DESIGN AND PERFORMANCE ANALYSIS FOR 50 MW GRID CONNECTED SOLAR PHOTOVOLTAIC POWER PLANT IN LIBYA

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الملخص

يركز تصميم النظام الكهروضوئي على خلق الظروف المثالية لمطابقة الطاقة الممنوحة للنظام من أشعة الشمس مع الطاقة اللازمة عند الحمل الذي سيغذيه النظام. تعتمد الطاقة المتولدة عن طريق النظام الكهروضوئي المتصل بالشبكة على عدة متغيرات مثل، المتغيرات البيئية (قوة الاشعاع الشمسي ودرجة حرارة وحدة اللوح الشمسي)، وخصائص المحول (نقطة العمل، وعتبة التشغيل، والمُعرَّفة على أنها الحد الأدنى المطلوب من الطاقة إلى ربط المحول بالشبكة)، ونظام الاقتران بالشبكة، والذي يعتمد على خصائص الطاقة التي ينتجها المحول وعلى استقرار الشبكة وتوافرها. من المهم لمصممي ومخططي الأنظمة الكهروضوئية أن يكون لديهم فهم عميق للمعلمات المهمة لأداء النظام وسلامته، والتي يمكن تخفيفها دون أن يكون لها تأثير كبير. يمكن التعرف على العديد من العوامل المهمة، بما في ذلك الموقع، والميل، والتوجيه، والطاقة الاسمية، والجهد النظامي، والخصائص والمواصفات الكهربائية لمكونات النظام الكهروضوئي، على أنها الأكثر أهمية للتصميم الناجح للنظام الكهروضوئي.

تقدم هذه الورقة البحثية إمكانية استخدام التضاريس المناسبة في ليبيا لإضافة قدرة توليد من محطات الطاقة الكهروضوئية واسعة النطاق إلى الشبكة الوطنية. يتناول هذا البحث مقارنة بين الألواح الثابتة والألواح المتتبعة، وبين محولات السلسلة والمحولات المركزية. يتناول البحث بشكل خاص تصميم محطة طاقة شمسية بقدرة 50 ميجاواط في مدينة بني وليد. تهدف الدراسة إلى تحديد التصميم الأمثل الذي يقلل من فقد الطاقة ويزيد من الطاقة المولدة من خلال تغيير المتغيرات التصميمية. تظهر النتائج أن الطاقة المولدة باستخدام الألواح المتتبعة تزيد بنسبة 25٪ عن الألواح الثابتة، وأن المحول المركزي يعاني من خسائر أعلى مقارنة بمحول السلسلة. وأخيرًا، تم حساب الحد من انبعاثات ثاني أكسيد الكربون (CO_2). تم إجراء التحليل باستخدام PVsyst.

ABSTRACT

The primary goal when designing a photovoltaic system is to ensure that the amount of energy generated from sunlight aligns with the energy needs of the load it is intended to power. Various factors, such as environmental conditions, inverter characteristics, and grid integration, impact the amount of energy a grid-connected photovoltaic system can generate. System designers must have a comprehensive understanding of the parameters that affect system performance and safety, as well as those that can be adjusted without significant consequences. Factors like location, tilt, orientation, power rating, system voltage, and electrical specifications of system components are considered critical for the successful design of a photovoltaic system.

This paper considers the comparison between fixed and single axis tracking panels, as well as the comparison between string inverters and central inverters. In this paper, the possibility of utilizing suitable terrain in Libya for large-scale photovoltaic power plants connected to the national grid is explored. The paper specifically examines the design of

A.C Power of 50 (MW_{AC}) grid-connected solar PV plant in Bani Walid City. The study aims to determine the optimum design that minimizes power loss and increases the generated power by varying design variables. The results show that the generated power using a tracking panel is 25% more than that used by a fixed panel, and the central inverter has higher losses compared to the string inverter. Finally, the reduction in carbon dioxide (CO_2) emissions was calculated. The analysis was conducted using PVsyst.

KEYWORDS: Photovoltaic; Solar Radiation; Central Inverter; String Inverter; Orientation; Libyan Network; Renewable Energy (RE).

I. INTRODUCTION

As renewable energy technologies continue to make significant progress globally, it is crucial to develop a clear vision and strategy for harnessing locally available renewable energy sources. Among these sources, photovoltaic generation plants have experienced rapid growth, ranging from small residential applications to large-scale grid-connected commercial projects. Solar energy has immense potential and even a small fraction of its utilization could have a substantial impact, with the electrical energy generated potentially exceeding global energy needs by a factor of 50 [1].

According to the International Energy Agency (IEA), solar photovoltaic (PV) technology accounted for 3.1% of global electricity generation, with a total of 821TWh, making it the third-largest renewable electricity source after hydropower and onshore wind. The IEA predicts that the total energy generated from PV may reach 6970 TWh by 2030 [2]. Photovoltaic solar cells offer a direct means of converting solar energy into electricity and are a promising technology in this regard.

The design of a photovoltaic system aims to optimize the match between the energy received from the sun and the energy required by the load it serves. The energy output of a grid-connected photovoltaic system depends on several factors, including environmental variables (such as incident irradiation and module temperature), inverter characteristics (such as yield and operating point), and the coupling system to the grid, which relies on the properties of the energy produced by the inverter and grid stability.

Designers and planners of photovoltaic systems need to understand the parameters that significantly impact system performance and safety and those that can be adjusted without significant consequences. Factors such as location, tilt, orientation, nominal power, system voltage, and electrical characteristics of the PV system components are critical for a successful design [3]. The growing number of stakeholders investing in new technologies has propelled the advancement of the solar energy sector, resulting in both affordability and profitability [4].

Numerous studies have been conducted to compare fixed-mount and solar tracking photovoltaic (PV) systems, as well as central and string inverters, in different regions. In Jakarta, Indonesia, a study comparing the energy output of PV systems using fixed-mount and solar tracking technology found that the latter consistently generated more energy, with a difference ranging from 15% to 29% throughout the year [5]. Similarly, research conducted in Germany and Italy indicated that the energy generated by tracking PV systems surpassed that of fixed systems by approximately 30% to 37% [6].

Regarding energy yield, the string inverter is considered the optimal choice for areas with uneven terrain and anticipated high voltage discrepancies. Conversely, in flat ground projects where voltage mismatch is low, there is no significant disparity between central and string inverters [7]. Furthermore, the technical calculations demonstrated that, under the same conditions of average annual solar radiation in Vietnam, the total energy loss of a plan utilizing a central inverter was higher compared to a plan using a string inverter [8].

This paper presents a research study focused on identifying suitable terrain in Libya for the establishment of large-scale photovoltaic power plants. The objective is to design a 50 MW_{AC} grid-connected solar PV plant specifically for implementation in Bani Walid City. The study includes specific conditions, such as a minimum operational lifespan of 25 years, supplying AC electricity to the national network's medium voltage distribution grid, and the inclusion of various components like PV arrays, support structures, tracking systems (optional), inverters, transformers, and data acquisition systems. The paper also presents a comparison between fixed and single axis tracking systems, as well as between central and string inverters. The paper is organized as follows: Section II presents an overview of site characteristics and solar radiation in the proposed site. Section III Design Methodology and Description of the PV plant. section IV represents the simulation result and discussion. Finally, in section V conclusion.

II. OVERVIEW OF SITE CHARACTERISTICS AND SOLAR RADIATION IN BANI WALID

Bani Walid, a city located in the Misrata District of Libya, has been identified as one of the suitable sites for the detailed design and analysis of photovoltaic (PV) systems. Spanning an area of 19,710 km2 and with a population density of approximately 94,424, [9]. Bani Walid offers favorable conditions for the installation of PV systems. Its geographic location makes it an ideal site due to its abundant solar radiation, and it benefits from easy accessibility via road transport. Additionally, the site provides a sufficiently large area suitable for the implementation of utility-scale solar power projects in the West Zone. The main characteristics of the site are summarized in Table (1).

Table 1: Site main characteristics

Bani Walid	**item**
Location	N31.404651°, E13.735237°
Height above sea level (m)	243
Available area	75 hectares
Road access	Flat even road

In this study, the solar climate data for the project site in Bani Walid was collected from satellite data rather than actual on-site measurements. The global horizontal irradiation (GHI) data used for yield simulations in this work is obtained from Metronome data, which is a satellite database providing global irradiation on a tilted surface.

According to the satellite data, the average annual sum of GHI on a tilted surface at the Bani Walid site is reported to be above 1875.8 kWh/m2/year. This data is indicative of the solar potential of the site, and it can be useful for assessing the solar resource availability and estimating the energy yield of photovoltaic systems in the area

III. DESIGN METHODOLOGY AND DESCRIPTION OF PV SYSTEM

In this study, a 50 MW_{AC} solar PV plant was designed specifically for the site in Bani Walid. The module mounting structure chosen for the plant is fixed, meaning the solar panels are stationary and do not track the movement of the sun. The modules are positioned at an optimal inclination angle of around 30 degrees from the horizontal. This angle is considered to be the most suitable for this specific location, and the orientation is typically directed towards the south to maximize solar exposure based on the geographical location of the site. To estimate the power output and analyse the performance of the photovoltaic system, the design and analysis in this study employed the use of the PVSYST simulation program.

A. Project Design

In PVSYST, users have the flexibility to modify various properties of a photovoltaic system. These properties include the type of module, manufacturer, shading conditions, peak wattage, battery type, module orientation, and many others. In the specific case of this study, the Longi Solar LR5-66 HPH 500 M solar module was chosen due to its status as one of the top-tier products available in the market [10], and distinguished for its notable conversion efficiency of 21.30% per cell. This high conversion efficiency is a significant characteristic of the Longi Solar LR5-66 HPH 500 M module, making it an attractive choice for the design of the photovoltaic system in Bani Walid. Table (2) provides electrical and mechanical characteristics (open circuit voltage, short circuit current, the voltage at maximum power, etc) of the Longi Solar LR5-66 HPH 500 M module, and Figure (1) shows the 25 years of power warranty for this type, where Table (3) shows the total number of modules of the system size which will be 50 MW_{AC} in this project as 30 modules in series and 4000 modules in parallel.

Table 2: Electrical and mechanical Characteristics of PV modules

<table>
<tr><th colspan="7">Electrical Characteristics</th></tr>
<tr><td>Power Class</td><td>480</td><td>485</td><td>490</td><td>495</td><td>500</td><td>505</td></tr>
<tr><td>Maximum Power W</td><td>480</td><td>485</td><td>490</td><td>495</td><td>500</td><td>505</td></tr>
<tr><td>Open circuit voltage Voc</td><td>44.95</td><td>45.10</td><td>45.25</td><td>45.4</td><td>45.55</td><td>45.7</td></tr>
<tr><td>Short circuit current A</td><td>13.59</td><td>13.67</td><td>13.74</td><td>13.89</td><td>13.90</td><td>13.97</td></tr>
<tr><td>Voltage at Max. power V</td><td>37.78</td><td>37.93</td><td>38.08</td><td>38.23</td><td>38.38</td><td>38.53</td></tr>
<tr><td>Current at Max. power A</td><td>12.71</td><td>12.79</td><td>12.87</td><td>12.95</td><td>13.03</td><td>13.11</td></tr>
<tr><td>Module efficiency %</td><td>20.4</td><td>20.6</td><td>20.9</td><td>21.1</td><td>21.3</td><td>21.5</td></tr>
<tr><th colspan="3">Operating Parameters</th><th colspan="4">Mechanical Loading</th></tr>
<tr><td>Operational Temperature</td><td colspan="2">-40^{0}C – 85^{0}C</td><td colspan="2">Front Side Max. Static Loading</td><td colspan="2">5400Pa</td></tr>
<tr><td>Power output tolerance</td><td colspan="2">0 – 5 W</td><td colspan="2">Rear Side Max. Static Loadi</td><td colspan="2">2400Pa</td></tr>
<tr><td>Voc and Isc tolerance</td><td colspan="2">+/- 2^{0}C</td><td colspan="2">Hail Stone Test</td><td colspan="2">25mm Hailstone at speed of 23m/s</td></tr>
<tr><td>Max. System Voltage</td><td colspan="2">DC1500V(IEC/UL)</td><th colspan="4">Temperature Rating (STC)</th></tr>
<tr><td>Max. series fuse rating</td><td colspan="2">25 A</td><td colspan="2">Temp. Coeff. Of Isc</td><td colspan="2">+0.048% /^{0}C</td></tr>
<tr><td>Nominal Oper. Cell Temp.</td><td colspan="2">45 +/- 2^{0}C</td><td colspan="2">Temp. Coeff. Of Voc</td><td colspan="2">-0.270% /^{0}C</td></tr>
<tr><td>Protection Class</td><td colspan="2">45 +/- 2^{0}C</td><td colspan="2">Temp. Coeff. Of Pmax</td><td colspan="2">-0.350% /^{0}C</td></tr>
<tr><td>Fire rating</td><td colspan="2">UL type 1 or 2</td><td colspan="2"></td><td colspan="2"></td></tr>
</table>

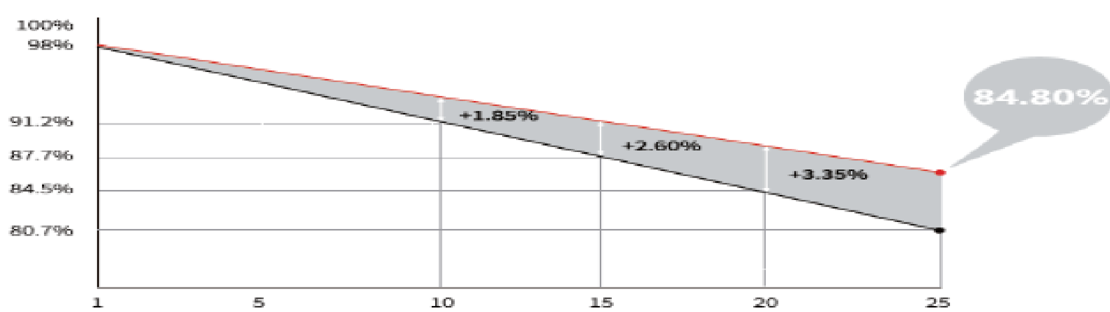


Figure 1: 25 years of power warranty

Table 3: Total number of modules of the system size

No	Attribute	Value
1	Model	LR5-66 HPH 500 M
	Type	Si-mono
	Manufacture	Longi
2	Total Number of PV modules	120000 unit
	In series	30
	In Parallel	4000
	Unit Nominal Peak Power	500Wp
3	Array Global Power	
	Nominal Peak Power (STC)	60000kWp
	At operating condition of 50^0C	54986kWp
4	Array operating characteristics (50^0C)	
	Voltage at max. Power Point (Umpp)	1034 V
	Current at max. Power Point (Impp)	53176 A

B. Inverter

In this study, two concepts of inverter connections were utilized to compare their impact on the output power, plant performance, and total energy loss of the solar power plant. The two concepts are central inverter and string inverter. The central inverter is a type of inverter where the entire photovoltaic array is connected to a single large-scale inverter. On the other hand, the string inverter configuration involves multiple smaller inverters, with each inverter connected to a string of photovoltaic modules. Table. (4) presents the specifications of each inverter model used in the study.

Table 4: Specifications of the inverters

Inverter	Specifications	
	Central Inverter	String Inverter
Model	Sunny Central 4000 UP	Sunny High Power SHP125-US-20-PEAK3
Manufactured	SMA	SMA
Nominal AC Power	4000kVA	125kW
Max. AC Power	4000kVA	125kW
Nominal Ac Current	3850A	151A
Max. Ac Current	3850A	151A
Max. Efficiency	98.8%	99.0%
Euro Efficiency	98.6%	98.71%
Min.Voltage at Max. Power Point	880v	705v
Max. Voltage at Max. Power Point	1325v	1450v

C. Near Shadings

By using PVsyst and AutoCAD, 3DMAX software can simulate the shading that could happen in the environment or by the arrays. We designed and simulated the movement of the sun to measure the distance between each array without affecting each other by shading, as shown in Figure (2). The spacing between each array should be about 9m, with a free space of 5m to allow the maintenance team and cars to move freely. Figure (3) shows the visual concept of the proposed solar power plant.

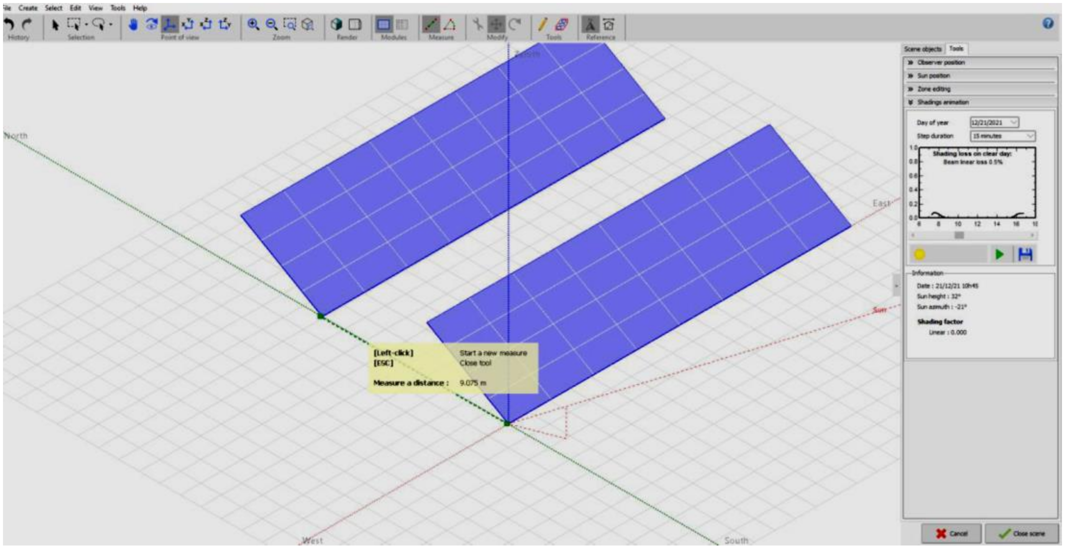


Figure 2: Near shading Simulation

Figure 3: Visual Concept of Proposed Solar Power Plant

IV. CASE STUDY RESULTS AND DISCUSSION

A. System Performance Simulation

The performance assessment of the grid-connected PV system has been conducted, and key indicators such as energy yield, yield factor (YF), capacity factor (CF), and performance ratio (PR) have been calculated. Among these indicators, energy yield and yield factor are particularly important for analyzing PV systems in grid-connected PV plants. Energy yield refers to the net AC energy produced by the PV array on an annual, monthly, or daily basis. Yield factor (YF) is obtained by dividing the annual energy yield output of the PV array by the peak power of the installed PV system [11]. In this study, the analysis of energy yield was carried out for both fixed and tracking plane systems, as well as central and string inverters.

B. Results and Comparisons

Case 1: Comparison between Fixed and Tracking tilted Plane System using Centralized inverter

For the fixed system, the general parameters of PV array characteristics, Array losses are shown in Figure (4), while the main results obtained by PVsyst are shown in Figure (5), and the same for Tracking system are shown in Figures (6,7).

PV Array Characteristics

PV module

Manufacturer	Generic
Model	LR5-66 HPH 500 M
(Original PVsyst database)	
Unit Nom. Power	500 Wp
Number of PV modules	120000 units
Nominal (STC)	60.00 MWp
Modules	4000 Strings x 30 In series
At operating cond. (50°C)	
Pmpp	54.09 MWp
U mpp	1034 V
I mpp	53176 A

Inverter

Manufacturer	Generic
Model	Sunny Central 4000 UP
(Original PVsyst database)	
Unit Nom. Power	4000 kWac
Number of inverters	13 units
Total power	52000 kWac
Operating voltage	880-1325 V
Pnom ratio (DC:AC)	1.15

Total PV power

Nominal (STC)	60000 kWp
Total	120000 modules
Module area	281545 m²
Cell area	261487 m²

Total inverter power

Total power	52000 kWac
Number of inverters	13 units
Pnom ratio	1.15

Array losses

Array Soiling Losses
Loss Fraction 3.0 %

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 29.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 0.32 mΩ
Loss Fraction 1.5 % at STC

Module Quality Loss
Loss Fraction -0.4 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

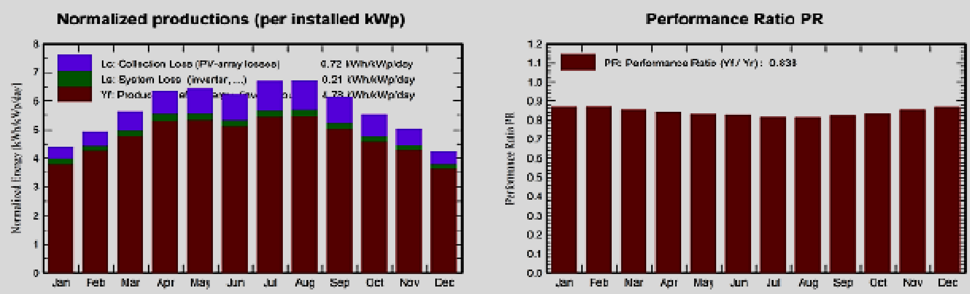
IAM loss factor
Incidence effect (IAM): User defined profile

0°	25°	45°	60°	65°	70°	75°	80°	90°
1.000	1.000	0.995	0.962	0.936	0.903	0.851	0.754	0.000

System losses

Auxiliaries loss
constant (fans) 26.0 kW
26.0 kW from Power thresh.

Figure 4: Fixed Plane Grid-connected System Parameters



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray GWh	E_Grid GWh	PR ratio
January	93.1	34.54	13.27	136.7	131.0	7.45	7.13	0.869
February	106.0	49.61	13.55	137.8	131.8	7.51	7.20	0.870
March	150.8	69.01	16.43	174.5	166.7	9.33	8.94	0.853
April	183.3	81.96	19.24	190.3	181.2	10.04	9.62	0.843
May	209.7	89.29	22.80	200.1	190.4	10.41	9.98	0.831
June	204.9	89.35	25.19	186.9	177.5	9.64	9.26	0.825
July	224.6	82.68	28.03	208.0	197.6	10.58	10.15	0.813
August	208.3	78.44	28.43	208.8	198.7	10.62	10.18	0.813
September	166.3	69.18	26.45	184.9	176.3	9.50	9.11	0.821
October	136.6	57.89	24.01	170.9	163.6	8.92	8.55	0.834
November	105.3	39.82	18.67	151.2	144.9	8.08	7.75	0.854
December	86.9	35.09	14.52	131.0	125.6	7.13	6.83	0.868
Year	1875.7	776.85	20.92	2081.3	1985.3	109.21	104.68	0.838

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

Figure 5: Fixed Plane Grid-connected System Main Results.

PV Array Characteristics

PV module		Inverter	
Manufacturer	Generic	Manufacturer	Generic
Model	LR5-66 HPH 500 M	Model	Sunny Central 4000 UP
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	500 Wp	Unit Nom. Power	4000 kWac
Number of PV modules	120000 units	Number of inverters	13 units
Nominal (STC)	60.00 MWp	Total power	52000 kWac
Modules	4000 Strings x 30 In series	Operating voltage	880-1325 V
At operating cond. (50°C)		Pnom ratio (DC:AC)	1.15
Pmpp	54.99 MWp		
U mpp	1034 V		
I mpp	53176 A		
Total PV power		**Total inverter power**	
Nominal (STC)	60000 kWp	Total power	52000 kWac
Total	120000 modules	Number of inverters	13 units
Module area	281845 m²	Pnom ratio	1.15
Cell area	261487 m²		

Array losses

Array Soiling Losses
Loss Fraction 3.0 %

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 29.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 0.32 mΩ
Loss Fraction 1.5 % at STC

Module Quality Loss
Loss Fraction -0.4 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

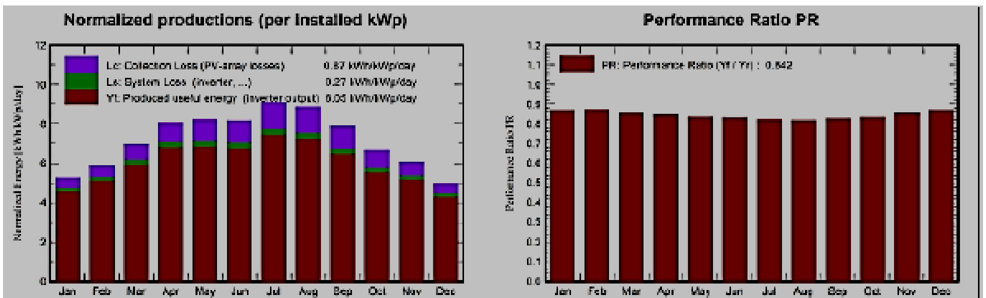
IAM loss factor
Incidence effect (IAM): User defined profile

0°	25°	45°	60°	65°	70°	75°	80°	90°
1.000	1.000	0.995	0.962	0.936	0.903	0.851	0.754	0.000

System losses

Auxiliaries loss
constant (fans) 26.0 kW
26.0 kW from Power thresh.

Figure 6: Tracking Plane Grid-connected System Parameters



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray GWh	E_Grid GWh	PR ratio
January	93.1	34.54	13.27	163.3	157.6	8.91	8.51	0.869
February	106.0	49.61	13.55	164.8	158.9	9.02	8.63	0.873
March	150.8	69.01	16.43	215.4	207.6	11.56	11.06	0.855
April	183.3	81.96	19.24	241.8	233.1	12.87	12.31	0.849
May	209.7	89.29	22.80	254.6	245.3	13.35	12.79	0.837
June	204.9	89.35	25.19	245.2	236.2	12.79	12.26	0.833
July	224.6	82.68	28.03	282.5	272.4	14.53	13.92	0.821
August	208.3	78.44	28.43	274.8	265.1	14.10	13.50	0.819
September	166.3	69.18	26.45	236.4	228.0	12.23	11.71	0.826
October	136.6	57.89	24.01	206.7	199.4	10.82	10.36	0.835
November	105.3	39.82	18.67	182.2	175.9	9.78	9.36	0.856
December	86.9	35.09	14.52	154.5	149.0	8.43	8.06	0.870
Year	1875.7	776.85	20.92	2622.4	2528.4	138.38	132.47	0.842

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

Figure 7: Tracking Plane Grid-connected System Main Results

From the Figures (5,7), it was observed that using the Fixed Tilt system and Tracking system, the energy generated by the Fixed Tilt system and injected into the grid over a year was 104.7 GWh. In comparison, the Tracking system design produced 132.5GWh, which is 26.5% higher than the Fixed Tilt system. This increase falls within the expected range of 20-35% improvement [5,6]. The Tracking system's ability to follow the direction of sunlight and utilize peak sunlight hours contributes to its higher efficiency. Additionally, when comparing the electricity production output of PV systems with fixed and solar tracker installed panels over a year, it was observed that the fixed plane system generated an average of 8.72 GWh per month, while the solar tracker system produced an average of 11.039GWh, as shown in Figure (7), this indicates that the solar tracker system consistently outperformed the fixed plane system in terms of electricity production. Furthermore, the Performance Ratios (PR) for the PV Power Plant were measured to be within the range of 82-85% at the output of the inverter, and the first-year overall PR was 83.83% for the Fixed plane system and 84.19% for the Tracking plane system. High-performance PV plants can achieve PR values of up to 80% [8]. However, it is worth noting that seasonal fluctuations in climatic conditions, particularly high temperatures during summer, can have a significant impact on the PR, even for well-operating systems. Figure (8) shows the monthly energy injected for fixed and tracking systems.

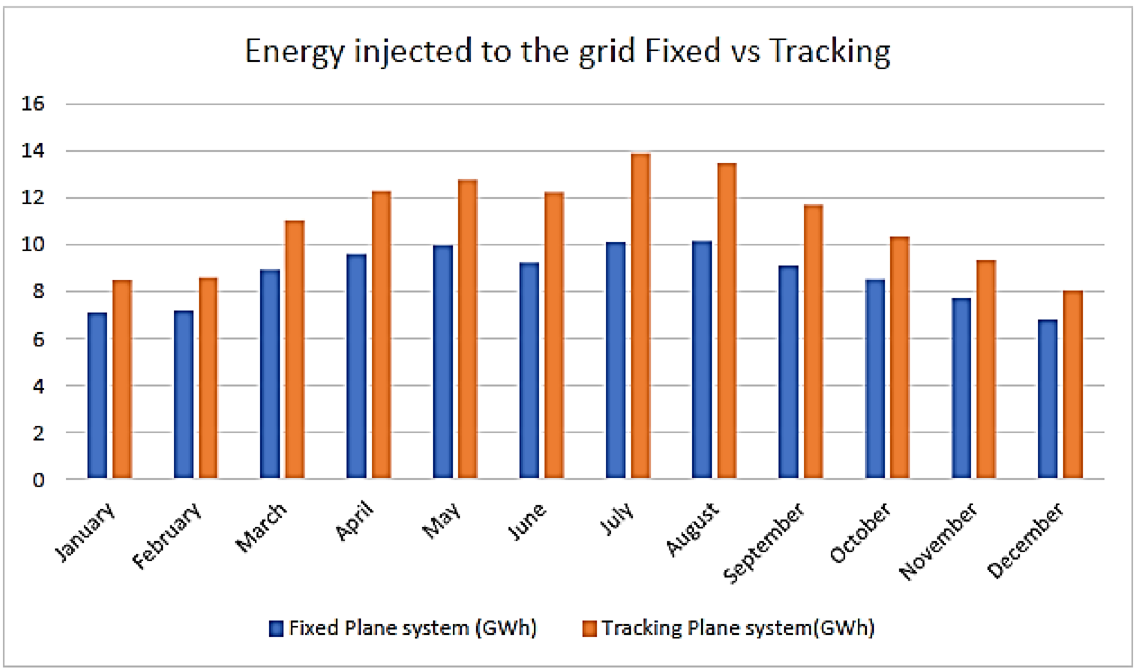


Figure 8: Energy injected to the grid.

Case 2: Comparison between Central and String inverter

PVSYST software is used to compare the output power, plant performance as well as the total energy loss of the solar power plant in the case of using a central inverter versus a string inverter. The Figures (9-14) show all the results for both cases.

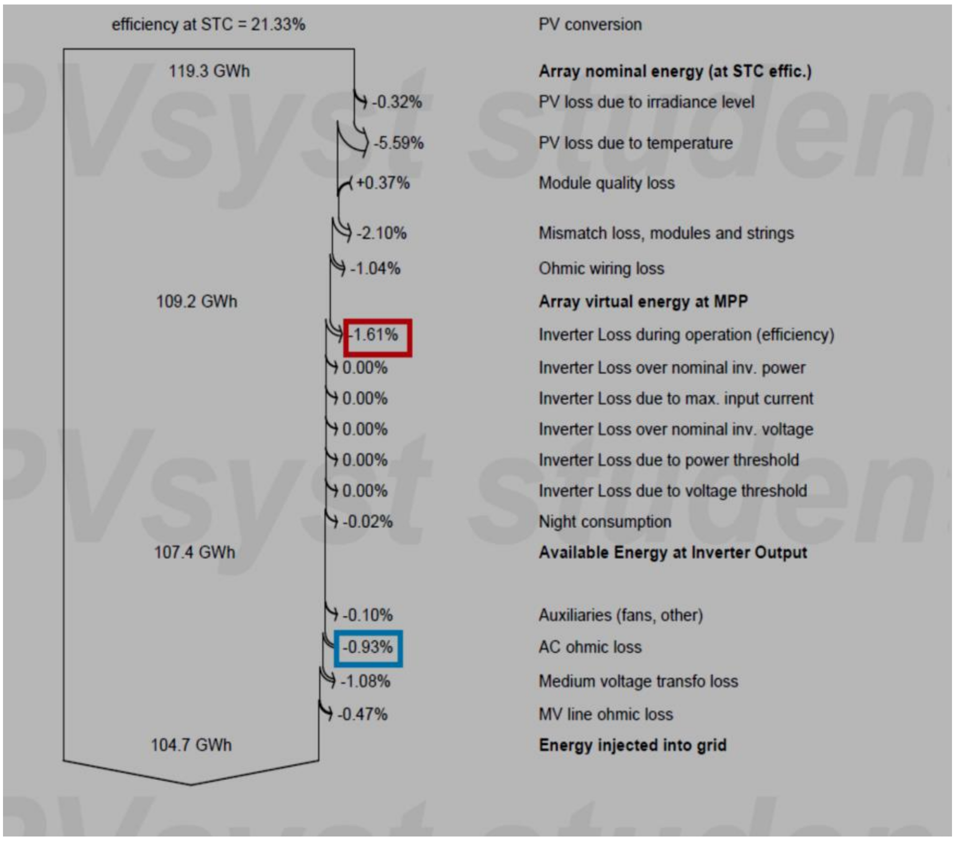


Figure 9: The loss diagram of solar power plant. Central inverter

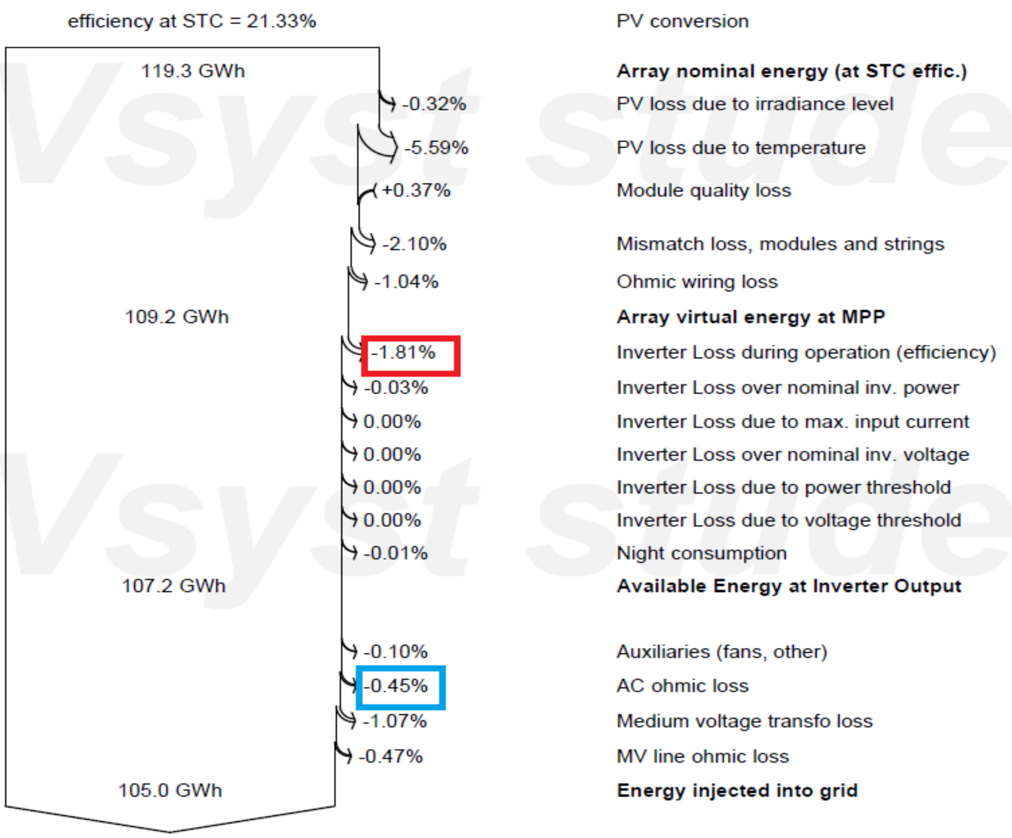


Figure 10: The loss diagram of solar power plant. String inverter.

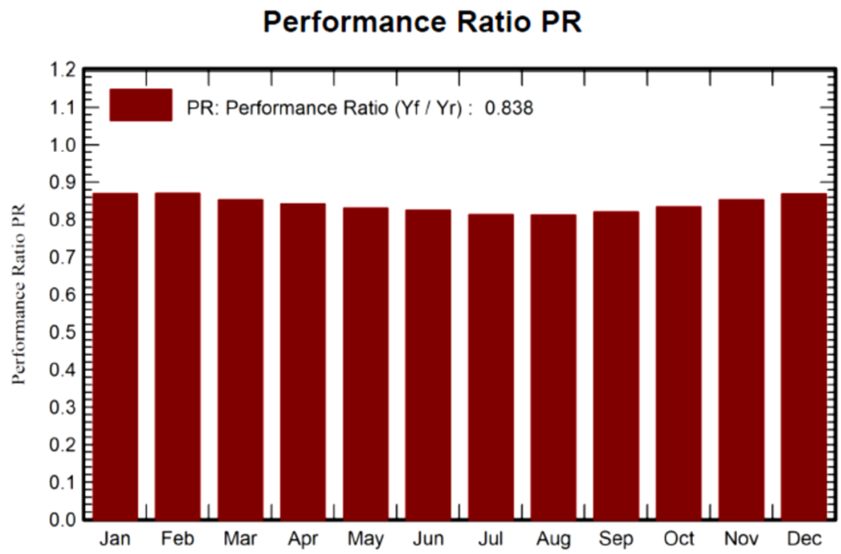


Figure 11: The performance of solar power plant. Central inverter

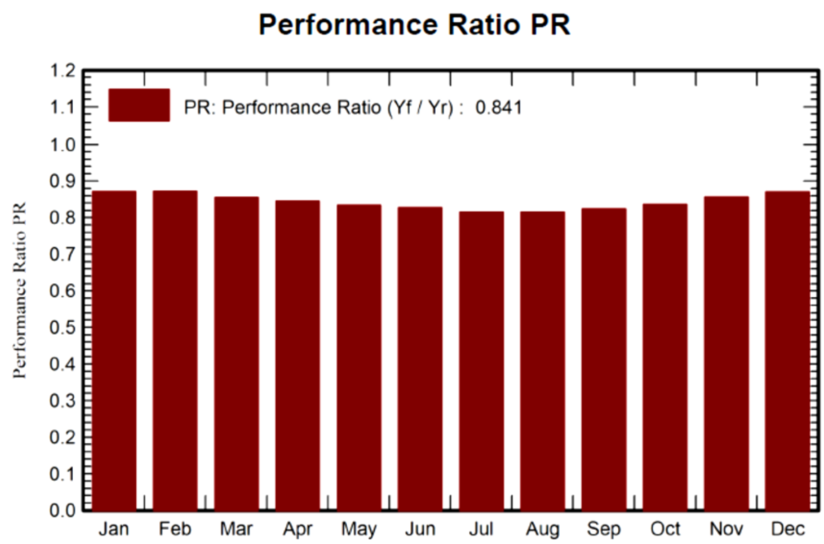


Figure 12: The performance of solar power plant. string inverter

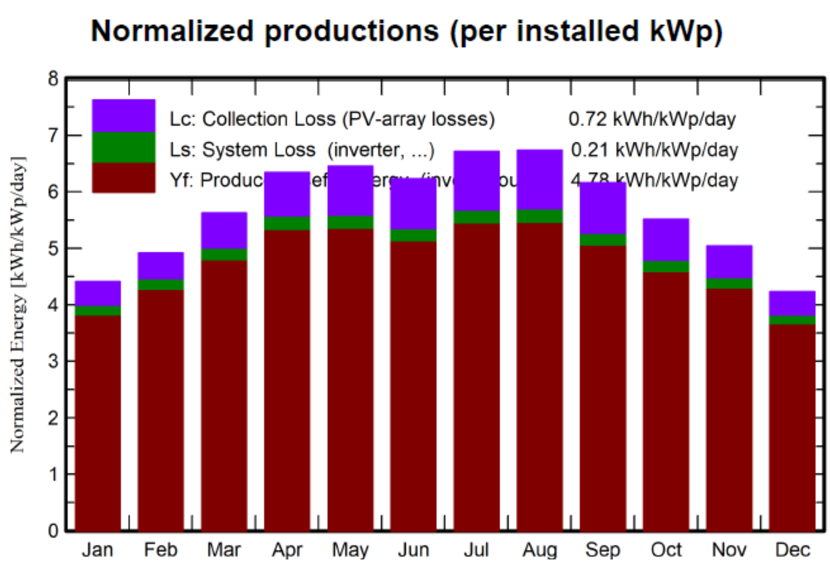


Figure 13: Impact of power loss on grid output. Central inverter

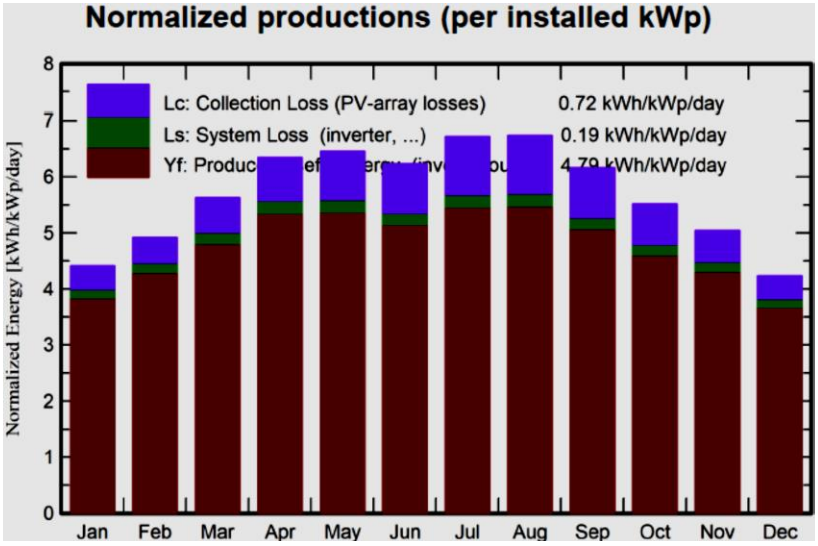


Figure 14: Impact of power loss on grid output. String inverter

The two approaches have similar values for most of the loss factors, except for inverter loss and AC ohmic loss. When using a central inverter, the inverter loss is 1.61%, which is 0.2% lower than when using a string inverter at 1.81%. This difference is because the central inverter can generate more power with the same design characteristics as the solar panel strings [7,8]. However, using a central inverter requires a larger section of the AC cable, resulting in higher AC ohmic loss. The AC ohmic loss for the central inverter scenario is 0.93%, which is 0.48% higher than the 0.45% in the case of using a string inverter. Consequently, the total energy loss for the central inverter scenario is 0.28% greater than the total energy loss for the string inverter scenario. This difference in loss values between the two scenarios affects both the electricity transmitted to the utility grid and the performance of the solar power plant.

According to Table (5), the solar power plant generates the highest amount of electricity to the utility grid from May to September, while the lowest amount is supplied in December. This pattern aligns with the change in monthly average global irradiation values. Additionally, the scenario using a string inverter generates a slightly higher amount of electricity, with 104.97GWh/year, compared to 104.68GWh/year for the scenario using a central inverter.

Table 5: Energy injected into the grid (E-Grid)

Month	Global irradiation (kWh/m²)	E-Grid (Central Inverter) (GWh)	E-Grid (String Inverter) (GWh)
January	93.1	7.13	7.14
February	106	7.20	7.22
March	150.8	8.94	8.95
April	183.3	9.62	9.65
May	209.7	9.98	10.01
June	204.9	9.26	9.28
July	224.6	10.15	10.18
August	208.3	10.18	10.21
September	166.3	9.11	9.14
October	136.6	8.55	8.58
November	105.3	7.75	7.77
December	86.9	6.83	6.85
Year	**1875.7**	**104.68**	**104.97**

C. CO_2 Emission

The installation of solar panels can lead to significant reductions in carbon emissions over the next three decades. According to the analysis, using solar energy instead of conventional technologies can help avoid approximately 2,290,757 tons of CO_2 emissions. This indicates that solar energy is an effective way to decrease greenhouse gas emissions and combat climate change. It's important to consider factors such as system size, efficiency, solar resource availability, and the energy mix of the grid when assessing the specific emissions reduction achieved by a PV system. In summary, transitioning to solar energy can contribute to reducing CO_2 emissions and promoting the use of clean, renewable energy sources.

V. CONCLUSION

- Traditionally, most PV power plants are designed with fixed installations. However, it is also possible to generate more energy using the same quantity of PV panels and inverters by utilizing tracker systems.
- Tracker systems offer an alternative to standard installations, employing mechanical construction with moving parts and software. Before investing, it is essential to understand the advantages and disadvantages of this type of installation.
- During the design phase, it should be noted that tracker systems have a higher initial investment cost and maintenance expenses compared to non-tracking systems. However, their significant advantage lies in their ability to produce more energy within the same area. According to the tracker system designer, it is possible to achieve an increase of 20-35% in energy production.
- The results obtained from the PVSYST tool indicate that, under the same conditions of annual average solar radiation in Libya, solar cell capacity, and loss factors, the total energy loss of the power plant using a central inverter is higher than that of the scenario using a string inverter. Consequently, the scenario with a string inverter demonstrates slightly greater generated electricity and overall performance compared to the scenario with a central inverter.
- By generating electricity from solar energy instead of conventional sources, CO_2 emissions were reduced by approximately 2,290,757 tons, thereby making a significant positive impact on the environment.

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