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Seasonal Performance of Solar Power Plants in the Sahel Region: A Study in Senegal, West Africa

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Abstract

The main objective of this study is to evaluate the seasonal performance of 20 MW solar power plants in Senegal. The analysis revealed notable seasonal variations in the performance of all stations. The most significant yields are recorded in spring, autumn and winter, with values ranging from 5 to 7.51 kWh/kWp/day for the reference yield and 4.02 to 7.58 kWh/kWp/day for the final yield. These fluctuations are associated with intense solar activity during the dry season and clear skies, indicating peak production. Conversely, minimum values are recorded during the rainy season from June to September, with a final yield of 3.86 kWh/kW/day due to dust, clouds and high temperatures. The performance ratio analysis shows seasonal dynamics throughout the year with rates ranging from 77.40% to 95.79%, reinforcing reliability and optimal utilization of installed capacity. The results of the capacity factor vary significantly, with March, April, May, and sometimes October standing out as periods of optimal performance, with 16% for Kahone, 16% for Bokhol, 18% for Malicounda and 23% for Sakal. Total losses from solar power plants show similar seasonal trends standing out for high loss levels from June to July, reaching up to 3.35 kWh/kWp/day in June. However, using solar trackers at Sakal has increased production by up to 25%, demonstrating the operational stability of this innovative technology compared with the plants fixed panel. Finally, comparing these results with international studies confirms the outstanding efficiency of Senegalese solar power plants, other installations around the world.

Keywords

Performance Study, Photovoltaic Power Plant, Season Variations, Senegal

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) highlights the growing global interest in renewable energy sources due to their environmentally friendly properties compared to harmful fossil fuels [1]. It is clear that the use of these energies is an important solution to ensure energy security, mitigate the effects of climate change and achieve significant economic benefits [2]. From 2015 to 2016, global electricity consumption and renewable energy source production reached 19.3% and 24.5%, respectively [3]. Global electricity increased tenfold between 2010 and 2020, reaching 2799 GW in 2020 [4]. Solar energy, mainly through photovoltaic installations, has become a dominant force in the global energy landscape, both in daily life and industry [5] [6]. PV panel production has shifted noticeably from Europe to Asia (especially China), which accounted for 54% and 45% of global capacity added in 2017 and 2018, respectively [7] [8].

Nonetheless, the continued growth of solar energy globally faces major challenges. The ability to achieve the best conversion into cheap electricity without losses remains a key goal for all solar power systems [9]. Solar panels must be installed in outdoor environments, which tend to reduce the performance of PV modules. The performance of grid-connected PV systems depends more on cell technology, installation configuration and operating (maintenance) conditions than on meteorological parameters [10] [11]. Knowing the performance of PV modules at a specific location is essential to design the right system for that specific location and application. The electrical parameters provided by manufacturers under standard test conditions (STC) are not sufficient to accurately determine the performance and reliability of PV modules under real conditions. For an accurate assessment, it is necessary to monitor the production and operation of solar power plants throughout their entire service life [12].

Over the years, many studies have been conducted around the world analyzing the performance of solar power plants. Attari *et al.* [10] evaluated the performance of a 5 kW AC grid-connected PV system installed on the rooftop of a building in Tangier, Morocco. They obtained final performance ranges from 1.96 to 6.42 kWh/kWc, efficiency ratio (PR) of 58% to 98%, and annual capacity factor of 14.48% [10]. Wang *et al.* [13] compared the seasonal characteristics of three different photovoltaic technologies (p-Si, a-Si and CdTe) in a climate transitioning from a typical Mediterranean climate to a semi-arid cold climate. In summer, capture losses were reported to increase due to thermal effects and inverter limitations of the three PV systems. However, for the a-Si network, the effect of thermal annealing results in lower capture losses (an absolute difference of 3%) compared to p-Si and CdTe PV networks. In Brazil, the performance of a 2.2 kWc photovoltaic system installed at the State University of Ceara, Fortaleza, was monitored from June 2013 to May 2014. Annual energy efficiency, final yield, system losses, system and inverter efficiencies, PR, and capacity factor were calculated. The results they found show the good potential for electricity production through photovoltaic solar energy in the state of Ceará, Brazil [14].

Nouar [15] calculated the final yield, reference yield, system efficiency, performance ratio, and total losses of a 20 MWc grid-connected PV system installed in a challenging environment in southern Algeria over one year. The results obtained show that the installation of photovoltaic stations gives good results encouraging investments in this region [15]. Mpholo *et al.* [16] monitored the performance of a newly installed 281 kWc photovoltaic solar farm at Moshoeshoe I International Airport in Lesotho, and the result of this study shows that the area is suitable for grid-connected photovoltaic systems. The analysis period covers both hot summer and cold winter [16]. In Italy, Congedo *et al.* [17] analyzed the performance of a 960 kWc PV system consisting of monocrystalline silicon PV modules over eight months. Final energy yield, system efficiency, performance ratio, and PV cell temperature losses were calculated. The performance analysis in this study is consistent with results reported in the literature for PV systems located in the Mediterranean [17]. Four different buildings equipped with grid-connected rooftop photovoltaic systems were analyzed in Abu Dhabi based on two different types of PV modules: polycrystalline and monocrystalline [18]. In Palestine, the technical performance, effects, and economic analysis of a 5 kWc grid-connected residential PV system for three different houses were analyzed over two years of operation [19]. The performances of the houses were also compared by varying the tilt angle using PVsyst software. In Morocco, the performances of 2 kWc of polycrystalline, monocrystalline, and amorphous PV modules were compared using real measured data over five years, and recorded and simulated data were also compared [20]. The simulation was carried out using Python to predict electricity production over a week. The mean square errors of the three types of PV modules were also compared. The performance parameters of the PV system were evaluated based on energy production over two years in 2018-2019 [21]. To improve outdoor PV system performance analysis, Hüttl *et al.* [22] proposed a Self-Referencing Algorithm (SRA) for high-precision outdoor measurements of PV modules. Additionally, several commercial software and models are available that use meteorological databases, PV module data, and inverter data to predict PV system performance at a specific location [23] [24]. Furthermore, results show that the performance of grid-connected photovoltaic systems depends on geographical location, PV module types, and weather conditions such as solar radiation and ambient temperature [25]. A performance analysis of the 23 MWc photovoltaic plant in Senegal showed that performance depends on on-site climatic conditions and technologies used [26].

This article focuses on Senegal, a Sahel country with significant solar potential and a unique climate. Although this potential was not fully exploited until 2000, since then the country has made significant progress in solar energy production through the installation of numerous solar power plants and other ongoing projects [27] [28]. The country is also characterized by the presence of desert aerosols and clouds, which have a significant radiative impact throughout the year [29] [30]. Careful seasonal analysis of solar power systems is therefore important to accurately predict performance, promote better planning of the electricity system, and manage seasonal demand more efficiently [31] [32]. This work is based on a rigorous methodology that combines field data to study seasonal changes in the production of four solar power plants. This provides valuable information for analyzing the performance of these facilities and highlights the importance of conducting research to better understand the underlying physical mechanisms and predict seasonal variability more accurately.

2. Description of Solar Power Plants

Senegal (11.5˚N, −18.5˚W), like other developing countries, is actively working to diversify its energy sources and reduce its dependence on fossil fuels [33]. The initiative has led to the installation of several solar power plants across the country in recent years to address energy shortages and reduce the country's carbon emissions.

Figure 1 shows the geographical distribution of the four solar power plants on the map of Senegal.

Table 1 provides the characteristics of the four solar power plants considered in this study. This includes geographical coordinates, type of panels installed, number of panels, installed capacity, panel configuration (fixed or mobile) and year of commissioning of each installation. In particular, with the exception of the Sakal power plant, all of these power plants use polycrystalline solar panels mounted on fixed poles inclined at about 15 degrees [34]. The latter is equipped with 62,100 solar panels installed on 240 trackers to track the sun's path. This configuration is designed to produce 30% more power compared to fixed panels, providing a more stable power supply to the grid [35]. All of these solar power plants are directly connected to the Senegal's national electricity company (SENELEC) network. Each installation is equipped with a distribution box in front of the solar inverter and is responsible for parallel connection of the solar circuits.

Table 1. Technical descriptions of the solar power plants.

Solar power plants	Kahone	Bokhol	Malicounda	Sakal
Latitude	14˚17 N	16˚31 N	14˚28 N	15˚85 N
Longitude	−16˚02 W	−15˚46 W	−16˚57 W	−16˚22 W
Installed capacity (MW)	20	20	20	20
Type of panel and Configuration	Polycrystalline/Fixed	Polycrystalline/Fixed	Polycrystalline/Fixed	Polycrystalline/Tracker
Power installed	270	270	230	320
Number of panel	75,000	75,000	86,000	62,100
Area (ha)	44	40	100	40
Year of Service	2018	2016	2016	2018

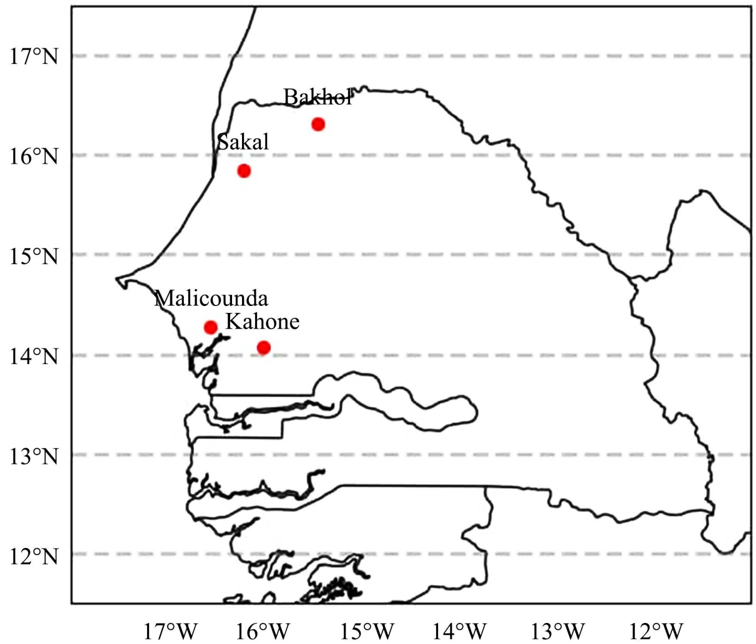

Figure 1. Location of the four solar power plants on the map of Senegal: Bokhol (20 MW), Sakal (20 MW), Malicounda (20 MW), and Kahone (20 MW).

The inverter converts the direct current generated by solar panels into alternating current and synchronizes it with three parameters of the distribution network: amplitude, phase and frequency. Additionally, these plants are equipped with environmental sensors including temperature, solar radiation, humidity, wind speed, and wind direction. This equipment continuously monitors weather conditions near solar modules. The collected data are stored on one of the data collection computers located in the control room.

3. Performance Evaluation Approach

3.1. Data Collection

To assess the seasonal and monthly performance of the photovoltaic system production, production data were collected over the entire period from January to December 2021 for the four solar power plants under study. The performance indicators used in this study include the reference yield, final yield, performance ratio, capacity factor, and system losses. Performance indicators are calculated using the performance indices developed by the International Electrotechnical Commission (IEC) standard 61,724 [36] and the International Energy Agency (IEA)—IEA-PVPS Task 13 [37], which are the most widely used documents for monitoring photovoltaic systems.

3.2. Key Performance Indicators Affecting Energy Production

To analysis the performance of solar energy systems, key indicators developed by the IEA and IEC are used, such as the performance ratio (PR), the final PV yield (Y_f) and the reference yield (Y_r) [16] [33] [34]. These parameters are standardized indicators that allow for the comprehensive analysis of existing PV systems concerning the energy produced, solar irradiation, and the overall impact of system losses.

3.2.1. Reference Yield (Y_r)

The reference yield (Y_r) is defined as the ratio of the total solar radiation H_t (kWh/m^2) reaching the solar panel surface to the reference radiation amount G_0 (1 kW/m^2) [10] [38]. This parameter represents the time corresponding to the reference illumination. Y_r determines the solar energy resource of the solar power system.

$$Y_r = \frac{H_t}{G_0} \tag{1}$$

The unit of reference yield is kWh/kWp/day or (h/day).

3.2.2. PV System Final Yield (Y_f)

The final yield (Y_f) is a significant indicator used to normalize the energy produced based on the system's size. It is influenced by the mounting structure, orientation, and location of the installed PV system [37] [38]. This parameter corresponds to the total energy output (E_{CA}) in kilowatt-hours (kWh) produced by the PV system over a specified period (day, month, or year) in relation to the installed nominal power (P_0) in kilowatt-peak (kWp), under standard conditions (STC: irradiation: 1000 W/m^2, ambient temperature: 25˚C, and reference spectrum AM 1.5-G) [39]. Y_f indicates the number of daily hours during which the photovoltaic generator operates at its nominal power.

$$Y_f = \frac{E_{CA}}{P_0} \tag{2}$$

The final yield unit is the kWh/kWp/jr (ou h/jr).

3.2.3. Performance Ratio

The performance ratio (PR) is determined by the ratio of the final yield (Y_f) and the reference yield (Y_r) [40]. The coefficient of performance is dimensionless and serves as a normalization factor for solar radiation incident on the aircraft. PR depends on the total losses of the system due to the conversion tasks performed by various components such as PV modules, inverters, cables, etc. [10]. The productivity coefficient is expressed by the following equation:

$$\mathrm{PR}(\%) = \frac{Y_f}{Y_r} \times 100 \tag{3}$$

Higher PR values indicate that the plant is operating close to rated capacity, while lower values indicate production losses due to technical or design issues. Typically, PR values vary between 0.6 and 0.8 due to different weather conditions [41]. In cooler climates it may exceed 0.9 [42].

3.2.4. Capacity Factor (CF)

It represents the relationship between the actual amount of energy produced by a solar power plant over a 24-hour period throughout the year and the maximum annual energy production of that plant at its rated output. Power utilization is usually expressed as a percentage [43].

$$\text{FC}(\%) = \frac{E_{AC}}{P_0 \times 24} \times 100 \tag{4}$$

The capacity factor (CF) is a site-dependent parameter. It varies based on the received solar radiation and the number of clear sunny days experienced by the photovoltaic plant site. It is significantly influenced by the type of module used [28].

3.2.5. System Total Losses

The total energy losses of the photovoltaic system (L_T), expressed in hours (h/day) or (kWh/kWp/day), can be defined as the difference between Y_r and Y_f, according to the following formula [44]:

$$L_T = Y_r - Y_f \tag{5}$$

These parameters include panel capture loss, module temperature loss, and overall system loss. Performance loss during operation can be caused by various factors such as radiation level and direction, thermal effects due to increased cell temperature, inverter losses, and contamination [45].

4. Results and Discussion

4.1. Monthly and Seasonal Distribution of Production Form the 4 Solar Power Plants

Figure 2 shows the monthly production variation of four solar power plants in Senegal.

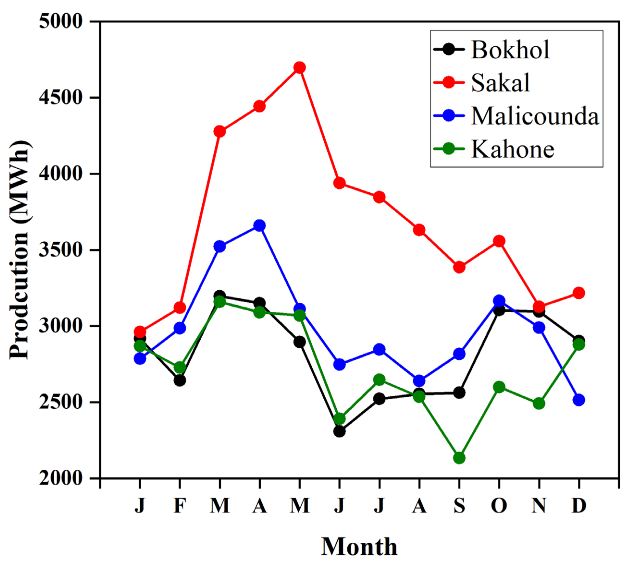

Figure 2. Monthly production of the solar power plants: Kahone (green), Bokhol (black), Malicounda (blue), and Sakal (red).

The resulting analysis highlights significant seasonal variations in the production of all solar power plants, which typically peaks in the spring between March and May. During this period, power plants in Bokhol, Malicounda, and Kahone reach maximum values of 3194 MWh, 3658.2 MWh, and 3156.2 MWh, respectively. These peaks appear to be closely related to increased solar activity during the dry season, which is characterized by clear skies [34] [46]. In particular, with the installation of solar trackers in Sakal, production increased significantly, reaching a peak of 4694.5 MWh in May, up to 25% more than using fixed solar panels. Conversely, minimum production is observed during the rainy season from June to September due to dust, clouds, and high temperatures [47]. These results are consistent with most studies conducted in the region [48].

To summarize the above results, **Figure 3** shows the seasonal power distribution of solar power plants in winter (December-February), spring (March-May), summer (June-August), and fall (September-November).

Across all the sites, power plant production peaks in spring, ranging from 3104.12 to 4694.5 MWh. This appears to be due to increasing solar energy intensity. On the other hand, minimum production is recorded in winter due to the low altitude of the sun, and in summer due to atmospheric clouds and Saharan dust affecting solar panels [49]. The minimum values for the three power plants (Bokhol, Malicounda and Kahone) range from 2513.2 to 2982.2 MWh. However, it is notable that Sakal also records high production levels during the monsoon season, suggesting a potential positive impact from mobile solar panels.

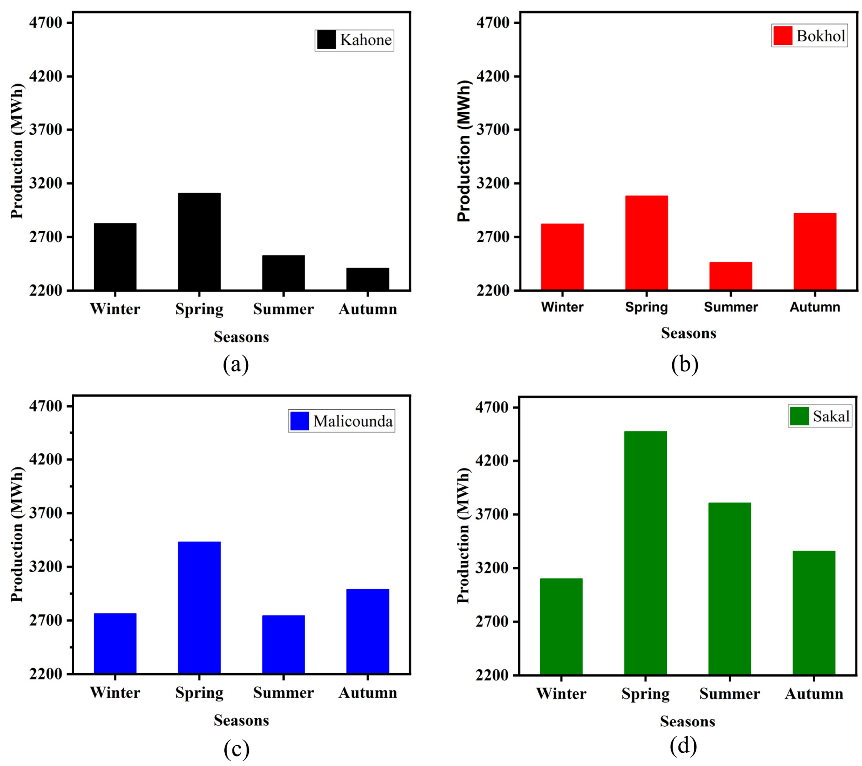

Figure 3. Seasonal variation in solar energy production for the solar power plants: Kahone (black), Bokhol (red), Malicounda (blue), and Sakal (green).

4.2. Analysis of Performance Indicators for the Four Photovoltaic Systems

4.2.1. System Efficiency

Based on the collected data, the profitability of the four solar power plants used in this study was calculated. Figure 4 shows the final and baseline yield from January to December.

The analysis of the results reveals significant seasonal variations in daily yields for all stations. Peak performances are observed in spring (March to May), autumn (October and November), as well as in winter (December and February), with values ranging between 5 and 7.51 kWh/kWp/day for the reference yield and from 4.02 to 7.58 kWh/kWp/day for the final yield. Conversely, minimum yields are recorded during summer, from June to September, with a reference yield ranging between 4.5 and 5.7 kWh/kWp/day, and a final yield varying from 3.86 to 6.20 kWh/kWp/day. These fluctuations are attributed to an increase in sunlight during this period, emphasizing the crucial importance of the season in energy production [38] [49]. Moreover, the Sakal station, equipped with mobile panels, achieves a remarkable final yield of 7.58 kWh/kWp in May, thanks to the use of solar trackers.

Table 2 summarizes the seasonal and annual averages of baseline and final yield for each station. These figures give a general idea of seasonal changes in performance indicators.

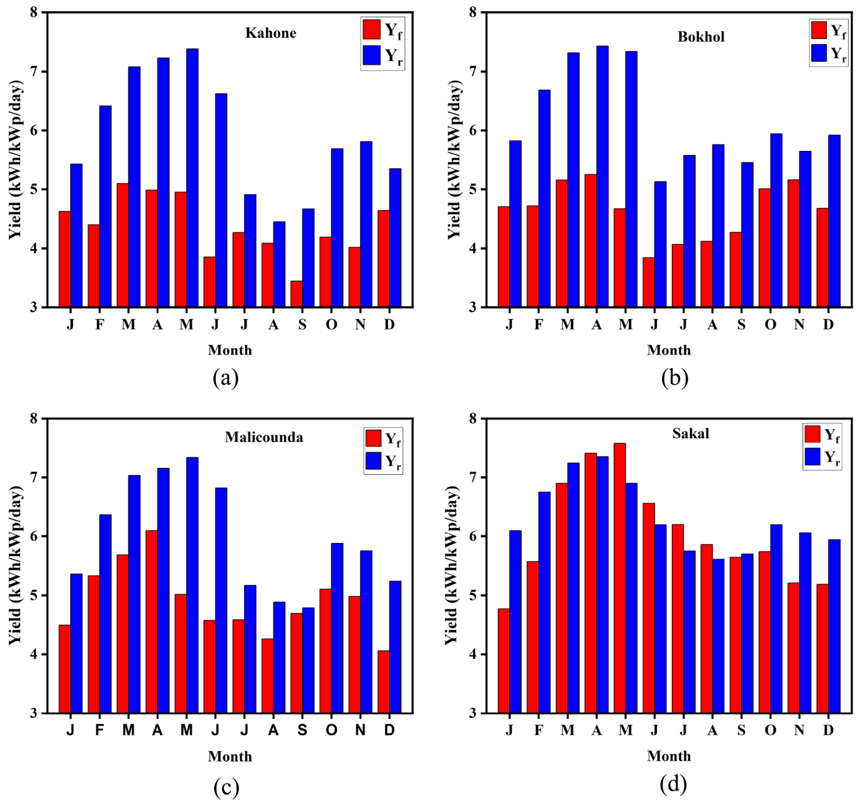

Figure 4. Variation in the monthly average of reference daily yields Y_r (in blue) and final yields Y_f (in red) for the four solar power plants.

Table 2. Seasonal averages of reference and final efficiencies for each station, as well as the overall averages for each solar plant.

Seasons	Reference Yield (kWh/kWp/jour)				Final Yield (kWh/kWp/jour)			
	Kahone	Bokhol	Malicounda	Sakal	Kahone	Bokhol	Malicounda	Sakal
Winter	5.73	6.14	5.66	6.26	4.56	4.70	4.63	5.18
Spring	7.23	7.36	7.17	7.16	5.01	5.03	5.60	7.29
Summer	5.33	5.49	5.62	5.85	4.07	4.01	4.48	6.21
Autumn	5.39	5.68	5.47	5.99	3.88	4.81	4.93	5.53
Annual average	5.92	6.17	5.98	6.32	4.38	4.64	4.91	6.05

The table results confirm that seasonal variations in solar energy production can be reliably anticipated. During spring and winter, yields reach their peak, with seasonal averages ranging between 5.66 and 7.36 kWh/kWp/day for the reference yield, and from 4.63 to 7.29 kWh/kWp/day for the final yield. These high values indicate that these periods offer ideal conditions for energy production. Conversely, during the rainy season, characterized by the summer months, yields drop to their lowest levels, with seasonal averages fluctuating between 4.01 and 6.21 kWh/kWp/day for the final yield. These lower values during summer confirm the negative relationship between weather conditions and solar performance, highlighting the significant influence of seasons on solar energy production.

4.2.2. Performance Ratio

Figure 5 represents the monthly performance ratios of the four solar power plants over the entire examined period.

The performance analysis of these four solar power plants reveals distinct trends and significant seasonal variations throughout the year. Kahone and Bokhol exhibit more pronounced seasonal fluctuations, recording lower performances during the summer months. This situation is likely related to the geographical location of these two plants. The Bokhol plant is situated in the northern part of the country, in a desert area where the presence of desert dust and cloud systems is frequent during the wet season [34].

Additionally, other meteorological factors such as extremely high temperatures may also contribute to the decline in the performance of these solar systems in summer (June-September). Indeed, the Kahone plant experiences peak performance in January (98%) and December (93%), but registers significant declines in June (65%) and September (63%). On the other hand, Bokhol exhibits high performances in November (91%) and October (90%), but undergoes notable declines in June (55%) and May (64%).

The performance ratio at Malicounda is relatively moderate and stable throughout the year, while the Sakal plant stands out with consistently high performances. Malicounda maintains relative stability, reaching its peak in November

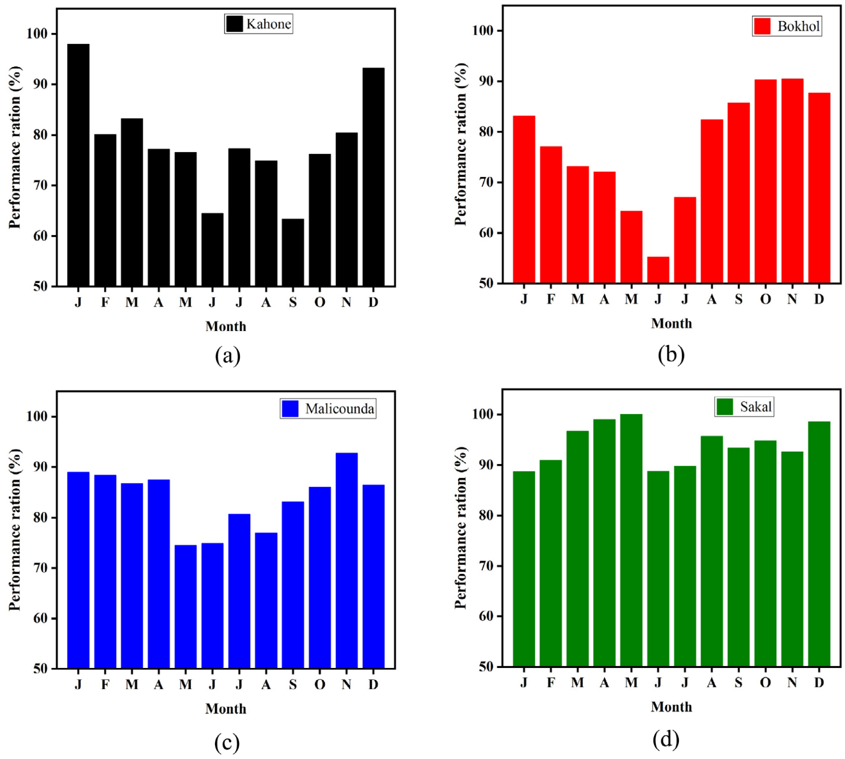

Figure 5. Monthly performance ratio for the four solar power plants.

(93%). The Sakal plant, equipped with mobile solar panels, demonstrates exceptional performances year-round, reaching peaks in April (100%), May (100%), and December (100%). These results underscore the positive impact of the mobile panel configuration, particularly at Sakal, indicating that this panel configuration plays a crucial role in optimizing energy production. As highlighted by Lee *et al.* [50], a PR exceeding 0.8 indicates performance approaching ideal conditions under STC, while a PR below 0.7 may suggest defects in components, installation conditions, or extreme weather conditions.

4.2.3. Capacity Factor

Figure 6 shows the monthly variation in daily average capacity factor (CF) observed at various solar power plants.

Capacity factor (CF) results for four solar power plants highlight significant seasonal variations reflecting the impact of weather conditions on solar energy production.

Spring, which runs from March to May and sometimes from October to fall, is the optimal production period with a high coefficient of productivity (CF). In fact, power factor peaks are often recorded between March and April with values of 15.79%, 15.98%, 18.30%, and 23.48% in Kahone, Bokhol, Malicounda, and Sakal, respectively. These results suggest higher energy efficiency over certain periods of time.

These seasonal fluctuations are closely linked to variable sunlight throughout the year, with higher light intensity during these months and clear skies [43].

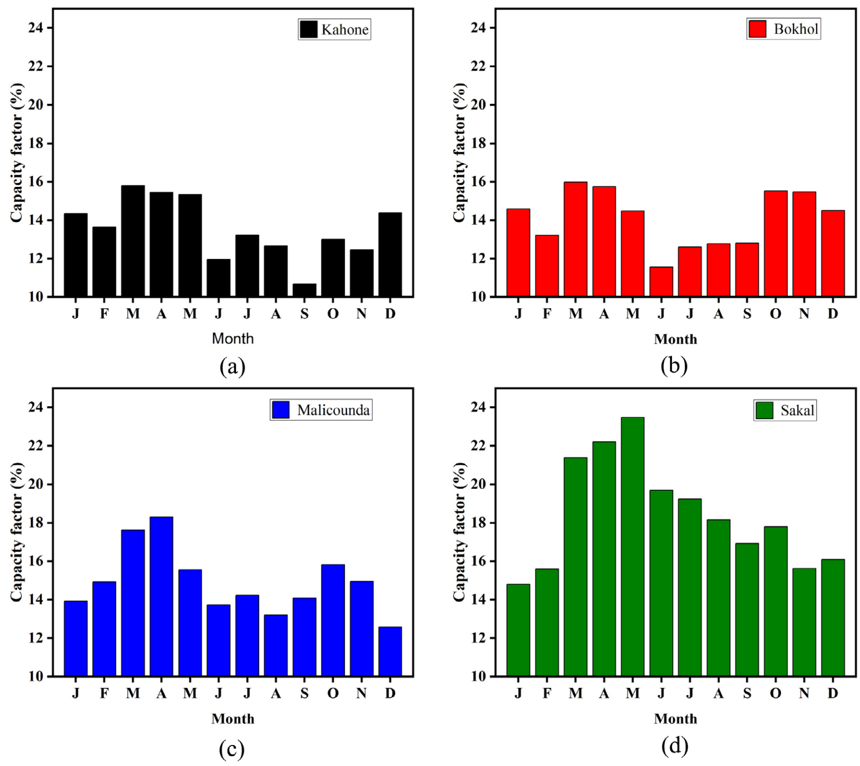

Figure 6. Monthly variation of the daily average Capacity Factor (CF).

Conversely, the months from June to September show relatively lower CF, which can be attributed to less favorable weather conditions. Solar panel technology, design choices, and site geography all play a crucial role in these variations, demonstrating the need for a holistic approach to understand and optimize solar energy production in each plant [26]. The Sakal plant, equipped with mobile panels, stands out with exceptionally high-capacity Factors, emphasizing the crucial importance of solar panel adaptability to track the movement of the sun.

4.2.4. System Losses

Figure 7 shows the overall system losses for the four solar power plants in this study.

The analysis of the total losses in the systems of the four solar power plants reveals distinct seasonal variations. The months of June and July, corresponding to the summer season, are characterized by high losses for all plants, reaching up to 3.35 kWh/kWp/day in June. These periods are likely to pose challenges due to high temperatures, denser cloud cover, and the presence of dust, leading to a decrease in the operational efficiency of the solar systems [44] [45]. In contrast, the winter and autumn seasons stand out with minimal losses, ranging between 0.38 kWh/kWp/day and 1.05 kWh/kWp/day, likely benefiting from more favorable weather conditions. In spring, Kahone, Bokhol, and Malicounda experience slightly higher average losses, highlighting specific challenges related to spring weather conditions [44], with values reaching 1.10 kWh/kWp/day, 2.42 kWh/kWp/day, and 1.75 kWh/kWp/day, respectively. Losses for the Sakal station,

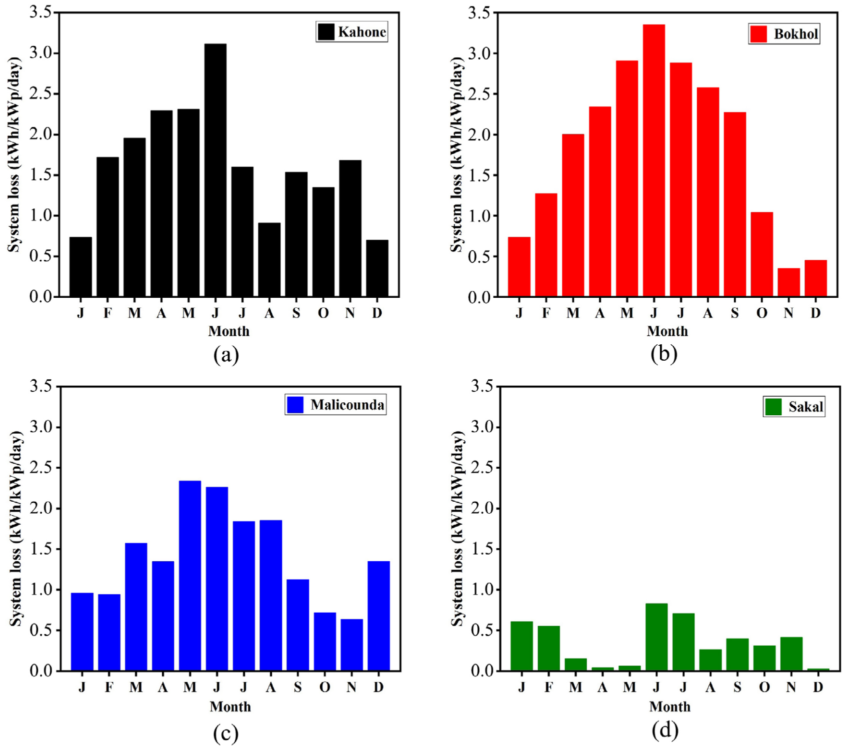

Figure 7. Seasonal variations in total losses from PV systems in Kahone (a), Bokhol (b) and Malicounda (c) and Sakal (d).

equipped with mobile panels, remain very low throughout the year, approaching zero values in spring, thanks to the operational stability of its innovative technology.

Table 3 summarizes the seasonal performance of the four photovoltaic plants.

The results in the table regarding the efficiency indicators of these solar power plants clearly confirm the quality and reliability of these installations. Final Yield ranging from 4.38 kWh/kW/day to 6.05 kWh/kW/day shows remarkable stability, demonstrating significant energy efficiency. A stable performance ratio ranging from 77.40% to 95.79% improves reliability, indicating optimal use of installed capacity. These promising results, combined with relatively limited system losses, highlight the plant's success in converting solar energy into electricity, laying the foundation for sustainable energy production in Senegal.

4.3. Comparison with Photovoltaic Installations on a Global Scale

To evaluate the performance of solar power plants in Senegal globally, we first investigated the final yield (Y_f) and the performance ratio of four solar power plants. Compared to other global studies, the results of the Senegal power plant were very meaningful, showing significantly superior performance. For a clearer understanding of the performance of photovoltaic systems compared to other studies, Table 4 summarizes the performance indicators of the selected studies. The Sakal plant with mobile panels surpasses with an impressive, highlighting the exceptional efficiency of Senegalese solar power plants.

Table 3. Annual review of performance indicators for the four solar power plants.

Solar Plants	Reference yield (kWh/kWp/day)	Final yield (kWh/kWp/day)	Performance Ratio (%)	Capacity Factor (%)	System losses (kWh/kWp/day)
Kahone	5.92	4.38	78.75	13.58	1.66
Bokhol	6.17	4.64	77.40	14.11	1.85
Malicounda	5.98	4.91	83.95	14.91	1.41
Sakal	6.32	6.05	95.79	18.42	0.37

Table 4. Daily yield and performance of senegalese solar power plants vs international comparisons.

Locations	Final yield (kWh/kWp/day)	Performance ratio (%)	References
Kahone	**4.38**	**78.75**	**Present work**
Bokhol	**4.64**	**77.40**	
Malicounda	**4.91**	**83.95**	
Sakal	**6.2**	**95.79**	
Morocco	4.45	77.4	[10]
Kuwait	4.5	77.5	[38]
Spain	3.8	64.5	[51]
India	3.99	76.97	[52]
Norway	2.55	83.03	[53]
Diass	4	78	[26]
Mauritania	4.27	63.59	[12]
Djibouti's	4.6	85	[54]

5. Conclusion

This in-depth study aimed to evaluate the performance of four solar power plants located in Kahone, Bokhol, Malicounda and Sakal in Senegal. Using analysis methods in accordance with IEC 61,724 standards, we examined various indicators such as the average reference daily yield, final yield, performance ratio, capacity factor, and system losses. The results show a strong seasonal trend, with production peaks in spring, fall and winter and minimum values recorded during the rainy season. Using solar trackers at Sakal has increased production by up to 25%. The performance ratio of the stations ranges from 77.40% to 95.79%, which represents optimal use of the installed capacity. The capacity factor shows seasonal variation, indicating an increase in energy efficiency in spring and fall. Total losses in the system show marked seasonal variation, with high levels in the summer months. The results confirm the outstanding efficiency of Senegalese solar power plants compared to global studies, highlighting their exceptionally good performance compared with other installations worldwide. These findings provide practical recommendations for energy planners and highlight the importance of considering seasonal conditions when planning and managing solar power plants.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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