IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 9, Issue 6, June 2021

DOI 10.17148/IJIREEICE.2021.9608

Review on Solar Tracker and Comparison on Single Axis Solar Tracker, Dual Axis Solar Tracker with Fixed Solar PV System

Shail Patel

Student, Dept. of Electrical Engineering, MITS Gwalior, M.P., India

Abstract: Nowadays electrical power is basic requirement in our life. We cannot survive without the electricity, solar energy is best way to produce electricity for basic need. Solar energy is comprehensive, larger, green renewable source energy. Due to their lots of characteristic overall world research the best way to use the solar energy, solar tracker is one of the best example. This paper reviews about the types of solar tracker technology and fixed solar photovoltaic system. It mainly focuses on comparison of single axis solar tracker, dual axis solar tracker and fixed solar PV system.

Keywords: solar energy, solar tracker, fixed PV panel, efficiency, sun rays, electrical energy.

I. INTRODUCTION

Energy is considering as never lasting object. The consumption of energy is related directly to the progress of industrialization and economy of the country, also beneficial to man power.
Solar power is converted sunlight into electricity that means solar energy into electrical energy, by directly using photovoltaic, or indirectly using concentrated solar power. Concentrated solar power that is CSP systems is use lenses or mirrors and system is focus to large area of sun rays into a small beam. By using photovoltaic effect they convert light into electricity. During the operation, PV panel generated or produce higher efficiency of energy when the sun ray is perpendicular to the surface of PV panel. This is achieved by using a PV panel mount or tracker system which tracks the movement of the sun for a whole day. Therefore researchers are done many investigations to increase the efficiency of PV panel using the solar tracking system.

II. LITERATURE REVIEW

Solar energy is a renewable energy using everywhere, in this paper explanation of solar tracker and fixed PV solar system and a comparison of efficiency of single axis solar tracker, dual axis solar tracker and fixed solar PV panel. Solar tracker produces the electricity in large amount because of their tracking technology, solar panel always track the sun as compared to the fixed mount PV system. Solar system produces more energy when sun is perpendicular to PV panel. At a perfect angle solar system consume large amount of solar rays and produce electrical energy. Solar tracker can be adjusted their angle towards the sun automatically therefore they produce more energy. Fix mounted PV panels are constructed at a fixed angle so they cannot consume sun rays all over day.

Ⅲ. SUN TRAJECTORY

The axis of the earth is tilted about 23.5 degrees, related to the plane of the earth's orbit around the sun. As the Earth orbits the Sun, this creates the 47° declination difference between the solstice sun paths, also because the hemisphere-specific difference between summer and winter. Because of the changing position of sun that is varies at different time and season to season due to earth continuous periodic rotation and evolution. As the result it is mandatory to locate the sun at particular movement. In the Northern Hemisphere, the winter sun (November, December, January) rises in the southeast, peaks out at a low angle in the south and then sets in the southwest. In the southern hemisphere, the winter sun (May, June, July) rises in the northeast, peaks out at a low angle in the north, and then sets in the northwest. In the Northern Hemisphere, the summer sun (May, June, July), rises in the northeast, peaks out slightly south of the overhead point, and then sets in the northwest, whereas in Southern Hemisphere, the summer sun (November, December, January), rises in the southeast, peaks out slightly north of the overhead point, and then sets in the southwest. The amount of solar radiation or intensity on the solar PV panel will be highest when the solar PV panel surface is at 90 degrees to the sun's radiation.

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Ⅳ. SOLAR TRACKER

Solar tracker is a device that rotates the panel always towards the sun. By use of solar tracker we can increase the electricity production and some investigations result are show that they produce as much as 40% more energy at some regions, compared with fixed PV solar system. In the solar application, the efficiency is improved when the system is continually adjusted to the correct angle as the sun is rotating in the sky. Solar tracker is rotating the solar panels in such a way that solar panel is always following the direction of the sun to produce maximum energy from the sun. In photovoltaic applications, tracking system is used to obtain the perfect angle for tracking the sun during the day by solar panel. Trackers are minimized the angle of incidence between the incoming sun rays and a PV panel. They increase the amount of energy production than fixed solar PV system that has also a power generating capacity.

Classification of Solar Tracker: Solar tracker are classified in below field based upon control system, drivers used, degree of freedom, tracking strategy.

1. Based On Control System:

1.1 Closed Loop Tracker: The closed-loop control system is basically predicted on a feedback system. It uses sensors and moves the axes of the PV tracking system after the sensor detects the position of the sun. The closed-loop tracking systems are more expensive than open-loop tracking system because they use sensor devices. When weather is change, closed-loop systems can consume more energy than is produced by simple photovoltaic system, so there combination gives additional and more benefits and it is called a hybrid control tracking system.

1.2 Open Loop Tracker: This system uses a controller which provides the driving signal to the motor on the basis of current data inputs and operating algorithm of the system. Open loop tracker has no feature of observing and calculating the output data in regards to the desired output. Therefore it is less expensive and simple to installation as compared with the closed loop tracking system. They involve no rectification process and therefore the system algorithm alone to ensure that it achieves the desired goal.

2. Based On Driving System:

2.1 Passive Tracker: Passive trackers are use pair of actuators and that they filled with expansible gas or an on-shape memory alloy. This system is depends on the concept of thermal expansion, or an imbalance in pressure between two points at the both ends of the tracker. When the PV panel is perpendicular with the sun, the two sides are at equilibrium. Once the sun moves, one side is heated and because of this one side is expand and the other to contact, causing PV panel to rotate. Passive tracker does not use sensors, any mechanical drives. Its working technology is not complex than active tracker. Passive systems are not used too much and they not need to additional power supply to operate. Therefore it is less complex and effective but it not gives high efficiency at low temperatures.
A new low cost shape memory alloy based sun tracker [3] developed which could collect up to 40% solar energy in comparison to the fixed solar panel.

2.2 Active Tracker: Active tracker is used electrical energy as there source, they are more accurate and efficient than passive solar tracker. They use sensors, motors and microprocessors for their tracking technology. The position of the sun is continuously identified by the sensors during the day. The sensor starts the motion of motor or actuator in a way that the solar panel will always face the sun for the day. Accuracy of active tracker is increase with the help of sensors. If the sun is not facing directly to the tracker there will be a difference in light intensity on one light sensor compared to another and because of this the calculation was not correct that in which direction the tracker has to tilt with the help of the stepper or dc motor in order to be facing the sun. They consist of motors and moving part therefore they required regular maintenance. But the main problem occurs when sensors fail to differentiate between measurements and give false signal or miss signal during cloudy days.
An active sun tracker was introduced [3] when experimenting for thermal efficiency enhancement. The result shows that the tracker based system showed an overall gain of 40% in stored thermal energy in comparison to the fixed one.

3. Based on Degree Of freedom: It represents number of directions in which independent movement can occur, based on this tracking system can be classified into single axis solar tracker and dual axis solar tracker.

Before going to this classification we have to understand the different kind of angles which play an important role in these trackers-

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A. Azimuth angle: it is the angle showing that the tilt of the sun rays to the north in clockwise direction. In the spherical coordinate it is angular measurement.

B. Altitude angle: It is angular height of sun measured from the horizon. Above the horizon the angle is positive and below it is negative.

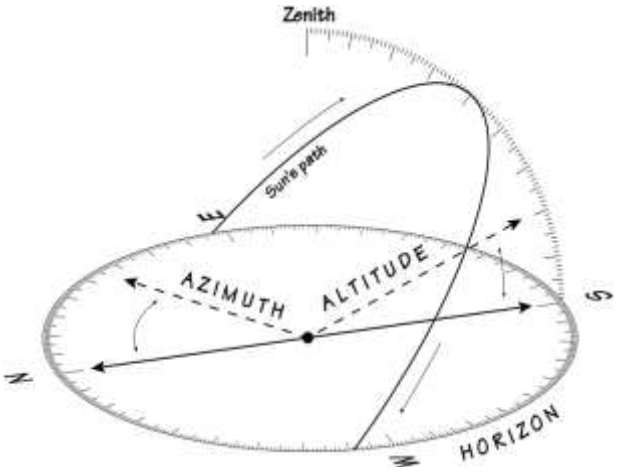

Fig. 1 Azimuth and Altitude angle [4]

C. Latitude angle: It is the measurement of position of point on the earth's surface that determines how north and how south point lies with respect to the equator.

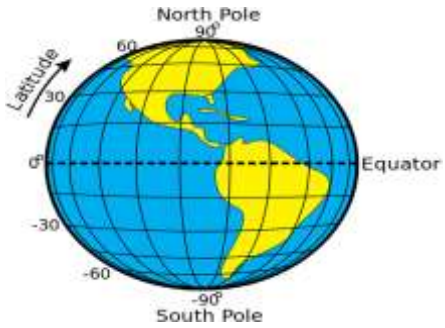

Fig. 2 Latitude [3]

D. Tilt angle: It is the angle between the PV solar panel and the horizontal axis. Angle of incidence is form of tilt angle.

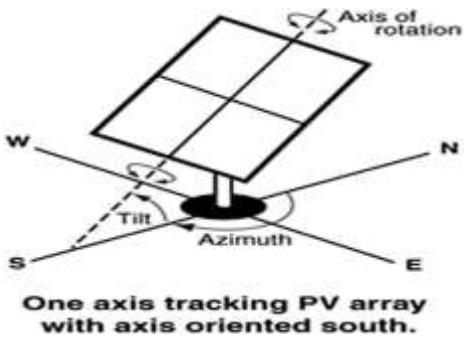

Fig. 3 Tilt angle [3]

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3.1 Single Axis Solar Tracker: This system has one degree of freedom, they continues follow the sun either vertical or horizontal. The horizontal type solar tracker are used in tropical regions where the sun gets very high at noon but the day is short whereas vertical type solar tracker are used at high latitudes where the sun does not get very high but the summer days can be very long. These are the classification of single axis solar tracker which include HSAT (horizontal single axis trackers), VSAT (vertical single axis trackers), TSAT (tilted single axis trackers) and PSAT (polar aligned single axis trackers). The name was based on these tracker is how tracker rotate in reference to the surface, like HSAT motion is horizontal to ground. VSAT motion is vertical to the ground and is aligned to the east to west direction. TSAT axis is projected at angle from the horizontal or vertical. And PSAT aligned to the polar star which has also a tilted axis. In the case of concentrated solar energy processes, single-axis trackers are used with flat surface solar module. Single axis solar tracker is less complex and cheaper but less efficient than dual axis solar tracker.

Fig. 4 Single axis solar tracker (TSAT, HSAT, VSAT) [7]

3.2 Dual Axis Solar Tracker: This system has two degree of freedom, whose axes are perpendicular to each other. In dual axis solar tracker, the axis which is fixed with respect to the ground called as primary axis and the axes which take reference to primary axis called as secondary axis. Dual axis trackers are capable to position themselves towards the sun so they contact sun direct for generating maximum power. They are more complex but also more efficient than single axis solar tracker. Also for large scale solar energy production always recommended dual axis solar tracker rather than single axis solar tracker. Dual axis solar tracker is classified in following two categories tip tilt dual axis solar tracker and azimuth altitude dual axis solar tracker. In tip tilt dual axis solar tracker (TTDAST) primary axis is horizontal to the ground and secondary axis is perpendicular to the primary axis. In azimuth altitude dual axis solar tracker (AADAST) primary axis is vertical to the ground and secondary axis is perpendicular to the primary axis.

Fig. 5 Dual axis solar tracker (TTDAT, AADATD) [7]

4. Based On Tracking Strategy:

4.1 Date and time: This tracking strategy purely depend on predefined mathematical calculation, they not use any sensors to track the sun. They not use any feedback loop to position the PV panel towards the sun. They work on predefined mathematical calculation of azimuth and altitude angle so that they can track the sun at a particular time and date.

4.2 Microprocessors and electro optical sensors: This tracking strategy uses sensors to detect the exact sun position and the signal is provide to microprocessor who gives signal to the motor for further work.

4.3 Sensors, date and time: This tracking strategy work on predefined algorithm, mathematical calculation but they use also sensor to check the operation. They verify position of the sun by predefined calculation and orient the panel according the position.

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V. FIXED SOLAR PV SYSTEM

Fixed PV system is represented as most common uses of PV system and can be mounted directly on roof of the buildings at a same slope according to roof of the building. Or it can be mounted on ground using steel frameworks. To achieving maximum efficiency from the solar panels they need to be pointed at a particular direction where they receive more amount of sunlight. For northern hemisphere it must be faces on southward direction whereas for southern hemisphere it must be faces on northward direction. Fixed solar system is stable, simple in construction, simple in design and easy for maintenance. Fixed solar system is flexible and need to be little maintenance. They are not moving towards the axis because they fixed at a particular axis for a day for a year so they are produce less amount of energy. As they installed on roof of the building there is no blockage from the tree or building.

Fig. 6 Fixed solar system [11]

1. Seasonal Tilt Solar System: Seasonal tilt solar system: it is a kind of fixed tilt solar panel except there angle is changed seasonally. It is more efficient than fix tilt solar panel. It gives high amount of solar energy than fixed tilt solar system because they consume more amount of solar radiation over the time. Seasonal tilting can be achieved in two ways by manually either twice or four times in a year. It is done by adjusting the bolts and nuts given in the slots. For the tilting of solar panel in twice a year, the tilting angle of solar PV module is changed by dividing one year into two periods. And for four times in a year, tilting angle of solar PV module is changed by dividing one year into four periods.

Fig.7 Seasonal tilt solar system [11]

VI. COMPARISON OF SINGLE AXIS SOLAR TRACKER WITH FIXED SOLAR PV SYSTEM

Many researchers are investigated performance analysis of single axis solar tracker with fixed solar PV system. Here are few performances given-

1. Single axis solar tracker is designed [2] in which sun tracking is done by two photo resistors. A PLC is using to control and monitor the automatic movement of PV panel and collect data and also store data which is related to sun

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radiation. It is measure from research that daily output power is increased by 20% as compared to fixed solar PV system.

2. A novel design of single axis solar tracker was introduced [7]. It uses two photo-resistors additional with low concentration reflector. It is a three position tracking PV module (morning, noon, afternoon). The result shows that approximately 56% and 25.4% higher energy production compared to fixed solar PV panel with and without use of low concentration reflector.

3. Efficiency of fixed solar PV panel over single axis solar tracker [10] is calculated and the power output for one single day is determined. The average power values proving that single axis solar tracker is more efficient than fixed solar PV panel. Single axis solar tracker produces more power. The power efficiency of single axis solar tracker is 13% more than fixed solar PV system.

4. Single axis solar tracker was [11] introduced for review and calculated the efficiency. Solar tracker surface is perpendicular to the sun, so that solar panel continuous track sun rays. As the result solar radiation loss was decreased which are related to energy that was reflected by collector side and the efficiency of solar device was maximum. So that the efficiency of solar tracker was increased by 1.4 times more than stationary operated flat plate solar panel.

5. Single axis solar tracker and fixed mounted solar PV system are introduced [12] and checking their efficiency for a single day. Result was proof that over a clear sky day the average efficiency of single axis solar tracker was about 67.65% whereas fixed solar PV panel was about 51.65% for the same the day. The increase in percentage of average power output of single axis tracker over fixed mounted solar panel was 30.12%. The efficiency of single axis solar tracker is higher than fixed solar PV system before 11 am and after 3 pm. At this time the average efficiency of single axis solar tracker was 66.70% and for fixed solar PV panel it was 39.96%. So the percentage increases of average power output for single axis solar tracker reached up to 66.92% compared to fixed solar PV system for this period. As well as the efficiency of single axis solar tracker is higher than fixed solar PV system at same period and reached up to 28.9% at 6 pm. Efficiency of both single axis solar tracker and fixed solar tracker at midday is almost equal. Because both panels received equal amount of solar radiation and the direction of sun was perpendicular to the panels.

Ⅶ. COMPARISON OF DUAL AXIS SOLAR TRACKER WITH FIXED SOLAR PV SYSTEM

There is lots of performance analysis is done by many researchers for dual axis solar tracker with fixed solar PV system. Here are few given below:

1. Dual axis solar tracker [2] designed and PLC is used. PLC is control the movement of solar panel surface. The result is compared with fixed solar panel which is tilted 32 degree towards south. And it is measured that dual axis solar tracker is produce daily 40% more energy than fixed solar system.

2. The design of two axis solar tracker system [3] is proposed with open loop control system of electric drive which gives good results in terms of tracking the motion of the sun. With the proper selection of elements of electric circuit and photo sensors is being used for the system control the tracking of the sun is very accurate. The result was evaluated that two axis solar tracker is produced more amount of electrical energy about 27% than fixed solar PV system.

3. A continuous dual axis solar tracker was designed [7] with two electronic circuits (comparators and solar intensity level), four relays, two phototransistors, two AC Siemens motors, gearbox MOTOVARIO and C+ programming language. The experimental result shows that dual axis solar tracker has 46.46% more solar energy gain as compared to fixed solar PV system during clear weather. In cloudy days the efficiency is reduced because of low intensity solar radiation due to sensor based technology.

4. Dual axis solar tracker was [8] introduced for review. A tracker that deployed an artificial intelligence approach, a PC based fuzzy logic control is provided that accomplished data through photo diode to drive motors. The system increased efficiency about 50% more than fixed solar panel.

5. Dual axis solar tracker [9] is designed that implement sun trajectory path algorithm to show the solar tracker position. This system uses GPS sensor to identify the solar panel position that is referring to longitude and latitude lines. The azimuth and altitude angle are employed to feed directly the positioning controller which command the motor to move either clockwise or anti clockwise. The result show that in clear weather and cloudy weather, the output energy is increased by 26.9% and 12.8% for dual axis solar tracker when compared to fixed solar PV system.

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6. Efficiency of dual axis solar tracker over fixed mounted solar panel [10] was calculated. The power output for a one single day is calculated. The average power values show that dual axis solar tracker produce more amount of energy than fixed mounted solar panel. The result show that dual axis solar tracker efficiency is 25% more than fixed mounted solar panel.

7. Automatic dual axis solar tracker was designed [13] to achieve the highest output power from the solar panel. Is uses sensors, microcontroller to motor drive with control algorithm, gear box and bearing arrangement for mounting and supports. It was concluded that solar tracker is more efficient than fixed solar PV system and produces output energy 30% to 45% more at atmospheric conditions.

VIII. FUTURE SCOPE AND LIMITATIONS

Solar photovoltaic tracker system has a big space for research purpose. At this area there is lots of space for innovations or improvements. The primary reasons for production and development of solar photovoltaic system is lower efficiency of photovoltaic tracker system as well as lower generation of electrical energy. Systems that improve the production of PV system are PV tracker system, PV system with concentrated mirrors, PV thermal or hybrid systems. Each of these systems has potential to increase the production of electrical energy. However the fixed PV system is less expansive to installation and much more uses over the world.

The area of research [3] for solar tracker is growing very fast therefore many development take place. The use of artificial neural network ANN in modeling different solar energy devices is produces higher accuracy higher capability to generate energy and taking short computational time. Artificial neural network and fuzzy logic are uses by overall world today, these tools are used everywhere every field so that it is also uses in solar tracker.

The purpose of fuzzy logic controllers are designed to obtain maximum power point tracking in PV system. Nowadays cascade control algorithm used for high concentrating PV system that is tracking the sun and capable to achieving tracking error of 1' (one minute). Many researchers and scientists are working on the optimization of energy extraction and an approach based on deep learning, low cost and computer vision open hardware has been developed to control the limitations regarding cost and operational problems. There are too many developments but many problems still faces so need more work in this field regarding operational efficiency, cost effectiveness and feasibility demand attention.

There are too many country uses solar energy to produce electricity but they still not use dual axis solar tracker. They mostly uses single axis solar tracker but dual axis solar tracker is more efficient. So that need to improve the single axis solar tracker efficiency but this will be more cost effective. As dual axis solar tracker installation is also more cost effective but produce more amount of energy. There are many factors affecting the solar radiation like humidity and solar intensity, so in future also need to work in this area.

IX. CONCLUSION

This paper represents the overall advancement of solar tracker and also the comparison between solar tracker and fixed mounted solar system by researcher point of view. This paper also review that efficiency of solar tracker is more but needed proper care while installment. Problems like failure of solar tracker also need equal attention while installing them. This paper shows the important factors regarding solar tracker. This paper concluded that solar tracking system is more effective method to track the sun radiation and provide economic consistency for electric power generation. The comparison of single axis solar tracker, dual axis solar tracker and fixed mounted solar tracker are given below-

1. Single axis solar tracker is more efficient than fixed mounted solar PV system, they produce more energy than fixed solar system and that is almost 30-50% more during clear weather.

2. Single axis solar tracker is almost equal energy produce during cloudy weather. There is little much difference between energy production.

3. Single axis solar tracker is more costly and more complex than fixed mounted solar tracker.

4. Dual axis solar tracker is more efficient than fixed solar PV system, they produces more energy almost 40-60% than fixed solar PV system during cloudy weather.

5. Dual axis solar tracker is produces little more energy than fixed solar PV system during cloudy weather.

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6. Dual axis solar tracker is more complex and more costly than fixed solar PV system.

7. In between comparison of single axis solar tracker and dual axis solar tracker, dual axis solar tracker is more efficient but also more complex design, control mechanism and more costly. They produce more energy than single axis solar tracker about 30-40%.

8. Dual axis solar trackers need more maintenance due to rotating parts.

9. Dual axis solar tracker is works well during cloudy weather than single axis solar tracker.

10. At midday or afternoon all panels produces almost equal amount of energy.

ACKNOWLEDGMENT

I would like to express my gratitude to my guides **DR HIMMAT SINGH** and **PROF RAHUL SAGWAL** for providing me a valuable guidance at every stage of this project work. I would like to show my appreciation. I offer my sincere appreciation for the learning opportunities provided by my guides.

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