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Dual-axis sun tracker sensor based on tetrahedron geometry

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ABSTRACT

This paper describes a new concept for solar detection sensor implementation in photovoltaic dual-axis sun tracker systems. The sensor uses only three units of identical light-dependent-resistors arranged in a tetrahedron and is able to track the source position of the sun or the strongest intensity of visible light. The prototype has been built and tested, resulting in a wide Field of View (289.4°) and minimum error. When this design is compared to other previous types of sun tracking sensors, it has great advantages in terms of sensor quantity, accuracy, effectiveness, and Field of View.

1. Introduction

The increase in world energy demand and the strong intervention goals of the Kyoto protocol [1,2] have made renewable energy sources one of the best options in the world. It has been found that renewable energy has the fastest growing rate compared to other sources of energy [3].

Solar energy is a renewable energy that is also the major source of energy for other life forms on earth. This energy's abundance makes it highly desirable to exploit. However, due to the current limitations of human technology, only a fraction of the energy can be extracted. In solar panel applications, the highest theoretical efficiency is approximately 55% [4] although it can be considerably lower in practice.

In general, there are two methods that maximize electrical energy output from solar panels: electrical and mechanical methods. The electrical methods are usually applied to control the power converter such that the energy output from the solar panel becomes maximal; the most common practice is the usage of Maximum Power Point Tracking (MPPT) systems.

The mechanical method is also commonly used, where solar panels are periodically adjusted to remain perpendicular to the light source. Thus, the energy input received by the solar panels will increase. This method is known as a sun tracker system or a solar tracker. These two methods can be performed simultaneously [5] or separately. However, this paper only focuses on the second method, which is a sun tracker system.

This paper presents a new concept for a light sensor, which can be applied to the sun tracker system. By integrating three light-dependent-resistors (LDR) in a tetrahedral arrangement, the device can be used as a dual-axis sun tracker sensor, which has an optimal control algorithm. The first section of the paper reviews prior research on the development of sun-tracker sensors. The next section presents the explanation of the proposed sensor in terms of structure and algorithm. Sensor testing, comparison, and a discussion are presented at the end of the paper.

2. Trend of sun tracker sensor

A sun tracker is a device used to maximize the energy received by solar panels by maintaining its position perpendicular to the light source. It has been demonstrated both mathematically and experimentally that a sun tracker can increase the amount of energy received by solar panels by up to 60% [6,7,8], depending on the installation location. For example, Fig. 1 is the comparison result between the amounts of energy received by two solar panel systems at Banda Aceh, Indonesia. Both systems have the same electrical equipment, but they differ in mounting system. It was found that the system implementing a sun tracker can extract 54% more energy than the fixed mounting system (tracker energy consumption not included).

Various sun tracker systems have been developed by many researchers, either using a special algorithms or different types of sensors.

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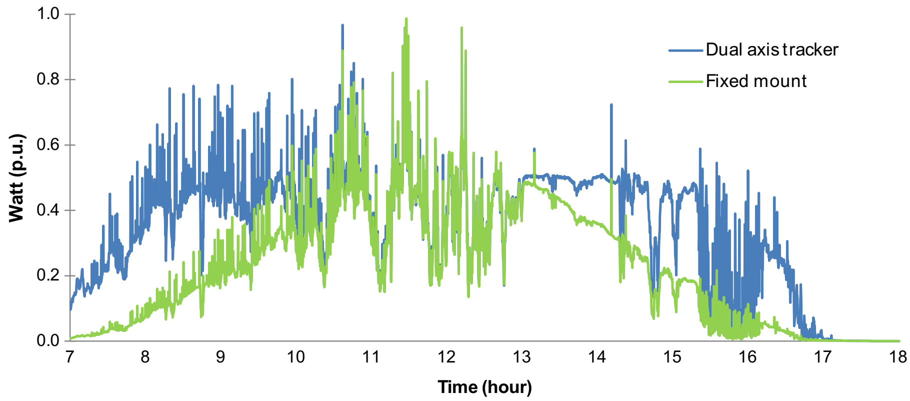


Fig. 1. The comparison results of energy output of a fixed amount and a dual axis tracker.

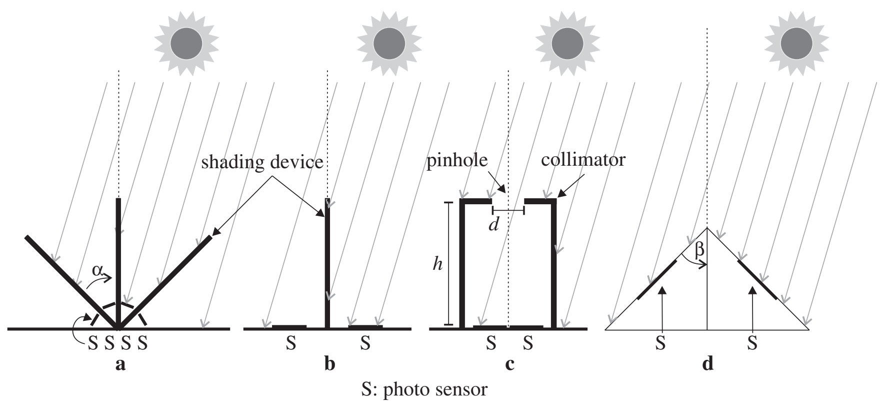


Fig. 2. Designs of sun tracker sensors.

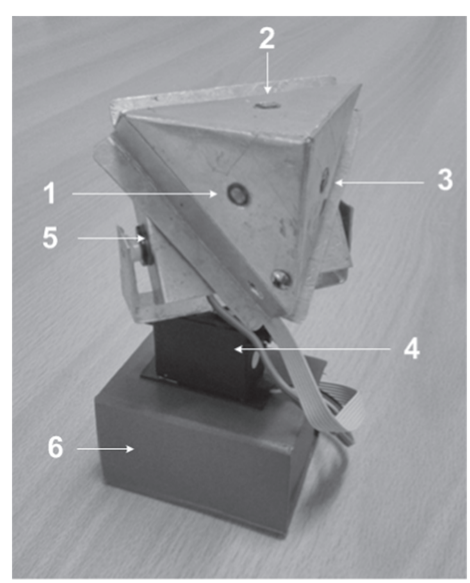
Generally, the development of physical structure of the sensor can be observed in Fig. 2 [9]. Each type of sensor has advantages and disadvantages.

3. Proposed sun tracker

The proposed device in this publication has the basic shape of a pyramid with three sides, known as a tetrahedron. Although the shape looks similar to a sensor that has been presented by Deger [10], the working principle and the configuration of the proposed sensor are not the same. This sensor can be used to control the motion of a dual-axis solar panel system toward the greatest intensity of light source in the sky. The basic concept of the proposed device is based on the equilibrium of light intensity received by the three sensors on each side. The geometry of the pyramid will cause each LDR sensor to be at a certain slope, whereas its internal resistance will change depending on the intensity and angle of light incidence.

3.1. The sensor structure

The prototype is shown as in Fig. 3, and its structure can be observed in Fig. 4. Three LDRs with identical electrical characteristic, that is, a reference sensor (S_{Rev}), the first axis sensor (S_{Ax1}) and the second axis sensor (S_{Ax2}), are placed in parallel and symmetrically to each side of the pyramid. Because the tetrahedral pyramid structure is equilaterally three-sided, the angle α will be 60° while the angle β may vary. However, in this paper, the angle β is 45°. The Field of View (FOV) of this configuration is extensive. Due to the system's tetrahedral shape and based on the fact that the system will sense light as long as at least one sensor is lit, in theory, the system will obtain its maximum FOV according to angle S-a′-o (or S-b′-o, or S-c'-o) relative to the pyramid base, which is



Note: *1) S_{Rev} sensor 2) S_{Ax2} sensor 3) S_{Ax1} sensor 4) 1st axis servo 5) 2nd axis servo (behind) 6) control box*

Fig. 3. Prototype of the proposed sun tracker sensor.

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