Efficient and Low-Cost Arduino based Solar Tracking System

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Abstract. Sun energy plays an important role as a primary source of energy which can be harvested successfully using solar cells. The solar cell efficiency depends on the location of sun and its light intensity. Hence, solar tracking can be exploited to maximize the efficiency of solar panel. In this work, we developed a novel system of an inexpensive automatic microcontroller-based scaled down solar tracker using Arduino platform. Servo-motor is controlled by an Arduino Mega unit in order to re-orient the solar panel according to the position of sun with the help of light dependent resistors (LDR) and servomotors. A dual-axis solar tracker prototype is designed to maximize the harvested solar energy. Experimental results show that the proposed system performs 25% better than a fixed solar panel under the same conditions.

Keywords: Green energy, dual-axis solar tracking, Arduino, light dependent resistor.

1. Introduction
Sun energy represents one of the major sources of green energy which can be harvested using solar panel. Iraq has several types of renewable energy resources such as solar and hydro energy. Unfortunately, these energy sources are not fully utilized especially solar energy. However, the efficiency of solar cells depends directly on sunlight which is continuously varying. Hence, the output of an immobile solar panel is significantly changing according to the sun’s position [1].

A solar tracker can be used to maximize energy production because a solar cell would generate the maximum output when its surface is perpendicular to the sun [1] [2]. There are two main types of solar trackers: passive and active tracker. Passive solar trackers use the idea of thermal expansion. The movement of the sun causes one side of the passive solar tracker to be extended and the other side to shrink; which results in the rotation of solar panel. However, this type of solar tracker is not commercially popular and not very accurate compared to an active solar tracker [3]. In the active solar tracking system, the position of the sun panel is controlled by a sensor. This sensor triggers an actuator to move a mounted panel of solar array according to the signal received from the sensor so the panel will be perpendicular to the sun throughout the day [4].

Several active tracking systems are available which have one or two axes of freedom as shown in Figure 1. There are several types of one axis trackers such as vertical single-axis and horizontal single axis [5].

While vertical axis trackers are used in places with long summer days, horizontal axis trackers are employed in tropical regions with shorter days and higher sun track. In order to offer the full flexibility of a tracker to be used in wide areas, dual-axis trackers come into play [6]. In this context, Kabalc et al. [7] proposed a single axis solar tracking system where RF transmitter is used to send data to a computer. However, this method has high cost since a PC is employed. Abadi et al. [8] presented a single-axis solar tracking system based on a microcontroller. The achieved improvement is 47% compared to an immobile panel. A similar approach was used in [9], however, using a single-axis system reduced the efficiency of the proposed system.
Elagib et al. [10] proposed a Microcontroller based method for solar tracking system employing solar maps, which can predict the position of the Sun. Although this method is simple but the proposed system needs to be upgraded continuously when changing its position as the solar map is different from one place to another. Altayeb et al. [11] proposed a two-axis solar tracking system using global positioning system (GPS) to determine the location of the tracker and sun. It can be argued that this method provides accurate positioning, however, the complexity of this system is high due to the use of GPS system.

This work proposes an inexpensive microcontroller based active dual axis tracker to maximize the harvested power for the solar panel. Eight lights dependent resistors (LDR) are used to sense the position of the sun and control the servo motor to re-orient the solar panel to stay perpendicular to the sun rays. Comparison with a fixed position solar panel confirmed the effectiveness of the proposed method. This paper is organized as follows. The next section introduces the developed method. Section 3 presents the results and discussion while Section 4 concludes this paper.

2. Proposed Method

In order to fully utilize the solar energy, a dual-axis solar tracker is proposed in this work. The proposed system consists of three main parts: the input from the LDR, Arduino as a controller and servomotors as an output. The eight LDRs were connected to Arduino analogue pin A0 to A7 while the servomotors are connected to the digital-pin number 9 and 11. The physical arrangement of the LDRs and their location on the board is determined empirically to give the maximum sun intensity. The block diagram and schematic diagram of the developed system is shown in Figure 2 and Figure 3, respectively.

![Figure 1: Single and dual axis solar tracking system.](image)

A dual-axis tracker is designed in order to maximize the harvested solar energy. The analog to digital convertor (ADC) converts the received values from the LDR into pulse width modulation (PWM) format in order to control the servomotors. The system is designed to move among 9 positions along the horizontal axis (Axis-1) from 0 to 180 degrees with a resolution of 22.5°. The angles are approximated to the nearest value as servomotors do not support a half-degree. According to the light intensity, the servomotor would move the solar panel to the location of the maximum intensity captured by the LDR among the 9 positions. The readings from the LDRs are taken with an interval of 30 minutes in order to reduce the amount of consumed power.
In terms of the vertical axis (Axi-2) the system supports three positions namely: 10, 20 and 30°. These values are chosen empirically according to the sun track in the test location. The hardware structure of the overall system is shown in Figure 4.

In the event that the readings from all the LDRs are below a certain threshold for a while, this indicates the beginning of the night mode. In this mode, the tracker will move to the initial position (facing east) and enter the idle mode waiting for the sun rise. The flow chart of the proposed system is shown in Figure 5.

**Figure 2:** Block diagram of the developed system.

**Figure 3:** Schematic diagram of the developed system.
3. Results and Discussion

Readings for the designed solar tracking system were taken from sunrise till sunset (approximately 6:00am till 7:00pm during August) for the period of one sunny week. In order to evaluate the performance and prove the efficiency of the proposed prototype, two scenarios are tested: one corresponding to the fixed solar panel and another for the mobile solar panel. The fixed solar panel is positioned to face the south at an open field. On the other hand, the mobile solar panel was automatically positioned to follow the sun along 9 positions in the horizontal plane and three positions in the vertical.

As the dual-axis tracker kept the solar panel almost perpendicular to the sun, an increased average power was recorded in comparison to the immobile solar panel. Figure 6 shows a comparison of the output from the immobile and mobile solar panel using 1-Axis tracker. It can be clearly seen that there is a good improvement in the harvested power using 1-Axis tracker. The power is almost the same in the middle of the day as the fixed solar panel was facing the south. However, the effect the mobile solar panel is clear when the sun changes its position during the beginning and end of the day. The improvement ratio of using 1-Axis tracker compared to a fixed solar panel is 17%.

Figure 4: Hardware structure of the overall tracking system.
Figure 5: The flow chart of the developed system.
Figure 7 compares the power using 1-Axis tracker vs. 2-Axis tracker. Similar to the first case, the two curves are close to each other in the middle of the day but the gap between the two curves increases before middle of the day or when the sun descends toward the west. The ration of improvement when using 2-Axis tracker compared to 1-Axis tracker is 10%. This will only cost an extra motor in the vertical axis.

On the other hand, Figure 7 illustrates the effect of horizontal angle of the solar panel versus the harvested power using fixed, 1-Axis and 2-Axis tracker. It can be seen that when the angel equals to 90°, the collected power is almost the same for all the three trackers as the sun is in the middle of the sky. However, the collected power varies significantly when the angle is 0, 22 and 45 or 135, 157 and 180 degrees. This can be attributed to movement of sun to far left or right of the sky. In this case, the immobile cell would not generate enough power compared to the 1-Axis or 2-Axis tracker. In fact, the 2-Axis tracker performance peaks at 0 and 22 or 157 and 180 degrees compared to the 1-Axis tracker for the same reason.

![Figure 6: Fixed vs. 1-Axis power.](image)
4. Conclusions and future work

A dual-axis scaled-down solar tracker was developed and designed using Arduino Mega microcontroller. Two servomotors were controlled with the help of 8 LDRs to move the solar panel within 9 positions vertically and 3 positions horizontally. The results show an improvement in the harvest solar power especially when using the dual-axis solar tracker. The improvement of using 2-Axis solar tracker was 25% better compared to an immobile solar panel. Our future work will focus on implementing the designed prototype in real life scenario. In addition, an MCU-platform could be added to transfer the solar information such as power, time and light intensity over the WIFI to log these data in a database for further analysis.
5. References

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