PV SOLAR TOWER

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ABSTRACT

The PV Solar Tower is an innovative arrangement of silicon solar cells designed to maximize the conversion of sunlight into electricity. Unlike traditional solar panel systems that are typically placed on rooftops or installed across open land at a certain degree, our PV Solar Tower introduces a zig-zag and ladder-like vertical configuration of bifacial solar panels. This unique structural design gives more efficient use of space and enhances exposure to sunlight throughout the day. One of the main feature of this system is its ability to produce up to 20% more power output compared to conventional solar cell arrangements. The greater performance is given by a combination of structure and the use of bifacial solar panels, which are capable of harvesting sunlight from both the front and back surfaces. The ladder-like arrangement of solar panels allows the reflected sunlight to fall on the opposite panel where it can again generate electricity, significantly increasing energy absorption and overall output. This approach of maximizing reflection and multi-surface exposure differentiates the PV Solar Tower from traditional solar arrangement. Additionally, this design requires less land area, making it ideal for space-constrained environments. Its applications can range from powering street lighting systems to supporting industrial energy needs, particularly in urban areas where land use efficiency is critical. By combining vertical design, bifacial panel technology, and enhanced sunlight capture through reflection, the PV Solar Tower represents a forward-thinking solution for improving solar energy efficiency in a variety of real-world applications

Keyword - *Solar Tower, Bifacial Solar Panels , Vertical Configuration , Zig-zag Structure , Ladder-like Arrangement , Solar Energy Efficiency , Sunlight Reflection , Multi-surface Exposure , Energy Absorption , Power Output , Land Use Efficiency , Space-constrained Environments*

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1. INTRODUCTION

In today's world, daily life is heavily dependent on electrical energy, due to this the requirement of the energy generation is rapidly increasing and also with the increase in generation the pollution caused by generation also increasing, Globally coal, followed by gas, is the largest source of electricity production, hydropower and nuclear make the largest contribution now a days. Due to this rapid increase in pollution the environment is very much effected.to reduce this pollution the world needs to shift to renewable energy resources, like hydroelectric power plant(water), wind power plant(wind), tidal power plant(ocean tides), solar power plant(solar panels), etc.

However, each of these renewable sources requires specific geographic conditions for efficient energy production—such as dams for hydroelectricity, coastlines for tidal power, and windy regions for wind farms. Among them, solar power stands out as the most versatile and mobile renewable energy source, capable of being installed in various locations. Still, it comes with notable drawbacks, such as large area requirements and lower energy conversion efficiency. Traditional solar panels only absorb about ~30% of sunlight, while the remaining ~70% of solar irradiation is reflected or re-emitted back into the atmosphere. This not only limits efficiency but, on a larger scale—like in solar farms—can cause localized atmospheric temperature changes, creating environmental instability in that area.

The major problem here is with the ~70% sun irradiation which is emitted back into the atmosphere which should be reduced. While considering a solar power plant the ~70% amount of re-emission of radiation may cause a change in the atmospheric temperatures in that specific area, which leads to an unstable environment in the specified area. There are several problems caused due to the re-emission of radiation like increase in greenhouse effect which leads to increase in global warming around the world. Hence the solution we came up with is The PV Solar Tower which uses the re-emitted radiation and decreases its after-effects significantly.

1.1 BACKGROUND

French physicist Edmund Becquerel is widely known as the "father of solar energy" for discovering the photovoltaic effect in 1839.The photovoltaic effect— a process that produces a voltage or electric current when exposed to light or radiant energy. The first solar panels were installed on a rooftop in New York City in 1883 by inventor Charles Fritts. Since 1883 till today, it's been nearly 150 years but still there is no change in the installation methods of solar panels. To shift the energy generation to non-renewable to renewable resources and to overcome those drawbacks, the latest technology should be used like Bifacial solar panels. There are 4 types of solar panels, 1. Monocrystalline Solar Panels (Mono-Si) which have ~18% to 24% efficiency with a lifespan of 25+ years and made up of single crystal structure of silicon., 2. Polycrystalline Solar Panels (Poly-Si) which have ~13% to 17% efficiency with a lifespan of 20+years and made up of multiple silicon crystals melted together, 3. Thin-Film Solar Panels which have ~10% to 13% efficiency with a lifespan of 10 to 20 years and made up of Made from a variety of materials like CdTe, CIGS, or amorphous silicon, 4. Bifacial Solar Panels. Bifacial solar panels generate solar power from both direct sunlight and reflected light (albedo), which means they are essentially double-sided panels, where front side have ~ 18% to 24% efficiency and back side adds up with ~ 5% to 20% more output efficiency depending on installation.

There is a big difference from the more common monocrystalline solar panels, which generate power only from the sun-facing side. Bifacial solar is not new. The first solar cells produced by Bell Laboratories in 1954 were bifacial. They are made of transparent glass, which lets some of the light pass through and reflect off of the surface below. To further increase the amount of light passing through, they use glass instead of metal frames or grid lines to hold them in place. The glass is tempered glass reduce scratching. Otherwise, they perform exactly as other PV panels work, using crystalline silicon to absorb sunlight and convert it into an electric current. The backside of a bifacial solar panel usually shares its circuitry with the front side, thus increasing the efficiency without increasing the circuitry and occupies less area. And because of using transparent glass the re-emitted ~70% sun's radiation is utilized. For the maximum energy generation and optimal area utilization this Bifacial panels are arranged in a zic-zac stack arrangement. This zic-zac stack arrangement of bifacial panels is named as "PV Solar Tower".

1.WORKING OF A SOLAR PANEL

A solar panel is an electrical device that converts sunlight into usable electrical energy through the photovoltaic (PV) effect. At the core of a solar panel are photovoltaic cells, commonly called solar cells, which are made from materials that release free electrons when exposed to light. These materials are typically semiconductors substances that have electrical conductivity between conductors and insulators. The most widely used semiconductor for solar panels is silicon (Si) due to its abundant availability, stability, and high efficiency. Other materials like gallium arsenide (GaAs) or even alkali metals such as sodium (Na), potassium (K), and lithium (Li) have applications in specific or experimental types of PV technologies.

Solar cells function by using two differently doped types of silicon: N-type and P-type. These two layers' form what's known as a PN junction, which is essential for generating electricity. The N-type silicon, placed at the top of the solar cell, is doped with an element like phosphorus that adds extra electrons, making it negatively charged. This layer is extremely thin around 0.3 micrometres (μm) to allow sunlight to pass through easily. Beneath it lies the P-type silicon, doped with an element such as boron to create "holes" or areas that can accept electrons, giving it a positive charge. This P-type layer is much thicker typically 300 micrometres to maximize light absorption and enhance charge separation.

When sunlight, which consists of energy packets called photons, hits the solar cell, the energy knocks electrons loose from atoms in the N-type layer. These freed electrons move toward the P-type layer, generating an electric current (DC – Direct Current). To capture and direct this current, metal fingers are printed on the top of the N-type layer. These fingers connect to larger conductive paths called bus bars, which collect the electricity and serve as the negative terminal of the cell. On the bottom side of the P-type layer, a copper back contact serves as the positive terminal, completing the circuit.

A single solar cell generates about ~0.5 volts (V) of electricity. To reach practical voltage and current levels for use in homes, businesses, or devices, many cells are connected together. Connecting cells in series increases voltage, while parallel connections increase the current. These interconnected cells form a solar module, and multiple modules combined form a solar panel. Solar panels are made up of several layers to ensure performance, safety, and durability. The central layer consists of the interconnected solar cells. These cells are encapsulated using EVA (Ethylene Vinyl Acetate) sheeting on both the front and back. EVA protects the delicate cells from environmental threats like moisture, physical shock, and vibration. On top of this structure, a layer of tempered glass acts as both a protective shield and an anti-reflective coating. It allows sunlight to pass through efficiently while minimizing reflection, thus increasing the panel's overall efficiency. At the bottom of the panel, a back sheet usually made from a durable polymer insulates and protects the electrical components from humidity and physical damage.

The electrical connections between cells are typically made with copper strips, which link the top (negative) of one cell to the bottom (positive) of the next, creating a complete electrical path. By carefully designing these layers and connections, manufacturers create efficient and reliable panels capable of producing solar electricity over 25 years or more. That says, a solar panel is a precisely engineered device made from semiconductor-based solar cells arranged in layers. Through the PV effect, it captures sunlight and converts it into direct current electricity. These panels are central to the shift toward renewable energy, offering clean, sustainable power for a wide range of applications from small electronics to entire buildings.

2. PV SOLAR TOWER

A PV Solar Tower is the construction or a systematic arrangement of solar panels in a zic-zac stack arrangement, such that there will be angular reflection of sun light on the panels. Here the panels are Bifacial, it means they have the PV Cells on both the sides of the panel, so it can absorb the solar radiation from both the sides from front side and back side, so such that there is low solar radiation wastage and helps to generate more power at same location, in same space occupied by the traditional solar panels. There Bifacial panels are placed one by one in one upon one structure like they are inter connected to each other. All these inter connected Bifacial panels are placed with a particular angels based up on the location of installation so there is angular reflection of sun radiation between those panels which helps to absorb maximum radiation so such that less amount of solar radiation is wasted.

These Bifacial panels and angular reflection leads to generate more power at the same time in less space or area when compared to the area occupied by the traditional way of installing the PV Solar Panels, because there are double number of panels then they are visible as they are Bifacial and their back side also generated electrical energy as the front side generates and for this the back side requires solar radiation ,so with the help of this angular reflection the solar radiation (Light) is uniformly distributed .

Fig -2-The Prototype Developed (PV SOLAR TOWER)

2.1 WIDE ANGLE LIGHT COLLECTION

Conventional solar cells become dramatically less efficient if the sun is not shining within a narrow range of incident angles. Sunlight that hits the cell outside of this range will be reflected off, and the reduced light energy causes the cell's internal efficiency to drop. Because of a unique wide angle design, our solar cell can maintain its high efficiency over a wider range of incident angles. It can capture more light in the morning and evening hours, as well as in the winter months when the sun is not directly overhead. The key to this breakthrough is a special design on the cell surface that collects sunlight over a wide range of angles. As the sun moves across the sky, throughout the day or year, the cell will be able to maintain its high conversion efficiency, as if the sun was directly above it. The angular reflection of sun light or sun radiation approximately happens as shown in the figure 1.

Fig -2: The approximate angular reflection of sunlight and solar panel arrangement in PV Solar Tower

2.2 CALCULATION OF A SOLAR PANEL EFFICIENCY

The efficiency of a module is given in terms of maximum power or peak power that module can generate for a given input solar radiation. For a given input power Pin, the value of the output power is directly determined by the value of the module's efficiency and module Area. So, the module with higher efficiency values will produce more power as efficiency is directly proportional to maximum power. As module efficiency is higher generation will be higher. The efficiency of a solar module (denoted as η or "n") indicates how effectively it converts input solar radiation (sunlight) into electrical power output.

It is calculated using the formula:

$\eta = P_{max}/(P_{in} \times Area)$

Where:

- η (efficiency) = Percentage of sunlight converted to electricity
- Pmax = Maximum power output of the module (in watts, W)
- Pin = Incident solar power per unit area (irradiance), typically in W/m²
- Area = Area of the module (in square meters, m²)

Example:

If a panel has:

- Pmax = 300 W
- Area = 1.6 m²
- Pin (standard solar irradiance) = 1000 W/m²

$\eta = 300/(1000 \times 1.6) = 300/1600$

Hence Total Efficiency, η = 0.1875 or 18.75%

3. Comparative Performance Evaluation

Here we are going to compare the performance of the PV SOLAR TOWER with respect to the different direction approaches used in the field according to the consumer demand

PV Solar Tower facing these directions

- EAST&WEST
- NORTH &SOUTH
- NORTH-EAST&SOUTH-WEST
- NORTH-WEST&SOUTH-EAST

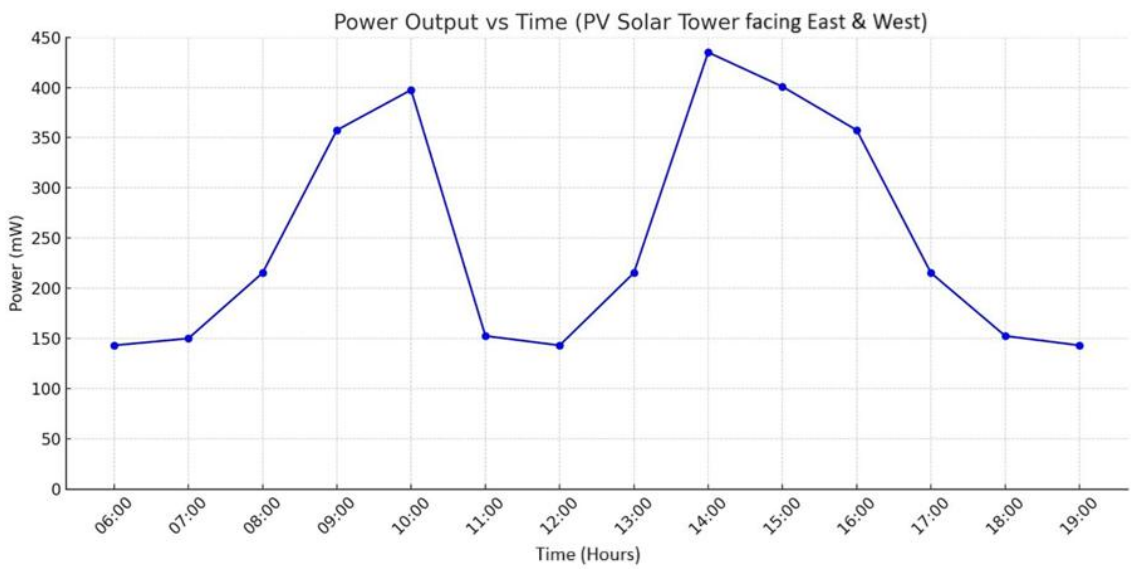

Fig -3: The output readings of the solar panels when they are installed facing East & West

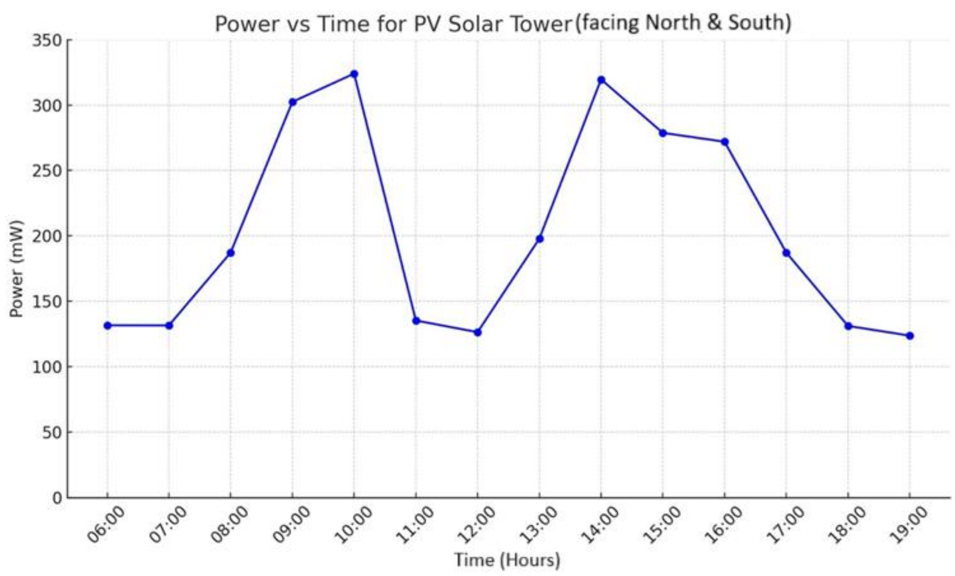

Fig -4: The output readings of the solar panels when they are installed facing North & South

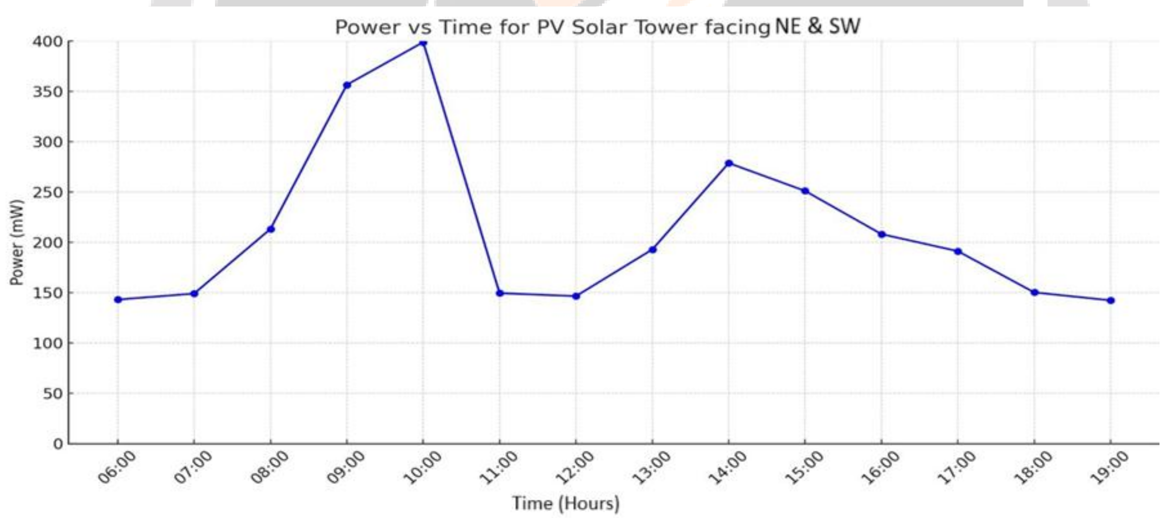

Fig -5: The output readings of the solar panels when they are installed facing North-East & South-West

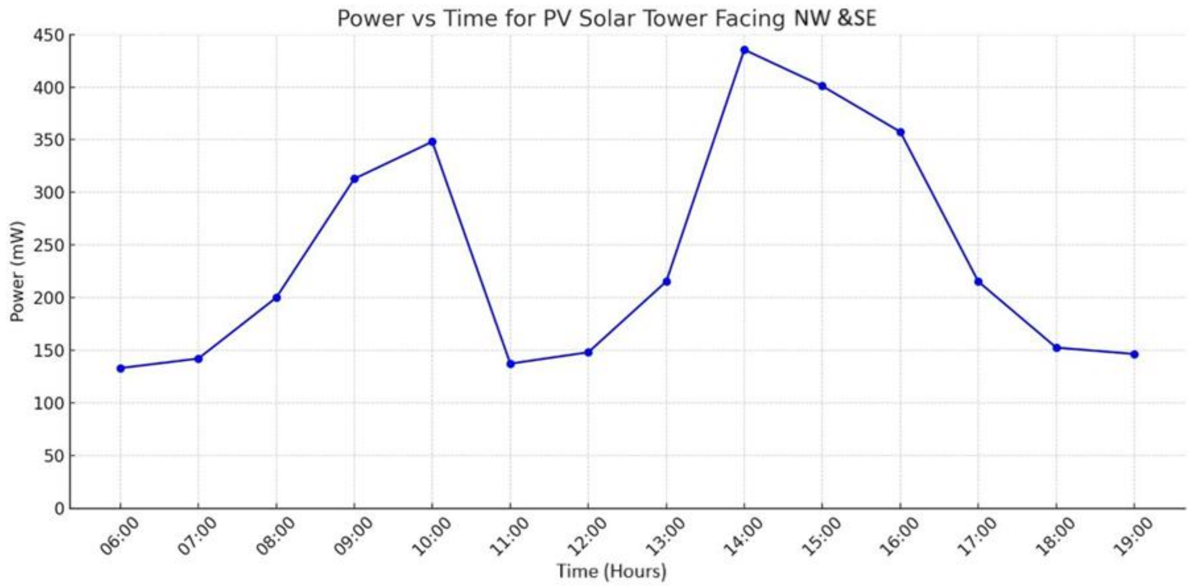

Fig -6: The output readings of the solar panels when they are installed facing South-East & North-West

4. CONCLUSION

The exploration of PV Solar Tower has demonstrated the revolutionary possibilities of using solar energy in a scalable, vertical, and space-efficient manner. PV solar towers are a practical and creative solution to the growing global demand for clean, renewable energy, especially in metropolitan areas and those with a shortage of available land. Up till now, we have looked at the fundamental design ideas, developments in technology, integration difficulties, and practical uses of PV solar towers. PV solar towers are a combination of sustainability and engineering, from the PV materials that turn sunshine into power to the creative architecture that makes vertical solar arrays both useful and aesthetically pleasing. These systems not only contribute to reducing carbon emissions but also redefine how we envision power generation in the 21st century. They offer benefits in grid independence, urban energy resilience, and long-term cost savings, all while minimizing the ecological footprint. PV solar towers, like all new technologies, have drawbacks, though, from expensive upfront prices to complicated maintenance and regulatory barriers. For widespread adoption, it will be crucial to address these problems by ongoing research, encouraging laws, and interdisciplinary cooperation.

PV solar towers, in summary, represent more than just vertical solar panels; they are a symbol of innovation that demonstrates how sustainable energy can be effectively and tastefully incorporated into the built environment. As we look to the future, embracing such technologies is not just an option but a necessity for a cleaner, greener planet.

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