AUTOMATIC SOLAR TRACKING SYSTEM, FOR SUSTAINABLE ENERGY EFFICIENT DISTRIBUTION.

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Abstract

Energy crisis is the most important issue in today's world. Conventional energy resources are not only limited but also the prime culprit for environmental pollution. 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. Solar cells those convert sun's energy into electrical energy are costly and inefficient. Different mechanisms are applied to increase the efficiency of the solar cell to reduce the cost. Solar tracking system is the most appropriate technology to enhance the efficiency of the solar cells by tracking the sun. The power from the sun intercepted by the earth is approximately 1.8x10^{11}*MW, which is many thousand times larger than the present consumption rate on the earth of all commercial energy sources. Solar tracking system can be used as a power generating method from sunlight. A microcontroller-based design methodology of an automatic solar tracker is presented in this paper work. Light dependent resistors are used as the sensors of the solar tracker. As a result, renewable energy solution has achieved a great demand today to save the natural resources and also to tackle the crisis of energy. Solar energy is rapidly gaining its popularity as an important source of renewable energy. But the efficiency of solar panel is a big factor. While* *the sun keeps following a parabolic path throughout the day, the panels which are used in our country are generally fixed to a pole or the roof of the house and hence, throughout the day, the efficiency decreases significantly. This project system is tracking for maximum intensity of light. When there is decrease in intensity of light, this system automatically changes its direction to get maximum intensity of light. The proposed method is to design an electronic circuit to sense the intensity of light and control the DC motor driver for the panel movement, and construct a Buck Boost converter for to step up and step-down the voltage, and store the maximum utilized output voltage in Lead Acid Battery. However, in this paper work, we have constructed a 2-axis solar tracker which can track the sun throughout the day to obtain the maximum efficiency.*

Key word: *Photovoltaic Cell, Solar Energy, Light Intensity, Maximum Power Point Tracker.*

1. Introduction

Solar energy is one of the most sought-after renewable resources. This comes as a result of its cheap source and its reliability to sustain. There are two different types of technologies involved in harvesting solar energy; these include photovoltaic panel and the solar-thermal panel. Photovoltaic panel is mainly used for power generation and solar-thermal is used for heating water or for drying. The solar thermal panel can also be used for power generation.

The sun rises from the east and sets in the west, travelling along the latitude during the day and along the longitude during the seasons. The relative position of the sun is a major factor in the performance of the solar energy system. Sunlight has two components, the “direct beam” that carries about 90% of the solar energy and the “diffuse sunlight” that carries the remainder. As majority of the sun energy is in the direct beam, this gives a considerable reason to track the sun rays using a solar tracker, Anusha, K., S. etal, (2013). A Solar tracker is a system or device that orients various photovoltaic and solar thermal panels toward the sun. It ensures that the direct beam from the sun is incident normal to the surface of the panels at all times. Installing a solar tracker to a solar system proves to be more efficient than a stationary solar system in terms of power generation.

The renewable energy is the source of energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible, unlike conventional fossil fuels. The global energy crunch has provided a renewed impetus to the growth and development of clean and renewable energy sources. Clean Development Mechanisms (CDMs) are being adopted by organizations all across the globe. Apart from the rapidly decreasing reserves of fossil fuels in the world, another major factor working against fossil fuels is the pollution associated with their combustion. Contrastingly, renewable energy sources are known to be much cleaner and produce energy without the harmful effects of pollution unlike their conventional counterparts.

With the alarming rate of depletion of the major energy resources worldwide, it has become an urgent necessity to seek for renewable energy resources that will power the future. According to the worldwide market economy, the increasing demand for energy had forced to put a huge price tag on natural combustible sources of energies, Anusha, K., S. etal, (2013). In fact, it has been predicted that in the near future the demand of energy will grow in such a rate that it will be completely impossible to find out or meet the demand with the resources that we had been using for so long, such as; oil, gas, coal, etc. This issue throws a positive challenge to the scientific community as more and more funds are being allocated for the research and development of new alternatives. In this context we have concentrated our focus on the research of renewable energy. Among these renewable energy resources solar energy is one of a kind. In today's world there is a growing demand to find greener ways to power the world and minimize greenhouse gas emission. The sun is a natural power source that will keep on shining for an estimated 4 billion years. Solar power (photovoltaic) systems are a sustainable way to convert the energy of the sun into electricity. The expected lifetime of a system is 25-30 years, Anyaka, B. O etal, (2013). The energy potential of the sun is immense, and it is one of the emerging energy sources, which is subsidized in order to secure the distribution of the technology worldwide. By tracking the sun the efficiency can be increased by 30-40%, Batayneh, W. etal (2013). The photovoltaic technology allows the conversion of sunlight directly to electricity with a conversion ratio of about 15%, Dhanabal, R. etal (2013).

2. Solar System Development

Solar Cells, also known as photovoltaic cells are used to convert light energy into electricity.

Photovoltaic cells work on the principle of the photovoltaic effect, which is similar to the photoelectric effect. Differences being that the electrons in photovoltaic are not emitted instead contained in the material around the surface, creating a voltage difference. Solar cells are forged with crystalline silicon. It is the most commonly used material in a solar cell. The use of silicon in the solar cell has been very efficient and low cost. Two forms of crystalline silicon can be used to make solar cells. Other than silicon, solar cells can be fabricated with cadmium telluride (CdTe), Copper indium gallium (di) selenide (CIGS) etc. the fabrication of solar cells with materials other silicon is slightly expensive, thus making silicon the best material to be used in solar tracking systems. Ganesh, N. etal, (2011).

One of the finest and extensively used material, is the monocrystalline silicon which has an efficiency of about 15-20%. While under high temperature, the performance of the cell material drops by 10-15% of the initial.

Polycrystalline silicon is another form, cheaper than the latter but has the same band gap as that of monocrystalline silicon. Though it has the same band gap energy, it lags in efficiency, hence this material is used in low-cost products. Amorphous silicon cells can work under extremely high temperatures, but the efficiency of these cells is comparatively lower than the other silicon forms, Robert, A. etal, (2014). The technologies which use CdTe, CIGS, Amorphous Thin-Film Silicon (a-Si, TF-Si) in the fabrication of solar cells are known as thin film photovoltaic modules. These thin-film solar cells are relatively cost-effective than the solar cells of crystalline silicon, Gupta, B. etal (2013).

Photovoltaic or solar cells, at the present time, furnish one of the most-important long duration power supplies. Since a typical photovoltaic cell produces less than 3 watts at approximately 0.5 volt dc, cells must be connected in series-parallel configurations to produce enough power for high-power applications. Cells are configured into module and modules are connected as arrays. Modules may have peak output powers ranging from a few watts, depending upon the intended application, to more than 300 watts. Typical array output power is in the 100-watt-kilowattrange, although megawatt arrays do exist. However, the solar system development is structured such as:

(a) Photovoltaic Cells

A photovoltaic (PV) cell converts sunlight into electricity, which is the physical process known as photoelectric effect. Light which shines on a PV cell, may be reflected, absorbed, or passed through; however, only absorbed light generates electricity one layer is an "n-type" semiconductor with an abundance of electrons, which have a negative electrical charge. The other layer is a "p-type" semiconductor with an abundance of holes, which have a positive electrical charge. Although both materials are electrically neutral, n-type silicon has excess electrons and p-type silicon has excess holes. Sandwiching these together creates a p-n junction at their interface, thereby creating an electric field. Figure:1 shows the p-n junction of a PV cell. When n-type and p-type silicon come into contact, excess electrons move from the n-type side to the p-type side. The result is the build-up of positive charge along the n-type side of the interface and of negative charge along the p-type side, which establishes an electrical field at the interface. The electrical field forces the electrons to move from the semiconductor toward the negative surface to carry current. At the same time, the holes move in the opposite direction, towards the positive surface, where they wait for incoming electrons.

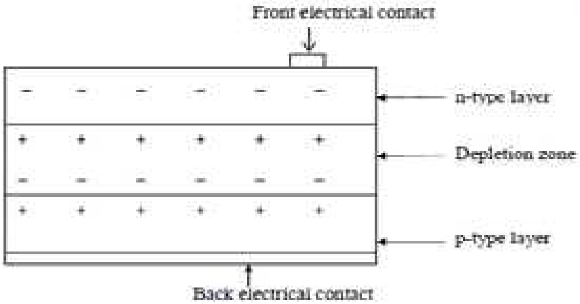

Figure1: Structure of P-V Cell

(b) Light Intensity

Variation in the intensities of light plays a significant role in depicting the amount of power output. This change in intensities monitors all the technical criterions such as voltage, circuit current, efficiency, shunt resistance etc. As a result, higher the intensities of light, greater is the power output.

The sun appears to rise in the eastward horizon and sets in the westward horizon. The planet earth rotates around the sun but however as the earth spins and rotate around the sun it appears to the inhabitants on the earth that the sun is moving across the sky. This is known as the movement of the sun. As depicted in Figure (2), the position of the sun with respect to that of the earth changes in a cyclic manner during the course of a calendar year. Tracking the position of the sun in order to expose a solar panel to maximum radiation at any given time is the main purpose of the solar tracking system.

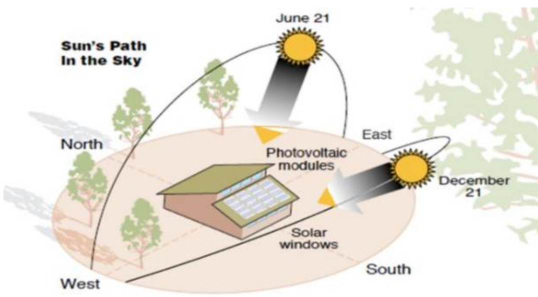

Figure 2: The movement of the sun from the south to northern hemisphere, and along the latitude form east to west ((http://greenpassivesolar.com/wp-ontent)

(c) The Efficiency of Solar Panel

The efficiency is one of the most significant criteria which defines the quality of the output of a certain device. There are many factors which alter the efficiency of a solar panel. Efficiency can be described as the ration of the input energy through the solar cell to the energy of the sun. The efficiency of the solar panel is monitored by the light intensity, material of the solar cell, temperature etc. For the calculation of the energy, we calculate the maximum power, which is defined as the product of open-circuit voltage (V_{OC}), short-circuit current (I_{SC}), and fill factor (F F), Panait, MA and Tudorache, T. (2008).

$P_{max} = V_{OC}\ I_{SC}$ FF

The efficiency (η) is then calculated as: $\eta = \frac{V_{OC} I_{SC}\ FF}{P_{in}}$ Where, P_{in} is the total input power.

3. Materials and Method

The idea that has been conceived primarily base on this concept, is how to make the best use of solar energy. The next path that unravels is firstly the method to be adopted in storing the solar energy at its maximum level which further ends up with hatching of this paper work called "THE DEVELOPMENT OF AN AUTOMATIC SOLAR TRACKING SYSTEM FOR EFFICIENT POWER DISTRIBUTION''. Culminating towards making the said paper work caviar in its utilization, several components have been unleashed, some of which as mentioned includes:

1. Solar Panel,
2. DC Motor,
3. L293D Motor driver module,
4. Microcontroller NodeMcu,
5. LDR sensor module,
6. Current sensor,

All in consolidation of the said components the concerned project is orchestrated, ought to seek for imbibing the sun rays at its maximum level through the LDR sensor module etched on the edges of the solar panel in accordance with the length of it, revolves in aid with the DC motor by maintaining the proportionality of the Sun's movement. Therefore, the genesis lies upon the fact of making solar energy a profitable source in the production of various other aspects which are in rest with the acute need of the society. In addition to which it would be further worthier to state that when the world is being maligned and sick through the pollution ruckus this project could unveil to be a robust endeavour.

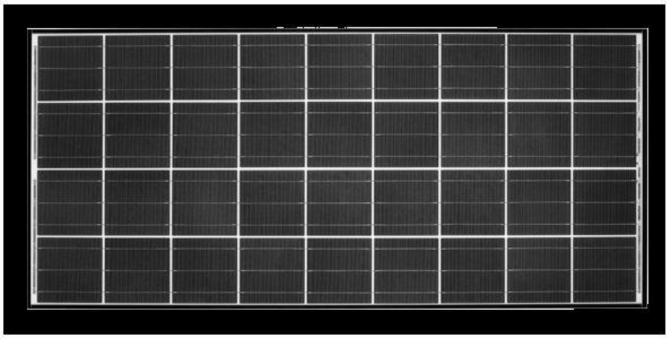

Figure 3: Picture of photovoltaic module

(d) Maximum Power Point Tracking

Maximum Power Point Tracking, (MPPT), is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power harvested from the modules is then made available as increased battery charge current. MPPT can be used in conjunction with a mechanical tracking system, but the two systems are completely different. The Peak Power Tracker is a microprocessor controlled DC/DC step down converter used by a solar power system to charge a 12v battery. It steps the higher solar panel voltage down to the charging voltage of the battery. The microprocessor tries to maximize the watts input from the solar panel by controlling the step down ratio to keep the solar panel operating at its Maximum Power Point.

(Peak Solar Panel Watts)/ (Battery Voltage) = MPPT Amps (*i.e. 240W/12V = 20A)*

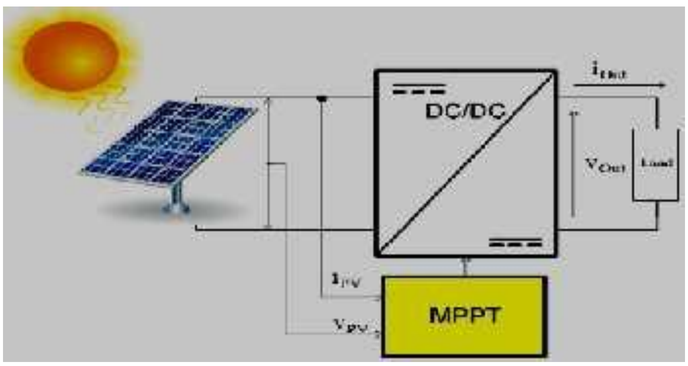

Figure 4; Diagram of MPPT system

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer technique, the output power of a circuit is maximum when the source impedance matches with the load impedance. In the source side, a buck converter is connected to a solar panel in order to enhance the output voltage. By changing the duty cycle of the buck converter appropriately by PWM signal the source impedance is matched with that of the load impedance.

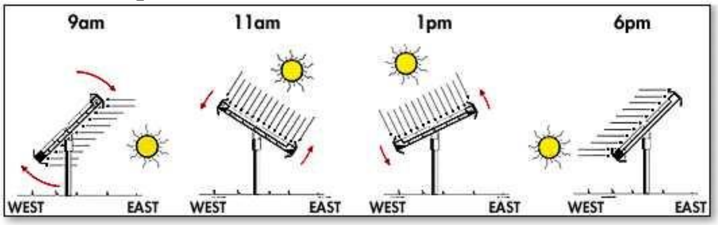

Fig 5: Tracking of solar panel with direction of sun

This is a power generating method from sunlight. This method of power generation is simple and is taken from natural resource. This needs only, maximum sunlight to generate power. This project helps for power generation by setting the equipment to get maximum sunlight automatically as demonstrated in figure 5. This system is tracking for maximum intensity of sunlight. When there is decrease in intensity of sunlight, this system automatically changes its direction to get maximum intensity of sunlight.

A Solar Tracker is basically a device onto which solar panels are fitted which tracks the motion of the sun across the sky ensuring that the maximum amount of sunlight strikes the panels throughout the day. After finding the sunlight, the tracker will try to navigate through the path ensuring the best sunlight is detected. The Solar Tracking System is made as a prototype to solve the problem. It is completely automatic and keeps the panel in front of sun until that is visible. The unique feature of this system is that instead of taking the earth as its reference, it takes the sun as a guiding source. Its active sensors constantly monitor the sunlight and rotate the panel towards the direction where the intensity of sunlight is maximum. The power generated from this process is then stored in a lead acid battery and is made to charge an emergency light and is made to glow during night.

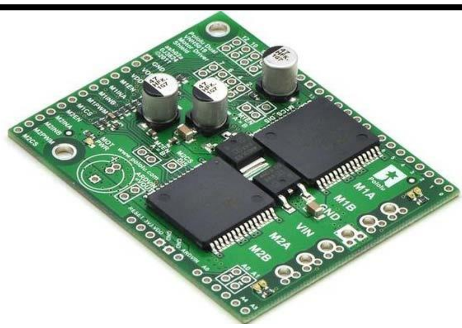

Figure 6: The Pololu Dual VNH5019 Motor Shield [Source: http://www.pololu.com/product/2502]

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

A small scale prototype of the solar tracker has been made to check feasibility of the design methodology. At initial stage a small plastic board, considered as the solar panel, is mounted on an aluminium shaft. Figure 7 illustrates the dummy panel along with other circuitry of the prototype.

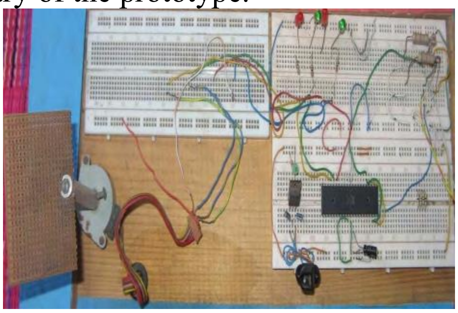

Figure 7: Solar tracker prototype circuit construction

Our system relies on automatic tracking mechanism instead of adaptive mechanism or predefined motion. The sensors are the main feedbacks of the system which send signals to the control system. While, the backbone of our control system is a microcontroller which determines which motor should move in which direction to adjust the system in such a way that the sun light falls orthogonally on the panel.

4. Results Analysis and Discussion

This paper work present the results and discussion base on the experimental scenario. However, the process of this experiment is quite simple. We used a light impenetrable object to cast shadows at different lengths from the panel and took the open circuit voltage and short circuit current of the panel. After getting enough data to satisfy our requirement, we plot a graph to show the results and its graphical representation.

4.1 Results Analysis

Variation of Voc and Isc with the distance of the object is shown in table 1

Table1

Distance of the object	Voc/V	Isc/mA
6in	17.31	14
1ft	17.88	19.2
2ft	17.89	24.5
5ft	18.15	27
6.5ft	18.3	29.5

After tabulating the above data, as shown in table1, we used Microsoft Excel to plot two bar diagrams since they can illustrate the phenomenon much better than line graph (figure 8 and figure 9).

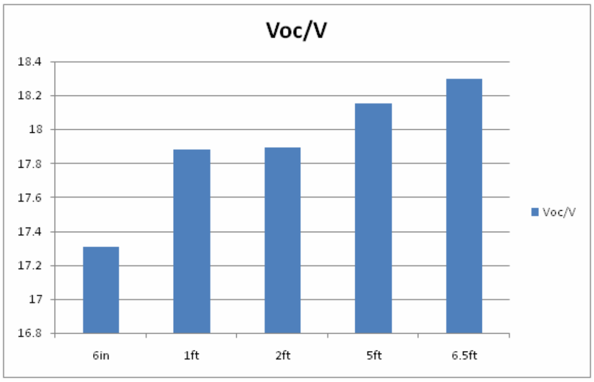

Figure 8: Voc vs. distance bar chart

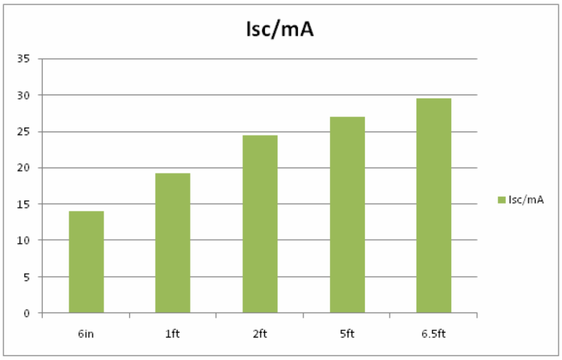

Figure 9: Isc vs. distance bar chart

4.2 Discussion

In both cases, we can see that open circuit voltage and short circuit current increases as the object that is casting the shadow moves away from the panel. But, the notable change is in current. Current varies more with the shadow than the variation of voltage. Current is the most important factor since it is the main parameter which determines the rate of charging a battery. So shadow causes a major drawback in how quickly the panel can charge the load battery, which is a prime factor that inspired us for the automatic solar tracking system which can easily overcome the shadow problem.

5. Conclusion

The PV has a powerful attraction because it produces electric energy from a free inexhaustible source, the sun, using no moving parts, consuming no fossil fuels, and creating no pollution or greenhouse gases during the power generation. So, it is our wish to make the P-V system more efficient so that it can help for betterment of life. This project has presented a means of controlling a sun tracking array with an embedded microcontroller system, a working software solution for maximizing solar cell output by positioning a solar array at the point of maximum light intensity. This project presents a method of searching for and tracking the sun and resetting itself for a new day. Development of a project based on maximum solar power tracking with various parameters being controlled by a microcontroller and maintained further to an optimum value required for charging of battery; using the stored solar energy only. An increase in output of solar panel due to the implementation of maximum solar power tracking. This project is very useful for hilly areas where there is scarce sunlight in winters and will have very fast response and will occupy minimum space. It can be built even on the rooftop of houses, in highly populated hilly areas. Energy can also be stored at a large scale and maybe utilized for heating the house water in winters available in tanks of house.

However, it is clear from the results that moveable arrays of solar panel can improve the efficiency around 40% and more which is almost 1.5 times more than the amount we get from a fixed panel. Thus, it can be concluded that it is feasible and practical to make the solar panel moveable to make it more efficient because at the current moment of the world, even a 1% improvement would be worthy – and the automatic sun tracking system can be of 40% more efficient than fixed panels; an appropriate way to harvest more solar energy.

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