International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 11 | Nov - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

A REVIEW OF Solar Panel Efficiency: The Influence of Installation Angles and Design

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Abstract - This contrasts performance under different conditions of air, how these solar cell technologies can optimize solar energy conversion efficiency in specific locations. The intention of this information on the best applications is to consider cost, efficiency, and environmental considerations. These findings of the present study will contribute to ongoing efforts at making solar energy use better and more efficient, thereby accelerating the transition towards a greener energy future. All these technologies, including monocrystalline, polycrystalline, thin-film, and Passivated Emitter and Rear Cell (PERC) solar cells, have been developed to convert the energy received from the sun efficiently. As far as conversion efficiency is concerned, every technology has its plus points and negative points, especially in different climatic situations. These monocrystalline solar cells are known for their great endurance and efficiency in functioning remarkably well, even in hot and sunny conditions. Even though not as efficient as the monocrystalline counterparts, polycrystalline solar cells are still affordable and work satisfactorily in temperate climates. With their flexibility and low weight, thin-film solar cells work well with low light conditions and may be applied in many applications, such as building-integrated photovoltaics. They have greater capacity for absorbing light and lesser electron.

Keywords**:** monocrystalline, polycrystalline, thin-film, and PERC (Passivated Emitter and Rear Cell).

1.INTRODUCTION

Now, there is a solar energy source that has become a major beacon in the search for clean and renewable sources of energy. By capturing the radiations from the sun, the solar cells convert into electricity, thus storing clean and inexhaustible energy. Among the several advancements conducted on efforts to improve efficiency in the conversion of solar energy, four main types of crystals, namely monocrystalline, polycrystalline, thin-film, and Passivated Emitter and Rear Cell (PERC) solar cells, are the most interesting ones. Each of these technologies has certain unique features and has its merits for certain types of applications and conditions. Monocrystalline solar cells, of course, boast great efficiency and remarkable longevity, as they are done very carefully from a single continuous crystal structure.

This uniform structure allows for better electron flow; the latter, again, enables conversion of energy at significantly greater rates. These solar cells perform quite well even under direct sunlight and in high-temperature conditions, and therefore are particularly suited for applications in those areas where sunlight is strongest throughout the year. Also, since their inherent strength lies in being tough and highly effective, monocrystalline-based solar cells prove to be an excellent choice in maximizing solar energy collection under such climatic conditions. Polycrystalline cells are made of several silicon crystals so they are less efficient but cheaper and relatively easier to manufacture. They work reasonably well in temperate climates, and because they optimize both cost and efficiency, this is the most commonly used type for residential and commercial applications. Thin-film solar cells are thin, flexible, and lightweight. Photovoltaic cells are those that involve depositing one or more photovoltaic materials on a substrate. The cells emit their radiations in poor light conditions and can be applied on different structures like building integrated photovoltaics. Their flexibility makes them suitable for cities and areas where sunlight is not constant. PERC solar cells have resulted in improved efficiency of regular crystalline silicon cells with a passivation layer on the back side; this layer reduces electron recombination and increases light absorption. Therefore, it offers an apparent superiority in terms of efficiency and especially performance under high-temperature as well as low-light conditions, making this technology extremely promising across diverse geographical locations. Understanding the performance and aptness of such photovoltaic technologies under diverse atmospheric conditions is important in maximizing deployment and energy yield.

The challenges and opportunities brought about by solar energy conversion will be different from region to region. Choosing an appropriate technology significantly influences the efficiency and cost-effectiveness of solar installations. The paper explores the comparative advantages of monocrystalline, polycrystalline, thin-film and PERC solar cells, which will clarify their potential to improve the efficiency of energy conversion in different geographical locations. It is going to provide detailed analysis regarding their strengths and weaknesses, which will be beneficial for a clearer understanding of how each technology is put to application and also its performance in different environmental conditions. This study will contribute to ongoing efforts for improvement in the production of energy through the sun. The results of this utilization and establish its support towards a transition to a much more sustainable energy future. By taking advantage of the different respective properties of each kind of solar cell technology, we will be able to optimize solar energy systems to meet specific needs by region.

Angle of installation-in relation to the sun-is one of the key factors affecting efficiency in solar panels. Angles of installation can be altered to what is simply referred to as arcs-shaped configurations, with the hope of getting a maximum absorption of sunlight all day long for more efficient cells. This can be particularly useful for the different forms of solar technologies, including monocrystalline, polycrystalline, thin film, and PERC (Passivated Emitter and Rear Cell) solar cells. Monocrystalline cells which are highly efficient, can take full advantage of their energy capture ability through precise angles while the polycrystalline as well as the thin film cells will also realize performance improvements from such optimizations though to a lesser degree. The design, which may further use PERC technology in improving the efficiency of solar cells through passivation at the rear, can be used to increase the energy yield in general. Awareness of the arcs and shapes contributing to the angles at which light is absorbed by the solar energy system indicates the potential to fine-tune systems for greater efficiency and toward a general increase in renewable energy solutions.

2. LITERATURE REVIEW

In "Hidayat" A Critical Analysis of solar Charging for performance of monocrystalline, polycrystalline, and graphene-coated monocrystalline solar panels in terms of power production and efficiency. The growth in the renewable source of energy is rapid with the assistance of solar panels, which contributes significantly towards power generation. Polycrystalline panels are more sensitive; otherwise, they can capture energy under low light conditions [1]. “Ali Hafiz Muhammad” the Six 40W photovoltaic modules (three monocrystalline and three polycrystalline) were exposed to sunlight at three different inclination angles. Performance ratio, module efficiency, fill factor were calculated for photovoltaic module at different inclination angles and results presented. PV modules at 33.74° tilt angle received high solar radiation and showed high output power.

In the work of “Machín” et al., [3] the advancement in photovoltaic cell development is presented underlined by the fact that such progress is highly related to the materials employed in the construction. The instability, scalability, and environmental questions pertinent and exposed in this paper give a full overview of the current situation and foreseeable perspectives. Of the materials used for photovoltaic cells, silicon remains the leader; this is because it has a very good efficiency as well as availability and durability. Silicon solar cells take the largest share in the solar energy market, and thus, the move to improve the production of solar energy is taken through them. The continually creating of new materials by silicon-based technologies significantly contributes toward improving overall performance and reliability of photovoltaic systems.

Continuing on this note, “Kang H”. et al. [4] discuss the types of crystalline silicon that are used in solar cells. These classify silicon into two main types: monocrystalline and polycrystalline. Silicon that is monocrystalline is of single continuous crystal structure where there are no grain boundaries because the composition is homogeneous.[3] The structure allows alignment of all silicon atoms uniformly across the material, greatly enhancing the rate of conversion of solar energy. On the contrary, silicon comprises several small silicon crystals due to its polycrystalline nature. Although, generally, polycrystalline panels are less efficient than their monocrystalline counterparts, they are more economical for large solar installations. But in both categories of crystalline silicon, development in solar technology is underway and optimized in design day after day to become even better in efficiency under different environmental conditions.

With further development in the fields of solar technology, optimization methods similar to those used by” Hidayanti et al”. [5] involve increasing integration of photovoltaics into wider real situations. In this experiment, particular interest is focused on the inclination angle of the solar panel because capturing maximum energy amounts becomes a serious matter in geographically confined regions like Indonesia during certain climatic periods. The adaptive design solar cells with changing angles of panels depending on the day time leads to an increased absorption of solar energy. This adaptive approach boosts efficiency and addresses some issues related to solar power use during long dry seasons and scarce sun conditions during parts of the year in other areas. The captured energy is stored in batteries, hence providing renewable power for lighting at night. This study relates to the research by “Aris Sutiyadi” et al. [6], who probe into the possibility of using semi-flexible monocrystalline solar panels in arch structures. This study shows the arch-shaped arrangement of solar panels is more potent in receiving solar power compared to flat setups, and there is therefore scope for more intensified usage in dynamic areas such as mobile charging of the farm robots. This advancement underlines the increase in wider interests in optimizing solar power generations through unique panel configurational designs so that the future of solar energy will rely heavily on such adaptable efficient designs. "Ayşegül Taşçıoğlu" et al. [7] continues to contribute evidence that innovative studies would play a role, in the development of solar energy systems in "Turkey": an analysis of the efficiency and performance of both polycrystalline and monocrystalline solar panels. The works have unveiled a certain positive correlation between solar radiation and the output of solar panels while, at the same time, having ambient temperature as impact factor. Relations with solar intensity, temperature, and energy output are established by statistics analysis within the study.

More documentation of how performances of solar panels might be influenced by temperature and solar intensity was further contributed by research articles by Eteruddin et al. [8] and Lesmana et al. [9]. Eteruddin et al. in the experiment revealed that lowering the temperature also lowers the output voltage of solar panels, therefore emphasizing that temperature must be controlled properly for maximum utilization. Meanwhile, Lesmana et al. observed that higher solar intensity is inversely proportional to increased voltage output but lower current, a trend that might significantly influence the total electricity generated and the efficiency of the solar panels. Thus, these results indicate the potential impact that environmental factors may have on the performance of solar energy systems and may be valuable for further optimisation.

In addition to environmental factors, Tarifa et al. [11] focus on the optimization of the design of solar cells by simulating the temperature distribution in monocrystalline solar cells. Their work examines the extent to which spectral absorptivity, thickness of layer, and thermal conductivity will contribute toward heat dissipation inside silicon layers. From their experiments, they suggest to have thinner glass layers and introducing thermally conducting materials such as SiC or BN in order to improve the global performance of the solar panel. This fits broadly into the direction of increasing the material and configuration of solar cells to be more efficient and compatible with most operating conditions. In aggregate, these studies will provide a divergent view of the challenges and opportunities that exist in solar energy technology, spanning material innovations through environmental optimizations, which forms a pathway for continued success in this renewable resource source

3. METHODOLOGY:

solar cells, photovoltaic or PV cells for that matter; they're really quite important parts of the technology that converts solar energy into usable electricity. There are several important ingredients contained in solar cells that work in tandem in order to capture sunlight and convert it into electrical energy before delivering the power for a broad array of applications. Some of these key ingredients are semiconductor material, antireflection coating, contacts of metal, P-N junction, glass cover, encapsulant, backsheet, frame, junction box, diodes, and conductive wiring. Each of these elements assumes a very important role in the efficiency, durability, and overall performance of the solar cell. The cell is primarily based on a semiconductor material, typically silicon but possibly in one of several different forms, including purely crystalline, polycrystalline, or amorphous- and absorbs sunlight to generate an electrical current through the photovoltaic effect. The extra layers include the antireflection coating and the protective cover of glass to make the cell surface bigger in absorbing light but still covered from all external factors. Other parts include metal contacts, along with the junction box which deals with and guides electricity flowing from the solar cell.

3.1 Solar Cell Components:

3.1.1 Semiconductor Material (Photovoltaic Material)*:*

The semiconductor material of the solar cell operates on the solar illumination and converts it into electricity. Among various semiconductor materials, silicon is utilized the most and is further categorized into three types, namely monocrystalline, polycrystalline, and amorphous. Thin-film materials such as cadmium telluride and copper indium gallium selenide are other semiconductor materials used for manufacturing solar cells. Since sunlight excites the electrons in these semiconductor materials, which brings about photovoltaic effect wherein the material begins to emit electric current, this conversion efficiency is a function of the quality and properties of the semiconductor implemented in the solar cell.:

*3.1.2 Cell (*Antireflection Coating*):*

Coating is applied on the surface of the semiconductor material that could evolve an antireflection mechanism to enhance the efficiency of the solar cell. In fact, such a coating minimizes the amount of reflection sunlight off the solar cell surface, thus allowing greater quantities of light to enter the semiconductor. Such a process is highly significant because the more sunlight the solar cell captures, the more energy it would produce. It maximally maximizes the absorption of light that would be converted into electricity, bringing about a great increase in overall efficiency of the solar cell.

3.1.3MetalContacts:

The metal contacts within the solar cell are responsible for making it possible for the electrical current generated by the semiconductor to emerge out of the cell and into the external circuit. These contacts comprise of the front contact-whose material is usually in the form of fine metal lines etched or printed on the surface of the cell-and the back contact-solid metal layer-found at the bottom of the cell. Designing the front contact, it should allow the passing of much sunlight to the semiconductor and as such it shouldn't disturb the absorption of light much. The P-N junction between the P-type and N-type materials forms the required electric field for the separation of excited electrons from the holes that would enable current flow, hence contributing to the production of the electrical energy.

3.1.4GlassCover:

The glass cover will serve as a protective layer of the solar cell that protects fragile material from damage as a result of physical damage, environmental exposure, and elements of the weather. This sheet allows light to pass through and helps provide strength and durability to the solar cell assembly. The cover is normally made of tempered glass, with the addition of anti-reflective properties; this assists in enhancing the ability of the solar cell to capture light and makes its total efficiency in terms of energy better.

3.1.5 Encapsulant and Backsheet

An encapsulant material, commonly EVA, below the glass cover protects and stabilizes the inner cells of the panel against the external environment. Encapsulant maintains the photovoltaic cells firmly in place and ensures moisture protection, while it also helps in maintaining the integrity of the cells over time. The other component is the backsheet of the solar panel. This is a polymer or plastic used for protecting the rear side of the solar panel against electrical insulation and environmental exposures such as water and dirt. With the encapsulant, these ensure long-term reliability and durability for the solar cell.

3.1.6 Frame and Junction Box

The frame provides a structural support for the solar panel. It securely holds the components in position and allows mounting on surfaces, such as rooftops. Normally, it is made of aluminum, that although durable, is at the same time lightweight. It does provide stiffness to the panel so that it should not bend under outer influences during operation. The junction box is an important feature that is used for accommodating the electrical interconnects between the photovoltaic cells and the exterior electrical circuit. In the junction box are present the critical components such as the bypass diodes which do not allow waste of energy through bypassing of shaded areas of the panel by allowing current flow in these bypassed parts and blocking diodes that ensure that once the panel is not generating the electrical output current will not feed back to the panel.

3.1.7 Conductive Wiring

Finally, the electricity generated by the solar cells is transmitted through conductive wiring to a system outside the panel for immediate usage or storage. The main wires employed are copper because they exhibit excellent electrical conductivity; they allow maximum transfer of the current while losing minimal energy. The connected wiring can transform the solar panel to AC electricity, which it will send to the inverter or battery storage system to be transferred to homes or businesses

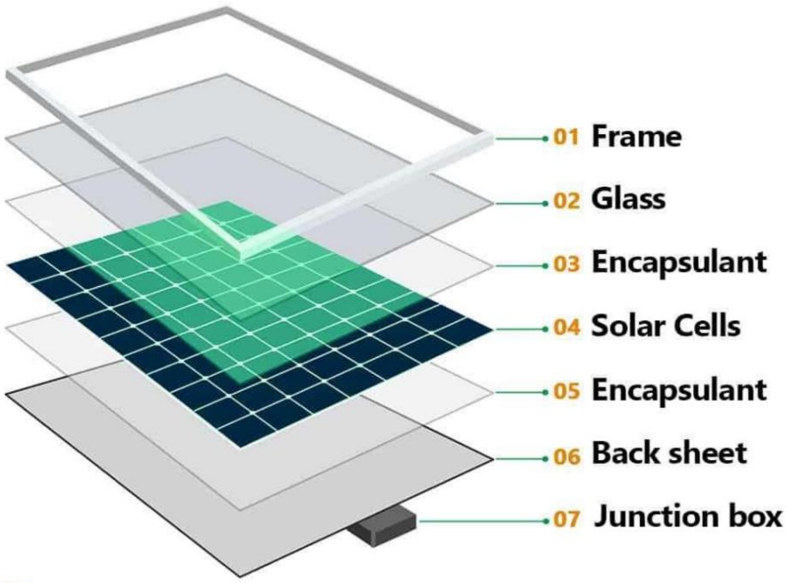


Figure:1

3.2: Monocrystalline Silicon Solar Cells

Monocrystalline silicon solar cells are made by using the Czochralski process, in which silicon is melted and then cooled slowly to form one very large single crystal. The thick slabs that are obtained are then cut into extremely thin wafers that make up the body of these cells.

3.2.1High Efficiency:
The cells are highly efficient, whose average efficiency range falls in the range of around 18-22%. This is because the relative lesser grain boundaries in the silicon structure allow better movement of electrons.

3.2.2Longevity:
These cells have a long duration of operation life and have been found to last up to between 25 to 30 years without much degradation, thus being quite reliable for lasting use. Aesthetic

3.2.3Attractiveness:
Monocrystalline cells are aesthetically attractive, and due to their uniform, dark color as well as a smooth surface, they are highly used for rooftop domestic installations.
Disadvantages Cost Due to the increased energy consumption and higher complexity involved in producing monocrystalline cells, these tend to be more expensive to produce than other types such as polycrystalline cells.

3.2.4Material Waste: Mostly due to sawing through large silicon ingots to produce thin wafers, material loss is highly significant.as stopping not only wastes energy but also increases travel time.

3.3Polycrystalline Silicon Solar Cells

This type of solar cells is done from silicon crystals melted and permitted to cool in a mold where they form many smaller crystals. It is less complex and inexpensive than compared to monocrystalline solar cells; less elaborate to produce.

3.3.1Main Advantages: The process of making polycrystalline cells is much simpler, and therefore, it is an expensive preference over that for monocrystalline cells.

3.3.2Reasonable Efficiency: Though not as efficient as monocrystalline cells, their performance is still reasonable enough, often between 15% and 18% in efficiency rates.

3.3.3Less Waste: There's less waste on production as compared to monocrystalline cells.

3.3.4Lower Efficiency: Due to the grain structure of silicon, polycrystalline creates more boundaries, hindering the flow of electrons and lowing the efficiency level.

3.4Thin-Film Solar Cells

Thin-film solar cells are constructed by the deposition of one or more layers of photovoltaic material onto a substrate, where such a substrate may be glass, or plastic. The most widely used materials in thin-film solar technologies include cadmium telluride (CdTe), copper indium gallium selenide (CIGS), and amorphous silicon (a-Si).

3.4.1Low Cost: Thin-film cells are relatively inexpensive to build as they use reduced raw materials inputs and are rather easy to produce in volume.

3.4.2Flexibility: Some thin-film solar cells are flexible and may be used in applications where rigid solar panels cannot be used.

3.4.3Aesthetic Integration: Thin-film cells offer a smooth, uniform surface, which makes them ideal for architectural integration inasmuch as they can easily integrate with building designs.

3.4.4Lesser Efficiency: The efficiency of thin-film solar cells is lesser compared to the crystalline silicon cell and the efficiencies range between 10% to 12%.

3.4.5Space Requirements: A much larger space is occupied by the thin-film cells for producing the same amount of power as that produced by crystalline silicon cells because the thin-film cells have lesser efficiency than that of crystalline silicon cells.

3.5 PERC (Passivated Emitter and Rear Cell Technology)

PERC technology is the upgraded version of monocrystalline solar cells, in which a passivation layer is applied to the rear side of the cell. The recombination of electrons gets removed and also protects better absorption of light inside it. It allows overall efficiency enhancement.
Important Advantages:

3.5.1High Efficiency: PERC cells have an extra passivation layer that improves its efficiency up to 22% because of reduction loss from the electron recombination process and improvement in light trapping. PERC cells perform better under low light conditions as compared to non-PERC cells, thus it can be utilized very conveniently in overcast conditions, dawn, or dusk.

3.5.2Lower Heat Loss: The back passivation layer also helps in reducing heat loss. This is very crucial in the realization of peak efficiency, especially during high-temperature application.

3.5.3Increased Cost: There is an added cost of building the passivation layer and additional processing steps in the manufacturing process compared to the traditional monocrystalline cells.

3.5.4High complexity production: the existence of a more complex production process of the PERC cells suggests that application in some markets is limited due to the high complexity in the production process

Table1: cost efficiency

Technology	Efficiency	Cost	Lifespan
Monocrystalline	18%-22%	High	25-30 years
Polycrystalline	15%-18%	Moderate	20-25 years
Thin-Film	10%-12%	Low	15-20 years
PERC	20%-22%	High	25-30 years

3.6 the Effect of Setting of Arches on Semi-Soft Monocrystalline Solar Panels

that changes in the setting of arches have on semi-flexible monocrystalline solar panels. Specifically, this paper discusses how differences in configurations can maximize efficiency and power output. The paper focuses on concave and convex arches and the influences of the flat setting on the panels. Data has been collected in Palembang, Indonesia in August 2019 at the dry season and January 2020 at the rainy season to compare seasonal effects of weather on the results.
3.6.1Test Configurations: this carried out experiments on three configurations of arches:
3.6.2Concave Setting: In this configuration, the solar panel is concaved inwards facing the sky.
3.6.3Convex Setting: In this setup, the solar panel is convexed outwards in forming a convex shape.
3.6.4Plane Setup: In this setup, the solar panel is flat with no curvature. Performance Results:
3.6.5Concave Setup: The concave setup produced the highest performance with an average power output of 20.27 Watts for dry season measurements and has an efficiency of 13.14%. This is probably due to that fact this setup was optimized to garner more sunlight energy based on the angle of incidence.

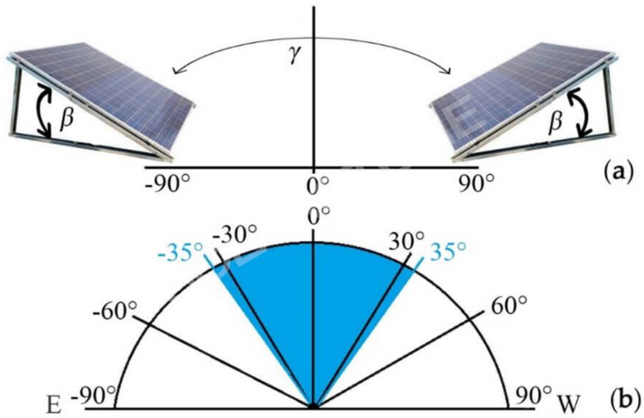
3.6.6Convex Configuration: In this configuration, a power output of 13.26 Watts was obtained at 9.30% efficiency, which was just a little better than the case of the flat panel configuration but still quite low compared to the concave one. So outward curvature would probably increase sunlight absorption relative to the flat panel configuration but obviously was never close to reaching the concentration capabilities that were achieved with the concave shape.

3.6.7Plane Geometry: This geometry was the worst performing one, with a power output of 10.24 Watts at an efficiency of 9.71%. Though the efficiency of this geometry is better than that of the convex geometry, its power output is the lowest. This again proves that high collection of solar energy is possible only if there exists curvature.
3.6.8Implications

The results showed that, in reality, the arc form does have a remarkable enhancement factor on the performance of monocrystalline semi-flexible solar panels, especially the concave one. Moreover, it is highly efficient for harvesting light in dry seasons when the solar irradiance is significantly more significant. Such results can be applied in many fields, such as mobile dynamic robot operations for agriculture. These require flexible, efficient solar panels that can be adapted to off-grid energy harvesting. Taking into account this consideration, concave design may offer some advantages to these devices in such areas with limited access or in rural regions.

Figure:2

3.6.9Further Applications:



This study also indicates that semi-flexible monocrystalline solar panels hold promise for various new arrangements other than the typical static setup. This might mean new renewable energy applications in which the stiffness of solar panels could be a problem. This would, for example, be the case for mobile or portable devices such as a solar-powered robot in an agricultural environment that will demand longer operation in the field and hence the higher efficiency of the concave configuration. Such results can, therefore, be used to design some sort of solar energy systems in off-grid applications, and the countryside particularly faces limited access to the electrical grid with the necessity to acquire efficient solar solutions.

3.7Effect of Angle on Photovoltaic Performance:
Photovoltaic (PV) modules are increasingly being installed off-grid, especially in rural areas far from the traditional electrical grids. In these applications, the proper orientation and mounting of the solar panels enhance the energy yield while ensuring effective working of the system. Of all the factors that influence the installation angle of PV modules, optimal exposure to sunlight is probably one of the most significant when the equipment is primarily intended for sunlight exposure. This section of the study tests various tilt angles impacting photovoltaic modules, primarily at three different inclination angles: 0°, 33.74°, and 90°. It reviews how tilt and the changing seasons affect the production of solar panels under various meteorological conditions.

3.7.1 0° Angle Tilt (Horizontal): In this type of setup, the solar modules lie flat parallel to the ground. It is very prevalent in huge solar farms or as an installation preference in cases where fixed installations are preferred. This setup requires minimum infrastructure. However, the efficiency of this setup depends upon the time of year and latitudes as they do not optimize on suns absorption at any particular time in the day.

33.74° Tilt It is the preferred angle of many for maximum exposure of sunlight to be realized in most places. The aspect is determined using the latitude of a site to install, hence better energy capture is found. This design enables higher absorption of sunlight at peak sunlight hours.

3.7.2 90° Tilt (Vertical): In this mounting position, panels are set at 90° angle from the ground level. It faces the sun directly. This is less efficient in most locations because it may minimize or cut exposure of the panel to the sunlight during most parts of the day. It's better used where the panels follow the sun or in special places around the sun paths; it generally calls for a more complex arrangement.

It further focuses on the role of latitude and time of year d in determining the optimum tilt angle for solar panels. The tilt angle β must be appropriately chosen to maximize the exposure of sunlight to each location. This tilt can be adjusted to make photovoltaic modules peak their operations at every point across the year

4. RESULTS & DISCUSSIONS:

4.1 Wireless Charging Infrastructure for Cities Systems:

The concentrated on various solar panel settings and particularly semi-flexible monocrystalline types where alterations in tilt angle impacts on efficiency and power outputs as well as the influence of the season were evaluated. The study made use of three different arch settings and tilts for the leading results to benefit photovoltaic system optimization.

4.2. Effects of Arch Settings on Performance of Solar Panels

The three different arch configurations used were: concave, convex, and flat. In this study, there were two different seasonal periods being tested: the dry season, August 2019 and the rainy season, January 2020. The findings revealed that the configuration and seasonal conditions significantly change the performance of the solar panels and their power generation.

4.3Concave Configuration

This was the highest performing setup for both seasons, even more so for the dry season. In a high value of solar irradiance recorded in August 2019, the concave configuration realized an average power output of 20.27 Watts with an efficiency level of 13.14%. The optimum angle of incidence during the day maximized the amount of sunlight absorption into the set configuration and captured more solar energy. Indeed, the results confirm that concave arches have a significant impact in maximizing energy harvesting when there is high solar irradiance as during the dry period.

4.4Convex Configuration: In the convex configuration, it managed to outdo the flat configuration. However, it performed worse than the concave configuration. During the dry season, the convex panel generated 13.26 Watts and achieved an efficiency of 9.30%. This would mean that despite the ability to produce more absorptions of sunlight than the flat panel, the curvaceous shape did not compare to the concave. The convex configuration may have captured better captures of the sun during a certain time in the day but lacked effectiveness just as the concave configuration had.

Flat (Plane) Configuration: The power output was the lowest here, at 10.24 Watts and an efficiency of 9.71%. While a bit more efficient than the convex setup, the flat configuration was the least effective overall, justifying the fact that curvature of panels does make a great difference in an improvement in the capture of solar energy.

4.5Seasonal Variation Effect

This comparison underlined that the seasonal change significantly influenced solar panel performance: dry season versus the rainy season. The overall good performance of all configurations was more so evident with the concave panel, whose performance significantly improved in the dry season due to high solar irradiance. However, the rainy season saw an adverse shift in power output and efficiency for all configurations because of the difficulties of cloud cover and sunlight with much lower intensity. Yet, the relative performance difference among the several configurations of arch is steady and indicates that maximum sunlight should be absorbed is an important requirement to have for systems operating in regions of large seasonal changes in irradiation.

4.6. Angle of Tilt Effect on PV Performance

The performance of the photovoltaic was observed in how it acted with three different tilt angles: 0°, 33.74°, and 90°. Three tilt setups were chosen to determine how each angle of tilt will affect the amount of sunlight the panel will capture.

0° Angle Tilt Horizontal: The horizontal orientation of 0° angle produced the poorest results. While this configuration is common in many large solar farms or low-maintenance setups, that configuration wasn't designed with a focus on light absorption specific to seasonal changes in those environments. This would lead to very inefficient energy capture for most of the year, significantly dependent upon time of year and sun angle.

33.74° Tilt: The 33.74° tilt, which corresponds to the latitude of the installation site, showed the best overall performance.

This tilt optimally balanced solar exposure throughout the year, capturing more sunlight during peak hours, particularly in the dry season. It highlighted the importance of tilt angle optimization in enhancing solar power generation.

90° Tilt (Vertical): The amount of overall energy captured at this tilt setting was the poorest. Although it was highly exposed to sunlight, a relatively narrow field of exposure meant the sunlight was absorbed by it for only a relatively small portion of the day. Panels can work pretty well in certain conditions with certain types of solar tracking systems and in particular locations with odd sun paths, but, generally, this tilt is not a good fit for energy generation in typical configurations.

4.7 Broader Implications and Future Applications

The results of this work open good prospects for the implementation of semi-rigid polycrystalline solar cells in off-grid and mobile applications, such as in remote regions, or even standalone photovoltaic systems, in some agricultural sectors. The best performance achieved with the concave configuration might be a better solution for environments with variable solar irradiance or wherever flexibility and efficiency are key.

This will focus on optimum panel curvature and angles as aspects of optimizing overall performance in photovoltaic systems. For mobile or portables for solar solutions-for example, agricultural or rural applications-a flexible solar panel that could change curvature and tilt angles may prove very useful and efficient at maximizing energy output.

Concave semi-flexible panels are especially well-suited for dynamic applications in high-efficiency changing environmental conditions. It would tend to open up the entire field of solar flexible technologies further, specifically on the following needs: off-grid rural locations, mobile energy solutions, or innovative applications of architecture, where rigid panels may not be recommended.

5. Conclusions:

In this comprehensive exploration of Wireless Power Transfer (WPT) systems for charging electric vehicles (EVs), we've delved into various critical aspects. Our journey into the realm of WPT systems has unveiled the multifaceted landscape of EV charging, emphasizing the significance of WPT as a viable solution to mitigate the limitations of electric vehicles, particularly the pressing issue of limited driving range. As the world embraces the imperative of reducing energy consumption and emissions, electric vehicles are at the forefront of this transition, promising a cleaner and greener mode of transportation. However, the restricted range of electric vehicles has been a significant obstacle to their widespread adoption. It is in this context that WPT technology emerges as a beacon of hope, enabling on-the-go charging and thereby alleviating "range anxiety." The core components of WPT systems, particularly Researchers have paid close attention to the coil structure and compensation topology. Our research has highlighted the importance of improving transfer efficiency, misalignment tolerance, and component stress. Traditional coil materials, such as copper, have been supplemented with newer materials, such as High-Temperature Superconductors (HTS), which provide different advantages.

In conclusion, this research marks a significant contribution to the field of Electric Vehicle Wireless Power Transfer, with a particular focus on dynamic systems. As the world continues its shift towards electricity as a primary source of energy in transportation, the promise of reduced CO2 emissions and a cleaner environment is tangible. Yet, there remain challenges on the path to making electric vehicles and WPT systems a practical and sustainable reality. The commitment to adhering to electromagnetic emission limits and, indeed, pushing for even stricter standards for vehicular applications showcases our unwavering dedication to safety and sustainability. Since the introduction of the In 2016, we saw the seeds of a binding standard for stationary chargers in the form of a voluntary guideline for the design and testing of EV WPT chargers. beginning to take root. The journey towards standards for dynamic wireless charging is underway, marking a new chapter in the story of electric vehicle charging technology. As the globe shifts to electric vehicles, the promise of lowering CO2 emissions at the point of application looks intriguing. We must, however, consider the broader ramifications of energy distribution networks. Stationary wireless chargers behave similarly to traditional conductive chargers, with peak demand typically happening in the evening.

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