An Analysis on Solar Trackers a Potential Need for Future Solar Power Growth in India

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Abstract— The 2016 World Cities Report released by the economic and social affairs department of the United Nations states that the number of mega cities in India will go eight fold more from the current five by 2030. Delhi will continue to be the world's second most populous city adding 9.6 million people to its population. Currently, India has five mega cities with a population of over 10 million people. According to the report, the number of mega cities will go up to 41 with a population of 730 million people - 8.7 per cent of the world's population - by 2030. India, home to 18% of the world's population, uses only 6% of the world's primary energy. India's energy consumption has almost doubled since 2000 and the potential for further rapid growth is enormous. India is set to contribute more than any other country to the projected rise in global energy demand, around one-quarter of the total. India's power system needs to almost quadruple in size by 2040 to catch up and keep pace with electricity demand that – boosted by rising incomes and new connections to the grid – increases at almost 5% per year. An innovative and technological adaption for effective use of renewable energy sources while optimally tapping the available natural resources is one of the important factors for the environment as well as for sustainable business. This can be achieved by using proper solar tracking system; the generation will be improved roughly by 20% to 40% with incremental value of capital project cost. The aim of this paper is to suggest the maximum use of the solar energy through solar trackers for optimum generation and mainly focused on need for solar tracking system, major types and benefits associated with trackers in solar PV project.

Key words: Solar Tracking System, fixed tilt, stationary array, Single Axis Tracker, Dual Axis Tracker, Solar Photovoltaic (PV)

I. INTRODUCTION

Solar trackers are rising in popularity, but not everyone understands the complete benefits and potential drawbacks of the system. Solar panel tracking solutions are a more advanced technology for mounting photovoltaic panels. Stationary mounts, which hold panels in a fixed position, can have their productivity compromised when the sun passes to a less-than-optimal angle. Compensating for this, solar trackers automatically move to "track" the progress of the sun across the sky, thereby maximizing output.

It's a incredible system for energy output, but there are a few considerations to bear in mind before pursuing one for a particular application.

Solar trackers allow modules to follow the sun's trajectory across the sky, greatly increasing the amount of energy a solar system can produce. Data recorded from modeling and multiple gigawatts of installed solar capacity demonstrate that trackers provide between a 15-25% production pickup over fixed-tilt systems, a gain that varies based on location and site conditions. The cost of a tracker over a fixed-tilt system is generally between 8-12%, meaning the value of the energy production gain greatly eclipses the added costs, improving the system's return on investment (ROI). Solar trackers also broaden the power-delivery profile of a solar plant by generating high production during peak energy demand times. For example, on a hot summer afternoon when air-conditioning and electricity demands are the highest is also when the solar trackers deliver peak energy production. Tracking systems are one of the single greatest innovations in the solar industry, one that has revolutionized the way in which power is generated.

It was not long ago that solar trackers were considered an unnecessary luxury while setting up solar power plants. Although they brought about an increase in plant performance, developers weren't willing to invest on the additional costs. Solar Trackers are devices that come in conjunction with the mounting structures and help direct the panels in the direction the sun moves. But as it stands today, trackers are gaining ground in India. Developers are becoming increasingly aware of the enhanced CUFs that tracker implementation could bring about. Basically, there are 2 types of trackers: Single-axis and dual-axis trackers as the name suggests, single-axis trackers rotate on one-axis, moving east to west, traversing the daily movement of the sun. On the other hand, dual-axis trackers perform both the daily as well as seasonal rotation of panels. Single-axis trackers can bring about a CUF of 21%. In comparison with solar plants without trackers, this means an increase in performance of around 20-25%. Dual-axis trackers do not make sense in the Southern states due to their proximity to the equator. But, in northern parts of India like Punjab, Rajasthan etc, which are located at higher latitude, these could be beneficial. They can produce an increase in performance of up to 35%.

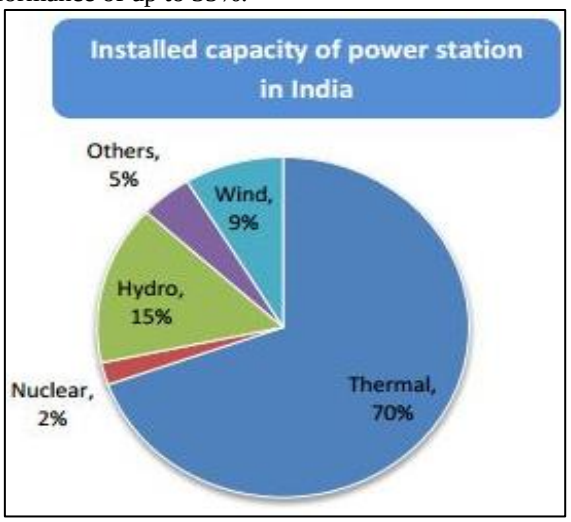

Fig. 1:

Programme/Scheme wise Physical Progress in 2015—16 (From MNRE, GOI)

A. Solar Energy Has Following Few Factors in Our Favor

1) Unlike fossil fuels and nuclear power, it is environmentally clean source of energy.
2) Available in adequate quantities in almost all parts of the world where people live.
3) Energy harnessing is free of cost.
4) It has no heavy mechanical sections & is free from noise and any pollution.

Problem associated with the use of solar energy is that its availability varies widely with time. The variation in availability occurs daily because of the day night cycle and depends on seasons because of the Earth's orbit around the Sun. The main problem with solar energy is that it is a dilute source of energy. Even in the hottest regions on the Earth, the solar radiation flux can be of a low value for technological utilization. To rectify the above problems the solar panel should be tilted such that it always receives the maximum intensity of light for the maximum output.

The generation capability of a photovoltaic (PV) cell is mainly dependent on the intensity of the solar radiation. On the other hand, the changes in position of the Sun cause a variable shining intensity in different seasons and different times of the day. For this, a digital based automatic Sun tracking system is proposed. Trackers helps the solar power generating equipment to automatically get the maximum Sunlight thereby increasing the efficiency of the system and thus the maximizing the generation. The solar tracker tracks the Sun from east to west and north to south depending on the types of trackers being used, automatically for maximum intensity of light and helps to produce optimal generation thus improving the revenue for the developer.

II. NEED FOR A SUN TRACKING SYSTEM

One way to make the Solar panel more effective is by adding the ability to track the Sun as it moves across the sky. A Solar tracker is a device used for orienting a Solar PV panel or lens towards the Sun by using the light sensors interfaced to motors, used for rotation, through a microcontroller, to have maximum solar radiation incident on the solar panel. The motors can be used to move the panels either along ONE or TWO axes.

Below are the advantages of the solar tracker:

- Increased power generation
- Surplus power generation brings in additional revenues for the company
- Less payback period because of additional revenue
- Increased investor confidence
- Increased power generation per unit area of land.
- Less land area is thus required as compared to conventional solar project of equal capacity.

How Does Tracking System Work:

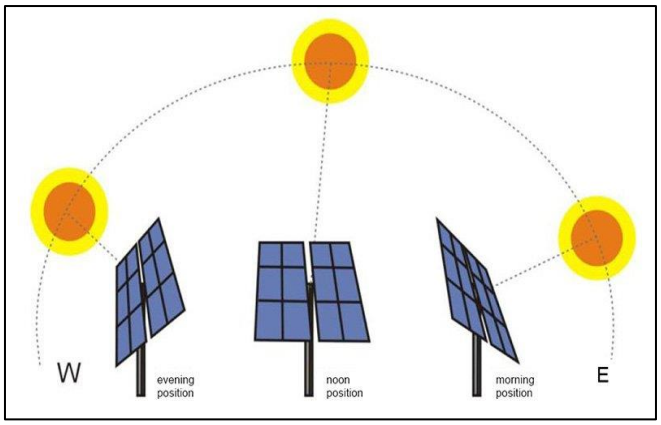

Fig. 1: Rotation of Sun

Source: www.media.lindn.com

Trackers systems works on two simple principles together. One being, the normal principle of incidence and reflection on which our tracker works and the other is the principle on which the solar (PV) panel works, which will produce electricity. Both these principles can be combined and as a result of which it can produce nearly double the output that the panel specifies normally. The working of the tracker system is explained below as per position of Sun and solar panels; they are categorized in four types.

A. Sunrise Position

Suppose at the time of sunrise the Sun is in extreme east the reflector will align itself in some position by which the incident rays will fall on the solar panel. The Track rack begins the day facing west. Now when the earth rotates and the Sun gets shifted from its earlier position the reflection of the incident rays will also change. As the morning Sun rises in the east, it heats the unshaded west-side canister with both direct and reflected rays (from the inter surface of the "shadow plate") forcing liquid into the shaded east-side canister and panel move to get direct sunlight.

B. Noon Position

As the Sun moves, the Track Rack follows (at approximately15^{o}per hour) continually seeking equilibrium as liquid moves from one side of the tracker to the other.

C. Evening Position

The Track Rack completes its daily cycle facing west. It remains in this position overnight until it is "awakened" by the rising Sun the following morning. Again the same cycle follows for next days.

III. TYPES OF TRACKER

Solar trackers are racks for photovoltaic modules that move to point at or near the Sun throughout the day. Trackers add to the efficiency of the system, reducing size and the cost per kwh for solar power projects. Single axis trackers will track the Sun from east to west on a single pivot point. Dual Axis trackers track east to west and tilt for north to south tracking.

Fig. 2: Single Axis

Fig. 3: Dual Axis
Source: www.renewableenergyworld.in

A. Single Axis Tracker

- Single Axis Trackers are used to minimize the angle of incidence between the incoming
- Sunlight and a solar panel with help of sensor. This system tracks the Sun only from east to west direction.

1) Advantages

Compared to solar panel in fixed tilt, single axis solar tracker has a better efficiency. The efficiency of single axis solar tracker is ~ 25 to 30%.

2) Disadvantages

- Single axis solar tracker tracks Sun only from east to west direction.

B. Dual Axis Tracker

Dual axis tracking system uses the solar panel to track the Sun from east to west and north to south. It can rotate simultaneously in horizontal & vertical directions and are able to point at the Sun at all times. Dual axis trackers track the Sun both East to West and North to South for added power output approx. 30 to 40% gains.

1) Advantages

Dual axis solar tracker has more efficiency than both fixed tilt panels and single axis tracker system.

2) Disadvantages

- More land requirement and higher cost associated w.r.t. other system.
- Operational complexity and more O&M cost

IV. SOLAR TRACKING SYSTEM

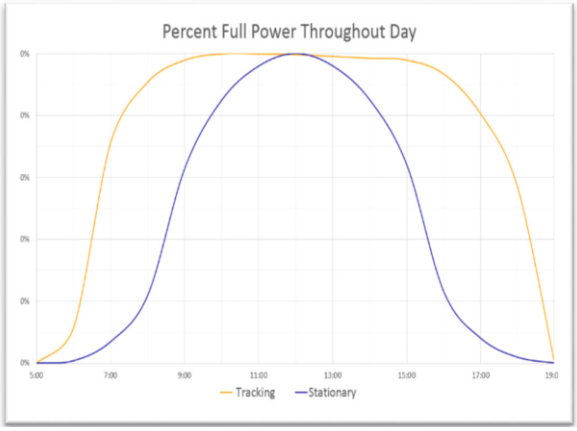

Fig. 4: Typical Power curve of Stationary Vs Tracking system

The graph shows the portion of the panels' highest power yield for the day throughout daylight hours and energy collected from a tracking PV system & a stationary/fixed tilt system on a clear sunny day. As the Sun rises, its direct solar radiation takes time to reach its peak. A tracking system follows this rise without loss, while a stationary system waits until noon to achieve its maximum power output. The slight decline in power into the afternoon is due to heating of the system. The results vary depending on location, season, and weather, but generally they will look the same: tracking systems quickly reach a plateau of power for several hours, and stationary systems only briefly reach their maximum power around midday.

A. The Advantages of Solar Tracking System

The main reason to use a solar tracker is to produce the more power by reducing the cost of the energy. Solar tracking system can be used to capture and increase revenue with the existing installation. A tracker produces more power over a longer time than a stationary array/fixed tilt system with the same number of modules. This additional output or gain can be quantified as a percentage of the output of the stationary array. Gain varies significantly with latitude, climate and the type of tracker we choose as well as the orientation of a stationary installation in the same location. The energy required to move the tracker is insignificant in these calculations.

Climate is the most important factor. The more solar radiation and less clouds, moisture, haze, dust, and smog, the greater the gain provided by trackers. At higher latitudes gain will be increased due to the long arc of the summer Sun. In the cloudiest, haziest locations the gain in annual output from trackers can be in the low 20 percent range. In a generally good area, annual gains between 25 to 40 percent are typical. Seasonally in sunny area, gain ranges from 25 to 30 percent in winter (October through March) to between 30 and 40 percent in summer depending upon use of tracker. In general, a tracker adds most to output during the hours when a stationary array produces the least power.

B. Financial Aspect of Solar Energy

As per the Central Electricity Regulatory Commission (CERC) guideline, Benchmark Capital Cost norm for Solar PV projects has established and shall be applicable for FY

2016-17. The major item-wise cost per MW is given below for the ready reference.

Sr No	Particulars	Capital Cost norm (Rs. lakhs/MW)	% of Total Cost
1	PV Modules	310.19	61.9%
2	Land Cost	25	5%
3	Civil and General Works	35	7%
4	Mounting Structures	35	7%
5	Power Conditioning Unit	30	6%
6	Evacuation Cost up to Interconnection point (Cables and Transformers, switchyard)	40	8%
7	Preliminary and Pre-Operative Expenses including IDC and contingency	26.13	5.1%
	Total Capital Cost	**501.32**	**100%**

Table 1: Cerc Benchmark Capital Cost Norm For Solar Pv Power Projects Applicable During Fy 16-17

Computation of additional revenue generation for 1 MW (single axis and double axis) trackers w.r.t. fixed tilt solar PV project for useful life of 25 years through sale of electricity are shown in Table 2. All values in crores (crs).

Sr. No.	Description	Fixed tilt PV	Single axis tracker - PV	Double axis tracker-PV
1	Cost/MW (Rs. Crs)	5.01	5.5	5.9
2	Additional cost	-	8.91	15.08
3	Generation (Mus)	1.50	2.19	2.72
4	Capacity Utilization Factor	19%	25%	30.%
5	Tariff (Rs/unit)	4.63	4.63	4.63
6	25 years Revenue	173.63	253.49	314.33
7	Payback Period (yrs)	-	4 to 5	6 to 7

Table 2: Additional Revenue With Trackers Vs Fixed Tilt - Solar Pv

Here, considered is a very conservative approach while calculating the additional MUs and revenue associated with fixed tilt vs trackers. The tariff considered are lowest tariff quoted in NTPC-developed solar park in Andhra Pradesh's for calculating additional revenue and payback periods for respective tracker.

In reality, a shift from fixed tilt to single or double-axis tracking is very complex and has cascading cost implications due to involvement various factors. Also get an accurate cost benefit analysis is equally complex. Many financial variables need to be quantified and compared, including state wise increased costs of land, labour, materials and O&M to get accurate cost as well as additional revenue projections.

Accordingly, by doing the cost–benefit analysis Single-axis tracker are more beneficial over double axis tracker in Indian scenario. The Indian solar power sector has ballooned more than 4 GW within a couple of years. The number of companies looking to enter solar power sector have also increased tremendously resulting in steep fall in the feed-in tariffs and also favorable condition of Government policies to fulfil Country's ambitious target of 100GW of solar capacity by 2022. Now Power Sector Companies should take advantage of the rapid evolution in the solar power generation technology as it has technical and commercial advantages to use solar tracker for additional generation and accordingly, more revenue.

V. CONCLUSION

Clearly, the advantages of having tracking equipment in a solar power project overwhelmingly mitigate the additional capital and O&M costs. Generally dual axis trackers are more accurate in pointing Sun, however, dual axis comes at higher price, more complexity, additional land, more O&M and lower reliability as compare to single axis tracker. On the other hand single axis tracker offers less land requirement, lower cost and higher reliability over double axis tracker. But it is obvious that power producers/developers will choose Single axis tracking system instead of double-axis tracking though power generation efficiency is high. As in Indian scenario the purchase of extra land is a very painful affair and requires a lot of effort, more time & additional cost. Thus it may not be viable to put extra cost for additional land requirement and O&M cost for useful life for double axis tracker w.r.t. single axis tracker. In view of the above, tracker will play a very crucial role in the upcoming solar power projects. In future there will be more & more technological upgradations/innovations on both the solar tracking systems and will make solar projects more viable with good returns. Also it will maximize the output and additional revenue, thus become need/ requirement for future solar power projects.

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