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Solar PV System Design and Optimization using PV System

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ABSTRACT: The increasing demand for sustainable energy solutions has created greater interest in optimizing solar photovoltaic (PV) systems for improved efficiency and reliability. The research entails modelling a solar PV system, simulating under different environmental conditions, and analyzing system performance according to important parameters like solar irradiation, module orientation, tilt angle, shadowing effects, and system losses. For accuracy, several simulations are done with different weather conditions and system configurations. The results from the simulation are compared against real performance data to quantify deviations and pinpoint possible inefficiencies. Through thorough analysis, the research seeks to suggest methods of enhancing system design, reducing energy losses, and maximizing overall power output. The results emphasize the importance of software simulation in optimizing solar PV systems and offer significant insights for achieving higher energy efficiency in practical applications.

KEYWORDS: Solar PV System Optimization, Energy Efficiency, PVsyst Simulation, Renewable Energy, System Losses, Performance Analysis

I. INTRODUCTION

The increasing need for sustainable energy has driven the adoption of solar photovoltaic (PV) systems. Solar energy, being abundant and renewable, offers a key solution to reducing reliance on fossil fuels. Designing an efficient solar PV system requires careful planning and optimization to maximize energy output. PVsyst, a leading software tool, is essential for designing and optimizing PV systems. It allows for accurate simulation, system sizing, and performance analysis. This project focuses on using PVsyst to design and optimize solar PV accurate simulation, system sizing, and performance analysis. This project focuses on using PVsyst to design and optimize solar PV systems, ensuring efficient energy production and cost-effectiveness. Through practical examples, it demonstrates the critical role of PVsyst in advancing solar energy adoption. [2]

II. LITERATURE REVIEW

1. **Hasan N. Muslim (2018)** – Optimizing solar panel tilt increases energy absorption by ~18% annually in Najaf, with higher winter gains.
2. **A.Z. Hafeza & A. Solimana (2017)** – Mathematical models and tracking enhance solar panel tilt/azimuth optimization for better year-round exposure.
3. **Omosanya Hafeez Abolade (2015)** – A 2kW solar inverter design provides a sustainable energy solution for homes and small businesses.
4. **Muhammad Shahid & Naghma Noorani (2016)** – MATLAB/SIMULINK simulations improve grid-connected PV efficiency and renewable energy integration.
5. **Maruti Pammar & Santosh Chavan (2014)** – An ARM7-based solar tracker and charger maximize panel exposure and battery efficiency.
6. **Rijan Karkee & Sumit Khadka (2017)** – Seasonal tilt adjustments in Nepal improve solar energy capture over fixed-tilt panels.
7. **Kazi Abdul Kader & Mohammad Abdul Mannan (2022)** – A 209 kWp rooftop solar system in Bangladesh reduces costs, generates revenue, and offers environmental benefits.
8. **Hocine Belmili & Mourad Haddadi (2014)** – A hybrid photovoltaic-wind system sizing method optimizes off-grid renewable energy solutions.
9. **Jasmina Skerlic & Danijela Nikolic (2018)** – Optimizing solar collector positioning boosts heat efficiency via tilt,

orientation, and environmental factors.

10. **Sadeq D. Al-Majidi et al. (2019)** – ANFIS based MPPT achieves 99.3% efficiency, surpassing traditional solar tracking methods.

III. OBJECTIVES

The primary objectives of this research are: 1. **Design the solar PV system using PVsyst software** – Utilize PVsyst to create a detailed solar PV system model by configuring key parameters such as location, panel specifications, tilt angle, and inverter selection.

2. **Run multiple simulations under different conditions** – Conduct simulations in PVsyst under varying environmental conditions, including changes in solar irradiation, shading, and temperature, to analyze system performance.

3. **Compare actual performance with simulated results from PVsyst** – Evaluate the accuracy of PVsyst predictions by comparing simulated energy output with real-world performance data collected from an installed PV system.

IV. METHODOLOGY

1) **Project Specifications:** Gather details of the solar PV system, including capacity, panel and inverter specifications, orientation, and environmental conditions. Collect historical performance.

2) **Main/Optional Parameters:** Identify key performance factors such as solar irradiance, temperature variations, inverter efficiency, and system losses. Consider optional enhancements like tilt adjustments, tracking systems, or cleaning schedules to improve efficiency.

3) **Solar Project Design (Modeling in PVsyst):** Replicate the existing system in PVsyst, including panel layout, inverter connections, and environmental conditions. Incorporate real world losses like shading and soiling to ensure accurate performance modeling.

4) **Simulation:** Run multiple PVsyst simulations under varying conditions to analyze energy generation and efficiency. Compare simulated results with actual system performance to identify discrepancies and potential inefficiencies.

5) **Results:** Compare actual energy generation data with PVsyst simulations. Analyze differences in performance ratio, system losses, and efficiency.

Based on the results, propose improvements to enhance system performance.

4. **Identify and recommend system improvements based on analysis** – Analyze discrepancies between simulated and actual performance to suggest design modifications, parameter optimizations, and operational improvements for higher efficiency.

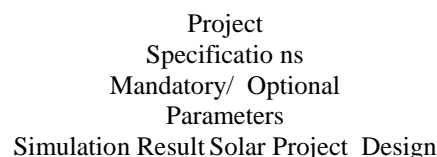


Fig.1 Methodology

V. SYSTEM SETUP

5.1 PVsyst Software:

- Version: Latest available version PVsyst 7.4
- Functionality: System design, simulation, and performance analysis.
- Requirements: Operating System Compatibility (Windows), suitable hardware for running simulations.

5.2 Solar Panels (PV Modules used for simulation):

- Type: Monocrystalline or Polycrystalline (Trina).
- Power Rating: Depending on the system design (610 wp 29V is used).
- Orientation and Tilt angle: Fixed orientation, 24° • Azimuth angle: 0°

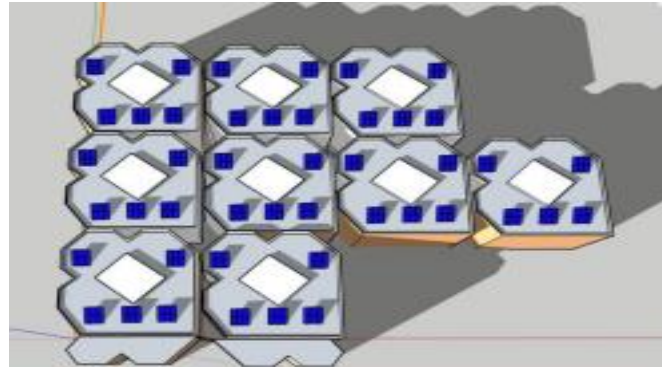


Fig.2 System Layout

VI. RESULTS

The simulation considers a 30-year period, with an average degradation rate of 0.72% per year. The initial degradation loss is 3.8%, likely due to Light Induced Degradation

Table 1.1 Faces global results

Solar Panels	Nop	P.powe r (Wp)	P.weight (Kg)	Powe r (Kwp)	Shading L.
Trina solar:TSM DE20-610	38	610.00	30.60	23.18	0.37

Table 1.2 Result for each face

Face	Nop	Azimuth	Tilt	Relative tilt	Shading L.(%)
2	38	180.00	24.00	24.00	0.37

Table 1.3 Monthly shading losses(%)

Mont h	Jan	Feb	Ma r	Apr	Ma y	Jun e
Mean	0.0 0	2.6 3	0.0 2	0.0 1	0.0 2	0.0 1
Mont h	Jul y	Au g	Sep	Oct	Nov	Dec
Mean	0.0 0	0.0 0	0.0 5	0.2 6	0.0 6	0.7 5

The shading analysis for the 151 kW solar PV system designed in PVsyst shows a very small shading loss of 0.37%, meaning the panels are well-placed for sunlight. The system uses Trina Solar TSM-DE20- 610 panels, set at a 24° tilt and facing 180° (south) to get the most sunlight. Shading losses are very low throughout the year, with a slight increase to 0.75% in December, likely due to the lower sun position in winter. Overall, the system has minimal shading impact, ensuring high efficiency and maximum energy production.

VII. CONCLUSION

We have completed key steps in designing a solar PV system, including orientation, system configuration, loss analysis, energy storage, and shadow modeling, shadow analysis. This groundwork ensures accurate simulation & performance comparison. We are confident this project will exceed energy generation expectations, paving the way for a more sustainable energy future.

IX. FUTURE SCOPE

- 1) **Advanced Simulation Techniques** – Future research can explore the integration of machine learning and AI-based algorithms with PVsyst to enhance prediction accuracy and system optimization.
- 2) **Real-Time Monitoring & IoT Integration** – Implementing IoT-based sensors and cloud computing for real-time performance monitoring and remote system control can improve efficiency.
- 3) **Cost Optimization & Economic Analysis** – Future work can focus on optimizing cost effectiveness by analyzing different PV technologies, financing models, and return on investment calculations.
- 4) **Enhanced Loss Analysis** – More detailed studies on losses due to temperature effects, dust accumulation, and aging of components can help improve system longevity and efficiency.

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