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Factors Affecting the Efficiency of Photovoltaic Power Stations

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Abstract: Photovoltaic (PV) power stations are becoming an essential part of the global shift towards renewable energy. However, their performance can be significantly influenced by various environmental and technical factors. This paper explores the main elements that reduce the efficiency of PV systems, such as dust accumulation, snow coverage, suboptimal solar angles, high operating temperatures, and equipment faults. Each of these factors can cause a noticeable drop in energy output over time if not properly managed. The study also discusses modern solutions like automated cleaning systems and real-time monitoring tools that can help maintain and even enhance the long-term efficiency of solar panels. By understanding these factors, solar energy systems can be designed and maintained more effectively to achieve maximum performance in different conditions.

Keywords: Photovoltaic power stations, solar panel efficiency, dust accumulation, snow coverage, solar angle, temperature effect, system maintenance, energy output, automated cleaning, performance monitoring.

Photovoltaic (PV) power stations are an increasingly important source of renewable energy, but their efficiency can vary greatly depending on several external and internal factors. Among the most significant of these are dust accumulation on the panels, snow coverage during colder months, the angle of sunlight, ambient and surface temperatures, and potential system malfunctions. Each of these factors can lead to noticeable drops in energy output, especially over extended periods.

For example, dust particles can block sunlight from reaching the solar cells, reducing their ability to generate electricity efficiently. Snow layers, although seasonal, can completely block solar input if not promptly removed. Additionally, the angle of the sun changes throughout the year, and if solar panels are fixed and not adjustable, they may not receive optimal sunlight. High temperatures can also negatively impact panel performance, as excessive heat reduces the voltage output of PV cells. Furthermore, hardware issues such as inverter failures or cable degradation can go unnoticed without proper monitoring.

To address these challenges, new technologies such as automated cleaning systems and IoT-based real-time monitoring have been introduced. These systems help maintain cleanliness, detect problems early, and allow for data-driven optimization of panel positioning and system performance.

Figure 1. Factors affecting efficiency in photovoltaic plants

Improving the efficiency of PV stations is not just a technical goal—it’s also an economic and environmental necessity. By understanding and mitigating these influencing factors, solar power

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systems can deliver more consistent and reliable energy, making renewable energy a stronger pillar of the global energy supply.

Statistical Summary

Factor	Efficiency Impact (%)	Notes
Dust	-10%	Noticeable drop after 2 weeks without cleaning
Snow Coverage	-80%	Heavy snow can block all sunlight
Sun Angle	-15%	Without seasonal adjustment
High Temperature	-8%	Above 45°C reduces voltage output
System Malfunctions	-5% to -20%	Sensor or inverter failures

Factors and Their Effects.

1. *Dust Accumulation:*
- Efficiency reduction up to 10%;
- Dust blocks sunlight, reducing panel output;
2. *Snow Coverage:*
- Efficiency loss up to 80% if snow is not removed;
- Seasonal but significant;
3. *Sunlight Angle:*
- Fixed panels may miss optimal sunlight;
- Tracking systems can increase output by 20–30%;
4. *Temperature Effects:*
- Efficiency drops 8–10% at high temperatures (e.g., 45°C);
- 25°C is considered optimal for PV panel performance;
5. *System Malfunctions:*
- Undetected inverter or wiring issues reduce performance;
- IoT-based monitoring can prevent long-term losses;

The performance of photovoltaic power stations is influenced by a variety of environmental and technical factors. Among the most critical are dust and snow accumulation, the angle of sunlight, ambient temperature, and equipment malfunctions. Dust and snow can significantly reduce the amount of sunlight that reaches the panels, leading to noticeable drops in energy production. The tilt angle of the panels also plays a vital role, as it changes with the position of the sun throughout the day and across seasons. High temperatures can lower the efficiency of semiconductor materials within solar panels, while system failures — such as issues with inverters or sensors — may interrupt overall operation. These challenges can be mitigated through automated cleaning systems, solar tracking technology, heat-resistant panel materials, and remote monitoring. By addressing these factors, it becomes possible to maintain high efficiency in solar power stations throughout the year.

Conclusion. Enhancing the efficiency of photovoltaic power stations requires a clear understanding of the factors that influence energy output. External elements such as dust, snow, solar angle, and temperature have a direct impact on panel performance, while internal system issues like technical malfunctions can lead to unnecessary energy losses. Through the use of practical solutions — including automated cleaning systems, seasonal adjustment of panel angles, temperature-resistant technologies, and continuous remote monitoring — these challenges can be effectively addressed.

Consistent implementation of such measures not only improves operational efficiency but also contributes to the long-term sustainability and reliability of solar energy systems.

References

1. Green, M. A. (2003). *Third generation photovoltaics: Advanced solar energy conversion*. Springer Science & Business Media.
2. Duffie, J. A., & Beckman, W. A. (2013). *Solar Engineering of Thermal Processes* (4th ed.). Wiley.
3. Makrides, G., Zinsser, B., Schubert, M., Georghiou, G. E., & Werner, J. H. (2010). *Performance of photovoltaics under actual operating conditions*. Solar Energy, 84(4), 515–524. https://doi.org/10.1016/j.solener.2009.12.002
4. Mani, M., & Pillai, R. (2010). *Impact of dust on solar photovoltaic (PV) performance: Research status, challenges and recommendations*. Renewable and Sustainable Energy Reviews, 14(9), 3124–3131. https://doi.org/10.1016/j.rser.2010.07.065
5. Skoplaki, E., & Palyvos, J. A. (2009). *On the temperature dependence of photovoltaic module electrical performance: A review of efficiency/power correlations*. Solar Energy, 83(5), 614–624. https://doi.org/10.1016/j.solener.2008.10.008
6. IEA (International Energy Agency). (2020). *Trends in Photovoltaic Applications 2020*. https://iea-pvps.org