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LUMIGRID: SELF ORIENTING SOLAR-INTEGRATED GLASS

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ABSTRACT

"Lumigrid" presents an innovative solution for sustainable energy by embedding self-orienting photovoltaic cells within glass panels. This technology enables transparent solar power generation while dynamically adjusting the glass orientation to capture maximum sunlight throughout the day. Seamlessly integrated into windows, facades, and automotive glass, Lumigrid offers a blend of aesthetics and functionality ideal for smart buildings and urban applications. By turning ordinary glass surfaces into adaptive energy generators, it optimizes energy efficiency without compromising architectural design. This approach enhances the potential for Building-Integrated Photovoltaics (BIPV), providing a versatile and efficient pathway to renewable energy in modern infrastructures

1. INTRODUCTION

Lumigrid is a next-generation solar panel technology that combines transparency with dual-axis solar tracking, offering a unique blend of aesthetics and efficiency. Unlike traditional opaque solar panels, Lumigrid's transparent design allows light to pass through, making it ideal for applications in buildings, greenhouses, and other environments where natural light is desired. This feature makes it particularly appealing for urban settings, where solar installations on windows and facades can contribute to energy generation without obstructing views or affecting building aesthetics.

The dual-axis tracking system integrated into Lumigrid is a game-changer in solar technology. This system enables the panel to adjust its orientation in both the horizontal and vertical planes, following the sun's path across the sky. By optimizing the angle throughout the day, dual-axis tracking significantly increases the amount of sunlight captured, boosting the overall efficiency of the panel. This feature is especially valuable in regions with high solar variability or where space for solar installations is limited, as it maximizes power output in a smaller footprint.

Lumigrid's innovative approach could pave the way for more sustainable architectural designs, merging energy production with functional building elements. The combination of transparency and high-efficiency tracking makes it a versatile solution, suitable for both residential and commercial settings. As cities move toward greener infrastructure, Lumigrid's potential to enhance urban sustainability while maintaining aesthetic appeal could make it an essential technology for future-oriented construction projects.

2. LITERATURE SURVEY

[1]. Baouche, F.Z.; Abderezzak, B.; Ladmi, A.; Arbaoui, K.; Suciu, G.; Mihaltan, T.C.; Raboaca, M.S.; Hudis,teanu, S.V.; T, urcanu, F.E. Design and Simulation of a Solar Tracking System for PV. Appl. Sci. 2022, 12, 9682.

The paper titled *"Design and Simulation of a Solar Tracking System for PV"* by Baouche et al., published in 2022, delves into the design and performance simulation of a solar tracking system specifically tailored for photovoltaic (PV) applications. Solar tracking systems are essential in enhancing the efficiency of PV panels by adjusting their position to align with the sun's trajectory. This paper emphasizes the development of a tracking mechanism that improves energy capture, particularly in areas where sunlight angles shift significantly throughout the day. The authors aim to address the limitations of fixed-panel systems, where energy capture can be compromised due to the static orientation of the panels.

In this study, the authors explore the engineering aspects of the solar tracking system, from its conceptual design to the simulation of its performance. They use simulation tools to model the impact of various design elements, such as rotation angles, motor control, and structural stability, on energy yield. By comparing different configurations, the research team seeks to identify the optimal parameters that balance energy gains with mechanical durability and cost-effectiveness. Their findings demonstrate how certain design choices can significantly boost energy output, particularly during times of day when sunlight angles are less favorable for fixed panels.

The research not only contributes valuable data on the effectiveness of solar tracking but also offers insights into the potential return on investment (ROI) for these systems. By simulating real-world conditions and evaluating the system's efficiency over time, the authors provide practical information for engineers and stakeholders considering solar tracking for PV installations. Their work supports the argument that while solar tracking systems involve higher initial costs and greater mechanical complexity

[2]. Sergio I. Palomino-resendiz1 , Frida A. Ortiz-martínez1 , Itzia V. Paramo-ortega1 , Juan M. González-lira1 , And Diego A. Flores-hernández. Optimal Selection of the Control Strategy for Dual-Axis Solar Tracking Systems. n 6 June 2023, date of current version 12 June 2023

This paper focuses on optimizing control strategies for dual-axis solar tracking systems, which are designed to maximize the efficiency of solar panels by adjusting their orientation in two axes to follow the sun's path. Dual-axis trackers can capture more sunlight than fixed systems, but they require a more sophisticated control mechanism. The authors analyze various control strategies and evaluate their effectiveness in terms of energy yield, system complexity, and cost. By comparing these strategies, the paper aims to identify the optimal solution that balances performance and feasibility.

The study likely involves simulations or real-world experiments to assess each strategy's performance under different conditions. The authors also explore the trade-offs between energy gains and the operational costs associated with each approach. The findings are valuable for both researchers and practitioners in the solar energy field, as they provide insights on how to enhance solar panel efficiency through advanced tracking mechanisms, ultimately supporting the development of more efficient and cost-effective renewable energy systems.

[3]. de Sá Campos, M.H.; Tiba, C. npTrack: A n-Position Single Axis Solar Tracker Model for Optimized Energy Collection. Energies 2021, 14, 925

This paper, titled "*npTrack: A n-Position Single Axis Solar Tracker Model for Optimized Energy Collection*" by M.H. de Sá Campos and C. Tiba, explores an innovative approach to solar energy collection using a specialized tracking model. Solar trackers are mechanisms designed to align solar panels or mirrors with the sun's path, maximizing energy capture throughout the day. The authors introduce the "npTrack" model, a single-axis solar tracker that uses multiple positions ("n-position") to optimize the orientation of solar panels. This setup is designed to provide a balance between high energy efficiency and cost-effectiveness, potentially making it more accessible than dual-axis trackers, which are typically more complex and expensive.

The npTrack model's single-axis design focuses on achieving optimal energy collection while minimizing mechanical and operational complexity. This approach enables solar panels to follow the sun more accurately than fixed-position systems and even some traditional single-axis trackers, which may have fewer tracking positions. By incorporating a multi-position mechanism, npTrack can adjust panel orientation with greater precision as the sun moves across the sky.

[4]. Hariri, N.G.; AlMutawa, M.A.; Osman, I.S.; AlMadani, I.K.; Almahdi, A.M.; Ali, S. Experimental Investigation of Azimuth- and Sensor-Based Control Strategies for a PV Solar Tracking Application. Appl. Sci. 2022, 12, 475

This paper, titled "*Experimental Investigation of Azimuth- and Sensor-Based Control Strategies for a PV Solar Tracking Application*" by N.G. Hariri, M.A. AlMutawa, I.S. Osman, I.K. AlMadani, A.M. Almahdi, and S. Ali, published in *Applied Sciences* in 2022, focuses on improving photovoltaic (PV) solar tracking systems. Solar tracking technology aims to maximize the efficiency of solar panels by adjusting their orientation to follow the sun's movement throughout the day. The study investigates two different control strategies—azimuth-based and sensor-based controls—and evaluates their effectiveness in enhancing solar energy capture. The findings offer insights into how each strategy could contribute to optimizing solar tracking systems, thus increasing overall energy generation.

The azimuth-based control strategy relies on calculating the sun's position based on time and geographical location to adjust the solar panel's orientation. In contrast, the sensor-based approach uses real-time data from sensors to dynamically align the panels based on actual sunlight conditions. The authors conducted experiments to compare the performance of these two strategies in terms of accuracy, energy efficiency, and responsiveness. By analyzing the data, the study provides a comprehensive comparison of the strengths and limitations of each method. Azimuth-based systems are typically more predictable and less dependent on external conditions, while sensor-based systems offer adaptability to sudden changes in weather or sunlight intensity.

[5] M. Kanoglu, Y. A. Çengel, and J. M. Cimbala, ''Introduction to renewable energy,'' in Fundamentals and Applications of Renewable Energy, 1st ed. New York, NY, USA: McGraw-Hill, 2020, pp. 1–15.

The paper titled "Introduction to Renewable Energy" by M. Kanoglu, Y.A. Çengel, and J.M. Cimbala, appears in the first edition of the book Fundamentals and Applications of Renewable Energy, published by McGraw-Hill in 2020. This introductory chapter serves as a foundational piece, offering readers an in-depth overview of renewable energy sources, including solar, wind, hydro, geothermal, and biomass. The authors begin by defining renewable energy, emphasizing its importance in addressing global energy demands while reducing dependency on fossil fuels. By laying out these basics, the chapter sets the stage for a deeper understanding of sustainable energy's role in today's world.

The chapter explores both the environmental and economic benefits of renewable energy, illustrating how these resources can mitigate climate change by reducing greenhouse gas emissions. Additionally, the authors examine how renewables contribute to energy security and economic resilience by providing sustainable, locally-sourced power. Comparisons are drawn between renewable and conventional energy sources, such as coal and natural gas, highlighting renewable energy's potential for long-term impact despite some limitations like intermittency and current technological constraint.**[6] R. F. Fuentes-Morales, A. Diaz-Ponce, M. I. Peña-Cruz, P. M. Rodrigo, L. M. Valentín-Coronado, F. Martell-Chavez, and C. A. Pineda-Arellano, ''Control algorithms applied to active solar tracking systems: A review,'' Sol. Energy, vol. 212, pp. 203–219,Dec. 2020**

The paper titled "*Control Algorithms Applied to Active Solar Tracking Systems: A Review*" by R.F. Fuentes-Morales, A. Diaz-Ponce, M.I. Peña-Cruz, P.M. Rodrigo, L.M. Valentín-Coronado, F. Martell-Chavez, and C.A. Pineda-Arellano, published in *Solar Energy* in December 2020, presents a comprehensive review of control algorithms used in active solar tracking systems. Solar tracking systems are essential for maximizing solar energy capture by adjusting the orientation of solar panels or mirrors to follow the sun's path. This paper examines a variety of control algorithms designed to optimize tracking efficiency, comparing different approaches based on their effectiveness, complexity, and adaptability to changing environmental conditions.

The authors categorize the control algorithms used in solar tracking into various types, such as closed-loop, open-loop, and hybrid methods. Closed-loop systems use real-time data from sensors to dynamically adjust the tracker's position based on sunlight intensity, providing high accuracy under variable weather conditions. Open-loop systems, on the other hand, rely on pre-determined calculations of the sun's trajectory and are generally simpler but less responsive to environmental changes. Hybrid algorithms combine both methods, aiming to leverage the advantages of each—accuracy from closed-loop systems and predictability from open-loop systems. The paper likely provides a detailed comparison of these algorithms, assessing their suitability for different geographical and climatic settings.

[7]. M. Dehghan, S. Rashidi, and A. Waqas, ''Modeling of soiling losses in solar energy systems,'' Sustain. Energy Technol. Assessments, vol. 53, Oct. 2022, Art. no. 102435.

The paper titled "*Modeling of Soiling Losses in Solar Energy Systems*" by M. Dehghan, S. Rashidi, and A. Waqas, published in *Sustainable Energy Technologies and Assessments* in October 2022, investigates the impact of soiling on solar energy systems. Soiling, which refers to the accumulation of dust, dirt, and other particles on solar panels, significantly reduces the efficiency of photovoltaic (PV) systems by blocking sunlight from reaching the solar cells. This paper focuses on the development of models to predict soiling losses and improve system performance through effective mitigation strategies.

The authors examine various factors contributing to soiling, such as geographical location, weather patterns, and environmental conditions. These factors influence the rate and severity of soiling, affecting the energy yield of solar installations. By creating accurate models for soiling losses, the authors aim to provide a tool for predicting the impact of soiling under different scenarios, which could help operators optimize cleaning schedules and maintenance. The models likely incorporate variables such as humidity, temperature, and wind speed, which play a role in the accumulation or removal of particles on solar panel surfaces.

3. COMPARITATIVE ANALYSIS OF LITERATURE REVIEWS

Table 1: Comparison Study of Papers

Paper Title	Authors	Comparative Study
Design and Simulation of a Solar Tracking System for PV.	Baouche, F.Z.; Abderezzak, B.; Ladmi, A.; Arbaoui, K.; Suciu, G.; Mihaltan, T.C.; Raboaca, M.S.; Hudis,teanu, S.V.; T, urcanu, F.E.	Baouche et al. (2022) design and simulate a solar tracking system for photovoltaic (PV) panels, focusing on improving energy capture efficiency through precise tracking mechanisms. In comparison, Hua et al. (2019) optimize the integration of multiple tracker types and storage systems for utility-scale PV plants, addressing both technical and economic aspects. While Baouche et al. emphasize standalone tracker performance, Hua et al. explore system-wide efficiency and grid demand alignment, highlighting different approaches to enhancing PV energy utilization.
Optimal Selection of the Control Strategy for Dual-Axis Solar Tracking Systems.	.Sergio I. Palomino-resendiz1 , Frida A. Ortiz-martínez1 , Itzia V. Paramo-ortega1 , Juan M. González-lira1 , And Diego A. Flores-hernández.	Palomino-Resendiz et al. (2023) focus on optimizing control strategies for dual-axis solar tracking systems, emphasizing precision and adaptability to environmental changes. This contrasts with Hua et al. (2019), which explores system-wide integration of multiple trackers and storage for utility-scale PV plants, and Baouche et al. (2022), which emphasizes the design and simulation of standalone tracking systems. Together, these studies highlight unique approaches to enhancing PV efficiency, from control mechanisms to large-scale system optimization.

A n-Position Single Axis Solar Tracker Model for Optimized Energy Collection	de Sá Campos, M.H.; Tiba, C	De Sá Campos and Tiba (2021) propose the npTrack model, a simplified n-position single-axis tracker for optimized solar energy collection. Unlike Hua et al. (2019) and Palomino-Resendiz et al. (2023), which focus on multi-axis trackers and system-wide integration, this study emphasizes efficiency in single-axis designs. All approaches aim to enhance PV performance but differ in complexity and scope.
Experimental Investigation of Azimuth- and Sensor-Based Control Strategies for a PV Solar Tracking Application	Hariri, N.G.; AlMutawa, M.A.; Osman, I.S.; AlMadani, I.K.; Almahdi, A.M.; Ali, S.	Hariri et al. (2022) experimentally investigate azimuth- and sensor-based control strategies for solar tracking, focusing on real-time adaptability and efficiency. Compared to Hua et al. (2019), which emphasizes system-wide integration of trackers and storage, and Palomino-Resendiz et al. (2023), which explores dual-axis control strategies, this study targets practical implementation and control accuracy. Together, they offer diverse perspectives on enhancing solar tracking, from experimental strategies to large-scale optimization.
‘‘Introduction to renewable energy,’’ in Fundamentals and Applications of Renewable Energy	M. Kanoglu, Y. A. Çengel, and J. M. Cimbala,	Kanoglu et al. (2020) provide an introductory overview of renewable energy, focusing on fundamental principles and applications across various technologies. Unlike studies such as Hua et al. (2019) and Hariri et al. (2022), which delve into specific optimization and control strategies for solar tracking, this work emphasizes a broader theoretical understanding. Together, they bridge the gap between foundational knowledge and specialized advancements in renewable energy systems.

Control algorithms applied to active solar tracking systems	R. F. Fuentes-Morales, A. Diaz-Ponce, M. I. Peña-Cruz, P. M. Rodrigo, L. M. Valentín-Coronado, F. Martell-Chavez, and C. A. Pineda-Arellano	Fuentes-Morales et al. (2020) review control algorithms for active solar tracking systems, focusing on efficiency and adaptability. Unlike Hua et al. (2019) and Palomino-Resendiz et al. (2023), which explore system optimization and dual-axis control, this study emphasizes algorithmic approaches. All aim to improve solar energy efficiency, but through different methods.
Modeling of soiling losses in solar energy systems	M. Dehghan, S. Rashidi, and A. Waqas	Dehghan et al. (2022) focus on modeling soiling losses in solar energy systems, highlighting the impact of dirt and dust on energy efficiency. This contrasts with studies like Hua et al. (2019) and Fuentes-Morales et al. (2020), which optimize tracking systems and control algorithms for performance improvement. While all aim to enhance solar energy efficiency, Dehghan et al. specifically address external factors like soiling that affect system output.

4.CONCLUSION

Recent studies on solar energy systems emphasize the importance of advanced tracking and control mechanisms to optimize energy capture. These systems improve efficiency by adjusting the orientation of solar panels to ensure they are always aligned with the sun, maximizing energy generation throughout the day. A self-orienting system could significantly benefit from these principles, offering better sunlight exposure and increased overall efficiency. However, external factors such as soiling, or the accumulation of dirt and dust on solar panels, can significantly reduce the performance of solar systems. As highlighted in the literature, it is important to account for these losses by incorporating cleaning or self-maintenance features into the system. This would help maintain optimal energy output over time and reduce the impact of environmental factors on performance.

Finally, the integration of solar trackers with energy storage solutions, as discussed in various studies, is key to optimizing the efficiency of larger solar energy systems. For a self-orienting solar system, incorporating similar optimization techniques can ensure better coordination with other energy sources and storage, leading to a more reliable and efficient energy generation system overall.

5. STATEMENTS AND DECLARATIONS

Author contributions: Every author contributed to the research topics by conducting a thorough analysis of all relevant research papers through a comprehensive literature review. The tasks of data collection and analysis were executed by NS, NP, RR, and TS, under the supervision and guidance of LG and MV. The first draft of the manuscript was written by RR and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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