A REVIEW ON SOLAR TRACKING SYSTEM

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ABSTRACT

The purpose of solar tracking system is to obtain optimization of captured energy. Solar tracker allows more energy to be captured and by the solar panel produced because the solar array is able to remain aligned to the sun since fixed facing of solar panel is widely used and may not effective for high power consumption. The average solar energy harvested by the conventional solar panels during the course day is not always maximized which is due to the static placement of the panel which limits their area of exposure. From the point of this review, it was obvious that the research through the invention of the solar tracking system including the improving system for obtaining optimum sun energy are very much recommended as tracking of sun position could be performed via many methods.

KEYWORD: solar tracker, solar tracking system

1. INTRODUCTION

Currently, renewable energy solutions are becoming increasingly popular. Renewable energy contributes to efficient energy collection, efficient storage and transport and efficient energy conversion. Among the renewable energy sources, typically solar energy affords great potential for conversion into electric power, able to ensure an important part of the electrical energy needs of the planet \[18\]. Solar energy has been widely used in human life, and it's expected to grow up in the next years. Solar energy is rapidly advancing as an important means of renewable energy resource. Solar energy is rapidly gaining notoriety as an important means of expanding renewable energy resources \[5\]. Solar energy systems have emerged as a viable source of renewable energy over the past two or three decades, and are now widely used for a variety of industrial and domestic applications \[6\]. Solar energy can be used as an electrical energy to operate an electrical appliances and devices. Nowadays, humans are becoming more conscious in seeking new energy sources that cause less pollution and do not threaten or harm the environment. This brought the solar energy as an ideal for generating electricity due to nonpolluting, free energy and inexhaustible energy \[21\]. Various methods in converting solar energy from the sun into electrical energy has been developed and use which most commonly through the use of a solar panel; so called photovoltaic. Solar panel or photovoltaic is now the biggest usage of solar energy around the world \[14\]. Photovoltaic cells are presently being used to convert solar energy into electrical energy as this energy is freely available and clean, therefore it is a source of energy that needs to be developed. An aspect affecting the performance of a photovoltaic cell is the angle of which the incident light form the sun strikes
the plane of the panel. The output is maximized when the light strikes the face perpendicularly. If the light from the sun can be kept perpendicular to the panel at all times, the power output of the cell would increase, and the number of cells needed to meet a demand would decrease. This minimizing the cost and increases the efficiency of the solar array \cite{20}.

2. SOLAR TRACKER

Currently, most solar panels are fixed and static position. The solar array has a fixed orientation to the sky and does not turn to follow the sun. This may contribute that the energy captured is not always maximized as the static placement of the panel limits their area of exposure from the sun. The efficiency with solar tracking methodology is 6.7\% higher than that with fixed angle. The oriented solar panels in the way of sun tracking would lead to the maximum power and increase the output by 30\%-40\% \cite{1}; significant enough to make tracking a viable preposition in spite of the enhancement in system cost.

![Figure 1: Position of the sun and solar panel](image)

Most solar panels are statically aligned where it has a fixed position at a certain angle facing to the sky. Therefore, the time and intensity of direct sunlight falling upon the solar panel is greatly reduced, resulting in low power output from the photovoltaic (solar) cells \cite{8}. Solar tracking system is the solution to this issue as it plays a major role in overall solar energy optimization. In order to ensure maximum power output from solar (panel) cells, the sunlight’s angle of incidence needs to be constantly perpendicular to the solar panel. This requires constant tracking of the sun’s apparent daytime motion, and hence develops an automated sun tracking system which carries the solar panel and positions it in such a way that direct sunlight is always focused on the solar panels. A solar tracker is a device for orienting a solar photovoltaic panel or concentrating solar reflector or lens toward the sun. The sun’s position in the sky varies both with the seasons (elevation) and time of day as the sun moves across the sky. Solar powered equipment works best when pointed at or near the sun, so a solar tracker can increase the effectiveness of such equipment over any fixed position, at the cost of additional system complexity \cite{13}. 
Solar trackers represent apparatuses that may significantly improve electric power production of photovoltaic panels. For detecting solar position, the trackers use different sensors such as photoresistor, photodiode receiver, phototransistor and etc \[^2\]. In solar tracking systems, solar panels are mounted on a structure which moves to track the movement of the sun throughout the day. Unlike the classical fixed solar panels, the mobile ones driven by solar trackers are kept under optimum insolation for all positions of the sun, boosting thus the solar conversion efficiency of the system \[^19\]. Maximizing power output from a solar system is desirable to increase efficiency. In order to maximize power output from the solar panels, one needs to keep the panels aligned with the sun \[^16\]. Solar trackers are devices used to orient photovoltaic panels, reflectors, lenses or other optical devices toward the sun. Since the sun’s position in the sky changes with the seasons and the time of day, trackers are used to align the collection system to maximize energy production.

**Figure 3: Examples of solar tracker**

3. CATEGORIES OF SOLAR TRACKER

3.1 Single Axis Solar Tracker

Single axis solar trackers can either have a horizontal or a vertical axis. The horizontal type is used in tropical regions where the sun gets very high at noon, but the days are short. The vertical type is used in high latitudes where the sun does not get very high, but summer days can be very long. In concentrated solar power applications, single axis trackers are used with parabolic and linear Fresnel mirror designs. The single axis tracking system is the simplest
solution and the most common method used in the research industry \(^{[13]}\). A single-axis solar tracker follows the movement of the sun from east to west by rotating the structure along the vertical axis. The solar panels are usually tilted at a fixed angle corresponding to the latitude of the location.

![Single axis solar tracker](image1.jpg)

**Figure 4: Single axis solar tracker**

3.2 Dual Axis Solar Tracker

Dual axis solar trackers have both a horizontal and a vertical axis and thus they can track the sun’s apparent motion virtually anywhere in the world. Dual axis tracking is extremely important in solar tower applications due to the angle errors resulting from longer distances between the mirror and the central receiver located in the tower structure. Dual axis solar tracker normally uses horizontal and vertical axis. The dual axis tracking system is used for concentrating a solar reflector toward the concentrator on heliostat systems. By tracking the sun, the efficiency of the solar panels can be increased by 30-40\% \(^{[12]}\). Currently the availability system in market are based on the sensor that capable in detecting the position of the sun. The systems complies with structure position adjustment by obtaining the signal from the sensor which conducted to the movement of two electrical motors. These systems have good accuracy, but are expensive in term setup costs \(^{[9]}\). A dual-axis solar tracker follows the angular height position of the sun in the sky in addition to following the sun’s east-west movement.

![Dual axis solar tracker](image2.jpg)

**Figure 5: Dual axis solar tracker**

4. METHODS OF SOLAR TRACKING

There are three methods of tracking: active, passive and chronological tracking. These methods can then be configured either as single-axis or dual-axis solar trackers. In active tracking, the position of the sun in the sky during the day is continuously determined by sensors. The sensors will trigger the motor or actuator to move the mounting system so that the solar panels will always face the sun throughout the day. This method of sun-tracking is reasonably accurate
except on very cloudy days when it is hard for the sensor to determine the position of the sun in the sky thus making it hard to reorient the structure [15]. Passive Tracking unlike active tracking which determines the position of the sun in the sky, a passive tracker moves in response to an imbalance in pressure between two points at both ends of the tracker. The imbalance is caused by solar heat creating gas pressure on a ‘low boiling point compressed gas fluid that is driven to one side or the others’ [15] which then moves the structure. However, this method of sun-tracking is not accurate. A chronological tracker is a timer-based tracking system whereby the structure is moved at a fixed rate throughout the day. The theory behind this is that the sun moves across the sky at a fixed rate. Thus the motor or actuator is programmed to continuously rotate at a ‘slow average rate of one revolution per day (15 degrees per hour)’. This method of sun-tracking is very accurate. However, the continuous rotation of the motor or actuator means more power consumption and tracking the sun on a very cloudy day is unnecessary.

5. COMPONENTS OF SOLAR TRACKER

The main elements of a tracking system are as follows [10]:

- Sun tracking algorithm: This algorithm calculates the solar azimuth and zenith angles of the sun. These angles are then used to position the solar panel or reflector to point toward the sun. Some algorithms are purely mathematical based on astronomical references while others utilize real-time light-intensity readings.
- Control unit: The control unit executes the sun tracking algorithm and coordinates the movement of the positioning system.
- Positioning system: The positioning system moves the panel or reflector to face the sun at the optimum angles. Some positioning systems are electrical and some are hydraulic. Electrical systems utilize encoders and variable frequency drives or linear actuators to monitor the current position of the panel and move to desired positions. The standard DC motor is not an acceptable method of controlling a solar tracking. This is due to the fact that DC motors are free spinning and subsequently difficult to position accurately. Thus, stepper motors are the most suitable as stepper motors are commonly used for precision positioning control applications with motion of angle by angle.
- Drive mechanism/transmission: The drive mechanisms include linear actuators, linear drives, hydraulic cylinders, swivel drives, worm gears, planetary gears, and threaded spindles.
- Sensing devices: For trackers that use light intensity in the tracking algorithm, sensors are needed to read the light intensity. Ambient condition monitoring for pressure, temperature and humidity may also be needed to optimize efficiency and power output.

6. SENSOR TECHNOLOGIES IN SOLAR TRACKING SYSTEM

6.1 Phototransistor

Phototransistor is act as the solar detecting device. The semantic of solar detection is the solar position in this case. The altitude direction of the detection addresses the solar position by the shade of parabolic shade. As shown in Figure 6(a), when the semantic of solar position is parallel to the phototransistors, the parabolic shape phototransistors will receive solar energy
in the ‘ON’ condition. In addition, when the sun orbits to its former position, the shades will form a shadow from and the phototransistor status will be on the ‘OFF’ condition. Note that the ‘OFF’ condition denotes little to no current flow in the system. Consider the semantic ‘ON’ status as ‘1’ and ‘OFF’ status as ‘0’. The phototransistor facing direction is 60°.

Figure 6: (a) Light Balance and Unbalance (b) Configuration

Therefore, in order to detect solar energy all the way through the altitude, the device is designed with 6 phototransistors; J1, J2, J3, J4, J5 and J6. As shown in Figure 6(b), the characteristic of this design assures that the device is capable of detecting solar energy whenever it begins.

6.2 Classical Sensor

A classical sensor for the sun position coordinate uses a pair of phototransistors mounted on titled planes. The angle of tilt of the plane is 90°. The device is encased to provide protection. The construction of the sensor is illustrated in Figure 7. There are two important problems: for each sensor the phototransistors must be quasi-identically, because the measurement method assumes identically currents in the case of identically irradiance. If the characteristics of the phototransistors are not identically, the position of the collector is not the optimal position. The second problem is the ageing semiconductor effect. The ageing phototransistors effects and the accidentally greasing of the sensor box induce a faulty function of the tracking system.

Figure 7: Classical Sun Sensor

6.3 Matrix Sun Sensor

The problems of the classical Sun sensor may be solved by the single matrix sun sensor (MSS) as it controls both axes of the tracking system. The inspiration for the MSS is the antique solar clock. MSS comprises 8 photo-resistors and a cylinder. The location of the cylinder is at
the center of the matrix structure of the photo-resistors, which are evenly distributed around a circle. If the position of the collector is not optimum, the shadow of the cylinder covers one or two photo-resistors. The photo-resistors are mounted circular, around the cylinder, as shown in Figure 7:

![Figure 8: Photoresistors Matrix](image)

The photo-resistor is a high resistance semiconductor whose resistance decreases with increasing intensity of incident light. It is a light dependent resistor device. The cadmium sulphide cell, CdS cell, is the most inexpensive type of photoresistor.

### 6.4 Sun Light Detector

The idea of the design consists of four light sensitive devices, such as LDR and photodiodes mounted on the solar panel and placed in an enclosure. The four light detectors are screened from each other by opaque surfaces as shown on the Figure 9. The sensors are configured in a way that LDR1 and LDR2 are used to track the sun horizontally meanwhile LDR3 and LDR4 allow tracking the sun vertically \[^3\]. To free the controller from reading each sensor output, each pair of the sensors, LDR1-LDR2 and LDR3-LDR4, is associated with a differential amplifier.

![Figure 9: Sun Light Detecting Mechanism](image)

In another application, the sensor system consists of two sensors: one to determine the position of the sun in the sky and another to determine the position of the sun’s movement from east to west. Each application consists of two Cadmium Sulphate (CdS) light dependent resistors (LDRs). The LDRs were placed as shown in Figure 10; a shadow will fall on one of the LDRs when the sensor is not pointing directly toward the sun resulting in difference of the level of resistance between the two LDRs \[^15\]. This difference will be detected by the microchip in the control system and will move the tracker accordingly so that both LDRs are pointing towards the sun.
6.5 Commercial Web Cam

The trackers currently in use apply discrete elements such as light dependent resistors or photodiodes to establish the approximate position of the sun. One of the main disadvantages of using this type of sensor is its high sensitivity to weather conditions such as temperature and humidity. To overcome this disadvantage, solar tracking systems which currently present a better performance and accuracy depend on sophisticated control systems and complex electronic circuitry. The use of low cost webcams as sensing elements in solar tracking systems has not been explored previously. Webcams provide a highly developed technological platform that can be easily adapted to any type of solar tracking mechanism [11]. Worth mentioning that in most of the solar concentrators, computers are frequently used to monitor and registering information regarding the amount of energy obtained, so that in most cases a computer is available and it does not imply any additional inversion.

The webcam was connected to a personal computer through USB port. MATLAB is used to implement a simple image processing algorithm on the incoming frames. Finally, the electronic control signal was output via the printer port of the computer Figure 10.

6.6 UV Sensor: Pyranometer

Pyranometers were first designed to measure total broadband solar radiation incident on the surface of the Earth. The pyranometer output presents, however, a dependence on the angle of incidence of the incoming radiation. The idea of using a pyranometer as sensor for the detection of solar position is related to two special needs [10].

Figure 10: Sensor response once a shadow is cast on one LDR

Figure 11: Block diagram of the solar tracker system using web cam
• First of all, it is the most suitable instrument for the measurement of solar radiation since this parameter is more important than sun position;
• Secondly, one should not forget that, in conditions of cloudy sky, there could be a small component of direct radiation and a substantial component of diffuse radiation. Using a pyranometer the PV (photovoltaic panel) can be located in order to be able to absorb the greatest amount of radiation as possible.

The pyranometer is manned to sense (Figure 12) and measure global irradiance, i.e. diffuse plus direct solar irradiance. The pyranometer can be mounted on a horizontal surface or in the same plane as a solar heat collector or photovoltaic (PV) panel when the global irradiation on these surfaces is of interest. Hence this UV Sensor is capable to be used in terms of indicates the optimize sun ray which may conduct the solar panel to the direct and maximize of energy captured.

![Figure 12: Pyranometer](image)

7. FINDING AND DISCUSSION

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<th>DUAL AXIS</th>
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<td>(capable to capture max sunlight)</td>
<td></td>
<td></td>
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<tr>
<td>Energy Capture</td>
<td>20% more than fix panel</td>
<td>40% more than fix panel</td>
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By referring to the table, comparisons of the solar tracker designed shows that the single axis is cheap, simple mechanism and running cost is low. This brought to the opposite of dual axis whereby it is more expensive with complicated mechanism and high running cost. For the
criteria of measuring movement, single axis track the sun by the motion of vertical system which the solar panel typically more in only east to west movement of the sun. Meanwhile, the dual axis uses vertical and horizontal system which move the solar panel to track the sun from east to west and north to south. This mean that dual axis capable to track the daily movement and also yearly movement of the sun. The comparisons of sun energy captured are different between single axis and dual axis. Through some review, the single axis able to captured 20% more sun energy than the fix panel and the dual axis able to captured 40% more sun energy than the fixed panel. This ensure that the dual axis is more efficient than the single axis as the dual axis is always aligned and parallel to the sun ray.

8. CONCLUSION

Fixed facing of solar panel is widely used but the capability for high power consumption of several load appliances are not efficient and stable. The conventional solar panels used during the course day are not always maximized which is due to the static placement of the panel which limits their area of exposure. In order to maximize power output from the solar panels, the panels has to be aligned with the sun. Tracking is carried to maximize the capturing of solar energy by solar panel. Hence tracking capabilities may help certain system due to the application usage of electricity.

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