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Solar Tracking System Using Stepper Motor

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Abstract

Solar energy is rapidly advancing as an important means of renewable energy resource. Solar tracking enables more solar energy to be generated because the solar panel is able to maintain a perpendicular profile to the sun's rays. Though initial cost of setting up a solar tracking system is high, this paper proposes a cheaper solution. Design and construction of a prototype for solar tracking system with single degree of freedom, which detects the sunlight using Light Dependent Resistors (LDR), is discussed in this paper.
The control circuit for the solar tracker is based on an ATMega16 microcontroller. This is programmed to detect the sunlight through the LDRs and then actuate the stepper motor to position the solar panel where it can receive maximum sunlight. Compared with any other type of motor, the stepper motor is more controllable, more energy efficient, more steady and has high tracking accuracy and suffers little environmental effect. Theoretical analysis and research results have been shown in this paper to advocate that the designed system realized precise automatic tracking of the sun and can greatly improve the utilization of solar energy.

Keyword: ATMega16, tracking, LDR, Stepper Motor.

1. Introduction

Energy is the prime factor for the development of a nation. An enormous amount of energy is extracted, distributed, converted and consumed in the global society daily. 85% of energy production is dependent on fossil fuels. The resources of the fossil fuels are limited and their use results in global warming due to emission of greenhouse gases. To provide a sustainable power production and safe world to the future generation, there is a growing demand for energy from renewable sources like solar, wind, geothermal and ocean tidal wave.

Solar panels directly convert solar radiation into electrical energy. Solar panel is mainly made from semiconductor materials. Si used as the major component of solar panels, which is maximum 24.5% efficient. Increasing the cell efficiency, maximizing the power output and employing a tracking system with solar panel are three ways to increase the overall efficiency of the solar panel.

Improvement of solar cell efficiency is an ongoing research work and people throughout the world are actively doing research on this. Maximizing the output power from solar panel and integrating solar tracking system are the two ways 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. 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. Solar tracking is a mechanized system to track the sun's position that increases power output of solar panel 30% to 60% than the stationary system. This is far more cost effective solution than purchasing additional solar panels.

2. Light Dependent Resistor Theory

A light sensor is the most common electronic component which can be easily found. The simplest optical sensor is a photon resistor or photocell which is a light sensitive resistor these are made of two types, cadmium sulfide (CdS) and gallium arsenide (GaAs).

The sun tracker system designed here uses two cadmium sulfide (CdS) photocells for sensing the light. The photocell is a passive component whose resistance is inversely proportional to the amount of light intensity directed towards it. It is connected in series with capacitor.

The photocell to be used for the tracker is based on its dark resistance and light saturation resistance.

The term light saturation means that further increasing the light intensity to the CdS cells will not decrease its resistance any further. Light intensity is measured in Lux, the illumination of sunlight is approximately 30,000 lux.

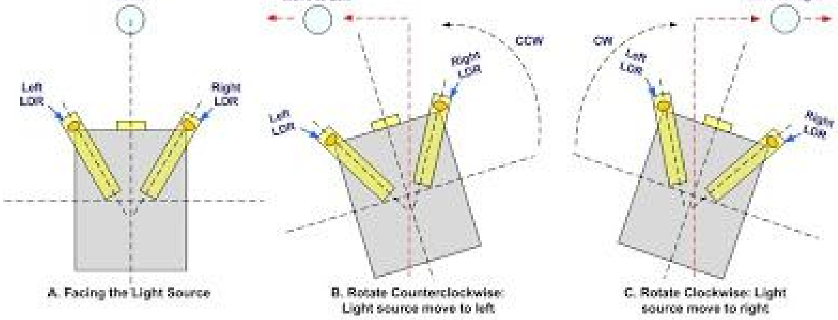

Fig. 1: Concept of using two LDRs for sensing.

Concept of using two LDRs for sensing is explained in figure 1.The stable position is when the two LDRs having the same light intensity (position A).When the light source moves, i.e. the sun moves from west to east, the level of intensity falling on both the LDRs changes and this change is calibrated into voltage using voltage dividers. The changes in voltage are compared using built-in comparator of microcontroller and motor is used to rotate the solar panel in a way so as to track the light source.

3. Prototype of Designed Tracker.

The major components those are used in the prototype are given below:-

- Photo resistor
- Microcontroller
- Stepper motor
- Photo resistor

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 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.

4. Microcontroller

The ATMEGA16 microcontroller has been used in the prototype.ATMEGA16 microcontroller requires a 5 volt regulated voltage supply.

ATMEGA16 has some features such as analog comparator (AC), analog to digital converter (ADC), universal synchronous asynchronous receiver transmitter (USART), times etc. Utilization procedure of these features is given below:

1) 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 and can be defined as,

ACO =0 (VAIN1 is more than V AIN0) else it is 1

2) Analog to digital converter:

Among 8 analog to digital converter input pins ADC0 and ADC1 have been used; where V_{ADC0} greater than V_{ADC1} is expected.

Differential input is converted into digital value and the most 8 significant bits are defined as *ADC_result* to compare with threshold.

ADC_result = [$V_{ADC0} - V_{ADC1}$] digital

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.

C. Stepper motor

Stepper motors are commonly used in precision positioning 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.

A typical controller for a hybrid stepper motor includes:-

(a) Logic Sequence Generator: - Generates programmed logic sequence required for operation of stepper motor.

(b) Power Drivers: - These are power switching circuits which ensure a fast rise of current through the phase windings which are to be turned on at a particular step in the logic sequence.ULN2003 stepper motor driver has been used in the prototype.

(c) Current limiting circuits: - These are meant to ensure a rapid decay of current in phase winding that is turned off at a particular step in the logic sequence.

5. Operation of the Solar Tracker

Solar tracker provides three ways of operation and control mechanism through the programme written in microcontroller.

A. 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. This condition is considered as normal day light condition and tracker rotates the panel 3.75° after every 15 minutes.

B. 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 threshold value to rotate the tracker. At the meantime, 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 rotate the stepper motor one step.

C. 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 rotates reversely in the eastern direction to set the tracker to the 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 morning.

6. Features of the Designed Tracker

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.

Fig. 2: Designed working Prototype of solar tracker.

The solar PV modules are generally employed in dusty environments which is the case in tropical countries like India. The dust gets accumulated on the front surface of the module and blocks the incident light from the sun. It reduces the power generation capacity of the module. The power output reduces as much as by 50% if the module is not cleaned for a month. To reduce this loss, a brush along with rollers was fixed with the panel. This brush-roller system rolls down twice in 24 hours, when the panel is in vertical position and makes this prototype a self-cleaning system.

7. Conclusion and Future Scope

As the proposed prototype is a miniature of main system, it has some limitations which can be mitigated through future developments. A small cardboard is rotated in the system and 12v solar panel is used for analysis. As a miniature system, it works out well. Larger Solar panel must be integrated with the system to prepare better result and cost analysis.

It has been proven through our research and statistical analysis that solar tracking system with single-axis freedom can increase energy output by approximately 20%.Further mechanical enhancement can be done to the prototype, to implement dual-axis tracking.

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