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Abstract: This work focuses on designing a 2.6 Kw Solar PV system operating in Grid-Connected mode. A 3-Step method of efficiency evaluation is done in order to assess the energy production potential of the designed PV system. This method of assessment covers all the technical, economic and annual performance aspects of the designed PV system. Assessment is done and the results are demonstrated that forecast the energy production potential of this 2.6 Kw Solar PV system. The results will be verified using PV Syst software.

Keywords: PV Syst, Grid Connected Solar PV system, Electricity, Meteorological data.

I. INTRODUCTION

In today's world of technological developments, electricity plays a crucial role for a nation's development, for both developing and developed nations the challenge is being able to meet the growing demand for energy. According to a report from the Central Electricity Authority in 2018, it is observed that there is 8629 million units in energy supply but simultaneously 3314 megawatts in peak power demand. [1] To satisfy such demand, production needs to increase. Considering the limitations of conventional power sources, we go for alternative energy sources like solar and wind. This paper discusses on solar energy generation by designing a Grid Connected solar PV setup of 2.6 Kw power capacity in the location of Mangalpalli, Telangana. These systems are capable of feeding electricity directly into the connected grid, operating alongside conventional sources of energy. These produce clean electricity near where it's used, reducing losses and eliminating the need for batteries. [2] Their performance depends on local factors such as climate, PV Array orientation, and inverter efficiency.[3] Hence there is a need of a method to determine efficiency of such PV installations in a way where all technical, economic and annual performance aspects gets covered. For such designing and analyzing of PV systems, there are various tools available. These tools are implemented by engineers and scientists for optimization and analysis. Such tool is PV Syst, a PC software that was developed by the University of Geneva, it offers prefeasibility analysis, simulation and forecasting for PV systems.[4] This research paper aims to design and simulate a 2.6 Kw solar PV system.

II. METHODOLOGY

This paper proposes a 3-Step methodology where the complete evaluation of a PV system is divided into three important steps. They are-

A. Parameter Analysis

The Primary Block that extracts electricity out of solar irradiation is a solar cell. A solar cell produces output power according to its characteristics under different conditions. These characteristics examine Voltage, Current and Power parameters of solar cell under normal under constant and varying temperature. These characteristics help us in understanding the stability, compatibility with the power grid, efficiency and performance under different levels of irradiation. Overall, this analysis covers aspects related to solar cell and its efficiency in generating a stable efficient power.

B. Performance Analysis

Performance analysis is studying the performance of the PV system by considering power production, losses, efficiency, balance, irradiation in order to achieve valuable information about power production and estimate forecasting of aspects that enable us to gain understanding about the efficiency of the technical aspects of a PV system. All the technical aspects of this PV system like power production, performance, efficiency are covered under performance analysis.



C. Financial Analysis

Financial analysis is the study in which installation costs and operating costs of the PV setup are considered to gain calculated analysis on income variation, yearly net profit which are necessary for the planning and organizing of a solar PV system. This also gives a proper estimate on return on investment and cumulative cash flow to the user which aids in pre-feasibility of the system. Overall, this analysis covers all the monetary aspects behind establishing a solar PV system. Fig I illustrates proper understanding of this methodology below.



Fig 1 represents visual illustration of the 3-Step methodology of complete evaluation of the proposed 2.6 Kw Solar PV system

III. SITE AND TECHNICAL DETAILS

A. Site Location and Climatic Resources

The proposed site is in Bharat Institute of Engineering and Technology (BIET) campus which is in Mangalpalli village of Ibrahimpatnam mandal of Ranga Reddy district (Telangana), India. The site is located at Latitude of 17.21'N and Longitude of 78.59'E at an altitude of 526 meters.



Fig 2 Satellite view of BIET campus

For estimation of Irradiation, temperature and Horizon data as per the geographical location, meteo database Metronorm 8.1 has been used.





Fig 3 Trajectory of sun at BIET with Horizontal outline

B. Solar PV technology

Solar PV converts solar irradiation into usable electricity. PV modules used for this simulation are polycrystalline. Number of PV modules used for the simulation are 8 units in 4 series connected modules in 2 parallel strings. Total area covered by PV modules is 15.5 sq.mts as calculated after running the simulation in PV Syst software as shown in Fig 4 below.

C. Inverter

Inverter should be perfect for overall requirement of the PV system. It must be easy to operate and reliable with low maintenance cost and longer life. In our simulation, we are using 3 KW AC inverter as shown in Fig 4 below.



Fig 4 PV Array and Inverter details

14010 1	miter of optimite	liono
Rating	3 Kw	
Voltage rating	125 – 440 V	
Nominal AC	5.6 A	
current		
Output AC	335 V	
voltage		
Efficiency	90-92%	
No. of inverters	1	

Table 1 Inverter specifications



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D. System Orientation

The orientation of the panel is shown in Fig 5 below. The tilt angle is kept at 20' and Azimuth is kept 0'.



Fig 5 Orientation of Panel

IV. PARAMETER ANALYSIS

A. V- I Characteristics with Irradiance

When the irradiation is high i.e., 1000 watts/sq.mt then maximum power output is 311 watts whereas, when irradiation is lowest i.e., 200 watts/sq.mt then minimum power output of the panel is 59.9 watts as shown in Fig 6.

PV module: Lubi Electronics, Poly 335 Wp 72 cells

Cells temp. = 45°C 10 Incident Irrad. = 1000 W/m 311.0 W Incident Irrad. = 800 W/m Current [A] Incident Irrad. = 600 W/m 186.1 Incident Irrad. = 400 W/m 122.9 V Incident Irrad. = 200 W/m 59.9 W 10 20 40 Voltage [V]

Fig 6 V-I Characteristics with Irradiation

PV module: Lubi Electronics, Poly 335 Wp 72 cells



Fig 7 V-I Characteristics with varying temperature



PV module: Lubi Electronics, Poly 335 Wp 72 cells



Fig 8 P- V Characteristics

B. V-I Characteristics with varying Temperature

In Fig 7 Graph shows when cell temperature is 10 degrees Celsius then maximum power output is 352.8 W. Similarly, for 25 degrees Celsius we get 335.1 W and for 40 degrees Celsius we get 317 W of maximum power.

C. P-V Characteristics with Irradiance

In Fig 8 Graph shows how power changes based on amount of sunlight received (irradiance). When irradiance is maximum i.e., 1000 watts/sq.mt we get maximum output power of 311 W whereas, when irradiance is minimum i.e., 200 watts/sq.mt we get minimum output power of 59.9 W.

D. P-V Characteristics with varying Temperature

In Fig 9 Graph shows when the temperature is lowest i.e., 10 degrees Celsius we get maximum output power of 352.8 W. It is clearly seen that as the temperature increases, maximum power is decreasing.



Fig 9 P-V Characteristics with varying temperature

After studying parameter analysis of the proposed 2.6 Kw PV system, we can say that the system is stable, compatible with the power grid and performs efficiently under different levels of irradiation and temperatures.



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V. PERFORMANCE ANALYSIS

A. Incident Irradiation Distribution

Fig 10 shows represents the incident irradiation distribution of global incident collection plane generated annually.



Fig 10 Incident Irradiation Distribution

B. Normalized Power Production

Fig 11 showcases the combined losses from PV array collection, system inefficiencies, and the resultant output from the inverter. This graphical representation clearly presents the monthly usable energy production as well as the losses incurred per kilowatt-hour (kWh). These normalized metrics, defined by the International Electrotechnical Commission (IEC), serve as standardized measures for assessing the performance of PV systems. Specifically, the collection losses or PV array capture losses are quantified as 0.99kWh/kWp/day. Additionally, the system loss amounts to 0.15kWh/kWp/day, while the solar energy generated stands at 4.21kWh/kWp/day.









C. Normalized Production and Loss Factors

Fig.12 represents the graph between normalized power production and loss factor which is yield on yearly basis. Here the energy supplied to the user is 78.7%, collection loss (PV array losses) is 18.5%, system losses is 2.9%.



Fig 12 Normalized Production and Loss Factors

D. Efficiency vs Incident Global

Fig 13 graph that represents the efficiency at the maximum power point (Pmax) compared to the incident global irradiation. The graph indicates that the relative efficiency, when compared to the standard testing conditions (STC) with an incident irradiation of 1000 watts per square meter, is 17.27%.



Fig 13 Efficiency vs Incident Global

E. Efficiency vs Cell Temperature

Fig 14 graph shows represents the efficiency at Pmax vs the cell temperature by varying the incident irradiation.



Fig 14 Efficiency vs Cell Temperature



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F. Balance and Main Results

Table 2 Main Simulation Results

Main Simulation Results	
System Production = 4121 kWh/year	
Specific Production = 1538 kWh/kWp/year	
Performance Ratio = 78%	

Specific Production-The produced energy/ Nominal power of the array ($P_{nominal}$ at STC)

This shows the potential of the system, Considering irradiance conditions like orientation, site, location, meteorological conditions. [4]

We can write,

Specific Production = Produced Energy / Nominal Power of the Array = 1538 kWh/kWp/year.

Table 3 shows the balance and main results of 2.6 kW Solar PV system. Yearly Global Horizontal irradiation is 1857.6 kWh/sq.mt. The yearly global incident energy on the collector plane is 1954.8 kWh/sq.mt.

Energy available at the output of the PV array is 4271.3 kWh. The energy injected into the grid is 4121.4 kWh. The average ambient temperature is 27.30 degrees.

Table 3 below shows Balance and Main results

	GlobHor	DiffHor	T_Amb	GlobInc	GlobEff	EArray	E_Grid	PR
	kWh/m²	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	ratio
January	150.3	47.45	23.32	184.4	180.2	406.8	393.2	0.795
February	156.5	55.61	26.25	180.9	176.7	394.0	381.1	0.786
March	194.3	70.02	29.71	206.6	201.7	440.7	426.1	0.769
April	193.1	75.36	31.94	190.6	185.6	403.5	389.8	0.763
May	193.4	89.57	33.53	179.3	173.7	381.7	368.4	0.767
June	152.2	82.77	29.24	138.5	133.7	303.2	291.8	0.786
July	129.4	83.45	27.40	119.8	115.5	266.1	255.4	0.795
August	138.2	88.03	26.38	133.1	128.9	296.8	285.5	0.800
September	136.0	74.19	26.29	138.1	134.1	305.7	294.4	0.795
October	140.5	70.09	26.33	152.8	149.0	337.0	324.9	0.794
November	136.1	56.73	24.17	160.0	156.4	355.1	343.0	0.800
December	137.7	51.24	22.98	170.6	166.8	380.6	367.8	0.804
Year	1857.6	844.51	27.30	1954.8	1902.3	4271.3	4121.4	0.787

G. Array Loss Diagram



Fig 15 Array Loss Diagram



The array loss diagram is generated through simulated studies, providing valuable insights into potential losses and constraints in PV plant installations. Fig 15 illustrates the array loss diagram, which highlights various system losses. The global irradiance on the horizontal plane measures 1858 kWh/Sq. m, while the effective irradiance on the collector is 1902 kWh/Sq. m. Consequently, there is a 0.6% energy loss due to the irradiance level. The photovoltaic module or array converts the simulated effective irradiance into electricity, resulting in a nominal energy of 5099 MWh at standard testing conditions (STC) with an array efficiency of 17.27%. The annual virtual energy from the maximum power point (MPP) of the array amounts to 4277 kWh. Among the array losses, temperature losses account for 9.6%, light-induced degradation accounts for 2%, module array mismatch accounts for 2.1%, and Ohmic wiring losses account for 1.1%. Annually, the inverter output of the plant yields 4156 kWh of available energy being injected into the grid as shown in fig.15 above.[6]

H. Performance Ratio

The performance ratio is used for performance analysis of the solar PV system. From Fig 16 it is observed that the performance ratio of most of the months is about 0.8 which is satisfactory.



Fig 16 Performance Ratio

From analysing the performance, it is clear that the designed PV system is potent for producing power upto long term scale of time. The designed PV system is efficient and is well performing in all technical aspects of the simulation.

VI. FINANCIAL ANALYSIS

A. Cost of the system

Item	Quantity	Cost	Total			
	units	INR	INR			
PV modules						
Poly 335 Wp 72 cells	8	11,400.00	91,200.00			
Supports for modules	8	500.00	4,000.00			
Inverters						
3 kWac inverter	1	18,400.00	18,400.00			
Other components						
Accessories, fasteners	1	1,000.00	1,000.00			
Wiring	1	1,000.00	1,000.00			
Combiner box	1	2,000.00	2,000.00			
Measurement system, pyranometer	1	9.000.00	9,000.0			
Surge arrester	1	1,000.00	1,000.0			
Studies and analysis						
Engineering	1	200.00	200.0			
Permitting and other admin. Fees	1	100.00	100.0			
Environmental studies	1	200.00	200.0			
Economic analysis		200.00	200.0			
Installation						
Global installation cost per module	8	500.00	4 000 0			
Global installation cost per inverter	1	500.00	500.0			
Transport		500.00	500.0			
Settings	1	100.00	100.0			
Grid connection	i i	100.00	100.0			
		Total	133 500 0			
	De	enreciable asset	114 600 0			
Operating costs			Tota			
Maintenance			integeo			
Provision for inverter replacement			3.680.0			
Repairs			2.000.0			
			5.680.0			
Total (OPEX)	Including inflation (1.00%)					
Total (OPEX) including inflation (1.00%)						
Total (OPEX) Including inflation (1.00%) System summary	ST D	ΕV	O			
Total (OPEX) Including inflation (1.00%) System summary Total installation cost	133,500.00 INR	ΕM	O			
Total (OPEX) Including inflation (1.00%) System summary Total installation cost Deprating costs (incl. inflation 1.00%/year)	133,500.00 INR 6,253.40 INR/year	ΞV	0			
Total (DPEX) Including Inflation (1.00%) System summary Total installation cost Joperning costs (inclustion 1.00%/year) Produced Energy	133,500.00 INR 6,253.40 INR/year 4121 kWhyear	ΞV	0			



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B. Financial Analysis

PVG	Financ	ial analysis —		
Simulation period				
Project lifetime 20 years	Start year	2020		
Income variation over time				
Inflation		1.00 %/year		
Production variation (aging)		5.00 %/year		
Discount rate		0.00 %/year		
Income dependent expenses				
Income tax rate		0.00 %/year		
Other income tax		0.00 %/year		
Dividends		0.00 %/year		
Depreciable assets				
Asset	Depreciation	Depreciation	Salvage	Depreciable
	method	period	value	(INR)
		(years)	(INR)	. ,
PV modules				
Poly 335 Wp 72 cells	Straight-line	20	0.00	91,200.00
Supports for modules	Straight-line	20	0.00	4,000.00
Inverters				
3 kWac inverter	Straight-line	20	0.00	18,400.00
Accessories, fasteners	Straight-line	20	0.00	1,000.00
		Total	0.00	114,600.00
Financing				
Own funds		80,100.00 INR		
Subsidies		53,400.00 INR		
Electricity sale				
Feed-in tariff	Peak tariff	5.0000 INR/kWh		
	Off-peak tariff	3.0000 INR/kWh	20:00-07:00	
Duration of tariff warranty		20 years		
Annual connection tax		5,000.00 INR/kWh		
Annual tariff variation		+1.0 %/year		
Feed-in tariff decrease after warranty		1.00 %		
Return on investment				
Payback period		6.1 years		
Net present value (NPV)		456,222.33 INR		
Internal rate of return (IDD)		20.35 %		
internal rate of return (IKK)				

Fig 17 Financial analysis shows Return of investment period of pay back to be 6.1 years.

C. Detailed Economic Results

Detailed economic results (INR)									
Year	Electricity	Own	Run.	Deprec.	Taxable	Taxes	After-tax	Cumul.	%
	sale	funds	costs	allow.	income		profit	profit	amorti.
0	0	80,100	0	0	0	0	0	-80,100	0.0%
1	15,587	0	5,680	5,730	4,177	0	9,907	-70,193	12.4%
2	16,833	0	5,737	5,730	5,366	0	11,096	-59,097	26.2%
3	18,153	0	5,794	5,730	6,629	0	12,359	-46,738	41.7%
4	19,554	0	5,852	5,730	7,972	0	13,702	-33,036	58.8%
5	21,040	0	5,911	5,730	9,399	0	15,129	-17,907	77.6%
6	22,615	0	5,970	5,730	10,915	0	16,645	-1,261	98.4%
7	24,286	0	6,029	5,730	12,526	0	18,256	16,995	121.2%
8	26,058	0	6,090	5,730	14,238	0	19,968	36,963	146.1%
9	27,937	0	6,151	5,730	16,056	0	21,786	58,749	173.3%
10	29,929	0	6,212	5,730	17,987	0	23,717	82,466	203.0%
11	32,043	0	6,274	5,730	20,038	0	25,768	108,235	235.1%
12	34,284	0	6,337	5,730	22,217	0	27,947	136,181	270.0%
13	36,660	0	6,400	5,730	24,530	0	30,260	166,441	307.8%
14	39,181	0	6,464	5,730	26,986	0	32,716	199,158	348.6%
15	41,854	0	6,529	5,730	29,595	0	35,325	234,482	392.7%
16	44,688	0	6,594	5,730	32,364	0	38,094	272,576	440.3%
17	47,694	0	6,660	5,730	35,304	0	41,034	313,611	491.5%
18	50,882	0	6,727	5,730	38,426	0	44,156	357,766	546.6%
19	54,263	0	6,794	5,730	41,739	0	47,469	405,236	605.9%
20	57,849	0	6,862	5,730	45,257	0	50,987	456,222	669.6%
Total	661,390	80,100	125,068	114,600	421,722	0	536,322	456,222	669.6%

Table 4 below shows Detailed Economic results



D. Yearly Net ProfitYearly Net Profit shows that by 2039 year our Net profit will be increased upto 52,000 INR Rupees.



Fig 19 Yearly Net Profit

Above figure shows as per estimation by there will be considerable increase in the Yearly Net Profit (in INR) and by the year 2039 plant will gain upto 52,000 INR rupees of profit.[8]

E. Cumulative Cash Flow







Fig 21 proves the designed system to be environment friendly and clean.



Hence, the above analysis clearly shows that we saved 64.238 tons of CO₂ emissions this proves the feasibility of this system. So, we can say that this PV system improves air quality, supports bio diversity and ecosystem.[6]

From Financial Analysis, we can say that this system efficiently produces energy of 4121 kWh/year spent installation cost of 133,500/-INR and operating cost of 6,253.40 INR/year. Considering Project lifetime to be 20 years with start year to be 2020. According to the forecasting results of this analysis, payback period is to be 6.1 years with Return of investment rate of 569.6%. This shows that financial analysis was successful for this PV system.

VII. CONCLUSION

In this paper, a 2.6 Kw Solar PV system integrated with Grid is designed and evaluated successfully using PV Syst software. It can be observed from all the analysis we have performed it proves this PV system to be stable, compatible with power grid, performs efficiently under different levels of irradiation and temperatures. Also, despite of minor losses the system is experiencing still persists to perform well and is potent in producing power for long term scale of time which makes this system financially secure and provides return on investment support and more profitability within 6.1 years of installation.

REFERENCES

- [1] Ministry of Power, Government of India, "Load Generation Balance Report 2018-19", Central Electricity Authority, July 2018, pp 1-3.
- [2] B.S Kumar and K. Sudhakar, "Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India, "Energy Reports, Vol 1, pp. 184-192, 2015.
- [3] T.M.Iftakhar Uddin, Md. Abrar Saad, Husnain-Al-Bustam, Md. Zakaria Mahbub, "Computational Modeling of a GRID Connected System Using PVSYST Software", International Journal of Scientific & Engineering Research, Vol.3, 2012.
- [4] C.P. Kandaswamy, P. Prabu, K. Niruba, "Solar Potential Assessment Using PVSYST Software", International Conference on Green Computing, Communication and Conservation of Energy (ICGCE), 2013.
- [5] P. Yadav, N. Kumar and S.S. Chandel, "Simulation and Performance analysis of a 1 KWP Photovoltaic System using PVSyst", 2015 International Conference on Computations of Power, Energy, Information and Communication (ICCPEIC), Chennai 2015, pp.0358-0363.
- [6] R. Rawat, V. Chaudhary, H.M. Dubey, "Performance Evaluation of 30.5 KWP On-Grid Solar System Using PVsyst", Springer International Publishing 2020, Cham, <u>https://doi.org/10.1007/978-3-030-44758-8_35</u>
- [7] Surabh sharma, C.P. Kurian, 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, India, 2018, pp.123-128, DOI: 10.1109/ICCPCCT.2018.8574334
- [8] Davide Baschierl, Carlo Alberto Magni, Andrea Marchioni, "Comprehensive Financial modelling of Solar PV Systems", EUPVSEC2020- 37th European Photovoltaic Solar Energy Conference and Exhibition. DOI: 10.4229/EUPVSEC202020-7D0.8.5
- Kazi Abdul Kader, Florina Rahman, Islam Nahid, Zahid Abedin, "Design and Analysis of an On-Grid Solar System Using PVSyst Software for Commercial Application", January 2022, Research gate
- [10] PV Syst Software https://www.pvsyst.com/
- [11] Azam Khan, Bilal Alam, Wajid Ali, "Comparative Study, Design and Performance Analysis of Grid-connected Solar PV System of Two Different Places Using PVsyst Software", Advances in Sustainability Science and Technology, Springer, July 2022.
- [12] Duan, S., et al. (2020). Assessment of Optimal Battery Sizing for Grid-Connected Residential Photovoltaic Systems Using PVsyst and Genetic Algorithm. IEEE Access, 8, 177656-177671.
- [13] Kaldellis, J. K., et al. (2019). Comprehensive Analysis of PV Performance Ratios for Optimal Module Tilt and Orientation. Sustainability, 11(22), 6353.
- [14] International Energy Agency (IEA). (2021). Renewables 2021: Analysis and Forecasts to 2026. IEA Publications.
- [15] Taherian, H., et al. (2022). Forecasting of Solar Photovoltaic Energy Generation Using Machine Learning Techniques: A Comprehensive Review. IEEE Transactions on Sustainable Energy, 13(1), 21-39.











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