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THE WIND EFFECT ON G+3 BUILDING ROOF MOUNT WITH SINGLE AXIS TRACKER AND GROUND MOUNT SINGLE AXIS TRACKER

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Abstract - *Daily life is heavily dependent on electricity. To generate electricity, fossil fuels must be used in different ways. In the modern world, fossil fuels are running out. This requires consideration of an alternative supply and sustainable energy resources are the best option available. Hydro, wind, solar and other renewable energy sources are all examples of sustainable energy resources. The use of solar energy to generate electricity can be considered a major source of energy because it is a renewable energy source and can contribute to large-scale energy production.*

Solar energy plays an important role in renewable energy resources and is an extraordinary source of energy. Thanks to photovoltaic cells, solar energy can be used to generate electricity. Non-polluting photovoltaic cells; profitability of the solar industry; minimal maintenance costs; a reliable source; and no moving parts.

In the release document, we analyze the ground mounted single axis tracker and the roof mounted with single axis tracker for the worst wind load and other load combinations. We are investigating the effect of wind on ground and roof mounted single axis trackers. The analysis depends on various factors such as angles of inclination, surrounding structures, building shape, height of surrounding structures and distance of steps, etc. This research will help future generation to understand the wind effect on the ground mount and roof mount single axis trackers.

Key Words: Solar Energy; Wind analysis; Cost-effective; Staad Pro etc.

1. INTRODUCTION

As one of the most ambitious renewable energy targets, India has made significant progress in recent years (Fig. 1), but industry analysts say the country is on track to failing to meet the goal of building 175 gigawatts (GW) of renewable energy capacity by 2022.

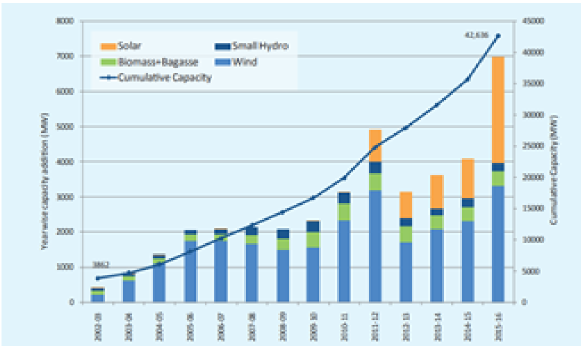

Fig. 1: Development of renewable energy generation capacity in previous (2002-16)

As the world's third largest producer of greenhouse gas emissions, the renewable energy sector is crucial to India's efforts to fight against climate change and minimize its dependence on fossil fuels. As India struggles to meet the 175 GW target, Prime Minister Narendra Modi has already focused on increasing installed renewable energy capacity to 450 GW by 2030, more than double the current capacity. But it was the introduction of a national medium-term objective in the EU's 2015 budget statement that received the most attention. India's ambitious target of 175 GW of renewable energy has now been officially adopted by the country's government.

The solar industry has studied the worst load combination on ground mounted single axis trackers and ground mounted structures with a fixed slope. Some research also focuses on fixed-slope roof mounting structures. However, there are no comparative studies for ground and roof mounted solar trackers. Thus, in this paper, our objective is to safely allow solar tracking movement of the structure at designed wind loads and to achieve optimum design solutions for ground mounting structures and mounting modules on the roof both at 0 degrees and at 45 degrees of inclination. Model all different types of structure combinations in STAAD Pro Analyzer and also understand the behaviour of reactive forces developed in the structure under various load combinations. Next, design the structure for strength and stability against various forces. Iterate a structural model to provide a best practice solution.

The objective of this present research is to study the efficiency of the solar tracking system of the solar panel with respect to different aspects such as the measurement of the deflection, the measurement of the bending stress, the measurement of the stress shear strength, 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 single axis tracker system.

b) Analysis & design of 0-degree & 45-degree rooftop mount type solar (G+3) with single axis tracker system.

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

2. 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 CREȚU 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].

3. 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:

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

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

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

In this project, we are working to install the single axis 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 single axis roof mount tracker 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.

3.1. Load Calculation for 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.

3.1.1. 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.

3.1.2. Live load (LL)

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

3.1.3. 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.

3.1.4. Earthquake load (EL)

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

$$V=AW \tag{1}$$

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

$A = (ZI\ S_a)/\ 2R_g$

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

4. MODELING & ANALYSIS

4.1. Analysis of Ground Mount Single axis Tracker

To analyze the ground mount Single axis Tracker we consider the following technical details in Table 3.

Strength combinations for Ground Mount Single axis Tracker shall be as per IS: 800-1984.

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

Table 3. Input and Load Calculation for Ground Mount Single axis Tracker

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

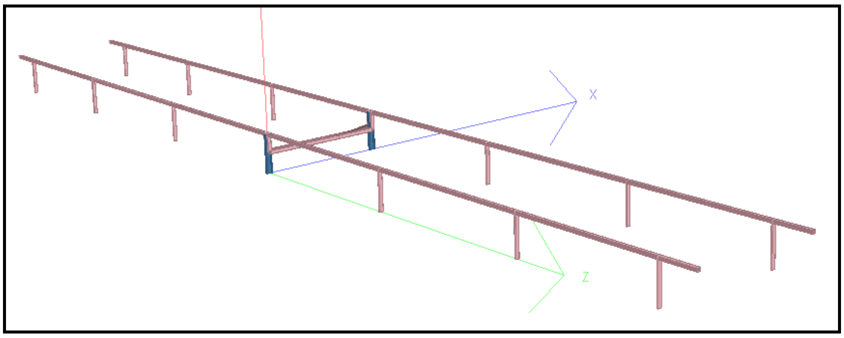

Fig. 2: 3D view of ground-mount single axis solar structure

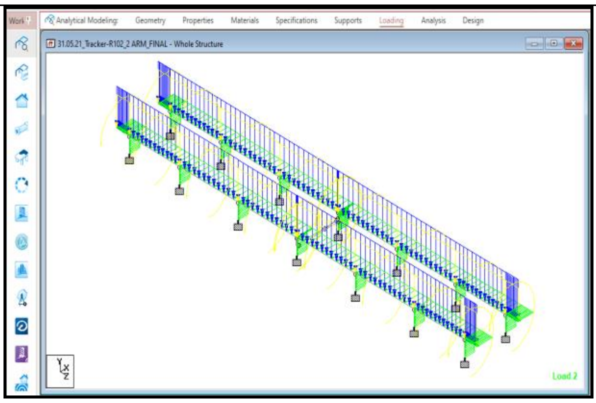

Fig. 3: Loading arrangement

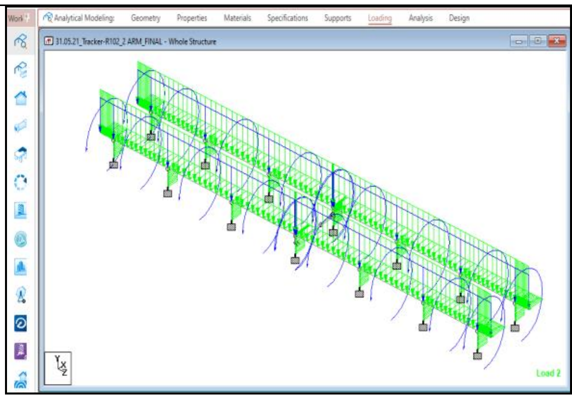

Fig. 4: Moments acting on the member

4.2. Analysis of Roof Mount single axis Tracker

Analysis of Roof Mount single axis Tracker on G+3 storey building. We consider the following technical details given in the Table 4.

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. Input and Load Calculation for Roof Mount single axis Tracker (G+3)

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

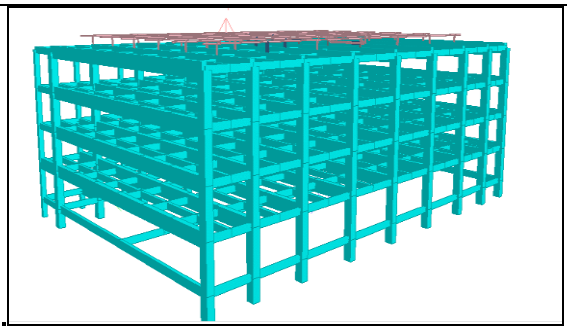

Fig. 5: 3D view of Rooftop mounts solar structure

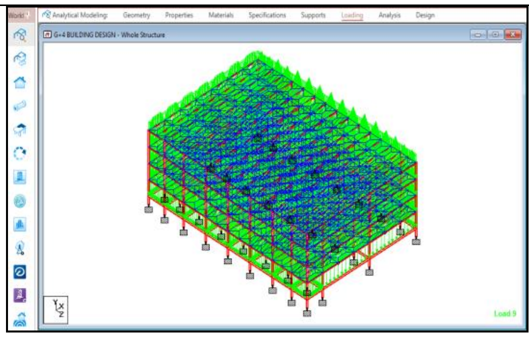

Fig. 6: Loading of structure

5. ANALYTICAL RESULTS

5.1. Structural design of the Single axis 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 Single axis Tracker Structure -@ 0 Deg. Stowing position (47 m/sec)

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

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

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

5.2. Comparative study between case 1 & case 3:

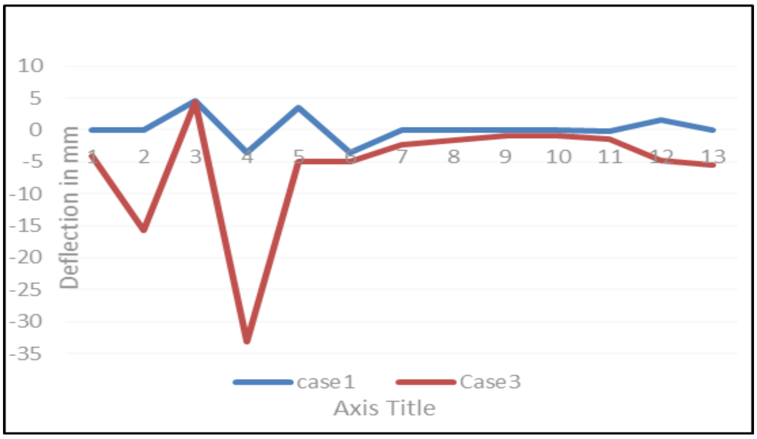

Fig 7: Deflection comparison graph between case 1 and case 3

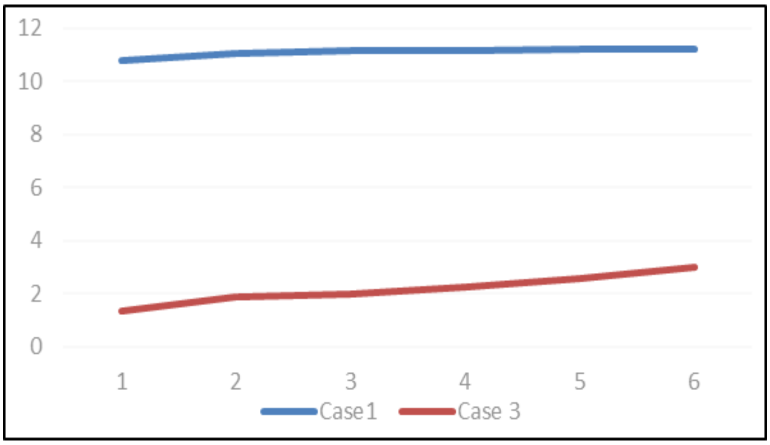

Fig 8: Frequency comparison graph between case 1 and case 3

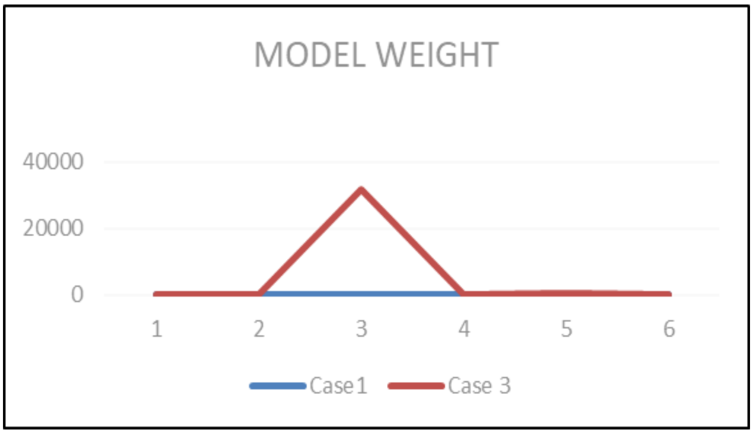

Fig 9: Structure weight comparison graph between case 1 and case 3

5.3. Comparative study between case 2 & case 4:

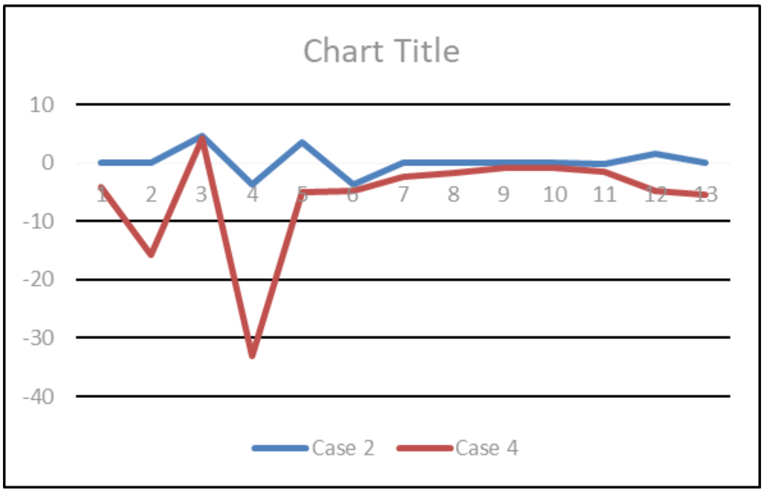

Fig 10: Structure Deflection comparison graph between case 2 and case 4

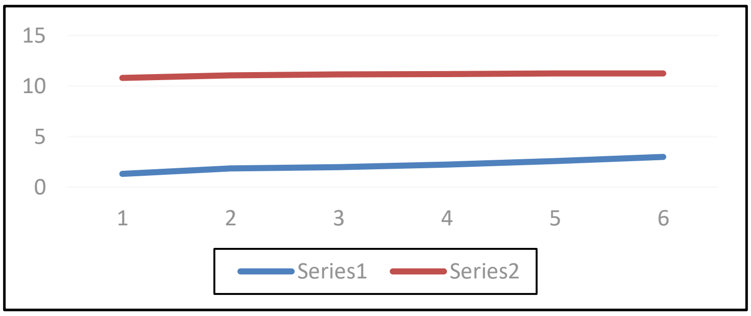

Fig 11: Frequency comparison graph between case 2 and case 4

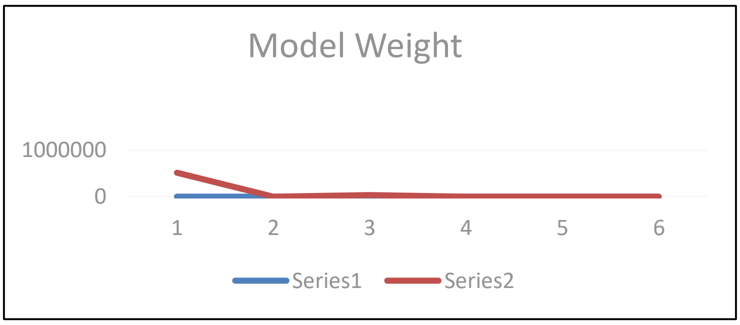

Fig 12: Model weight comparison graph between case 2 and case 4

6. CONCLUSIONS

Ground Mount Single axis 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 single axis 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 single axis 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 single axis 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.

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