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# Comparative Study between Ground Mount and Roof Mount Solar Tracker Structure

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**Abstract:** Everyday living relies heavily on electrical energy. In order to generate electrical energy, fossil-based fuels must be used in a variety of ways. Fossil fuels are running exhausted in the modern world. This necessitates the consideration of an alternate supply, and sustainable power resources are the best available option. Hydroelectric, wind, solar, and other renewable energy sources are all examples of sustainable power resources. Using the sun's power to generate electrical energy can be considered a major source of power since it is a renewable energy source and can contribute to large-scale power production.

Solar energy has a significant role in renewable energy resources, and it is a tremendous source of energy. Through photovoltaic cells, the sun's power can be used to generate electrical energy. Non-polluting photovoltaic cells; cost-effectiveness of the solar sector; minimal maintenance expenses; a reliable source; and no moving parts.

In publish paper we are analysing the ground mount tracker and roof mount tracker for worst wind load and other load combination. We are analysing the wind effect on ground mount and roof mount trackers. Analysis depends on the various factors like Tilt angles, Surrounding structures, Shape of building, Height of surrounding structures and pitch distance etc. This research will help future generation to understand the Ground mount and roof mount tracker effect on the ground and roof slab. They need further investigation for different condition like irregularities of buildings, Material, type of roof, Location and inclination of PV panel etc.

**Keywords:** Solar energy; Solar tracker; Photovoltaic cell; Cost-effective, Staad-Pro etc.

## Introduction

As one of the most ambitious targets for renewable power, India has achieved significant progress in recent years (Fig.1), but industry analysts say that the country is on track to miss its target of constructing 175 gigawatts (GW) of renewable energy capacity by 2022.

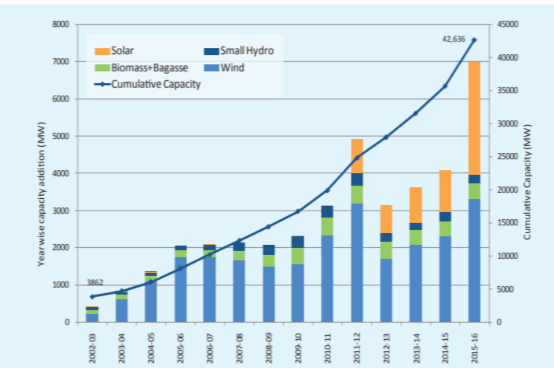


**Fig. 1: Growth of renewable energy generation capacity in past (2002-16)**

As the world's third-largest producer of greenhouse emissions, the renewable energy sector is critical to India's efforts to combat climate change as well as minimize its reliance on fossil fuels. Even as India struggles to meet the 175 GW objective, Prime Minister Narendra Modi has already set his sights on boosting the installed capacity of renewable energy to 450 GW by 2030, which is more than double the current capacity. But the introduction of a medium-term national aim in the 2015 union budget statement has drawn the most attention. The ambitious 175 GW renewable energy target that India has set for itself has now been officially adopted by the country's government.

In this paper, our aim is to safely allow the sun-tracking motion of the structure at designed wind loads and achieve optimum design solutions for both ground mount and rooftop module mounting structures at both 0-degree and 45-degree tilt. For that modeling all the different types of combinations of structure in STAAD Pro. Also, analyze and understand the behavior of reacting forces developed in the structure under various load combinations. Then design the structure for strength and stability against various forces. To iterate a structural model for providing an optimal practical solution.

The focus of this present research is to study the effectiveness of the sun tracking system of the solar panel with respect to different aspects such as deflection measurement, bending stress measurement, shear stress measurement, stability against overturning, etc. The project contains two case studies, which are as follows.

a) Analysis & design is of 0-degree & 45-degree ground mount type solar with tracker system.

b) Analysis & design of 0-degree & 45-degree rooftop mount type solar (G+4) with tracker system.

Analysis and design are aided by computed software based on the STAAD Pro.

## Literature

The wind load analysis of solar farms using computational fluid dynamics has been carried out by P. Surendra Reddy, G. Kiran Kumar, and A. Venkataravindra & K. P. V. Krishna Varma [1]. Ovidiu BOGDAN and Dan CREŢU have investigated the wind load effect on the power plants by comparing the design codes as well as tunnel tests [2].

Dr. G. Genc Celik and O. Celik have done the case study of the structural collapse of solar panel mounting systems in south-eastern Turkey. Research on the effects of extreme weather conditions on design parameters like the local and site-specific investigation is studied [3].

Sun 2 Car" Project of Mahindra Reva Ltd is designed for the worst wind Analysis case. The impact of wind forces on solar Panel Supporting Structure and stability for a different location and same structure shall be used all over India. It is easy for installation, dismantalation, and transportation. The study of this paper is carried by Alex Mathew, B. Biju, Neel Mathews and Vamsi Pathapadu"[4].

Hassan Irtaza as well as Ashish Agarwal have investigated "CFD implementation of Turbulent Wind effect on a Ground-Mounted Solar Photovoltaic Panels array". [5]

The study of mounting rail spacers for the solar panel is examined and they can be used rear to the module and over the mounting structure. It may be used for the installation of new structures and retrofit structures to existing systems. Andrew Anselmo, Andrew M. Gabor, as well as Rob Janoch Solar Panel Mounting Rail Spacers for Longer Life" IEEE's annual meeting will be held in 2019. [6].

Two-column mount structure with rigid base is studied in detail with structural analysis. Also, optimization of fixed PV mount is studied By Wen Feng.China International Conference on Electricity Distribution, 2016[7].

## Methodology

For civil design engineers, it is a challenging job to determine the structural feasibility of rooftop-mounted solar. There are three stages to choose the underlying attainability of the existing structure:

Determine the capacity of the current roof framing. Checking of Load redistribution, Adding new elements, and Reinforcing existing individual floor members.

Select the racking & connection framework for a mounting component like ballasted, fully attached, or hybrid, etc.

Check the practicability of the rooftop floor to accommodate the PV solar system.

In this project, we are working to install the solar tracker on the roof and as the height increase then it will be largely influenced by wind loads. The major constraint in the design of a solar roof mounting Structure to have enough stability is to resist various types of loads such as lateral forces, buckling, uplift pressure, to control lateral drift and displacement of the structure. The purpose of the damping system in Solar Module Mounting Structures has been widely used to decrease seismic as well as wind load consequences causing major damage to the MMS. Besides sun tracking system is installed to obtain greater efficiency.

In spite of the fact that Ground mount and rooftop mount frameworks are utilized for comparative reasons, their impact shows inconsistent varieties and conduct. This moving part has its own vibrations, thus making the structure more susceptible. Thus more material and its arrangement are required. This increased material puts a direct economic impact. If the production of electricity increases, considerably with the installation of a tracking system then only this installation is reasonable. Thus, to carry out the extra material required for its overall safety analysis and design are performed. Both systems have significance in structural performance. Therefore, there is a need to do a comparative study of analysis between ground solar and roof-mounted tracker.

### *A. Roof Mounted Solar Panels*

The most typical method of installation is a roof-mounted. These panels are held in place by solar racking put directly onto the roof. If your roof is made of materials like metal or rubber, panels are a great option for covering it.

Following are points to be considered if installing a rooftop:

a) Your roof's age as well as condition

b) The effect solar energy could have on your roof warranty

### *B. Ground Mounted Solar Panels*

These solar panels can be attached to a rack structure that is grounded by metal posts, such as steel beams. It is possible to use ground mounts in a parking lot or in an open location.

People who lack useful roof space or just prefer not to have solar panels fixed to their rooftops can use ground mounts, which can be erected anywhere conditions are optimal for solar power generation.

Following are points to be considered when installing a ground mount:

a) The plot of land's long-term plan

b) Your property's terrain

**Table 1. Roof Mount Solar System Pros and Con**

| Roof Mount Solar System | | |
|---|---|---|
| **Sr. No.** | **Pros** | **Cons** |
| 1 | Roof mounts take advantage of areas that might otherwise go unused. | Shingle roofing necessitates penetration of the roof. |
| 2 | A roof-mounted system's installation costs are often cheaper than those of a ground-mounted system. | You might have to remove and reinstall panels for roof repairs or to install a new roof |
| 3 | Doesn't consume the land that could be used for other purposes | Before installation, a new roof may be necessary. |
| 4 | Unauthorized visitors are prevented from gaining access to the panels. | Additional support mechanisms may be needed in some circumstances because of this weight. |
| 5 | Certain elements can be protected from the roof's exposure by the use of panels. | Some argue that solar panels detract from a home's curb appeal. |

**Table 2. Ground Mount Solar System Pros and Cons**

| Ground Mount Solar System | | |
|---|---|---|
| **Sr. No.** | **Pros** | **Cons** |
| **1** | Ground mounts can be erected in any orientation and in practically any location to maximize energy production. | Rocks or other particles ejected from a mower or other equipment have a higher potential of causing inadvertent damage. |
| **2** | They can be set up in a variety of angles. | Takes up large areas |

| | | |
|---|---|---|
| **3** | The system may be accessed quickly and easily for maintenance. | In most cases, the cost of installation is more expensive. |
| **4** | Carports could be constructed in existing parking lots, providing shade, illumination, and protection for parked cars. | Will likely be required to install a fence adding cost to the project |
| **5** | Protecting the roof from certain elements can be done with the use of panels. | Multiple posts and limited clearance are likely to necessitate a mowing. |

### *C. Calculation of loads on the structure*

The structural capacity, as well as integrity of structures, must be sufficient to safely and efficiently resist all loads but also effects of load combinations that may be reasonably expected. Loads utilized in the design of the buildings, structures, as well as foundations must meet the requirements of the governing IS rules and specifications. Wind load, live load, Dead load as well as seismic load must all be included in the design loads at a minimum. SI units will be employed for design as well as drawing purposes.

**Dead Loads (DL)**

Dead load comprises of the dead weight of solar PV module & the structures self-weight will be determined using the following unit weights: Dead loads include the weight of all structural and architectural components and plus hung loads, other permanently applied external loads & equipment dead load.

**Live load (LL)**

The building's "live loads" are those loads that are generated by the building's intended usage and occupants.

**Wind load (WL)**

Air in motion in relation to the earth's surface is what we refer to as "wind." Because of the earth's rotation and variations in terrestrial radiation, the wind is mostly caused by the air passing over the planet. The convection currents are primarily driven by radiation effects, which can move either upwards or downwards.

High-velocity wind usually blows horizontally to the ground. Horizontal winds are usually always called 'winds' and vertical winds are always called 'winds' because the vertical components of atmospheric motion are quite modest. In meteorological observatories, anemometers or anemographs are often mounted at heights ranging from 10 to 30 meters above the ground, are used to measure wind speeds. Basic wind speed is found out Vb which is provided in IS 875 part three.

Design Wind Speed $V_z = V_b \times k_1 \times k_2 \times k_3 \times k_4$

Where, $k_1$ = Probability Factor, $k_2$ = Terrain Factor, $k_3$ = Topography Factor and $k_4$ = Importance Factor

Calculations of wind coefficients on the roof:

6 of IS-875 Part III is used to estimate wind load on the roof.

Pressure coefficients equivalent to roof angle 0 shall be used.

For ease of calculations max suction of -0.8 is considered for the calculation of wind load.

**Earthquake load (EL)**

Classifications of the country's four seismic zones are used to measure seismic forces.

$$V = AW \quad (1)$$

Where,

A = the horizontal seismic coefficient can be designed for a structure

W = A building's seismic weight

A structure's design horizontal seismic coefficient is A is given by

$A = (ZISa)/ 2Rg$

Z is the zone factor in Table 2 of IS 1893:2016 (part 1) and I is the importance factor

## I. MODELING & ANALYSIS

### *A. Analysis of Ground Mount Solar Structure*

To analyze the ground mount solar structure we consider the following technical details in Table 3.

Strength combinations for Ground Mounting Structure shall be as per IS: 800-1984.

1.0*DL + 1.0*LL and 1.0*DL +1.0*(WL or EQ)

**Table 3. Ground Mount Input and Load Calculation**

| | | | |
|---|---|---|---|
| **Structure Size:** | 43.8 m x 5 m | **Purlin Cantilever Length:** | 0.4 m |
| **No. of Panel:** | 2 x 40 | **Grade of concrete:** | M25 |
| **The gap between Two Panels:** | 20 mm | **Grade of steel:** | Fe-500 & Fe-415 |
| **Wind Speed:** | 47 & 20 m/s | **Concrete Density:** | 25 kN/m3 |
| **Orientation:** | Portrait | **The density of masonry infill:** | 20 kN/m3 |
| **Panel Size:** | 992 mm x 1956 mm | **Clear Distance From Ground Level:** | 500 mm |
| **Panel Load:** | 22.5 kg/m3 | **Module dead load in running meter:** | 0.23 kN/m |

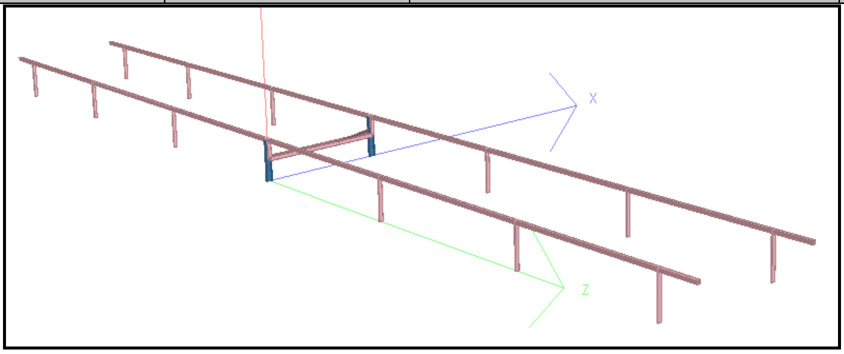

**Fig. 2: 3D view of ground-mount solar structure**

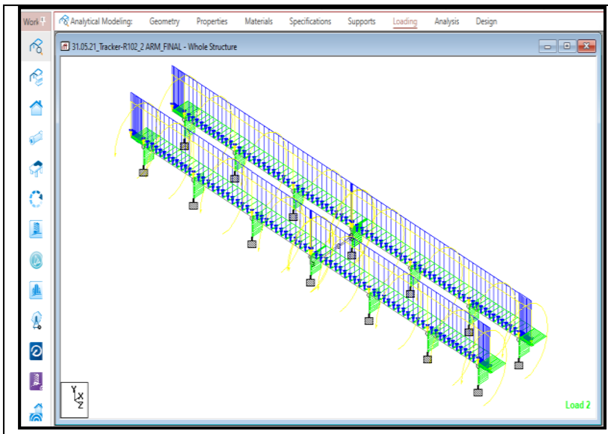

**Fig. 3: Loading pattern**

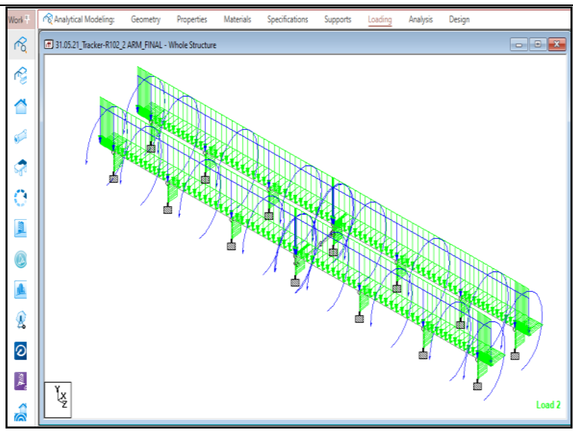

**Fig. 4: Moments acting on the member**

***B. Analysis of Rooftop Mount Solar Structure (On G+4)***

To analyses the rooftop mount solar structure we consider the following technical details given in the Table 4.

**Load Combinations for RCC:**

As per IS: 456-2000 the Service load combinations for buildings are:

1.0*DL + 1.0*LL

1.0*DL + 1.0*(WL or EQ)

1.0*DL + 1.0*LL + 0.8*(WL or EQ)

As per IS: 456-2000 the Strength load combinations for buildings are:

1.5*DL + 1.5*LL

1.5*DL + 1.5*(WL or EQ)

1.5*DL - 1.5*(WL or EQ)

0.9*DL + 1.5*(WL or EQ)

0.9*DL - 1.5*(WL or EQ)

1.2*DL + 1.2*LL + 1.2*(WL or EQ)

1.2*DL + 1.2*LL - 1.2*(WL or EQ)

Loading of structure shown in Fig.6 is as:

Dead Load without roof solar tracker (Slab Load + Floor Finish = 5 + 1.5 = 6.5 kN/m2)

Parapet load = 0.27 *1*20 =5.4 kN/m2

**Table 4. Rooftop Mount (G+4) Input and Load Calculation**

| | | | |
|---|---|---|---|
| **Column size:** | (500mm X 500mm, 750 mm X 900 mm and 750 mm X 1000 mm) | **LOAD CALCULATION** | |
| **Beam size:** | (300mm X 600mm, 300mm X 750mm and 500mm X 1200mm) | **Dead Load:** | Self-weight |
| **Slab thickness:** | 200 mm | **Wall Load:** | 19.44 kN/m |
| **Clear cover of Column:** | 40 mm | **Parapet Wall Load:** | 5.4 kN/m |
| **Clear cover of beam:** | 30 mm | **Floor Live Load:** | 7.5 kN/m |
| **Clear cover of slab:** | 25 mm | **Roof live load:** | 1.5 kN/m |

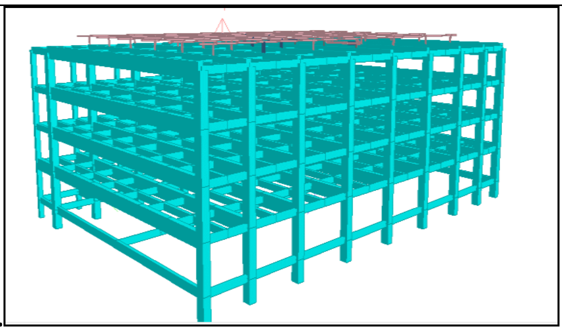

**Fig. 5: 3D view of Rooftop mounts solar structure**

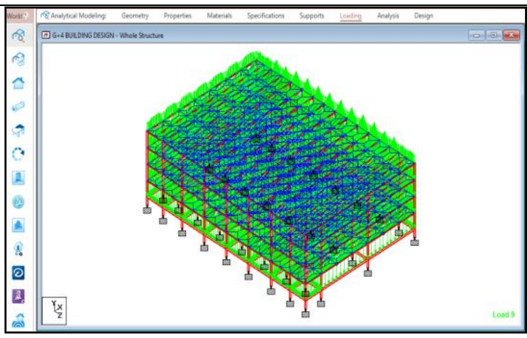

**Fig. 6: Loading of structure**

## Analytical Results

The structure of Ground Mount and Roof Top Solar Tracker is modelled using the software STAAD Pro. Analysis models of the structure comprise all elements that determine the stiffness, strength mass, as well as deformability of structures. Columns, braces, slabs, Beams, torque tubes, walls, as well as foundations make up the structural system.

Various kinds of mechanical arrangements can be found in solar panel structures.

a. The 1st mechanical arrangement includes structural link members, a turntable mechanism, as well as straight bevel gearing. Straight bevel gearing is utilized in these mechanical arrangements for precision, but the material cost of the system is high because several link members are utilized to carry wind load.

b. A 2nd solar tracker mechanical configuration depends on the number of columns that may withstand both dead and live loads of the solar tracker itself. It is possible to utilize Tracking data is kept in one or two columns. Due to wind load, the structure's single column is not stable or rigid.

c. The 3rd mechanical arrangement of the solar tracker is the use of two columns in the structure, which is extremely stable as well as resistant to wind stress. Deadweight and expense are also increased because of braking systems and actuators in the framework.

The structure and mechanical design of the solar tracker are carried out using the following methodology:

Step 1: Solar Tracker Mechanical Design

Step 2: Choice of a Motor

Step 3: Solar Tracker Tracking Resolution

Step 4: Solar Tracker Structural Design by using Software

***A. Structural design of the solar tracker***

Structural parts must be designed to bear the wind load at the target location based on appropriate wind speed estimations. Cyclic circumstances are taken into account when designing the structural part. The wind load on particular structures must be calculated in order to provide an accurate approximation of the impact. Individual structural elements are subjected to wind loads F in a direction orthogonal to the wind direction. Following cases are prepared in Staad-pro analysis.

Case 1: -Ground Mount Tracker Structure -@ 0 Deg. Stowing position (47 m/sec)

Case 2: - Ground Mount Tracker Structure -@ 45 Deg. Operational position (20 m/sec)

Case 3: - Roof Mount Tracker Structure @ 0 Deg. stowing position (47 m/sec)

Case 4: - Roof Mount Tracker Structure @ 45 Deg. Operational position (20 m/sec)


**Fig 7: Structure Deflection comparison graph between case 1 and case 3**

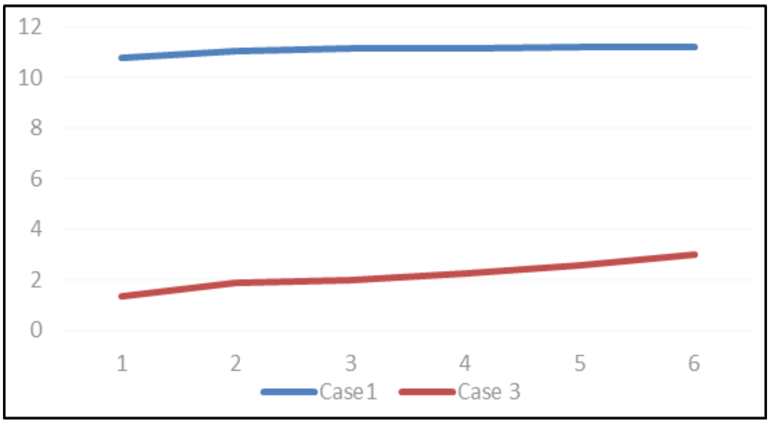


**Fig 8: Frequency comparison graph between case 1 and case 3**

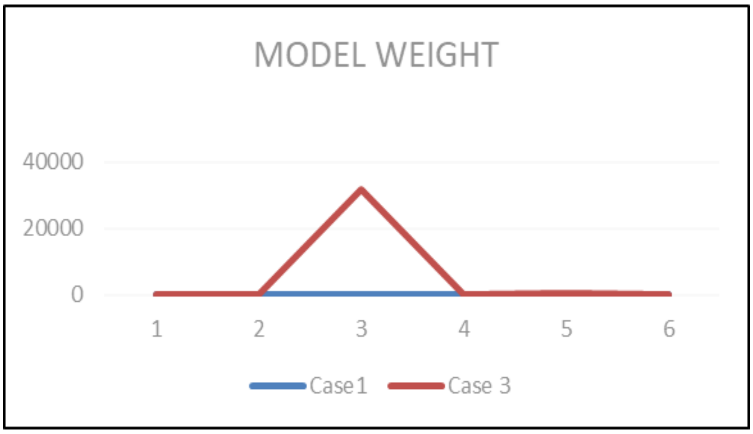


**Fig 9: Model weight comparison graph between case 1 and case 3**

**Comparative study between case 2 & case 4:**

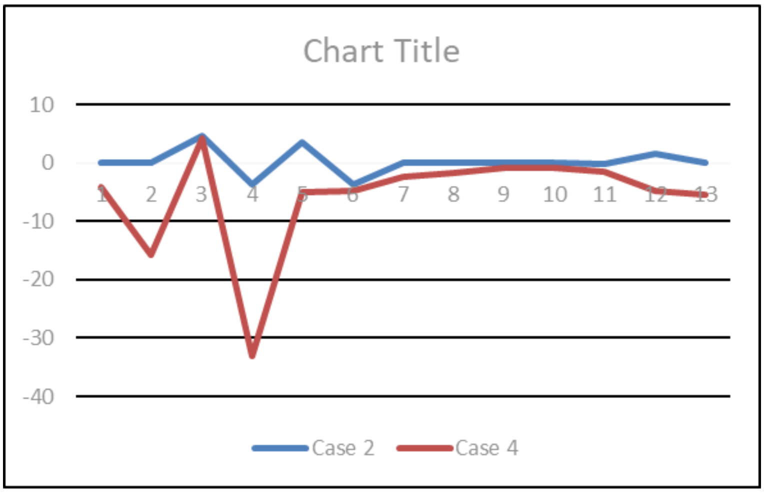


**Fig 10: Structure Deflection comparison graph between case 2 and case 4**

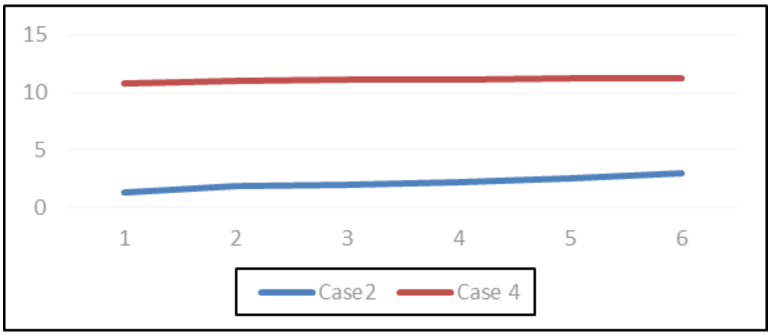


**Fig 11: Frequency comparison graph between case 2 and case 4**

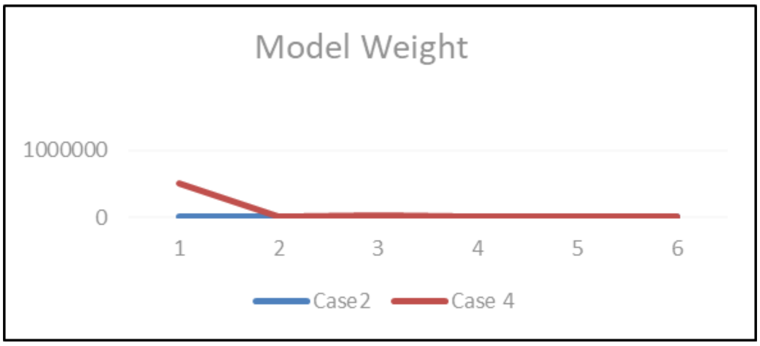


**Fig 12: Model weight comparison graph between case 2 and case 4**

## Conclusions

**Ground Mount Solar Tracker**

Analyzing the observations, it may be concluded that, as tilt angle increases the forces acting on it exerts more stresses and cause the structure to deflect considerably. So providing a tracker system is more beneficial to install. As it can detect wind speed and change tilt angle so that the structure is less susceptible to wind force. As we have observed, if the module mounting structure is of fixed type then members with more strength are required which is a costly alternative and can significantly increase the overall cost of the project.

**Roof Mount Solar Tracker**

Solar panel support structures are subjected to a wind load during their service lives. The presence or absence of a parapet has also had an impact on the effectiveness of solar panels on flat rooftops. A solar panel support structure's performance might be affected by the placement of the structure itself

Roof-mounted solar trackers are not suitable for an existing residential structure. It is only suitable for the structure, which has a provision for extra story load in the building.

In cities, it is suitable for new construction, but it is costlier because there is surrounding structure. This shadow will affect the generation of solar power.

It is suitable for new construction, which has no buildings surrounding area or having low height buildings in the surrounding area.

In recent years, the development of various solar thermal, as well as photovoltaic systems for a wide range of applications, has been facilitated by breakthrough designs in sun-tracking systems. Tracking the sun's path over the course of a day allows solar systems to collect substantially more solar energy, resulting in much higher output power. The quantity and diversity of sun-tracking systems have grown significantly over the past two decades. These sun-tracking devices have been categorized as either single axis or dual axis based on the direction in which they rotate. In addition, it can be characterized as either an active or passive tracker based on the actuator that is used.

It has been discussed in detail the sub-division as well as the fundamental concepts of each approach in detail. It is clear that the azimuth, as well as a dual-axis tracking system for altitude, is more efficient than other tracking methods based on this review's findings. However, in terms of cost and versatility, a single-axis tracking device outperforms a dual-axis tracking system in terms of accuracy and reliability. The information in this article will be helpful in the future when picking a precise and specific tracker based on location, available space, as well as an estimated cost. Solar tracking systems may benefit from this research, which aims to improve their design qualities.

According to the results of the aforementioned study, solar trackers can improve the efficiency of SPV systems, but they must be installed with care. While installing solar trackers, issues such as tracker failure must be given equal consideration. There's also the issue of whether or not to use trackers on the ground or the roof. In addition, the researchers in this study attempted to examine all of the critical elements required for solar tracker optimization.

The government must give financial assistance to customers in order to encourage the adoption of solar rooftop systems for domestic usage. The Indian government can promote solar rooftops in two ways:

a) Cost of Capital Subsidy
b) based on the age group Incentive

As a means of increasing the country's supply of renewable energy, the government should offer some sort of incentive to encourage the use of solar power in cities. As a bonus, this campaign will help cut emissions of greenhouse gases.

Currently, the expense of installing a solar rooftop system is prohibitive for the average family. Only if they are provided with certain benefits will a family decide to install solar panels on their roof.

**Acknowledgment**

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