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Optimizing Grid-Interfaced Rooftop Solar Plant Installation for Sustainable Energy Generation

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Abstract: Grid-interfaced rooftop solar plant deployment marks a big step towards the production of sustainable and renewable energy. This study examines a number of grid-interfaced rooftop solar plant installation issues, with a particular emphasis on design optimisation, technology selection, and operational effectiveness. The numerous grid-connected solar photovoltaic (PV) system components are the main emphasis of this study, along with their operation, installation plan, and design considerations. There is a case study on a 100 kWp grid-connected solar photovoltaic (PV) system in the Department of Electrical Engineering in the College of Technology and Engineering, MPUAT, Udaipur.. The actual output of installed system has been recorded and emission of CO_2 is also avoided. The comparison is done between the actual output and simulation based model. The solar system is very beneficial in educational institute to avoid bills and also helpful in research area.

1. Introduction

The promotion of renewable energy resources is helpful due to change in climate, global warning and sudden increase in pollution. Government of India also promote the renewable energy resources by various scheme such as, on the purchase of solar module government will give the subsidy[19]. On the government institute, government office and other government building if solar system installed then fund will be allotted by Ministry of New and Renewable Energy[2]. The project of solar power plant are constructed on larger scale in India. Before installation we can verify the efficiency of the installed component because that is costly. Currently the world is facing pollution problem by using conventional power plant such as fossil fuel in the other hand solar energy almost free of cost and clear form of energy[20].
Renewable energy technology adoption has surged because of the need to combat climate change and reduce greenhouse gas emissions. Grid-interfaced rooftop solar plants are one of these technologies that has grown in popularity because of its accessibility and potential for wide-scale adoption[21]. These systems transform solar energy into electrical energy, enabling owners of residential and commercial properties to produce sustainable energy while minimising their reliance on traditional power sources. In order to maximise the advantages of solar energy, this study focuses on the installation optimisation of grid-interfaced rooftop solar plants[1]. The optimisation process includes a number of steps, such as site evaluation, system design, component selection, safety precautions, and financial considerations[22].
In solar photovoltaic(PV) system the most important work is to identify the need and design system accordingly after that installation part is came which will be satisfactorily done because each system have these life line and duration of these work. If any disturbance occur due to installation then

supply will be interrupted. Due to interruption in supply the user will be dissatisfied and do not believe in reliable operation of the PV system[3].

2. Grid Interconnection and Regulations

The process of connecting a rooftop solar system to the current electrical grid is known as grid connectivity. It makes it possible for power to move back and forth between the grid and the solar installation. Grid-tie inverters are essential components of this process because they transform the direct current (DC) generated by solar panels into alternating current (AC) that is compatible with the grid. The regulatory framework controlling grid connections is crucial in order to make it possible for solar electricity to be integrated safely and effectively. Safety requirements are crucial, and following them guarantees that the installation doesn't put the public or utility personnel at risk. These criteria are frequently detailed in the National Electrical Code (NEC) and local regulations [4].
Grid interconnection has certain standards set forth by utility companies, including technical requirements and application processes. For a seamless connection to the grid to be established, adherence to certain utility criteria is essential. Grid interconnection is also impacted by net metering regulations[5]. The financial viability of solar systems is impacted by these rules, which specify how extra electricity produced by the solar system is applied to the owner's utility account. Interconnection agreements are legal contracts outlining the terms and circumstances of grid access between property owners and utility corporations. These contracts include duties, payment schedules, and conflict resolution procedures[6].

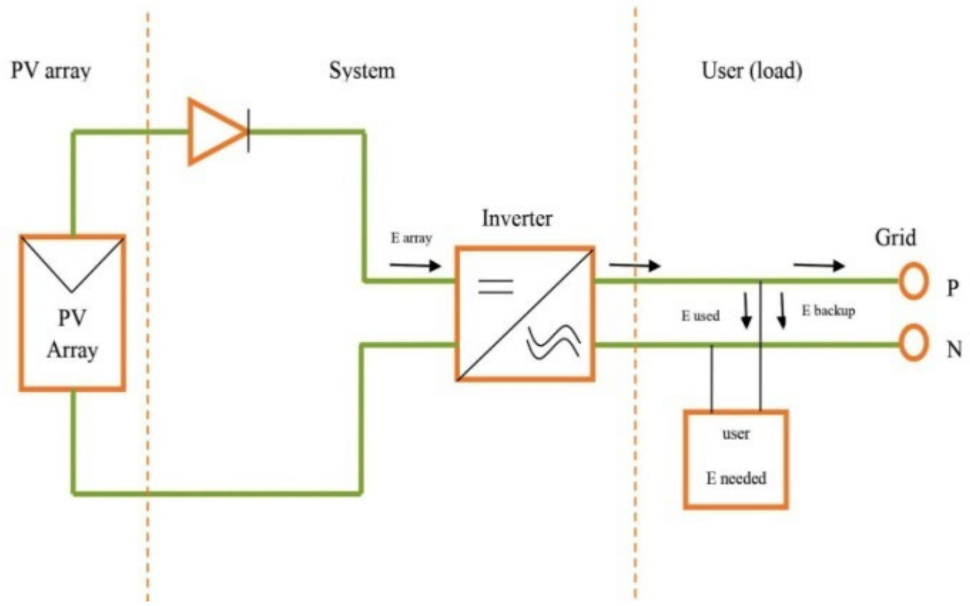


Fig. 1 Grid Connected Solar Photovoltaic System

A key component of rooftop solar installations is grid connections. It allows electricity to flow from solar panels to the grid, which has positive effects on the environment and the economy. A successful and compliant grid-interfaced solar system is ensured by adherence to safety standards, utility requirements, net metering policies, and interconnection agreements[7].

3. Site Assessment and Design

3.1 Location and Orientation

Performing a thorough site assessment is the first stage in optimising a rooftop solar installation. In order to generate energy, the position of the solar panels is vital. The majority of the day's sunshine typically shines onto rooftops with a south or north orientation, respectively, in the Northern Hemisphere and the Southern Hemisphere[23]. According to the coordinate the latitude 24.60 N, longitude 73.73 E, and altitude 423m is situated at Electrical Department of college of technology and engineering. Energy production can be greatly impacted by proper alignment and tilt angles. The PV field orientation is fixed plane with 25 tilt angle[8].

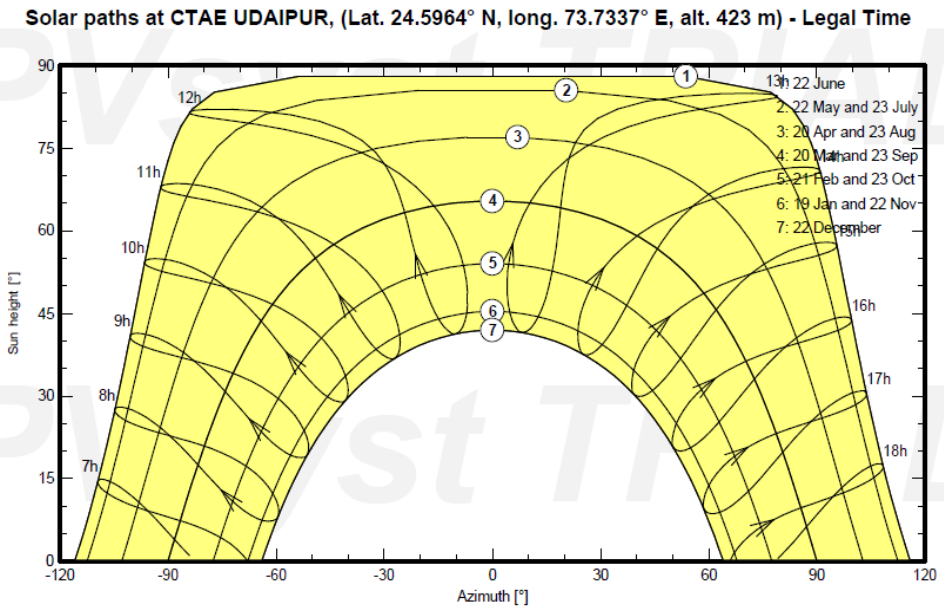


Fig. 2. Solar paths at College of technology and engineering, Udaipur

3.2 Shading Analysis

To find potential obstacles that could lower the effectiveness of solar panels, shading research is essential. When designing the solar array, it is important to take into account adjacent structures, trees, and other objects that can cast shadows on it. This assessment is aided by tools like sun path calculators and shade analysis software[8].

3.3 System Sizing

To best serve the property's energy requirements, the solar system should be optimised for size. Both oversizing and undersizing may result in excessive energy production or insufficient power production. For the right system size to be chosen, extensive information on energy use and past weather trends should be examined[9].

3.4 Designing with Software

A 100kW solar power plant's design and output estimation are possible with the aid of software version 7.3.2. The system is created to provide the necessary energy based on the aforementioned criteria. The figure below. shows the solar module, inverter, and array designs as a system[9].

4. Component Selection

Four hundred PV panels, each producing hundreds of watts, are needed when developing PV facilities. The right number, size, and type of PV modules and inverters must be selected by the designer of the PV plant throughout the design phases. In addition, components for installing PV plants that will increase energy output and improve lifespan maintenance are required. The design of a 100kW PV plant necessitates some understanding of the system and its parts. As a result, the designer will need to be more knowledgeable about solar data, component specifications, solar PV efficiency, and design optimisation[9].

Table 1 Commercial Solar PV Electrical Data Specification

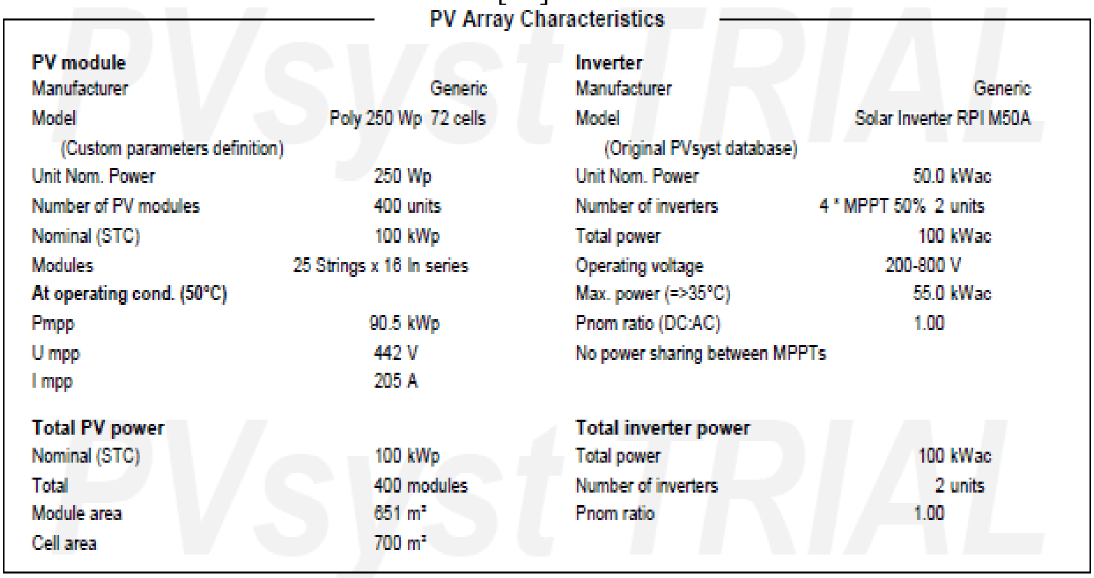
Type	Poly Crystalline
PV Module Make	REIL Solar Make
No's of Module	400
Maximum Power (P_{max})	320 W_p
Maximum Power Voltage (V_{mp})	38.1 V
Maximum Power Current (I_{mp})	8.40 A
Open Circuit Voltage	46 V
Short Circuit Current	8.90 A
Maximum System Voltage	1000 V
Inverter Make	DELTA
Number of Inverter	2
Inverter Model	Inverter 1 RPI M50 Inverter 2 RPI M50

4.1 Selection of Solar Panel

Efficiency, durability, and warranty considerations should be made when choosing solar panels. With each having advantages and limitations, monocrystalline and polycrystalline panels are popular options. Poly crystalline solar panels are thought to be the most effective, with an average efficiency of about 20% and a fair price. The total number of panel is 400 Numerous PV panel possibilities were researched for this design in terms of power, price, type, and warranty. As a result, 320 Wp of commercial solar power was chosen for this work[10].

4.2 Selection of Inverter

Grid-tie inverters are necessary to convert the DC power generated by solar panels into usable AC power for the building and grid. Micro and string inverters are the two most common varieties. Each has advantages. But in design configuration two string inverter is used such as Inverter 1. RPI M50 and Inverter 2. RPI M50 which having DELTA inverter model. The size, design, and price of the system all affect the inverter that is chosen[11].


PV Array Characteristics

PV module		**Inverter**	
Manufacturer	Generic	Manufacturer	Generic
Model	Poly 250 Wp 72 cells	Model	Solar Inverter RPI M50A
(Custom parameters definition)		(Original PVsyst database)	
Unit Nom. Power	250 Wp	Unit Nom. Power	50.0 kWac
Number of PV modules	400 units	Number of inverters	4 * MPPT 50% 2 units
Nominal (STC)	100 kWp	Total power	100 kWac
Modules	25 Strings x 16 In series	Operating voltage	200-800 V
At operating cond. (50°C)		Max. power (=>35°C)	55.0 kWac
Pmpp	90.5 kWp	Pnom ratio (DC:AC)	1.00
U mpp	442 V	No power sharing between MPPTs	
I mpp	205 A		
Total PV power		**Total inverter power**	
Nominal (STC)	100 kWp	Total power	100 kWac
Total	400 modules	Number of inverters	2 units
Module area	651 m²	Pnom ratio	1.00
Cell area	700 m²		

Fig. 3 The PV array and inverter characteristics

5. Result and Discussion

Results from a suggested photovoltaic system's simulation are examined in this section. The 100 kW polycrystalline photovoltaic system's simulation model's output is displayed in PV systems in accordance with the project's requirements and limits. In this simulation, energy, particular production, and performance ratio were the key outputs. collected data was analysed to determine how well the polycrystalline photovoltaic system performed[12].

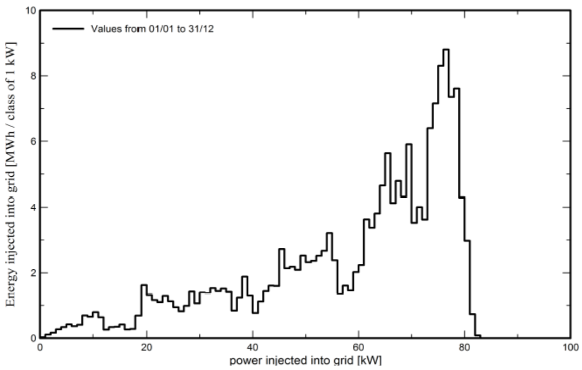


Fig. 4 System output power distribution at college of technology and engineering, Udaipur

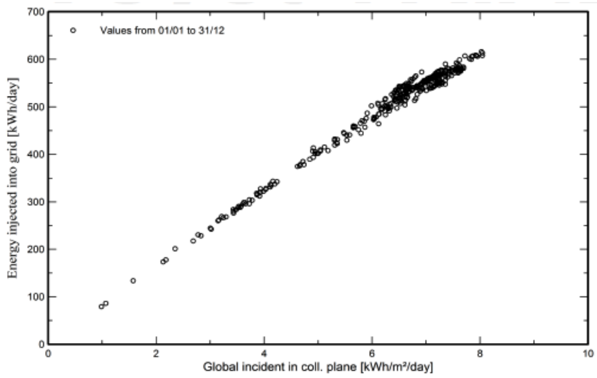


Fig. 5 Daily Input/ Output Diagram

Table 2 Result Overview of 100kWp Poly Crystalline Photovoltaic System

System Kind	No shading
System production	182MWh/yr
Specific production	1818 kWh/kWp/yr
Performance ratio	0.791
Normalized production	4.98 kWh/kWp/yr
Array losses	1.14 kWh/kWp/yr
System losses	0.18 kWh/kWp/yr

5.1 Main Simulation Results

Table 3 100kWp Poly Crystalline Photovoltaic System Balances and Main Results

Months	GlobHor (kWh/m^2)	DiffHor (kWh/m^2)	T_Amb ºC	Globlnc (kwh/m^2)	GlobEff (kwh/m^2)	EArray kwh	E_Grid kwh	PR ratio
January	138.8	41.77	15.56	189.6	180.2	16230	15660	0.826
February	159.5	39.23	23.81	201.0	191.3	16351	15769	0.785
March	199.0	56.39	24.23	222.6	211.0	17993	17351	0.779
April	222.5	64.59	30.15	224.9	212.7	17751	17133	0.762
May	234.4	79.18	32.86	219.2	206.8	17298	16716	0.763
June	183.0	87.60	30.47	166.8	157.0	13479	13049	0.782
July	156.6	95.10	26.69	145.3	136.8	12069	11697	0.805
August	145.0	89.29	25.21	141.2	132.8	11806	11437	0.810
September	165.2	68.29	25.80	176.4	166.9	14510	14021	0.795
October	173.5	54.93	25.41	206.9	196.4	16858	16271	0.787
November	151.1	40.26	22.57	203.4	193.2	16768	16180	0.796
December	142.0	38.19	18.03	201.9	192.0	17069	16469	0.816
Year	2070.7	754.80	25.05	2299.1	2176.8	188182	181753	0.791

Where;
GlobHor: Global horizontal irradiance.
DiffHor: Diffuse horizontal irradiance.
T_Amb : T ambient.
Global incident in a plane, Glob Inc.
GlobEff: Globally Effective, corresponding for 1 AM and shadings.
EArray stands for effective energy at the array's output.
E_Grid: The grid's energy injection.
Performance Ratio (PR)

5.2 Performance ratio and normalized production

The performance ratio is a grading factor that evaluates the quality of a PV facility. It demonstrates how the theoretical and actual energy output of the PV plant relate to one another. After deducting energy losses and consumption, the PR shows the energy. Due to the inevitable losses that occur during operation, the performance ratio typically hovers around 80%.

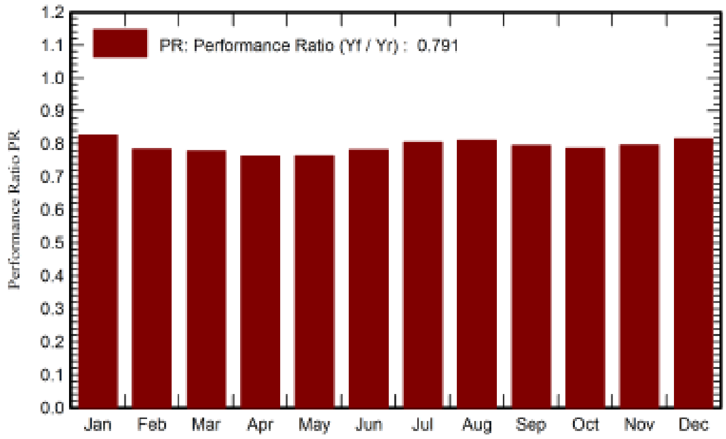


Fig. 6 Performance ratio (%)

As the PR gets closer to 80%, the system will become more effective and efficient. The performance ratio (PR) of the 100 kW polycrystalline photovoltaic plant is depicted in the following graph. Since the PV system covers 20% of MPUAT university, the monthly performance ratio of the plant is roughly 79.1%, which is regarded as a significant quantity[13].

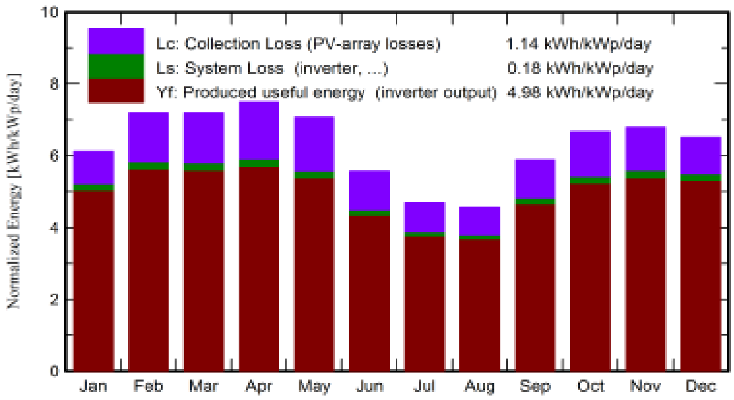


Fig. 7 Normalized production energy per month

The PV power plant's normalised output is shown in the graph in figure 7 below. It covers the amount of usable energy generated by inverter output, system losses, and PV array collection losses. The monthly output and losses per kwh are both clearly displayed.

Draw a graph between the yield, which represents the annual loss factor, and normalised power production. In this case, the rate of useable energy production is 1.14kWh/kWp/day, the rate of collecting losses (losses on the PV array) is 1kWh/kWp/day, the rate of system losses and battery charging is 0.18kWh/kWp/day, and the rate of leftover energy (the energy remaining after the battery is fully charged) is 0.8.5%[13-14].

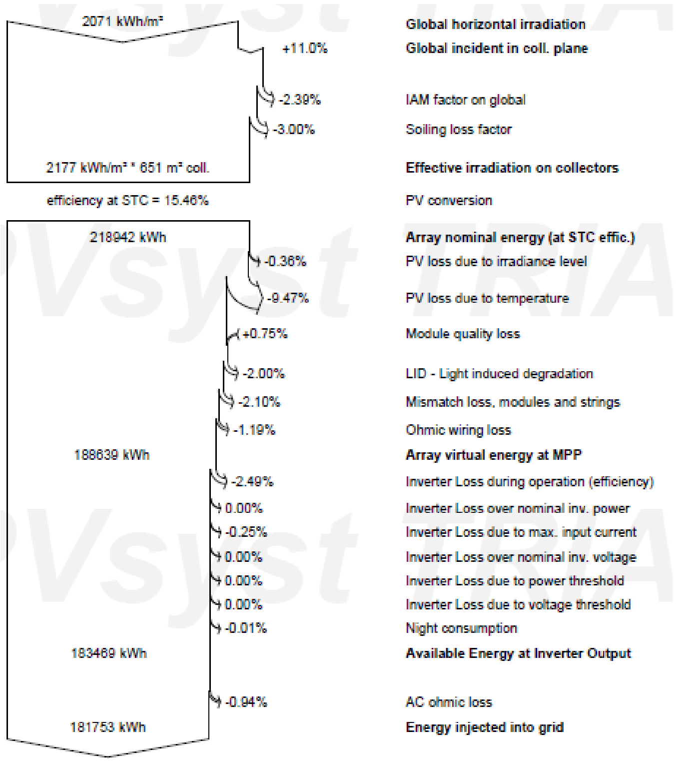


Fig. 8 Loss Diagram of Solar PV System

6. Financial Consideration

Evaluating costs, incentives, and return on investment (ROI) is necessary for rooftop solar installation financial elements to be optimised. The economic viability of the project can be considerably impacted by financial incentives such as tax credits, rebates, and net metering. Planning should take accurate cost projections and finance possibilities into account[12-13].

Table 4 Financial Consideration by PVSyst

Total Installation Cost	6,873,000.00 INR
Operation Cost (Incl. inflation 1.00%/year)	22,594.56 INR/year
Produced Energy	182 MWh/year
Cost of Produced Energy (LCOE)	0.124 INR/kWh
Feed-in tariff	9.3000 INR/kWh
Duration of tariff warranty	20 years
Payback period	4.1 year
Net present value (NPV)	41,698,021.89 INR
Return of investment (ROI)	606.7 %

7. Environmental Benefits

Grid-connected rooftop solar panels benefit the environment in addition to the economic benefits. Because it helps to lessen greenhouse gas emissions and prevent climate change, solar power is crucial to creating a cleaner and more sustainable energy future.

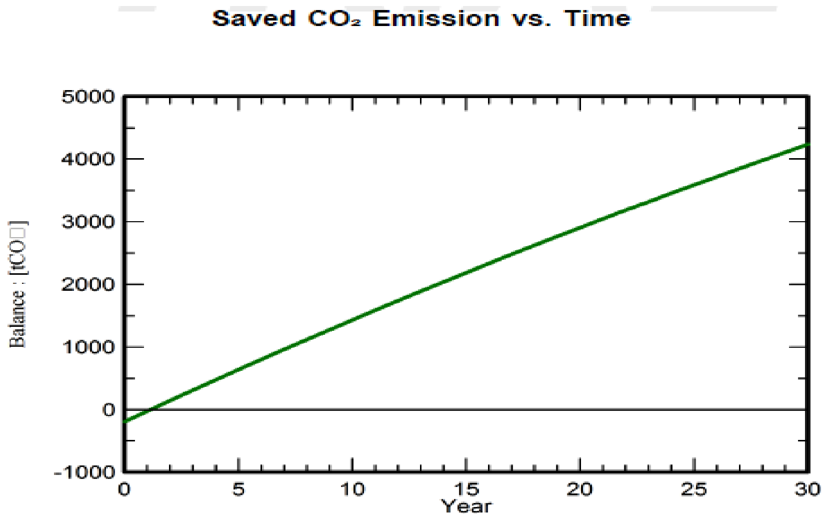


Fig. 9 Saved CO_2 Emission vs. Time

The environment will benefit from the use of a PV power plant. When energy is produced from fossil fuels, it helps to lower greenhouse gases including carbon dioxide, sulphur dioxide, and nitrogen oxide. Additionally, it aids in reducing ash accumulation[14-15].

Table 5 Values for power plant goods with information on system lifecycle emissions

Item	LCE	Quantity	Subtotal [kg CO_2]
Modules	1712 kg Co_2/kWp	97.8 kWp	167418
Supports	6.24 kg Co_2/kg	3910 kg	24411
Inverter	619 kg Co_2/units	2.00 units	1237

8. Conclusion

The electrical department of CTAE, MPUAT, Udaipur, which is situated at the latitude of 24.60 N and longitude of 73.73 E, conducted an energy yield analysis for 1818kWh of PV solar power generation utilising PV SYST simulation. About 79.05% of the ratio was performance. 1818 kWh are produced in total. This much energy can be produced each month by setting up 100kW. This study presents the design modelling and simulation of a grid-connected solar PV power generation facility with a monthly capacity of 100kW, along with its technical and financial possibilities. Energy injection into the grid has fluctuated from 17351 kWh in the month of March to 11437 kWh in the month of August. The study's findings were as follows: This investigation unequivocally demonstrates the impact of temperature change on the daily and annual performance of solar modules. Compared to solar radiation, efficiency is more responsive to temperature. The plant's efficiency is highest in the morning, peaks in the afternoon, and then starts to decline until dusk. With variations in average module temperature from 40º C to 70º C, the efficiency of the module ranges from 19.08% to 14.5%. Therefore, cooling solar modules may be advised to improve efficiency[16].

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