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DESIGN AND IMPLEMENTATION OF BIAXIAL SOLAR TRACKER USING ARDUINO

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Abstract

Solar energy is a renewable free source of energy that is inexhaustible and sustainable, unlike fossil fuels that are finite. Research is being performed for the development of more efficient systems by absorbing maximum sunlight and converting it into electrical power. The purpose of this work is to make more efficient solar panels for photovoltaic perpendicular rays of the sun throughout the year. This includes the design and implementation of research-based Arduino® dual axis solar tracking system. The development of experimental setup is comprised of two parts: hardware and software. During hardware development phase, four light dependent resisters have been installed in "+ shaped" mounting on the top of solar panel. Two DC geared motors have been fixed to rotate the solar panel in mutually perpendicular axes so that the plane of each solar panel remains normal to the incident rays of the sun throughout the day. Firstly, code in C language is developed and programmed on the microcontroller Arduino UNO®. The graphical user interface (GUI) is developed in LabVIEW® and connected with microcontroller to examine the real time displacement of solar panel in both axes by the feedback information of LDR sensors. This allows two-axis tracking of solar energy and the solar panel is capable of producing electrical energy with sunlight throughout the day. Therefore, average power produced by biaxial solar tracker in a day is 20.98% more than that by simple static system.

Keywords: Renewable energy, Bi-axial solar tracking system, Arduino, Graphical user interface, Pulse Width Modulation

1. Introduction

The demand for energy is increasing day by day whereas the resources of conventional energy are depleting. The production of electricity using fossils fuels is costly and causes environmental pollution. World energy demand and CO_2 emissions is expected to rise about 30% by the end of 2030 [1]. In order to cater for rising energy demand, the renewable energy is a feasible source of clean energy. One of the most promising renewable energy sources considered by enormous prospective of transformation into electrical form is the solar energy.

The transformation of solar radiations into electrical form by Photo-voltaic (PV) outcome is very auspicious technology has no moving parts, and therefore requires less maintenance cost and small environmental effect. Photovoltaic (PV) technology is widely used in urban areas and remote locations [2].

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In previous work the output power of the static solar panel was found variable, and therefore, the overall output of static panel is lower [3]. Peripheral Interface Controller (PIC) microcontroller based system is used to control such a system [4] that uses Pilot and Panel mechanism. The Light Dependent Resisters (LDR) are mounted on the Pilot that locates the sun while second LDR is on the panel that aligns panel with the sun. This system is not efficient due to time lag in pulses and misalignment of Pilot and Panel may occur. Normal adjustment and daily adjustment techniques have been compared to control the dual axis solar tracker [5] which results that the normal adjustment is better and more efficient. Static solar panels were found less efficient because they cannot change the direction to absorb maximum energy. Power efficiency of single and dual axis panel is more than fixed mount and dual axis solar tracker is more efficient among all of these [6]. The dual axis solar tracker was found superior to single axis solar tracker and fixed solar panel. There is 28.61% increase in efficiency by dual axis solar tracking system found by comparing outputs of dual axis solar tracker with single axis solar tracker [7, 8].

In another study [9] two techniques, namely traditional Proportional–Integral-Differential (PID) controller; and Orientation based controller with respect to location & time, were used to control dual axis solar tracker. PID controller technique was found the best technique among all these systems because of its perfect response time, stability and performance. PID is also easy and best technique to move the panel and Pulse Width Modulation (PWM) gives good and accurate speed to the motors [10]. Power efficiency of the dual axis solar tracking system was increased up to 37% using Maximum Power Point Tracking (MPPT) approach [11]. These solar tracking system have open loop control system with heavy mechanical structure using high power AC motors that cause the wastage of energy and rise in capital cost.

The efficiency of PV modules changes with the change in weather conditions as well. The rated values of PV modules are tested at standard test conditions (STC) which may not agree with real time conditions due to change in environmental conditions [12]. Ali et al. [2], performed experiments to investigate effect of module temperature on the performance of PV panels. They found that with the increase in module temperature from 20-31 °C (winter) to 34-50 °C (summer), efficiency of mono crystalline PV module decreased to 14.9%.

The purpose of current research work is to design and fabricate a closed loop control system for biaxial solar tracking system that can track the position of the sun precisely throughout the day and the year for maximum output/efficiency with slight capital cost.

2. Experimental Setup

Before real time implementation of this solar tracking system, its graphical model was developed in solid edge software. Figure 1 shows the complete model design and its different parts as labelled. Monocrystalline solar panel (dimensions 53 x 28 x 2.5 mm) was subjected to rotate with a DC geared motor coupled with a chain and sprocket mechanism. This mechanism is attached to the supporting frame and supporting collar. A sensor mounting is installed on the top of solar panel.

Four LDR sensors were arranged as shown in Figure 2. At the top of this system, a “+” shape wooden assembly contains the network of sensors to trace the sun light. Light dependent resistor (LDR) is made of a high resistance semiconductor. These sensors were used for measuring light intensity and generating a corresponding analogue voltage signal to the controller. LDR is very high resistance, sometime as high as 10^6 Ω. When they are illuminated with light, the resistance drops dramatically.

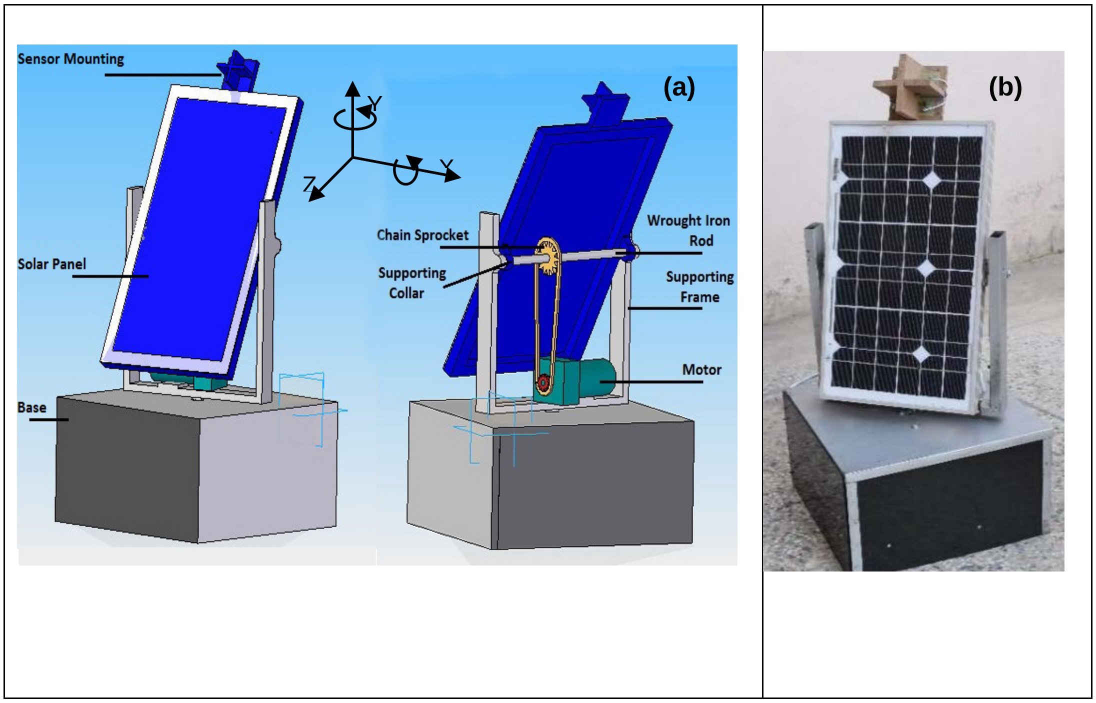

Figure 1: (a) Model of solar tracking system, (b) Solar tracking system.

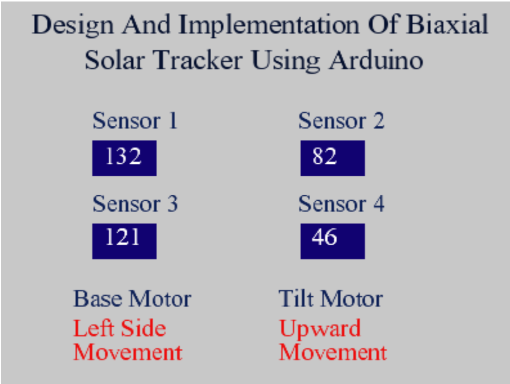

Figure 2: Arrangement of LDR sensor in the mounting of solar tracking system.

The block diagram and circuit diagram to control the motion of the solar panel are shown in Figure 3 (a) and 3(b), respectively. Four sensors are mounted on the top of solar panel Two (LDR) sensors for movement of base motor and two for the movement of tilt motor. Specific threshold value is adjusted for the movement of motor to track the sun. The difference in the sensor values is calculated. Based on this difference corresponding signal is sent to controller for motor movement. Solar Panel only moves when the values of sensors exceed certain threshold value. This movement can also be checked on GUI screen. The GUI source code was developed using LabVIEW® as is given in Annex A.

The solar tracking system consists of three main parts; mechanical part, control part and electronic part. The design of the experimental setup is discussed firstly. Figure 3 (a) shows the block diagram whereas 3(b) shows Proteus made circuit diagram of the solar tracking system.

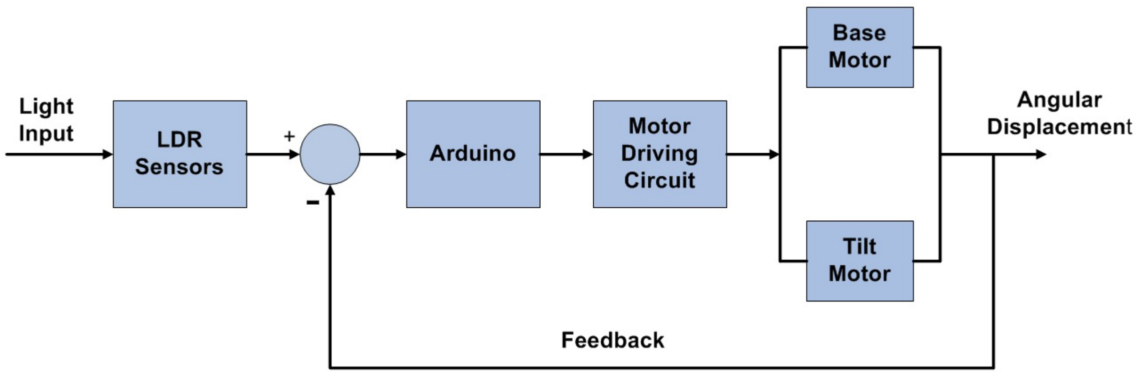

Figure 3 (a): Block Diagram of the solar tracking system.

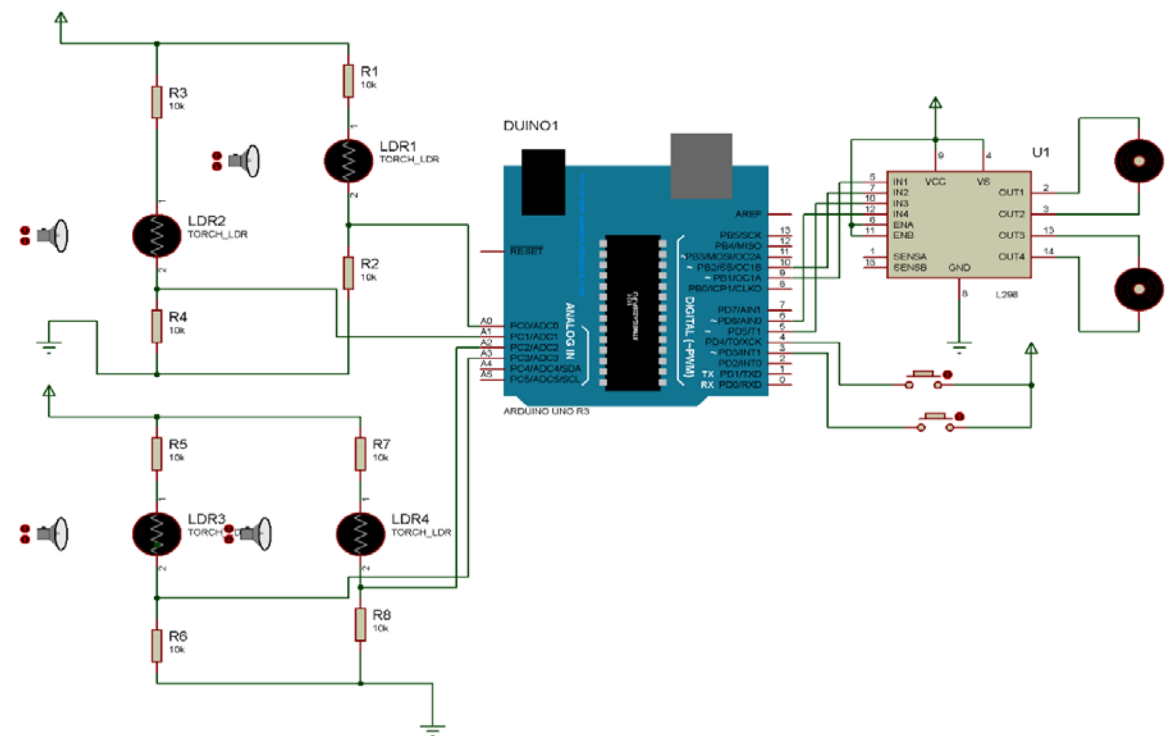

Figure 3 (b): Circuit diagram of solar tracking system.

An Arduino UNO® was used as a microcontroller board based on ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), a 16 MHz quartz crystal, 6 analogue inputs, a power connector, a USB connection, a reset button and an ICSP header. Working voltage range was 7-12v. The electric specifications of the solar panel used are given in Table 1. The H-Bridge was designed using MOSFET to drive the motors clockwise and anticlockwise.

Table 1: Specifications of the solar panel

Parameters	Value
Peak Power	20.00 W
Maximum Current	1.17 A
Maximum Voltage	17.20 V
Short Circuit Current	1.30 A
Open Circuit Voltage	21.60 V
Maximum System Voltages	1000.00 V
Wind Resistance	2400.00 Pa

The overall power consumption by the motor and the control system is 8.2 W. Detail power consumption of each component is given in Table 2.

Table 2: Power consumption details of solar tracker

Parameters	Value
Arduino Power	0.50 W
Base Motor Power	3.48 W
Tilt Motor Power	4.20 W
One LDR Power	1.40 mW
Four LDR Power	5.60 mW
Total power Consumption	8.2 W

Arduino's C++ has an edge over other open source software. At the same time, loops and conditional data matrices, indicators and knowledge of the functions, applications and programs development in C++ language is effective and user friendly.

The Arduino® integrated development environment (IDE) is a cross-platform application written in Java, and derives from the IDE for the Processing programming language. It includes a code editor with features such as brace matching, syntax highlighting and automatic indentation, and is accomplished of uploading and compiling programs to the board with a single click. Algorithm of the microcontroller Arduino UNO is shown in Figure 5. The algorithm is given in Annex. B. The experiments were performed at Chakwal, Pakistan (latitude 32.9311° N and longitude 72.8551° E). Solar panels with equal dimensions and same specifications were used for static and solar tracking systems. Static solar panel was placed on a structure facing towards south and was tilted at a fix angle of 12º with horizontal.

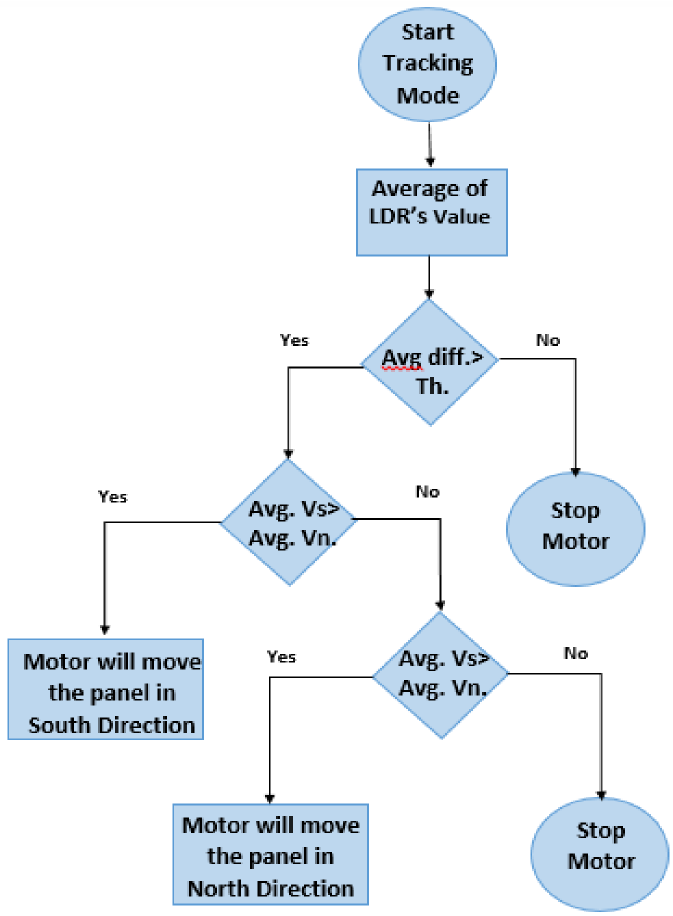

Figure 4: Flow chart of the algorithm used by Arduino.

3. Results and Discussions

Real time experiments were performed on 16th April 2016, on the top floor of Department of Mechatronics Engineering, University of Engineering & Technology Taxila (UET Taxila), Sub Campus Chakwal, Pakistan. Data was collected after every hour from 7:00 am to 6:00 pm by finding voltages and current of solar panel in both static and tracking mode. Temperature variations on that day were from 21 °C to 38 °C. The readings of voltage, current and power at consecutive hour are given in Table 3.

Figure 6 shows graph between power and time for both static and tracking system. Maximum power generation was found from 11 AM to 12 PM. From 1 PM -2 PM, decrease in power was found because of clounds. From this graph it is clear that the power generation by solar panel in tracking mode in morning and evening time is greater than the power generation in static mode except at the mid-day when both panels have almost same power. As at this point, the sun rays have approximately same angle with the surface of both panels.

Power generation in the morning and evening by designed biaxial solar tracking system was 66% and 53% more than that static panel respectively; However, average power generated was 20% more than that of static solar panel. The standard deviation of the power generated by this dual-axis solar tracking is almost half of the static system, which shows uniformity of power production throughout the day.

Table 3: Output of the static and tracking solar system at different hours in a day.

	Static Solar System			Tracking Mode Solar System		
Time (am/pm)	**Voltage (Volt)**	**Current (Ampere)**	**Power (watt)**	**Voltage (Volt)**	**Current (Ampere)**	**Power (watt)**
7:00	20.5	0.21	4.30	21.0	0.61	12.81
8:00	21.1	0.58	12.23	20.9	0.84	17.56
9:00	21.2	0.74	15.68	21.0	0.84	17.64
10:00	20.8	0.89	18.51	20.4	0.95	19.38
11:00	20.9	0.99	20.65	20.6	1.02	21.01
12:00	20.1	0.97	19.49	20.2	0.97	19.59
01:00	20.0	0.59	11.8	20.1	0.73	14.67
02:00	20.0	0.58	11.6	20.1	0.60	12.06
03:00	20.2	0.75	15.15	20.8	0.79	16.43
04:00	19.6	0.52	10.19	20.4	0.78	15.91
05:00	18.9	0.42	7.93	19.8	0.74	14.65
06:00	18.3	0.32	5.85	19.2	0.66	12.67
Average	**20.1**	**0.60**	**12.80**	**20.4**	**0.80**	**16.20**
Stand. Dev.	**0.84**	**0.24**	**5.06**	**0.51**	**0.13**	**2.81**

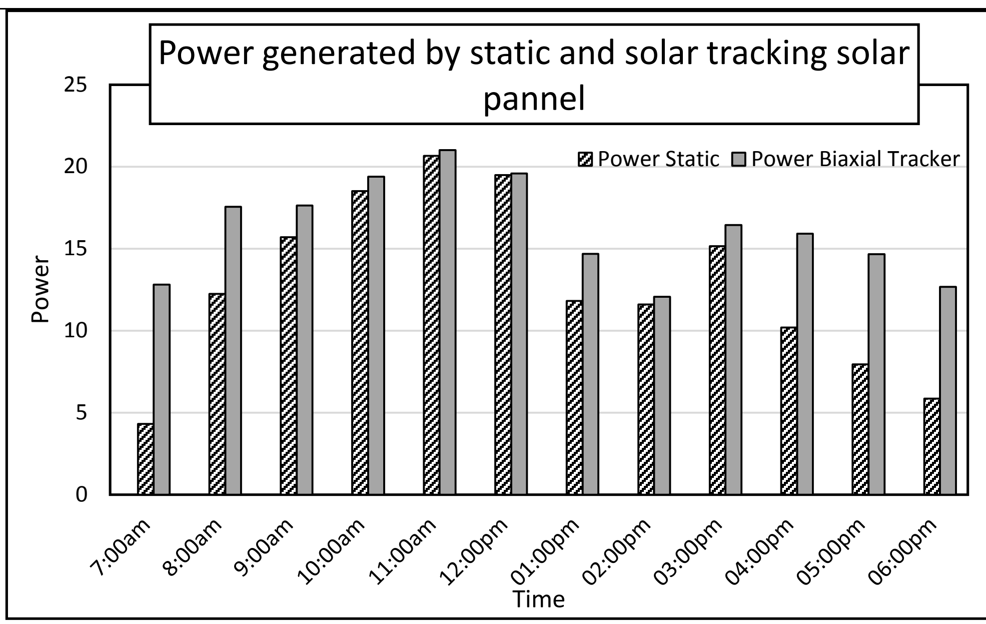

Figure 5: Comparison of power output for static and biaxial solar panel

However, at morning and evening time more than 100% improvement in the power generation was found. These results prove the effectiveness of the designed dual-axis solar tracking system.

4. Conclusion:

In this research work a solar tracking system was designed and fabricated. The solar panel is capable of rotating about two axis and keeping it aligned with the sun on all orientations from morning to evening and summer to winter. Power output was monitored from sun-rise time to sun-set time in the month of April. Results were compared with the static solar panel with the following conclusions;

- The power generation by solar panel in tracking mode in morning and evening time is greater than the power generation in static mode except at the mid-day when both panels have almost same power. At this point, the sun rays have approximately same angle with the surface of both panels.
- The average power generated by this designed dual-axis solar tracking system was 20% more than that of static solar panel.
- The standard deviation of the power generated by this dual-axis solar tracking is almost half of the static system. This shows uniformity of power production throughout the day. However, at morning and evening time, more than 100% improvement in the power generation was found.

Acknowledgement

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