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Design and Construction of an Automatic SolarTracking System

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Abstract— The global energy problem is now the top priority. The use of traditional energy sources is not only problematic due to their scarcity, but also because they are a major contributor to pollution. The globe is increasingly investing in renewable energy sources as a means of decreasing its reliance on traditional ones. Solar power is quickly becoming a hot topic as a viable option for increasing the usage of renewable energy sources. The solar cells used to generate electricity from sunlight are expensive and inefficient at their job. In order to decrease the price of solar panels, several processes are used to boost their efficiency. The most effective way to increase solar cell efficiency is using a solar tracking system. In this research, we offer a technique for designing an autonomous solar tracker that uses a microcontroller. Sensors in the solar tracker are light-dependent resistors. The three distinct modes of operation will be accessible via the planned tracker's precision control mechanism. of demonstrate the approach of design provided here, a miniature solar tracking system prototype is built.

***Keywords*— Photovoltaic cell, solar tracking, photo resistor, micro controller, stepper motor.**

I. Introduction

Energy is the most important aspect in a country's progress. Every day, people all across the world extract, distribute, transform, and consume vast quantities of energy. Fossil fuels are used in 85% of the energy generation process [1]. Fossil fuels are a finite resource, and their combustion contributes to climate change by releasing greenhouse gases. Renewable energy sources such as solar, wind, geothermal, and ocean tidal wave are in high demand to ensure future generations have access to reliable electricity and a secure environment

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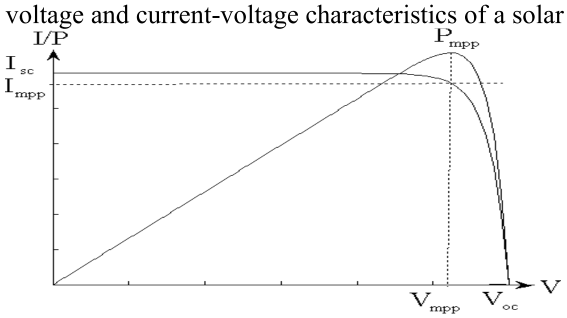
Indirectly or directly, the sun provides the energy that powers most renewable power sources. When compared to other renewable energy sources, photovoltaic systems have the best possibility of completely replacing traditional energy sources. A solar panel is a device that directly transforms sunlight into electricity. The majority of a solar panel's components are semiconductors. Solar panels often employ Si as the main component, however its efficiency only goes up to 24.5% [2]. A solar panel's efficiency can only be improved by increasing the amount of light falling on it, at least until more powerful solar panels are developed. Keeping solar panels aligned with the sun's position is the most effective way to maximize their efficiency, and solar trackers are the most suited and established technology for doing so. In recent years, solar trackers have gained widespread use as a means of efficiently collecting solar energy. Instead of spending money on new solar panels, you may do this instead [3].

In this work, we present the design process for a microcontroller-based automated solar tracker that is both straightforward and easy to program.
is presented. A prototype of automatic solar tracker ensures feasibility of this design methodology.

PHOTOVOLTAIC TECHNOLOGY

Photovoltaic cells can collect the sun's energy, which is both plentiful and easy to use. Solar energy's foundation is made up of photovoltaic cells. The words "photo" and "voltaic" are the origins of the term "photovoltaics." Thus, "generating power directly from sunlight" best describes the photovoltaic process. A photovoltaic cell's power production is proportional to the intensity of the light falling on the cell. The output power is also affected by the time of day, season, panel location, and panel orientation. In Fig. 1 we see the power-voltage and current-voltage characteristics of a solar cell..



g. 1 *I-V* and *P-V* characteristics of photovoltaic cell.hotovoltaic cells are the smallest part of a solar panel. Solarpanel gives maximum power output at the time when sun is directly aligned with the panel.

Stepper motor

Photo resistor

TECHNOLOGY TO ENHANCE POWER OUTPUT FROM SOLAR

PANEL

Increasing the cell efficiency, maximizing the poweroutput and employing a tracking system with solar panel arethree ways to increase the overall efficiency of the solar panel[4]. Improvement of solar cell efficiency is an ongoingresearch work and people throughout the world are activelydoing research on this. Maximizing the output power fromsolar panel and integrating solar tracking system are the twoways where electronic design methodology can bring success. Maximum power point tracking (MPPT) is the process to maximize the output power from solar panel by keeping the solar panel's operation on the knee point of *P-V* characteristics (Fig. 1). A number of MPPT algorithms have been developed and employed around the world [5]. MPPT technology only offers the maximum power that can be received from a stationary array of solar panels at a particular time; it cannot, however, increase the power generation when the sun is not aligned with the system.

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By maintaining the solar panel's alignment with the sun's movement, an automatic solar tracker maximizes the panel's output. The power production of solar panels may be increased by 30% to 60% when compared to a stationary system thanks to solar tracking, which is a mechanical mechanism to follow the sun's location [6]. Recently, many different approaches to designing sun tracking systems have been presented [7–9]. Sun light detecting, supplying a starting location for the solar panel, and motor power consumption are identified as important obstacles in the solar tracking literature.
Increasing the solar panel's efficiency by diffuse reflection is another option. Through the action of clouds, dust, and water, the sun's rays are amplified before reaching Earth's surface. Diffused rays are the source of the decrease in solar cell output. Diffused rays that are reflected back onto the panel from the reflectors will boost the panel's total output [10].
Automatic Solar Tracker Prototype The evolution of tracking systems for solar panels has

occurring over a period of years. To maximize energy production, solar panels should follow the sun throughout the day so that they remain perpendicular to the sky at all times. The high cost of available solar trackers makes their incorporation into a solar panel system prohibitive [11]. This research presents a solar tracking prototype that might be a useful tool for addressing the problem of high technology integration costs in underdeveloped nations. Here are some of the key features of the prototype:-

Photo resistor
Microcontroller

Cadmium sulphide (CdS) photo resistor is used in the designed prototype. The CdS photo resistor is a passive element that has a resistance inversely proportional to the amount of light incident on it. To utilize the photo resistor, it

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is placed in series with another resistor. A voltage divider is thus formed at the junction between photo resistor and another resistor; the output is taken at the junction point to pass the measured voltage as input to microcontroller. Fig. 2 represents the resistance value of the photo resistor with the illumination of light.

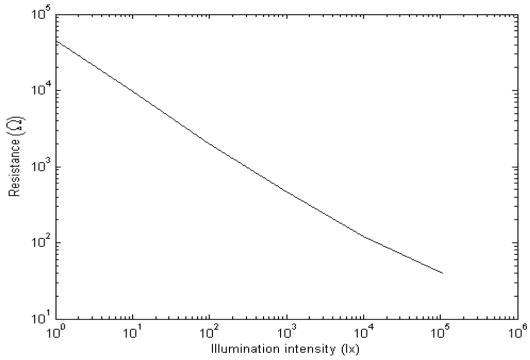


Fig. 2 Resistance value of CdS at various illumination level of light

Fig. 3 Schematic of solar tracker circuitry

In the solar tracker prototype, it is desired that output voltage at junction point will increase as the light intensity increases and so the photo resistor is placed at the top position in series connection with resistor.

Stepper motor

Stepper motors are commonly used in precisionpositioning control applications. Five characteristics of the stepper motor have been considered while choosing stepper motor for the solar tracker prototype. Stepper motor is brushless, load independent, has open loop positioning capability, good holding torque and excellent response characteristics. The stepper motor that has been used in the prototype has the specifications of 24 volts, 130 Ω resistance,

7.5˚per step, 4 phase, unipolar. Half stepping rotation is considered for the tracker to control position accurately with sun's rotation which results in 3.75˚per step.

Microcontroller

The ATMEGA32 microcontroller has been used in the prototype. Microcontroller is the heart of overall system. ATMEGA32 microcontroller requires a 5 volt regulated voltage supply. '7805' voltage regulator is used to provide fixed 5 volts supply to the microcontroller [12]. ATMEGA32 has some features such as analog comparator (AC), analog to digital converter (ADC), universal synchronous asynchronous receiver transmitter (USART), times etc [13]. Utilization procedure of these features is given below:

Analog comparator: There are two pins which are known as analog input 0 (AIN0) and analog input 1 (AIN1). Two analog voltage signals coming from two junctions of photo resistor circuit are fed to these pins. There is a bit called analog comparator output (*ACO*) which is set to either '1' or '0' andcan be defined as:-

Fig. 3 shows the schematic diagram of the prototypedesigned in Proteus 7 professional software. ⎧0

$V_{ADC0} > V_{ADC1}$

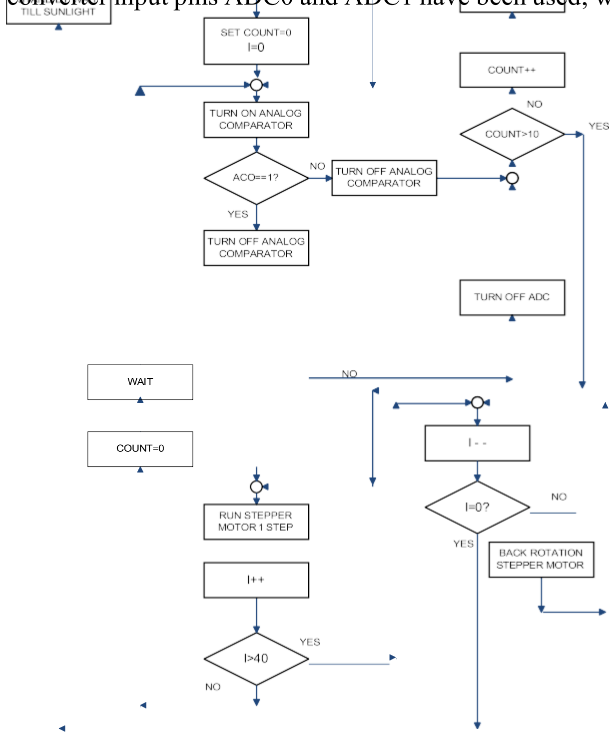
s expected. Differential input is converted

$ACO = \{ \lfloor 1 \; V_{AIN1} > V_{AIN0}$

$V_{AIN1} < V_{AIN0}$

(1)

Analog to digital converter: Among 8 analog to digital converter input pins ADC0 and ADC1 have been used; where



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nto digital value and the most 8 significant bits are defined as *ADC_result* to compare with threshold.*ADC_result* =

$$[V_{ADC0}\ V_{ADC1}]_{digital} \quad (2)$$

This threshold value, set according to the photo resistor response against the solar radiation intensity, is provided, since *ADC_result* alone might be insufficient for rotation of motor.

And if *ADC_result* > *Threshold*; motor rotates one step.*Timers*: Built-in timer of ATMEGA32 is utilized tocreate delay. The Earth rotates on its own axis, with respectto the sun 360° in a day and so it rotates, (360°/24=) 15° an hour or 3.75° in 15 minutes. Delay for 1.5 minutes and 15 minutes are required. These delays are mentioned as *short delay* and *moderate delay* respectively.

Algorithm: In the proposed algorithm two variables *I* and *Count* have been used. *I* represents total number of rotation the motor must make to track the sun from dawn to dusk. First hour after the sunrise and last hour before the sunset is not considered for the tracking, as in the first hour after sunrise the west sensor does not have sufficient light than the east one; the tracker remains off (Fig. 6). The last hour before sunset will provide additional energy to rotate thepanel in the initial position and so the tracker no more rotates to the west rather it will rotate reversely. As 2 hours in day time are not considered for tracking, (2X15°=) 30° of rotation is not required to be done by the solar tracker. Half stepping of stepper motor is considered which gives 3.75° rotation in each stepping; approximately ((180°-30°)/3.75°=) 40 rotations are required in each day to track the sun at daylight. *Count* is used for counting the number of '*wait*' states when weather is cloudy and ADC does not permit to rotate the motor.

A small scale prototype of the solar tracker has been made to check feasibility of the design methodology. At initialstage a small plastic board, considered as the solar panel, is mounted on an aluminium shaft. Fig. 4 illustrates the dummy panel along with other circuitry of the prototype.

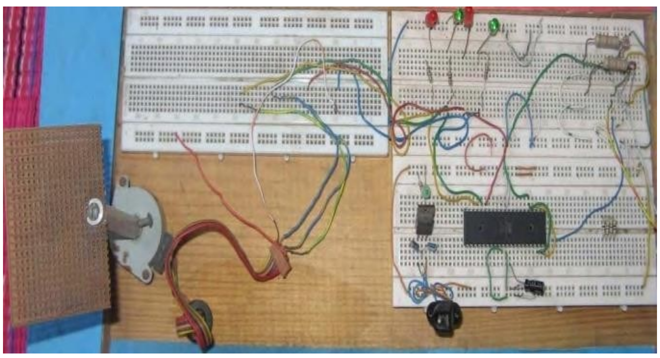
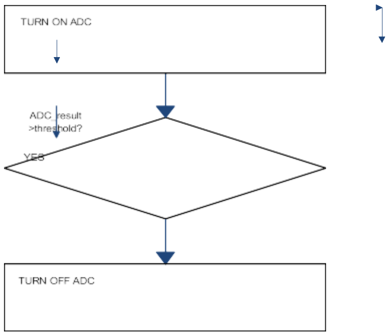


Fig. 4 Solar tracker prototype

OPERATION OF THE SOLAR TRACKER

Solar tracker provides three ways of operation and control mechanism through the programme written in microcontroller.Operational flow chart of the solar tracker is given in Fig. 5.

Fig. 5 Operational flow chart of the solar trker*Normal day light*



condition

Two photo resistors are used in the solar tracker to compare the output voltages from two junctions. As the sun rotates from east to west in the day time, AIN0 needs to provide higher voltage than AIN1 to sense the rotation of the sun (Fig. 6). This condition is considered as normal day light condition and tracker rotates the panel 3.75° after every 15 minutes.

Bad weather condition

When the sky gets cloudy, there will be less striking of light on both the photo resistors and so sufficient voltages might not be available at junction point. The difference of voltage at junction point will not be greater than the thresholdvalue to rotate the tracker. At the mean time, sun continues rotating in the western direction. To solve this problem, a *short delay* is provided which will check for voltage input from junction point in every 1.5 minutes. Microcontroller will use the variable *Count* to check for consecutively 10 times to make the '*wait*' state equal to 15 minutes (*moderate delay*) to rotatethe stepper motor one step.

Bidirectional rotation

At day time, the solar tracker will rotate in only one direction from east to west. Variable *I* will count the total rotation in day time and that is approximately calculated as 40 rotations considering 150° rotation. When the sun sets, no more rotation is needed in western direction. For the next day, the solar panel needs to go to the initial position in the morning to track the sun's position again. To do so, the variable *I* that counts the number of rotation in the day time will work out.

When the variable (*I*) shows value greater than 40, the tracker stops rotating in the western direction and rotatesreversely in the eastern direction t

initial position for the next day. When it goes to initial position, power supply to the tracker will be turned off and the tracker will be in stand by till sunlight in the next mornin

VII. CONCLUSION

The paper has presented a means of tracking the sun's position with the help of microcontroller. Specially, it demonstrates a working software solution for maximizing solar cell output by positioning a solar panel at the point of maximum light intensity. The prototype represents a method for tracking the sun both in normal and bad weather condition.Moreover, the tracker can initialize the starting position itself which reduce the need of any more photo resistors. The attractive feature of the designed solar tracker is simple mechanism to control the system. The solar tracker also provides lucrative solution for third world countries to integrate it into their solar system with a comparatively low cost through software based solution. Though the prototype has limitations in hardware areas as an initial set up, still it provides an opportunity for improvement of the design methodology in future.

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After Sunrise (B) Equal light on the sensors (C) Tracker WorksFig. 6 Solar tracker working mechanism

FEATURES & FUTURE WORK OF THE SOLAR TRACKER

While developing the overall system, hardware andsoftware portions of the project are separated into stages consisting of light detection, microcontroller input, software enhancements, motor driving and finally dummy panel rotation.

The attractive feature of the constructed prototype is the software solution of many challenges regarding solar tracking system. The designed prototype requires only two photo resistors to sense the light, which lessens the cost of the system. Power consumption of the system is negligible as *'wait'* states are calculated perfectly with the sun's position. Another major problem of system initialization at the start of the day is solved through a simple programming application. All these software based solution reduce the system cost far more than all other systems proposed to date.

As the prototype is a miniature of main system, it has some limitations which can be mitigated through future developments. In stead of solar panel, a small plastic board is rotated in the system. As a miniature system, it works out well. Solar panel must be integrated with the system to prepare result and cost analysis.

CdS photo resistors which have been used in the prototype have a better response on 500nm to 700nm of wave length [14]. As shown in Fig. 7, sunlight covers greater ranges than CdS photo resistors [15]. Hence more sensitive photo diodes should be used for wider range of sensitivity.

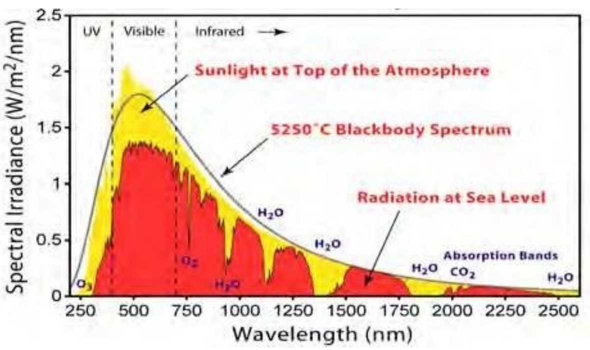

Fig. 7 Spectral irradiance of the Sun

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