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COMPARISON OF THE RELIABILITY OF MONO/POLY-CRYSTALLINE SILICON OF PV SOLAR MODULES IN A HOT ENVIRONMENT (ZAOUIET KOUNTA)

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This research presents a comprehensive model and simulation of a 6 MW solar photovoltaic grid-connected facility located in the town and commune of Zaouiet Kounta, Adrar Province, and southwest Algeria. As the paper demonstrates, a comparison is made between mono-crystalline and polycrystalline solar modules and their performance in a hot climate. The PVsyst7 software program was used to investigate the system's performance ratio as well as the various types of losses that occur inside the system, and the system's viability as measured by the number of CO_2 emissions from a solar installation.

Keywords: Pvsyst software, Grid-connected, PV system, Performance ratio, Mon-Si, Poly-Si

1. Introduction

Sustainable development, development, and utilization of renewable, clean energy are important directions to take to solve these problems, which is one of the reasons why the Algerian government has prepared a programmer for the development of renewable energies, in particular photovoltaic solar energy, with a total installed capacity of 540MW by the end of 2022[1]. The expansion in the number of PV systems deployed on a global scale has necessitated the development of supervision and control algorithms [2], as well as design and simulation tools for researchers and engineers working on these applications. Among the several techniques for PV system design and simulation that exist today [3], the most common tools are commercially available programmers that aid in the design of PV systems, such as PV-Sol [4], Homer Pro [5], RET-screen [6], and PV-sys [7]. These tools provide a sound methodology for the design and operation of PV systems under various scenarios. This study describes the modeling of a 6 MWp grid-

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connected PV system erected in the difficult Sahara climate of Zaouiet Kounta, Algeria's south. The simulation is performed using the software PVsyst 7.1 selecting the right rating for PV panels and inverters, the tilting angle of PV panels, solar azimuth selection, shading calculation, loss calculation, performance, and technical assessment are all necessary steps in designing the overall system. Designing a grid-connected system in PVsyst7.1 involves the following fundamental steps: establishing the location and meteorological data for the project and specifying the module's azimuth and tilt for orientation. System-choose the system modules, inverters, and electrical design, and provide specifics Losses—mismatch is adjusted to 0% for a grid-connected system by checking a summary of the system's energy production after the simulation. [7].

The plant at Zaouiet Kounta has a total capacity of 6 MWp and was erected there. The facility consists of six arrays linked to inverters, and the provided electricity is transmitted at 30 kW. This article compares the performance and efficiency of monocrystalline and polycrystalline solar modules in hot climates. Polycrystalline solar modules have a greater temperature coefficient than monocrystalline solar modules, suggesting a somewhat worse heat tolerance than monocrystalline solar modules. This indicates that the output decreases less as the temperature of the panel rises. Typically, the efficiency of polycrystalline solar panels ranges from 14 to 16%, resulting in reduced space efficiency.

In the case of polycrystalline panels, more area is required to provide the same amount of output power as mono-crystalline panels. [8] The examination and comparison of solar photovoltaic (PV) technologies assist in determining their appropriateness for a particular site. The primary purpose of this research is to evaluate the applicability of mono-crystalline silicon (Mono-Si) and poly-crystalline silicon (Poly-Si) PV modules with almost identical characteristics in the Zaouiet-Kounta climate. [9] Temperature, global irradiance, wind speed, and dust density are among the parameters that impact the performance of a solar cell in outdoor operation. The reduction in module electric power output is caused by a rise in module temperature. In the PV power plant design, it is determined that the output power of mono-Si PV modules is larger. During March, the PV plant produced and injected extra electricity into the grid, amounting to 15,800 kWh. December had the lowest quantity of energy pumped into the system, at 1,106 kilowatt-hours. The annual average final yield (Yf) is calculated to be 5.52 kWh/kWp/day for mono-Si PV systems and 5.46 kWh/kWp/day for poly-Si PV systems. The performance ratios (PR) for mc-Si and poly-Si photovoltaic (PV) systems are 0.801 and 0.793, respectively.

2. Methodology for PVsyst simulation :

System Design and Objectives: The overall goal in constructing a solar power plant is to match the plant's capabilities to the load needs of the customer at the lowest possible cost to the consumer. To do this, the designer will need to know the answers to the following system-related questions: (1) Power Requirements, (2) Solar Data Availability, (3) Type and Size of Solar Power Plant Needed, (4) Cost of Energy Produced, (5) Solar Power Viability, (6) System Characteristics, (7) System Requirement, (8) Evaluation Criteria, (9) Design Optimization, (10) Economic Viability, and (11) Cost Reduction Prospects. The PVsyst software simulation method is shown in a flowchart in Fig. 1. PVsyst is a simulation program that was created in Geneva and aids in estimating the operation and functioning of PV systems [7]. PVsyst software gives accurate results for inverter and PV panel sizing. Solar isolation or irradiance, ambient temperature, wind speed, and the physical characteristics of PV panels must be used in conjunction with the PVsyst software and real-time physical data to execute simulations. Additionally, the longitude and latitude information are crucial factors in determining the sun's irradiance measurement. PVSYST is a well-designed program that incorporates an enormous database of PV-related items and a large number of capabilities for describing the PV system.

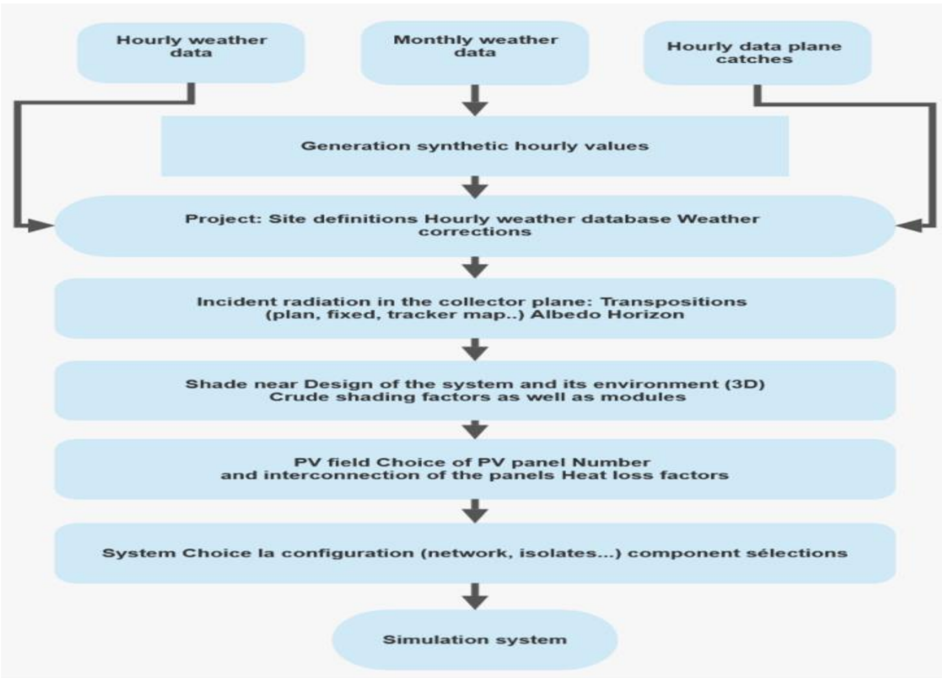

Fig. 1. PVsyst simulation process flowchart

PVSYST has algorithms for calculating temperature and wind impacts, wire losses and incidence angle modifier losses, albedo values, and horizon correction. Numerous comparison studies [10, 11–12] have awarded this program very excellent ratings and recommendations.

Meteonorm and NASA-SSE are sources of meteorological and global irradiance data imported by PVSYST. Additionally, other external datasets may be included in the analysis. PVsyst incorporates theoretical models for the computation of both global and diffuse irradiation on an inclined plane [13, 14]. The PVsyst program is a PV system design and simulation tool that gives inverter and PV panel sizing such that the selected inverter and PV panel are neither undersized nor oversized.

The PVsyst program has a comprehensive collection of meteorological data for the whole globe, and it also allows for the manual entry of data that is not included in the database. To acquire the sizing, correct design, and technical and economic assessment of the PV system, we must submit all the inputs required by the program, such as (i) location (ii) tilting angle (iii) azimuth angle (iv) PV module and inverter specifications (v) shading, etc. The simulation output parameters of the PVsyst program are as follows: (1) Meteorological data; (2) efficiency and varied losses; (3) efficiency ratio; (4) energy production equilibrium; (5) financial evaluation, etc. [15]

3. Solar PV Plant Overview of Zaouiet-Kounta

3.1 Description

Using PVsyst 7 modeling software, inverters, and photovoltaic panels are sized appropriately. The Zaouiet kounta Solar Power Station is not shaded. The image of the Google map of the Zaouiet kounta Solar Power Station is shown in Fig. 2. The coordinates for the Zaouiet Kounta Solar Power Station are 27.24 degrees north latitude and -0.17 degrees west longitude.

Fig. 2. Location of Zaouiet Kounta Solar Power Station via Google map.

3.2 Configuration System

The facility uses 24,552 solar panels, as seen in Fig. 3. It features 12 inverters for converting DC to AC, each with a 500 kW capacity (Sungrow; model number SG500MX). The facility also features six transformers (type SCLB10-1250/30/2 0/315, manufactured by SUNTEN). The produced electricity is then sent to the grid.

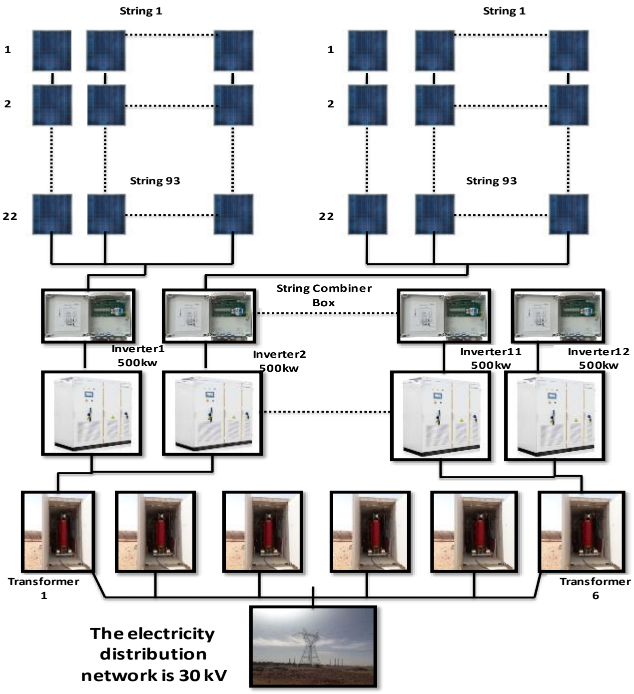

Fig.3. Schematic of a 6 MWp grid-connected PV facility

3.3 Solar PV Technology

The photovoltaic module is the most essential component of a grid-connected PV system since it converts solar radiation energy into electrical energy. Connecting several PV modules to build a solar array increases the output power. The PV array must be adequately scaled to fulfill the annual load. In our investigation, the YL245P-29b PV module from Yingli Solar was used. Table1 displays the photovoltaic panel's specifications.

Table 1

Solar Panel SpecificationKounta

Maximum Power (P_{max})	245 W
Maximum Power Voltage (V_{mp})	30 V

Maximum Power curent (I_{mp})	8,18 A
Open Circuit Voltage (Voc)	37,5 V
Short Circuit Current (Isc)	8,17 A
Type	Poly crystalline
Number of modules	24552
Efficiency	15%
Area of single panel	1.633 m²
Tilt angle of PV Module (°)	26
Azimuth angle of PV Module (°)	0
Mounting	Fixed Type

4. Solar horizon

Fig. 4 depicts the solar horizon simulation for the Zaouiet Kounta Solar Power Station. To run the simulation, it is assumed that the PV panels are slanted to face true south at an angle of 26 degrees and that the solar azimuth is always at zero. The 22nd of June sees the sun at its zenith, while the 22nd of December sees it at its nadir.

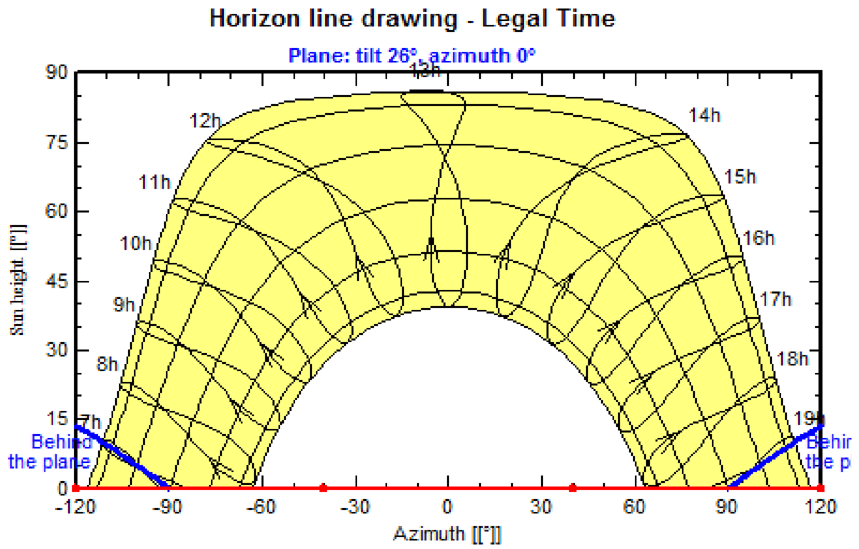

Fig. 4. Solar horizon for Zaouiet Kounta estimated by the PVsyst software

5. Performance Analysis:

Performance measurements determine a photovoltaic (PV) system's effectiveness. PVsyst uses these equations to determine yield, performance, and losses..

5.1. Reference yield (Yr) :

The reference yield is the ratio of the total solar radiation (Ht) absorbed by the solar module plane over a specific period, usually a day (measured in kWh/m².day), to the reference solar irradiation (G0) at a given location (standardized to 1 kW/m²). This ratio indicates the maximum possible daily sun hours that a solar plant could receive at that location. The field orientation of the site and the prevailing weather conditions significantly influence the reference yield (YR). The reference yield is expressed as hours per day (h/d) because the total in-plane solar radiation is measured in kWh/m²/day. [16]

$$Y_r = \frac{H_t}{G_0} \quad \text{in (h/d)} \tag{1}$$

5.2. Array yield (Ya) :

It is the ratio of the PV array's energy generated (EDC, in kWh) over a fixed period (annual, monthly, or daily) to the rated DC capacity to its nominal power (Po, in kWp) under standard conditions. [17]

$$Y_a = \frac{E_{DC}}{P_0} \quad \text{in (h/d)} \tag{2}$$

5.3. Final yield (Yf) :

The final yield (Yf) is the usable AC energy (EAC) in kWh. over a fixed period (annual, monthly, or daily) divided by the nominal power (Po) in kWp during a specific time. [18] [19]

$$Y_f = \frac{E_{AC}}{P_0} \quad \text{in (h/d)} \tag{3}$$

5.4. Performance ratio (PR)

A solar power plant's efficiency is determined by its performance ratio (PR). The PR is often expressed as a percentage and is used to compare PV systems installed at various locations. The PR is defined by the relationship between the final yield and the reference yield. [20] [21]

$$PR = \frac{Y_f}{Y_r} \tag{4}$$

5.5. Array capture losses (Lc) : The difference between the reference yield (Yr) and the array yield (Ya) is known as the array capture losses (Lc). [22]

$$L_c = Y_r - Y_a \quad \text{in (h/d)} \tag{5}$$

5.6. System losses (LS) : The difference between the yield of the array and the final yield. [22]

$$L_s = Y_a - Y_f \qquad \text{in (h/d)} \qquad (6)$$

6. Results and Analysis : The PVSYST program is the foundation of this study. This program was used for modeling purposes. All of the figures and tables in this study were created during the simulation process for Zaouiet Kounta site.

Data such as irradiance, ambient temperature, module temperature, and wind speed are relevant. Solar radiation is higher during spring, summer, and autumn (March to October) and lower during winter (November to February), as shown in Fig. 5.

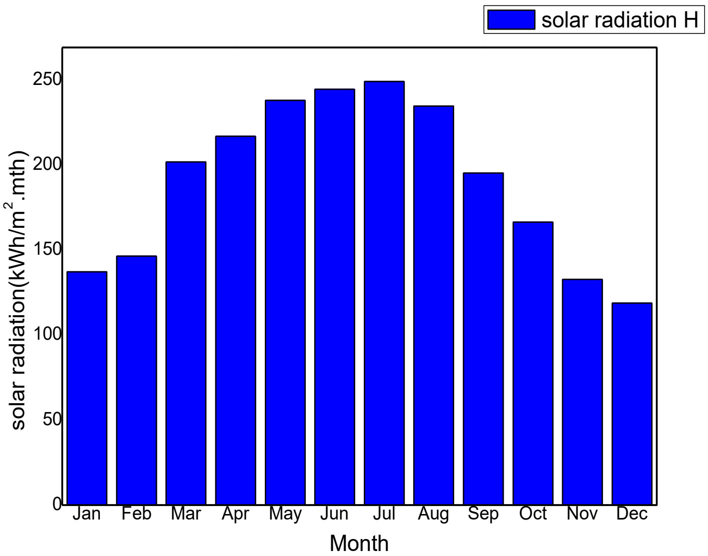

Fig. 5. Monthly variation of daily average ambient and solar radiation (H) in 2020

Fig. 6 shows monthly changes in the average daily ambient temperature and wind speed. The mean temperature varies from 12.4°C in January to 36°C in July. The latter ranges from a low of 5.7 meters per second in November to a high of 6.8 meters per second in May.

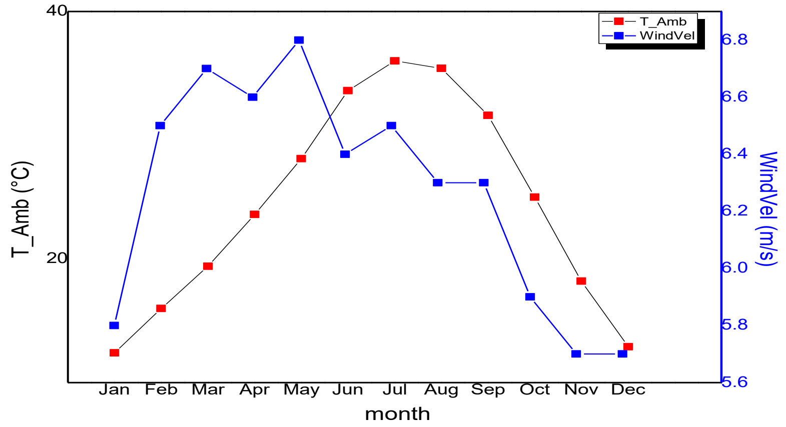

Fig. 6. Monthly variation of daily average ambient temperature, temperature, and wind speed.

Table 2

Parameters of average monthly weather and total energy produced in 2020(p-Si and m-Si PV modules)

	T_amb °C 2020	*GlobHor kWh/m².mth*	*GlobInc kWh/m².mth*	*GlobEff kWh/m².mth*	*EArray kWh (2020)*		*E_Grid kWh (2020)*		*PR Ratio (2020)*	
					Poly-Si	Mono-Si	Poly-Si	Mono-Si	Poly-Si	Mono-Si
Jan	12,4	137	198,1	193,5	1028958	1036631	1017565	1025142	0,854	0,86
Feb	16	146,2	189,6	185,4	959458	967672	948571	956682	0,832	0,839
Mar	19,4	201,5	232,5	227,1	1140929	1152221	1127791	1138941	0,806	0,814
Apr	23,6	216,6	221,7	216	1067500	1078419	1055421	1066194	0,792	0,8
May	28,1	237,8	221,8	215,4	1047282	1058615	1034291	1045525	0,775	0,784
Jun	33,6	244,2	216,8	210,1	994915	1006556	982536	994087	0,753	0,762
Jul	36	248,9	226,1	219,3	1022821	1035527	1010116	1022713	0,743	0,752
Aug	35,4	234,4	230,4	224,2	1042577	1055757	1030547	1043564	0,743	0,753
Sep	31,6	195	214,2	209	995728	1007201	984421	995748	0,764	0,773
Oct	25	166,2	205,4	200,8	994180	1004127	982836	992664	0,796	0,804
Nov	18,2	132,6	184,6	180,4	936561	944097	925988	933438	0,834	0,841
Dec	12,9	118,7	172,9	168,7	904816	911252	894766	901124	0,861	0,867
Year	24,3	2279,1	2513,9	2450	12135725	12258077	11994848	12115824	0,793	0,801

In relation to a solar panel system, Table 2 provides important information and results: irradiation from space in the horizontal plane (GlobHor), average air temperature (T amb), and Global irradiation in the collection plane (GlobInc), after transposition but without any optical corrections (often referred to as POA for Plane of Array), and effective global irradiation on the collectors (GlobEff), that is, after optical losses (far and near shadings, soiling losses), After losses associated with the inverter and the AC wire, energy generated by the PV array (EArray) input of the inverters is injected into the grid (E_Grid).

6.1 Standardized Productions :

Figs. 7 and 8 illustrate the monthly fluctuation of the average daily final yield, thermal capture losses, and system losses for the p-Si and m-Si modules. The p-Si modules' monthly average daily value of final yield was 4.8 h/d (1752hours/year) in December and 6.05 h/d (2208.25hours/year) in March, with a yearly average of 5.46 h/d (1992.9 hours/year) . In December and March, the equivalent numbers for the m-Si modules were 4.83 h/d(1762.95 hours/year) and 6.11 h/d(2230.45 hours/year) , with an annual average of 5.52 h/d (2014.8 hours/year) .

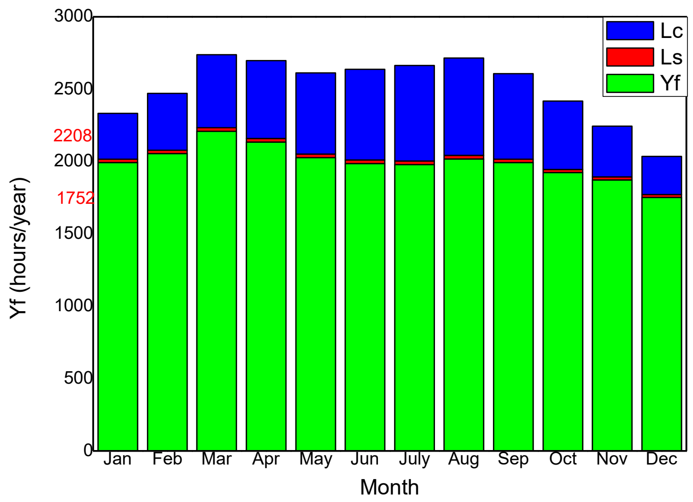

Fig.7: Monthly variation of daily average PV array capture losses (Lc), system losses (LS) and final yield (YF) for Poly-Si modules estimated by the PVsyst

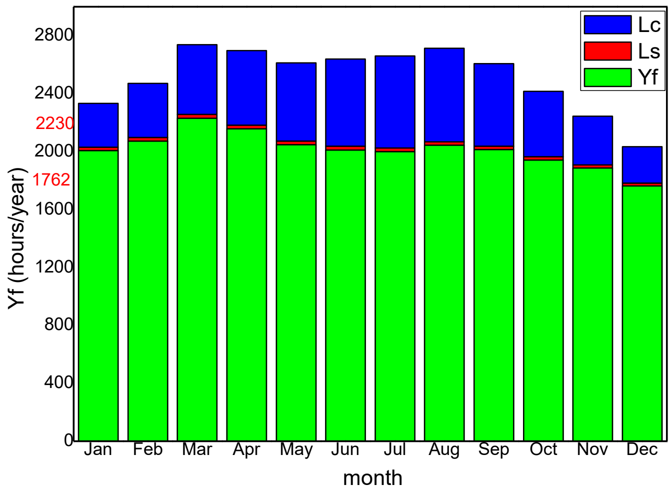

Fig. 8: Monthly variation of daily average PV array capture losses (Lc), system losses (LS), and final yield (YF) for mono-Si modules estimated by the PVsyst

6.2 Ratio of performance :

The efficiency of a PV system is in large part calculated by the performance ratio. It is the sum of the effects of array temperature losses on the rated output of the array while it is operating at less than 100% capacity. In Fig. 9, we can see how p-Si modules compare to m-Si ones in terms of performance.

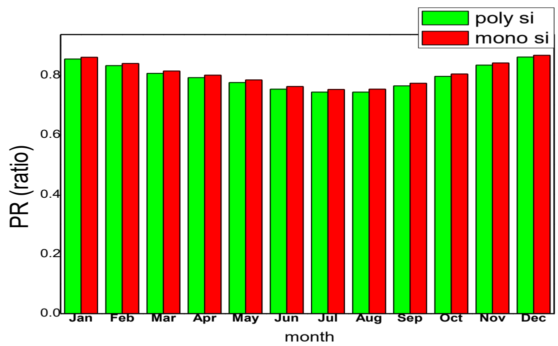

Fig. 9: Monthly average performance ratio of p-Si and m-Si PV modules estimated by the PVsyst

The efficiency ratio for p-Si modules was between 74.3 and 86.3 percent in July and August. There was typically a 79.3 percent annual performance ratio. The efficiency of m-Si modules in July ranged from 75.2% to 86.7%. The stated annual performance ratio averaged 80.1%. When both the atmospheric and module temperatures are higher (as they are in the summer), the performance ratio decreases on average than it is in the autumn and winter.

6.3 Energy Injections to the Grid : Energy added to the grid and energy produced by the PV array cannot be the same. To feed the grid [23], the DC energy from the PV array must be transformed into AC energy. During this period, some energy is wasted due to AC wire loss. The planned 6 MWp solar plant injects 11994848 kWh and 12115824 kWh in 2020 into the grid using Poly-Si and Mono-Si modules, respectively. During March 2020, the PV facility produced and added 1127791 kWh of extra electricity to the grid. The month of December 2020 has the lowest quantity of AC energy fed into the grid, with 894766 kWh. Fig. 10 shows the information on the AC energy that is injected into the grid for Poly-Si modules and Poly-Si modules in 2020.

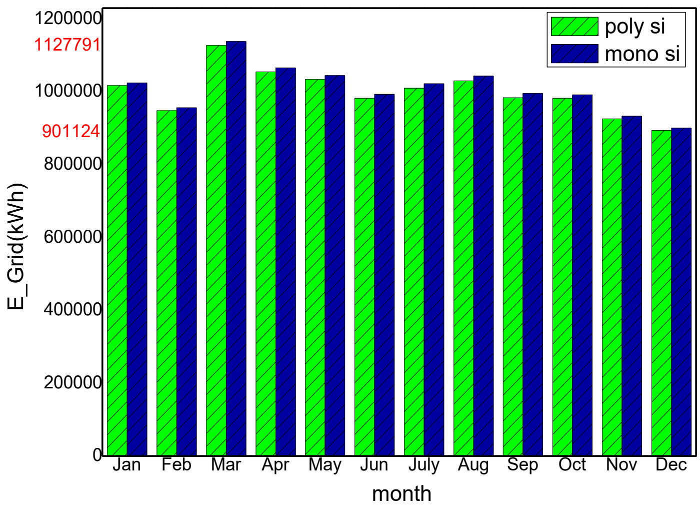

Fig. 10: Monthly average Energy injected into the grid of p-Si and m-Si PV modules estimated by the PVsyst

6.4 Arrow loss diagram

Figs. 11 and 12 show the yearly loss diagrams for poly-Si and mono-Si solar systems in 2020. The two figures were generated using the PVsyst programme.. Global horizontal irradiation is 2279,1 kWh/m^2. 2450 kWh/m^2 is the effective irradiation on the collecting plane. After PV conversion, solar energy is converted into electricity by the PV cell. Poly-Si PV modules have a nominal array energy output of 14743 MWh in 2020. Under Standard Test Conditions, the PV array efficiency is 15%.

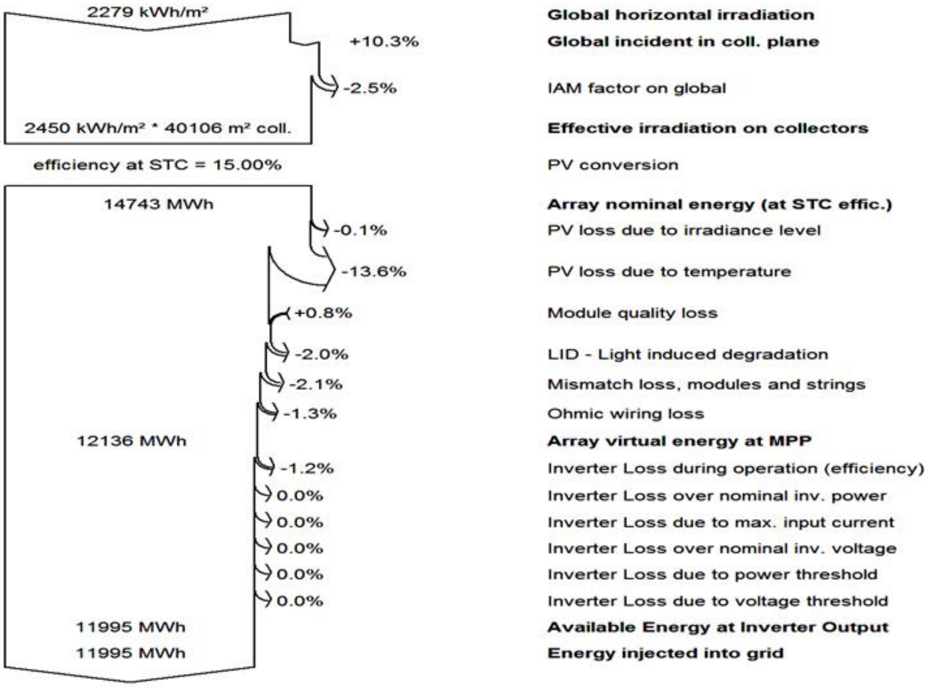

Fig.. 11. Annual loss diagram for a poly-Si photovoltaic system in 2020. estimated by the PVsyst

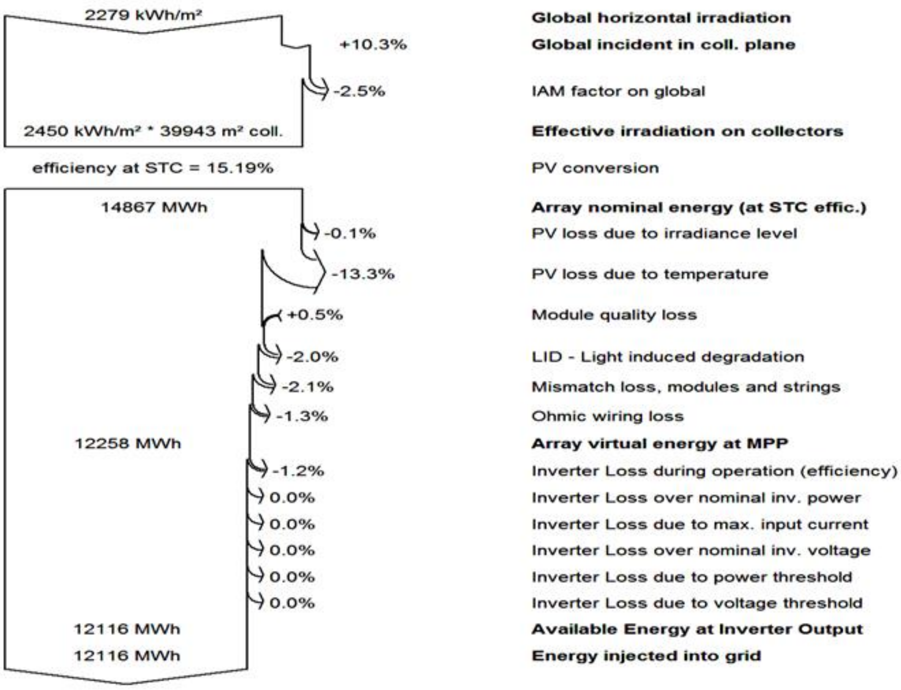

Fig. 12. Annual loss diagram for a mono-Si photovoltaic system in 2020. estimated by the PVsyst

12136 MWh of virtual array energy is obtained. After inverter losses, the energy available at the inverter output is 11,995 MWh in 2020. Thus, the energy pumped into the grid is 11995 MWh. The nominal energy of the array for mono-Si PV modules is 14867 MWh in 2020. The standard Test Condition (STC) efficiency of the PV array is 15.19%. The array's acquired virtual energy is 12258 MWh in 2020. After inverter loss, the energy available at the inverter output is 12,116 MWh in 2020. Therefore, the energy introduced into the system is 12116 MWh in 2020.

6.5. Distribution of probabilities for the creation of total energy:

PVsyst 7.0 generates a simulated Probability Distribution Function (PDF) graph to calculate the total energy produced. Fig. 13 shows the highest probability for the maximum power output of 11994.848 MWh per year(2020) and 12115.824 MWh(2020) per year for Si-poly and mono-poly PV modules.

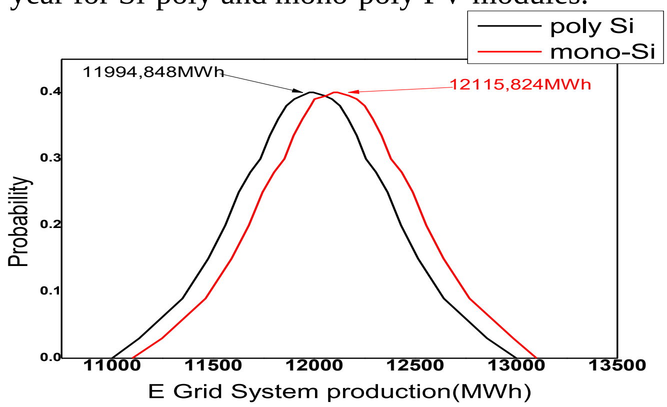

Fig. 13. Probability distribution for maximum generation for p-Si and m-Si PV modules estimated by the PVsyst

6.6 Emissions Reduction

The influence of an energy conversion technology on climate change may be measured in terms of its carbon emissions, which represent the amount of CO_2 released into the atmosphere per unit of energy generated. [24] [25]. It was thought that the solar PV power plant in question would reduce carbon emissions by:

$$E_{MAV} = E_C\left(MWh\right) \times F_C\left(t_{CO_2}/MWh\right) \tag{7}$$

where EC is the amount of energy produced by the conventional system (MWh) and FC is the carbon mitigation factor (0.596 tCO_2/MWh for Algeria). Note that this number doesn't include the CO_2 that goes into the air when PV panels are made. Fig. 14 shows that Mono-Si and Poly-Si modules can reduce carbon emissions by 3,49,774,151 and 346,168,664 metric tonnes over 50 years compared to traditional energy supplies for a 6 MW power station.

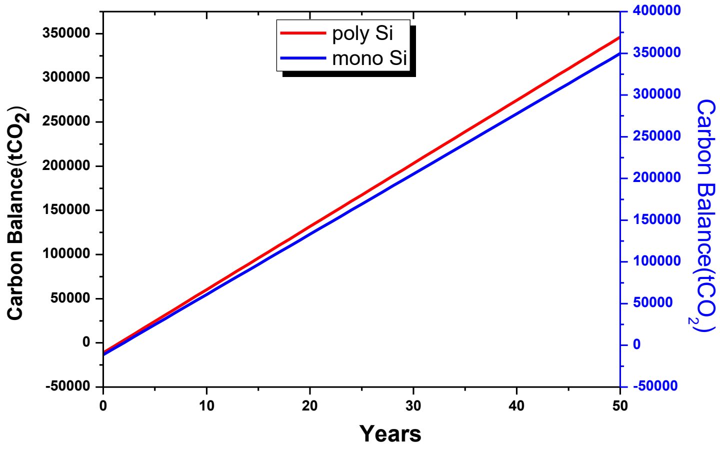

Fig. 14. Yearly carbon emission balance (CO_2).

7. Conclusions:

Due to the huge number of PV technologies available on the market, it is essential to gather information on their outdoor performance. This article compares the performance of two widely available solar modules (m-Si and p-Si) in Zaouiet Kounta's difficult environment. The data acquired during the twelve months of testing, from January 2020 to December 2020, under identical settings, led to the following inferences:

The YF and PR of the Mono-Si system are, respectively, 5.52 kWh/kWp/day and 80.1%. The Poly-Si system's YF and PR are 5.46 kWh/kWp/day and 79.3%, respectively. It is expected that this Mon-Si system and this Poly-Si system would cut CO_2 emissions by 349,774,15 t and 346,168,66 t, respectively, over 50 years if they were replaced with a fossil fuel power generating unit of the same size. We can figure out that the mono-Si system performs slightly better than the poly-Si system.

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