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SOLAR TRACKING SYSTEMS FOR INCREASING THROUGHPUT OF SOLAR PANELS: A STUDY

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ABSTRACT

This paper attempts to study solar tracking systems and compare various techniques employed to create solar tracking systems with respect to conventional fixed photovoltaic cells. Emphasis is on sensor, controller and tracker types. The study has been done to help select the appropriate technique to make best use of the solar panels. It also tries to explore the areas open for future works in this field.

Keywords - ***Dual axis tracking, Photovoltaic (PV) cell, Single axis tracking, Solar energy, solar tracking.***

[1] INTRODUCTION

Solar energy is the mother of all forms of energy on earth, an important and integral part of human lives. With the growing concern for carbon emissions and a kinetic shift towards adoption of renewable sources of energy has brought electrical energy generated with the aid of solar panels at the limelight of governments globally. India pledging to increase its solar capacity to 100 GW by 2022 upsurges its standing severely [1]. The increase has been proposed by increasing the area under solar trap umbrella but there exist some proposed techniques which claim to increase the throughput of solar panels without altering the size of panel. The methods can be either electrical or mechanical viz increasing the output by improving the power conversion or by employing dynamic structural adaptation. Of many techniques proposed and being employed, solar tracking is a novel mechanical scheme to achieve this objective. The concept of solar tracking is to employ mechanical devices, mostly motors, controlled by an electronic circuit to move the panels in direction aligned towards the maximum solar radiation. Since there are different methods proposed to accomplish it, there needs to be a comparison of techniques employed. This study attempts to review electronic and mechanical aspects of techniques employed to create solar tracking with respect to conventional fixed photovoltaic cells. This review can be of help to select the appropriate technique to make best use of the solar panels.

[2] OVERVIEW OF SOLAR TRACKING SYSTEM

Accurate solar tracking can be achieved by using either open loop tracking approach or closed loop tracking approach for dual axis solar tracking [2, 3].

A. Open loop trackers

In open loop approach, tracking is done by using the initial time, date and position of the sun at that previous instant. They are based on calculation or data of Sun's position in sky. The plate needs to be reoriented at lapse of fixed interval throughout the day [2].

B. Closed loop trackers

In closed loop approach, sensors are used to sense the solar position to achieve maximum intensity [2]. Reorientation is done as per the negative feedback from the sensor.
Study [3] shows that both Open and Closed loop systems have improvement in radiation reception with a difference less than 1.5% in all cases. Though the solar tracking systems show considerable increase compared to a tilted fixed latitude mounted PV [3].

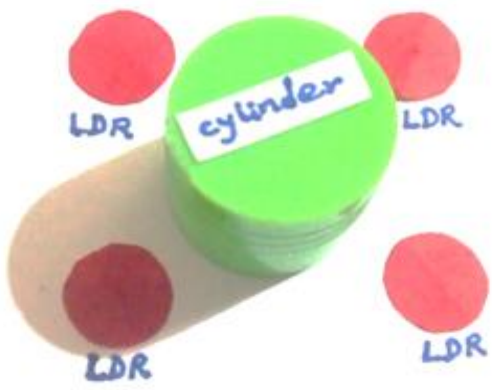

Fig. 1 Simplest sensor setup for a dual axis tracking [2].

[3] COMPONENTS OF SOLAR TRACKER

Open loop trackers need better data for implementation whereas the closed loop trackers depend on the sensors and mechanical setup to continuously orient the system. As such the areas of interest are the sensors (along with the electronic circuit to control it) and the mechanical setup. In the following sections we will try to glance through the diversities in both the domains [4].
The throughput or efficiency of solar system is the most common parameter for comparison of PV cells. It is the ratio of incident energy from Sun to the energy converted into electricity.

$$\eta = {(V.I)(FF)}/{P_{incident}} \tag{1}$$

Where η = throughput or efficiency, V = open circuit voltage, I = short circuit current, FF= fill factor (which is the measure of squareness of solar cell) and $P_{incident}$ = incident power which is taken as $1kW/m^2$ or $100mW/cm^2$ [5].
The aim of all the alterations is to increase this throughput either by ensuring the maximum sunlight on the solar cells or by improving conversion efficiency of cells or both. In this paper we are focusing on methods of increasing throughput by ensuring maximal sunlight.

[4] ELECTRONIC SETUP

A. Sensor

LDR (light dependent resistor) is the most common sensor used to compare the light intensity and provide feedback to the control circuit. The LDR's resistance is inversely related to intensity of light. As in Fig 1 four LDRs are used to track the position of the sun where two of them are capable of sensing one-axis(east-west) and the other two for the other axis (north-south). If Sun-rays are not falling perpendicularly on the solar plate, the cylinder in between the four LDR will have its shadow which will definitely cover one or two LDRs. Now, the different intensities of light are sensed by the LDR sensors and this sensed signal then goes to a light comparison unit [2].

There have been different proposed sensor physical structures. Some of them can be seen in Fig. 2 [4,6]. Each one has merit and demerits. Like the one proposed in [4] and shown in Fig. 1(e) has reduced the error in detection to less than 2^{o} for a sole light source.

LDRs are cost effective light sensors and its use involves use of voltage divider circuit. But this is accompanied by power consumption due to the resistive element. Thus, the use of a large number of sensors to improve tracking will charge more on power front [4]. There are other sensors too which has been used like photodiodes and photocells [7,8], which are active devices and their usages in large numbers will result in power addition without increasing power consumption.

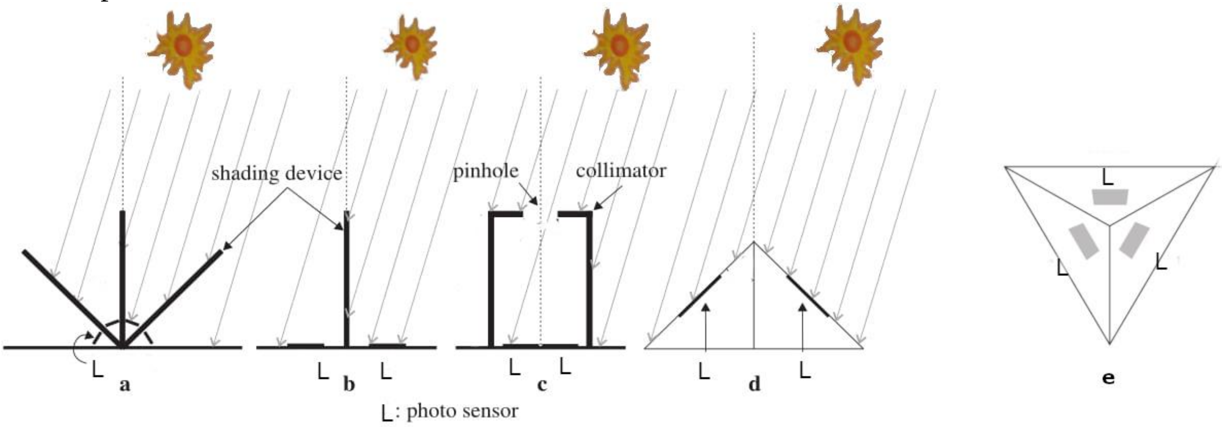

Fig. 2 Physical designs of sensors for Sun tracking (a), (b) Shade balancing setups, (c) Collimator based setup, (d) Titled mount of sensors, (e) Tetrahedron arrangement of sensor to control using 3 LDRs [4, 5].

B. Controller

The different intensities of light are sensed by the LDR sensors and this sensed signal goes to a comparison unit. The unit compares the intensities to generate control signals for the mechanical unit. The control circuit has been designed using microcontroller [2], microcontroller boards like Arduino [9] and comparators [10]. Microcontroller based circuits are costlier whereas the comparator-based circuits needs to be improved as they are bulky.

[5] MECHANICAL SETUP

Two mechanical setups have been employed in solar tracking systems – single axis and dual axis.

A. Single axis tracker

In a single axis tracker, the tilt of fixed PV plates is maintained and azimuthal is controlled by a motor. The sensor's one axis feedback is only required.

B. Dual axis trackers

For dual - axis solar tracking, two motors are set perpendicular to each other such that one controls the horizontal motion of the solar panel whereas the second motor controls the vertical movement. The controller decides the direction in which the motors should move to control the horizontal and vertical axis of the plate so that the solar plate always lies perpendicular to the sunlight and receive maximum intensity [2].

Dual axis shows an improvement of 40% over fixed systems whereas single axis shows 28% improvement. At the same time the complexity of dual axis tracker questions it's reliability and increases the cost as well [11].

Some setups use stepper motor while others use DC motor which requires an additional motor driver IC. Stepper motors generate noise and require more power but provide better control whereas DC motors have lesser power requirements but is unable to provide precise control.

[6] SUMMARY

Different aspects of Solar tracking systems have been studied in this review. From the discussion it can easily be observed that no best practices have yet been developed for solar tracking systems. Yet the advantage of using a tracked solar plate is evident. In case good data and computational mechanisms are available for a place an open loop tracker can be employed but for versatility closed loop systems will be certainly the way out. Presently the most used sensor is LDR in spite of the fact that it is a passive device. Alternates to LDR with improvement in sensor physical structure to better the accuracy is scope for further studies. Choice of controller depends on the cost and expertise availability. As for the mechanical setup, dual axis has the advantage of giving better results but it's setup and maintenance can be a concern. For such cases a single axis shows considerable advantage too. A choice between maximum power trapping and system simplicity is to be made. This area too keeps itself open for future improvements.

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