Design & Implementation of a Dual Axis Solar Tracking System

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Abstract. The aim of this paper is to present a solar energy collection technology by a photovoltaic cell. To present this efficient solar distributed generation system, a dual-axis solar tracker is designed, built and tested. The tracker actively tracks the sun and changes its position accordingly to maximize the power output. The designed tracking system consists of sensors, comparators and microcontroller operated control circuits to drive motors and gear-bearing arrangements with supports and mountings. Two geared stepper motors are used to move the solar panel so that sun's beam is able to remain aligned with the solar panel. The built system has a calculated power gain of 52.78% compared to a static solar panel.

Keywords: Solar tracker, LDR, Microcontroller, Geared stepper motor, Power gain.

1 INTRODUCTION

The present condition of worldwide crisis for major energy resource causes a huge raise in the prices of combustible sources of energy. So there is a growing demand to find greener ways to power the world and minimize green house gas emission. In this worst challenging condition there is no other way than to find for renewable energy resource [1].

The sun is the natural power source that will keep on sharing its energy and most unlikely to vanish. It is a renewable resource that is clean and economical. This energy is available everywhere but due to geographical location Bangladesh receives the maximum amount of energy from sun [2]. Therefore, solar energy is rapidly getting popularity as an important means of expanding renewable energy resources. But most of the solar panels in Bangladesh are positioned on a fixed surface such as roof. As sun is a moving object, this approach is not the best method. One of the solutions is to use a solar tracker that will actively follow the Sun. A solar tracker is a sensory device built with the solar panel which tracks the motion of the sun across the sky and moves the solar panel according to that motion of the sun, ensuring that the maximum amount of sunlight strikes the panels throughout the day. After finding the sunlight, the tracker tries to navigate through the path ensuring the best sunlight is detected. Commercially, single-axis and two axis tracking mechanisms are available. Previous researchers [3] used single axis tracking system which 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 where as the annual motion causes the sun to tilt at an angle of 23.5° while moving along east-west direction [4]. So the maximum efficiency of the solar panel is not being used by single axis tracking system. To track the sun movement accurately dual axis tracking system is necessary. With the sun always facing the panel, the maximum energy can be absorbed as the panel operates at its greatest efficiency. The main objective of this paper is to improve the power gain by accurate tracking of the sun.

To develop this dual axis tracking system light dependent resistor (LDR) is used as sensor. The resistance of LDR decreases with increasing light intensity [5]. Two dual Op-amps are used as comparator for comparing the light intensity in two different axes. Again diodes are used for neglecting the negative voltages coming from the comparators. Microcontroller generates the suitable control signals to move the motors in the proper direction. But the microcontroller output ranges from 0 to 5 volt [6]. So to increase the voltage and current level motor driver is used. Two 12 volt full geared stepper motors are used here for rotating the solar panel in two different axes.

2 METHODOLOGY

In order to simplify the design process the whole system is divided into four different units. These are: light sensing unit, light comparison unit, control unit and movement adjustment unit. Fig. 1 shows the overall block diagram of the whole system.

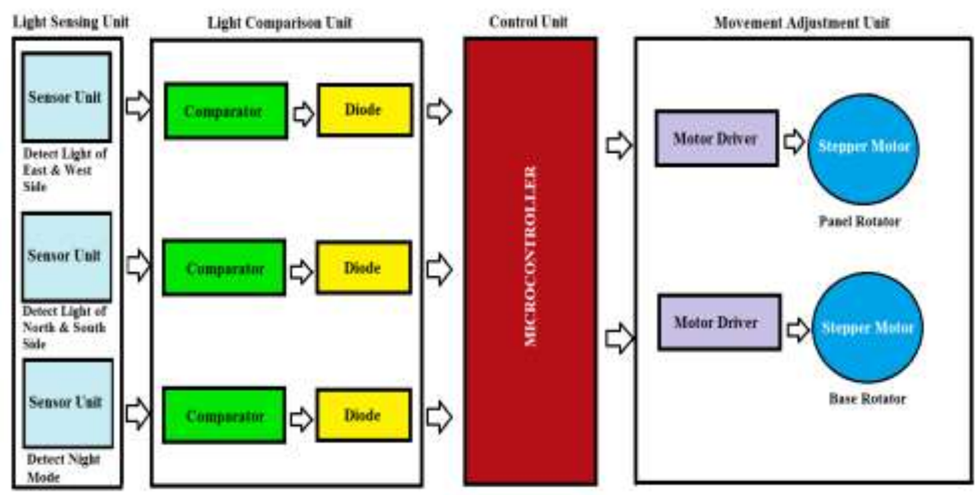

Fig. 1. Block diagram

2.1 Light sensing unit

Light sensing unit consists of five sensors. Sensors are used for measuring light intensity and generating a corresponding analog voltage signal into the input of the comparator circuit. Since this is dual axis tracking system, so two pair of light dependent resistors (LDR) is used as sensors to track the sun's exact position. One pair senses the position of the sun in vertical axis i.e. east and west side and other pair in the horizontal axis i.e. north and south side. This information is then passed to the light comparison unit. The rest LDR senses the night mode and the signal is sent to the light comparison unit.

A light dependent resistor (LDR) is a resistor whose resistance decreases with increasing incident light intensity. The relationship between the resistance ($R_{L)}$ and light intensity (Lux) for a typical LDR is given in equation.1 [7]. Fig. 2 shows the basic LDR circuit.

$$\mathbf{R_L} = (500 / \mathbf{Lux}) \text{ kohm} \ldots\ldots\ldots\ldots \mathbf{(1)}$$

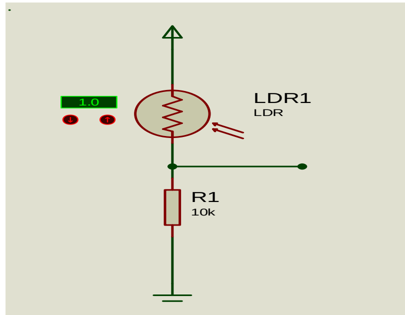

Fig. 2. Basic LDR circuit

2.2 Light comparison unit

Light comparison unit consists of comparator circuits and diodes. Comparator circuit is used to compare the voltage level between two sensors (LDRs). Two dual comparator ICs LM1458 are used here for comparing the voltage levels of both the horizontal and vertical axis i.e. both north-south and east-west side respectively. After comparing their voltages in the respective axis +Vcc and –Vcc are sent to the diodes from two individual outputs of LM1458. The last comparator compares the voltage level coming from the night detecting sensor with a predetermined reference voltage and the output is sent to a diode. Diodes are used here for neglecting the reverse voltage drop as the microcontroller works only in between 0 to +5 volt. Fig. 3 shows the comparator circuit for comparing the light between east and west side.

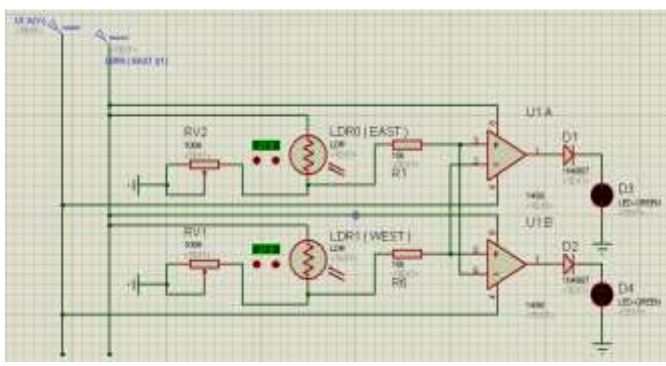

Fig. 3. Comparator circuit for east and west side

2.3 Control unit

Microcontroller is the main control unit of this whole system. The output from the light comparison unit comes to the input of the microcontroller which determines the direction of the movement of the motors both in the horizontal and vertical axes. For this project ATmega32 microcontroller is used. This is from the Atmel AVR family. Figure 4 shows the flowchart of ATmega32 microcontroller programming. In the following flow chart microcontroller pin number A0, A1, A2, A3 and A4 represents light intensity in west side, east side, north side, south side and night mode respectively.

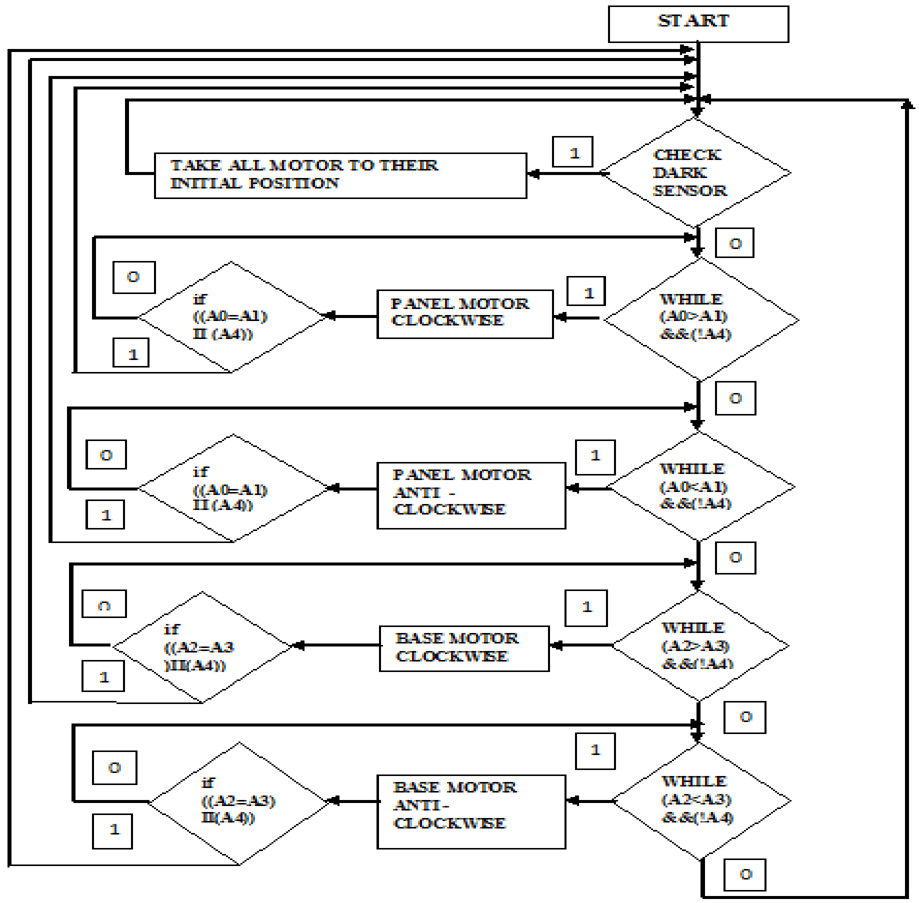

Fig. 4. Flow chart of microcontroller programming

2.4 Movement adjustment unit

Movement adjustment unit consists of two driver circuits and two geared stepper motors. The output from microcontroller is sent to the driver circuit which executes the proper sequence to turn the stepper motors in the required direction. TIP 122 is used as motor driver IC. As the output of microcontroller ranges between 0-5 volts so it is impossible to drive a 12v motor with this voltage range. Motor drivers are placed after microcontroller to step up the signal level in a suitable value for driving the motors. Figure. 5 shows the motor driver circuit for base (horizontal axis) movement.

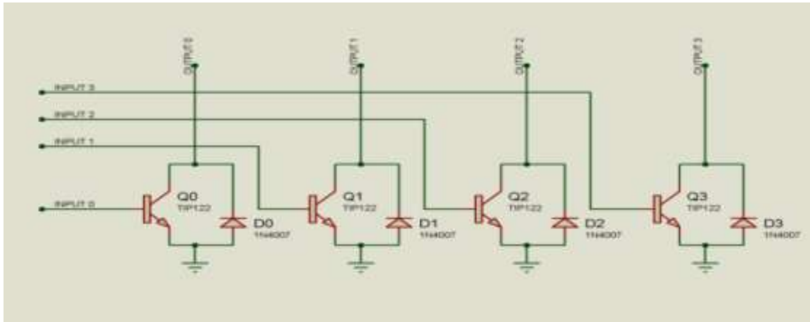

Fig. 5. Motor driver circuit forl base (horizontal axis) movement

Now two full gear stepper motors 35byj46 are used here for the accurate tracking of the sun. These gear stepper motors are used here because it has detent torque of minimum 39.2mN.m which is sufficient enough to rotate the panel in required direction [8]. The step angle of this stepper motor is 7.5̊ but by using half step mode this can be decreased to 3.75̊ .The half step stepper motor operating mode also increases the motor torque [9]. One of the motors controls the horizontal axis movement (north-south movement) of the sun while the other controls the vertical axis movement (east-west movement). Again to minimize power consumption only one motor is given pulse at a time while the other is not. So during the change in the intensity of light in vertical axis LDRs, the panel motor rotates but base motor does not. Once the light intensity on vertical axis LDRs i.e. East and West side LDRs is equal only then the panel motor stops and base motor rotates. So both the motor movement operation is vice-versa.

2.5 Assembling the mechanical parts

The whole system consists of two parts: base carrier part and panel carrier part. Each part consists of one stepper motor for their movement in the required direction. The 7 watt solar panel is attached in the panel carrier part with the help of a rod. Fig. 6 shows the experimental set up of the whole system.

Fig. 6. Experimental set up of the dual axis solar tracker

3 EXPERIMENTAL RESULTS & DATA ANALYSIS

Table.1 shows the current and voltage values received from both the static and tracking panel for different times in a day. From the table it is seen that at 8:00 am there is much improvement in current by tracking panel compared to the static panel. But as time goes on this difference in current between this two technology decreases up to around 1:00 pm. After that when the sun rotates more towards west this difference increases again. The highest current of static panel and tracking panel is 0.31amp and 0.34amp respectively at 12:00 pm. But in case of voltage the variation is lesser compare with current as the voltage has no direct relation with the sun light intensity. Fig. 7 shows the comparison of current curves for both the static and tracking panel.

Table 1. Current and voltage values of static and tracking panel at different times in a day

Time	Static panel		Tracking panel	
	Current (ampere)	Voltage (volt)	Current (ampere)	Voltage (volt)
8:00 am	0.113	20.1	0.26	20.7
9:00am	0.25	19.9	0.31	20.2
10:00 am	0.26	20	0.32	20.1
11:00 am	0.28	20.2	0.32	20.3
12:00 pm	0.31	20.7	0.34	20.7
1:00 pm	0.30	20.6	0.32	20.6
2:00 pm	0.28	20.6	0.30	20.6
3:00 pm	0.18	19.6	0.28	20.4
4:00 pm	0.0369	18.1	0.1067	19.7
5:00 pm	0.0087	15.77	0.00975	16

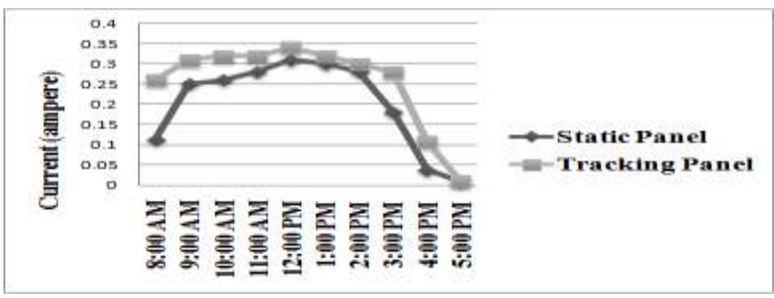

Fig. 7. Current vs. time curve for both the static and tracking panel

Table 2 shows the power values of both the static and tracking panel. The power gain of tracking panel over static panel for different times is also given in table 3.2. The maximum power output of the static panel and tracking solar panel is 6.417 watt and 7.038 watt respectively is found at 12:00 pm. Much more power gain is achieved in the morning and afternoon because the tracking system can accurately track the sun at these times while the static system not. For both technology power fall were very fast from 3:00 pm to 5:00 pm because of the low duration of day light. Fig. 8 shows the comparison of power collection bar diagrams for both static and tracking panel.

Table 2. Power values of static and tracking panel and the corresponding power gain by tracking panel over static panel at different times in a day

Time	Static panel Power (watt)	Tracking panel Power (watt)	Power gain by tracking panel
8:00 am	2.27	5.382	137 %
9:00 am	4.975	6.86	37.89%
10:0 am	5.2	6.432	23.69%
11:00 am	5.656	6.496	14.85%
12:00 pm	6.417	7.038	9.68%
1:00 pm	6.18	6.592	6.67%
2:00 pm	5.768	6.18	7.14%
3:00 pm	3.528	5.712	61.90%
4:00 pm	0.667	2.10	215.14%
5:00 pm	0.137	0.156	13.86%

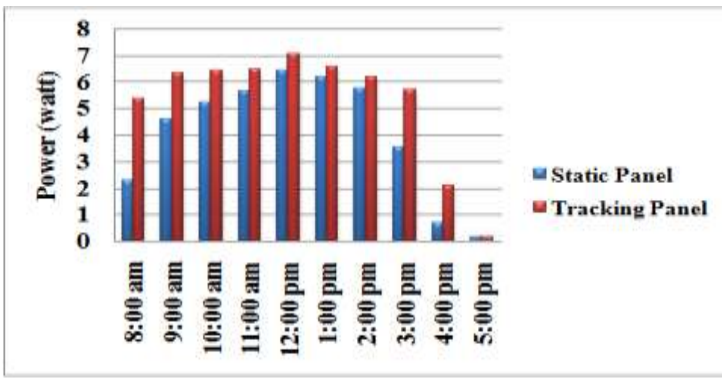

Fig. 8. Power vs. time bar diagram for both the fixed and tracking panel

The total power of static panel throughout the day is 40.798 watt. Meanwhile the total power of tracking panel throughout the day is 52.948 watt.
Therefore the average power gain by tracking panel over fixed panel = 52.78%

4 CONCLUSIONS

In this paper a dual axis sun tracking system has been successfully designed, built and tested. It follows the sun's path from morning to evening and then gets back to the initial position facing towards east side. So the system saves lot of energy by keeping the motors off during night period. This tracking technology is very simple in design, low in cost and accurate in tracking. Several solar technologies are available on the market. But this dual axis tracking technology has higher energy gain comparing with both fixed solar panel and single axis solar tracking technologies. This system has an energy gain of 52.78% compared to static system. Considering all above aspects of this dual axis tracking system it can be concluded that, it is an efficient tracking system with low cost electromechanical set up and low maintenance requirements.

References

Ahamad Tanvirul Alam Chowdhury , Mahmud Habib Zaman (February 2012) , *Uses of* Alternative forms of Sustainable Energy : Case of Solar Photovoltaic System in the Rural Areas of Bangladesh ,International Journal of Business and Management Tomorrow, Vol.2,No.2,2249-9962. www.ijbmt.com/issue/226.pdf

Khairul Anam, Husnain8Al8Bustam (September 2011), Power Crisis & Its Solution through Renewable Energy in Bangladesh, Cyber Journals: Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Renewable and Sustainable Energy (JRSE). http://www.cyberjournals.com/Papers/Sep2011/02.pdf

Andrew Hsing (2010) , Solar Panel Tracker , Senior project, Electrical Engineering Department, California Polytechnic State University , San Luis Obispo .http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1060&context=eesp

C. Alexandru and M.Comsit, Virtual prototyping of the solar tracking systems , Department of Product Design and Robotics , University Transilvania of Braşov , 29 Bd. Eroilor, 500036 Brasov, Romania . http://www.icrepq.com/icrepq07/226-alexandru.pdf .

Light Dependent Resistor (LDR) datasheet website, http://www.biltek.tubitak.gov.tr/gelisim/elektronik/dosyalar/40/LDR_NSL19_M51.pdf

Microcontroller Atmega32 datasheet website, http://www.atmel.com/Images/doc2503.pdf

EMANT Pte Ltd web site, http://www.emant.com/316002.page

Geared stepper motor datasheet website, http://smart-elektronic.strefa.pl/silnik/datasheet.pdf

B.L. Theraja, A.K. Theraja , A Text Book of Electrical Technology, Volume 2,AC & DC Machines in S.I . Systems of Unit,S. Chand & Company Ltd, Ram Nagar, New Delhi , India .

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