	-5,38	-4,87	1,66	1,61
March	4,04	4,09	7,82	8,24
April	9,03	8,74	10,73	10,59
May	11,30	10,82	9,66	9,09
June	1,86	1,69	1,77	1,61
July	-2,36	-2,06	-0,14	-0,13
August	1,42	1,18	10,02	9,10
September	-4,29	-3,68	6,18	5,89
October	-2,53	-2,33	8,46	8,71
November	-3,56	-3,20	5,40	5,31
December	3,30	2,87	11,63	11,07
Year	0,14	0,27	5,81	5,64

To give a further comparative assessment of measured and predicted production, we have calculated the annual results for solar irradiation, final energy yield (Yf), capacity factor (CF) and performance ratio (PR). The annual results are shown in Table 5.

Table 5: Annual results for solar irradiation

Parameters	RETScreen	PVsyst	Measure
Annual irradiation (kW/m²)	2280,22	2215.8	2172,80
Annual energy produced (kWh/year)	12032,26	12746,00	11995,94
Final yield (kWh/kWp)	1718,89	1820,57	1716,95
Capacity factor (%)	16,35	20,36	19,48
Performance ratio (%)	71,04	79,50	76,27

4. CONCLUSION

For the most appropriate design and analysis of photovoltaic systems, various programs are used in the solar energy industry. These programs are used to predict the energy production and economic gains of PV systems using meteorological data. In this study, a simulation of the grid-connected 7MWp PV system installed in MALBAZA was carried out using PVsyst and RETScreen software. Energy production was monitored for three years, from 2019 to 2021. The simulation results obtained are compared with actual data in terms of annual irradiation, annual photovoltaic energy production, final yield, capacity factor and performance ratio. After a detailed case study, the following conclusions are drawn:

- The predicted energy using both PVsyst and RETScreen simulation software is 12032.26 MWh 12746.00 MWh respectively.
- The annual energy production at the current location of the solar PV plant is 11995.94 MWh, according to the monitoring database.
- The measured performance ratio is approximately 76.27% compared to 79.50% and 71.04% estimated by PVsyst and RETScreen respectively.
- Both PVsyst and RETScreen estimated the final yield at 1820.57 kWh/kWp and 1718.89 kWh/kWp respectively and the measured final yield is 1716.96 kWh/kWp.
- The experimental capacity factor is approximately 19.48%, compared with 20.36%, 16.35% and 16.48% estimated by the PVsyst and RETScreen software respectively.
- The comparative study shows that the annual average MBE varies from 0.14% (RETScreen) to 5.81% (PVsyst) and that the average NMBE varies from 0.27% (RETScreen) to 5.64% (PVsyst).

According to the results of the comparison, RETScreen can be considered the most reliable software in this case study. However, PVsyst and PVGIS have low errors and can be suggested.

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