Introduction

The amount of electricity generated off a solar PV module is maximum when the angle of solar incidence on the module is near perpendicular or near normal.

Now the sun as we know, moves east to west during the day. This daily east to west path of the sun also shifts along north south during the year. It is higher during summers and lower during winters.

During the early growth years of the Solar PV installations this variation in the sun's path (both daily and seasonal) was accounted for by arriving at an optimum angle for the solar PV array for a specific location. This angled installation ensured the best aggregated yield for the given location.

However, as the industry matured with increased investments in utility scale solar PV installations, realizing optimum efficiencies in performance and yield from these installations was the logical concern. As solar energy became commercially viable and energy costs began looking comparable to conventional sources like thermal, improvement on Levelised Cost of Energy (LCoE) became the focus.

By this time the costs like those of Solar PV modules and the Balance of System (BoS) costs had already plateaued. The areas that help scope for improvement were the MMS (Module Mounting Structure) and plant efficiencies.

This is where Solar Tracking comes into serious reckoning.

1. Solar Tracking Systems

A solar tracking system or a solar tracker is a specific device intended to move the PV modules in such a way that they continuously face the sun with the objective of maximizing the irradiation received by the PV array.

Such a solar tracking system would necessarily include the following differentiated components:

1.1 MMS

1.2 Mechanism

1.3 Drives

1.4 Tracking Controller

1.1.1 MMS

This pertains to a specifically designed Module Mounting Steel Structure that in addition to holding the solar PV modules in a desired configuration, should be able to withstand required weather conditions like wind speeds, flood clearance etc. Is should also have an estimated useful life similar to that of PV modules.

1.2.1 Mechanism

The mechanism is the part of the system responsible for providing the solar array with precision in tracking. This too must be designed to withstand harsh weather conditions and have an estimated useful life equal to or similar to that of the PV modules.

1.3.1 Drives

Motors or systems to provide the requisite force to move the PV array and hold it in place for the desired duration of time. In addition the drive system is also used to move the solar array in stow position during extreme weather conditions.

The most common driving mechanism is an electric motor because it allows a simpler and precise control of the movement. One motor is required for Single-axis trackers, whereas dual-axis trackers require two motors.

1.4.1 Tracking Controller

Solar trackers can be classified into systems that orient the PV panels based on previously computed sun trajectories (open-loop control) and solar trackers that used a solar radiation sensor to control the orientation of the system (closed-loop control).

Feedback Controllers use direct solar sensors to detect the position of the Sun. For this purpose, photosensitive sensors are mounted on the panel. However at dawn and under low radiation conditions (cloudy days), the trackers controlled by photosensors may become disoriented, making it essential to have an auxiliary tracking system in place to control the rotation until the orientation is restored again.

Open-Loop Controllers use a microprocessor and do not need sensors to determine the position of the Sun. The movement of the Sun is predicted using astronomic relationships programmed in the microprocessor itself. This type is not affected by cloud cover or other low radiation circumstances that may lead to errors in accuracy.

2. Types of Trackers

Taking into account the type of mechanism, solar tracking systems can be classified into one-axis trackers or two-axis trackers.

2.1 Single Axis Trackers

A single-axis solar tracking system uses a tilted PV panel mount and one electric motor to move the panel on an approximate trajectory relative to the Sun's position. The rotation axis can be horizontal, vertical, or oblique. Fig. 2.1 shows a general scheme of a one-axis tracker showing both the rotation axis (unit vector e) and the collector plane (unit vector normal to the collector plane). The angle between these two unit vectors is usually kept constant in this type of tracker.

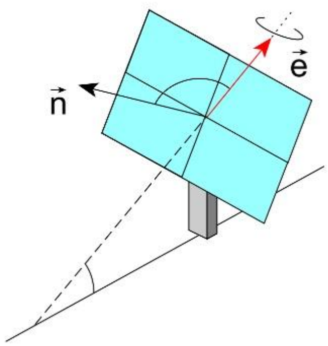

Figure 2.1. Characteristic vectors in a Single Axis Tracker

Solar tracking implies moving parts, control systems and automation, each of these is an added cost. Single axis trackers having less moving parts, requiring a single drive are therefore perceived to be less expensive and therefore more popular.

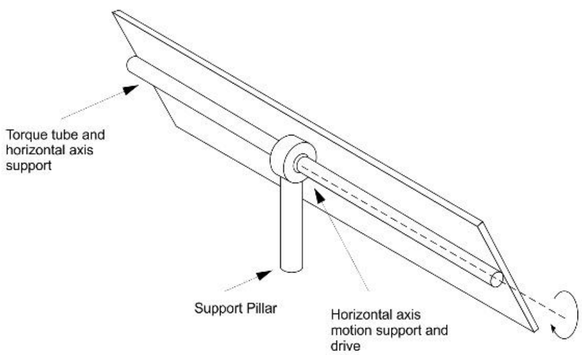

Figure 2.2.Typical Single Axis Tracker

Even in Single Axis Tracking, East–West horizontal axis tracking configuration is the most prevalent for its simplicity of design. The rotation axis is placed parallel to the ground and panels rotate east to west. Though commanding a dominant market share, the configuration has design limitations that compromise yield, especially during winter months. The disadvantage becomes obvious once we compare the tracker design with seasonal changes in the path of the sun.

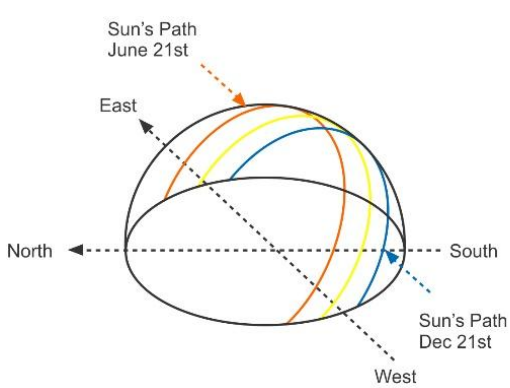

Figure 2.3. Typical changes in the path of the sun across seasons

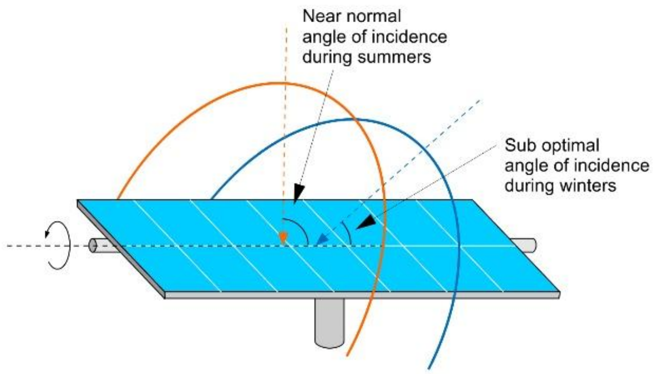

Figure 2.4. Horizontal Mount East West Tracking

Now we can see that why the tracker horizontal mount single axis tracker performs well during peak summer because the trajectory of the sun is high. But the output begins to falter as we approach winters because the sun's trajectory is low, whereas the panels are fixed in a horizontal plane parallel to the ground. During certain winter months the output falls even lower than that of a no tracker fixed installation. Thus the annual aggregated yield from the single axis tracker leaves much to be desired.

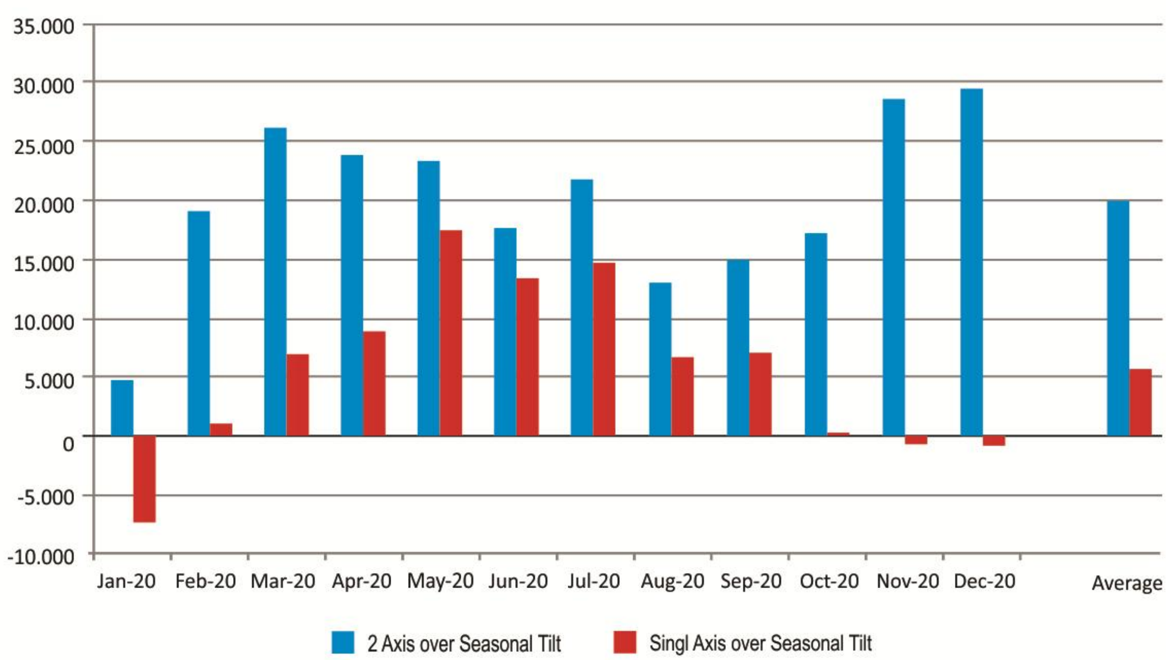

Chart 2a. Monthly aggregated Yield Comparison between Single Axis and 2 Axis Tracker over Fixed Installation with Seasonal Tilt Based on actual data from Pilot site at Roorkee, Uttarakhand, India

2.2 Two-Axis Trackers

A Two-axis tracker therefore hold the potential for maximum yield owing to its total freedom of movement (north–south and east–west), the tracker can face the sun's rays throughout the day, across seasons (Fig. 2.5).

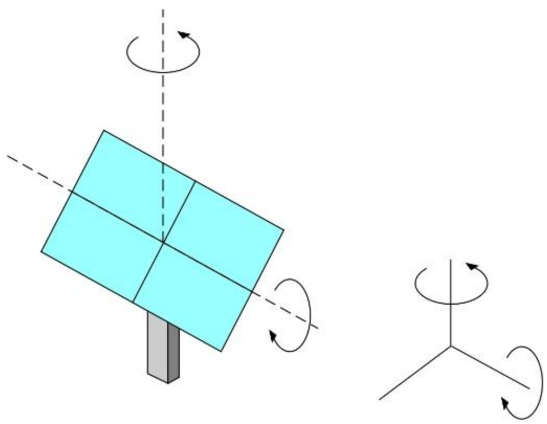

Figure 2.5. Characteristic movements in a two-axis tracker.

Since this design obviously requires higher automation and more moving parts driving up the costs, the solution was sought in creating large tracker tables with more Solar PV modules packed together, thus minimizing the costs.

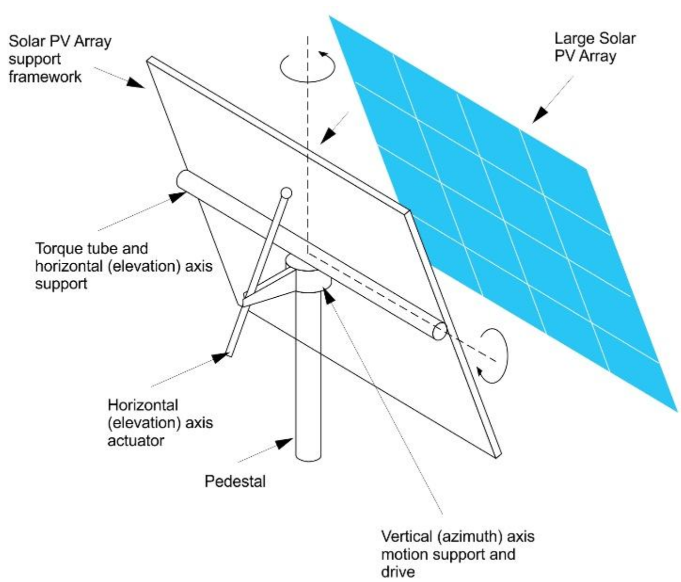

Figure 2.6. Typical large table two axis tracker

Another reason for larger tracker tables in 2 axis trackers was their efficacy in CPV. However the larger table of solar modules with its heavy weight added more challenges.

Big tables called for heavy support framework and an extremely heavy structure overall due to two reasons. First, to support their own weight, second, larger table area calls for higher wind loads therefore stronger structure for wind tolerance.

Also larger tracker tables while holding more modules require larger spacing from one tracker to the next to avoid shadowing, resulting in lesser coverage for a given area of land.

Thus the prevailing structural designs and resulting high capital costs, nullify the gains for most locations.

3. Design Innovation – Asun 2 Axis Tracker

3.1 Unique Design

Acknowledging the MMS structure as the key impediment in cost optimization Asun 2 Axis Tracker offers a solution with highly optimised weight, lower tracker table height and great terrain adaptability.

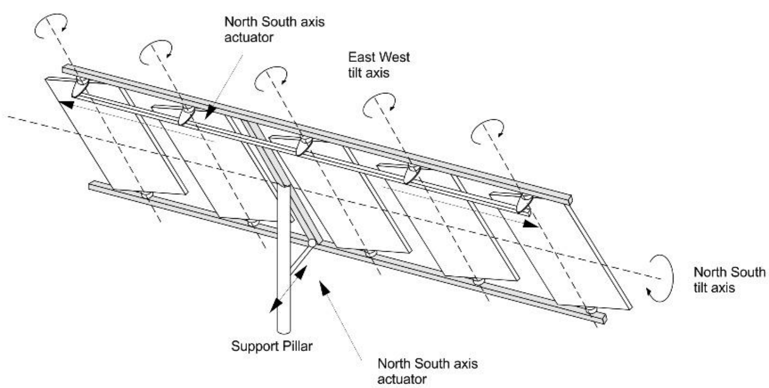

Figure 3.1. Asun 2 Axis Tracker

The result of this disruptive design is 2 Axis Tracking at a single axis cost. This has been made possible by highly optimized structure weight and efficient drive utilization. The design configuration comprises of light modules of 5 solar panels each, joined by proprietary couplings resulting in a flexible single tracker configuration of 20 to 30 panels each (comprising of 4 to 6 modules).

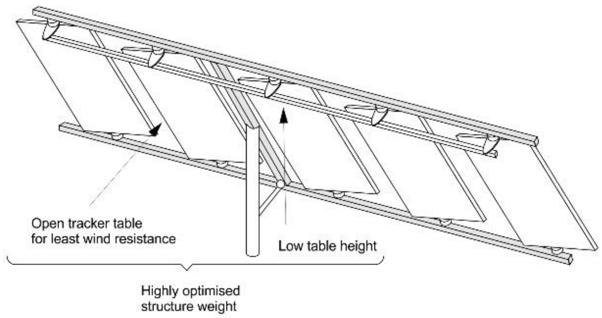

Figure 3.2. Optimised structure of Asun 2 Axis Tracker

While the modular design ensures that each tracker is driven by one east west axis actuator and one north south axis actuator each. It also results in incomparable terrain adaptability, making it suitable for undulating terrains, those with a high gradient slope or simply irregular shaped small land parcels.

Figure 3.3 Modular design for drive efficiency and high terrain adaptability

3.2 Salient Design Features of Asun 2 Axis Tracker

In brief, the following design features make Asun 2 Axis Tracker a highly suitable choice.

3.2.1 Highly Optimised Structure

Lower structure weight directly translates into and highly competitive cost which coupled with the performance advantage of the 2 axis design means improved IRR for any solar PV asset investment.

3.2.2 Decentralised Design

The tracker is designed for easy installation and the decentralized design also means higher plant availability at all times.

3.2.3 Modular Configuration

The 5 panel module configuration with properietory coupling offers unprecedented terrain adaptability as well irregular shaped land parcel utilization.

3.2.4 Programable Stow Position

Automatic stow position ensures overall plant safety in extreme weather conditions, especially high winds.

3.2.5 Wind Speed Tolerance upto 160 kmph

The tracker structure is designed to withstand wind speeds reaching upto 160 kmph. Moreover the structure design can be customized for specific requirements.

3.2.6 Better Suited for Bifacial

Asun 2 Axis Tracker has a unique single panel configuration that allows for better bifacial module efficiency as compared to any other design

3.2.7 Self-lubricating Polymer Bearings

To offset the fears concerning high number of moving parts in 2 Axis trackers the tracker employs state-of-the-art self-lubricating polymer bearings for minimal maintenance

3.2.8 IoT Ready

The tracker controllers are provisioned with optional features like remote monitoring, self-diagnostics and trouble shooting

3.2.9 Increases Yield by upto 28%

The incident free pilot plants operation over 2 years has real time data comparison available with a seasonal tile installation, a single axis tracker installation and all at the same location. This data is available on request. Simulated data comparisons are also available for a number of locations all over the world.

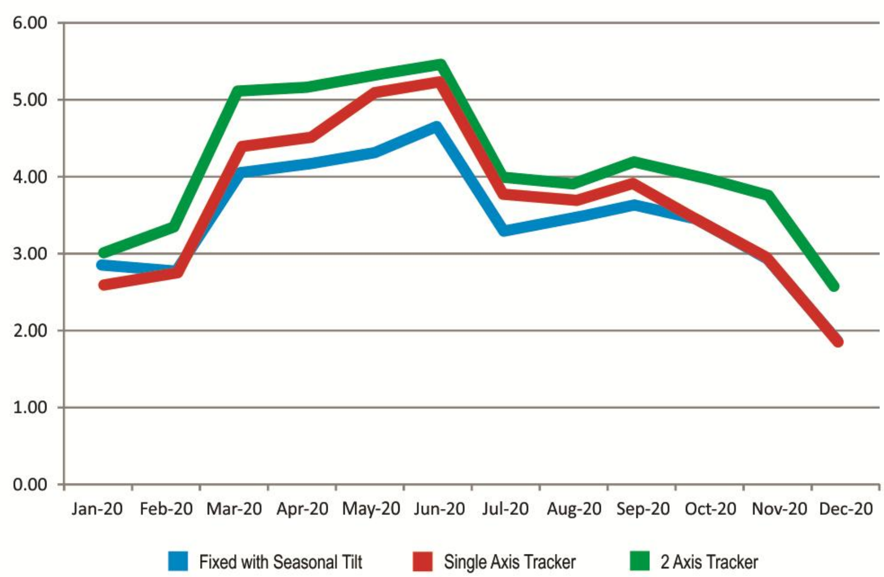

Chart 3a. Monthly aggregated Yield Comparison between Single Axis and 2 Axis Tracker and Fixed Installation with Seasonal Tilt Based on actual data from Pilot site at Roorkee, Uttarakhand, India

4. Asun 2 Axis Tracker Control System

The controller is designed for an array of Solar PV Panels mounted on rectangular platform. This platforms is expected to change orientation as per the changing sun position from morning to evening and in different seasons. The system controls the two actuators used in each tracker.

4.1 Overall Features

- Modular Design to suit small solar fields of 100 KW to large fields like 10MW or more.
- Two axis control for maximizing power yield
- Current position feed back from each tracker using inclination sensors
- Self Powered and AC Powered (using 24V SMPS) capability
- Weather inputs used for site safety and power saving
- Power generation data can be taken from inverters if protocol is made available
- Site status and data uploaded to cloud based server using GSM/GPRS/LAN communication
- Single point console for complete site operation and monitoring down to each actuator
- Wired or wireless connectivity options for field communication
- Sun position determined using SPA algorithm
- Back tracking to avoid panel shadows on each other

4.2 The Complete Controller Unit

Two Axis PV Tracker System consists of one Site Control Unit, Multiple Tracker Control Unit, Inclination Sensors, GSM/GPRS Gateway and RS-485 Hubs. These are detailed below.

4.2.1 Site Control Unit

Site Control Unit is the master unit for all trackers. It computes optimal angles for the trackers and transmits to all the Tracker Controllers through. Following specific tasks are performed by Site Control Unit:

- Computation of solar position based on date time, location and height from MSL
- Transmits the computed position to all Trackers
- Commands all or selected trackers to go to safety position if so required due to weather conditions or user inputs
- Monitors operational parameters at each tracker for logging and generates alarm if parameters go beyond user set limits
- Takes inputs from weather station and controls site as per user selected options

4.3.2. Two Axis Tracker Controller

- One Controller for 4 Two Axis Trackers (8 Actuators)
- Inputs from 4 Inclino-sensors Mounted on each Tracker
- Opto-isolated RS-485 Port for Connectivity with Site Control Unit
- One Seven Segment Digit for Status Display
- Supports Hand Held Control Unit for Configuration and Calibration
- 24VDC operated supported Battery or SMPS
- In-Built MPPT Charger for LiIon Battery using 36V PV Panel
- Recommended Battery Capacity 25V15AH
- Recommended Panel Capacity 60Watt @36V
- Safety features include Overload and Overheat protection
- IP65 Plastic Enclosure Size 225x160x100mm (LxWxH)
- Based on 32 bit ARM Processor

4.3.3 Inclination Sensors

- Compact sealed unit of 60x40x20mm
- Two wire connectivity for greater reliability
- 3 Axis measurements with 0.5 degree accuracy
- Required to be mounted on PV panel frame for accurate position feed back
- One sensor required for each tracker

4.3.4 RS-485 Hub

- Opto isolated hub with 1+4 RS-485 ports
- Each port support upto 31 nodes
- Power requirement 12-24VDC 100mA Max

4.3.5 Hand Held Unit

- Used for Configuration, Calibration and Monitoring Two Axis Tracker controller
- LCD Based Display
- Navigation keys for Parameter Selection and Modification
- It is advised that two such units are kept at each site