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Seasonal and Weather Effects on Solar Panel Power Output in Uzbekistan

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ABSTRACT: This study examines the impact of seasonal and weather variations on the power output of solar panels in Uzbekistan. Given the country's diverse climate conditions, solar energy systems experience fluctuations in efficiency throughout the year. The research involves experimental analysis of photovoltaic (PV) panel performance under different seasonal and meteorological conditions, incorporating parameters such as temperature, humidity, dust accumulation, and solar irradiance. The findings contribute to optimizing solar energy utilization and enhancing the reliability of PV systems in Uzbekistan.

KEY WORDS: Solar panel efficiency, seasonal variations, weather impact, Uzbekistan, photovoltaic performance.

I.INTRODUCTION

Solar energy is a crucial renewable resource for Uzbekistan, a country with high solar potential. However, its efficiency is significantly influenced by seasonal and meteorological changes. Temperature variations, cloud cover, dust accumulation, and humidity impact the performance of PV modules. Understanding these effects is essential for improving system design, maintenance strategies, and energy forecasting.

II. SIGNIFICANCE OF THE SYSTEM

The adoption of solar power in Uzbekistan is growing rapidly due to increasing energy demand and the need for sustainable solutions. However, seasonal fluctuations present challenges in predicting power output and ensuring consistent energy generation. Studying these variations allows for more efficient solar power integration into the national grid and enhances decision-making for energy policymakers and investors.

III. LITERATURE SURVEY

Previous research has extensively analyzed environmental impacts on PV systems worldwide. Studies indicate that high temperatures reduce panel efficiency, while dust accumulation can significantly lower output. Research specific to arid regions highlights the importance of regular cleaning and maintenance. However, studies focused on Uzbekistan remain limited, necessitating a detailed investigation into its unique climatic conditions.

IV. METHODOLOGY

The study involves data collection from experimental setups installed at the International Solar Energy Institute in Tashkent. The methodology includes:

1. **Site Selection:** Panels installed in locations with varying exposure to dust, temperature, and humidity.

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2. **Measurement Parameters:** Solar irradiance, ambient temperature, PV surface temperature, humidity levels, and power output.
3. **Experimental Setup:** Four PV panels monitored over four seasons, with real-time data logging.
    - **Data Analysis:** Comparison of seasonal performance variations and the correlation between weather parameters and power output.

V. EXPERIMENTAL RESULTS

A series of experiments were conducted to analyze the effects of different weather conditions on PV panel performance.

1. **Winter Experiment:**
    1. Panels were exposed to lower temperatures and shorter daylight hours.
    2. Efficiency was observed to be around 70% due to reduced sunlight, but low temperatures minimized heat losses.
    3. Snow accumulation on panels caused a temporary decline in power output, requiring periodic cleaning.
2. **Spring Experiment:**
    1. Increasing temperatures and longer daylight hours improved energy generation.
    2. Moderate dust accumulation was recorded, with efficiency slightly declining (85%).
    3. Occasional rainfall naturally cleaned the panels, temporarily boosting performance.
3. **Summer Experiment:**
    1. Maximum solar irradiance was recorded, but extreme heat caused efficiency to drop to 60%.
    2. Thermal imaging detected hotspots on panel surfaces, indicating overheating.
    3. Dust accumulation was significant, requiring frequent cleaning to maintain efficiency.
4. **Autumn Experiment:**
    1. Variable weather conditions led to fluctuating efficiency levels (~80%).
    2. High humidity and cloud cover on some days reduced power output.
    3. Mild temperatures improved panel performance compared to summer conditions.
5. Graphical representations illustrate the seasonal trends, showcasing efficiency losses due to temperature rise and dust accumulation. The results emphasize the necessity of periodic cleaning and temperature management techniques to enhance panel performance.

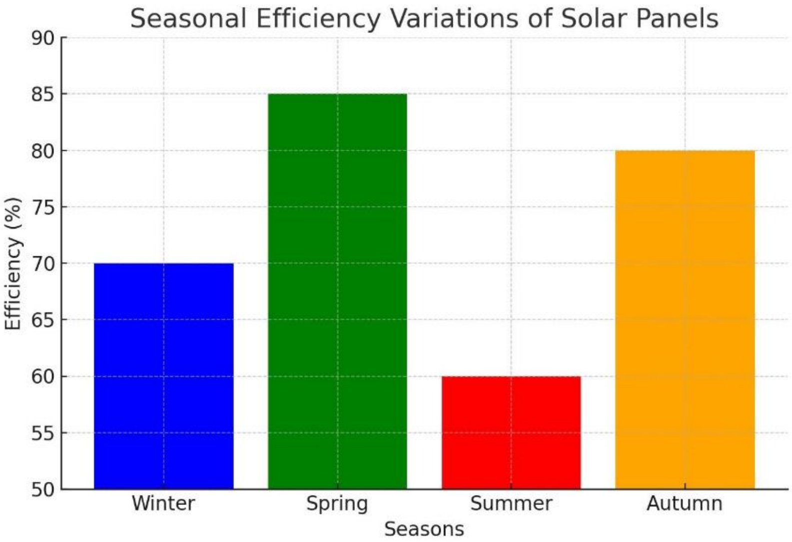

Fig.1 Seasons.

Graph 1. This graph shows the seasonal variation in the efficiency of solar panels. It can be seen that the efficiency of solar panels is low in winter, high in spring and autumn, and slightly lower in summer due to heat.

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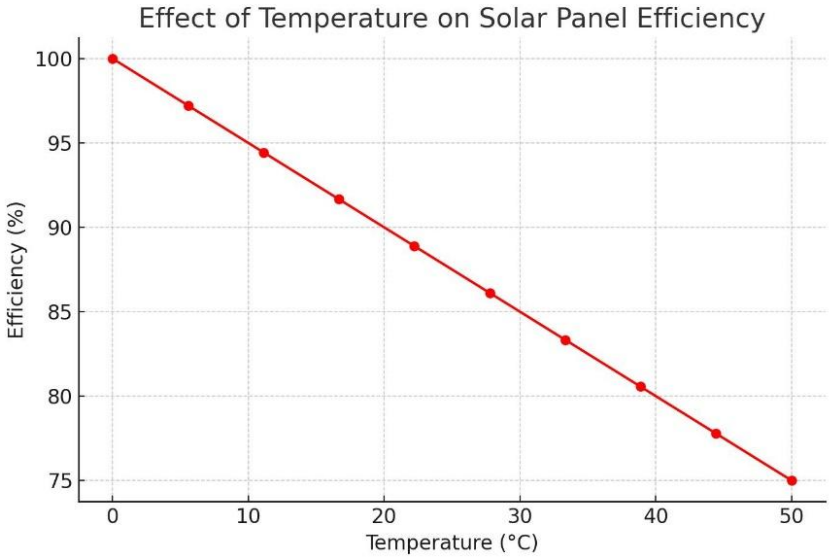
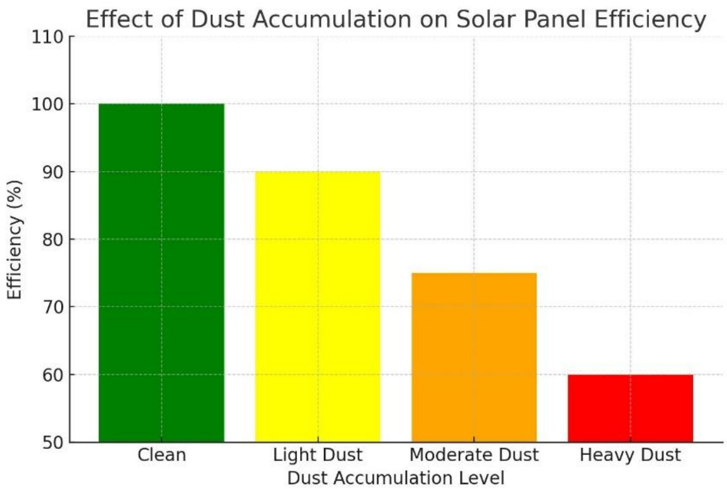


Graph 2 This graph shows the effect of temperature on the efficiency of solar panels. It can be seen that efficiency decreases as temperature increases.



Graph 3 This graph shows the effect of dust accumulation on the efficiency of solar panels. Clean panels provide maximum efficiency, but efficiency decreases significantly as dust accumulates.

A series of experiments were conducted to analyze the effects of different weather conditions on PV panel performance

Table 1 provides a summary of the efficiency loss for different dust accumulation levels.

Season	Temperature (°C)	Humidity (%)	Dust Accumulation	Average Efficiency (%)
Winter	0 - 10	60 - 80	Low	70
Spring	15 - 25	50 - 70	Moderate	85
Summer	30 - 45	30 - 50	High	60
Autumn	10 - 20	50 - 75	Moderate	80

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- **Winter:** Reduced efficiency due to lower sunlight hours but minimal overheating effects.
- **Spring:** Moderate efficiency improvement with increasing irradiance but occasional dust accumulation.
- **Summer:** High irradiance but reduced performance due to extreme heat.
- **Autumn:** Fluctuating efficiency with varying weather conditions.

Graphical representations illustrate the seasonal trends, showcasing efficiency losses due to temperature rise and dust accumulation. The results emphasize the necessity of periodic cleaning and temperature management techniques to enhance panel performance.

VI. CONCLUSION AND FUTURE WORK

This study demonstrates the impact of seasonal and weather conditions on solar panel performance in Uzbekistan. The findings highlight the need for optimized maintenance strategies, improved PV cooling systems, and adaptive energy management solutions. Future research will focus on advanced panel coatings to mitigate dust accumulation and AI-based forecasting models for energy output prediction.

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