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Full Length Research Paper

Design, Construction and Installation of Sun Tracking Operated Solar Street Lighting System

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ABSTRACT: This project is a design, construction, and installation of a sun-tracking operated solar street lighting system. An automatic solar tracker increases the efficiency of the solar panel by keeping the solar panel aligned with the rotating sun. Solar tracking is a mechanized system to track the sun's position that increases the power output of the solar panel than the stationary system. In order to achieve this, two Light Dependent Resistors (LDRs) are mounted on the solar module to automatically "track" the progress of the sun through the day, thereby maximizing output. The unique feature of this design system is that instead of taking the earth as its reference, it takes the sun as a guiding source with an innovative alignment procedure for accurate and precise alignment between LDR and the panel so that maximum energy is achieved. At maximum, the solar tracker was perpendicular to the light source by 1.5 degrees. The built system had a calculated annual energy gain of 48.982% compared to the conventional practice where solar panels are fixed mid-way between the geographical east and west with approximately 30 degrees towards the south. For synchronization purposes, two active sensors; LDR (light dependent resistor) constantly detects the sunrise and ultrasonic sensors detect the east position while the servo motors rotate the panel towards the direction where the intensity of sunlight is maximized. The two systems are driven by a microcontroller ATMEGA 328P programmed in c-language. It was found out that the output on this system charges the battery at a faster rate and discharges slowly making the brightness of the lamp at its maximum brightness. It is therefore recommended that if the number of batteries is increased, larger motors, incorporates microcontroller to monitor more LDRs, more PV modules, there would be a wider coverage of provision of security lights and it has low maintenance.

Keywords: Sun tracking, light-dependent resistors, ultrasonic sensors, servo motors, microcontroller

INTRODUCTION

Energy exigency is the most important issue in today's world and one of the most important building blocks in human development. Presently, the principal sources of energy available for our world are fossil fuels. These conventional energy resources are not only limited but also the prime culprit for environmental pollution.

Considering the rate at which fossil fuels are consumed today, studies suggest that most of the known reserves of fossil fuels are likely to get exhausted by the end of this century (David and Ralph, 2009). To provide a sustainable and safer power generation to the future generation, there is a growing demand for renewable energy sources like wind, solar, geo thermal and ocean tidal wave. Renewable energy resources are getting priorities in the whole world to lessen the dependency on conventional resources. Solar energy is rapidly gaining the focus as an important means of expanding renewable energy uses (Fernando et al., 2011). Lots of researches have been carried out in improving solar cells efficiency which also involves the positioning of the cells to maximize energy extraction during the day using solar tracker (David and Ralph, 2009).

A solar tracker is a device used for orienting a solar photovoltaic (PV) panel or lens towards the sun by using the solar or light sensors connected with the machine (example: stepper motor, servo motor, gas filled piston etc.) in order to maximize energy extraction during the day and increasing the photovoltaic cell efficiency against the conventional practice where solar panels are fixed mid-way between the geographical east and west with approximately 30 degrees towards the south. Mostefa 2013 revealed that this is not ideal position in maximizing energy extraction from the sun. It has been estimated that the yield from solar panels can be increased by 30 to 60 percent by utilizing a tracking system instead of a stationary array. A better way is to orient the panels continuously towards the sun, using single axis or double axes (Bill, 2008).

Several factors must be considered when determining the use of trackers. Such factors includes; the amount of direct solar radiation, solar technology being used, expenses to install and maintain the trackers, and feed-in tariffs in the region where the system is deployed.

Concentrated applications like concentrated photovoltaic panels (CPV) or concentrated solar power (CSP) require a high degree of accuracy to ensure the sunlight is precisely directed at the focal point of the reflector or lens.

Non-concentrating applications do not require tracking but using a tracker can improve the total power stored by the battery. Photovoltaic systems using high efficiency panels with trackers can be very effective (Rockwell, et al., 2011). The automatic solar tracking system is designed around two sub-systems. The first is the LDR for detecting the position where maximum energy could be extracted and the second is the solar panel with the control strategy.

The aim of the LDR is to detect the maximum energy from the sun, and picks up the voltage induced. That voltage is compared with that sensed by the sensor mounted on the panels. If the panel voltage is less than that of the LDR voltage detection by a predetermined threshold offset, then the panels move and align themselves, otherwise they stay in their current position. A better way to orient the panels continuously towards the sun using a detecting mechanism (LDR) which detect the maximum energy from the sun is to align the panel with the direction of the sun.

Justification of the project

This project is aimed at designing, constructing and installing an automatic solar tracking double lamp street light using a hybrid of hardware of ultrasonic sensors and micro controller. The system was designed to automatically provide precise and accurate alignment procedure of solar panel with the sun to obtain maximum electric power output. In order to achieve this aim, the following objectives are outlined:

(i) To develop a detecting mechanism Light Dependent Resistor (LDR) which detect the maximum energy from the sun and an optimal energy extraction mechanism called the intelligent panels (two of them), which aligns.
(ii) To achieve a perfect synchronization between the two mechanisms.
(iii) To develop an accurate alignment procedure capable of optimal energy extraction during the whole day.

Limitations

The goals of this project were purposely kept within what was believed to be attainable within the allotted timeline. As such, many improvements can be made upon this initial design. That being said, it is felt that this design represents a functioning miniature scale model which could be replicated to a much larger scale. Adding to this, when the sky gets unpredictably cloudy especially in rainy, the sensor tends to sense lower energy than expected.

Conceptual framework

Several significant points in the progress of solar technologies have led to the development of solar cells (Williams, 1876).The history of photovoltaic energy (solar cells) started back in 1876. Williams along with one of his student, Richard discovered that the exposure of selenium to light will produce electricity. Meanwhile, Werner von Siemens, an electricity expert, thus stated that this discovery was “scientifically of the most significant importance of its time”. The selenium cells itself were not potent, but it has been proven that light, without heat or moving parts, could be converted into electricity (Ignacio and Geotzberger, 2007). Ribbon and thin-film silicone are recently known types of silicon gaining popularity, however, each individual solar cell is typically made from crystalline silicon. Solar panels are thus formed out of solar cells connected in parallel or series. When connected in parallel, there is overall increase in current, while connection in series, increases the overall voltage (Goetzberger al., 2002). PV cells consist of arranged parts or pieces of silicon that is doped with different elements to form a p-n junction. However, the p-type side usually contains extra holes or positive charges, while the n-type side also contains extra

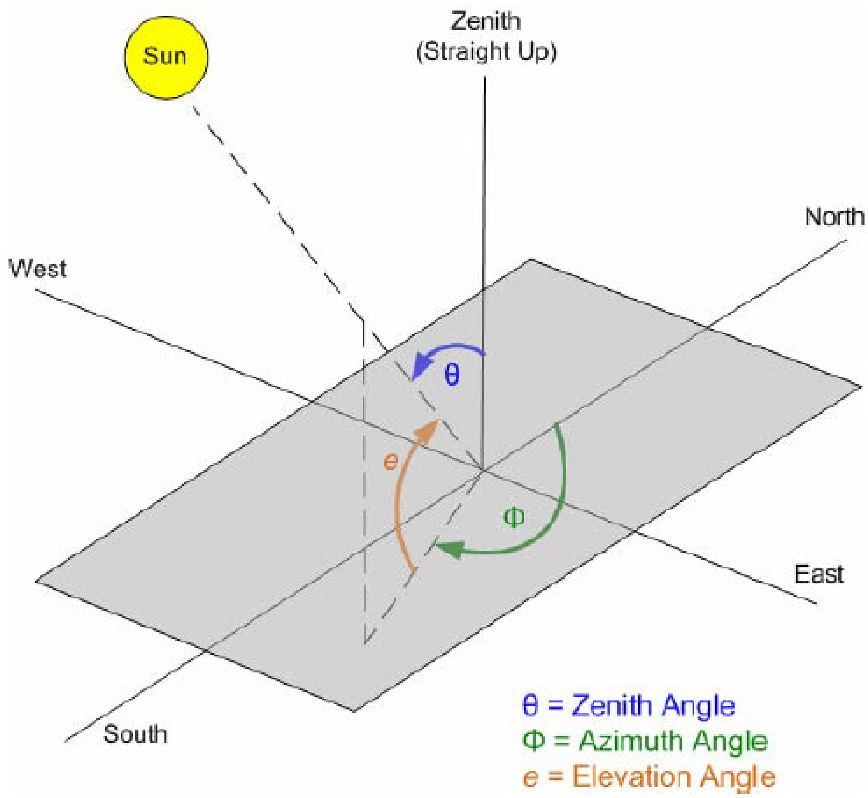

Figure 1: A three (3)- dimensional angle between the surface normal and the curent sun position.

electrons or negative charges. This difference in charges forms a region that is charge neutral and acts as a sort of barrier. When the p-n junction is exposed to sunlight, photons with the correct frequency will then form an extra electron/hole pair. At the same time, since the p-n junction creates a potential difference, the electrons cannot jump to the other side due to the forbidden gap only the holes can. Thus, the electrons must exit through the metal connector and flow through the load, to the connector on the other side of the junction (Krauter, 2006). Inasmuch the photovoltaic cells generate current; cells/panels can be modeled as DC current sources. The amount of current a PV panel produces has a direct correlation with the intensity of light the panel is absorbing. Figure 1 shows a simple illustration of the angle of incidence between the surface normal and the current sun position of solar cell system (Adrain, 2010). The normal to the cell is perpendicular to the cell's exposed face. The sunlight comes in and strikes the panel at an angle. The angle of the sunlight to the normal is the angle of incidence (θ). Assuming the sunlight is staying at a constant intensity (λ) the available sunlight to the solar cell for power generation (W) can be calculated as: $W = A \lambda \cos(\theta)$ (1)

Here, 'A' represents some limiting conversion factor in the design of the panel because they cannot convert 100% of the sunlight absorbed into electrical energy. By this calculation, the maximum power generated will be obtained when the sunlight is hitting the PV cell along its normal and no power will be generated when the sunlight is perpendicular to the normal. Panel not kept perpendicular to the sun's rays will definitely lost significant power during the day because the solar panel is in fixed position. However, a tracking system can keep the angle of incidence within a certain compass and would be able to maximize the power generated and performance evaluation (Mousazadeh et al., 2009). Meanwhile, the amount of power gained by tracking the sunrays can come close to an ideal 57% difference (Mousazadeh et al., 2009). There are many types of solar trackers, of varying costs, sophistication, and performance evaluation.

Types of solar tracker

There are two basic categories of trackers, namely:

single axis and dual axis.

Single axis

This type of solar trackers moves forth and back in a single direction rotating on one axis. Different types of single-axis trackers include horizontal, vertical, polar-aligned, and tilted which rotates as the names implies. The horizontal type is majorly used in tropical regions where the sun gets very high at noon, but the days are short. The vertical type is used in high latitudes where the sun does not get very high, but summer days can be very long. Single axis trackers are normally used with parabolic and linear Fresnel mirror designs in concentrated solar power applications. Figure 2 also shows a pictorial representation of single axis tracker.

Figure 2: Single axis trackers using photovoltaic (PV) panel application.

Dual axis

This solar tracker system is the combination of both the horizontal and a vertical axis and thus they can track the sun's apparent shifting because they can move in two different directions. The types include azimuth-altitude and tip-tilt. Dual axis tracking is surpassingly significant in solar tower applications due to the angle errors resulting from longer distances between the mirror and the central receiver located in the tower structure. Figure 3 is a pictorial representation of dual axis tracker (Allen, 2011). The dual axis tracker was the one used in the implementation of this project due to its combination of both horizontal and a vertical axis and its ability to track the sun's apparent shifting virtually anywhere in the region in which it is installed to maximize energy capture. There are also several methods of driving solar trackers.

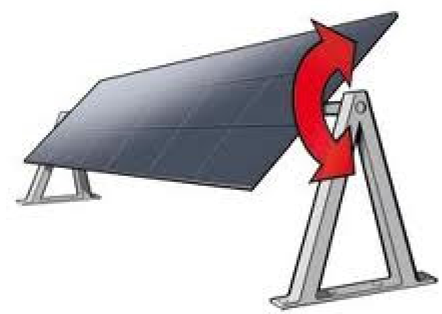

Figure 3: Dual axis tracker for solar photovoltaic (PV) panel applications.

Solar panel trackers drivers are used to reduce the angle between the incoming light and a photovoltaic panel to increase the performance evaluation of the amount of energy extracted. The effectualness of solar receptors depends on the incident angle (i.e. the output energy is ideally proportional to the cosine of the incident angle). This objective can be realized by the incorporation of a sun tracking mechanism (the tracker) in the solar receptor, increasing the performance evaluation up to 75% compared to a fixed type solar receptor (Duffie and Beckman, 2006). Solar tracker drivers, can be divided into three main types depending on the type of drive and sensing or positioning system that they incorporate, namely; the passive, the active and then the open loop trackers. Figure 4; is the block diagram classification of the various types of solar tracker driver.

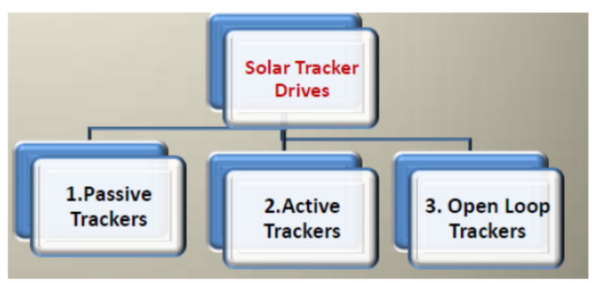

Figure 4: Block diagram classification of solar tracker drivers.

Passive trackers

The passive trackers use the sun's radiation to heat up gases that move the tracker across the sky. Passive trackers use a compressed gas fluid in two canisters each place in west and east of the tracker. The mechanism is in such a way that if one side cylinder is heated the other side piston rises causing the panel to tilt over the sunny side. This affects the balance of the tracker and causes it to tilt. The excellences of this system are; this system is very reliable, needs little maintenance, cheaper and effectively increases the performance evaluation efficiency of the solar panel. While its short comings are; Gas tracker is not very accurate in pointing the solar panels directly to the sun, due to the temperature variation from day to day. Meanwhile, during an overcast day, the sun shows up and fades off behind clouds, affecting the gas and liquid in the cylinders to expand and contract resulting in desultory movement of the device, which however causes damages (Allen, 2011).

Active trackers

The active trackers use an electric or hydraulic drives and some type of gearing system or actuator in the movement of the tracker. It thus measures the light intensity from the sun by using "light sensors" known as LDR, (light dependent resistor) to determine where the solar modules should be pointing. Light sensors are usually positioned on the tracker at various locations in specially shaped holders. If the sun is not facing the tracker directly there will be a difference in light intensity on one LDR compared to the other one and this causes it to determine which direction the tracker has to tilt to with the help of the dc motor or stepper in order to be facing the sun for maximum energy extraction. This system has the following drawback on an overcast day because it will not work properly and actively due to clouds (Allen, 2011).

Open loop trackers

The open loop trackers use no sensing but instead determine the position of the sun through pre-recorded data for a particular site. It determines the position of the sun using computer controlled algorithms or simple timing systems. Open loop tracker can be sub-classified into timed tracker and altitude/azimuth tracker.

Timed tracker

A time tracker used timer to move the tracker across the sky. Gradational movement during the day keeps the solar panel focusing on the sun. The excellence of timed tracker device is that it can be used as one or two axes panels while one of its drawbacks is it do not take into consideration the seasonal variation in sun position.

Altitude / Azimuth trackers

It uses the astronomical data or sun position algorithms to determine the position of the sun for any given time and location by using micro controller. Once the position has been calculated, the modules are moved using servo motors and their position measured by encoders built into the tracker frame (Allen, 2011). However, the active tracker was used in the implementation of this project because it uses an electric or hydraulic drive in the movement of the solar panel as the light sensors are positioned on the panel at various locations in specially shaped holders and thus measures the light intensity from the sun using LDR, (light dependent resistor) to determine where the solar modules should be facing at a particular time of the day.

MATERIALS AND METHODS

Materials

(i).LDR (light dependent resistor)
(ii) Solar tracker drive (Jack driver)
(iii) Solar photovoltaic (PV) panel
(iv) Microcontroller
(v) Indicator
(vi) Battery
(vii) Variable resistors
(viii) Relays
(ix) Solar charge controller
(x) Solar lamp (LED)
(xi) Pole
(xii) Limiting button
(xiii) Diodes
(xiv) Resistors
(xv) Transistors (BJT)

Production process

The automatic solar tracking system is to maximize energy extraction; a modular approach was used to break the project into separate tasks. The signal from the light sensor is used to determine the direction of movement to align the solar panel to the sun. A motor circuit is used to perform this movement based on the signal received from the controller and limiting button. The hardware sections consist of Light Dependent Resistor, Indicator, limiting button, Diodes**,** Resistors, Transistors (BJT), Microcontroller, variable resistors, and assembling structure.

(i) The two (2) Light Dependent Resistors (LDRs) detects sunrise and sunrise respectively, while the two (2) Limiting buttons detects the starting and ending position respectively, to control the motor stops.
(ii) The programming in the processor of the microcontroller converts analog photocell voltage into digital values and provide for output channels to control the motor rotation.

(iii) The device automatically returns in the evening few minutes after the sunset. The vertical illumination on both sides of the sun visor cannot be exactly equal, so that the control circuit will control the motor movement, thereby driving the receiving device to east rotation, until the solar receiver at the sun up.
(iv) Solar panel extract maximum energy during the day when position mid-way between geographical east and west with approximately 30 degrees towards the south.
(v) Variable resistors set the predetermined threshold by which the panels move to align itself facing the sun.
(vi) Two 12V 150A DC supplies is used power two 12V 36W LED street lighting system.

The design consists of two sections developed to improve the extraction of the solar energy which is achieved by an accurate alignment procedure capable of optimal energy extraction. The energy output energy performance is compared with a fixed solar panel which receives the morning and evening sunlight at an acute angle, thus reducing the total amount of electricity generated each day. The value from PV panel in fixed mode and in tracking mode were measured and obtained at different hours of the day. In an ideal situation where atmospheric influence is negligible, the theoretical calculation of the energy surplus is carried out assuming, the maximum radiation intensity, $I=1100 w/m^2$ is falling on the area perpendicular oriented to the direction of radiation and the day length, t=12 hours (43,200 seconds). The design implementation consists of two sections, the micro controller programming and the hardware section. For the microcontroller programming section, the program is written in C language using Atmel studio. The micro-controller could also be erased and reprogrammed online using the In-Circuit Serial Programming technique (ICSP).

The hardware section was also divided into several parts: Light Dependent Resistor and the limiting button, Microcontroller, Relays, Solar modules, variable resistors, power supply and assembling structure (Figure 5). From the block diagram shown above, it can be seen that the whole system is divided into the following sub-units:
(a) Power supply; Light Dependent Resistors (Light sensors); Position sensor; Control unit
(b) Motor drives; and Panels

Power supply design

The source of power for this project work is from two (2) 12 volts, 150Ah DC battery supply, which supplies the lighting of the solar DC lamps.

Light dependent resistors

They are light sensitive resistors whose resistance decreases as the intensity of light they are exposed to increases. The resistance of an LDR may typically have the following resistances: Daylight = 5000Ω, while when it is dark = 20000000Ω. This design work is using two LDRs for sensing the light, that is, the sun moves from east to west, the level of intensity falling on both the LDRs changes and this change is calibrated into voltage using voltage dividers shown in (Figure 6). Figure 7 gives the pictorial representation of LDR. The two LDRs in this project work perform the following functions;

(a) Sunrise and Sunset detection
(b) Voltage level detection.

Sunrise and Sunset detection: The sunrise and sun set detection circuit in (Figure 8) illustrates the detection capabilities of LDR in this project design; When sun rises, the LDR resistance decreases and the current through it increase. The voltage at the transistor base builds up until the transistor is forced into saturation. The collector current in turn increases and the coil is energized, and in turn it pulls the relay to close connecting the supply to the micro controller input (Figure 8). When darkness falls, the LDR resistor increases and the transistor base current decreases cutting the collector current, and in turn disconnecting the relay (The flywheel diode is connected to protect the transistor against the di/dt effect). An identical circuit is used for the sun set, with small difference where the input is connected to the micro controller.

Position sensor

This is the middle LDR that does the automatic on and off of the lamp at night and morning respectively.

Control units

The control unit uses a microcontroller ATMEGA 328P which has internal ADC and memory. The controller was clocked with a frequency of 16MHz. This is used to achieve a compact system since two ADC is needed to check both the voltage and current. The controller is programmed to communicate with the LDRs, Position sensor, and relay connected to the entire system while the LDRs are responsible for the east and west switching. The basic connection of the controller is shown in (Figure 9). Pin 7 which is the V_{cc} is connected to 5V as specified in the datasheet which is to power the controller while pin 8 is grounded.

Panels

Panels directly convert solar radiations into electricity energy. This design incorporates an individual solar cell

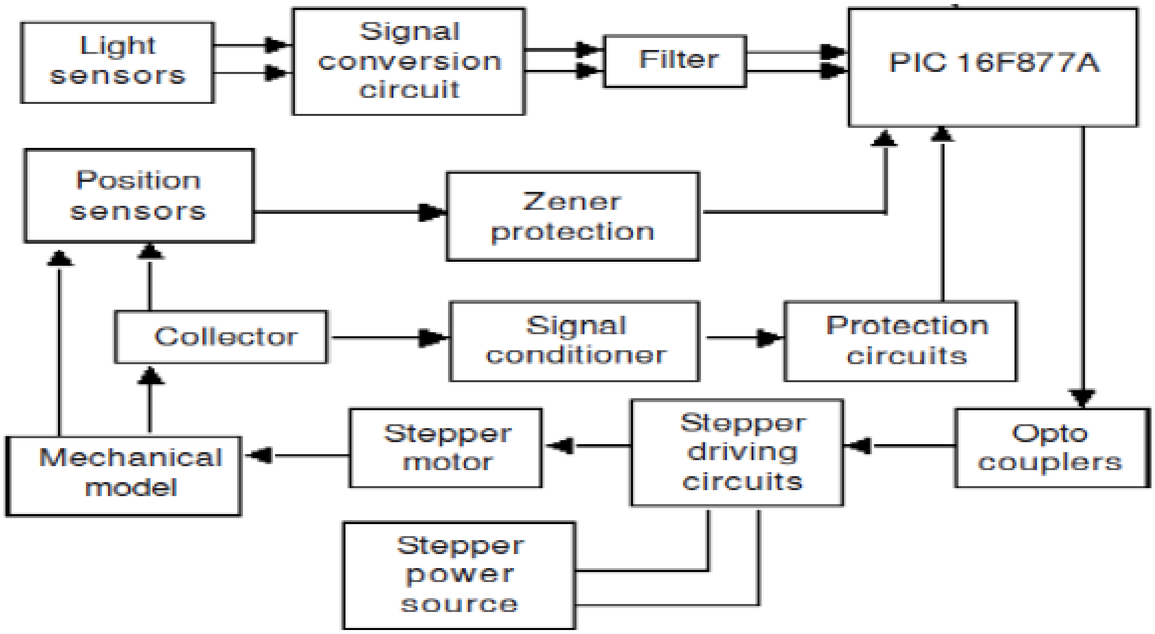

Figure 5: Block diagram of the hardware sections.

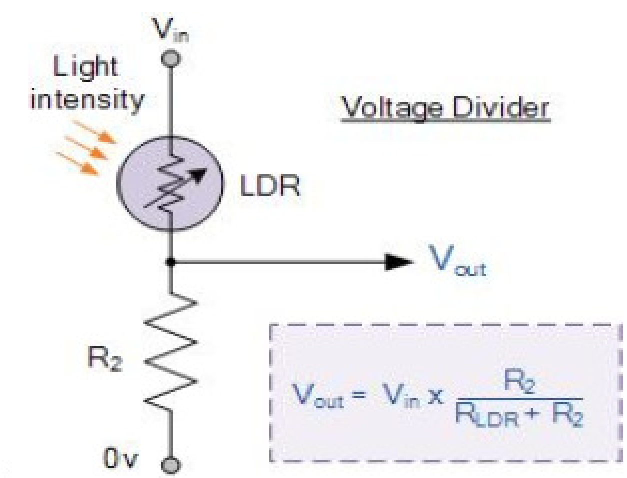

Figure 6: Voltage divider for the determination of the equivalent value of the LDR.

which typically made out of crystalline silicon. The equivalent circuit of the solar cell is shown in (Figure. 10).

Description of project

Solar trackers are rising in popularity, but not everyone understands the complete benefits and potential drawbacks of this system. It is a fantastic system for energy output. Solar panel tracking solutions are a more advanced technology for mounting photovoltaic panels, unlike stationary mounts, which hold panels in a fixed position, can have their productivity compromised when the sun passes to a less-than-optimal angle. In other to overcome this, solar trackers automatically move to “track” the progress of the sun across the sky, thereby maximizing output. The unique feature of this system is that instead of taking the earth as its reference, it takes

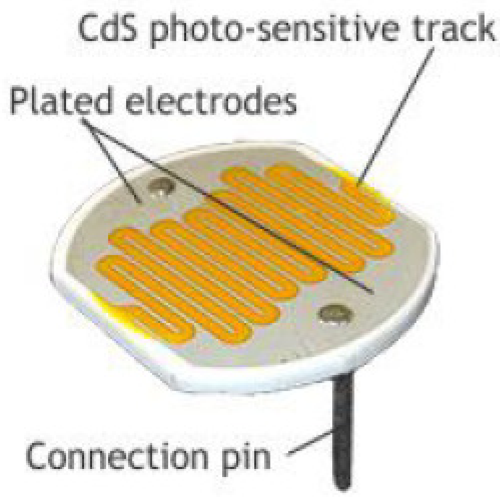

Figure 7: Physical representation of an LDR sections.

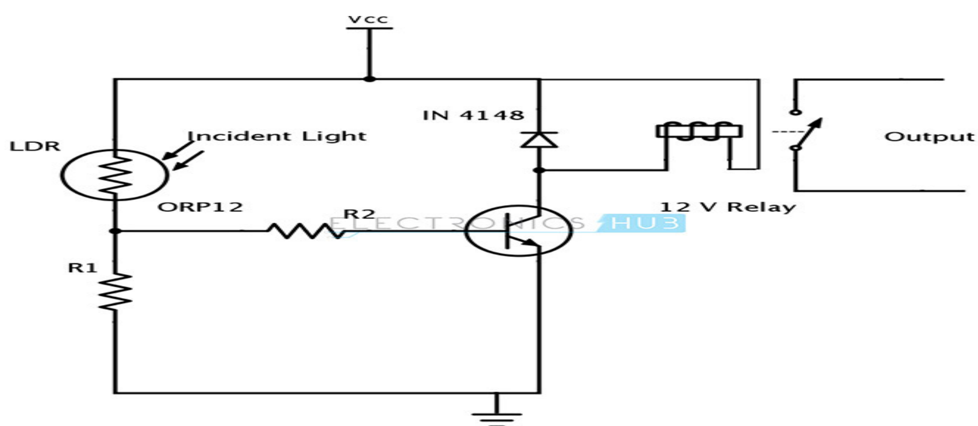

Figure 8: Sunrise and sunset capture.

the sun as a guiding source. Its active sensors (LDRs) constantly monitor the sunlight and align the panel towards the direction where the sun intensity is at maximum. Should the sun get invisible e.g. in cloudy weather, then without tracking the sun the ASTS keeps rotating the solar panel in opposite direction to the rotation of earth. But its speed of rotation is same as that of earth's rotation. Due to this property when after some time e.g. half an hour when the sun again gets visible, the solar panel is exactly in front of sun.

Operational sequence

The circuit consists of the following stages for the proper operation. The circuit uses two LDRs subjected to the same illumination. The half the operating voltage is then applied to the non-inverting input terminal (positive terminal) of the battery and to the inverting input terminal of battery. The sensor stage comprises of the two LDRs, when the position of the sun changes, the illumination affecting LDRs, R1 and R2 is different, provide if they are at an angle to each other. In this case, the illuminated LDRs will provide information to the DC motor (Jack Drive) which gives the output by comparing the initial half supply voltage to the input voltage from the illumination light falling on the LDRs thereby resulting into clockwise and anticlockwise rotation of the solar panel along its axis. The driver stage comprises of the two transistors T_1 is connected in a bridge for reversing of the motor. The transistor T_1 provides clockwise rotation of the motor, why the transistor T_2 provides anticlockwise rotation of the motor.

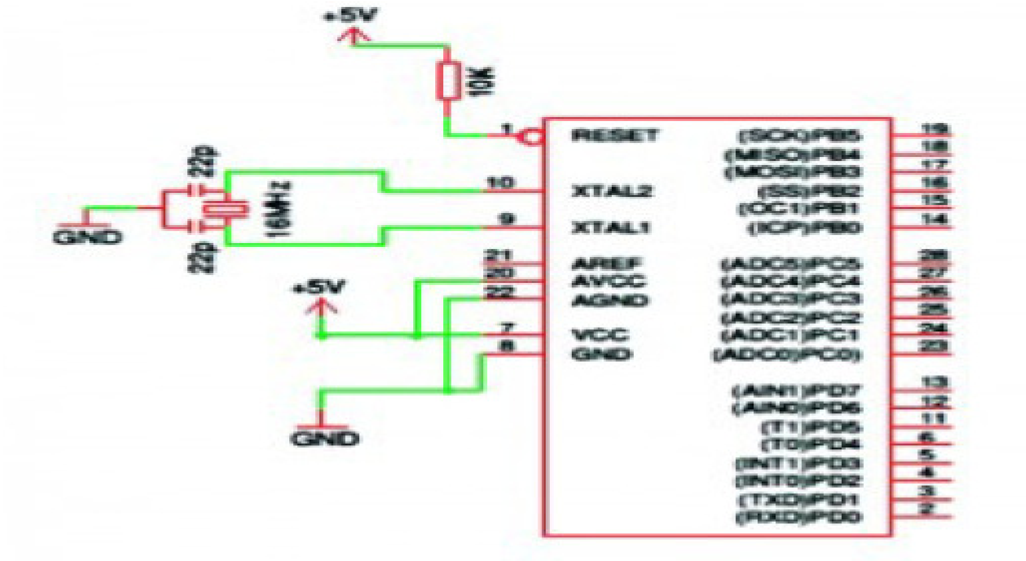

Figure 9: Microcontroller Circuit Connection (Microchip technology Inc. 2006).

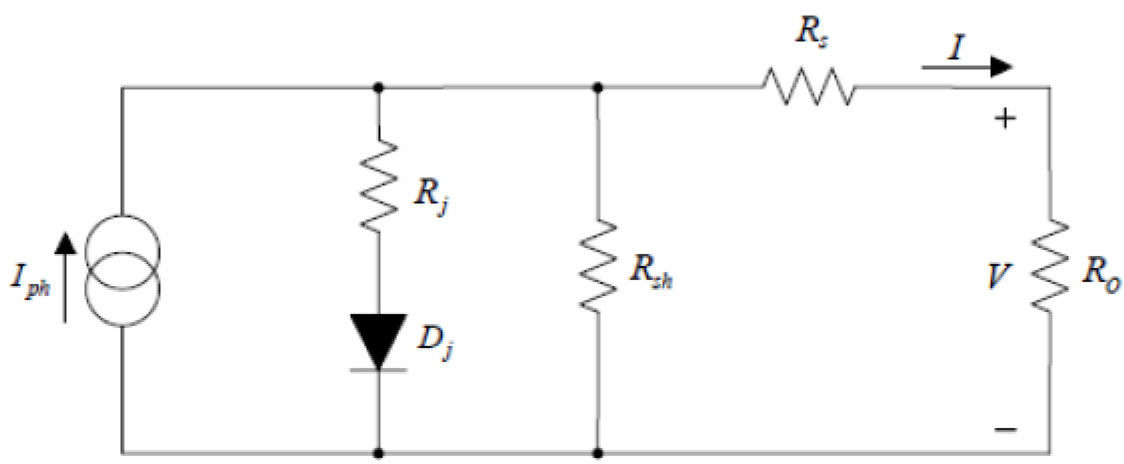

Figure 10: Solar cell equivalent circuits.

The protecting devices are the Diodes D_1 to D_2 which functions are to save the motor by suppressing the effect of the voltage peak of the motor when switched on. The presetting stages comprise of the three variables resistor P_1, P_2 and P_3. Two of which are adjusted so that the motor is idle when the LDRs are subjected to the same illumination while the third is for the adjustment of the solar lamp. If more light reaches R1 and R2, voltage at point A rises to more than half the supply voltage. The result is that the comparing output of A1 goes high and transistor T_1 conducts. The motor then runs a clockwise direction. If the illumination of the LDRs changes so that the voltage at point A drops to less than half the supply voltage, output of A2 goes high and transistor T_2 conduct, motor then rotates in an anticlockwise direction.

Precaution

Safety was part of our concern during the construction and testing of this project. Therefore, it was ensured that all components were well couple and they met all the requirement of our circuit. It was ensured that there is no

Table 1: Solar output of PV panel in fixed mode

Time of the day	Voltage (V)	Current (A)	Power (W)
9.00	13.87	0.88	12.21
10.00	15.29	0.97	14.83
11.00	15.09	0.95	14.34
12.00	16.17	1.07	16.33
13.00	18.08	1.17	21.15
14.00	16.25	1.06	17.23
15.00	15.88	0.99	15.72

Table 2: Solar output of PV panel in tracking mode

Time of the day	Voltage (V)	Current (A)	Power (W)
9.00	16.04	0.95	15.24
10.00	16.48	1.02	16.81
11.00	16.40	0.98	16.07
12.00	16.75	1.09	18.26
13.00	18.09	1.17	21.16
14.00	17.30	1.13	19.55
15.00	16.83	1.11	18.68

form of shade, impediment or obstruction to the solar emission. It was also ensured that the work area was conductive enough and void of things that could constitute fire or electrical hazard. Disassembling or remover of any part of the system will void manufacturer warranties. Also small children and pets should be kept away from the installation. Soldering lead of low melting point was used for the component soldering; extreme care was taken while soldering component like transistor since excessive heat can damage the components. A 60W soldering iron was used and the components were not heated too much to avoid failure of the components. After soldering proper inspection was made to ensure the connection were corrected and the component were all soldered to prevent the effect of the open circuit and short circuitry.

Testing

The most important process in engineering is testing which one cannot do without. Testing is process of detecting any fault in the component before any complications would arise. After the construction and designing of the solar tracker, it must be put into test in order to make sure that it complies with requirement for the installation. At the beginning, the automatic solar tracker is oriented towards the east where the limiting button (start), test for the east positioning. After the design was installed, it was put through several tests of functionality to ensure that it met its purpose of design requirements. The tracker's angular error, jack drive mechanism and power consumption were measured to calculate the tracker's power generation in comparison to fixed solar panel systems. The value from PV panel measured and obtain in fixed mode is shown in (Table 1) while the tracking mode is shown in (Table 2) at different hours of the day. This experiment was carried out on 20th November 2017 between 9am and 3pm at 1-hour intervals. The readings are as shown in (Tables 1 and 2).

Maintenance

The following maintenance practices are suggested to improve the life span of the system and prevent hazard to the users:

(i) Dead batteries should not be used with the solar panel.
(ii) The battery terminals should not be removed too often. When it is removed replacement of correct polarity must be ensured.
(iii) The solar panel must be put where there is no shade.
(iv) The battery compartment must not be too sealed so as to allow in-out flow of air.

Findings

The solar tracker operates with an applied voltage between 12 volts and maximum operating current of 300Ah. When the project was tested, the following findings were made.

(i) Dead batteries should not be used with the solar panel.
(ii) The battery terminals should not be removed too often. When it is removed replacement of correct polarity must be ensured.
(iii) The solar panel must be put where there is no shade.
(iv) The battery compartment must not be too sealed so as to allow in-out flow of air.

Conclusion

The project was tested and it was found to be working effectively and efficiently. It revealed the likely problems and challenges that could come in future as a practicing electronics and solar technologist and how to solve them. Also the practical knowledge as an electronics student has been improved through this project work. The result of this project design and construction make the system to be user friendly because the user that is going to operate it doesn't require any special training to operate or understand how it works. The system operation doesn't always require manual operation due to the fact that the system operates itself automatically. This project was implemented with minimum resources. The circuitry was kept simple, while ensuring efficiency is not affected.

Recommendations

The following recommendations are provided as ideas for future expansion of this project:

(i) Increasing the sensitivity and accuracy of tracking using different light sensor. A phototransistor with an amplification circuit would provide improved resolution and better tracking accuracy/precision.
(ii) Incorporating a microcontroller to monitor an array of LDRs that will control the switching ON and OFF of a number of motors to make the solar tracker more intelligent.
(iii) It will be economical if photovoltaic cell is used to power the project. If large DC motor is used, the project can be used to generate electricity if a solar panel of considerable mask is incorporated on it.
(iv) Increasing the power of the battery by adding more batteries amp and more PV modules to lighten more solar street lamps.

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