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A Review of Solar Tracking Mechanisms for Photovoltaic Systems

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Abstract: Solar tracking systems are devices used to optimize the harnessing of solar energy by the receiver. These systems use electro-mechanical devices which orientate the angle of solar receiver so that it is perpendicular to the sun. Therefore, developing tracking systems is vital as these systems could be used to track the bidirectional path of sun which constantly changes every day and seasonally. Dual axis tracking systems are often complex and consume a lot of energy when compare to single axis tracker but are usually more efficient. This paper provides a review of active solar tracking systems for PV modules. Future work will focus on the development of a dual axis

Key words: Dual axis tracking devices, Electro-mechanical, Photo-voltaic (PV) Module

1. INTRODUCTION

The uses of renewable energy resource in power generation have increased as they are environment friendly and are abundance. These resources also create an alternative source rather depending on the use of depleting fossil fuel. Among renewable resources solar is the most vital resource as it is widely and easily accessible. A significant body of research in renewable energy has been committed to photovoltaic system (PV). Photovoltaic system converts solar energy into electrical energy with the use of semiconductors. Though the use of PV is commonly associated with low conversion rates, years of testing and research have led to improvement of the conversion output of the PV system. Improved solar cells have been developed and the use of solar tracking system over the use of conventional fixed PV system has grown. In fixed photovoltaic system the solar receiver (PV module) is in a stationary position facing the true north.

Solar trackers are devices used to direct solar panels or modules toward the sun. These devices change their orientation from to time as they follow the sun's path to maximize energy capture resulting in minimized incidence angle between the incoming solar radiation and module surface. The system is made up of different components such as; receiver, solar irradiance sensors, automation/ control system and mechanical system.

2. LITERATURE REVIEW

2.1. Classification Of Solar Tracking Devices

Tracking devices are either that is passive or active solar trackers. Passive trackers are simple device which uses thermal expansions properties of a material (i.e. thermo-sensitive fluid or shape memory alloys). These types of tracker are commonly single axis as they only orientate the module along the east-west (azimuthal) direction. Low boiling point liquids are used to sense solar irradiance making use of their temperature increase and the resulting compression. (1) Passive trackers uses direct energy from the sun involuntarily to drive the whole tracking system without the use of generated electric energy. Though these

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trackers do not follow the sun precise they are used in the equatorial region which has an abundance of solar irradiance.

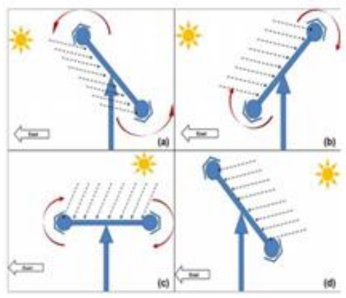

Figure 1: Fluid based passive solar tracker (1)

2.2. Active trackers

Electronic systems or mechanical systems are normally used to achieve more accurate sun tracking than that of the passive tracker. The active tracking can be further categorized into different classes according to the number of axial rotation, the type of actuator and the control system deployed on the tracking system. Solar trackers named according to the number axial of rotation are the single axis and the dual axis.

2.2.1. Single Axis Solar Tracking Devices

The single axis trackers have one degree of rotation which plays the role of the axis of rotation, which is aligned to the true north, therefore tracking the sun in only one direction of east-west, this tracking can either be open loop or closed loop controlled system for different types of actuator motorised or hydro/pneumatic system that drives the tracking devices. Varies types of single axis

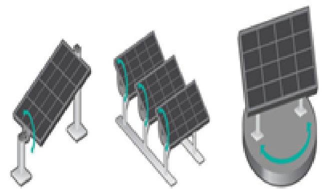

Figure 1: different types of single axis tracking device (from left to right; TSAT, HSAT and VSAT) (2)

tracker include; horizontal single axis tracker

(HSAT), vertical single axis tracker (VSAT) and tilted single axis tracker (TSAT) which are illustrated on *figure 2* below. Different studies shows that a single axis tracking system can yield an increase of about 20% above the conventional system of fixed system (2). Though common in application than the dual axis tracker for their simplicity but are limited since they only track the sun in single direction. A theoretical comparison of different solar tracking devices report scores, the single tracking devices 67% over the fixed system whereas the dual axis tracking system realised a 84.11% increased output over the fixed system (3).

2.2.2. Dual Solar Tracking Devices

Dual axis tracking system has two degree of freedom which are perpendicular to each other. These tracking devices are generally classified as tip-tilt and the azimuthal-altitude trackers.

2.3. Mechanical Trackers

These tracking devices entirely uses the mechanical systems to track the path of the sun with the help of predefined mathematical algorithms which are derived from sun path diagrams, the control of the devices is normally a real time mechanical clocks. Agarwal, Rohit (4) describe a tracking device that uses the mechanical potential energy to drive the whole system. Whereas train gears are deploy as control of the tracking speed as

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they reduce the speed of the system per the hourly and seasonally pre-calculated mathematical algorithms in order predict the sun position. In the study it was concluded that though the tracker could increase the output of the PV system tracks even when the weather conditions are unfavourable such as when there is cloud cover still tracks

(5)Presents a hydraulic tracking system which uses high pressure fluid to convert the potential energy in the mechanical structure that hold up the PV panel into kinetic energy. This kinetic energy is then used to move panel toward the sun. In this system the use of levers is important to manipulate the weight of the entire body which is the main source of energy and for control, hydraulic valves are used to regulate the flow of the fluid (i.e. direction, flow rate) before it reaches the actuator (hydraulic cylinder) which transmit the motion from the fluid to the mechanical positioning mechanism. This tracking device is based on the real timer control principle.

2.4. Automated Control Strategy

The control strategy of solar tracking system is categorized into two main types which are; the open loop (also referred to as passive control) and the closed loop control (active control). The open loop is a non-feedback system and commonly uses the solar algorithms to follow the path of the sun, whereas the closed loop is feedback systems that compensate the realised disturbance of the system. Combination these two methods; result in a hybrid control which in some instances can be used in tracking devices.

2.5. Open Loop Control

This type of control system uses an electronic logic device which uses of mathematical formulae to manipulate the positioning mechanism. Though sensors are not importance in this system they can be used in calibration of the device. This mode of solar tracking ensures that the receiver is positioned at the calculated solar angle for a specific time and date, through the use of solar astronomical algorithms or formulae which are developed based on the sun path chart (maps) that predict the sun`s position according azithumal and altitude angle of the sun at specified geographical location and time of certain point similar to the one depicted on *figure 3*.

A reference (6) reports a high performance rate for PV system with a tracking device. The study shows a 40% improvement of power generation due to the installation of tracking device rather the fixed panel. The research employed a real time clock tracking method. A DC motor is controlled by ARM processor which is programmed to a local solar time and compares the input value of the timer. At pre-set value the system is moved to the required position.

2.6. Closed Loop Control

The main characteristic of the control system is the uses of electro-optic sensors and microprocessor as main controller for the plant. Light dependent resistor (LDRs), photo-transistor and PV cell are commonly used as sensor to detect the coordinate of the sun through light intensity. (7; 8) Designed a optical sensor based dual axis tracking devices, both of the studies used LDRs arranged in criss-cross manner whereby a single LDR receive a higher light intensity than it another which is coupled to . This system uses 2 pairs of the LDRs one for the east-west direction and another for south-north, as the light strikes the sensor the microcontroller compares the input signal therefore executing the command through an H-bridge drive circuit which determines the direction of the motors. In these studies a gain of 25% and 28.31% were realized respectively.

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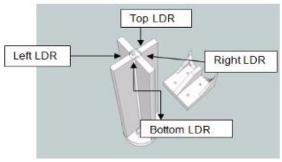

Figure 2: A crisis-cross arrangement of LDRs for dual tracking devices (8)

A PV cell based tracking is reported to have increased the energy gain by 16-20% which was attained by a system made up of four mini- solar module positioned on the North-south and east-west that detect the light intensity, this is system also use the Programmable Logic Controller (PLC) manipulate the two positioning mechanism through two DC motors (9)

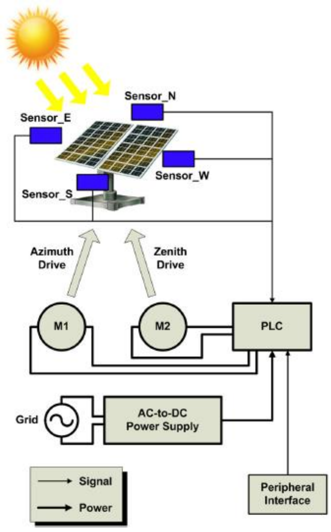

Figure 3: solar cell based dual tracking devices (9)

2.7. Hybrid Loop Control

Hybrid loop controllers combine the open and the closed loop systems. (10) Designed and implemented a hybrid control strategy, whereby a module tilt angle was varied by the means of a controller which is real time based as the altitude position of the sun according to seasons. This tracking system followed the sun in a chorological manner. As for azimuthal angle, the author implemented closed loop (photo-sensor based) tracking that followed the sun continuously. The authors concludes that the implemented tracking strategy was approximately equal with the continuous tracking in terms of energy gained when compared to the fixed conventional system, while it saved about 44.44% of power used for system operation.

2.8. Tracking Method (Motion Of Tracking)

Solar tracking device are proven to be vital in improving the efficiency of PV array. But factors as the installation and maintenance costs, reliability and high energy consumption of the tracking device reduce the performance of tracking devices. These factors led to different development of tracking methods in-terms of the motion of tracking this is divide into two main; chronological and continuous tracking.

Chronological trackers track the sun`s position in a predefined time intervals or in steps. The method of tracking is commonly applied for change of the altitude angle of the sun as change is gradual in this case, but in some researches chronological tracking is implemented for azimuthal direction as position correcting device that is the actuator is only engaged to orientate the PV system toward the sun after a certain period of time.

As for continuous is a method of tracking whereby the PV is moved along with the change solar vector it can be in a single or dual manner. but the literature shows that this tracking method is more practical for daily/ azimuthal direction rather than the altitude

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direction. This is due to increased energy consumption of the system while gain is relatively equal with the chronological tracking method.

2.9. Postioning Mechanism

A mechanical system of the solar tracking device is made up of the actuation devices, transmission system. The main function of this component is to convert any form of input energy into the require kinetic energy as it orientate the PV module towards the sun. Different actuator can be used in the solar tracking but the commonly used trackers are; hydraulic, pneumatic linear actuator and electric motor (that is either DC motor or servo-motor).

3. DISCUSSION

This study reviewed different solar tracking devices presented in various literature sources, and the various architectural designs of the solar tracking system. It was found that solar tracker can be classified according to whether is active or passive, the number of rotational axes, motion of tracking, control mechanism, and the type of positioning mechanism which can be referred to in the *appendix 1*. Also it was found that dual axis tracking mechanism can improved conversion rate of PV system by about 40% and an ideal system the conversion rate can reach approximately 85%.

4. CONCLUSION

It is therefore concluded that solar tracking devices are of great importance in photovoltaic system for improve efficiency of the system and reliability. However trackers still faces challenges such as loss of energy due to factors such as mechanical configuration, climatic condition, tracking efficiency, energy consumption of the tracking system and energy loss in the tracking system.

5. RECOMMENDATIONS

This study recommends:

- A design of electro-mechanical dual axis tracking with energy recycling and regeneration system to enhance the energy efficiency of tracking system.
- Improvement of tracking device to withstand unfavourable weather/ environmental conditions such as strong wind, dust etc.

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APPENDIX

Appendix 1: solar classification tree