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Azimuth-Altitude Dual Axis Solar Tracker

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Abstract: *People in underprivileged countries could benefit from the use of a solar distributed generation system. To provide an efficient solar distributed generation system, a scaled down dual-axis solar tracker was designed, built and tested.*

I. Introduction

The Need for Electricity in Underprivileged Countries and a Possible Solution.

Not all countries possess all the commodities that are available to humanity. These so called underprivileged countries lack amenities such as; abundant food, clean water, medicine, wealth, education, and a healthy environment. The World Bank and other institutions believe that the lack of access to clean and efficient energy services is a factor involved in underprivileged countries from gaining more resources associated with higher living quality, such as wealth. There are a few new forms of advanced energy, but electricity has been proven to be one of the cleanliest and most efficient forms.

One possible solution to unreliable or nonexistent central electricity distribution systems is to have distributed generation system (DG). A distributed generation system is characterized by the fact that the electricity is produced locally rather than externally. DG is often used in underprivileged countries; however, usually in the form of small generators that run on different types of fossil fuels. The use of renewable types of DG is preferable, since they provide a more sustainable and healthier environment. The most common DG options include; solar, wind, and thermal.

In comparing the various forms of renewable DG, five factors must be considered: location, ease of installation, reliability, capacity, and cost. Thermal power is a location dependent, high cost option whereas wind has a lower cost but is unreliable due to changing wind conditions and requires regular mechanical maintenance. Solar power has a relatively lower cost, easy to install and maintain, and for underprivileged countries near the equator, ideal for the location.

However the problem with solar power is that it is directly dependent on light intensity. To produce the maximum amount of energy, a solar panel must be perpendicular to the light source. Because the sun moves both throughout the day as well as throughout the year, a solar panel must be able to follow the sun's movement to produce the maximum possible power. The solution is to use a tracking system that maintains the panel's orthogonal position with the light source. There are many tracking system designs available including passive and active systems with one or two axes of freedom.

The goal of our project was to design an active, dual axis, solar tracker that will have a minimum allowable error of 10° and also be economically feasible to market towards underprivileged countries. We started by examining the prior work done in solar tracking methods to determine our course of action. From there we designed and tested several mechanical and electrical options and chose the ones with the most desirable characteristics. Finally, we built our final tracking system, tested and compared it to ensure that we met our original goal.

II. Background

Solar Technology

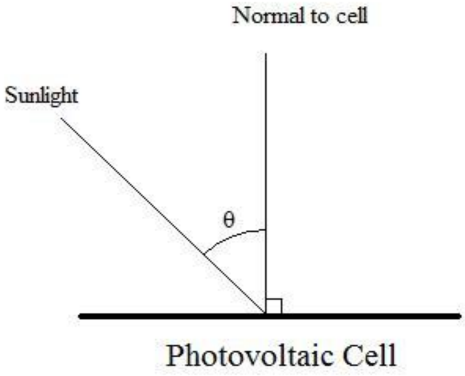
As mentioned above in the introduction, the use of a tracking system greatly improves the power gain from solar radiation. This background goes into further detail on the operation of solar cells and the reason tracking is needed. The different tracking technologies are also described and how they compare to one another.

2.1. Solar Power Fundamentals

A fundamental understanding of how a photovoltaic panel works is essential in producing a highly efficient solar system. Solar panels are formed out of solar cells that are connected in parallel or series. When connected in series, there is an increase in the overall voltage, connected in parallel increases the overall current. Each individual solar cell is typically made out of crystalline silicon, although other types such as ribbon and thin-film silicone are gaining popularity.

PV cells consist of layered silicon that is doped with different elements to form a p-n junction. The p-type side will contain extra holes or positive charges. The n-type side will contain extra electrons or negative charges. This difference of charge forms a region that is charge neutral and acts as a sort of barrier. When the p-n junction is exposed to light, photons with the correct frequency will form an extra electron/hole pair. However, since the p-n junction creates a potential difference, the electrons can't jump to the other side 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.

Because the PV cells generate a 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. Below is a simple drawing of the system:



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:

$$W = A \lambda \cos(\theta)$$

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 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. With a fixed solar panel, there is significant power lost during the day because the panel is not kept perpendicular to the sun's rays. A tracking system can keep the angle of incidence within a certain margin and would be able to maximize the power generated.

2.2. Existing Tracking Technology

As mentioned in the previous sub-section (2.1) the absorption of light by a PV panel is dependent on its angular position to the sun. A PV panel must be perpendicular to the sun for maximum solar absorption, which is done by using a tracking system. Multiple tracking systems exist, which vary in reliability, accuracy, cost, and other factors. A tracking system must be chosen wisely to ensure that the tracking method increases the power gained instead of decreasing it.

2.2.1. Immobile Versus Mobile

Different power applications require different tracking systems. For certain applications a tracking system is too costly and will decrease the max power that is gained from the solar panel. Due to the fact that the earth rotates on its axis and orbits around the sun, if a PV cell/panel is immobile, the absorption efficiency will be significantly less at certain times of the day and year. The use of a tracking system to keep the PV cell/panel perpendicular to the sun can boost the collected energy by 10 - 100% depending on the circumstances.

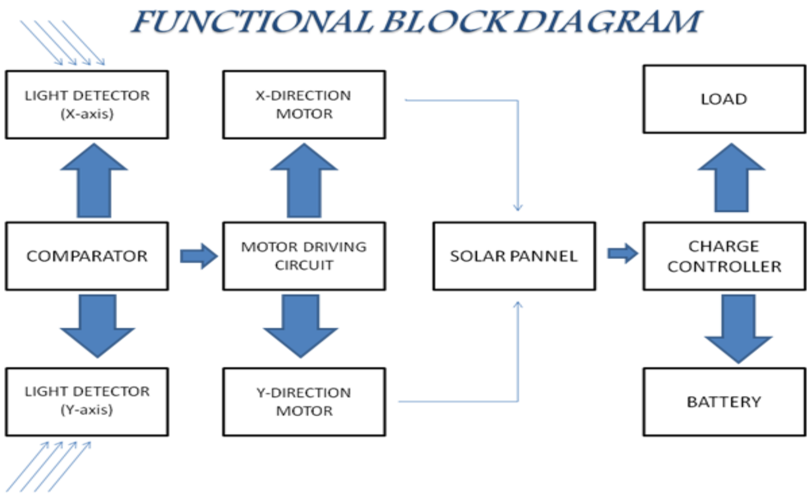
If a tracking system is not used, the solar panel should still be oriented in the optimum position. The panel needs to be placed where no shadow will fall on it at any time of the day. Additionally, the best tilt angle should be determined based on the geographical location of the panel. As a general guideline for the northern hemisphere, the PV panel should be placed at a tilt angle equal to the latitude of the site and facing south. However, for a more accurate position and tilt angel a theoretical model of the suns iridescence for the duration of a year is created and the angel and position is matched to the model.

Using one axis of tracking can provide a significant power gain to the system. Wikipedia claims that one axis trackers are placed into the following classifications: horizontal single axis tracker (HSAT), vertical single axis tracker (VSAT), tilted single axis tracker (TSAT), and polar aligned single axis tracker (PASAT). However, these terms don't seem to be used in most articles discussing tracking methods. One article did mention that a TSAT at a tilt angle of 5° increases the annual collection radiation by 10% compared to a HSAT, a HSAT increases the annual collection radiation by 15% to a VSAT, and finally a PASAT increases the annual collection radiation by 10% over a HSAT. Thus for one axis a PASAT or TSAT configuration would collect the most solar radiation.

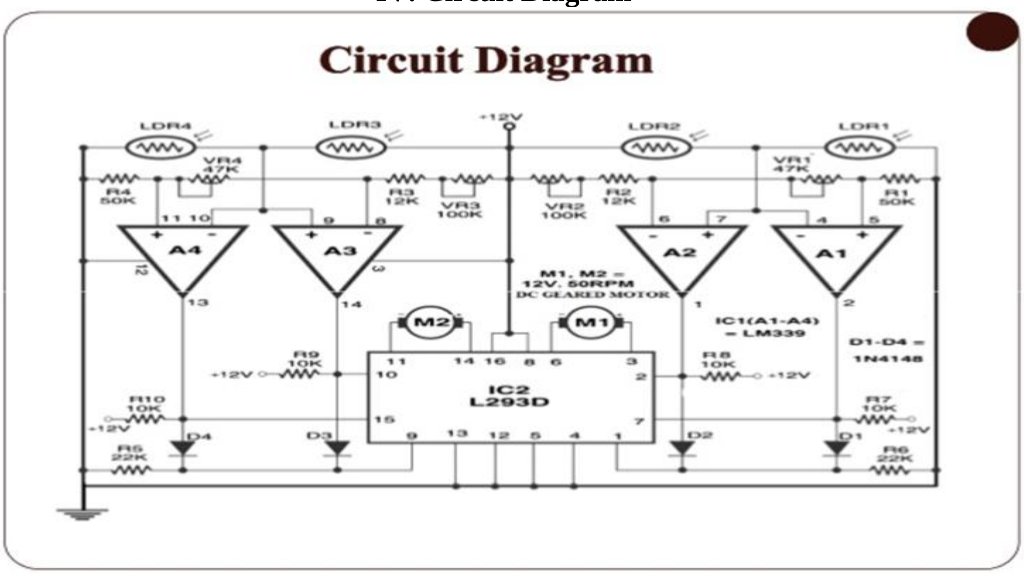
For an additional power gain a dual-axis tracking system can be used. The percent gain from going from a PSAT to a dual-axis system is small, but as long as the system doesn't use more power than gained, it still helps. Again Wikipedia mentions two classifications for dual axis trackers: Tip-Tilt Dual Axis Tracker (TTDAT) and Azimuth-Altitude Dual Axis Tracker (AADAT). The difference between the two types is the orientation of the primary axis in relation to the ground. TTDAT's have the primary axis horizontal to the ground and AADAT's have theirs vertical. The azimuth/altitude method seems to be largely used, based on its reference in multiple research articles on tracking.

III. System Design

The purpose of a solar tracker is to accurately determine the position of the sun. This enables solar panels interfaced to the tracker to obtain the maximum solar radiation. With this particular solar tracker a closed-loop system was made consisting of an electrical system and a mechanical system. The electrical system consists of four LDR sensors which provide feedback to a comparator IC-lm339. This comparator processes the sensor input and provides output to the H-bridge IC-l293d. The entire electrical system is powered by a 12V source. The H-bridge controls the two DC motors, which are also part of the mechanical system. The mechanical system also contains two gear assemblies that adjust the PV panel.



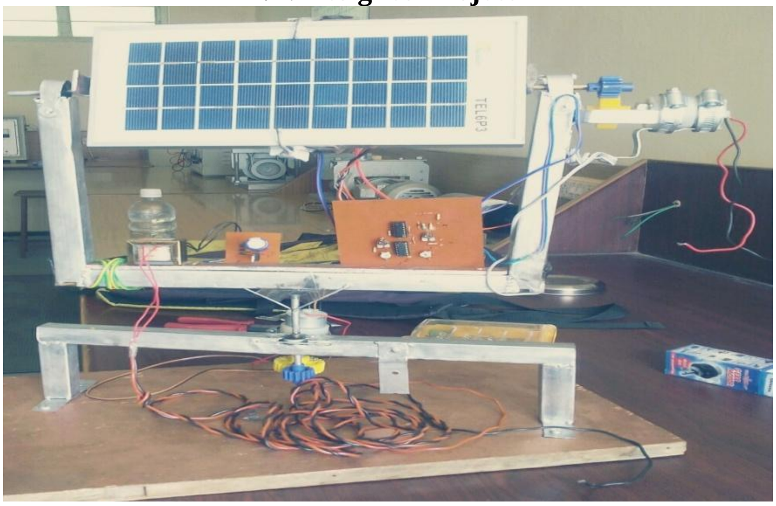
IV. Circuit Diagram



V. Basic Components

- Solar Panel
- LDR(Light dependent resistors)
- IC-LM339
- IC-L293D
- Permanent magnet DC Motor

VI. Designed Project



Advantages

- ➢ Proposed dual axis solar tracker is cost effective.
- ➢ Average power gain of the solar panel with dual axis tracking system over normal stationary arrangement is up to 40-50%.
- ➢ Less power consumption by internal circuit and PMDC motors.
- ➢ Ability of tracking sun light at any weather.
- ➢ Installation is easy and operates automatically.

Disadvantages

- ➢ Solar tracker are slightly more expensive than their stationary counter parts, due to the more complex technology and moving parts necessary for their operation.
- ➢ Some ongoing maintenance is generally required, though the quality of solar tracker can play a role in how much and how often this maintenance is needed.

Note:-Overall, solar tracker are highly efficient installations, and are a great fit for many smaller jobsites.

VII. Applications

- ➢ Dual axis sun tracker can be used for large & medium scale power generations.
- ➢ It can also be used for power generation at remote places.
- ➢ It may be used as domestic backup power systems.
- ➢ It can be used in solar street lighting system
- ➢ It may be used in water treatment technologies and solar heating.

VIII. Discussion

The main theme of this project is to generate electricity using sun light efficiently by developing a advance dual axis solar tracking system. Proposed dual axis solar tracking system is more efficient than single axis & static panels and also cheaper than the other trackers available in market. Uses of four LDR‘s enable the tracker to keep the panel exactly perpendicular to the sun throughout the day. It enables the panel to grab energy throughout the day, which increase the efficiency of solar panel. Average power gain of the solar panel with proposed dual axis tracking system is up to 40-50% over normal stationary arrangement and 15-20% over single axis tracking system. Basically, this project is a miniature model for large scale electrical generating system. According to this implementation in future it can be implemented in large scale in perspective of Bangladesh. A considerable amount of power could be obtained if it is implemented as a large project with comparing of fossil fuel resources.

IX. Conclusion

The proposed dual-axis solar tracking system will be reliable and accurate throughout the year and maximize the output power when compared to static system and single axis tracking system. It will be a good and competitive solution for the market place as it is expected to compete with more complex and expensive **systems.**

X. Recommendation

- Hybrid super-capacitor energy storage system can be used to store energy quickly.
- Solar thermal power plant may be included in large scale power generation.
- An automatic dust sensor wiper or cleaning robot can be provided for cleaning of solar plate.

XI. Bill of Material

- Main circuit:-
- L293D = Rs50
- LM339 = Rs40
- Electronic components = Rs80
- Supply circuit:-
- L7812 = Rs30
- Capacitor = Rs50
- Transformer = Rs150
- Output circuit = Rs400
- Solar panel = Rs450
- Model base = Rs500
- Gear = Rs120
- PCB + Rod = Rs150
- 2-DC Motor = Rs400

Total = Rs2420

XII. Result

As we know that the working on renewable sources of energy is continuously going on from past many years and solar is one of the renewable sources of energy and it has been seen that the stationary sources of solar power plants gives only 30%-40% of efficiency, so for this invention of single axis tracker was done and some amount of efficiency has been improved and reached to the 50%-60%. And now to make it more efficient working on dual axis solar tracker is going on which resuts in increase in 10%-15% efficiency of single axis and 20%-25% efficiency of stationary.

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