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Design of 50 MW grid-connected photovoltaic power using PVsyst software in Tininai region, Bani Walid

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تصميم محطة طاقة شمسية متصلة بالشبكة بقدرة 50 ميجاوات باستخدام برنامج PVsyst لموقع تينيناي بمدينة بني وليد

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Abstract:
At present, the extensive use of fossil fuel-based power generation has led to an increase in carbon dioxide emissions affecting the environment. If this continues, the air temperature is expected to rise, increasing storms, hurricanes, droughts and floods. Therefore, urgent action is needed now to change the existing energy system to renewable energy as it leads to little or no emissions. This paper presents the design and simulation of a 50 MW grid-connected solar power generation system in the Tininai region. It also represents the technical and economic potential and annual performance of the solar PV system. The design was validated and simulated using PVSYST to determine the optimal size and specifications of the grid-connected power and electrical generation system. Electricity generated from solar PVP is 50 MW. This energy can be utilized to reduce the load on the General Electricity Company and to help reduce the annual electricity bill for the Tininai and Bani Walid regions in general. The study provides an overview of solar PVP. The results of this project will encourage my country, Bani Walid, to decide on installing a photovoltaic solar energy system in order to reduce loads and reduce the cost of maintenance and transportation. Moreover, the solar power plant helps conserve oil and reduce environmental impacts.

Keywords: PVsyst Software, Solar Photovoltaic, Renewable Energy.

الملخص
في الوقت الحاضر، أدى الاستخدام المكثف لتوليد الطاقة المعتمدة على الوقود الأحفوري إلى زيادة انبعاثات ثاني أكسيد الكربون التي تؤثر على البيئة، وإذا استمر ذلك فمن المتوقع أن ترتفع درجة حرارة الهواء، مما يزيد من العواصف والأعاصير وحالات الجفاف والفيضانات. ولذلك، هناك حاجة إلى اتخاذ إجراءات عاجلة الآن لتغيير نظام الطاقة الحالي إلى الطاقة المتجددة لأنه يؤدي إلى انبعاثات قليلة أو معدومة. تعرض هذه الورقة تصميم ومحاكاة نظام توليد الطاقة الشمسية المتصل بالشبكة بقدرة 50 ميجاوات في منطقة تينيناي. كما أنه يمثل الإمكانات الفنية والاقتصادية والأداء السنوي لنظام الطاقة الشمسية الكهروضوئية. تم التحقق من صحة التصميم ومحاكاته باستخدام *PVSYST* لتحديد الحجم والمواصفات الأمثل لنظام توليد الطاقة والكهرباء المتصل بالشبكة. الكهرباء المولدة من الطاقة الشمسية *PVP* هي 50 ميجاوات. ويمكن الاستفادة من هذه الطاقة في تخفيف الحمل على الشركة العامة للكهرباء وللمساعدة في تخفيض فاتورة الكهرباء السنوية لمنطقتي تينيناى وبني وليد بشكل عام. تقدم الدراسة لمحة عامة عن الطاقة الشمسية. نتائج هذا المشروع ستشجع بلدي بني وليد على اتخاذ القرار بشأن تركيب نظام الطاقة الشمسية الكهروضوئية من أجل تقليل الأحمال وتقليل تكلفة الصيانة والنقل. علاوة على ذلك، تساعد محطة الطاقة الشمسية في الحفاظ على النفط وتقليل التأثيرات البيئية.

الكلمات المفتاحية: برنامج *PVsyst*، الطاقة الشمسية الكهروضوئية، الطاقة المتجددة.

1 Introduction

In a world facing increasing energy challenges, sustainable energy is the cornerstone of sustainable economic and social development [1]. In particular, electricity is the vital nerve that feeds various sectors and contributes to improving the quality of life of people [2]. However, reliance on traditional energy sources, such as fossil fuels, represents an imminent risk because of their depletion and negative impacts on the environment [3]. This research presents the design and simulation of the grid-connected solar PVsyst system at 50 MW using the PVsyst simulation program [4]. The system is designed to include the identification of the optimal composition of the system, the selection of appropriate components, the analysis of energy production and the evaluation of the system's performance [5].

This study presents a design and calculation of the solar (electrical) energy system using a system for the proposed energy station in the Tininai region [6]. This area is located about 60 kilometers from the center of the city of Bani Walid, and about 240 kilometers from the capital, Tripoli, Libya [7]. The Tininai region has a latitude of 31.76 N˚ and a longitude of 13.99 E˚, rising to about 280 at sea with a population of about 8,000 [8]. In this context, solar energy is emerging as a promising and clean alternative capable of meeting the growing energy needs, especially in areas that God loved with abundant solar radiation, such as the city of Ben Walid al-Libya [9]. This city, located in the northwest of Libya, enjoys a strategic geographic location that allows it to benefit from sunlight almost throughout the year. Statistics indicate that the population of Bani Walid is approximately 120,000 [10]. The city's daily power usage is expected to range from 45 to 85 MW, with noticeable fluctuations over the several seasons of the year. Research suggests that building a solar power plant with a capacity of up to 50 MW per day might meet the energy requirements of the city and potentially allow it to be connected to the public electricity grid [11]. The station planned for the Tininai neighborhood, which is 1.35 kilometers away from the 66 V station, has a suitable infrastructure. This includes an existing power distribution station near the main transportation network, which makes it easy to link the station [12]. The presence of ample and appropriate land for solar panels is also a favorable aspect for the success of this crucial project.

Energy comes from the sun in two heat and light forms: in solar thermal techniques, thermal side of solar energy is used to produce energy while in solar PV techniques, photon light is used from the sun to produce energy. Solar panels generate continuous current energy and are then converted into a frequency current and submitted to the network for distribution and use. Given that solar radiation is in its strongest condition during the day, it may be possible to obtain as much electricity as possible from the electrical system; the energy produced in the grid will be injected.

2 Design and Objective

The design of PV plants required the usage of thousands of PV panels, each capable of producing hundreds of watts. During the PV plant design operations, the designer must select the proper number, size, and type of PV modules and inverters. Furthermore, components need to set up PV plants in order to maximize energy output while also enhancing plant lifetime maintenance. A thorough grasp of the system and components is essential when constructing a 50 MW PV plant. As a result, the designer will need to understand more about site selection and solar statistics, components and specifications, solar PV efficiency, design optimization, and cost analysis.

2.1 Selection of locations and solar data for the solar energy facility

Situated in the Tininai district, on the outskirts of Bani Walid City, the station site spans around 75 hectares as shown in Figure 1.

Figure 1: Location Tininai Station.

The information gathered from the locations of the city of Bani Walid is displayed in Figure 2 and can be found on the websites of the National Aeronautics and Space Administration (NASA) and the Libyan National Center for Standardization and Measurement. (7) kWh/m^2/day as shown Figure 2.

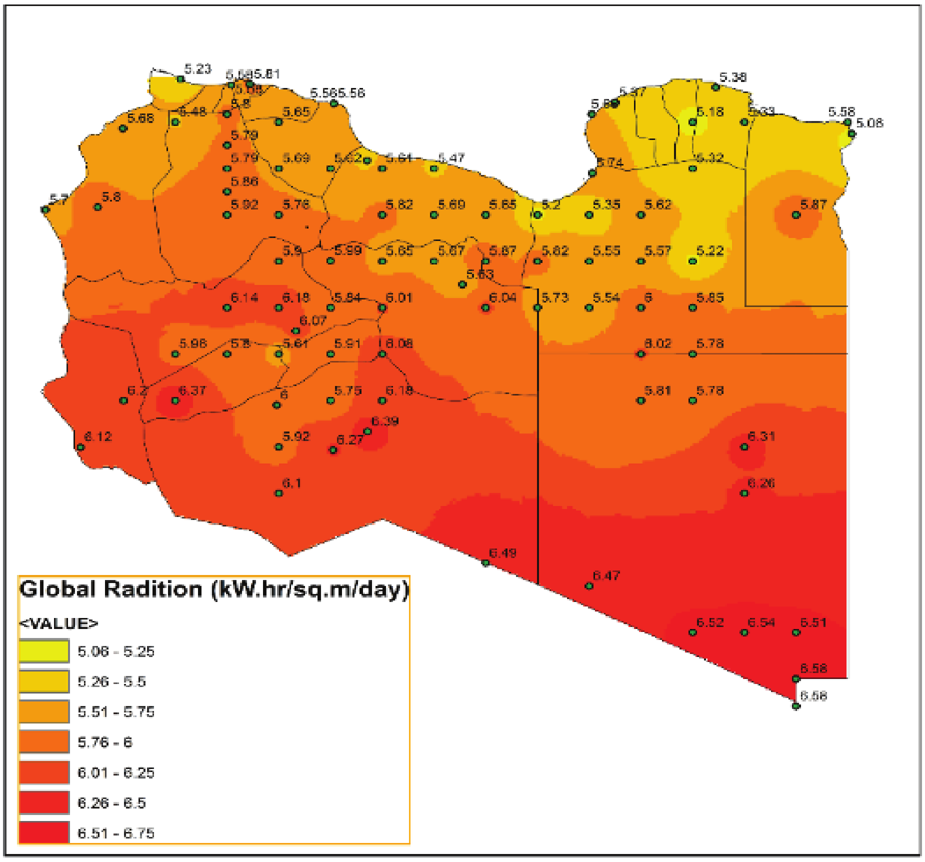


Figure 2: A Solar Irradiation Map of Bain Walid (kWh/m2/year).

Table 1: The Weather, Temperature, and Radiation in Bani Walid.

	Global horizontal irradiation	Horizontal diffuse irradiation	Temperature	Wind Velocity	Linke turbidity	Relative humidity
	kWh/m²/mth	kWh/m²/mth	°C	m/s	[-]	%
January	94.6	38.0	13.1	3.90	3.547	67.7
February	108.6	45.2	13.5	4.29	3.989	65.4
March	152.1	71.3	16.5	4.30	5.542	61.8
April	182.2	81.0	19.4	4.51	7.000	58.2
May	210.3	93.1	22.9	4.50	7.000	55.9
June	208.1	92.7	25.4	4.00	6.157	57.5
July	225.2	81.7	28.2	3.70	5.533	57.8
August	209.0	79.3	28.6	3.60	5.401	60.1
September	169.0	68.5	26.6	3.90	6.440	63.2
October	138.3	58.6	24.2	3.61	5.291	60.8
November	106.1	38.5	18.8	3.59	4.170	62.0
December	88.0	33.1	14.5	4.00	3.617	65.4
Year	**1891.5**	**781.0**	**21.0**	**4.0**	**5.307**	**61.3**

Global horizontal irradiation year-to-year variability 3.4%

2.2 Selecting and sizing of solar PV and inverter

Following the system's technical and engineering calculations, the panels and inverters must be selected in a precise technical manner, taking into account the equipment's capacity and efficiency. Table 2 depicts the PV array and inverter characteristics. The first solar 445WP- polycrystalline silicon solar panel is proposed for the construction of a 50MW/day PV power plant, as well as for simulation in PVSYST software.

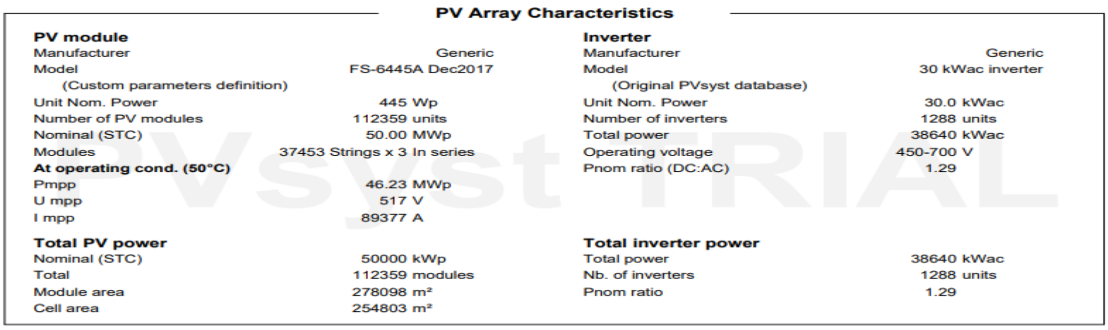
Table 2: Electrical Data specification for commercial Solar PV.

Type	MONO CRYSTALLINE
No of module	*112359*
Maximum Power (Pmax)	445Wp
Maximum Power Voltage (Vmp)	185.60V
Maximum Power Current (Imp)	2.560A
Open-circuit Voltage (Voc)	220.40V
Short-circuit Current (Isc)	2.560A
Module Efficiency	19.73%

Inverters are used to convert direct current (DC) to alternating current (AC) and reduce the harmonics that come from the conversion. Table 3 shows the electrical data requirements of a commercial inverter. The PV power array and inverter characteristics are the most essential considerations when choosing and developing a solar PV system. The attributes include information about the PV modules, the overall power of the array, the array's working circumstances, and the inverter. Figure 3 Provide a report that describes in full the features of both the PV module and the inverter.

Table 3: Electrical Data Specification for Commercial Inverter.

Type	Grid Inverter
Input DC voltage	900Vdc
Input DC	450 dc
Output AC voltage	400VAc
No. of Phases	3 phases
Efficiency	94.00%
No of inverters	1288



PV Array Characteristics

PV module		Inverter	
Manufacturer	Generic	Manufacturer	Generic
Model	FS-6445A Dec2017	Model	30 kWac inverter
(Custom parameters definition)		(Original PVsyst database)	
Unit Nom. Power	445 Wp	Unit Nom. Power	30.0 kWac
Number of PV modules	112359 units	Number of inverters	1288 units
Nominal (STC)	50.00 MWp	Total power	38640 kWac
Modules	37453 Strings x 3 In series	Operating voltage	450-700 V
At operating cond. (50°C)		Pnom ratio (DC:AC)	1.29
Pmpp	46.23 MWp		
U mpp	517 V		
I mpp	89377 A		
Total PV power		**Total inverter power**	
Nominal (STC)	50000 kWp	Total power	38640 kWac
Total	112359 modules	Nb. of inverters	1288 units
Module area	278098 m²	Pnom ratio	1.29
Cell area	254803 m²		

Figure 3: The PV array and inverter characteristic.

2.3 efficient solar PV.

This system necessitates a thorough investigation of all elements influencing the efficiency of solar photovoltaic energy. Solar PV typically achieves a maximum efficiency of about 25%. Studying the elements affecting the solar PV system is crucial since it helps enhance its efficiency, as listed below:

- Direction of the photovoltaic unit: Changing the direction of the photovoltaic unit does not depend on azimuth; it will reduce current and result in low power. Solar panels should face south. The Tininai region is located on the north side of the land. There are two techniques to calculate the azimuth angle.

The first step is to employ a solar tracker, which aids in transmitting PV energy to maximum . The second method involves manually using a compass, pointing to the south at an angle of (30) degrees and an azimuth of 0 .

- Angle of the PV modules: Angle is another factor that needs be changed after placing the PV module in the south. The angle of solar PV should face the sun, and the best angle varies based on location and season. The lower the slope angle, the more productive the summer months are. In the winter, larger inclination angles are employed for low radiation circumstances.
- PV module radiation: The input variable influences the radiation efficiency of solar modules. As the radiation grows, so does the plate's short circuit current, increasing the module's output efficiency. If the radiation increases, so does the maximum power and efficiency.
- PV module temperature: The solar PV module meets laboratory standards at 25°C and 1000W/m2. As the temperature rises, both current and voltage drop. The conversion efficiency of the module diminishes as the surface temperature of the module rises.
  As a result, it is critical to select the appropriate type of PV module for the temperature and location.
- Shading of the PV module: The passage of clouds as well as the proximity to buildings or trees reduces the performance of solar PV. In the case of shading, the short circuit current reduces the power output. As a result, solar panels work best when not shaded.
- Ingress protection for photovoltaic modules. IP is an indicator device for protection against water and dust. The devices display two numbers: the first reflects the water level and the second represents the dust level. A higher number indicates more protection, while a lower number indicates minimal.

3 Design based on software

The simulation component of our research focuses on simulating the stationary unit and the possibility of benefiting from radiation falling on solar panels based on the angles, number of panels, their capacity, the number and capacity of inverters in the design, and the amount of energy. energy. PVSYST 7.1.2 was used to extract electricity from the system. PVSYST is organized into four sections: initial design, project design, databases, and tools. The project design area is divided into four subsections: grid-connected, self-contained, amplified, and DC. Our study focuses on the design of grid-connected photovoltaics; hence we are particularly interested in this subject. Using meteorological data from NASA satellites, simulations will be done to determine the annual energy production of the one presented in Figure 4. Based on the foregoing, design and estimate the results of a solar power plant using PVSYST software as shown in Figure 5.

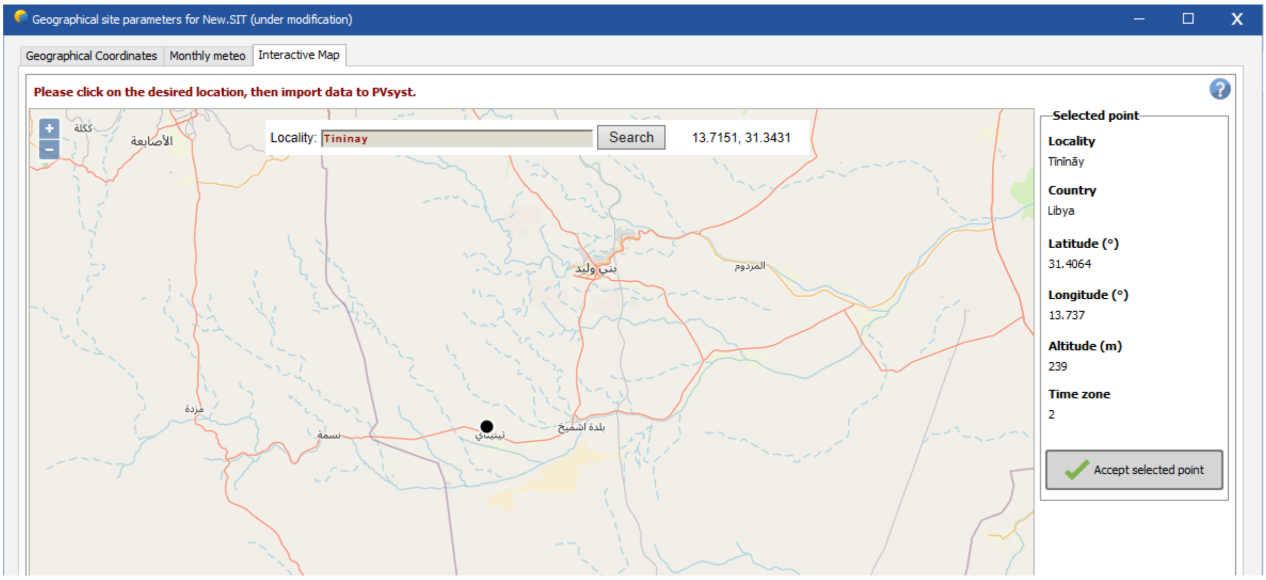


Figure 4: Geographical Conditions.

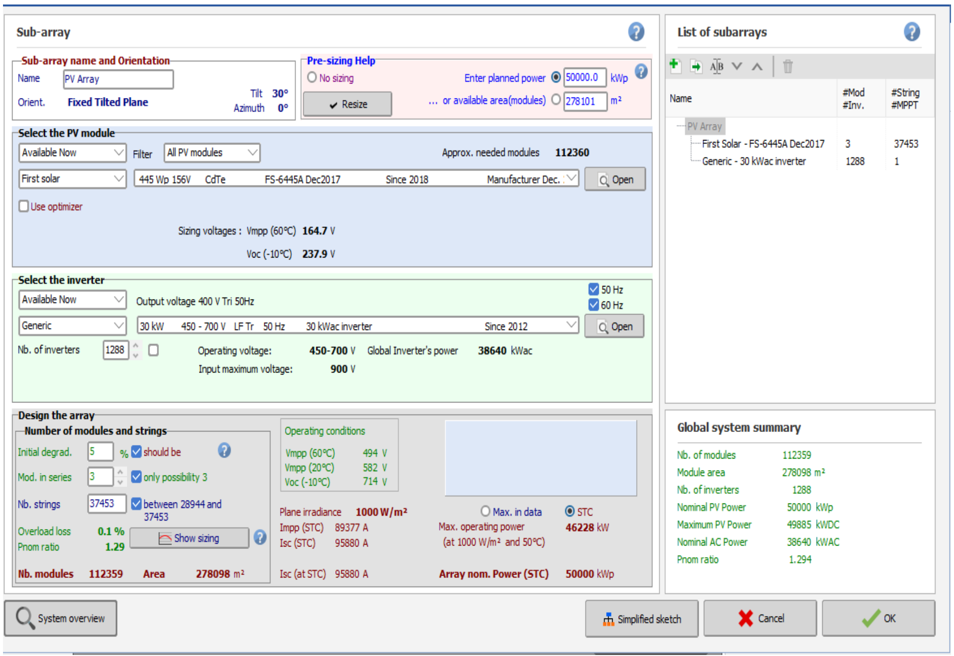


Figure 5: System Design (Solar Module, Inverter, Array Design).

3.1 Design Layout

A PV grid-connected system comprises of a solar array, inverters, a user (load), and a grid connection. The grid does not include a storage component because the generated energy is fed into the public power grid. Figure 6 illustrates the proposed model using PVsyst software. It clearly demonstrates how the system is connected and how the user receives power from the PV power plant.

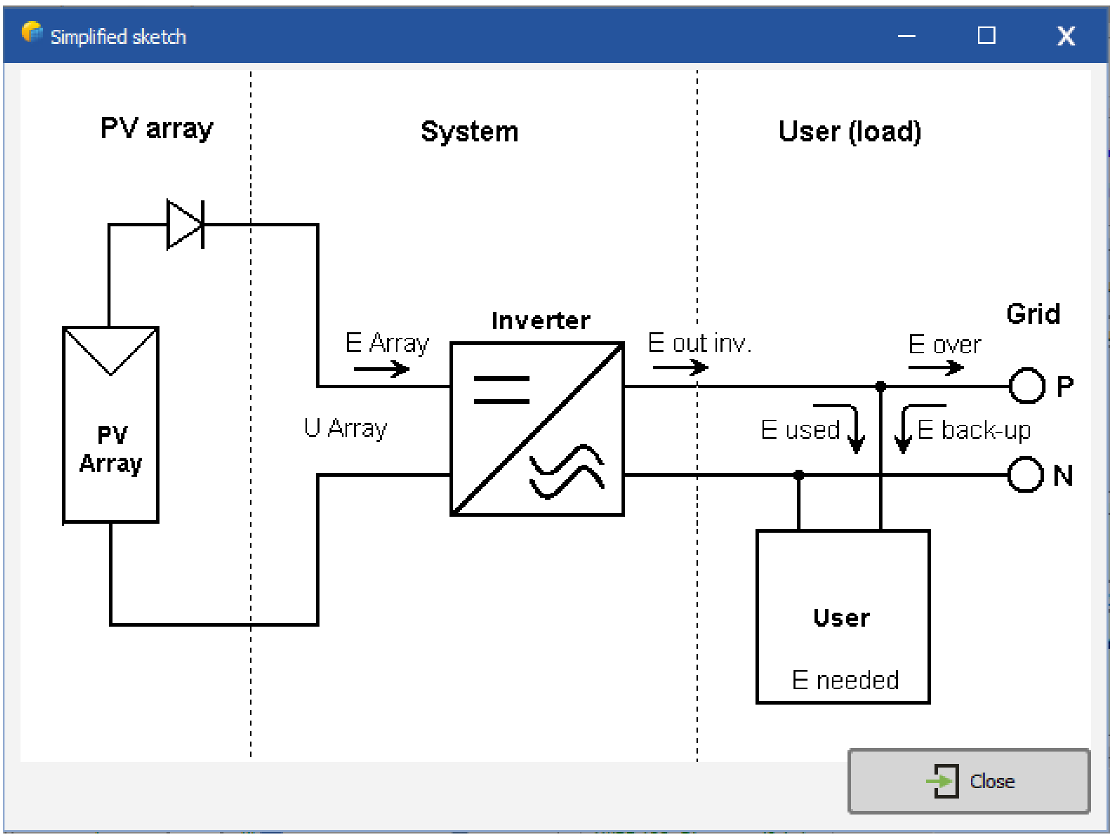


Figure 6: PVsyst Schematic Diagram of System.

3.1.1 Calculate the required space

A total of 112359 panels/modules were used in the design of our PV power plant. The area of each unit is 2,475 m2 and hence the total generating area of the plant is 278098 m2 while the total area of the plant will be larger than the generating area of the plant.

The distance between the panels must be calculated (these panels need a stand), and thus the total area required is estimated by dividing the total area by 0.7

4 Results and discussion

A simulation of a solar power plant designed to provide 50 MW of required power, system efficiency and system losses has been performed. The results are based on simulation software for the case and analysis of system components, a full report on which is published. The report contains several important features that describe the system.

4.1 Main Simulation Results

Table 3 presents the major balances and simulation findings for the Tenaynai PV facility. According to the table, the highest monthly energy production occurred in August (8796 MWh) and the lowest in December (6021 MWh). The E Array's annual effective energy output is (84937) kWh. However, it should be remembered that the E Array uses DC power. After converting DC electricity to AC power, we have an electronic network, which is connected to the grid. The annual power connected to the grid is 18,922,027 kilowatt hours.

The difference between the electronic array and the electronic grid defines the inverter's efficiency (0.807).

Table 4: Balances and main results.

Balances and main results

	GlobHor	DiffHor	T_Amb	GlobInc	GlobEff	EArray	E_Grid	PR
	kWh/m²	kWh/m²	°C	kWh/m²	kWh/m²	MWh	MWh	ratio
January	94.6	38.05	13.10	137.3	136.1	6218	5791	0.843
February	108.6	45.21	13.49	143.0	141.5	6413	5974	0.836
March	152.1	71.25	16.46	175.5	173.2	7769	7238	0.825
April	182.2	80.96	19.43	189.5	186.6	8249	7683	0.811
May	210.3	93.06	22.94	200.8	197.5	8634	8037	0.801
June	208.1	92.66	25.35	190.0	186.5	8093	7529	0.793
July	225.2	81.68	28.19	208.1	204.2	8715	8110	0.780
August	209.0	79.26	28.59	210.0	206.7	8796	8193	0.780
September	169.0	68.49	26.60	189.2	186.4	8025	7474	0.790
October	138.3	58.60	24.17	173.2	171.4	7468	6963	0.804
November	106.1	38.49	18.78	153.7	152.1	6800	6341	0.825
December	88.0	33.12	14.51	133.6	132.4	6021	5603	0.839
Year	1891.6	780.83	21.01	2103.8	2074.7	91200	84937	0.807

Where;

GlobHor: Horizontal global irradiation.
DiffHor: Horizontal diffuse irradiation.
T_Amb: T ambient Temperature
Glob Inc: Global incident in coll. plane
GlobEff: Effective Global, correspond for IAM and shadings.
EArray: Effective energy at the output of the array.
E_Grid: Energy injected into grid.
PR: Performance Ratio

4.2 Performance ratio

The ratio of the effective power generated at the output of the array to the power produced by an ideal PV system under the conditions is known as the performance ratio.Typically, standard test conditions (STC) are used, which have the same “global” radiation level. System and array losses in PV systems, array losses, wiring, mismatch, module quality, shading effects, PV power conversion rate, and IAM contribute to their performance ratio According to Figure 7, the overall performance of our system was 81%. System performance was good, but there was a noticeable difference in monthly performance between the summer and winter seasons. The reason for this was high temperatures in the summer, which had a negative impact on performance. July and August had the lowest performance. During these months.

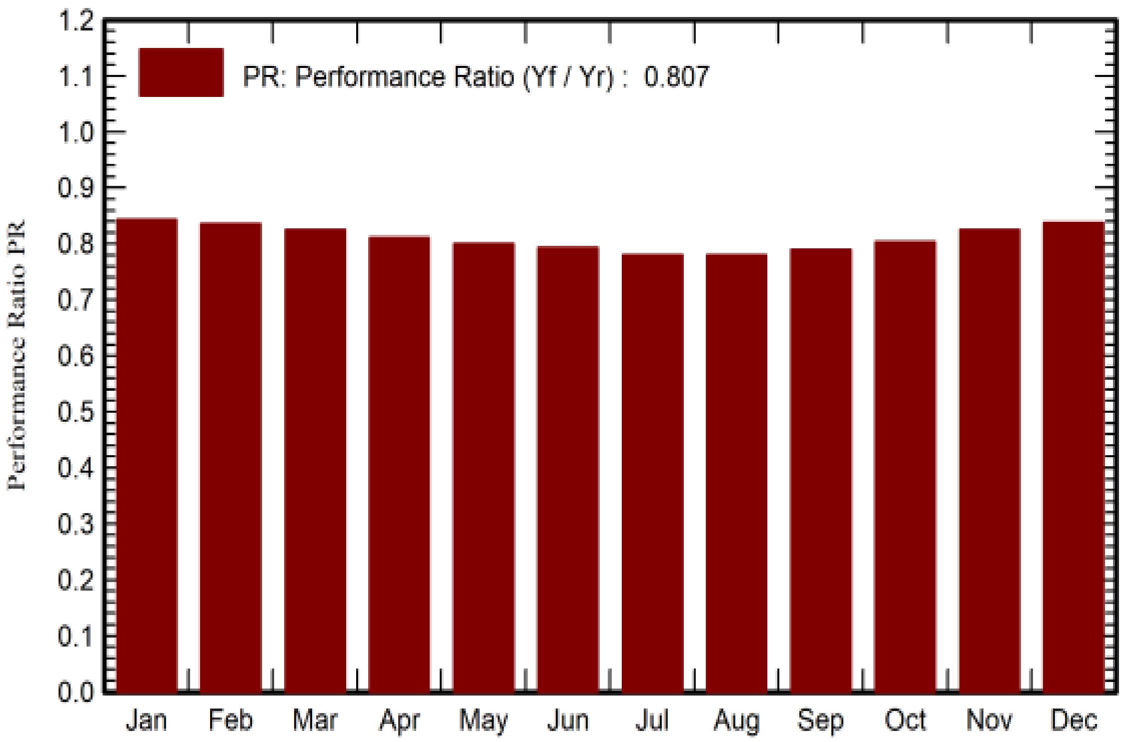


Figure 7: Performance ratio (%).

4.3 Normalized production

The subsequent the normalized production of a photovoltaic power plant is shown in Figure 8. It provides the system losses, PV array collection losses, and useable energy generated by the inverter output. The monthly output and losses per kWh are displayed clearly.

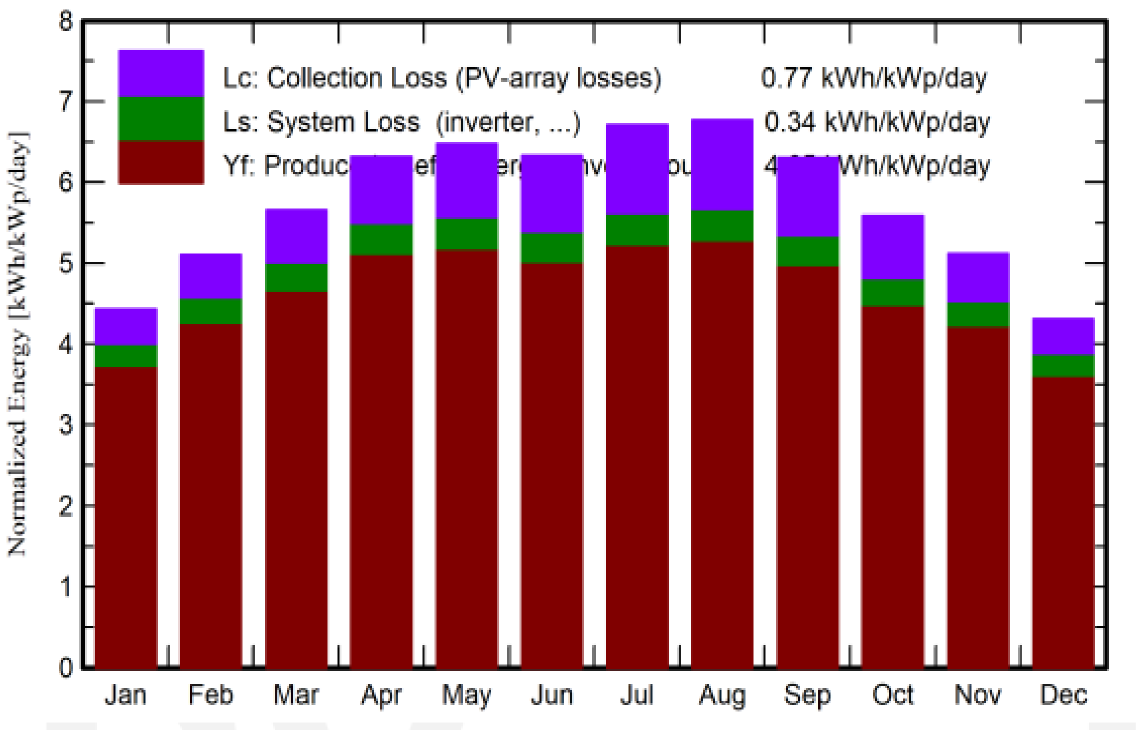


Figure 8: Normalized productions kWh/KWp/day.

Table 5: Result overview.

Results	Value
System production	MWh/yr84937
Specific prod	KWh/kwp/yr1699
Performance Ratio	0.807
Normalized prod	KWh/kwp/day 4.65
Array losses	KWh/kwp/day 0.77
System losses	0.34 KWh/kwp/day

5 Conclusion

The main objective of this study is to develop a plan to reduce the dependence of the Tininai region on the public electricity company, while enhancing the availability of electricity, which would accelerate social and economic growth in the city of Beni Walid. This will be achieved by using PVSYST software to design, simulate and evaluate a 50 MW PVC plant per day. The following conclusions were drawn from this study: This project effectively demonstrates how temperature fluctuations affect the performance of solar units on an annual and daily basis. The heat has a greater impact on the efficiency of solar light. Data efficiency increases to the highest level in the morning and peaks in the afternoon before beginning to decline until sundown. As each solar unit has a different level of efficiency, it may be better to cool them to improve performance.

References

1. Mujaahid, F., et al. Design of Solar Power Plant: Analyze Its Potential in Parangtritis Area Using PVsyst Simulator. in 4th International Conference on Sustainable Innovation 2020–Technology, Engineering and Agriculture (ICoSITEA 2020). 2021. Atlantis Press.
2. Kaddour, A., et al. Improvement of the stand-alone PV system performance by PVSYST software. in 2019 7th International Renewable and Sustainable Energy Conference (IRSEC). 2019. IEEE.
3. Hossain, M.I. and S.R. Islam, EFFECTIVE PUMPING SYSTEM USING PVSYST TO HARNESS SOLAR POWER FOR BANGLADESH AGRICULTURE SECTOR.
4. Selmi, T., H. Dhouibi, and J. Ghabi, Matlab/Simulink and PVSyst based modeling and validation of photovoltaic cells. European Journal of Engineering Research and Science, 2019. **4**(11): p. 11-16.
5. Verma, A. and A.K. Kori. Higher efficiency solar and thermal hybrid power plant based on PI controller. in 2020 Fourth International Conference on Computing Methodologies and Communication (ICCMC). 2020. IEEE.
6. Balo, F. and L.S. Sua, Solar Radiation Analysis Model and PVsyst Simulation for Photovoltaic System Design. Emerging Photovoltaic Materials, 2018: p. 763.
7. Alnoosani, A., et al., Design of 100mw solar pv on-grid connected power plant using (pvsyst) in Umm Al-Qura university. International Journal of Science and Research (IJSR), 2019. **8**(11): p. 356-363.
8. AlMakhzzom, O.M. and A.A. Ahmed, Design and Evaluation of Solar PV On-Grid Connected Power Plant Using PVsyst Software in Bani Walid Hospital/Libya. African Journal of Advanced Pure and Applied Sciences (AJAPAS), 2022: p. 128-138.
9. Al-Refai, M.A., Optimal design and simulation of solar photovoltaic powered cathodic protection for underground pipelines in Libya. Journal of Electrical Engineering, 2019. **7**: p. 61-73.
10. Maka, A.O., S. Salem, and M. Mehmood, Solar photovoltaic (PV) applications in Libya: Challenges, potential, opportunities and future perspectives. Cleaner Engineering and Technology, 2021. **5**: p. 100267.
11. Mayouf, O.M., M. Rekik, and L. Krichen. Designing a hybrid system using solar cells and batteries to power a clinic in Tajarhi desert village in the Libya-Niger border off-grid. in 2022 IEEE 21st International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA). 2022. IEEE.
12. Amrani, F.Z.B., F. Boutlilis, and B. Bekkouche, Performance evaluation and degradation analysis of 20 MW photovoltaic power plant located in the southwestern highlands of Algeria. Building Services Engineering Research & Technology, 2024: p. 01436244241257220.