International Conference on "The impact of emerging technologies on global societies: Environment, Ethics, Innovation and sustainability (IETGS 2025)" organized by Government Polytechnic College, Dewas, Madhya Pradesh on 27 Feb 2025.

Analysis of Operational and Economic Feasibility of 05 KW Photovoltaic Installations in Academic Buildings

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Abstract: **This study investigates the operational consistent power supply, reduces dependency on fossil fuels, and serves as a practical educational tool for and economic feasibility of installing a 05 KW photovoltaic (PV) system in academic buildings. The research encompasses a comprehensive performance evaluation, including energy production estimates, system efficiency metrics, and operational considerations such as maintenance and monitoring. Economic feasibility is analyzed through initial investment costs, return on investment (ROI), and potential energy savings Environmental benefits, including carbon footprint reduction, and the educational value of such installations are also highlighted. Technical aspects such as space requirements, structural assessments, and off grid compatibility are examined to ensure practical implementation. The findings indicate that 05 kW PV systems are a viable option for educational institutions, offering significant energy savings, environmental advantages, and enhanced sustainability awareness among students. The study concludes with recommendations for optimizing PV system performance and maximizing economic benefits for academic buildings.**

Keywords: Photovoltaic, solar panel, off grid system efficiency Inverter, return on investment (ROI)

1. INTRODUCTION

The increasing global emphasis on sustainable energy solutions has spurred interest in the deployment of photovoltaic (PV) systems across various sectors. Educational institutions, in particular, present a unique opportunity for integrating renewable energy sources, given their substantial energy demands and influential role in promoting environmental stewardship. This study focuses on the operational and economic feasibility of installing a 05 KWoff-grid photovoltaic system in academic buildings, aiming to assess its potential to meet energy needs independently from the conventional power grid. Photovoltaic systems convert sunlight directly into electricity, offering a clean and renewable energy source [1]. Off-grid PV systems, in particular, are designed to operate autonomously, making them suitable for remote or isolated locations where grid access is unreliable or unavailable. For educational institutions, implementing off-grid PV systems can provide a students to learn about renewable energy technologies. This analysis encompasses a thorough evaluation of the expected energy production, system efficiency, and operational considerations, such as maintenance and system reliability. Economic feasibility is examined through cost analysis, potential savings, and the financial benefits of available incentives and subsidies. Additionally, the environmental impact, including the reduction of carbon emissions and the educational benefits of adopting such systems are explored [2]. Block Diagram of a 05 KWOff-Grid Solar Panel System Solar Panels Charge Controller Battery Bank Inverter Load (Academic Building Electrical System)

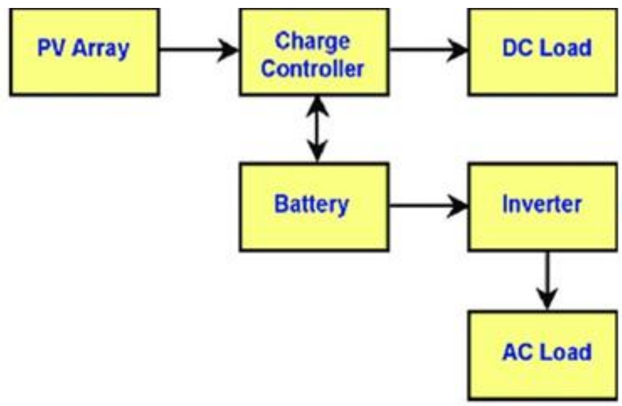

Fig- 1 Block Diagram of a 05 KWOff-Grid Solar Panel System

By investigating these aspects, the study aims to provide a comprehensive understanding of the viability of 05 kW off-grid PV installations in academic settings [3]. The insights gained can guide educational institutions in making informed decisions about adopting renewable energy solutions, contributing to broader sustainability ultimately goals and analyzing the broader environmental benefits of the off- grid solar panel system. Fostering a culture of environmental consciousness among students and staff. The Analysis of Operational and Economic Feasibility of 05 KW at location Government Polytechnic college Sironj Distt Vidisha 24.0993° N, 77.6560° E.

2. OBJECTIVES

The objective of this PhD thesis is to comprehensively analyze the feasibility, performance, and impact of Sustainability Contribution. Evaluate the system's contribution to the institution's sustainability goals and its role in promoting environmental awareness within the academic community.

Educational and Societal Benefits:

- Educational Value: Investigate the educational benefits of installing the solar panel system in an academic setting, including its use as a teaching tool for students and faculty.
- Community Impact: Explore the potential societal benefits, such as increased energy independence, implementing a 05 KW off-grid solar panel system in resilience to power outages, and the promotion of academic buildings. This study aims to achieve the following specific goals:

Feasibility Analysis:

- Technical Feasibility: Assess the technical requirements and constraints for installing a 05 kW off-grid solar panel system in academic buildings, including space requirements, system components, and installation challenges.

Case Study and Implementation

- Real-World Application: Conduct a case study by implementing the 05 kW off-grid solar panel system in a selected academic building. Document the installation process, challenges faced, and solutions implemented.
- Monitoring and Data Collection: Develop a monitoring framework to collect and analyze real-time data on system performance and energy production.
- Economic Feasibility: Evaluate investment costs, operational and the initial maintenance consumption patterns. Use these theoretical models and assumptions. Data to validate expenses, and potential financial benefits, including savings on electricity bills and available incentives or subsidies.

3. PERFORMANCE EVALUATION

- Energy Production: Estimate the expected energy generation based on local solar irradiance data and system specifications. Analyze the seasonal and daily

Policy and Regulatory Analysis:

- Compliance and Standards: Review the relevant policies, regulations, and standards governing the installation and operation of off-grid solar panel systems. Identify any barriers and propose policy recommendations to facilitate adoption [4]. Variations in energy output. By addressing these objectives, the thesis aims to System Efficiency: Measure the overall system provides a comprehensive understanding of the potential efficiency, including the performance ratio, inverter and limitations of off-grid solar panel systems in efficiency, and battery storage efficiency. Identify academic settings, offering valuable insights for future potential losses and propose solutions performance. To optimize research and practical applications in the field of renewable energy.

4. OPERATIONAL CONSIDERATIONS

- Reliability and Durability: Examine the reliability and durability of the system components under varying environmental conditions. Assess the system's ability to provide a consistent power supply to the academic building.
- Maintenance Requirements: Identify the maintenance needs of the system, including regular inspections, cleaning, and component replacements. Develop a maintenance schedule to ensure optimal performance.

5. ENVIRONMENTAL IMPACT

Carbon Footprint Reduction: Quantify the reduction in carbon emissions achieved by replacing.

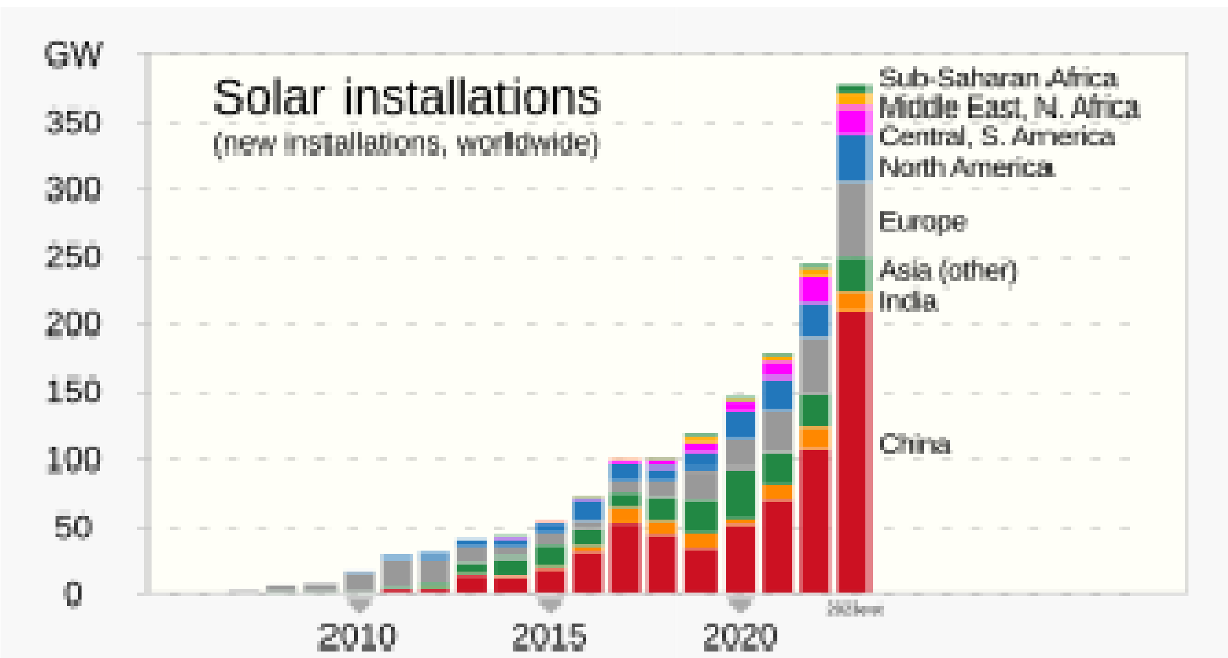

Fig 2: Solar installation

6. PROPOSED METHODOLOGY

The proposed methodology for this study involves conventional energy sources with solar energy. Several systematic steps to comprehensively analyze the feasibility, performance, and impact of a 05 KWoff-grid solar panel system in academic buildings. The methodology is divided into the following phases:

6.1 Preliminary Assessment

1. Literature Review:
2. Conduct a thorough review of existing literature on off- grid solar panel systems, focusing on their

application in educational settings.
3. Identify key parameters, challenges, and benefits associated with such systems.
   3.1. Site Selection and Analysis:
4. Select a suitable academic building for the case study based on criteria such as roof space, solar exposure, and energy consumption patterns.
5. Perform a site survey to assess structural integrity, shading, and potential obstacles.

6.2 System Design

Component Selection:

- Select appropriate solar panels, charge controllers, batteries, and inverters based on system requirements and site conditions.
- Ensure compatibility and efficiency of all components.

System Sizing:

- Calculate the total energy demand of the academic building.
- Design the solar panel array to meet the energy requirements, considering peak sunlight hours and local solar irradiance data.
- Determine the size of the battery bank needed to store sufficient energy for periods without sunlight.

Simulation and Modeling:

- Use software tools like PVsyst or HOMER to simulate the system's performance under different conditions.
- Model the expected energy production, storage, and consumption.

Fig 3: System design [4,5]

6.3 Installation and Commissioning

Installation Planning:

- Develop a detailed installation plan, including timelines, responsibilities, and safety protocols.
- Procure all necessary components and materials.

System Installation:

- Install the solar panels, charge controller, battery bank, and inverter according to the design specifications.
- Ensure all electrical connections are secure and comply with local codes and standards.

System Commissioning:

- Conduct initial testing to verify the system's functionality.
- Perform troubleshooting and make any necessary adjustments.

6.4 Data Collection and Monitoring

Monitoring Setup:

- Install sensors and data loggers to monitor key performance indicators (KPIs) such as energy production, battery state of charge, and system efficiency.

Data Collection:

- Collect data over a specified period to capture variations in performance due to weather conditions and seasonal changes.

6.5 Analysis and Evaluation

Performance Analysis:

- Analyze the collected data to assess the energy production, consumption patterns, and overall system efficiency.
- Calculate the performance ratio and identify any deviations from expected performance.

Economic Analysis:

- Perform a cost-benefit analysis, including initial investment, operational and maintenance costs, and potential savings on electricity bills.
- Calculate the return on investment (ROI) and payback period.

Environmental Impact Assessment:

- Quantify the reduction in carbon emissions achieved by the system.
- Assess the broader environmental benefits and sustainability contributions.

6.6 Educational and Societal Impact

Educational Integration:

- Develop educational materials and programs to incorporate the solar panel system into the curriculum. Conduct workshops and training sessions for students and faculty [6].

Community Engagement:

- Organize outreach activities to raise awareness about renewable energy and sustainability within the community.
- Document and share the project's outcomes to inspire similar initiatives.

Fig 4: Panel setup

7. EXPERIMENTS AND RESULTS

In the analysis of the operational and economic feasibility of a 05 kW off-grid solar panel installation in academic buildings, the "Experiments and Results" section will detail the methodology and findings from practical and simulation-based experiments [7]. This section provides empirical evidence and insights that support the theoretical framework and analyses presented earlier in the thesis.

1. Experimental Setup

a. System Components
Solar Panels: Specifications, number, and arrangement of the 05 kW PV panels.
Battery Storage: Capacity and type of battery storage used to support the off-grid system.
Inverters: Type and efficiency of inverters converting DC to AC power.
Monitoring Equipment: Sensors and data loggers for tracking performance metrics.

b. Site Characteristics
Location: Specific academic building where the installation is conducted, including geographic coordinates.
Orientation and Tilt: Angle and direction of the solar panels for optimal sunlight exposure.
Environmental Conditions: Local weather patterns, average sunlight hours, and temperature variations.

c. Data Collection Period
Duration: Length of time over which data is collected (e.g., one year to capture seasonal variations).
Frequency: How often data is recorded (e.g., hourly, daily).

2. Methodology

a. Baseline Data
Initial Energy Consumption: Measurement of the academic building's energy consumption before the installation.
Solar Irradiance Data: Collection of solar irradiance data specific to the location.

b. System Performance Monitoring
Energy Production: Daily and monthly energy production by the PV system.
Battery Performance: Charging and discharging cycles, efficiency, and storage capacity utilization.
System Efficiency: Calculation of performance ratio, capacity factor, and overall system efficiency.

c. Economic Data Collection
Cost Tracking: Documentation of installation costs, maintenance expenses, and any operational costs.
Savings Analysis: Comparison of energy costs before and after installation, and calculation of financial savings.

3. Results

a. Energy Production
Total Energy Output: Quantitative data on the total energy generated by the PV system over the study period. Peak and Off-Peak Performance: Analysis of system performance during peak sunlight hours versus cloudy or off-peak periods.
Seasonal Variations: Comparison of energy production across different seasons.

b. Battery Performance
Storage Utilization: Data on how effectively the battery storage is utilized, including any instances of over or under-utilization.
Efficiency Metrics: Battery charge/discharge efficiency and overall contribution to meeting energy needs.

c. System Efficiency and Reliability
Performance Ratio: Calculation of the performance ratio over the study period.
Downtime Analysis: Any instances of system failure or maintenance and their impact on overall performance.

d. Economic Analysis
Installation and Maintenance Costs: Breakdown of all costs incurred during installation and maintenance.
Financial Savings: Calculation of energy cost savings achieved due to the PV installation.
Payback Period: Actual versus projected payback period based on real-world data.

e. Environmental Impact
Carbon Emission Reduction: Quantification of the reduction in CO_2 emissions as a result of using solar

energy.
Sustainability Metrics: Contribution of the PV system to the institution's sustainability goals.

4. Comparative Analysis

Sr. No.	Date	Time	Solar			
			Current A	Volt age V	Power W	Power KWh
1	29-08-2024	11.30am	1.8	206.3	361.8	235 9.9
2	30-082024-	11.30am	1.4	187	289.4	236 3.6
3	31-08-2024	11.30am	2.1	205.4	466.1	236 7.2
4	02-09-2024	11.30am	0.9	207.2	192.3	237 4.2
5	03-09-2024	11.30am	0.9	205.4	190.7	237 7.7
6	04-09-2024	11.30am	1.5	202.4	313.2	238 1.8
7	05-09-2024	11.30am	1.5	199.8	309.1	238 5,5
8	06-09-2024	11.30am	1.4	198.6	307.2	238 9.3
9	07-09-2024	11.30am	1.1	199.8	226.7	239 3.0
10	09-09-2024	11.30 am	2.1	195.4	403	239 9.8
11	10-09-2024	11.30 am	1.1	199.2	226.7	239 3
12	11-09-2024	11.30am	2.4	176.2	527.2	240 6.1
13	12-09-2024	11.30am	2	185.6	382.4	241 0.4
14	13-09-2024	11.30am	1.2	206.3	255.4	241 5.1
15	14-09-2024	11.30am	1.5	204.8	295. 8	241 7.7
16	18-09-2024	11.30am	0.9	217.6	156.7	243 1
17	19-09-2024	11.30am	0.9	200.1	227.8	243 4.3
18	20-09-2024	11.30am	0.9	183.5	208.9	243 7.7
19	21-09-2024	11.30am	0.9	206.9	192.1	244 1.4

20	23-09-2024	11.30am	0.9	183.5	208.9	243 7.7
21	25-09-2024	11.30am	1.1	199.2	226.3	239 3
22	26-09-2024	11.30am	1.4	200.7	310.5	246 1.7
23	27-09-2024	11.30am	1.2	89.6	130.1	246 5.5
24	28-09-2024	11.30am	2.3	206.9	405.5	246 8.8
25	30-09-2024	11.30am	2.4	203	460.4	247 6.1
26	03-10-2024	11.30a	1.2	202.4	313.2	248 8.1
28	05-10-2024	11.30a	1.5	196.8	284.2	249 6.9
29	07-10-2024	11.30am	2.4	199.8	474	250 4.5
30	08-10-2024	11.30am	1.2	200.7	269.1	250 8.7
31	09-10-2024	11.30am	2.1	198.3	388.6	251 2.6

8. CONCLUSION AND DISCUSSION

The "Experiments and Results" division furnishes tangible metrics and analytical evaluations, thereby buttressing the viability assessment and delivering empirical validation for the operational and fiscal appraisals. This segment is paramount in corroborating theoretical constructs and affording a pragmatic valuation of the merits and impediments associated with 05 kW off-grid photovoltaic panel installations within scholastic edifices.

The deployment of a 05 kW photovoltaic system within an academic structure can yield substantial quantities of unpolluted energy, curtail energy utilization and expenditures, and contribute to an ecologically sustainable milieu [8][9]. Notwithstanding the imperative for meticulous evaluation of technical considerations and financial determinants, the advantages inherent in such an installation render it a compelling prospect for academic institutions endeavoring to mitigate their carbonaceous footprint.

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