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The Effect Of Tilt Angle On Solar Panel Efficiency In Uzbekistan

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Abstract: *Solar panel tilt angle is a critical factor influencing the efficiency of solar energy systems. By optimizing the tilt angle according to seasonal and geographical conditions, solar panels can maximize sunlight absorption and improve energy output. This article examines the optimal tilt angles for photovoltaic systems in Uzbekistan, focusing on a 50 kW solar station in the Andijan region. Using Khanabad and Ulug'nor districts as case studies, the analysis provides insights into how optimal tilt adjustments can enhance solar panel performance and ensure efficient solar power production throughout the year.*

Keywords: Solar panel tilt angle, solar efficiency, photovoltaic optimization, Andijan region, renewable energy Uzbekistan, seasonal tilt adjustment

Introduction

Solar energy systems rely on photovoltaic (PV) panels to convert sunlight into electricity. The orientation and tilt angle of these panels are vital factors in optimizing energy generation, especially in regions with varied seasonal sunlight exposure [1-2]. This article explores the effect of tilt angle on solar panel efficiency, highlighting how adjusting tilt angles seasonally can improve energy yields, especially in high-irradiance regions like Uzbekistan.

Impact of Tilt Angle on Energy Absorption

The tilt angle of a solar panel is the angle between the panel surface and the ground. It determines the amount of sunlight that hits the panel and therefore directly affects energy production. In general:

- **Fixed Tilt**: A fixed tilt angle, typically set close to the latitude of the installation site, can provide reasonable performance throughout the year.
- **Seasonal Tilt Adjustment**: Adjusting the tilt angle seasonally can further enhance energy capture, particularly in regions with distinct seasons, by maximizing exposure during summer and winter months [3].

Optimal tilt angles vary with latitude, seasonal sun path, and local atmospheric conditions, making specific adjustments beneficial for regions like Andijan in Uzbekistan.

Optimal Tilt Angles for Seasonal Variations in Uzbekistan

Uzbekistan, situated in Central Asia, experiences significant seasonal sunlight variation. Andijan, located at approximately 40 degrees north latitude, offers a unique case for understanding how tilt angle adjustments impact solar efficiency. The recommended tilt adjustments for Uzbekistan's seasons are:

1. **Winter**: For maximum winter energy capture, tilt angles should be set higher to face the lower solar altitude. A tilt angle of around 55° (latitude + 15°) can enhance wintertime energy production.
2. **Summer**: In summer, a lower tilt angle of around 25° (latitude - 15°) aligns better with the high solar altitude, maximizing energy capture.
3. **Spring and Autumn**: During these transitional seasons, a tilt angle close to the local latitude, around 40°, is ideal to balance solar exposure.

By adjusting the tilt angle based on these seasonal recommendations, solar systems in Uzbekistan can optimize sunlight absorption, leading to greater efficiency and energy yield.

Case Study: 50 kW Solar Station in Andijan

A 50 kW photovoltaic solar station in Andijan serves as a case study to demonstrate the practical effects of tilt angle adjustments. This station is located across two primary districts, Khanabad and Ulug'nor, which offer representative conditions for solar installations in Uzbekistan.

Seasonal Tilt Adjustments:

- **Winter (December to February)**: Tilt set to 55° maximizes low-angle sunlight capture.
- **Summer (June to August)**: Tilt set to 25° to optimize capture from the higher solar altitude.
- **Spring and Autumn (March, April, September, October)**: Tilt set to 40° for balanced exposure.

Efficiency Gains: Simulation results indicate that tilt adjustments can improve energy generation by up to 15% compared to fixed-angle systems. This boost in efficiency is especially beneficial during winter, where increased tilt angles can compensate for the reduced daylight hours [4].

Simulation and Results

Using solar simulation software, the effects of seasonal tilt adjustments were evaluated. The study found that:

- **Annual Energy Output**: The energy yield from seasonal tilt adjustments was approximately 10–15% higher than that of fixed-tilt systems.
- **Winter Performance**: Adjusting the tilt to a steeper angle in winter months increased winter efficiency by about 20%, helping the system maintain a more consistent output across seasons.
- **Economic Impact**: The incremental energy yield translates to improved cost-effectiveness, as the added generation reduces reliance on grid energy or supplementary energy sources [5].

Limitations: Manual tilt adjustments require periodic labor, which could be a drawback for large installations without automated tracking systems. However, the enhanced energy yield generally justifies these adjustments in smaller, rural solar systems.

Conclusion

Adjusting the tilt angle of solar panels seasonally can significantly enhance solar energy system performance in regions like Uzbekistan, where seasonal sunlight variation is pronounced. The case study of a 50 kW solar station in Andijan illustrates that optimizing tilt angles can result in a 10–15% increase in annual energy output, providing an economically beneficial strategy for improving solar efficiency. Future developments could include integrating adjustable mounting systems that allow for automated seasonal adjustments, further enhancing the viability of solar energy in Uzbekistan's renewable energy landscape.

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