



# Optimizing Solar Energy Harvesting Through Sun Tracking Solar Panels

<sup>1</sup>Ira Sharma, <sup>2</sup>Khushi Gupta, <sup>3</sup>Isha Sharma, <sup>4</sup>Gaurav Yadav, <sup>5</sup>Shraddha Shrivastava  
<sup>1-4</sup>Research Scholar, <sup>5</sup>Professor

Department of Electronics and Communication Engineering,  
Lakshmi Narain College of Technology, Bhopal, India

**Abstract - The utilization of solar energy has emerged as a pivotal solution in addressing the escalating energy demands while curbing environmental degradation. In this paper, we delve into the optimization of solar energy harvesting through the implementation of sun tracking solar panels. Sun tracking systems dynamically orient solar panels to the sun's position, maximizing energy absorption throughout the day. We explore various strategies, technologies, and their impacts on enhancing solar energy efficiency. Additionally, economic feasibility and environmental benefits are discussed, showcasing the potential of sun tracking systems in revolutionizing renewable energy utilization.**

*Index Terms- Solar Energy, Sun Tracking, Solar Panels, Optimization, Renewable Energy*

## I. INTRODUCTION

The significance of solar energy in addressing global energy challenges cannot be overstated. As the world grapples with pressing issues such as climate change, dwindling fossil fuel reserves, and energy security concerns, the transition to renewable energy sources like solar power has become imperative. Solar energy is abundant, clean, and renewable, making it a sustainable alternative to fossil fuels. Unlike coal, oil, and natural gas, solar power generation produces no greenhouse gas emissions or air pollutants, thereby mitigating climate change and reducing harmful impacts on human health and the environment.

Solar energy offers countries greater energy independence by reducing reliance on imported fossil fuels, which are subject to price volatility and geopolitical tensions. By harnessing the sun's energy, nations can diversify their energy mix and enhance energy security, ensuring a stable and reliable supply of electricity.

The solar energy industry has emerged as a major driver of economic growth and job creation globally. Investments in solar infrastructure, manufacturing, and installation stimulate economic activity, attract capital investment, and foster innovation, leading to job creation and economic prosperity. Solar energy has the potential to improve energy access and alleviate energy poverty, particularly in rural and remote areas with limited or no access to grid electricity. Off-grid solar solutions, such as solar home systems and mini-grids, provide clean and affordable electricity to underserved communities, enabling socioeconomic development and improving quality of life. Solar energy plays a crucial role in mitigating climate change by reducing greenhouse gas emissions and transitioning to a low-carbon energy system.

By displacing fossil fuel-based electricity generation, solar power contributes to decarbonizing the economy and meeting emissions reduction targets outlined in international climate agreements such as the Paris Agreement.

*Objective of the paper- To provide a comprehensive understanding of the concept of sun tracking solar panels and their role in maximizing solar energy harvesting efficiency.*

## II. FUNDAMENTALS OF SOLAR TRACKING

The fundamentals of solar tracking encompass the mechanisms and principles behind the dynamic orientation of solar panels to optimize energy absorption from the sun. Solar tracking systems operate based on the movement of the sun across the sky, adjusting the angle and position of solar panels to maximize solar irradiance. There are two primary types of solar tracking systems: single-axis and dual-axis. Single-axis systems track the sun's movement along one axis, typically the east-west axis, while dual-axis systems track both the east-west and north-south axes, allowing for more precise alignment with the sun's position. These systems employ various tracking algorithms, sensors, and actuators to continuously monitor the sun's position and adjust the orientation of solar panels accordingly. By dynamically tracking the sun's path throughout the day, solar tracking systems can significantly increase energy yield compared to fixed solar panels, making them an essential technology for optimizing solar energy harvesting efficiency.

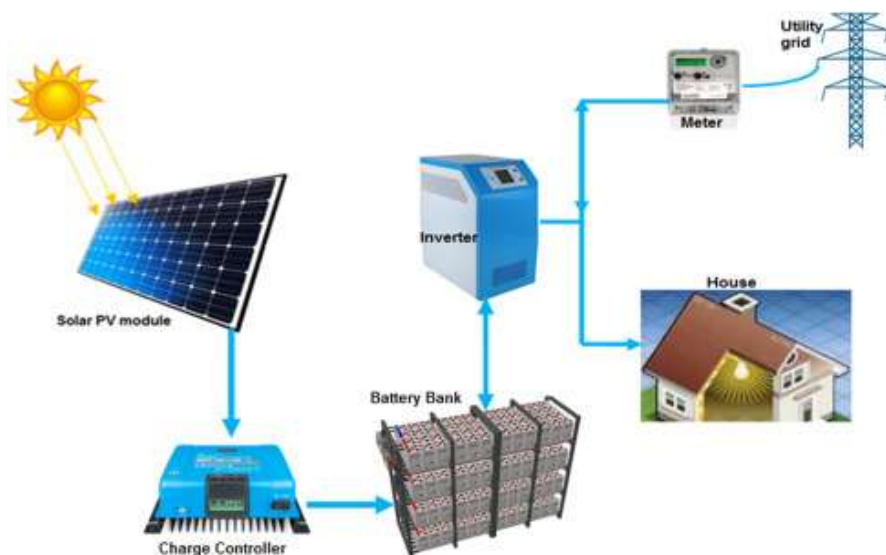


Fig 1. Solar Tracking Mechanism

## III. TECHNOLOGICAL INNOVATIONS IN SUN TRACKING SYSTEMS

Technological innovations in sun tracking systems have revolutionized the efficiency and effectiveness of solar energy harvesting. Advanced tracking algorithms, often incorporating real-time data from weather forecasts and solar position calculations, enable precise and dynamic adjustment of solar panel orientation. Integration of sophisticated sensors, such as light sensors, GPS receivers, and inertial measurement units (IMUs), enhances tracking accuracy and reliability by continuously monitoring environmental conditions and solar position. Actuators, such as servo motors or linear actuators, translate tracking commands into physical movements, ensuring optimal alignment with the sun's position.

Furthermore, the application of machine learning and artificial intelligence techniques has enabled predictive tracking algorithms that anticipate solar trajectory variations and optimize panel positioning accordingly. These technological advancements not only maximize energy yield by optimizing solar panel alignment but also improve system efficiency, reliability, and resilience to environmental factors, making sun tracking systems increasingly viable and effective solutions for solar energy harvesting optimization.

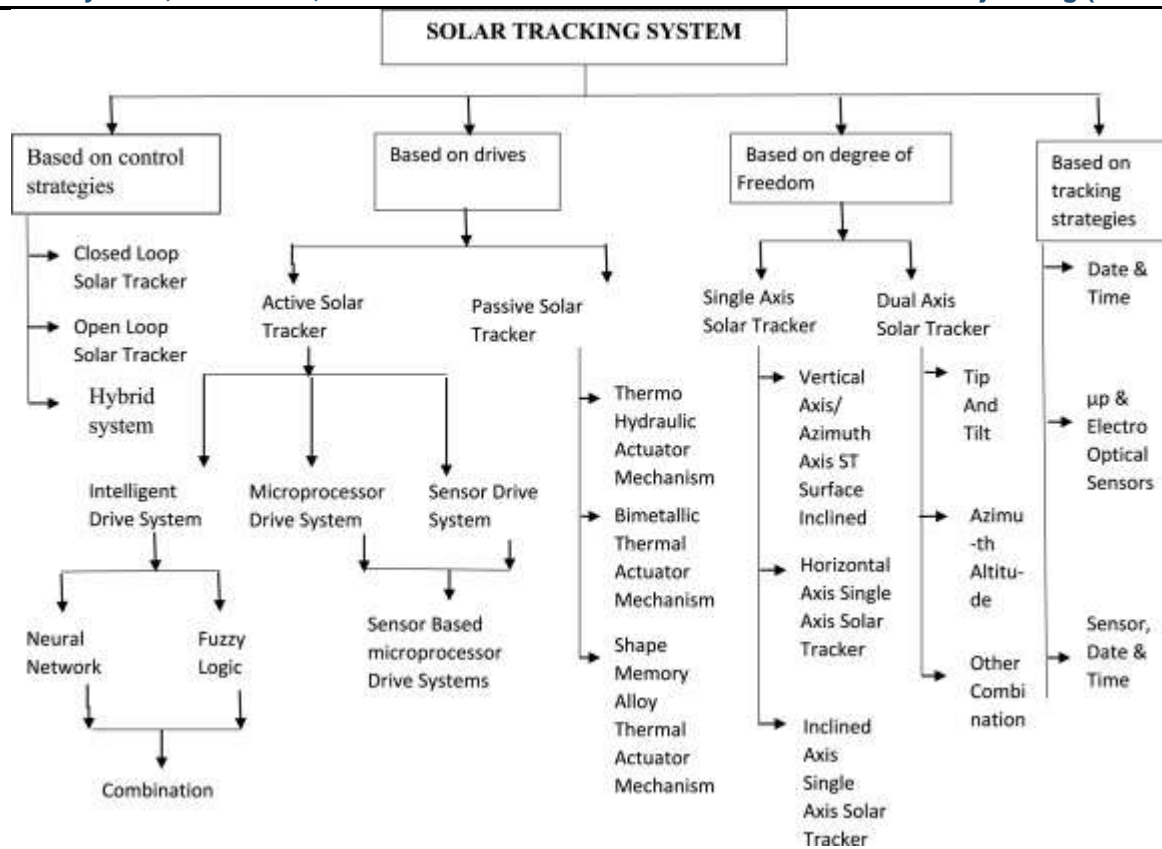


Fig 2. Solar Tracking System

#### IV. PERFORMANCE EVALUATION

The performance evaluation of sun tracking solar panels is crucial for assessing their efficacy in maximizing solar energy capture compared to fixed panels. Through comparative analysis of empirical data and case studies, the energy output of sun tracking systems is quantified under varying environmental and geographical conditions. Performance metrics such as energy yield per unit area, capacity factor, and operational uptime provide insights into the relative efficiency and reliability of sun tracking technology. Factors influencing performance, including weather conditions, tracking accuracy, and maintenance practices, are evaluated to understand their impact on energy generation. Despite the benefits, challenges such as mechanical wear, sensor calibration, and tracking algorithm optimization are recognized as potential limitations. By addressing these challenges and optimizing system performance, sun tracking solar panels demonstrate their potential to significantly enhance solar energy harvesting efficiency and contribute to a sustainable energy future.

The performance evaluation of sun tracking solar panels is a critical aspect of assessing their effectiveness in maximizing solar energy capture compared to fixed panels. Through comprehensive analysis, including empirical data collection and case studies, the actual energy output of sun tracking systems is measured across various environmental and geographical conditions. This evaluation allows for a direct comparison of the energy yield per unit area, capacity factor, and overall operational efficiency between sun tracking and fixed panels.

Moreover, by examining the performance metrics such as energy efficiency, tracking accuracy, and system uptime, a deeper understanding of the relative advantages and limitations of sun tracking technology can be gained. For instance, tracking accuracy plays a vital role in ensuring that solar panels are consistently aligned with the sun's position throughout the day, thereby maximizing energy capture. Additionally, system uptime and reliability are crucial factors in determining the overall effectiveness of sun tracking systems, as any downtime or maintenance issues can directly impact energy production. Despite the potential benefits of sun tracking technology, several challenges and limitations need to be addressed. Mechanical wear and tear, sensor calibration issues, and the optimization of tracking algorithms are among the key challenges faced by sun

tracking systems. These challenges can impact the long-term reliability and performance of the systems and require ongoing maintenance and optimization efforts. By analysing empirical data, case studies, and performance metrics, stakeholders can make informed decisions regarding the deployment and optimization of sun tracking technology, ultimately contributing to the transition towards a more sustainable and renewable energy future.



Fig 3. Solar Tracking System Prototype

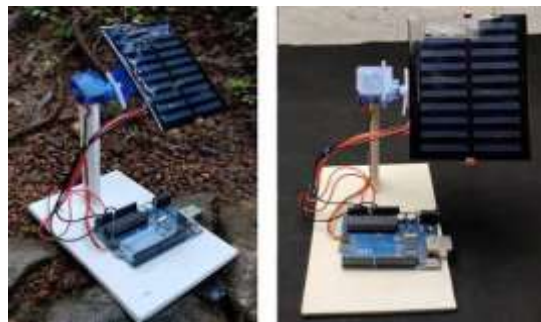


Fig 4. Solar Tracking Prototype Testing Model

## V. ECONOMIC VIABILITY AND COST-BENEFIT ANALYSIS

In the quest for sustainable energy sources, solar panels have emerged as a promising solution to reduce our dependence on fossil fuels and mitigate the impacts of climate change. While the environmental benefits of solar panels are evident, many potential adopters grapple with the question: Are solar panels worth the investment? This article explores the cost-benefit analysis of solar panels, exploring the economic considerations that can help individuals and businesses make informed decisions about harnessing solar energy.

### Initial Costs:

One of the primary barriers to adopting solar panels is the initial investment required for installation. The cost of solar panels has significantly decreased, thanks to technological advancements and increased production. However, the upfront expenses can still be substantial. Factors influencing the price include the size of the solar installation, the efficiency of the panels, and regional variations in installation costs. On the positive side, various financial incentives and rebates governments and utility companies provide can help offset the initial costs.



Fig 5. Solar Panel System



### Long-Term Savings:

The actual value of solar panels becomes apparent when assessing the long-term savings they offer on energy bills. Solar panels generate electricity from sunlight, which translates into reduced reliance on traditional grid power. Over time, this can lead to substantial savings on monthly utility bills. The amount of savings depends on factors such as the size of the solar installation, local energy prices, and the panels' efficiency. Additionally, some regions allow for net metering, enabling solar panel owners to sell excess electricity back to the grid. This contributes to a cleaner energy grid and provides an opportunity for additional income or credits on electricity bills.

### Environmental Benefits:

Beyond the economic considerations, solar panels offer undeniable environmental benefits. By harnessing the sun's power, solar energy production produces minimal greenhouse gas emissions compared to traditional energy sources. Reducing carbon footprint contributes to mitigating climate change and promoting a more sustainable future.

Furthermore, as solar technology advances, the environmental impact of manufacturing and disposing solar panels continues to decrease.

### Maintenance Costs:

An often-overlooked aspect of solar panels is their low maintenance requirements. Unlike traditional energy sources that involve ongoing fuel costs and frequent maintenance, solar panels generally have minimal upkeep needs. Routine inspections and occasional cleaning to remove dust or debris are usually sufficient to keep the system operating efficiently.

The longevity of solar panels also contributes to their economic viability. Most solar panels come with warranties ranging from 20 to 25 years, with many systems exceeding these expectations and continuing to generate power for several decades. This extended lifespan enhances the return on investment and makes solar panels a reliable long-term energy solution.



Fig 6. Solar Tracker

### Resale Value and Property Appreciation:

Installing solar panels can positively impact the resale value of a property. Many homebuyers are increasingly interested in energy-efficient homes equipped with renewable energy sources. Studies have shown that homes with solar panels sell faster and command higher prices in the real estate market. Therefore, the investment in solar panels is a valuable addition to a property, providing a potential return when selling the home.



Fig 7. Solar Panels Cohort

## VI. ENVIRONMENTAL IMPACT

The environmental impact of sun tracking solar panels extends beyond their direct contribution to renewable energy generation. By maximizing solar energy harvesting efficiency, these systems significantly reduce the reliance on fossil fuels for electricity generation, thus mitigating greenhouse gas emissions and air pollutants. The displacement of conventional energy sources with clean solar power helps combat climate change and its associated impacts, such as global warming, extreme weather events, and sea-level rise. Additionally, sun tracking systems minimize land use conflicts by optimizing energy yield per unit area, reducing the need for expansive land clearing for energy infrastructure development. Moreover, the deployment of solar tracking technology promotes sustainable land management practices and biodiversity conservation by preserving natural habitats and ecosystems. Overall, sun tracking solar panels play a crucial role in advancing environmental sustainability, facilitating the transition to a low-carbon economy, and fostering a cleaner, healthier planet for present and future generations.

## VII. CHALLENGES AND FUTURE DIRECTIONS

Solar power has been now considered as the fastest growing source of electricity generation. It is considered as a pollution free source of energy. In India, power distribution company BSES Yamuna has launched a pilot project to establish solar micro grids, which is emerging as one of the first Discoms in the country. These rooftop micro grids vary between 5 kW and 7 kW and have energy storage between 7 kWh and 10 kWh. It has been estimated that about 1245 l of diesel and 0.24 million units of electricity which costs up to Rs.20 Lakh can be saved on an annual basis by the solar micro grids while reducing 205 tonnes of CO<sub>2</sub> emission. This rooftop solar scheme aims to achieve total rooftop solar power generation capacity of 40,000 MW (Anon, 2019a). In Singapore it is expected that utility scale solar installations will reach 108 GW in 2019 and 119 GW in year 2020 (Anon, 2019b).

This area of research is growing very fast and hence many developments are taking place. Like the usage of Artificial Neural Networking in modeling different solar energy devices is leading to higher accuracy, higher generation capabilities and short computational time (Elsheikh and Haiou, 2019). Artificial neural network and fuzzy logics have owned the world today, these tools are being utilized in every field and so is here. Fuzzy logic controllers are being designed to obtain maximum power point tracking in a PV system (Farajdadian and Hassan Hosseini, 2019). Today cascade control algorithms are being used for high concentration photovoltaics which can achieve a sun tracking error of 1' (one minute) (Garrido and Díaz, 2016, Bahrami and Okoye, 2018, Bahrami et al., 2017, Bahrami et al., 2016). Scientists and researchers are working on the optimization of energy extraction and doing so, an approach based on deep learning, low cost and computer vision open hardware has been developed to curb limitations regarding cost and operational problems (Carballo et al., 2018, Okoye et al.,

2018). In spite of many developments, this field still faces some impediments and hence more work in this field regarding operational efficiency, cost effectiveness and feasibility demands attention.

## VIII. CONCLUSION

In conclusion, the deployment of sun tracking solar panels represents a pivotal advancement in the field of renewable energy technology, offering a potent solution for maximizing solar energy harvesting efficiency. Through dynamic orientation to the sun's position, these systems significantly enhance energy yield compared to fixed solar panels, thereby promoting the widespread adoption of solar energy as a sustainable and viable alternative to fossil fuels. Technological innovations such as advanced tracking algorithms, sensor integration, and machine learning algorithms have propelled the effectiveness and reliability of sun tracking systems, making them increasingly competitive and economically feasible. Furthermore, the environmental benefits of solar energy, including greenhouse gas emissions reduction, land use optimization, and biodiversity conservation, underscore the crucial role of sun tracking technology in mitigating climate change and advancing environmental sustainability. As we navigate the global energy transition towards a low-carbon future, the optimization of solar energy harvesting through sun tracking solar panels stands as a beacon of hope, driving us towards a cleaner, greener, and more resilient energy landscape for generations to come.

## IX. REFERENCES

- [1]. International Renewable Energy Agency (IRENA). (n.d.). Solar Energy: A Key Player in the Global Energy Transition.
- [2]. Baloch, J. A., Shaikh, N., Memon, A. A., & Memon, N. A. (2018). Design and Implementation of Solar Tracking System with Dual-Axis Using Arduino and LabVIEW. *\*International Journal of Scientific and Research Publications\**, 8(9), 265-269.
- [3]. Albadr, O., Alharbi, A., & Alkhalifah, F. (2016). Review of Solar Tracking System Technologies. *\*International Journal of Advanced Engineering Research and Science\**, 3(4), 162-169.
- [4]. Ramasamy, K., Arumugam, P. K., & Rajagopal, K. (2018). Economic Feasibility of Solar Tracking Systems: A Review. *\*International Journal of Renewable Energy Research\**, 8(1), 1-9.
- [5]. Athienitis, A., Santamouris, M., & Doukas, H. (2010). Environmental Impact Assessment of Solar Energy Systems: A Review of the Literature. *\*Renewable and Sustainable Energy Reviews\**, 14(1), 745-752.
- [6]. Fthenakis, V., Kim, H. C., & Alsema, E. (2008). Life Cycle Assessment of Solar Photovoltaic Technologies: Environmental Impacts and Improvement Potentials. *\*Solar Energy\**, 85(8), 1609-1628.
- [7]. National Renewable Energy Laboratory (NREL). (n.d.). Environmental Benefits of Solar Power.
- [8]. Böer, K. W. (Ed.). (2014). *\*Advances in Solar Energy: An Annual Review of Research and Development\**. Routledge.
- [9]. Karki, R., Phadke, A., & Srivastava, R. (2019). Technological Advances in Solar Energy: A Comprehensive Review. *\*Renewable and Sustainable Energy Reviews\**, 105, 457-468.
- [10]. Anand, S. R., Pandey, P. C., & Mukherjee, M. (2021). Machine Learning Applications in Solar Energy: A Review. *\*Renewable and Sustainable Energy Reviews\**, 138, 110558.
- [11]. Mekhilef, S., Saidur, R., & Safari, A. (2012). Comparative study of different solar tracking systems. *\*Renewable and Sustainable Energy Reviews\**, 16(2), 1080-1090.
- [12]. Zeng, P., Zhang, J., Chen, B., Cao, L., & Chen, C. (2017). Review on modeling and control of solar photovoltaic arrays. *\*Renewable and Sustainable Energy Reviews\**, 68, 1114-1131.

- [13]. Belmili, H., Arab, A. H., & Rekioua, D. (2017). A review of maximum power point tracking techniques of PV system for uniform insolation and partial shading condition. *\*Renewable and Sustainable Energy Reviews\**, 76, 608-624.
- [14]. Giaouris, D., & Papadopoulos, A. M. (2015). Solar tracking systems: A review. *\*Energy Conversion and Management\**, 91, 228-244.
- [15]. Ebrahimkhani, S., & Ghoneim, A. A. (2020). Solar tracking systems and their energy management algorithms: A comprehensive review. *\*Sustainable Energy Technologies and Assessments\**, 41, 100775.
- [16]. Kaldellis, J. K., & Zafirakis, D. (2011). Innovative solar tracking systems in Greece: A review. *\*Renewable and Sustainable Energy Reviews\**, 15(8), 3803-3813.
- [17]. Pandey, A., & Tyagi, V. V. (2016). Solar tracking systems: A review. *\*Renewable and Sustainable Energy Reviews\**, 57, 39-59.
- [18]. Liu, Z., Wu, W., & Yang, H. (2016). Review on recent advances in solar trackers. *\*Renewable and Sustainable Energy Reviews\**, 56, 644-660.
- [19]. Vyas, A. P., Satsangi, P. S., & Pandey, G. N. (2017). Solar tracking techniques: A review. *\*Renewable and Sustainable Energy Reviews\**, 68, 862-884.
- [20]. Hussain, I., Javed, U., Afzal, M., Khan, I., & Alam, M. (2017). A comprehensive review on solar tracking systems. *\*Renewable and Sustainable Energy Reviews\**, 70, 952-967.