

DESIGN AND PERFORMANCE ANALYSIS OF A 5 KW ROOFTOP SOLAR PHOTOVOLTAIC SYSTEM

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ABSTRACT

Solar energy photovoltaic (PV) systems are one of the most ecologically friendly and highly durable renewable technology that is widely used in residential and institutional applications globally. The paper describes the design, calculation, and test analysis of a 5kW solar photovoltaic system connected to the grid through the roof. The system planning includes load estimation, solar resource assessment, panel selection, inverter sizing, and energy output estimation. The output of a solar installation depends on the geographic location and weather conditions during the year. Here based on the average solar irradiance values available in India, the system can produce approximately 7,0008,000 kWh of energy per year with a performance ratio of 80%. This paper demonstrates that a 5kW roof-top solar power system could be very effective in being environmentally friendly and saving electricity expenses significantly.

Keywords— Solar photovoltaic, rooftop solar system, renewable energy, PV system design, solar irradiance.

I. INTRODUCTION

The rising demand for electricity and the decline of fossil fuels have increased the need for renewable energy sources. Solar energy is one of the most promising options because it is abundant and sustainable. Rooftop solar photovoltaic systems are popular for residential, commercial, and institutional uses because they make use of unused rooftop space and reduce reliance on traditional power sources [1]. A 5kW rooftop solar PV system works well for small households or institutional buildings. Research indicates that these systems can generate around 7,000 to 7,900 kWh each year, depending on solar exposure and system losses [2, 3]. This paper discusses the design calculations, system components, and expected energy generation of a 5kW rooftop solar PV system.

2. SYSTEM COMPONENTS

The main components of a rooftop solar PV system include [4, 5]:

1. Solar PV Modules
2. Solar Inverter

3. Mounting Structure
4. DC and AC Cables
5. Net Meter
6. Protection Devices (MCB, Earthing)

3. SOLAR RESOURCE ASSESSMENT

The performance of a solar PV system depends on solar irradiance [6].

Average solar radiation in India:
Solar Irradiance=5–6 kWh/m²/day.

Assuming: Average Sunlight =5 hours/day

4. SYSTEM DESIGN CALCULATIONS

4.1 Load Calculation

Assume the building requires:

Appliance	Power (W)	Quantity	Total
Lights	20	10	200 W
Fans	70	5	350 W
AC	1500	1	1500 W
Computers	150	5	750 W

Total Load = 2800W ≈ 3kW

Hence, a 5kW system provides sufficient margin.

4.2 Solar Panel Selection

Assume solar module rating: Panel Capacity = 400W

Number of panels required: $N = \frac{\text{System Capacity}}{\text{Panel Capacity}} = \frac{5000}{400} = 12.5 \approx 13$ panels

4.3 Roof Area Requirement

Average panel area = 2 m²

Total area required = 13 × 2 = 26 m²

Approximately 300 sq ft roof area is required.

4.4 Energy Generation Calculation

Daily energy generation: $E = \text{Capacity} \times \text{Sunlight} = 5\text{kW} \times 5\text{h} = 25\text{kWh/day}$

Thus, Daily generation ≈ 25 units/day.

4.5 Monthly and Annual Generation

Monthly generation: 25 × 3 = 750kWh

Annual generation: 750 × 12 = 9000kWh

Considering system losses (15-20%), Net Energy ≈ 7200–7800kWh/year.

This aligns with simulation studies where a 5kW rooftop system generates about 7,900 kWh annually.

5. SYSTEM EFFICIENCY AND LOSSES

Typical losses include:

Loss Type	Percentage
Temperature losses	5%
Dust losses	3%
Inverter losses	4%
Cable losses	2%

Total losses ≈ 14–18%.

Performance Ratio (PR):

$PR = \frac{\text{Actual Energy}}{\text{Theoretical Energy}}$

Typical PR ≈ 0.75 – 0.85.

6. ECONOMIC ANALYSIS

System cost:

Item	Cost
Solar Panels	₹1,50,000
Inverter	₹50,000
Structure & Installation	₹40,000

Total cost: ₹2,40,000

Electricity saving per year: 7200 × ₹6 = ₹43,200/year

Payback period: $\text{Payback} = \frac{\text{Cost}}{\text{Annual Savings}} = \frac{240000}{43200} \approx 5.5$ years

7. ADVANTAGES OF ROOFTOP SOLAR

- Reduces electricity bills
- Clean and renewable energy
- Low maintenance
- Government subsidies available
- Reduces carbon emissions

8. CONCLUSION

This study described a 5kilowatt (kW) rooftop solar photovoltaic (PV) system, its layout and performance evaluation. The computations indicate that the system could produce about 25kilowatt-hour (kWh) daily and 7,0008,000 kWh yearly roughly depending on weather conditions. Besides falling solar panel prices and solar PV system incentives from the government, rooftop solar PV systems are practical and environmentally friendly solutions to energy generation for residential and institutional buildings.

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