Design of Arduino-Based Dual Axis Solar Tracking System

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***Abstract*— Green and clean energy depends meanly on the Solar energy, especially at urban area. This paper presents the Arduino-based new design of dual-axis solar tracking system with high-efficiency using through the use of five-point sunlight sensors. The main objective of this research is to convert the maximum sunlight to electrical power by auto movement of the solar panel. This research is divided into two stages, first stage related to hardware design and the second related to software development. In hardware design, five light dependent resistors (LDR) have been used for tracking light direction source. Two linear actuators have been used to move the solar panel towards the maximum light intensity direction by using LDR sensors. Moreover, the software is constructed using C++ programming language and uploaded to the Arduino UNO platform. The efficiency of the designed tracking system has been examined and compared with fixed and single axis solar tracker and results shows that the new system has better efficiency than the fixed or single axis system, where the increment in voltage (ΔV) in tracking system as percentage with day time (10 am to 3 pm) has been increased with 10 to 17%.**

Keywords—solar panel, tracking system, sensors, Arduino, microcontroller

I. Introduction

Due to fast development of technology, most of the people around the world need to use energy to complete their daily work. Many natural energy sources are increasingly being used in the society. One of them is solar energy that uses the solar panel and solar tracker. The Solar panel is the panel that is designed to convert the sun's light and make it as a source for generating electricity.

Using dual axis principle for solar tracking could produce 40% more power compared to the single axis solar tracker [1]. The tracking system with dual axis give maximum energy from solar panel because of their ability to change the position and follow the Sun light vertically and horizontally whatever the Sun position in the sky, tracking system with dual axis are able to angle themselves to be in line with the Sun light compare to the single axis solar tracker. The previous researches use the single axis solar tracker which causes the solar energy received is wasted and not track the sunlight accurately to give maximum production of electricity. It is proven that the tracking system with dual axis had an yearly energy gain of 36.504% compared to single axis [2].

II. Solar Tracking System

The tracking system with single-axis principle depends on rotating the panel around a tilted shaft under the action of controlling a bi-directional DC Motor according to the sun light direction estimated by means of two light intensity sensors [3]. The light sensors include two LDRs placed on each side of the solar panel separated by a black card box. Depending on the intensity of the sunrays one of the LDRs will has a shadow and the other will be illuminated.

The tracking system with dual axis principle depends on rotating the panel toward the position of the sunlight using two motors, so that the solar panel will always face perpendicularly the sun light, the 5 (LDRs) as a sensor to provide feedback by sense the higher intensity area of sunlight to the Arduino UNO microcontroller. It can move in every direction towards the higher intensity of the light.

Some research papers suggest some calculation related to find the sun position depending on time, location, and day of the year. Firstly, these calculations depend meanly on Solar Declination Angle (δ), and Δ angle which between the plane of the equator and a line drawn from the center of the sun to the center of the earth, this angle (Δ) varies between +23.45º and -23.45º. There are various formulas to find the declination angle, but none of them can find the exact values of declination, simply because δ varies slightly from year to year. One of the calculations for solar declination is representing in (1).

$$\delta = \delta_o \sin\left[360 \times \frac{(284+n)}{365}\right] \quad (1)$$

Where n is the day number counted from the beginning of the year and δº is 23.45º for declination [4], and Equation of Time (EOT), apparent solar time (AST), time zone (TZ), local clock time (LCT), longitude (L), equation of time (EQT) are calculated by the equations (2) and (3) below [5].

$$\mathrm{EOT} = 9.87 \sin 2\mathrm{B} - 7.53 \cos \mathrm{B} - 1.5 \sin \mathrm{B} \quad (2)$$

$$\mathrm{AST} = \mathrm{LCT} + \mathrm{TZ} + \frac{\mathrm{L}}{15} + \frac{\mathrm{EQT}}{60} \quad (3)$$

III. Methodology

The explanations of the hardware design and software development with the electrical circuit diagrams also included in this section.

Basically, the tracking system of any solar panel is operating according to the direction of the sunlight. The tracking system depends mainly on an auto-tracking technique instead of adaptive technique or pre-defined movement. The system will automatically move the solar panel until it is faced perpendicularly towards the sunlight. The sensors provide the feedback signals to the controller to control the system.

The main part of the control system is the microcontroller, which collect the sensors signals and decide which motor should move to which direction for adjusting the system in such a way that the sun light falls directly on the panel. The 5-point sensor (Fig. 1) will detect the direction of light depending on the light intensity detected by each sensor and send the data to microcontroller. The microcontroller will compare the intensity of light based on the data collected from the sensor and accordingly controlled the actuator.

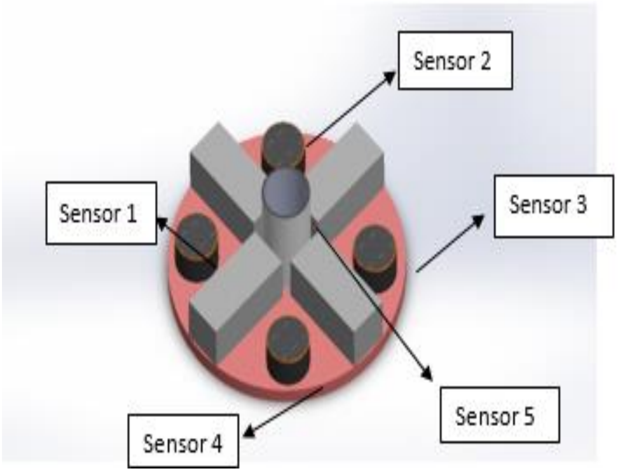

Fig. 1. Design of the sensors

Instruction of the sensors when sunlight detected in Fig 1 by the following; sensor 1 as west-north direction, sensor 2 as east-north direction, and sensor 3 as east-south direction.

The complete mechanical design of tracker shown in Fig. 2, this figure illustrates the positions of linear actuators to control directions with wide range of movement between east to west, and with small rage between north and south. The controller performs signal comparison and it is the main deciding element. The control algorithm for controller is shown in Fig.3 and the circuit diagram in Fig 4. The system procedure starts with read the signals from the 5 sensors, S_1 represent the direction to the West-North, S_2 represent the direction to the East-North, S_3 represent the direction to the East-South, S_4 represent the direction to the West-South, and S_5 represent the direction to the direct sun light. After collecting 5 sensors signals, the Arduino will decide about the movement direction and step angle of linear actuator motors. Table 1 illustrates the condition to move the solar panel at which direction depending on the sun position. Controller algorithm is showing that the Arduino will drive linear actuator motors only if sensors light are not equal for all. This process will continued until light falling on sensor pairs is equal and solar panel is adjusted in a position for optimum power.

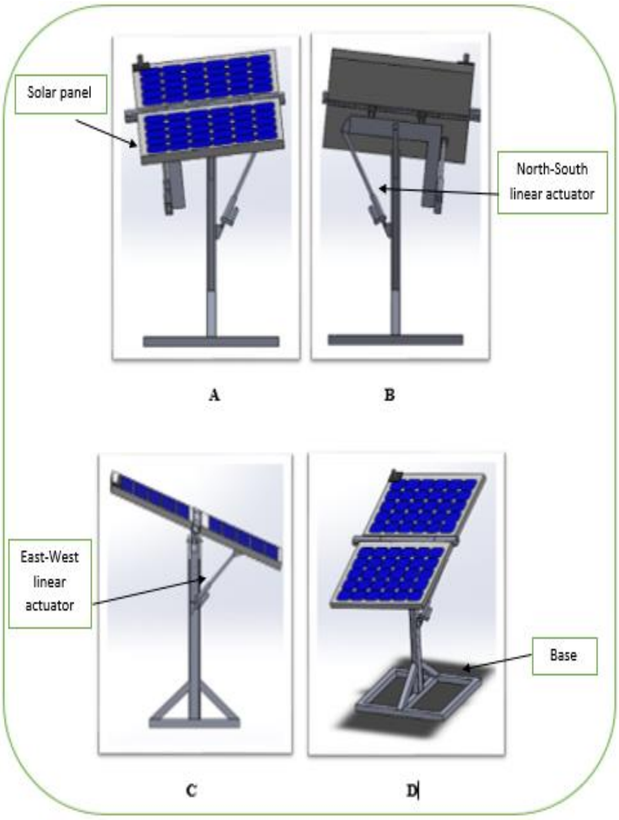

Fig. 2. Final design, A: front view, B: back view, C: side view, and D: isometric view

TABLE I. ANGLE OF SOLAR HOUR AS A FUNCTION OF SOLAR TIME [6]

Solar Time	Solar hour angle (ω) in degree
6 hours before solar noon	-90
5 hours before solar noon	-75
4 hours before solar noon	-60
3 hours before solar noon	-45
2 hours before solar noon	-30
1 hours before solar noon	-15
solar noon	0
1 hours after solar noon	15
2 hours after solar noon	30
3 hours after solar noon	45
4 hours after solar noon	60
5 hours after solar noon	75
6 hours after solar noon	90

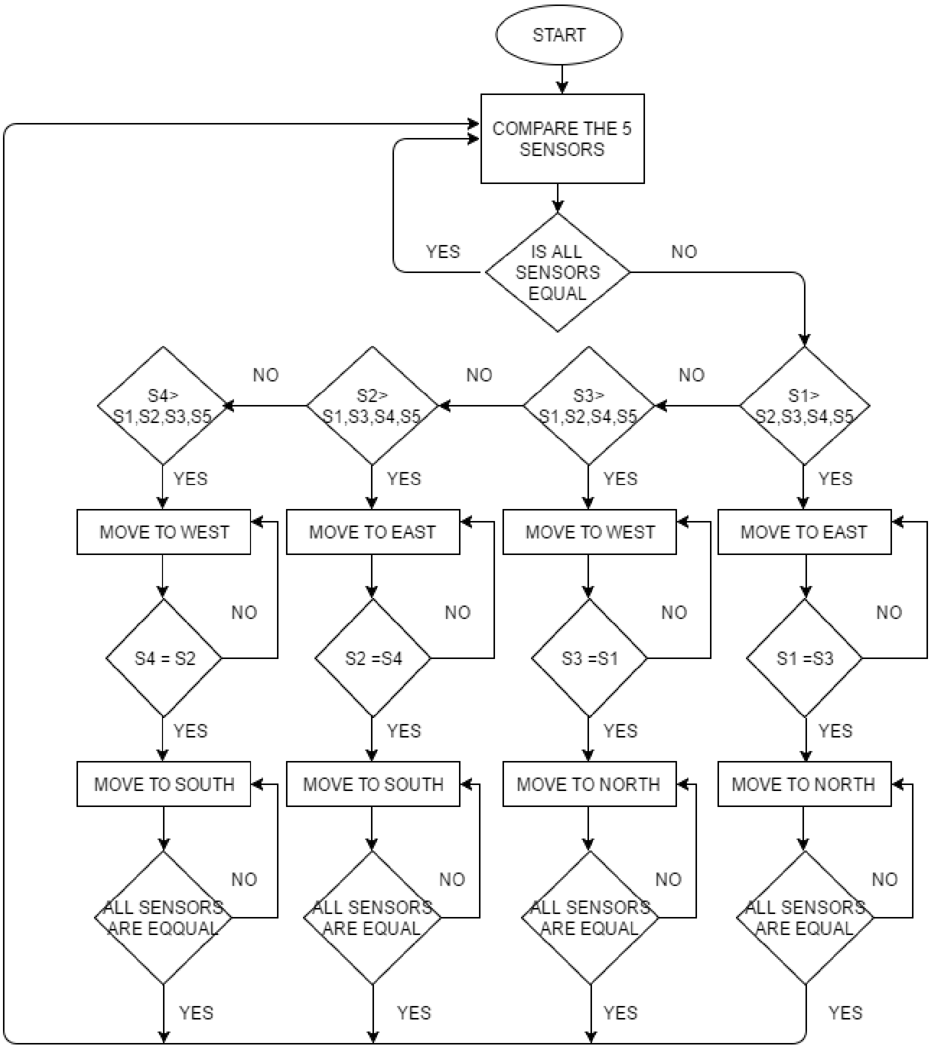

Fig. 3. Control algorithm of tracking system

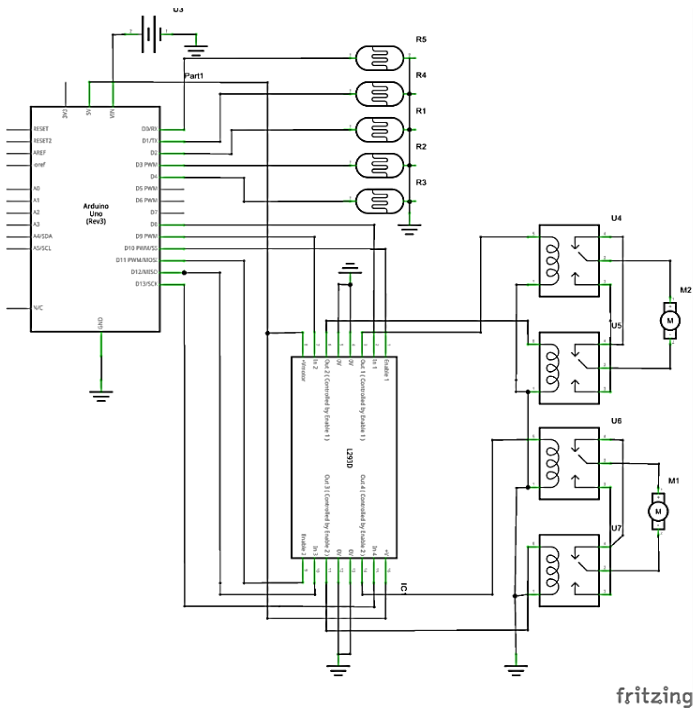

Fig. 4. Circuit diagram of tracking system

When the actuator receives the data from the microcontroller, the actuator will elongate and tilt the solar panel so that the solar panel will face the directly to the sources of light. The solar tracker is able to move in two different directions by following the angle of the sun height in the sky also to following the sun's east-west motion. The dual axis tracking system is working in principle like single axis, but it convert the solar energy more effectively by rotating in directions, the horizontal and the vertical axis. Fig. 4 presents the proposed model for dual axis tracking system. The new tracking model is used 5 Light-Dependent Resistor (LDR) sensors, two linear actuator motors and Arduino UNO microcontroller.

IV. Results and Discussions

From the result in Figs. 5-7, the highest output voltage is between 13 PM to 15 PM in fixed mode as the amount of sunlight hits the solar panel is high at this range. There is less cloud during the time. So the sun ray can pass through the atmosphere clearly and directly hits the solar panel. From the result above, the voltage output is the highest at 14 pm as the solar panel can track most of the sunlight that hits it at this point.

From the result above, we can conclude that the highest output of voltage is in the tracking mode compare to the fixed mode and the time is between 13 pm to 15 pm for both modes. During the data collection, there is no cloudy time so that we get the maximum light intensity through the solar panel. The power less produces in the morning which is from 9am to 11am as after 15pm the voltage output also decrease.

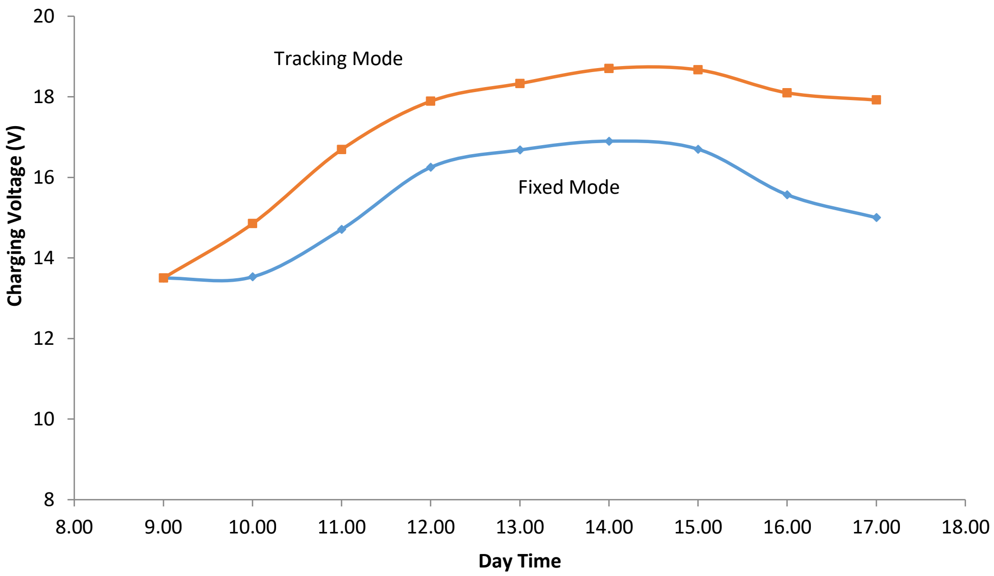

Fig. 5. Charging level with tracking and fixed mode

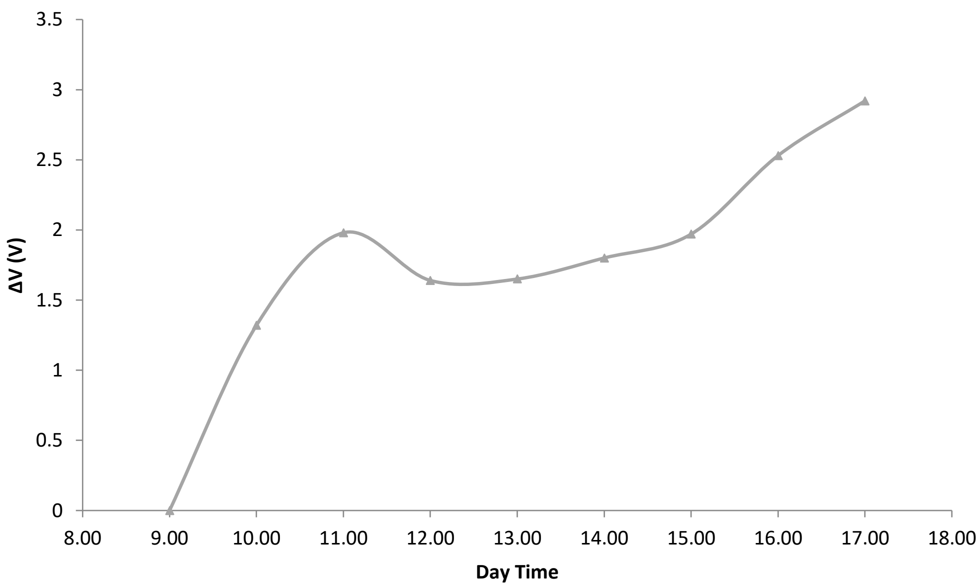

Fig. 6. Increment in voltage (ΔV) with day time

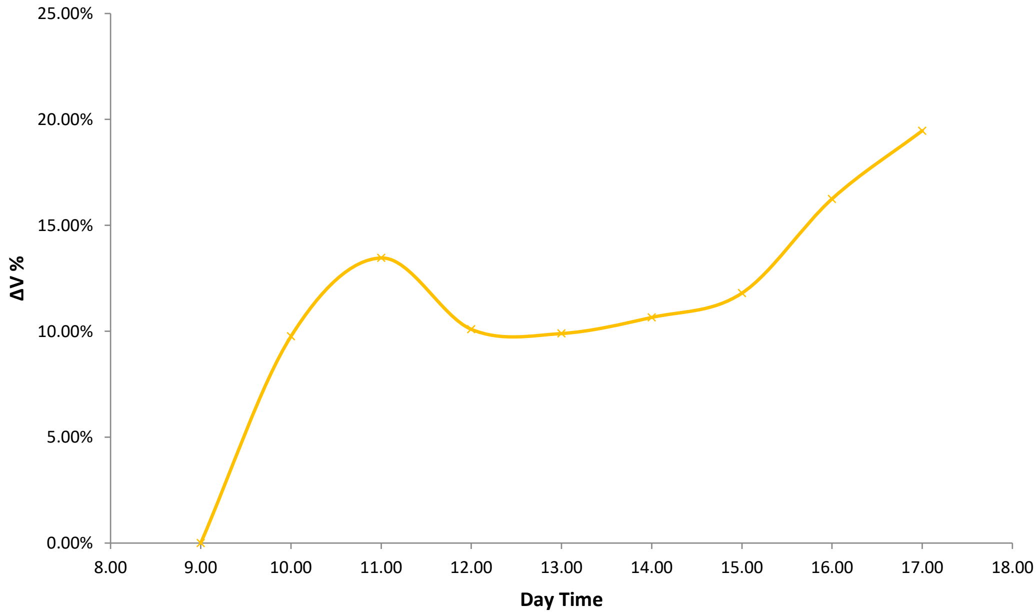

Fig. 7. Increment in voltage (ΔV) as percentage with day time

V. Calculation

Calculations of this research can be formulated as follows:

$$FF = \frac{Pmax\ (W)}{Isc\ (A) \times Voc\ (V)} \quad (4)$$

$$FF = \frac{100\ (W)}{5.70\ (A) \times 22.53\ (V)} = 0.79$$

Where Voc is the open-circuit voltage, Isc is the short-circuit current, FF is the fill factor ration of maximum obtainable power to the product of the open-circuit voltage and short-circuit current, and n is the efficiency.

When, Pmax = 100W, Voc = 22.53V, Isc = 5.70A, Area of solar panel = 0.820 m × 0.808 m.

$$P_{in} = \frac{1000W}{m^2} \times (0.820 \text{ x } 0.808) = 662.56\ W$$

$$n(\%) = \frac{VocIscFF}{Pin} \quad (6)$$

$$n = \frac{22.53 \times 5.70 \times 0.79}{662.56\ W}$$

$$n = 0.1531\ @\ 15.31\%$$

From the calculation above, it shows that our solar module has good efficiency compare to the previous study which is single axis solar tracker.

VI. Conclusion

In this project we can conclude that by implement the Tracking system with dual axis is more efficient instead of using tracking system with single axis due to the bigger difference of the voltage output and also the factor of materials and parts use in solar tracker. According to the final results, it is found that the tracking system with dual axis can increase power output by about approximately by 20% of the tracking system with single axis.

Acknowledgment

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g". Avoid the stilted expression "one of us (R. B. G.) thanks ...". Instead, try "R. B. G. thanks...". Put sponsor acknowledgments in the unnumbered footnote on the first page.

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