Design and Implementation of an Efficient Solar Tracker System

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Abstract. The world is highly interested in using solar energy as an alternative to fossil energy. Changing the shape of solar systems was adopted to improve its work efficiency. Although the solar tracker is made to be more efficient than the fixed solar system, the work to develop it is yet uncompleted. In this paper, the solar tracker system is used, which works by (LDR) sensors, microcontroller Arduino UNO for controlling the system, and DC motors. The extent of the impact of the solar tracker was studied with its work time. The worked electric circuit for the timer was run the system for one minute and shut-down the system circuit for 29 minutes, the comparison of the work of the tracker was done with a timer and without timer. Finally, according to the amount of gain and loss of energy, it was found that the energy gains about 96.25% from timer system only, and the lost energy from the solar panel because used the timer is about (0.238 to 0.475) % only. The workplace lies in (32°01’49.08” N, 44°22’21.83” E, in Iraq), in August, to real solar panel type.

Keywords: Solar Tracker, Timer system, Arduino microcontroller, Arduino Nano, Renewable Energy, LDR sensor.

1. Introduction
Energy is always the backbone of life, in terms of human life requirements and countries' energy needs. In the modern era, there is a growing demand for energy on the one hand, and there is a growing complaint about pollution due to the production of energy (fossil, for example) because of many problems. So, science has moved towards the use of renewable energy of all kinds (such as solar energy), in particular. It is Non-polluting to environment [1,2]. It is one of the best clean power technologies with high-global growth types, due to its minimalism, affordability and availability. Sun power systems are one of the fastest-growing interventions, and its application is now available beyond domestic exploit to commercial and industrial dependence [3]. So, its use has increased especially in areas far from the city [4].

To understand the motion of the earth relative to the Sun, and in order to understand how the solar tracker works, figure (1)[5], shows the Azimuth angle, figure (2) shows the simple diagram for it, and figure (3) show the ) LDR sensors system, if L is the girder height, M is the distance of the LDR sensor from the girder, Θ the angle of shadow, Θ = 2π [6].
In 2015 (Djilali Chogueur, Said Bentouba and Amraoui Merouane), they created a solar system in southern Algeria that operated at one degree of freedom, and the sun was detected using a photovoltaic cell[7]. Carlos Morón and others, used stepper motor with Arduino platform to make a prototype photovoltaic solar tracker using dual axes system in 2017[8]. In 2018 the authors used stepper motor and a solar panel mounted to a time-programmed with Arduino controller, to track the sun, this work was done by Arbaj N.Aga, Sanket
G.Govekar and AsifAli S.Jamadar[9]. Finally, in 2019, the Timothy Laseinde and Dominic Ramere used Arduino board to make multi-axis solar tracking system, it is Low-cost, automatic, for performance improvement solar panels [3].

This work aims to establish an economical solar tracker system by treating the parts that consumed unnecessary energy and attempting to minimize loss energy. The motion of sun with studies a length of the shadow, after that, make a timer circuit to shut-down the system 29 minute with one-minute work and measure the amount of solar panel power loss due to the timer. The workplace lies in (32°01′49.08″ N, 44°22′21.83″ E, in Iraq) [10], in August, to real solar panel type.

2. The Practical Device

To study the motion of sun with shadow length, for the horizontal motor controlled by motor 1, it comes from the light and shadow difference on the left and right LDR sensors. According to figure (1), the horizontal path of the Sun is from less than π to more than π in any one-day path according to the location of the day on the year. We can note the tan Θ become as equation (1):

\[
\tan \Theta = \frac{M}{L} \tag{1}
\]

\[
M = L \tan \Theta \tag{2}
\]

\[
\frac{dM}{dt} = L \sec^2 \Theta \left(\frac{d\Theta}{dt}\right) \tag{3}
\]

\[
\int \frac{dM}{dt} = L \int \sec^2 \Theta \left(\frac{d\Theta}{dt}\right) \tag{4}
\]

\[
\int dM = L \int \sec^2 \Theta \; d\Theta \tag{5}
\]

Now in Zenith path as in figure (1) and similarly in figure (2):

Here \( L \) is the girder height , \( N \) is the distance of the LDR sensor from the girder , \( \Phi \) the angle of shadow: \( \Phi = \frac{\pi}{2} \).

\[
\tan \Theta = \frac{M}{L} \tag{6}
\]

\[
N = L \tan \Phi \tag{7}
\]

\[
\frac{dN}{dt} = L \sec^2 \Phi \left(\frac{d\Phi}{dt}\right) \tag{8}
\]

\[
\int \frac{dN}{dt} = L \int \sec^2 \Phi \left(\frac{d\Phi}{dt}\right) \tag{9}
\]

\[
\int dN = L \int \sec^2 \Phi \; d\Phi \tag{10}
\]

Figure (4) is the final form of the practical circuit tracer in the diagram below, figure (5) represents the real images to the system (the real image to the panel, Arduino UNO, Arduino Nano, LDR sensors and DC motor with gearbox). The practical study to determine the amount of power loss represented table (1), where \( V_1, I_1, P_1 \) are the voltage, current, and power respectively. These represent the parameters for the system without the timer circuit. \( V_2, I_2, P_2 \) the voltage, current, and power respectively, it is representing the parameters for the system with the timer circuit. Figure (6), figure (7) and figure (8), show the relationship between voltage, current, and power respectively.
Figure 4: Diagram of Operator

Figure 5: The Real Images to The System

Figure 6: Relationship Between Voltage

Figure 7: Relationship Between Current
3. Results and Discussion

In the horizontal path of the Sun
If \( L = 10 \text{ cm} \) .................................................................(11)

to obtain \( \Theta \) when \( M = 1 \text{ cm} \)

\[ \frac{M}{L} = \tan \theta_2 \]

\[ \frac{\theta_2}{\theta} = \tan^{-1} 0.1 \]

\[ \theta_2 = 5.71 \] .................................................................(12)

return to equation (3):
The earth globe rotates 360 degrees in one roll every 24 hours.

\( \frac{d\Theta}{dt} = \frac{2\pi}{24h} = \frac{2\pi}{86400} (\text{sec}) \)

\[ \frac{dM}{dt} = \left(\frac{L}{\cos^2 \Theta}\right) * \left(\frac{2\pi}{86400}\right) \]

\[ \frac{dM}{dt} = 7.27 \times 10^{-6} \]

for \( M = 1 \text{ cm} \)

\[ t = 1375.5 \text{ sec} = 23 \text{ min} \] .................................................................(13)

so, every (5.71) degree take (23) minute.

In Zenith path: \( \Phi = \pi/2 \),

return to equation (10)

if \( L = 10 \text{ cm} \)

to obtain \( \Phi \) when \( N = 1 \text{ cm} \)
\[ N = L \tan \Phi_2 \]
\[ \frac{N}{L} = \tan \Phi_2 \]
\[ \Phi_2 = \tan^{-1} 0.1 \]
\[ \Phi_2 = 5.71 \] \hspace{1cm} \text{(14)}

return to equation (6):
The sun ray path about 180 degrees the sun goes up and down every day during about 12 hours, \( \Delta \Phi = \frac{2\pi}{2} \).
\[ \frac{d\Phi}{dt} = \frac{2\pi}{2 \times 12 \text{h}} = \frac{2\pi}{86400} \text{(sec)} \]

for \( N = 1 \text{ cm} \)
\[ t = 1375.5 \text{ sec} = 23 \text{ min} \] \hspace{1cm} \text{(15)}

so, every (5.71) degree take (23) minute, similar result in azimuth path.

As a result, from the equation (13) and equation (15), with the fact that (5.71 degrees) does not affect by the power of the solar panel, but it is hardly felt for the solar panel. We can conclude that the timer, that works with the microcontroller Arduino card can be used [11]. As an experimental option, we will take 30 minutes of extinguishing with a one-minute working.

The main reason for using the timer is to save the energy of the sun tracker, during which time it does not make sense for the work of the tracker, which will take the noise mode only because of the Lack of sensors teams of LDR sensors. On the other hand, to maintain the motors of the sun tracker by turning off this period of rest. With the possibility of reducing the quality of the motors operating in the tracker because of the lack of working time, and the low temperature that was generated inside the motor because of continuous work.

Now with using a timer in the system, so to calculate the power consumed in the tracker circuit within an hour (assuming that the motors worked only a quarter to half the time).

I. Without Timer Circuit

In normal circuit in one hour it has 3600 seconds, if the motor work in quarter time it has (900 seconds, 240 watt), in the resume time has (2700 second, 1.8 watt), in halve time motor work it have (1800 second, 240 watt), in the resume time have (1800 second, 1.8 watt).

Power (in quarter time) = \((900 \times 240) + (2700 \times 1.8)\)
\[ = 220860 \text{ Watt in one hour} \] \hspace{1cm} \text{(16)}

Power (in halve time) = \((1800 \times 240) + (1800 \times 1.8)\)
\[ = 435240 \text{ Watt in one hour} \] \hspace{1cm} \text{(17)}

II. With Timer Circuit

In timer circuit, through one hour, work about 2 minutes (120 second), it is shutdown in (3360 second), the circuit of the timer is working continuously (Nano Arduino microcontroller and relay shield) take (31 watt) and (1.8 watt) without relay shield, if the motor work in quarter time, it is having (30 seconds, 240
+ 31) watt), in the resume time have (90 seconds, 1.8 watt), if the motor work in halve time, it is has (60 seconds, (240 + 31) watt), in the resume time have (60 second, 1.8 watt).

Power (in quarter time) = (30*(240+31)) + (90*1.8)

= 8292 Watt in one hour ....................... (18)

Power (in halve time) = (60*(240+31)) + (60*1.8)

= 16368 Watt in one hour ..................... (19)

Depending on the power factor consumed by the system only, and by comparing equation (16) with equation (18) and equation (17) with equation (19), we find that:

((P13 – P11) / P13)* 100% = ((220860 - 8292) / 220860)*100 %

= 96.25 % ...........................................(20)

((P14 – P12) / P14)* 100% = ((435240 - 16368) / 435240)*100 %

= 96.25 % ............................................. (21)

Note from equations (20), (21) that the results are very close to the same type of work, depending on the power factor only.

From table (1), the results were as follows: the current loss ratio was 0.332%, the voltage loss ratio was 0.106%, and the power loss ratio is 0.475%. These percentages are considered that the state in which the timer works is permanent by shifting 1.1 cm from the shadow, but this is not true, every half-hour will the tracker is work to make the shadow value of zero, after that the shadow continues to increase during this time to the end of the period where it is of 1.1 cm, so on periodically, therefore, it is closer to the fact that we divide the loss ratio by half the value obtained, therefore, the proportion of the loss of power is 0.238%. More precisely the proportion of the loss of power is (0.238 to 0.475) %.

Table (1): Tracking System and Tracking System with Timer

|   | Tracking Panel | Tracking Panel With Timer |
|---|----------------|---------------------------|
| P1(w) | V1(v) | I1 (A) | P2(w) | V2(v) | I2(A) | time |
|---|---|---|---|---|---|---|
| 0.50 | 16.50 | 0.03 | 0.50 | 16.50 | 0.03 | 5:30 |
| 1.26 | 18.00 | 0.07 | 1.26 | 18.00 | 0.07 | 6:00 |
| 2.88 | 19.20 | 0.15 | 2.88 | 19.20 | 0.15 | 6:30 |
| 5.94 | 22.00 | 0.27 | 5.94 | 22.00 | 0.27 | 7:00 |
| 6.83 | 20.70 | 0.33 | 6.83 | 20.70 | 0.33 | 7:30 |
| 74.47 | 21.40 | 3.48 | 74.47 | 21.40 | 3.48 | 8:00 |
| 74.40 | 20.90 | 3.56 | 74.20 | 20.90 | 3.55 | 8:30 |
| 75.30 | 20.80 | 3.62 | 74.88 | 20.80 | 3.60 | 9:00 |
| 77.38 | 20.80 | 3.72 | 76.96 | 20.80 | 3.70 | 9:30 |
| 77.63 | 20.70 | 3.75 | 77.21 | 20.70 | 3.73 | 10:00 |
| 77.33 | 20.90 | 3.70 | 76.70 | 20.90 | 3.67 | 10:30 |
| 78.00 | 20.80 | 3.75 | 77.21 | 20.70 | 3.73 | 11:00 |
| 78.69 | 20.60 | 3.82 | 77.90 | 20.50 | 3.80 | 11:30 |
| 84.32 | 21.40 | 3.94 | 84.32 | 21.40 | 3.94 | 12:00 |
4. Conclusions:

It can be concluded from the overall research results that the solar tracker works with microcontroller, DC motors and LDR sensors, with a working timer is more efficient and with more economical gain than fixed systems, after knowing the number of daylight hours during the year and the small amount of shade length increase during time, every (5.71) degree take (23) minutes. Also it found that the zenith angle is close to the azimuth angle in the results. Furthermore, it is found that it is logical to use a timer that turn on the circuit for one minute and turns it off for 29 minutes, found here that the amount of gain of power in the system from working the system only It was 96.25%, and measured the power loss of the solar panel due to the timer, it is about (0.238 to 0.475) % only. Overall, the study shows that the timer system is efficient, economical and well-earned.

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