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A Review on Advanced Solar Tracking Systems

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ABSTRACT

Solar energy is vast, abundant, cost free, green renewable source of energy. Due to the aforementionedqualities, the world is today researching and exploring the most feasibly optimized way of harnessingthis energy and solar tracking system is a result of this quest. This paper begins with a briefintroduction to the solar PV cells and the materials used in their construction. It mainly discusses the types of solar tracking systems. It mainly focuses on the design andperformance analysis of the various dual-axis tracking solar systems proposed in recent years.

Althoughthe choice on the use of trackers mainly depends upon the physical features of the landbut ingeneral this system has proved to be more efficient and advantageous than its single-axis and fixedcounterparts.

INTRODUCTION

Energy is required for large applications such as transportation, industrial applications, agricultural applications, household requirements and office requirements. It can have many forms like heat energy, electrical energy, chemical, energy nuclear energy, light energy and so on. The relationship between social development and use of energy is very clear; nations with more use of energy are in more advanced state of development. The supply of energy should be secure and sustainable as the use of energy has become an integral part of our life.

Sun is the most abundant source of energy and one day it could be the greatest luminous energy source. People commonly use fossil fuels like oil, natural gas and coal for the need of electricity. However, using fossil fuels as energy sources have negative impacts like acid rain pollution and global warming which harmfully effect many animals, plants and humans in the surroundings. Therefore, solar energy is considered best among all the energy resources as it is a renewable resource and abundantly available. It gives an endless static supply through the time. As solar energy is free from pollution it is also known as a green source of energy [1].

Solar energy is obtained from sun in the form of light and heat. It is replenish able and freely obtainable source of energy on earth and can be converted into electricity using the photovoltaic cells. It is sometimes called PV cells or solar cells. A photovoltaic cells use sunlight and convert it directly to electricity leaving the environment free from pollution. The maximum efficiency of solar panel is 24.5%.

Efficiency can be improved by enlarging the cell efficiency, maximization of power output and by using a tracking system.

Solar tracking system is a device that orients a solar panel according to the movement of sun for maximising the intensity of sunlight. It automatically changes its position when the intensity of sunlight decreases. Solar tracker is designed in such a way that the angle between the sunlight and solar panel is maintained around 90 degrees at all the times. Using solar trackers electricity production can be increased by around 40% when compared with fixed modules. This tracking system can move a 180 degree of rotation. Therefore, solar tracker is much superior then a stationary module.

SOME COMPONENTS REQUIRED IN SOLAR TRACKING SYSTEM

Solar tracking system has the following main components:

1. **Tracking algorithm**
   They are exerted to determine the angles which are used to figure out the position of solar tracker. Basically tracking algorithm are of two types- Astronomical algorithms and real-time light intensity algorithms. An astronomical algorithm is completely mathematical that is programmed through computer which drives the motors forrotating the panels in precise angle. Whereas, the real-time light intensity algorithm is based on the readings of real time light intensity.

2. **Tracker mount**
   It is the skeletal used for holding of solar panel upon which the panel is placed in a proper inclined position.

3. **Drives**
   Drives are used for controlling the rotation of the motor shaft that is based on the load.
4. **Sensors and Sensor Controller**
   They are used to detect pertinent parameters stimulated by the sun and manipulate it in the controller which then gives output.

5. **Motor and Motor Controller**
   A motor is used to convert electrical energy into mechanical energy. Whereas a motor controller determines that correct amount of current is given to microcontroller and motor.

COMPARISON BETWEEN SOLAR TRACKING SYSTEM AND FIXED PANEL

In a region of renewable resources, sun has been chosen as the most important energy sources because it is abundant in nature and will not be limitedly available. The energy from sun can be attained by using a device called solar panel. It generates electricity by absorbing sunlight as a source of energy. There are two methods in generating electricity from sunlight: fixed-tilt system and solar tracking system. A fixed-tilt system placed the module at fixed position which means that even if the sun moves it will not follow the sun accordingly. Whereas solar tracking system follows the movement of sun automatically and continuously track the sun throughout the day. Figure.2 shows the comparison of power energy obtained from the sun between fixed-tilt and tracking system. Solar tracking system can be single axis or dual axis trackers. These tracking system increases the energy level by 15-30% compared to fixed-tilt system.

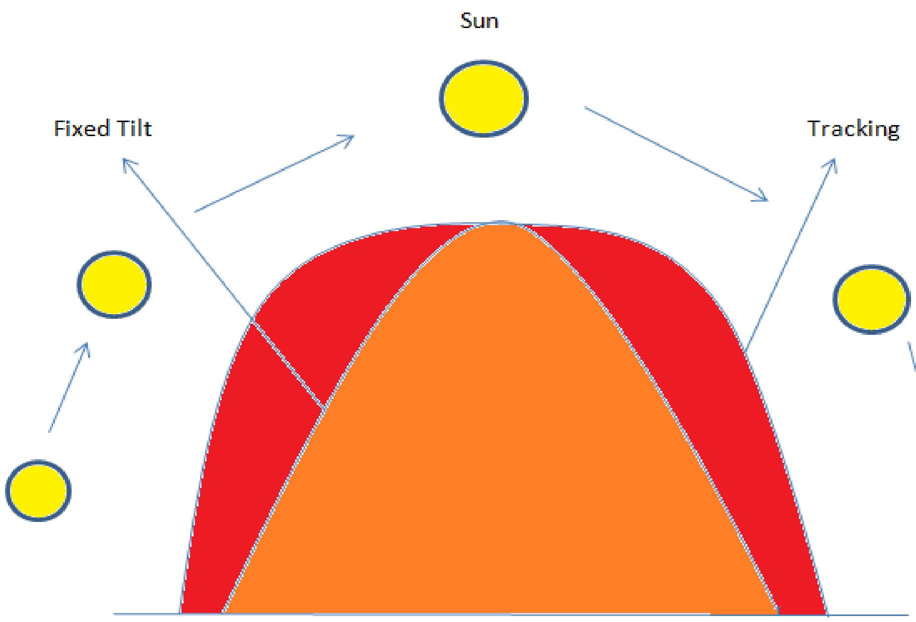

Figure-1: Fixed-Tilt vs. Solar Tracking

The mostly used tracking system today is single axis tracker as it is economical and suitable in operation. However, the cost and maintenance in dual axis tracker is high and complex but it can boost the energy level by 5-10% compared to single axis trackers. Because of the quick drop in PV module cost has led investors to improve a system's power capacity (number of modules) to attain more energy rather than working on complex tracking systems that enhance efficiency. However, single axis trackers have some drawbacks that they are not always suitable in technical and economical. Technical issues are mainly site topography, wind loads and soil conditions.

To obtain and install the system trackers are more extortionate than fixed-tilt tracking systems. This include the most basic additional cost in a financial model. Tracker systems cost a premium of 15-20% for the overall system of similar size and generally have larger footprints per megawatt when compared to fixed-tilt systems.
Typically tracking systems need 4-7 acres per megawatt whereas fixed tilt need 4-5 acres per megawatt. An additional 20% of acreage for tracking systems is a good rule thumb for checking the economics.

Compare to fixed system, tracking systems are more expensive to maintain as they contain sensors, motors, and moving parts whereas fixed-tilt systems do not possess. Because of these they require extra maintenance and add cost. But the tracking systems can achieve more energy compared to fixed-tilt systems.

DIFFERENT TYPES OF SOLAR TRACKING SYSTEM

Basically there are two types of solar tracking system- Single axis tracker and Dual axis tracker.

SINGLE AXIS TRACKER

Single axis tracker merely means that it has single axis of rotation. It's axis of rotation is normally aligned along a true north meridian. They normally follow the sun's movement from east to west on a period of day. It enhances energy level by 25-35%. The axis of rotation that single axis tracker consists are:

Horizontal single axis tracker (HSAT):
It is the most common type of single axis tracker design and is more suitable for small latitudes. Its axis of rotation lies horizontally concerning to the ground. They are very flexible and rotate from east to west on a fixed axis which is parallel to the ground. Suitable gaping can maximise the ratio of energy fabrication to cost, depending on topical area and shadow climate and a period of day value of the energy output. Horizontal tracker typically face the module situated aligned to the axis of rotation. It brushes a cylinder like a module paths which is rotationally symmetric close to the axis of rotation. These trackers are classically utilized for huge allocated generation projects and feasibility scale projects.

Vertical single axis tracker (VSAT):
These trackers have vertical axis of rotation with respect to the ground. They usually rotate from east to west throughout the day. Comparing to horizontal axis trackers these trackers are more operative at high latitudes. To keep away from needless energy losses and to enhance land utilization, a field layout must observe. Limitation in optimizing for dense packing is observed due to the nature of shading over a year. Vertical single axis trackers typically have face of the module oriented at an angle with respect to the axis of rotation. It brushes a cone like a module paths which is rotationally symmetric surrounding the axis of rotation.

Tilted single axis tracker: They are usually known because of the trackers having its axes of rotation between horizontal and vertical. For reducing the wind profile and decreasing the elevated end height, tilt angles of this angle are often limited. They typically face the module oriented parallel to the axis of rotation. It brushes a cone like a module tracks which is rotationally symmetric surrounding the axis of rotation. This trackeroffers optimal efficiency and solar tracking capabilities by tracking the sun throughout the day.

Polar aligned single axis trackers
These trackers are well known standard technique in ascending a telescope reinforce shape. The tilted single axis is aligned to the axis of rotation at polar star. Therefore, it is called a polar aligned single axis tracker.

DUAL AXIS TRACKER:

Dual axis tracker has two degrees of freedom. It tracks the movement of the sun from East to West through the day, and from East to North or South through the season. The movement from East to West also known as Zenithal Angle and the other from East to North or South that happens through the year also called Azimuthal Angle. As this tracker move along the sun's direction vertically and horizontally, they help to achieve maximum solar energy. It improves the solar output by 40-45%. They are classified by the orientation of their primary axes with regard to ground. This tracker has two standard implementations. They are –

Tip-tilt dual axis trackers (TTDAT):
A tip-tilt dual axis tracker has primary axis which is set horizontally with respect to the ground. Its secondary axis is normally referred to the primary axis. In this tracker, a panel array is ascended on top of a long pole. By spinning the array about the peak of a pole a movement from east to west takes place. To reduce the installation price, one end posts of the primary axis of rotation can be distributed among trackers.

They are very flexible and its axis of rotation which is parallel to one another is mandatory for suitably orienting the trackers with regard to one another. They can be packed without shading at any density with backtracking. Its axis of rotation is usually
positioned either along a true North Meridian or an east-west line of latitude. Using advanced tracking algorithm, it is feasible to orient them in any fundamental direction.
Azimuth-altitude dual axis trackers (AADAT): These trackers have its primary axis which is set vertically with reference to the ground. The elevation axis also known as secondary axis is ordinary just as the primary axis. Its function is quite same to tip-tilt system, but they vary in the array rotation for everyday tracking. They use a large ring mounted on the ground with the array mounted on a series of rollers instead of rotating the array around the top of the pole. The main advantage of this tracker is that it allows to support larger arrays. However, compare to TTDAT, it may decrease the system density especially considering inter-tracker shading when the system is placed close together than the diameter of the ring. They are largely used in different research on tracking system based on their references.

SOME IMPORTANT LITERATURE SURVEY

The following are the review paper on two different tracking systems based on their mode of rotation.

Review on single axis solar tracker:

1. **Mayank Kumar Lokhande** presented an automatic solar tracking system. He designed a solar panel tracking system based on microcontroller and observed that single axis tracker increases efficiency by 30% compared to the fixed module.

2. **Guiha Li, Runsheng Tang, Hao Zhong** investigated horizontal single-axis tracked solar panels. They obtained result as east-west axis tracking was poor to improve the energy while tracking the sun about south-north was best. The efficiency increased for east-west axis was less than 8% whereas for south-north axis increased by 10-24%.

3. **Chaiko and Rizk**developed a tracking system using solar panels efficiently. They designed a simple single axis tracking system using stepper motor and light sensor. They observed that this system stretches the efficiency of power collection by keeping a solar panel perpendicular to the sun rays. And they also found that the power gain was increased by 30% over static PV system.

4. **Imam Abadi, Adi Soeprijanto and Ali Musyafa** designed fuzzy logic based single axis solar tracker. They implement a fuzzy logic controller on ATMEGA 8353 microcontroller to improve the power energy of PV panel. They found that the PV panel has maximized and it exceeded upto 47% compared to the stationary system.

5. **Ashwin R, Varun A.K** presented a sensor based single axis solar tracker to achieve highest degree of energy through solar panel. It keeps tracking continuously for the maximum strength of light. This system spontaneously changes its direction when the sun moves from its position to get maximum light energy. Therefore, the experimental result shows the robustness and productiveness of the proposed method.

6. **Gamal M DOSOUKY, Abou-Hashema** presented an enhanced orientation design for energy-productivity in PV panels. For maximum incident radiation, the panels are pitched with monthly-based angle. They investigate the proposed strategy in two cities i.e. Japan (Fukuoka) and Egypt (AI-Kharijah). The results showed that the proposed design attained a growth of energy building in both the cities.

7. **In 2013, Anusha, Chandra, and Reddy** designed solar tracking system based on real time clock. They compared a static photovoltaic (PV) panel and single axis tracker based on real time clock using ARM processor. The experiment demonstrated that the tracking system build up the efficiency about 40% and the energy achieved from the sun is enhanced from 9:00 am to 6:00 pm.

8. **Tiberiu Tudorache and Liviu Kreindler** presented a tracking system devoted to the PV conversion panels. The proposed design certifies the perfection of converting solar energy into electricity by genuinely aligning the solar panel according to the actual posture of sun. The result concluded as output energy is maximized by the PV panel through desirably locating implemented only for adequate amount of light intensity.

9. **Hussain S. Akbar** designed a single axis tracker using AVR microcontroller. The sun was tracked in Azimuth axis. The result showed that the designed sun tracker improved the output power gain by 18-25% compared to static panel in Kirkuk city, Iraq. In order to get more efficiency, they modified the tracker system using another solar panel which is placed parallel (infront side) and opposite to the first panel (in front side). Therefore after the modification, result showed that output power in opposite solar panel gives about 56.49% higher than single axis panel tracker and 64.60% compared with the fixed panel.

10. **Asmarashid Ponniran** developed an automatic solar tracking system which tracks the intensity of light by keeping the solar panel perpendicular to the sun in order to maximized power energy. Besides, they also used DC geared motor with low speed for omitting parameter of motor speed so that the panel focus only in following the sun's intensity. Therefore, the result showed successful that maximum output power was tracked regardless motor speed.

Review on Dual Axis Solar Tracker:

11. **V Sundara Siva Kumar and S Suryanarayana** proposed a dual axis tracking system to implement and develop a simple and efficient control scheme with only single tracking motor. Their main motive is to improve the power gain by accurate tracking of the sun. In this paper they successfully designed, built and examined a dual axis sun tracking system and received best result. They concluded saying that this tracking technology is very simple in design, precise in tracking and inexpensive.

12. **Dhanalakshmi.V, Lakshmi Prasanna H.N** presented a smart dual axis solar tracker. They used arduino uno for the development of their proposed model. After the experiment, they observed that maximum voltage was tracked about 25% to 30% and the generating power increased by 30% compared to static system.

13. **M.Kacira** overlooked the cause of a dual axis solar tracking with development of power energy compared to a fixed PV panel in Sanliurfa, Turkey. They found that everyday power gain is 29.3% in solar radiation and 34.6% in power generation for a particular day in the month of July.

14. **In 2017, Chaitali Medhane, Tejas Gaidhani** implemented a microcontroller based dual axis model working on a solar panel. Through this model, they observed that the solar panel extract maximum power if the solar panel is aligned with the intensity of light receiving from the sun. It improves the power output and also precaution necessary for the system from rain and wind.

15. **Midriem Mirdanies, Roni Permana Saputra** proposed dual axis system with a combined method of an Astronomical algorithm and camera based feedback processing for localizing and tracking light intensity to increase the efficiency in achieving power energy. They also designed a compound algorithm method to merge approximation data of the sun acquired from astronomical based and visual based feedback. After simulation, it resulted that the azimuth and elevation sum squared errors from the proposed algorithm are 0.3688 and 0.3874 degree, and the astronomical algorithm are 1.0997 and 1.2877 degree.

16. **S.B. Elagib, N.H. Osman** describes the development of solar tracking system based on solar maps using microcontroller, which can forecast the real detectable position of the sun by latitude's location for maximizing the efficiency of energy level. Their main motive of this design was to work with minimal operator interaction in the isolated areas where there is lack network coverage.

17. **Jing-Min Wang and Chia-Liang Lu** presented a simple execution of sun tracker with one dual-axis AC motor to predict the sun's position and used a stand-alone PV inverter to energise the whole system. They worked on May 2012 in New Taipei City, Taiwan and the day was slightly cloudy. A static panel was placed along the south at a tilt angle of 23.5 degrees with maximal standard solar radiation when the latitude of Taiwan is 23.5 degree along north. The experiments resulted that their system raised the energy level up to 26.31% for a slightly cloudy day.

18. **M.M. Abu Khader**observed an experiment under Jordanian climate on the cause of utilizing two-axis sun tracking systems. They found that the power outcome improved by 30-45% compared to static system for particular days.

19. **Song et al.** presented dual axis tracking system based on hybrid scheme. This system was based on two stage tracking process using a photosensitive sensor and a coarse adjustment with coordinate calculation algorithm. They used optical fibres for tracking of concentrated sunlight. Therefore, they observed that system followed the sun's focal area with a position accuracy of less than 0.3mm and the tracking angle accuracy is 0.1o.

20. **In 2010, Mohammed et al.**designed an automatic two axes sun tracking system using solar cooker. This system removed standing in the sun for a period of time to get continual tracking and

facing the intensive solar cooker. In the year 2008, they performed the test continuously for three days from 8:30 to 16:30 hours and the result obtained that for maximum registered ambient temperature i.e. 36o C, a water temperature inside the cooker's tube reached 90o C in normal sunny days.

WORKING PRINCIPLE OF SOLAR TRACKING SYSTEM

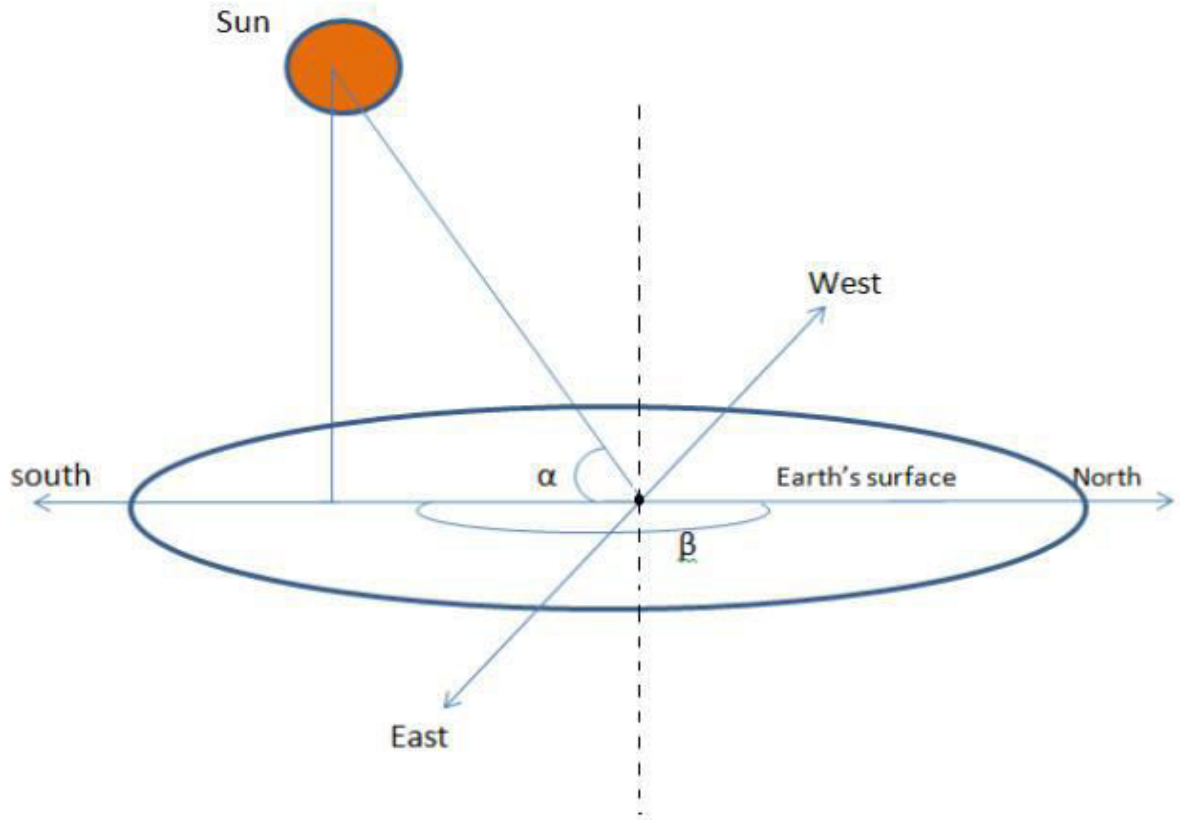

Figure -2: Illustration of solar angles.

Solar tracking system is a device which follows the movement of sun all over the day and gives successive reflection to the solar. The illustration of solar angles (a) altitude angle, α and (b) azimuth angle, β is shown in figure.2. The rays of the sun tumble directly on the solar panel and also the reflector reflects the incident rays on the solar panel. Assuming that, the sun is in highest degree at the time of sun rise then the reflector will adjust itself in sun's position by which the incident rays will fall on the solar panel. Thus the light will fall on the sensors kept on each side of the solar panel. The tracking system is so designed that when reflection falls on the sensor attached to the right of the panel, the tracker will move towards the left and vice-versa. Similarly, when the reflection falls on the sensor attached at the top of the panel, circuit will make the tracker to move downwards. The tracker is liable for two kinds of rotation, one is on the vertical axis for right-left movement of the reflection on the panel, and the other is on the horizontal axis for up-down movement of the panel.

The motion of the tracker is controlled by two different drivers: Passive and Active trackers.

Passive solar tracking method generally uses an open-loop approach using a closed loop. In order to guide and move the tracker, this tracker solely depends on solar heat. To change the position and variation of the tracker generated by the heat from the sun, a low boiling point compressed gas fluid should be driven to one side or the other.
Active trackers trace the direction of the sun's movement using a controller in order to direct motors that move the trackers.

Light Dependent Resistor (LDR) working as a sensor is mostly used in active solar tracker. The outcome of this tracker is used to create error signals. In these systems, sun tracking from east to west ends when the outputs of both eastern and western LDR's become equal. They use complex algorithm to calculate the distinction in light of different sensors and also to calculate the present sun's position. With this, they determine how much and in which position the solar panel will move so that the panel gets align 90 degrees to the sun.

FUTURE SCOPE

Solar tracking system is the most prominent and is chosen as the best alternative for obtaining maximum energy production in the photovoltaic (PV) system. It tracks the sun and maintained the solar panel perpendicular to the intensity of sun continuously. In future, details of this paper will be useful in selecting a precise tracker with regard to location, cost and space available. The current work may be helpful in improving the model characteristics and performances of different tracking systems. My work ahead is designing a two axis solar tracker without using sensor to predict the sun's apparent position.

CONCLUSION

This paper has presented a review of many researchers on different tracking system which makes the solar panel perpendicular to the sun for obtaining maximum solar energy. Overall, the result showed successful in all the review paper. Different types of tracking system like single axis trackers and dual axis trackers has also been discussed here. However, overviewing the cost, maintenance and flexibility single axis trackers is more preferable than dual axis trackers. Therefore, for capturing more energy, tracking the solar is the best way because it results an efficient, profitable and clean energy production.