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Optimal Design of Solar Roof Top Photovoltaic Plant Under Various Operating Conditions

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Abstract

As conventional energy sources are quickly exhausted, the need to switch to sustainable alternatives has never been more urgent. The transition from conventional energy resources to renewable sources, particularly solar energy, has emerged as a pivotal step towards sustainable development This paper explores the advantages of solar power plants, with a focus on rooftop solar installations. Installing solar panels on a roof is revolutionizing the industry. The design phase of a solar power plant is a critical stage that lays the foundation for its long-term performance, efficiency, and economic viability. This project presents detailed designing process of a solar power plant, encompassing technical consideration, various layouts and key elements essential for successful implementation. However, rooftop solar plant faces several challenges, ranging from technical constraints to financial barriers. This paper sets out the technique and significance of planning and simulating a 116KWP demo site with solar roof top plant. Firstly, it begins with a comprehensive site assessment that is portion of the design process which includes several critical steps. To ensure maximum solar irradiance and energy output, terminologies such as roof orientation, tilt angle, shading and available space should be attentively evaluated. Moreover, local regulations, building codes, and structural integrity are important in ensuring that designs comply with standards and safety regulations. Simulation is instrumental in assessing the performance of the proposed design under different circumstances. Affordable software tools permit accurate modelling of parameters like solar irradiance, panel efficiency, system losses and financial projections. By simulating various configurations and parameters, one can find best options in terms of design that maximize electricity produced.

Keywords: Roof top, solar plant, design, simulation, efficiency, solar irradiance

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INTRODUCTION

Solar energy is primarily captured and converted into electricity through photovoltaic (PV) panels, this process is called Photovoltaic effect. The photovoltaic effect is the mechanism by which solar panels harness sunlight to generate electricity. It begins with the absorption of photons, particles of light, by semiconductor materials within the solar panel. These photons transfer their energy to electrons in the semiconductor material, causing them to become excited and break free from their atoms. This process creates an electric current within the material, guided by an electric field established by the structure of the solar panel. As the excited electrons flow in a specific direction, they generate direct current (DC) electricity. This DC electricity can be utilized immediately to power electrical devices or stored in batteries for later use. Alternatively, it can be converted into alternating current (AC) electricity using an inverter for integration into homes, businesses, and the electrical grid. Overall, the photovoltaic process exemplifies a clean, sustainable, and renewable energy solution, contributing to a greener and more resilient future [10].

Solar energy utilization in India is becoming more popular day by day in all means ranging from small scale to commercial scale usage [1]. However, other few problems associated with the solar energy, these includes the variations in energy output due to change in solar irradiance levels and the behaviour of module based on its materials used during the manufacturing [2]. However, a simulated performance study is needed to understand the process of efficient conversion of available solar energy resource into PV electricity at a particular site with suitable PV capacity designed as per the load conditions [4]. There are wider applications of solar energy those includes grid connection use, domestic use, street lighting, water pumping etc [5]. Hence it is essential to study the simulated performance of the PV systems. The objective of this paper is to analyse the performance of solar plant under the Doddaballapura, Karnataka weather.

LITERATURE SURVEY

The PVsyst evaluation confirms the feasibility of a grid-connected solar PV plant at Dhalipur, Dehradun. Cost-effective and reliable without battery storage, optimal performance is achieved at a 30° inclination angle [8]. The system demonstrates efficient energy conversion with a performance ratio of 78.1%, despite daily yield variability [6]. The research paper underscores the effectiveness of grid-connected solar PV power plants, showcasing their reliability and cost efficiency without the inclusion of battery storage due to high initial costs and maintenance implications [9]. The dependable performance of the proposed plant is highlighted, with varying tilt angles affecting performance ratios but maintaining overall reliability [3]. The study's comprehensive depiction of experimental results provides valuable information for future analysis and comparisons with real-world generation data. Furthermore, the payback analysis projects significant cumulative savings for the Institute [7].

DESCRIPTION OF THE PROPOSED ON ROOF SOLAR PHOTOVOLTAIC PLANT

The PV system is composed of solar panels, inverters, a power conditioning unit. The proposed solar Photovoltaic plant is an Shed near Doddabalapura Main Road, Karnataka, India, and it utilizes approximately 869.12 sq. m of roof. The proposed solar on Roof plant will have a capacity of 116 KWP & is presented in Figure 1 below.

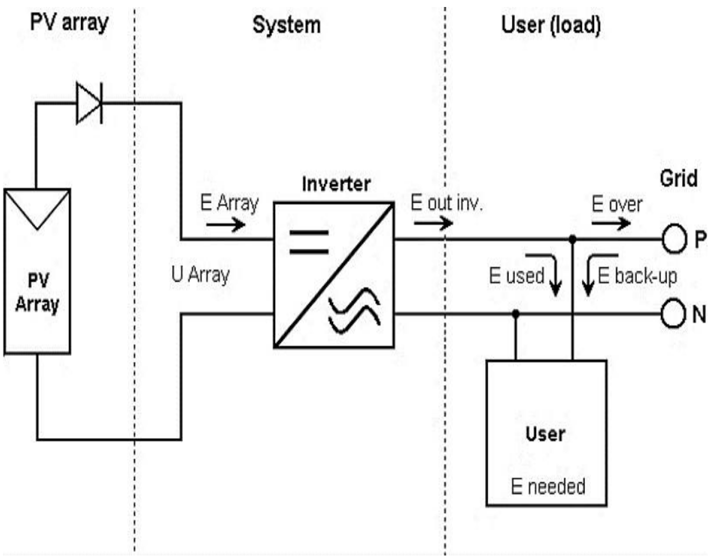


Figure 1. Proposed Solar PV plant.

Geographical Conditions

The geographical location 13°09’22’N latitude and 77°34’04’E longitude and has a building height of 10 meter the relevant geographical conditions for the round the year generation (Table 2) since the location has excellent geographical conditions for the environment condition of temperature, radiation, humidity and wind speed as relevant throughout the year. This is a great location in geography where sun-based radiation can be canned for the entire year because power generation in the solar photovoltaic plant is 100% isolation reliant. The Geographical features of the site is shown in Table 1.

Table 1. Geographical features of the site.

Site Name	**Karnataka, India**
Latitude	13° 09' 22" N
Longitude	77° 34' 04" E
Time Zone	UTC +05:30
Temperature Range	11°C to 37°C

Plant Layout

The proposed plant’s overall capacity is 116 KWP and will cover approximately 869.12 sq. meter roof. The modules in this plant uses P type Mono-crystalline cell. The modules are north-south oriented. The Photovoltaic modules used are labelled as 550WP per module. The Solar PV plant using Sketch Up is shown in Figure 2.

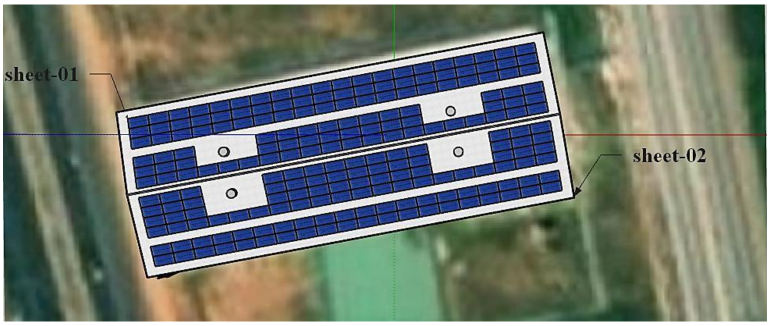


Figure 2. Solar PV plant using SketchUp.

On sheet 01 there are 102 modules having a fixed tilt of 5.8 and azimuth of -10.6°. similarly on sheet 02 there are 108 modules having a fixed tilt of 5.9 and azimuth of 169.4°. Roof comprises of 210 modules having 6 strings of 17 modules in series and 6 strings of 18 modules in series. Solis inverters are used to convert DC to AC and the output AC is fed directly to the building load. The irradiation is measured using Pyranometer. The Module & Inverter specifications provided in Tables 2 & 3.

Table 2. Module Specification.

PV Module	**Specifications**
Module Technology	P type Mono-crystalline
Type of Module	JKM550M-72HL4
Total No. of Module	210
Panel Dimension	2274×1134×35mm
Maximum Power (Pmax)	550Wp
Maximum Power Voltage (Vmp)	40.90 V
Maximum Power Current (Imp)	13.45 A
Open Circuit Voltage(Voc)	49.62 V
Short Circuit Current(Isc)	14.03

Table 3. Inverter Specification.

Input	
Illustration	***Parameters***
Max. input Voltage	1100 V
MPPT Voltage Range	160-1000 V
MPPT Number/Max. input strings Number	6/12.
Output	
Description	***Specifications***
Rated Output Power	80KW
Max. Output Power	88KW
Max. Output Current	133.7 A
Efficiency	
Description	***Specifications***
Max. Efficiency	98.50%

The orientation of Solar PV Sheets are shown in Figure 3 & Figure 4.

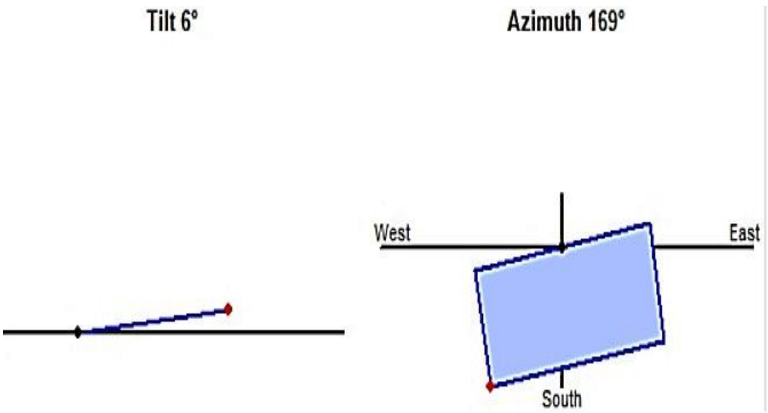


Figure 3. Orientation of sheet-01.

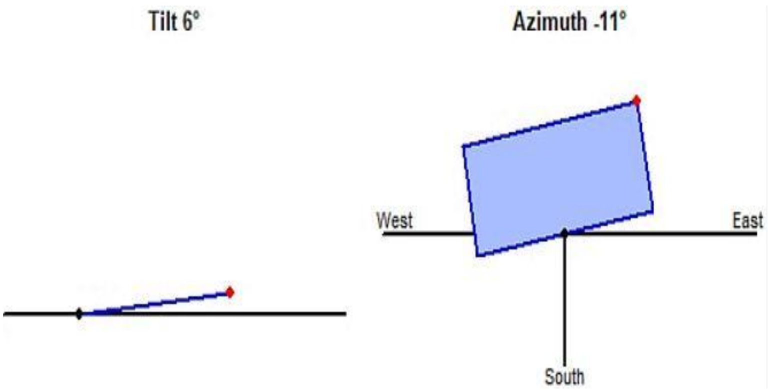


Figure 4. Orientation of sheet-02.

Overall System Configuration

The Overall system configuration of PV system is shown in Figure 5.

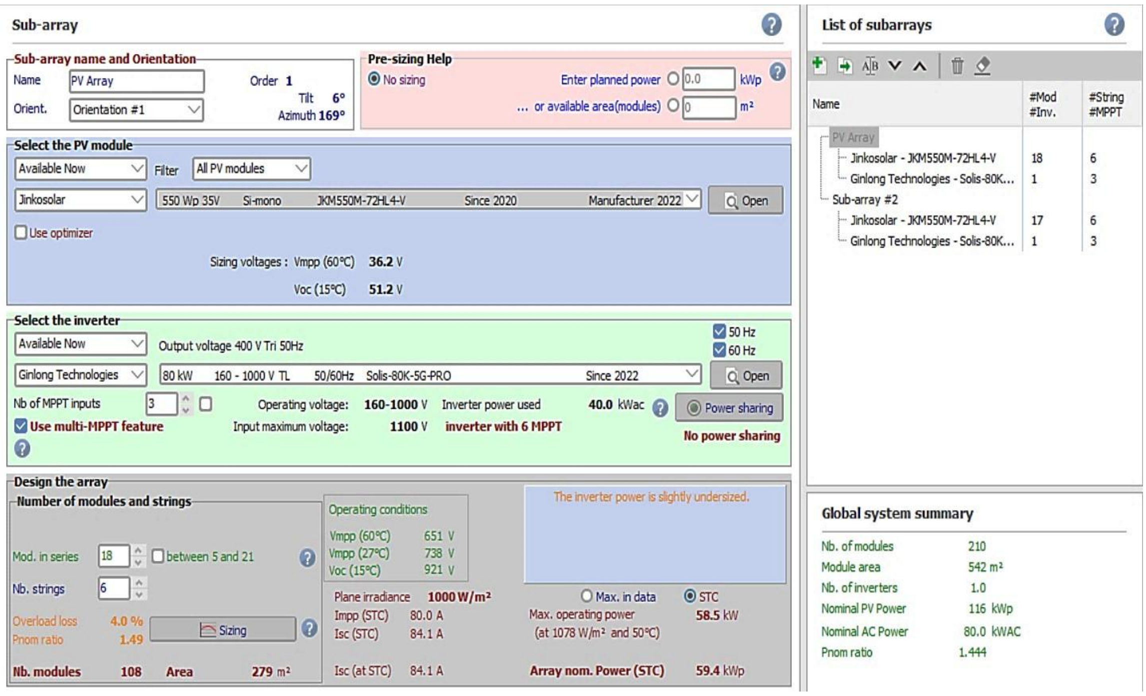


Figure 5. Overall system configuration.

METHODOLOGY

At Standard test conditions STC of 1000 W/m2 of irradiance, cell temperature 25°C, Air mass 1.5,

The rated capacity of the module is 550 Wp

The No of modules required to achieve the required capacity was calculated as follows:

No. of modules		=	DC Capacity of plant(kW)	
			Module capacity (Wp)	
		=	116*1000	
			550	
		=	210	

In general, DC:AC Ratio can go upto 30–50%.

In our project the we considered 44% overloading by Choosing 80kW as inverter capacity.

DC:AC Ratio		=	DC Capacity	
			AC Capacity	
			116	(in kW)
			80	
			1.45	

Performance Ratio

The performance ratio, seen as a quality metric, evaluates the quality and effectiveness of a PV plant without being influenced by its location. The performance ratio (PR) is expressed as a percentage and indicates the correlation between the real and potential energy outputs of the solar plant. Therefore, it demonstrates the percentage of energy that remains usable after accounting for energy loss, such as thermal and conduction losses.

PR Ratio	=	**Energy Generated(kWh)**			
		Installed plant Capacity(kWp) * Irradiance(W/m2)			

PR was calculated for two different soiling losses as the results are as follows:

The following cases are considered for overall performances of solar cell as:

Case-1: Performance of Plant Without Shadow and Dust

In case 1 no external shadow obstacles are considered. From morning 9:00 AM to 4:00 PM, no shadow is falling on the modules. Therefore the overall performance ratio is 80.29%. Considering the Performance of Plant Without Shadow and Dust is shown in Figure 6.

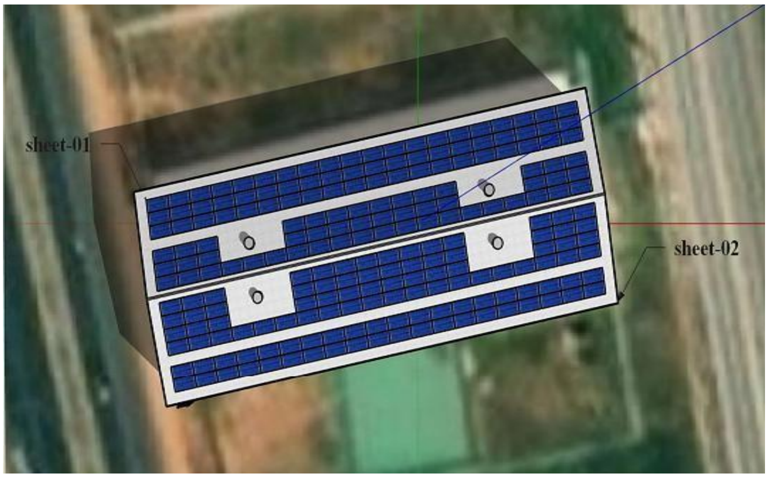


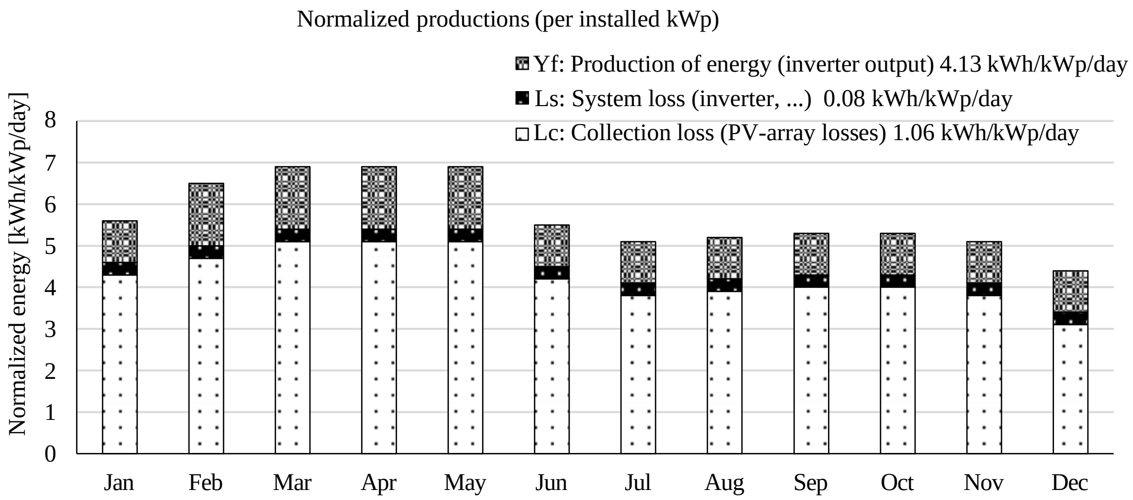
Figure 6. Considering performance of plant without shadow and dust.

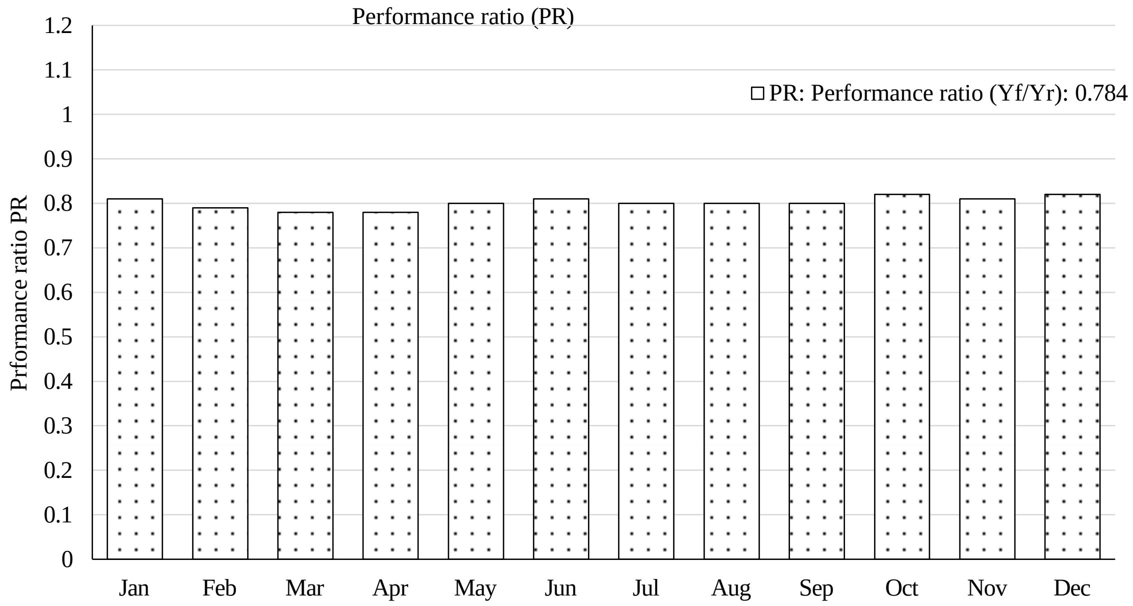
Result

The Results of Performance of Plant without Shadow and Dust is shown in Figure 7.

System Production

Produced energy	178501	Specific production	1545 kWh/kWp/year
		Perf. Ratio PR	80.29%





Balances and main results

	GlobHor	DiffHor	T Amb	Globinc	GlobEff	EArray	PR	E Grid
	kWh/m2	*kWh/m2*	*°C*	*kWh/m2*	*kWh/m2*	*kWh*	*ratio*	*KWh*
January	165.1	50.24	21.51	164.6	153.6	15775	0.815	
February	165.6	49.51	23.87	165.1	155.2	15396	0.793	15118
March	194.2	69.04	26.44	193.8	183.0	17905	0.786	17584
April	189.4	72.52	27.14	189.1	179.0	17279	0.777	16964
May	191.0	87.80	26.43	191.0	180.4	17960	0.800	17635
June	157.3	80.57	24.02	157.1	147.8	14978	0.810	14703
July	143.1	77.68	23.62	142.7	134.5	13527	0.805	13271
August	146.5	79.71	23.21	146.1	137.8	13859	0.806	13596
September	150.5	76.18	23.26	150.1	141.3	14214	0.805	13953
October	151.6	77.37	23.41	151.2	142.3	14545	0.817	14274
November	132.9	56.67	21.88	132.3	123.7	12701	0.816	12465
December	142.4	54.23	21.18	141.8	132.3	13696	0.821	13446
Year	1929.6	831.51	23.83	1924.8	1810.9	181834	0.803	178501

Legends

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

Figure 7. Results of case 1 performance of plant without shadow and dust.

Case-2: Performance of Plant with Shadow

The shadow considered is huge tree. The duration of shadow on the modules is for half an hour. When the shadow of a tree falls on solar PV modules the max power generated by the modules will reduces, thereby it will affect the overall generation and performance ratio by 1%. So the performance ratio for this case is79.46%. The consideration of the Performance of the Plant with Shadow is shown in Figure 8.

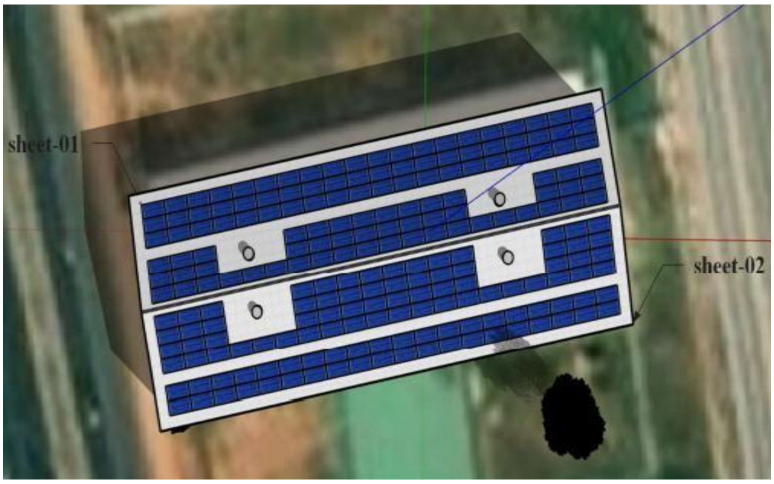
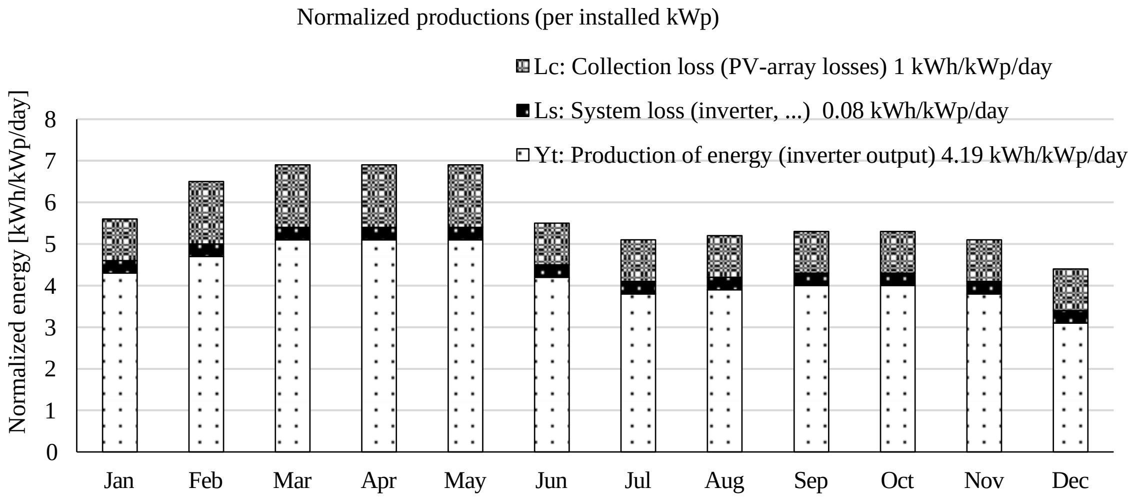


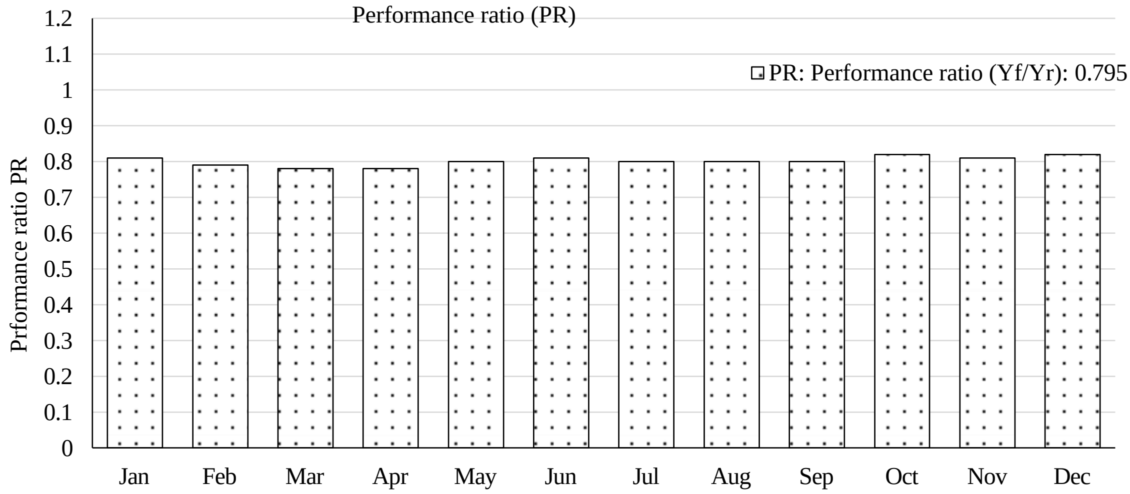
Figure 8. Considering the performance of plant with shadow.

Result
Considering the Performance of Plant with Shadow & result is shown in Figure 9.

System Production

Produced energy	176648 kWh/year	Specific production	1529 kWh/kWp/year
		Perf. Ratio PR	79.46%





	GlobHor	DiffHor	T. _Amb	Globinc	GlobEff	EArray	PR	E_Grid
	kWh/m2	*kWh/m2*	*°C*	*kWh/m2*	*kWh/m2*	*kWh*	*ratio*	*kWh*
January	165.1	50.24	21.51	164.6	151.2	15529	0.802	15248
February	165.6	49.51	23.87	165.1	153.2	15231	0.784	14956
March	194.2	69.04	26.44	193.8	180.9	17754	0.779	17436
April	189.4	72.52	27.14	189.1	177.0	17153	0.771	16841
May	191.0	87.80	26.43	191.0	178.4	17807	0.793	17484
June	157.3	80.57	24.02	157.1	146.2	14840	0.803	14567
July	143.1	77.68	23.62	142.7	132.9	13404	0.798	13150
August	146.5	79.71	23.21	146.1	136.2	13734	0.799	13474
September	150.5	76.18	23.26	150.1	139.7	14090	0.798	13831
October	151.6	77.37	23.41	151.2	140.5	14390	0.809	14122
November	132.9	56.67	21.88	132.3	122.0	12533	0.805	12300
December	142.4	54.23	21.18	141.8	130.3	13485	0.808	13239
Year	1929.6	831.51	23.83	1924.8	1788.5	179950	0.795	176648

Legends

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

Figure 9. Results of performance of plant with shadow.

Case-3: Performance of Plant with Excessive Soiling Loss

Generally soiling losses for normal roof considered is 3%. But if the roof or a solar plant is near to query, or it is cotton factory then the duct accumulation on the modules are in very high percentage, So soiling losses considered is 6%. The performance ratio is 78.39%, it is reduced by 2% from actual PR. The Performance of Plant with Excessive Soiling Loss is shown in Figure 10.

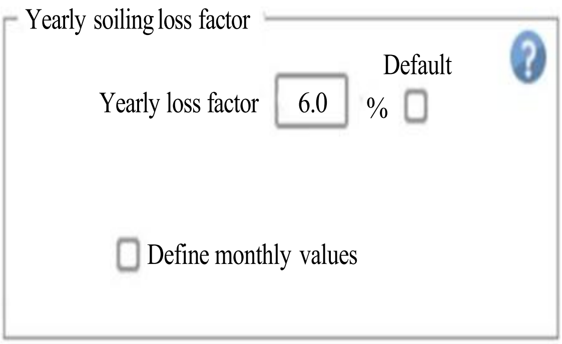


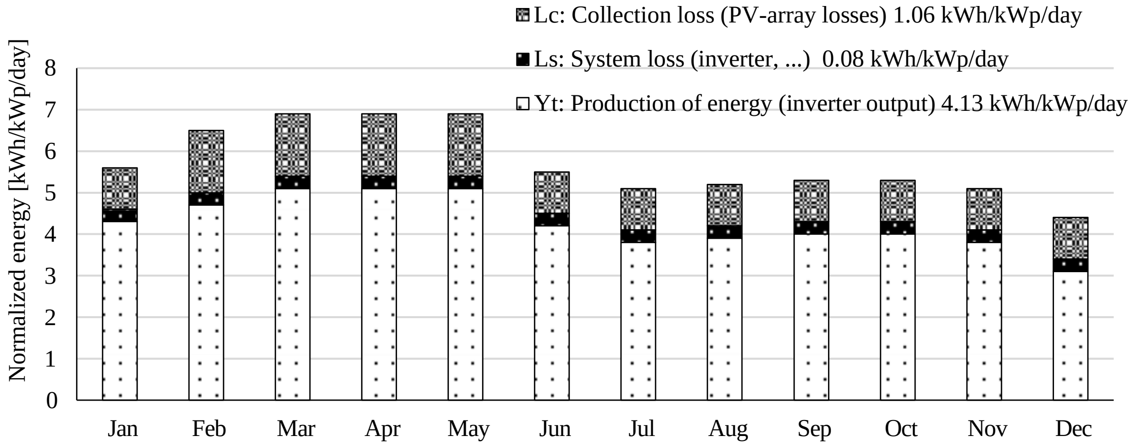
Figure 10. Performance of plant with excessive soiling loss

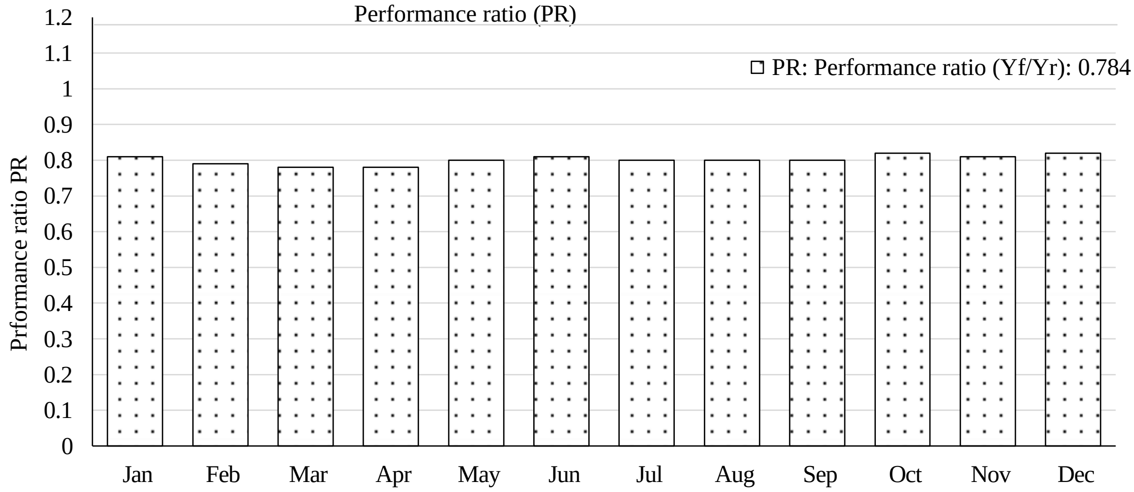
Result

Considering the Performance of Plant with Excessive Soiling Loss is shown in Figure 11.

System Production

Produced energy	174277 kWh/year	Specific production	1509 kWh/kWp/year
		Perf. Ratio PR	78.39%





Balances and Main Results

	kWh/m2	**kWhim**	**°C**	**kWhim**	**kWhim**	**kWh**	**ratio**	**kWh**
January	165.1	50.24	21.51	164.6	148.8	15359	0.793	15083
February	165.6	49.51	23.87	165.1	150.4	15069	0.776	14798
March	194.2	69.04	26.44	193.8	177.4	17534	0.769	17220
April	189.4	72.52	27.14	189.1	173.4	16933	0.761	16625
May	191.0	87.80	26.43	191.0	174.8	17530	0.780	17213
June	157.3	80.57	24.02	157.1	143.3	14605	0.790	14337
July	143.1	77.68	23.62	142.7	130.3	13204	0.786	12953
August	146.5	79.71	23.21	146.1	133.5	13530	0.787	13273
September	150.5	76.18	23.26	150.1	136.9	13890	0.787	13634
October	151.6	77.37	23.41	1512	137.9	14172	0.796	13908
November	132.9	56.67	21.88	132.3	119.9	12381	0.795	12150
December	142.4	54.23	21.18	141.8	128.2	13326	0.799	13084
Year	1929.6	831.51	23.83	1924.8	1754.9	177532	0.784	174277

Legends

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

Figure 11. Results of Performance of Plant with Excessive Soiling Loss.

Overall comparison of the cases:

The Overall comparison considering shadow & soiling losses is given in Figure 12.

	Energy produced IN kWh/year	Specific production kWh/kWp/Year	Performance ratio
case-01: Without Shadow and Soiling Losses	178501	1545	80.29%
case-02: Considering Shadow Effect	176648	1529	79.46%
case-03: Considering Soiling Losses	174277	1509	78.39%

Figure 12. Overall Comparison Table.

Shadow Losses

Shadows causes a reduction of approximately 1.04% in annual energy production. Specific production is slightly affected, decreasing by about 1.04%. Performance ratio drops by 0.83%, indicating a minor but noticeable impact.

Soiling Losses

Soiling causes a reduction of approximately 2.37% in annual energy production. Specific production is decreases more significantly by 2.33%. Performance ratio drops by 1.90%, indicating a more substantial impact compared to shadows.

In conclusion, both shadow & soiling losses negatively impact the energy production, specific production & performance ratio of PV systems. While shadow losses are relatively smaller, where as soiling losses have a more considerable effect, necessitating regular cleaning & maintenance to maximize the systems efficiency.

CONCLUSION

In conclusion, Reducing the amount of sunlight that reaches the photovoltaic cells directly affects the efficiency of solar panels due to soiling losses. Over time, solar panels collect dust and dirt particles on their surface, creating a layer that blocks sunlight and reduces their electricity production capacity.

Solar plant performance is determined by the performance ratio (PR), calculated as the actual energy output divided by the maximum energy output possible under standard test conditions. Reducing the energy generated compared to the available sunlight directly affects the PR of solar plants due to soiling losses. The buildup of dirt on solar panels reduces their performance, resulting in lower energy output and financial gains.

Implementing effective cleaning strategies is crucial to reducing the effects of soiling losses on solar panel efficiency and keeping a high PR. One strategy that can assist in enhancing the efficiency and energy production of solar panels is to boost the frequency of cleaning cycles to eliminate dust and dirt buildup.

REFERENCES

1. Bhubaneswari Parida, S. Iniyan, Ranko Goic. “A Review of solar photovoltaic technologies. Renewable and Sustainable Energy Reviews” 2011; 15(3): 1625–1636.
2. “Performance Evaluation of Grid Connected Solar PV Power Plant” Kanchan Matiyali M.Tech Scholar, Department of Electrical Engineering Faculty of Technology, UTU, Dehradun, India kmatiyali@gmail.com Alaknanda Ashok Professor, Department of Electrical Engineering College of Technology, GBPUA&T & UTU, Dehradun, India alakn@rediff.com
3. “Feasibility study and Performance evaluation of a grid-connected Rooftop Solar PV system” Jaya Vasita1, Querie Shakhiya2, Jvalant Modi 3 1 Gujarat Energy Research and Management Institute, P. D. P. University, jaya.v@germi.res.in, Gandhinagar 382007, India. 2 Silver Oak Institute of Technology, queriesakhiya.gn@socet.edu.in, Ahmedabad 382481, India. 3 Aditya Silver Oak Institute of Technology, jvalantmodi.gn@socet.edu.in, Ahmedabad, Gujarat 382481, India.
4. S. Prajapati, E. Fernandez “Rooftop solar PV system for commercial office buildings for EV charging load” 2019 IEEE international conference on smart instrumentation, measurement and application (ICSIMA), IEEE (2019), pp. 1–5.
5. Y.F. Nassar “Solar energy engineering active applications” Sebha University, Libya (2006)
6. P. Winston, D. Kumaravel, S. Kumar, B. Devakirubakaran "Performance improvement of solar PV array topologies during various partial shading conditions," Solar Energy, vol. 196, pp. 228– 242, 2020.
7. D. Infield, L. Freris, “Renewable Energy in Power Systems”, 2nd Edition, John Wiley and Sons, Feb. 2020.
8. S. Sharma, C. P. Kurian and L. S. Paragond, "Solar PV System Design Using PVsyst: A Case Study of an Academic Institute," 2018 International Conference on Control, Power, Communication and Computing Technologies (ICCPCCT, Kannur, pp. 123–128, 2018.
9. Rathore, P.K.S., D.S. Chauhan, R. P. Singh. 2019. “Decentralized solar rooftop photovoltaic in India: On the path of sustainable energy security, Renewable Energy”, 131. Pp. 297–307.
10. Atluri K, Hananya SM, Navothna B. “Performance of rooftop solar PV system with crystalline solar cells”. In: 2018 national power engineering conference (NPEC). IEEE; 2018. p. 1–4.

