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Design, construct and Performance Study of Microcontroller Based Self-Powered Dual-Axis Solar Tracking System for Photovoltaic Panel.

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Abstract: *The consumption of conventional energy causes heavy environmental pollution. To solve these problems, solar energy can play a vital role as an alternative energy source. This paper presents the design, construction and performance study of an Arduino-based self-powered dual-axis solar tracking system for photovoltaic panel which allows more energy reproductionby keeping the solar panels aligned with the Sun. When the intensity of light is decreases due to change of Sun's position, the system automatically changes its direction to get maximum intensity of light. For this purpose four light dependent resistance are used along with four 100kΩ ordinary resistance for constructing a voltage divider circuit. The whole function is continuously monitored and controlled by an ArduinoUNO R3 microcontroller. Besides the system is entirely self-powered, so that no external conventional energy sources needed. A computer simulation of the proposed system was first designed using proteus 7 software and then the prototype was carried out according to the simulation. This systemcan be used in industrial and residential sectorfor increasing the efficiency of a photovoltaic panel or any solar energy conversion device which will contribute in solving the increasing demand of electrical energy.*
Keyword: *Solar tracker, Arduino, LDR, Servo motor.*

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I. Introduction

Sunlight is electromagnetic non ionizing radiation emitted by the sun in particular infrared, visible, and ultraviolet light. It is possible to transform the solar energy to other useful forms of energy including electricity, fuel, and heat [1]. It covers light-harvesting technologies including traditional semiconductor photovoltaic devices (PVs), emerging photovoltaic, solar fuel generation via electrolysis and artificial photosynthesis [2].

A tracker can increases output energy of solar energy conversion device. A solar tracker is a device that orients a payload toward the Sun. Payloads are usually solar panels, parabolic troughs, fresnel reflectors, lenses or the mirrors of a heliostat. A single axis tracker increases annual output by approximately 30% while a dual axis trackerincreases an additional 10-20% [3].

For flat-panel photovoltaic systems, trackers are used to minimize the angle of incidence between the incoming sunlight and a photovoltaic panel, sometimes known as the cosine error. Reducing this angle increases the amount of energy produced from a fixed amount of installed power generating capacity [4].

Here a self-powered solar tracking device is designed and constructed by using Arduino microcontroller, light dependent resistance, servo motors, and rechargeable battery with associated electric circuits. The performance of the developed system was then studied and compared with static photovoltaic panels and single axis photovoltaic panel.

II. Working mechanism

2.1 Working mechanism

The main objective of this project is to capture maximum solar energy on the solar panels. A practical way of achieving this is by positioning the panels so that the rays of the sun fall perpendicularly on the solar panels. As the angle of incidence is reduced, the flux of sunlight hitting the collector increases and the solar panel can absorb more solar energy simply because the projected areaorthogonal to the incoming sunlight increases [5].

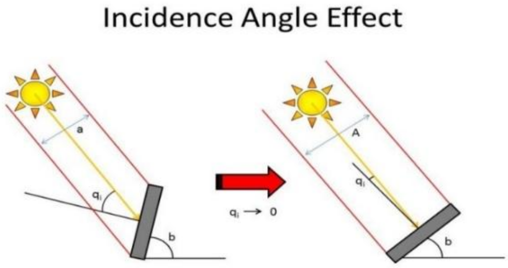

Figure 1. Effect of Incidence Angle's on Efficiency

A solar tracker is a device that orients a payload toward the Sun. It is able to remain aligned to the sun. There are two types of solar tracker:

- Single axis solar tracker
- Dual axis solar tracker

Single axis tracking system follows only the Sun's east-west movement. But the earth has two types of motion, the daily motion and the annual motion. The daily motion causes the sun to appear in east to west direction over the earth whereas the annual motion causes the sun to tilt at an angle of 23.5° while moving along east-west direction. So the maximum efficiency of the solar panel is not reached by single axis tracking system. To track the sun movement accurately dual axis tracking system is necessary [6].

III. Research Methodology

The main part of the proposed system is Arduino UNO R3 microcontroller. Four light dependent resistance (LDR) are used with four 100kΩ ordinary resistance to form a voltage divider circuit. The resistance of the LDR deceases as the increase of light intensity. Here the highest voltage from the voltage divider circuit is limited on 5 volt and comply this voltage with Arduino input requirement. When the suns position changes the resistance of LDR increases and voltage from the divider circuits also changes. Arduino microcontroller continuously monitor and analyze the input voltage and sends instructions to the servo motor.The microcontroller is powered by a rechargeable 12 volt battery which automatically collects power from the photovoltaic panel.

3.1 Arduino Microcontroller

A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system. A typical microcontroller includes a processor, memory and input/output peripherals on a single chip[7].

The major advantage of the Arduino microcontroller is it does not need a separate piece of hardware called a programmer in order to load new code. Additionally, the Arduino uses a simplified version of programming language C++[8].

3.2 Photovoltaic Solar Panel

Photovoltaic solar panels absorb solar radiation as a source of energy to generate direct electricity. Photovoltaic solar panels consist of small photovoltaic cells that are connected together. The most abundant and convenient source of renewable energy is solar energy, which can be harnessed by photovoltaic cells. Photovoltaic systems convert solar radiation to electricity by means of the photovoltaic effect in materials such as silicon and selenium. These solar cells are composed of two different types of semiconductors a p-type and an n-type which are joined together to create a p-n junction. When light of a suitable wavelength is incident on these cells, energy from the photon is transferred to an atom of the semiconducting material in the p-n junction. Specifically, the energy is transferred to the electrons in the material. This causes the electrons to jump to a higher energy state known as the conduction band. This movement of the electron create a voltage.

The output power of a photovoltaic cell depends on the amount of light projected on the cell. Time of the day, season, panel position and orientation are also the factors behind the output power. Solar panel gives maximum power output at the time when sun is directly aligned with the panel [9].

3.3 Light dependant resistors (LDR)

Photo-resistor or light dependant resistor (LDR) is a resistor whose resistance decreases with increasing light intensity or it can be said that the LDR exhibits photoconductivity. For this work, the intensity of light sensed by the LDR becomes an input to the main controller. The relationship between the resistance R_{LDR} (resistance of LDR) and light intensity (Lux) for a typical LDR is given in following equation [10]:

R_{LDR} = (500 / Lux) kΩ (1)
Where, R_{LDR} = Resistance of LDR

The Light Dependent Resistor (LDR) has a light sensitive part which is made of semiconductors on an isolating base and acts as a photo-resistor. The most common semiconductors used in this LDR structure are cadmium sulphide, lead sulphide, germanium, silicon and gallium arsenide. LDR consists of a pair of metal film contacts separated by a snake like track of cadmium sulphide film which is the light sensitive part. It is design to provide the maximum possible contact area with the two metal films. [11].

3.4 Servo Motor

A servo motor is an electrical device which can push or rotate an object with great precision. It is possible to rotate an object at some specific angles or distance, by using a servo motor. Servo motor is one of the various types of DC motor available in electronic application. This type of motor requires supply either 4.8V or 6V. This motor consists of three wires namely signal, positive and ground wire. It also comprises several parts which are the motor and gearbox, position sensor, an error amplifier, motor driver and a circuit to decode the requested position [12].

3.5 Twelve Volt Rechargeable Battery

A constant and reliable power source is needed for powering up Arduino and running the servo motors. External power source can be used in this purpose but those power source will need a continuous monitoring, adjustment and replacement. So here we used a 12 volt rechargeable battery which collects and stores energy from the photovoltaic panels and gives a continuous power supply to the system.

IV. Circuit design of the proposed system

4.1Block Diagram

For simplifying the entire system a block diagram was built. Block diagram are often helpful for designing an electrical system because it shows different parts of the system along with their interconnections.The connections of different parts and flow of information are represented by arrows. The main work was carried out step by step according to the block diagram.

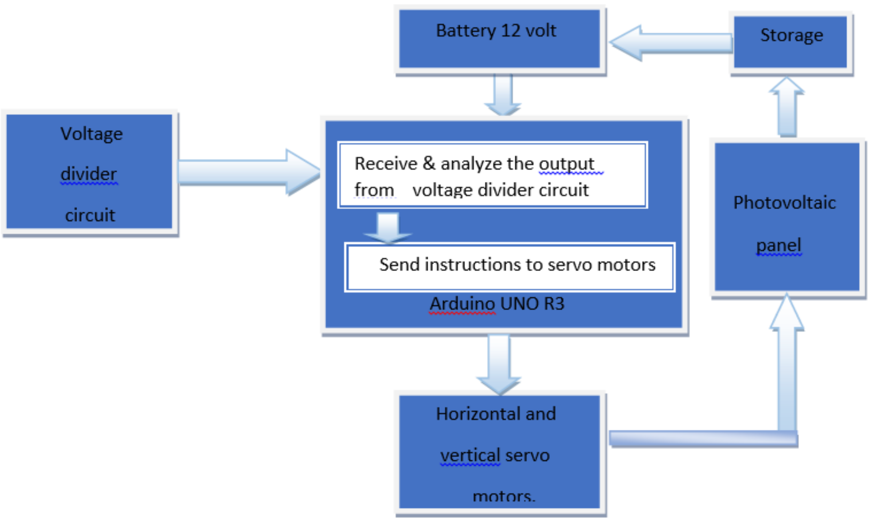

Figure 2. Block Diagram of the developed system

4.2 Circuit diagram

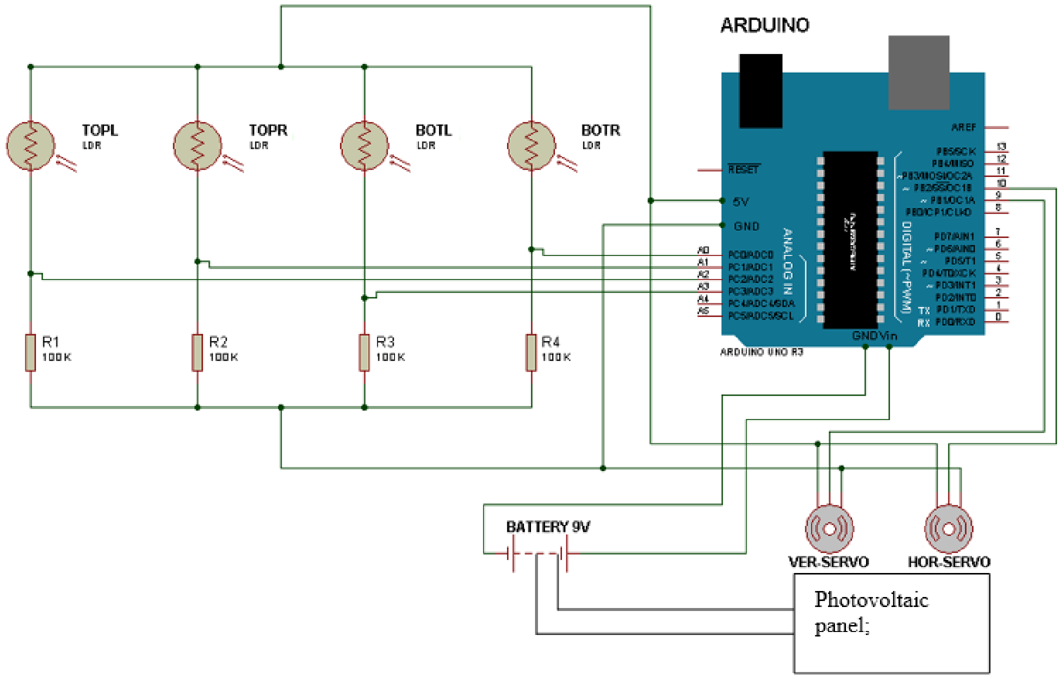

Figure 3. Complete circuit diagram of developed system

V. Programming

In the developed system Arduino UNO R3 microcontroller has been used to sense the analog input, convert the analog signal into digital signal and rotates the servos according to the digital signal. The used microcontroller should be programmed accurately in order to perform the particular task. C programming language has been used to build up the programme and instruct the microcontroller. Arduino (Genuino) software was used to build up the programming. The programming was uploaded to the microcontroller from a PC through a data cable and Arduino (Genuino) software. A flowchart has been designed to understand the programme easily. The flowchart is shown in figure 5.

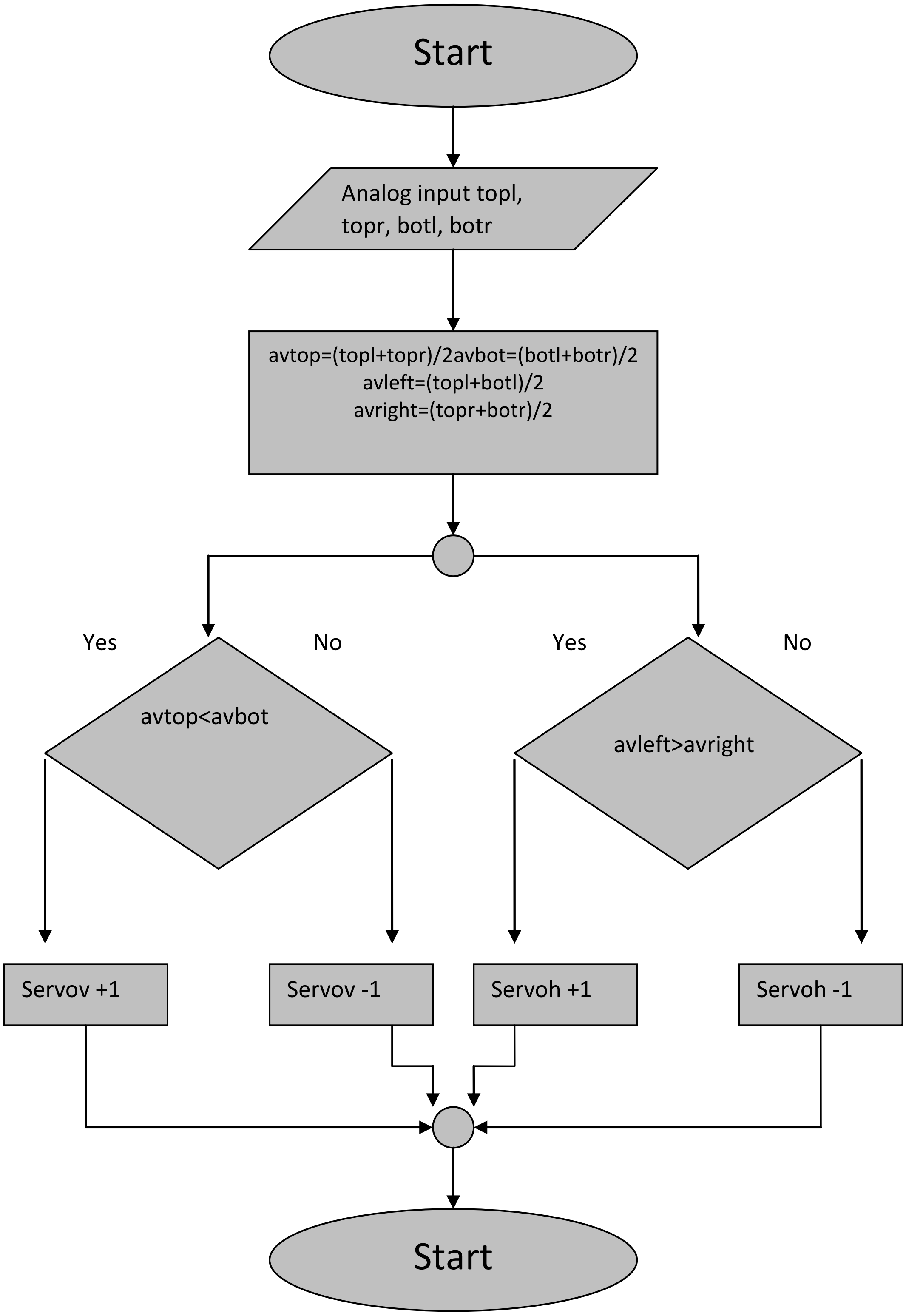

Figure 4. Flowchart of the program

VI. Result

Once the work of the design and simulation of the prototype was done, real fabrication began.The results revealed that the location for the solar panel is one of the important things in collecting its output power.. The measurements of the data were taken from a wide area where there was no obstruction that would prevent the tracker from getting the maximum sunlight. The readings for a (60×60)mm static solar panel and a (60×60)mm solar panel with dual-axis tracker system were taken for a day from morning 8 am to evening 5 pm for every one hour. The following readings are tabulated and two graph were plotted from the data. The table is shown in table 9 and these graph are shown in figure 10 and figure 11 respectively.

Hours	Static Panel			Solar Tracking (Dual Axis)		
	V	mA	mW	V	mA	mW
08.00 AM	4.79	0.27	1.29	5.43	0.32	1.74
09.00 AM	5.09	0.29	1.47	5.58	0.35	2.00
10.00 AM	5.32	0.31	1.64	5.66	0.36	2.04
11.00 AM	5.54	0.32	1.77	5.8	0.37	2.15
12.00 PM	5.61	0.35	1.96	5.88	0.38	2.24
01.00 PM	5.44	0.33	1.79	5.84	0.38	2.22
02.00 PM	5.37	0.32	1.71	5.78	0.37	2.14
03.00 PM	5.21	0.31	1.61	5.74	0.36	2.07
04.00 PM	5.12	0.29	1.48	5.69	0.36	2.05
05.00 PM	4.78	0.26	1.24	5.39	0.30	1.62
Average Power			1.596			2.032

Table 1. Comparison between output of a (60×60)mm static panel and the panel with dual axis solar tracker system.

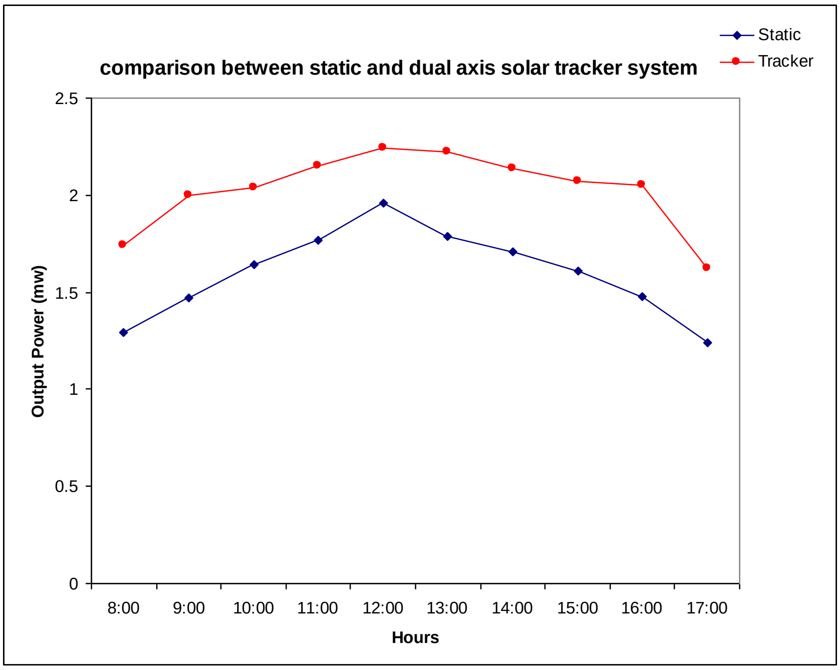

Figure 5. comparison between static and dual axis solar tracker system

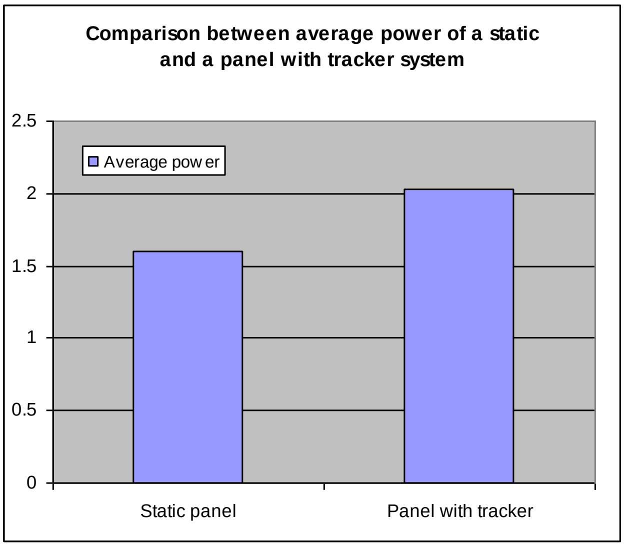

Figure 6. Comparison between average power of static and dual axis solar tracker system

VII. Discussion

Dual-axis trackers move on two axes to point directly at the sun, taking maximum advantage of the sun's energy. Sothe developed system have both horizontal and vertical axis and thus they can track the sun's apparent motion virtually anywhere from the world. Dual axis tracking can also be used in solar power towers and dish (Stirling engine) systems. This device can be extremely important in solar tower applications for minimizing the errors resulting from longer distances between the mirror and the central receiver located in the tower structure[13].

A tracker can increases a significant amount of output energy of solar energy conversion device. The efficiency of the single axis tracking system is smaller than dual axis solar tracking system [14]. The main disadvantage of the single axis tracker is that it can only trackthe daily movement of the sun but not the yearly movement.. The efficiency of the dual axis tracking system over that of the static panel is calculated to be 27.32%.

The performance of PV module can be influenced by several parameters such as ambient temperature, humidity, rain, cloud and dust. Such as, in a desert environment the operational performance is impeded via sand particles accumulation on surface and higher ambient temperature [15].

VIII. Conclusion

Self-powered dual axis solar tracker was designed and constructed successfully. According to the collected data, it can be concluded that the dual axis solar tracking system is better than the static solar panel in terms of output voltage, current and power. For this reason, the system has been proven effective for capturing maximum solar energy for solar harvesting applications. This low cost and environment friendly dual axis solar tracking system can be a great technique in utilizing the superiority of solar energy thus solving the increasing demand of electrical energy.

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