Arduino based Solar Tracker in Dual Axis

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***Abstract*—A solar tracker system positions the object at an angle relative to the Sun. The system maximizes the electricity production by moving solar panels to follow the sun throughout the day, optimizing the angle at which the panels receive solar radiation. The goal of the project is to develop a laboratory prototype of a solar tracking system, which is able to enhance the performance of the photovoltaic modules in a solar energy system. The operating principle of the device is to keep the photovoltaic modules constantly aligned with the sunbeams, which maximises the exposure of solar panel to the Sun's radiation. As a result, more output power can be produced by the solar panel. The system utilises an ATmega328P microcontroller to control the motion of two servo motors, which rotate the solar panel in two axes. The amount of rotation is determined by the microcontroller, based on inputs retrieved from the four photo sensors located next to solar panel. The objective of the project is to design and implement a functional solar tracking system which is able to keep the solar panel aligned with the sun, or any light source repetitively.**

***Index Terms*—Solar Tracker, Microcontroller, Radiation, Bioenergy**

I. Introduction

With the unavoidable shortage of fossil fuel sources in the future, renewable types of energy have become a topic of interest for researchers, technicians, investors and decision makers all around the world. New types of energy that are getting attention include hydroelectricity, bioenergy, solar, wind and geothermal energy, tidal power, and wave power. Because of their renewability, they are considered as favourable replacements for fossil fuel sources. Among those types of energy, solar photovoltaic (PV) energy is one of the most available resources. This technology has been adopted more widely for residential use nowadays, thanks to research and development activities to improve solar cells' performance and lower the cost. According to International Energy Agency (IEA), worldwide PV capacity has grown at 49% per year on average since early 2000s. Solar PV energy is highly expected to become a major source of power in the future.

However, despite the advantages, solar PV energy is still far from replacing traditional sources on the market. It is still a challenge to maximise power output of PV systems in areas that do not receive a large amount of solar radiation. More advanced technologies are being used by the manufacturers to improve the capability of PV materials, but improvement of system design and module construction is a feasible approach to make solar PV power more efficient, thus being a reliable choice for customers. Aiming for this purpose, the project had been carried out to support the development of such promising technology.

One of the main methods of increasing efficiency is to maximise the duration of exposure to the Sun. Tracking systems help to achieve this by keeping PV solar panels aligned at the appropriate angle with the sun rays at any time. The goal of this project is to build a prototype of light tracking system at smaller scale, but the design can be applied for any solar energy system in practice. It is also expected from this project a quantitative measurement of how well tracking system performs compared to system with fixed mounting method.

The work of the project included hardware design and implementation, together with software programming for the microcontroller unit of the solar tracker.Design of the solar tracker from this project is also a reference and a starting point for the development of more advanced systems in the future.

II. Literature Survey

The biggest crisis we are heading into is the climate change due to excessive use of fossil fuels and to overcome these issues, one possible solution is to utilize Renewable Energy. Renewable energy is a type of energy that is harnessed from the nature without causing ill effects to the environment. One of the most prominent kind of renewable energy is solar energy. In recent past, researchers have tried to use the solar energy in various applications.Researchers are trying to collect Solar radiation from the sun by various means and converted into electrical energy.

Barsoum et. al [1] have designed a control circuit for the solar tracker based on a PIC16F84A microcontroller (MCU). The MCU is programmed to detect the sunlight through the photocells and then actuate the motor to position the solar panel where it can receive maximum sunlight.

Khan and et. al [2] have developed a microcontroller based automatic solar tracker. Light dependent resistors are used as the sensors of the solar tracker. The designed tracker has precise control mechanism which will provide three ways of controlling system. A small prototype of solar tracking system is also constructed to implement the designed methodology.

A prototype of two-axis solar tracking system based on a PIC microcontroller is developed by Hlaing and et. al [3] . The parabolic reflector or parabolic dish is constructed around two feed diameter to capture the sun's energy. The focus of the parabolic reflector is theoretically calculated down to an infinitesimally small point to get extremely high temperature. This two axis auto-tracking system has also been constructed using PIC 16F84A microcontroller. The assembly programming language is used to interface the PIC with two-axis solar tracking system. The temperature at the focus of the parabolic reflector is measured with temperature probes. This auto-tracking system is controlled with two 12V, 6W DC gear box motors. Time Delays are used for stepping the motor and reaching the original position of the reflector. The designs of the gear and the parabolic reflector are carefully considered and precisely calculated.

Bawa and et. al [4] have discussed various types of tracking techniques like active tracking, passive tracking, and chronological tracking, and also a comparison with the different tracking systems. From these discussions, one can select the tracking method adopted for a specific application.

The goal of the work done by Zolkapli and et. al [5] is to trace the maximum sunlight source to power the solar panel. In hardware development, five light dependent resistor (LDR) has been used for capturing maximum light source. Two servo motors have been used to move the solar panel at maximum light source location sensing by LDR. Moreover, the code is constructed using C programming language and targeted to Arduino UNO controller. The efficiency of the system has been tested and compared with static solar panel on several time intervals, and it shows the system react the best at the 10-minutes intervals with consistent voltage generated.

An inexpensive active dual-axis solar tracking system for tracking the movement of the sun so as to get maximum power from the solar panels as they follow the sun is being consructed by Kaur [6]. It uses Light Dependent Resistors to sense the position of the sun which is communicated to a Arduino Uno microcontroller which then commands a set of two servo-motors to re-orient the panel in order to stay perpendicular to the sun rays. The design was constructed successfully and tested using Lab View to determine the improvements in efficiency. Evaluation results show that the new system performs 13.44% better than the immobile solar PV system.

Othman and et. al. [7] have tried to investigate whether static solar panel is better than solar tracker, or the opposite. Five light dependent resistors (LDR) were utilized to capture the maximum light source from the sun and Two servo motors to move the solar panel to maximum light source location sensed by the LDRs. C programming language is use to program the Arduino UNO controller. The performance of the solar tracker was analyzed and compared with the static solar panel and the result showed that the solar tracker is better than the static solar panel in terms of voltage, current and power. Therefore, the solar tracker is proven more effective for capturing the maximum sunlight source for solar harvesting applications.

III. Benefits of Solar Energy

Solar energy is obtained from the sun's radiation and it can be converted to electricity or heat. It is freely available and thanks to advances in technology, we can now harness even more of the solar energy that is continuously available to us. The below list gives the main benefits of solar energy

- Solar energy is a clean and renewable energy source.
- Once a solar panel is installed, the energy is produced at reduced costs.
- Whereas the reserves of oil of the world are estimated to be depleted in future, solar energy will last forever.
- Solar energy has the least negative impact on the environment compared to any other energy source. Thus it is pollution free.
- Solar cells are free of any noise. On the other hand, various machines used for pumping oil or for power generation are noisy
- Once solar cells have been installed and running, minimal maintenance is required. Some solar panels have no moving parts, making them to last even longer with no maintenance.
- On average, it is possible to have a high return on investment because of the free energy solar panels produce.
- Solar energy can be used in very remote areas where extension of the electricity power grid is costly.

IV. Methodology/Approach

The solar tracking system has three salient components;

- An input stage with light sensors and potentiometer - The input stage is two LDRs which are part of voltage divider circuit.
- A program in embedded software in microcontroller - C-program loaded into MSP430 forms the embedded software.
- A driving circuit in form of H-bridge- L293D chip forms the driver circuit

All the parts are designed independently and then assembled into a solar tracking system. Finally, a wooden frame is used to house the components required to execute the tracker. Fig 2 gives the flow diagram of the system designed

The working principle is:

- Step 1: The signals from the light source fall on the sensors
- Step 2: Pairs of sensors receive the signals for horizontal and vertical movement of the panel

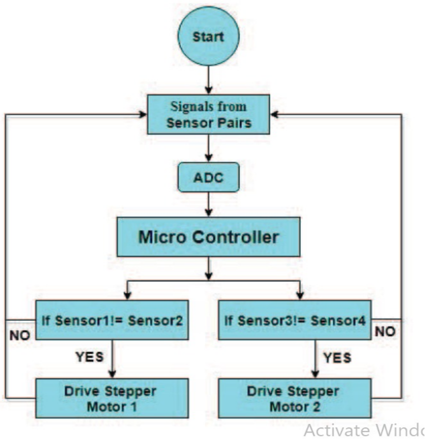

Fig. 1. Flow diagram of the Solar Tracking System

- Step 3: An analog to digital converter is used to convert the signals into digitised data
- Step 4 : The signals are thus forwarded to Arduino UNO for computations.
- Step 5: The signals from horizontal sensors are compared first, if not equal the motor rotates towards sensor with greater intensity. If equal, different signals are sensed again.
- Step 6:The signals from vertical sensors are compared, if not equal the motor rotates towards sensor with greater intensity. If equal, different signals are sensed again.

Hardware and software components of the project were separated into stages while developing the overall system. The hardware consisted of light detection, motor driving, software tracking, and software enhancements. Building and testing smaller Chapters of the system made the project more manageable and increased efficiency by decreasing debugging time.

The project performs the required functions envisioned at the proposal phase. However, while satisfied with software operation and simulation, less satisfaction was obtained from two hardware areas.

First, there is a potential for problems with motor/photocell movement due to the photocell wires creating binding issues. There are two wires attached to the photocell then connected to control circuit. Once the tracker has moved approximately 30 to 45 degrees, the wires place a counter torque on the motor and the motor slips. This creates positioning error. The present workaround for this is to hold the photocell wires in a way as to keep them close to the wooden frame which holds the photocell as the tracker moves.

The second issue deals with the photocell. It was discovered that the photocell needs to be shielded such that light can be directed narrowly to its surface. This was done by placing a black vinyl tube around the photocell to create a tunnel and help shield it from light that is not directly in its direct path.

A. Arduino

Arduino is an open-source stage utilized for structure gadgets ventures. Fig. 2 gives the pin diagram of the Arduino board.

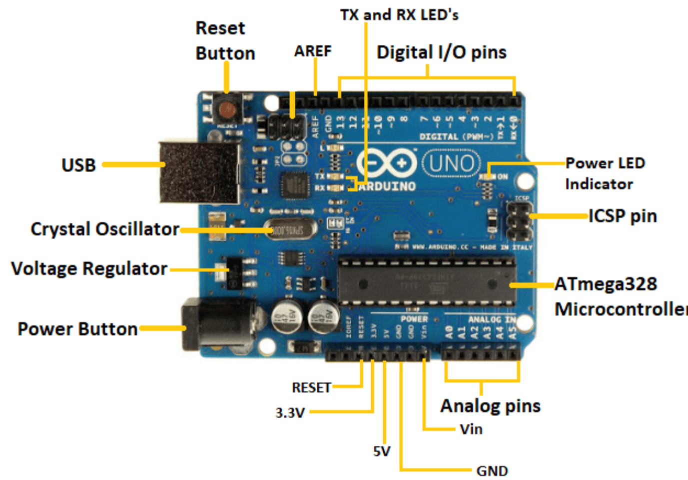

Fig. 2. Arduino Pin Diagram

The various components of the board are :

- Power USB : Arduino board can be powered by using the USB cable from your computer.
- Voltage Regulator : The function of the voltage regulator is to control the voltage given to the Arduino board and stabilize the DC voltages used by the processor and other elements.
- Arduino Reset : Reset the Arduino board to start the program from the beginning.
- Pins (3.3, 5, GND, Vin)
  - 3.3V (6) : Supply 3.3 output volt
  - 5V (7): Supply 5 output volt
  - GND (8)(Ground) : There are several GND pins on the Arduino, any of which can be used to ground your circuit.
  - Vin (9) : This pin also can be used to power the Arduino board from an external power source, like AC mains power supply.
- Analog pins : The Arduino UNO board has six analog input pins A0 through A5. These pins can read the signal from an analog sensor like the humidity sensor or temperature sensor and convert it into a digital value that can be read by the microprocessor.
- ICSP pin : Mostly, ICSP (12) is an AVR, a tiny programming header for the Arduino consisting of MOSI, MISO, SCK, RESET, VCC, and GND. It is often referred to as an SPI (Serial Peripheral Interface), which could be considered as an ”expansion” of the output.
- TX(transmit) and RX (receive) LEDs: They appear in two places on the Arduino UNO board. First, at the digital pins 0 and 1, to indicate the pins responsible for serial communication. Second, the TX and RX led (13). The

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TX led flashes with different speed while sending the serial data. The speed of flashing depends on the baud rate used by the board. RX flashes during the receiving process.

- Digital I/O : The Arduino UNO board has 14 digital I/O pins (15) (of which 6 provide PWM (Pulse Width Modulation) output. These pins can be configured to work as input digital pins to read logic values (0 or 1) or as digital output pins to drive different modules like LEDs, relays, etc. The pins labeled " " can be used to generate PWM.
- AREF: AREF stands for Analog Reference. It is sometimes, used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

Arduino comprises of both a physical programmable circuit board (frequently alluded to as a microcontroller) and a bit of programming, or IDE (Integrated Development Environment) that keeps running on your PC, used to compose and transfer PC code to the physical board. The Arduino stage has turned out to be very prevalent with individuals simply beginning with hardware, and all things considered. Not at all like most past programmable circuit sheets, the Arduino does not require a different bit of equipment (called a developer) so as to stack new code onto the board - you can basically utilize a USB link. Furthermore, the Arduino IDE utilizes an improved variant of C++, making it simpler to figure out how to program. At last, Arduino gives a standard structure factor that breaks out the elements of the small-scale controller into an increasingly available bundle.

V. Results

In this 21st century, as we build up our technology, population growth, the energy consumption per capita increases exponentially, as well as our energy resources (e.g., fossils fuels) decrease rapidly. So, for sustainable development, we have to think alternative methods (utilization of renewable energy sources) in order to fulfil our energy demand. In this project, a demo model of solar tracker is developed to track the maximum intensity point of light source so that the voltage given at that point by the solar panel is maximum. Fig. 3 and Fig. 4 shows the model designed.

The vital importance of a dual axis solar tracker lies in its better efficiency and sustainability to give a better output compared to a fixed solar panel or a single axis solar tracker. The tracking system is designed such that it can trap the solar energy in all possible directions. Generally, in a single axis tracker that moves only along a single axis, it is not possible to track the maximum solar energy. In case of dual axis trackers, since the solar rays are perpendicular to panel throughout the year, maximum possible energy is trapped throughout the day as well as throughout the year. Thus, the output increases indicating that the efficiency more than a fixed solar panel (about 30-40% more) or a single axis solar tracker (about 6-7% more).

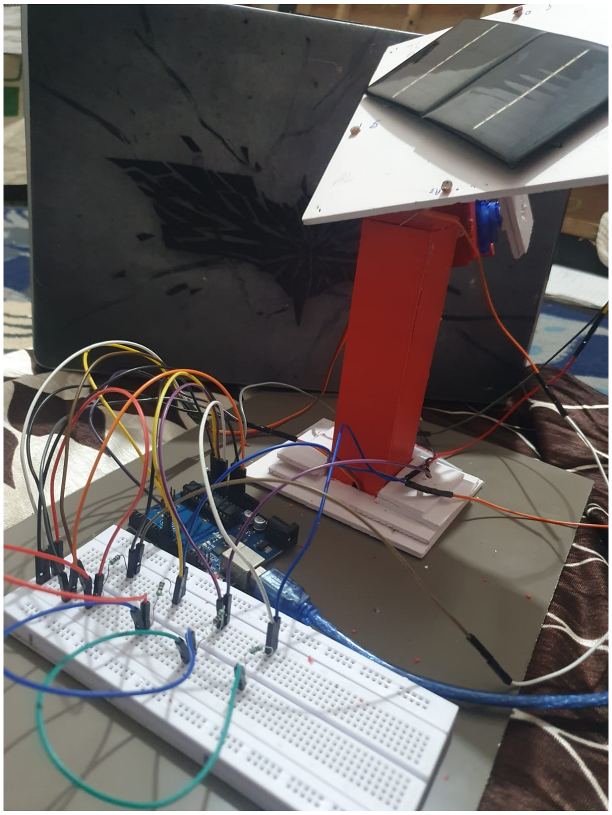

Fig. 3. Prototype of the Solar Tracker1

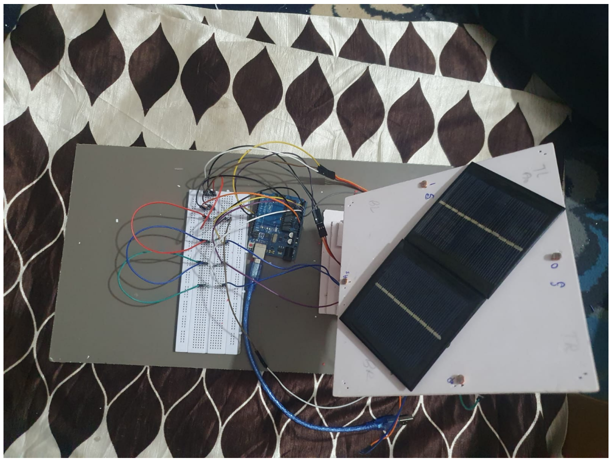

Fig. 4. Top view of the Solar Tracker prototype model

VI. Future work and Conclusion

Solar Radiation Tracker has played a vital role in increasing the efficiency of solar panels in recent years, thus proving to be a better technological achievement. The project aims to develop an Arduino based Solar Tracker to track the maximum intensity point of light source so that the voltage given at that point by the solar panel is maximum.

Now, like every other experiment, this project has couple of imperfections.

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- Solar panel senses the light in a sensing zone, beyond which it fails to respond.
- If multiple sources of light (i.e., diffused light source) appear on panel, it calculates the vector sum of light sources moves the panel in that point.
- As dual-axis tracking generates 40% more power from each panel, you can achieve the same power output with fewer panels, frames and so on, which reduces a project's upfront costs and offsets to a great extent the additional cost for tracking hardware.

The above limitations can be overcome in the furure work.

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