Improvement the effectiveness of multi-directional low weight solar panel tracking system based on dC relay

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Abstract: Rotating prototypes are utilized to track the sun path and allow solar panels to head towards the sun as long as possible, to growing additional solar power and increasing their efficiency. Therefore, to develop the suggested prototype for Advanced Virtual RISC microcontrollers, the paper suggests that instead of traditional materials like Iron and plastics, it would be possible to use foam polyvinyl chloride material. It can withstand more heat and is capable of reducing the design's weight and energy consumption in comparison to different materials. Furthermore, this work proposes that the sun position tracking is adjusted through a switch operates in a direct current relay to minimize the effects of energy expenditure in control circuits and motors. Consequently, the aforementioned operation will lead to improve the total power system and to set an optimum period for peak direct current relay. Lastly, the advantages of combining solar cells in a series on output voltage from panels are discussed in this work. The experiments revealed that the proposed prototype is more efficient than a static solar system in absorbing higher sunlight, with an average power increase of 34%. In addition, measurements have shown that the optimal duration of a suggested tracking system can be discretized every 20 minutes in order to achieve maximum efficiency i.e. 34%. In contrast to a system that monitors continuously, an optimum discretizing time period minimizes 89% of the power used by the moving and microcontroller units.

1 Introduction

Especially in areas, where the weather is most favorable, solar energy can produce efficient electricity [1, 2, and 3]. The problem is that solar photovoltaic PV does not produce the optimum output power from sunlight; therefore it has a weak efficiency. A number of measures were taken to correct this problem by using a solar tracker system which maintains photovoltaic panels parallel to the sun's rays, so that output power efficiency can be increased [4, 5, and 6]. Based on an annual estimation, this could raise the efficiency of energy production by up to 35% [7, 8, and 9]. A single axis tracking system was one of the initial suggested systems for solar tracking [10, 11, and 12]. Later, a simulation and implementation of the most active algorithm to set the DAST system, which could move in the direction of azimuth and altitude, was carried out [13, 14, 15, 16, and 17]. The kinds of the tracking designs that were suggested in the previous studies: the first kind is equipped with a large solar panel and can be used for the generation of electrical energy, because the total average value of generated power exceeds that of electricity consumed [18, 19 and 20]. There is also a second type for the purpose of research in laboratories and educational institutes, which contained low output energy panels. The key issue here is that, despite these prototypes produce the typical level of electricity. The amount of overall energy expenditure is still higher.

The aims of this paper are to keep the PV model on a sunward orientation all daytime and validate the results using a variety of materials properties and comparisons to previously models in same study. The contributions of the study will be as follow:

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To minimize the weight and energy consumption of the suggested model, foam polyvinyl chloride material is proposed. To increase the generated energy gain of the suggested model, several connection cases of panels are discussed. To decrease the energy consumption of suggested model, an innovative DC relay method is presented. To raise the effectiveness of the suggested model, an efficiency equation is applied. The rest of this paper will be as follow: Section 2 explains the suggested model designing and its components. Section 3 shows the simulation and control process of the suggested model. Section 4 indicates the test results and discussions. Section 5 summarizes the conclusion and suggestions for future works.

2 Methodology

The development and implementation of the dual axis tracker for photovoltaic panels is covered in this part. Since it is considered to be the main part of using PVC foam in a computer numerical control machine CNC, the proposed DAST's structure was created using AutoCAD. It sent the necessary parts to the PVC foam cutting machine (CNC) for cutting. Then, we position the foam polyvinyl chloride material under the machine, the length sets to 1 meter and thickness sets to 1 cm, and we switch on the cutting device. The CNC immediately began cutting in accordance with the plans, the drawings, and the scales. We use LDRs to measure the position of sunlight's high intensity. Four LDRs are positioned in square configuration on the top area of the suggested system, and the value of the voltage differential between them drives the proposed design. As soon as the value is reached, the panel will start rotating automatically. The proposed DAST prototype, as shown below in Fig. 1, is composed of a sensing unit, microcontroller and rotation units.

![Fig 1. Block Diagram of DAST System](image-url)

The modules of the proposed DAST system for monitoring photovoltaic panel have a very high sensitivity. Thus, during the activities, it is necessary to apply high precision and concentration. It consists of electrical, electronic and mechanical components. There are two major circuits of the suggested solar panel tracking system: the initial circuit's goal is to employ LDRs to capture solar energy and an Arduino Uno as the design's primary brain to drive two servo motors both vertically and horizontally. Solar energy conversions, and electricity supply to the load, are the purposes of the second circuit which is composed of photovoltaic panels. The Arduino Uno board receives signals from the light-dependent resistors via the input (A) ports and delivers output data to the horizontal and vertical motors via the PWM ports. As a result, this microcontroller's input voltage is 9V. The proposed design's mechanical element is a Servo motor, 946MGR. Its gears are made of strong metal. This kind of servo motor is ideal for use with solar panel tracking systems due to their excellent quality and strong torque. The motor's three primary wires are colored by the orange is for PWM; the
red one is for supply voltage, and the black is for neutral. Horizontal and vertical servo motors are included in the suggested system.

The light dependent resistor (LDR) serves as the suggested design's sensing element. This component can function as a light sensor to determine if there is light or not. Their low price, exceptional sensitivity, and straightforward design led us to choose them. At the top of the design, four light dependent resistors were positioned in a square pattern. The light dependent resistors will deliver signals to the control circuit as soon as they detect light. Additionally, the supply voltage is 5V. The series connection of the fixed resistors and LDRs compose a potential divider circuit. The analog pins on the Arduino board are fed by the potential divider's center point. In the actual design, we selected four fixed resistances, each with a value of (360).

A DC to DC step down regulator is the voltage regulation (LM2596). Its adjustability and suitability for the suggested design is called for reducing the supply voltage from 9V to 7V which is considered the selected voltage of the mechanical components. The upper variable element of LM2596 is used to change the voltage flowing.

The PVs temperature is measured by using a thermometer. The component unit is Celsius degrees. It measures the temperature quite precisely. This component's input voltage is 5V.

A resistance of 300 ohm is the load that connects to the PV panels. The solar radiation absorbed by the PV panels that convert into the generated energy results will be monitored by the AVO meter.

Cheap and very efficient in transforming the solar radiation amount into electrical energy are 10 small PV panels that each produces 0.1 watts. Even if the solar panel's output power is quite little, it is enough to show that the solar radiation amount can be captured as much as possible since the PV panels move according to the light presence that is detected by light dependent resistors.

3 The Working Principle

The proposed prototype's operating concept is that when sunlight hits the LDRs, the microcontroller will use its analog ports to detect changes in light positions. There are three statuses:

Status 1
If the solar radiation falls on one side of the DAST prototype, the sensing unit will detect the voltage variation. For example, if the solar radiation falls on the left side; the moving unit will change the DAST system motion to the left in order to equalize the sensing unit voltages by balancing the solar radiation amount falls on LDRs as shown in figure 2.

Status 2
If the solar radiation falls on two sides (not in one side) of the suggested system, the sensing unit is going to measure the voltage variation. For example, the solar radiation falls on the left down side; the moving unit will change the DAST system motion to the left and down sides in order to equalize the sensing unit voltages by balancing the solar radiation amount falls on LDRs as shown in figure 2.

Status 3
The two servo motors will be instructed by the microcontroller to remain stationary in their current positions (no motion) especially when darkness falls or an equal amount of solar radiation falls on the four LDRs as shown in figure 2.

The utilizing of the Arduino and Proteus programming software environments are to develop the codes of the control equipment and communicate the commands coming from the sensing parts to the rotating unit by using a data cable. Figure. 2 & 3 depicts the flow chart and simulation of control process.
Fig 2. Flow Chart of Control Process

Fig 3. Simulation Process of DAST System
Fig. 4 depicts the suggested DAST system that has actually been accomplished.

![The Actual DAST System](image)

4 Results and Discussion

The reviewing of the findings from the suggested study will be in this section. The beginning is by evaluating another prototype created by University of Baghdad against our own. The prototype was comprised of iron, plastic, and cement materials and was constructed in the Renewable Energy Laboratory for research. The using of 10 PV panels with the same output power is to compare the produced output energy by the fixed design with the DAST system. Both cases series and parallel connection will be covered. Following that, the display of the DAST and fixed systems results for parallel case will be shown and determine the average produced power. The resulting findings of the DAST and static systems for the series including maximum energies will then be shown. The DAST system will follow the sun for 12 hours by intermittently switching the DC relay for 5, 10, 15, 20, 30, 40, 50, 55 minutes and 1, 2, 3, 4, and 6 hours while the fixed prototype will be positioned at a fixed 90-degree angle toward the sun throughout the daytime. The prototype's efficiency will be determined by computing how much energy it uses and generates in each position. The measurements were performed in Baghdad (33°21'03.9"N 44°16'35.6"E) on 30 August and the findings were recorded in accordance with particular time intervals all the daytime.

4.1 Material of Suggested DAST System

Figure 5 depicts the comparison of the DAST system's weight to that of a system constructed at the University of Baghdad from iron, plastic, and cement. Additionally, the comparison of the systems' weight properties will show in table 1.

<table>
<thead>
<tr>
<th></th>
<th>DAST Prototype</th>
<th>Base Prototype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>2.5 Kilograms</td>
<td>4 Kilograms</td>
</tr>
<tr>
<td>Material</td>
<td>Foam Polyvinyl Chloride</td>
<td>Different Material</td>
</tr>
</tbody>
</table>
As a result, the suggested DAST design is less weight than the reference design.

4.2 10 PV Panels in Parallel Connection

The average power value will be determined by connecting 10 PV panels in parallel to the load as depicted in Figure 6. The data of generated power that were gathered by both fixed and DAST systems for the first day are shown in this figure. The fixed PV output data shows that the highest value of the output power is 0.2 W. The data of the DAST system shows that the highest generated power is 0.2 W. Fig. 6 shows that during the testing period, the output power produced by the DAST system are roughly equal. However, it can be notified that the sun intensity increases for the fixed panel from 6:00 to 7:00 until 9:00 to 10:00. Then, until somewhere between 17:00 and 18:00, the solar intensity starts to gradually diminish.

Comparing the overall average power collected from the DAST system to the overall average power gathered from the fixed system, Figure 6 demonstrates an increase in the overall average power.
4.3 10 PV Panels in Series Connection

10 PV panels in a series case will be wired in order to compute the average output energy value. Over the course of 12 hours, the DC relay will be switched at various intermittent intervals (5, 10, 20, 30, 40, 50, 55 minutes and 1, 2, 3, 4, 6 hours). The first instance involves switching the DC relay over 12 hours with a 5-minutes intermittent interval.

![DAST and Fixed Systems Energies](image)

Fig 7. DAST and Fixed Systems Energies for DC Relay Intermittent Time Period of 5 Minutes

The output energy received from the fixed and DAST systems are shown in the results in fig. 7. The DAST mechanism allowed for the highest captured energy of 237 J can be obtained between 11:00 and 11:05. On the other hand, the highest gathered energy obtained from 12:00 to 12:05 is 178 J by the static system. Additionally, the energy received by the DAST system at any other time is greater than the energy obtained by the fixed panel at the same time. Comparing the overall average energy gathered from the DAST system to the overall average energy received from the fixed system, Figure 7 likewise demonstrates an increase in total average energy. Total average energy for the solar tracking system (Et) = 25872 J/Day is determined by computing the area under the cover of the generated energy curve. It follows the sun all over the daytime by relay intermittent time period of five min., therefore the overall average energy collected is equal to 25872- 10761 = 15111 J/day. On the other side, 11323 J/Day is equivalent to the entire average of the produced energy by the fixed system (Ef). As a result, the effectiveness of the DAST design equation is:

\[
\text{The efficiency} = \frac{(Et-Ef)}{Ef} \times 100\% \quad (1)
\]

Where

Et: The tracking system's overall average energy output.

Ef: The overall average energy that the fixed system produces.

With a switching time of five minutes, our system has 33.45% efficiency according to equation 1. These computations can be used on additional cases in order to display the desired outcomes.

4.4 Energy Consumption of Suggested DAST System

Here, we'll assume that the DC relay will be switched using a 1 second interval by the continuous sun following system. The control circuit consumes 10459 J of energy, while the motors require 89424 J of energy to move for one second and 4.14 J of energy to return to the first position when the sun has gone out. The total energy required to the DAST system when switch a DC relay with a 1 second
interval all over the daytime is 99887 Joule and fig. 8 illustrates the energy consumed by the DAST system for each intermittent time period of relay.

![Energy Expenditure of DAST System](image)

**Fig8.** Chart of DAST Design Energy Consumption

According to figure 8, switching the DC relay at intervals of five minutes results in the highest overall energy consumption, while switching it at intervals of 6 hours results in the lowest overall energy consumption.

### 4.5 Energy Gain of Suggested DAST System

As shown in figure 9, the relay intermittent time period of twenty minutes generates the maximum energy gain of the suggested DAST system which is approx. 15189 J while the minimum value of energy gain is 3394 J generates at the relay intermittent time period of six hours according to the equation:

\[
\text{The energy gain} = Et - Ec
\]

(2)

Where

Ec: The consumed energy of DAST system in joule.
4.6 Efficiency of Suggested DAST System

As illustrated in fig. 10, the relay intermittent time period of twenty minutes makes the performance of the DAST system working at maximum level i.e. 34% while the minimum efficiency of the suggested system is -70% at the relay intermittent time period of six hours according to the equation (1).
5 Conclusion

In this study, a DAST prototype was built and implemented to follow the sun's motion throughout the daytime. A computer numerical control (CNC) was used to cut the DAST structure. Also, by using an AVR microcontroller, the control circuit was created and put to use. Then, in order to make the prototype lighter and consume less energy, we also suggested using PVC foam material. PVC foam material can resist the hot weather in Iraq, which can reach 56 degrees. The paper suggested discretizing the DAST operation system by utilizing the relay to reduce energy consumption and boost the prototype's effectiveness. In order to boost our prototype's efficiency to 34%, the ideal switching interval time of relay was 20 minutes. Compared to the normal operation (without relay), the ideal discretizing time period which was 20 minutes reduced the needed energy for the control circuit by 89%. In comparison to a fixed panel system, the suggested DAST system is more suitable to absorb the maximum solar radiation with an increase in average output produced energy of 34% utilizing the ideal switching time period. Many recommendations could be optimizing the DAST system in light of the findings and experiments in this paper, such as determining the ideal switching time periods for larger solar panels. The DAST prototype system's control circuit can also be replaced with a new one, which consumes less energy.

6 References


