

Solar PV System Performance Analysis

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ABSTRACT

The increasing demand for electrical energy and the depletion of fossil fuels have accelerated the adoption of renewable energy sources. Among them, solar photovoltaic (PV) systems have emerged as a clean, reliable, and sustainable solution. The performance of a solar PV system depends on various factors such as solar irradiance, temperature, orientation, and system losses. This paper presents a comprehensive performance analysis of a grid-connected solar PV system. Key performance parameters such as energy yield, performance ratio, capacity utilization factor, and system efficiency are analyzed. The study highlights the impact of environmental conditions on PV system output and emphasizes the importance of proper system design and monitoring. The results demonstrate that solar PV systems can deliver efficient and reliable power when appropriately installed and maintained.

Keywords: - Solar Photovoltaic System, Performance Ratio, Energy Yield, Renewable Energy, PV Efficiency

1. INTRODUCTION

The global energy sector is undergoing a significant transition from conventional fossil fuel-based power generation to renewable energy sources. Solar energy is one of the most abundant and environmentally friendly renewable resources available. Solar photovoltaic (PV) technology directly converts sunlight into electrical energy without producing greenhouse gas emissions.

In recent years, large-scale and rooftop solar PV installations have increased rapidly due to decreasing module costs and supportive government policies. However, the actual energy output of a PV system often differs from its rated capacity due to environmental and system-related factors. Therefore, performance analysis of solar PV systems is essential to evaluate system reliability, efficiency, and economic viability.

This paper focuses on analyzing the performance of a solar PV system using standard performance indicators and discusses the influence of operating conditions on system output.

2. SOLAR PV SYSTEM OVERVIEW

A typical solar PV system consists of the following main components:

- Solar PV modules
- Mounting structure
- DC combiner box
- Inverter
- AC distribution system
- Energy meter and monitoring system

PV modules generate direct current (DC) electricity when exposed to sunlight. The inverter converts DC power into alternating current (AC), which can be supplied to loads or fed into the electrical grid. The overall system performance depends on component efficiency, installation quality, and environmental conditions.

3. . PROPOSED METHODOLOGY

The performance analysis was conducted using measured data collected from the monitoring system. Solar irradiance, module temperature, ambient temperature, and AC power output were recorded at regular intervals. The collected data was processed to calculate daily and monthly energy generation along with performance indices.

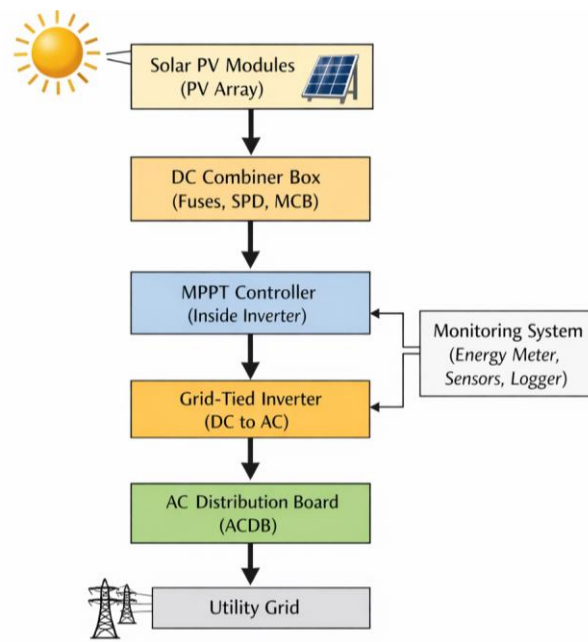


Fig 1 : Block Diagram

3.1. Solar PV Modules

Convert solar irradiance into DC electrical power using photovoltaic effect.

3.2. DC Combiner Box

Combines output of multiple PV strings and provides protection using fuses, surge protection devices, and isolators.

3.3. MPPT Controller

Ensures maximum power extraction from PV array by continuously tracking the maximum power point.

3.4. Grid-Tied Inverter

Converts DC power into AC power synchronized with grid voltage and frequency.

3.5. AC Distribution Board (ACDB)

Provides protection and safe connection between inverter and utility grid.

3.6. Utility Grid

Receives generated power from PV system and supplies electricity when solar power is insufficient.

3.7. Monitoring System

Continuously records voltage, current, power, energy, irradiance, and temperature data for performance analysis.

4. FACTORS AFFECTING SOLAR PV SYSTEM PERFORMANCE

4.1 Solar Irradiance

Solar irradiance is the most dominant factor influencing PV output power. The generated current of a PV module is directly proportional to incident solar radiation. Any reduction due to cloud cover, shading, or atmospheric pollution causes a proportional decrease in power output.

Higher irradiance → Higher current → Higher power

Low irradiance conditions reduce system efficiency

4.2 Temperature Effect

PV module efficiency decreases with an increase in temperature. As module temperature rises: Open circuit voltage decreases

Power output reduces

The temperature coefficient of power for silicon PV modules typically ranges from -0.4% to -0.5% per $^{\circ}\text{C}$.

4.3 Dust and Soiling Losses

Dust accumulation on PV modules blocks sunlight and reduces energy generation. In dry and dusty regions, soiling losses can range between 5% to 20% annually.

Regular cleaning significantly improves system performance and energy yield.

4.4 Shading Losses

Partial shading due to nearby buildings, trees, or poles can cause: Hot spots in PV modules Reduction in string output Mismatch losses

Proper site survey and shadow analysis are essential during system design.

5. SYSTEM LOSS ANALYSIS

Parameter	Value
Installed Capacity	5 kW
Average Daily Energy	20–22 kWh
Performance Ratio	0.75
Capacity Utilization Factor	18%
Inverter Efficiency	96%

The total losses in a PV system can be classified as:

5.1 Optical Losses

- Reflection losses
- Dust accumulation
- Angle of incidence losses

5.2 Electrical Losses

- DC cable losses
- Mismatch losses
- Inverter losses

5.3 Inverter Efficiency

- Inverter efficiency typically ranges between 95%–98%. Losses occur due to:
- Switching losses
- Conversion inefficiencies
- Harmonic distortion

6. MONITORING AND DATA ACQUISITION

A reliable monitoring system is essential for performance evaluation. Commonly measured parameters include:

- Solar irradiance (W/m^2)
- Ambient temperature ($^{\circ}\text{C}$)
- Module temperature ($^{\circ}\text{C}$)
- DC voltage and current
- AC power output
- Energy generation (kWh)

Data is collected at intervals of 5–15 minutes and stored for analysis.

7. RESULT

The results show that the PV system produces maximum energy during clear sky conditions with high solar irradiance. An increase in module temperature leads to a slight reduction in output voltage, affecting system efficiency. The calculated performance ratio ranged between 0.72 and 0.82, indicating good system performance. Losses were mainly attributed to: Temperature effects, Inverter inefficiency, Soiling losses, Wiring and mismatch losses. Despite these losses, the system demonstrated reliable operation and consistent energy generation.

8. CONCLUSION

This paper presents a detailed performance evaluation of a grid-connected solar PV system under real operating conditions. The analysis confirms that solar irradiance and temperature significantly influence PV system output. The obtained performance ratio and energy yield values indicate efficient system operation. Regular

maintenance, real-time monitoring, and optimal system design are essential for improving long-term performance. The study validates solar PV technology as a reliable and sustainable solution for electricity generation.

9. REFERENCES

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