NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 4, ISSUE 3, Mar.-2017

DUAL AXIS AUTO SOLAR TRACKING SYSTEM (SOLAR TRACKING SYSTEM)

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ABSTRACT
The objective of this project is to design a Dual Axis Solar Tracking system. The concise definition of this system is to design and develop a prototype of mechanical based dual axis solar array that actively tracks the sun so that maximum power is gained by the array at all time of the day

KEYWORDS: polar trackers, PHI, PV, DC.

INTRODUCTION

Renewable energy is rapidly gaining importance as an energy resource as fossil fuel prices fluctuate. One of the most popular renewable energy sources is solar energy. Solar tracking enables more energy to be generated because the solar panel is able to maintain a perpendicular profile to the sun's rays.

Renewable energy in the form of electricity has been in use to some degree as long as 75 or 100 years ago. Sources such as Solar, Wind, Hydro and Geo-thermal have all been utilized with varying levels of success. The most widely used are hydro and wind power, with solar power being moderately used worldwide. This can be attributed to the relatively high cost of solar cells and their low conversion efficiency. Solar power is being heavily researched, and solar energy costs have now reached within a few cents per kW/h of other forms of electricity generation, and will drop further with new technologies such as titanium-oxide cells. With a peak laboratory efficiency of 32% and average efficiency of 15-20%, it is necessary to recover as much energy as possible from a solar power system. This includes reducing inverter losses, storage losses, and light gathering losses. Light gathering is dependent on the angle of incidence of the light source providing power (i.e. the sun) to the solar cell's surface, and the closer to perpendicular, the greater the power.

If a flat solar panel is mounted on level ground, it is obvious that over the course of the day the sunlight will have an angle of incidence close to 90 degree in the morning and the evening. At such an angle, the light gathering ability of the cell is essentially zero, resulting in no output. As the day progresses to midday, the angle of incidence approaches zero degree, causing a steady increase in power until at the point where the light incident on the panel is completely perpendicular, and maximum power is achieved. As the day continues toward dusk, the reverse happens, and the increasing angle causes the power to decrease again toward minimum again. From this background, we see the need to maintain the maximum power output from the panel by maintaining an angle of incidence as close to zero degree as possible. By tilting the solar panel to continuously face the sun, this can be achieved. This process of sensing and following the position of the sun is known as Solar Tracking.

LITERATURE REVIEW

In this project an extensive study of up-to date's relevant literature and background material has been carried out. This was necessary in order to deep understanding of this topic and highlights any new interesting or useful facts. For the purposes of this project mainly available report on solar tracker were read and consulted. In this project on variety of topics including voltage different with solar cells, Implementation of Video lecture on solar photovoltaic's out of vast literature survey that has been referred, few important literature survey are noted below which are worth in the project.

S. P. Sukhatme & J. K. Nayak, Book titled "Solar Energy Principle of Thermal Collection and Storage", McGraw Hill, 2010. ISBN-978-0-07-026064-1. This book contains principles of solar energy collection and its conversion in electricity. This book suggest various means of the storage of solar energy like lead acid, lead antimony batteries, solar cells and their principle of operation. This book also represents the use of solar energy in thermal applications like heating of water, cooking and many industrial applications.

Chetansingh solanki, Book titled "Solar Photovoltaic Fundamental, Technologies and Application", PHI Learning, 2011. ISBN-978-81-203-4386-3. This book gives details knowledge and basic information of solar photovoltaic cell and measure the degree of solar energy by the fraction of total energy that comes from the renewable sources. This book also gives information about the constructional details of solar PV module and its operation features.

V. Shirish Murty, Paper title "Smart Grid Designs for The Improvement in Solar Technology and its Development", ISSN: 2278-8948, Vol.2, Jan 2013. This paper gives the information of small solar cells. A solar tracker is designed employing the new principle of using small solar cells to function as self-adjusting light sensors, providing a variable indication of their relative angle to the sun by detecting their voltage output. By using this method, the solar tracker was successful in maintaining a solar array at a sufficiently perpendicular angle to the sun. The power increase gained over a fixed horizontal array was in excess of 30%.

Andreas Poullikkas, Paper title "Technology and market future prospects of photovoltaic systems" Volume 1, Issue 4, 2010 pp.617-634, this paper gives brief knowledge about photovoltaic panels & their construction. In this work, an investigation of the technology and market future prospects of PV systems is carried out. In particular the PV key benefits are presented and the various PV solar cell technologies ar21e described and compared.

AIM OF PROJECT

It is clear that solar energy is becoming an important source of energy all over the World and especially in India. Very few solar plants have been installed in India so far, and therefore no historical experience available is important to investigate the performance of solar power plants. Knowledge about the performance of solar power plants will result in correct investment decisions, better regulatory framework and favorable government policies.

The objective of this project is to design a Dual Axis Solar Tracking system. The concise definition of this system is to design and develop a prototype of mechanical based dual axis solar array that actively tracks the sun so that maximum power is gained by the array at all time of the day

PROBLEM DEFINITION

In years to come the need for energy will increase manifold while the reserve of conventional energy will deplete in rapid pace. To meet the growing demand of energy harnessing of non-conventional / renewable energy is the necessity. Among all the available non-conventional sources, solar energy is the most abundant and uniformly distributed. Though the technology of trapping the solar energy is in existence the process can be in proved to increase efficiency and make it cost-effective. Global warming has increased the demand and request for green energy produced by the renewable sources like solar power. The end user will prefer the tracking solution rather than a fix ground system because:

- The efficiency increases by 30 to 40% , resulting more earning.
- The space requirement for a solar park is reduced, and they keep the same output.
- The return of the investment timeline is reduced.

Tracking the sun from east in the morning to the west in the evening will increases the efficiency of the solar panel by 20 to 62% depending on whom you ask and where you are in the world. Near the equator, you will have the highest benefit of tracking the sun.

THEORY

1.5.1 SUN'S PATH IN THE SKY ON DIFFERENT DAYS

These are not the only factors that affect the total amount of energy that a solar system receives. One factor that seriously impacts it is the number of hours of sunlight a location receives in a day. If sunlight is striking a spot for more time during a day, then more total energy will be delivered, and vice versa. The amount of time that sunlight is shining during the day depends both on the location and the time of year. This is due to the fact that the earth is a sphere that is spinning with its axis at an angle of 23.5 with respect to the vertical to the plane of its orbit around the Sun. This means that the path that the sun will take in the sky on a given day changes. Figure shows a diagram of a typical situation found in the continental U.S. As you can see, the length of the path that the Sun follows on these four different days varies, as does the noonday angle of the Sun. These different lengths correspond to different travel times, which mean different amounts of daylight.

In the India, there are about 8-10 hours of sunlight on the Winter Solstice (Dec. 22nd) and 14- 16 hours of sunlight on the Summer Solstice (Jun. 21st), depending upon at what degree of latitude you live. Sites that are further north have shorter days in the winter and longer days in the summer. If one were to live at the equator, the length of the path across the sky would not vary, which results in 12 hours of daylight every day. At the Poles, the situation is even stranger. There, the Sun is up for 6 months at a time, followed by 6 months of darkness. The noonday angle of the Sun in the sky can also have an effect on a solar energy system unless it has a way to track the Sun.

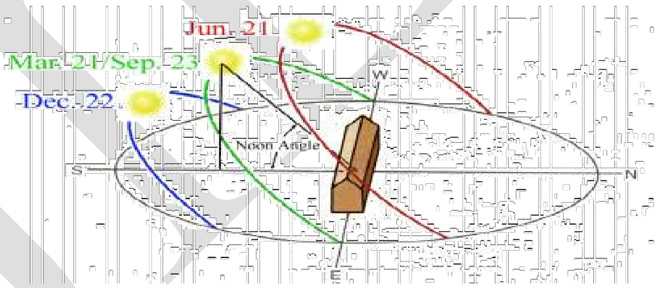

Fig: 1.5.1.a) Sun Path in the Sky on Different Days

If it cannot do this, then sunlight will always strike the system's collecting surface at some angle, thereby spreading the energy over a greater area and reducing the amount that actually strikes the surface. The angle of the Sun's rays changes throughout the year, as well as throughout the day. As previously stated, these angles will depend upon the location of the system on the Earth's surface.

1.5.2 EXISTING TRACKING SYSTEM

Solar tracker may be active or passive and may be single axis or dual axis. Single axis tracker usually uses a polar mount for maximum solar efficiency. Single axis tracker will usually have a manual elevation adjustment on a second axis which is adjust on regular intervals throughout the year. Compare to a fixed mount, a single axis tracker increases annual output by approximately 30% and a dual axis tracker an additional 6%. There are two types of dual axis trackers, polar and altitude-azimuth. These systems are explained below with their respective advantages and applications.

1.5.2.1 POLAR TRACKERS

Polar trackers have one axis aligned to be roughly parallel to the axis of rotation of the earth around the north and south poles-hence the name polar. (With telescopes, this is called an equatorial mount).

Fig: 1.5.2.a) Typical Polar Trackers

Single axis tracking is often used when combined with time of use metering, since strong afternoon performance is particularly desirable for grid tied photo voltaic system, as production at this time will match the peak demand time for summer season air-conditioning. The polar axis should be angled toward the sun du north, and the angle between the axis and the horizontal should be equal to your latitude. Simple tracker with angle axis tracking may also have an adjustment along a second axis: the angle of declination. This allows you to angle the panel to face the sun when it is higher in the sky (and further northward) in the summer, and to face it lower in the sky (and further southward) in the winter. It might be set with manual or automated adjustment, depending on your polar tracking device. If one is not planning on adjusting this angle of declination at all during the year, it is normally set to zero degrees, facing your panel straight out perpendicular to the polar axis, as that is where the mean path of the sun is found. Occasional or continuous adjustment to the declination compensate for the north ward and southward shift in the sun's path through the sky as it moves through season over the course of the year. When the manual method used for adjustment of the declination, it should be done at least twice a year: once at the autumnal equinox to establish the best position for the winter, and a second adjustment on a vernal equinox, to optimize it for the summer. The sun's declination at the spring equinox is 0 degree. It moves up to 22.5 degree in the summer, and then drifts back down through 0 degree at fall equinox and down to -22.5 degree in the winter. So, for example, you might choose to set the declination at 15 degree or 20 degree as a reasonably optimal position for the summer months. Such tracker may also be referred to as a "single-axis tracker", because only one drive mechanism is needed for daily operation. This reduces the system cost and allows the use of simple tracking methods, including passive and chronological tracking.

1.5.2.2 HORIZONTAL AXLE TRACKERS

Fig: 1.5.2.b) Horizontal Axle Trackers

Several manufacturers can deliver single axis horizontal tracker which may be oriented by either passive or active mechanisms, depending upon manufacturer. In these, a long horizontal tube is supported on bearings mounted upon pylons or frames. The axis of the tube is on a north-south line. Panels are mounted upon the tube, and tube will rotate on its axis to track the apparent motion of the sun through the day. Since these do not tilt toward the equator they are not especially effective during winter mid-day, but add a substantial amount of productivity during the spring and summer season when the path is high in the sky. These devices are less effective at higher latitude.

This principle advantage is the inherent robustness of the supporting structure and the simplicity of the mechanism. Since the panels are horizontal, they can be compactly placed on the axle tube without any danger of self-shading and are also readily accessible for cleaning. For active mechanism, a single control and motor may be used to actuate multiple rows of panels. Manufacturers include Array Technologies, Inc. Watson Solar Trackers (gear driven active), Zomeworks (passive) and power light (active)

1.5.2.3 VERTICAL AXLE TRACKERS

Fig: 1.5.2.c) Vertical Axle Tracker

A single axis tracker may be constructed that pivots only about a vertical axle, with the panels either vertical, at a fixed, adjustable, or tracked elevation angle. Such trackers with fixed or (seasonably) adjustable angles are suitable for high latitudes, where the apparent solar path is not especially high, but which leads to long days in summer, with the sun travelling through a long arc. This method used in the construction of a cylindrical house in Austria (latitude about 45 degrees north) that rotates in its entirety to track the sun, with vertical panels mounted on one side of the building.

1.5.2.4 ALTITUDE-AZIMUTH TRACKERS

Fig: 1.5.2.d) Altitude- Azimuth Type Tracker

A type of mounting that supports the weight of the solar tracker allows it to move in two directions to locate a specific target. One axis of support is horizontal (called the altitude) and allows the telescope to move up and down. The other axis is vertical (called the azimuth) and allows the telescope to swing in a circle parallel to the ground. This makes it easy to position the telescope: swing it around in a circle and then lift it to the target. However, tracking an object as the Earth turns is more complicated. The telescope needs to be adjusted in both directions while tracking, which requires a computer to control the telescope.

1.5.2. 5 TWO -AXIS MOUNT TRACKERS

Restricted to active trackers, this mount is also becoming popular as a large telescope mount owing to its structural simplicity and compact dimensions, one axis is a vertical pivot shaft or horizontal ring mount that

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allows the device to be swung to a compass point. The second axis is a horizontal elevation pivot mounted upon the azimuth platform. By using combination of the two axes, any location in the upward hemisphere may be pointed. Such system may be operated under computer control according to the expected solar orientation, or may use a tracking sensor to control motor drives that orient the panels toward the sun. This type of mount is also used to orient parabolic that mount a Sterling engine to produce electricity at the device.

Fig: 1.5.2.e) Two Axis Mechanical Mount type Tracker

1.5.2.6 MULTI-MIRROR REFLECTIVE UNIT

A recent development, this device uses multiple mirrors in a horizontal plane to reflect sunlight upward to a high temperature photovoltaic or other requiring concentrated solar power. Structural problems and expense are greatly reduced since the mirrors are not significantly exposed to wind loads. Through the employment of a patented mechanism, only two drive systems are required for each device. Because of the configuration of the device it is especially suited for use on flat roofs and at lower latitude. While limited commercial availability was expected in 2007 the company has removed the descriptive web page from their site and is now promoting a two axis clustered Fresnel lens device. The unit illustrated each produce approximately 200 peak DC watts. A multiple mirror reflective system combined with a central power tower is employed at the Sierra Sun Tower, located in Lancaster, California. This generation plant operated by Solar is schedule to begin operations on August 5, 2009. This system, which uses multiple heliostats in a north-south alignment, uses pre-fabricated parts and construction as a way of decreasing start up and operating costs.

Fig: 1.5.2.f) Multi-Mirror Reflective type Tracker

1.5.3 TYPES OF SOLAR TRACKING SYSTEM

There are many different types of solar tracker which can be grouped into single axis and double axis models.

1.5.3.1 FIXED AXIS SOLAR PANEL

The fixed axis solar system is now a days and it is convenient over traditional power generating methods. But in fixed axis tracking system it is not possible to convert total available solar energy into useful energy form. For the purpose of utilizing the available solar energy into light energy we have to move towards multi axis solar tracking system which follow the path of sun as well as position of earth and gives maximum output.

Due to rotation of earth the solar panels can't maintain their position always in front of sun. This problem results in decrease of their output. Thus to get a constant output, we are implementing an automated system which should be capable to constantly move the solar panel in both east-west and north-south direction.

Fig: 1.5.3.a) Fixed Axis Solar System

1.5.3.2 SINGLE AXIS SOLAR TRACKER

Single axis solar trackers can either have a horizontal or a vertical axle. The horizontal type is 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 (such as in UK) where the sun does not get very high, but summer days can be very long.
These have a manually adjustable tilt angle of 0 - 45 Degree and automatic tracking of the sun from East to West. They use the PV modules themselves as light sensor to avoid Unnecessary tracking movement and for reliability. At night the trackers take up horizontal position. Fig shows single axis solar tracking system project made by B.E .electrical student.

Fig: 1.5.3.b) Single Axis Solar Tracker

1.5.4 COMPONENTS OF PROJECT

1.5.4.1 SOLAR PANEL

Solar panels are devices that convert light into electricity. They are called solar after the sun or "Sol" because the sun is the most powerful source of the light available for use. They are sometimes called photovoltaic which means "light-electricity". Solar cells or PV cells rely on the photovoltaic effect to absorb the energy of the sun and cause current to flow between two oppositely charge layers.

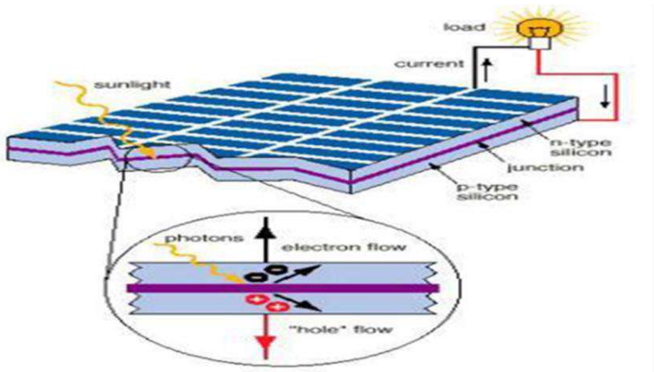

Fig: 1.5.4.a) Working Principle of Solar Panel

A solar panel is a collection of solar cells. Although each solar cell provides a relatively small amount of power, many solar cells spread over a large area can provide enough power to be useful. To get the most power, solar panels have to be pointed directly at the Sun.
The development of solar cell technology begins with 1839 research of French physicist Antoine-Cesar Becquerel. He observed the photovoltaic effect while experimenting with a solid electrode in an electrolyte solution. After that he saw a voltage developed when light fell upon the electrode. According to Encyclopedia Britannica the first genuine for solar panel was built around 1883 by Charles Frits. He used junctions formed by coating selenium (a semiconductor) with an extremely thin layer of gold. Crystalline silicon and gallium arsenide are typical choices of materials for solar panels. Gallium arsenide crystals are grown especially for photovoltaic use, but silicon crystals are available in less-expensive standard ingots, which are produced mainly for consumption in the microelectronics industry.
Norway's Renewable Energy Corporation (REC) has confirmed that it will build a solar manufacturing plant in Singapore by 2010 - the largest in the world. This plant will be able to produce products that can generate up to 1.5 giga watts (GW) of energy every year. That is enough to power several million households at any one time. Last year, the world as a whole produced products that could generate just 2 GW in total.

A) BASIC PRINCIPLE OF SOLAR PANEL:
Electricity can be produced from sunlight through a process called "photovoltaics", which can be applied, in either a centralized or decentralized way. "Photo" refers to light and "voltaic" to electrical voltage. The term describes a solid-state electronic cell that produces direct current (DC) electrical energy from the radiant energy of the sun. The basic steps from the PV solar cell to a fully operating PV system are presented in Figure 1. PV solar cells are made of semi-conducting material, most commonly silicon, coated with special additives. When light strikes the cell, electrons are knocked and become loose from the silicon atoms and flow in an in built circuit producing electricity. Individual solar cells can be connected in series and in parallel to obtain desired voltages and currents. These groups of cells are packaged into standard modules that protect the cells from the environment. PV modules are extremely reliable since they are solid state and there are no moving parts.
A cell is created when a positively charged (p-type) layer of silicon is placed against a negatively charged (n-type) to create a diode for the flow of electrons. When silicon is exposed to light, electrical charges are generated. Referring to Figure 2, light entering the cell through the gaps between the top contacts metal gives up its energy by temporarily releasing electrons from the covalent bonds holding the semiconductor together; at least this is what happens for those photons with sufficient energy.

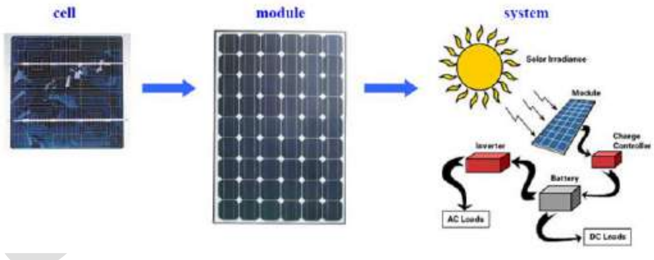

Fig: 1.5.4.B) Basic Steps From PV Cell To PV System

B) PRINCIPLE OF OPERATION:
The p-n junction within the cell ensures that the now mobile charge carriers of the same polarity all move off in the same direction. These electrical charges are conducted away as DC power by placing metal contacts on the top and bottom of a PV cell. If an electrical load is connected between the top and rear contacts to the cell, electrons will complete the circuit through this load, constituting an electrical current in it. Energy in the incoming sunlight is thereby converted into electrical energy. The cell operates as a "quantum device", exchanging photons for electrons. Ideally, each photon of sufficient energy striking the cell causes one electron to flow through the load. In practice, this ideal is seldom reached. Some of the incoming photons are rejected from the cell or get absorbed by the metal contacts (where they give up their

energy as heat). Some of the electrons excited by the photons relax back to their bound state before reaching the cell contacts and thereby the load. The electrical power consumed by the load is the product of the electrical current supplied by the cell and the voltage across it. Each cell can supply current at a voltage between 0.5V-1V, depending on the particular semiconductor used for the cell. Since the electrical output of a single cell is quite small to generate sufficient amount of electricity multiple cells are connected together to form a module or a panel.
The PV module is the primary component of PV system and any number of PV modules can be connected to generate the desired amount of electricity. The modular structure of a PV system is considered an advantage since at any instant a new module can be incorporated to the system to satisfy the new electricity requirement. Different PV modules vary in structure; however, they generally include the following elements: glass cover in which the transparent glass cover is placed over the PV cell for protection reasons, anti-reflective sheet which is used to enhance the effect of the glass cover while the anti-reflective coating is used to block reflection, cell and frame and panel backing which are used to hold all the pieces together and protect the PV cell from damage .

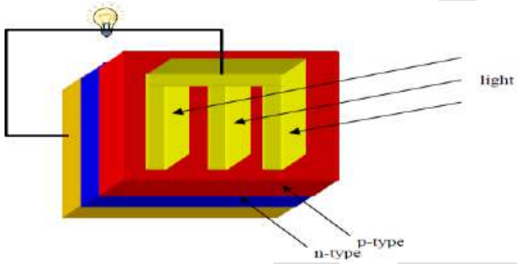

Fig: 1.5.4.C) PV Solar Cell Operating Principle

1.5.4.1.1 PV TECHNOLOGIES
The choice of the semiconductor defines the PV technology. There are two main PV technologies, such as, crystalline silicon solar cells and thin film solar cells as described in the following sections.
A) CRYSTALLINE SILICON SOLAR CELLS
The technology used to make most of the crystalline silicon solar cells, fabricated so far, borrows heavily from the microelectronics industry and is known as silicon wafer technology. The silicon source material is extracted from quartz, although sand would also be a suitable material. The silicon is then refined to very high purity and melted. From the melt, a large cylindrical single crystal is drawn. The crystal, or “ingot”, is then sliced into circular wafers, less than 0.5mm thick, like slicing bread from a loaf.
Sometimes this cylindrical ingot is “squared-off” before slicing so the wafers have a “quasi-square” shape that allows processed cells to be stacked more closely side-by-side. Most of this technology is identical to that used in the much larger microelectronics industry, benefiting from the corresponding economies of scale. Since good cells can be made from material of lower quality than that used in microelectronics, additional economies are obtained by using off-specification silicon and off specification silicon wafers from this industry. The first step in processing a wafer into a cell is to etch the wafer surface with chemicals to remove damage from the slicing step. The surface of crystalline wafers is then etched again using a chemical that etches at different rates in different directions through the silicon crystal. This leaves features on the surface, with the silicon structure that remains determined by crystal directions that etch very slowly. The p-n junction is then formed. The impurity required to give p-type properties (usually boron) is introduced
During crystal growth, so it is already in the wafer. The n-type impurity (usually phosphorus) is now allowed to seep into the wafer surface by heating the wafer in the presence of a phosphorus source. Crystalline silicon solar cells hold 93% of the market. Despite the fact that it is a relatively poor light absorbing semiconducting material, over the years it has been the primary raw material used in most solar PV cells due to its ability to yield stable and efficient cells, with efficiencies between 11-16% in terms of converting sunlight energy to electrical energy .
There are two types of crystalline silicon solar cells that are used in the industry, such as, mono crystalline silicon cells (single-Si) and (b) multi crystalline silicon cells (multi-Si or poly-Si). The mono crystalline

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silicon cell is made using cells saw-cut from a single cylindrical crystal of silicon. The main advantage of the mono crystalline silicon cells is the high efficiency which is around 15%. The multi crystalline silicon cell is made by sawing a cast block of silicon first into bars and then into wafers. Multi crystalline cells are cheaper to manufacture than mono crystalline ones due to the simpler manufacturing process. However they are slightly less efficient than the mono crystalline with average efficiency of approximately 12%. In general crystalline silicon solar cells have a relatively high production cost and subsequently high selling price. Moreover, its dependence on purified silicon as the key raw material creates additional difficulty since there is global shortage of the material. The relative high costs result from the complex and numerous production steps involved in wafer and cell manufacturing and the large amount of highly purified silicon feedstock required.

B) THIN-FILM SOLAR CELLS

Due to the high production cost of the crystalline silicon wafers, the PV industry has been seeking for alternative ways of manufacturing PV solar cells using cheaper materials such as the thin-film solar cells. Thin-film technology approach In the thin-film technology approach, thin layers of semiconductor material are deposited onto a supporting substrate, or superstrate, such as a large sheet of glass as indicated in Figure. Typically, less than a micron (µm) thickness of semiconductor material is required, 100-1000 times less than the thickness of silicon wafer. Reduced material use with associated reduced costs is a key advantage. Another advantage is that the unit of production, instead of being a relatively small silicon wafer, becomes much larger, for example, as large as a conveniently handled sheet of glass might be. This reduces manufacturing costs.

1.5.4.1.2 PV LAMINATE GEOMETRY

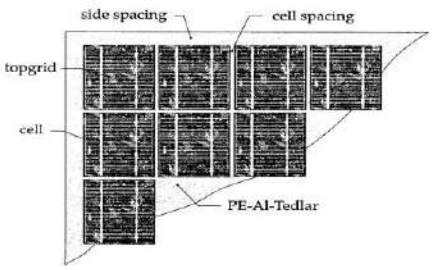
The reflection factor of a surface depends upon the angle of attack, the wavelength and the polarization of the incident light. Furthermore, it depends on the index of refraction of the material and the structure of the surface. The absorption of the light in the material through which it travels depends on the material properties and the thickness of the layer. In the next section the composition if the PV laminate, the optical properties of the materials and the spectrum chosen for the calculation will be discussed.

A) COMPOSITION OF THE PV LAMINATE

As different part of the surface of the PV laminate have different composition the absorption factor for the whole laminate is an integrated value in our calculation of the absorption coefficient we will the take the configuration of the shell solar IRS 95C laminate as shown in the following figure. This laminate is connected with a heat conducting adhesive to spectral selective layer of a thermal collector in a prototype of a panel. The relative contributions of the different surfaces are shown.

The largest part of the laminate, the cells and the top grid has the composition shown in figure. The layer thicknesses used are presented in the table. The cell and side spacing have the same configuration as shown in figure but without antireflection coating cell and top grid. It is assumed that in the antireflection coating no absorption takes place at the PE-AI-Tedlar film the wavelength dependent reflection factor is measure therefore the thickness of this two reflection layers need not to be known in the model

material	area in [m^2]
active area of pv cells	0.65
cell spacing + side spacing	0.15
top grid	0.072
total	0.87



Areas of Various PV Laminate Top View Of An Edge Of PV Cells Surface Part

Fig: 1.5.4.d) Composition of PV Laminate

1.5.4.2 MOTOR

Motors are use to drive the Solar Tracker to the best angle of exposure of light. For this section, we shall look at some of the motor types available on the market.

A) DC MOTOR

DC motors are cheaper to buy, and simple to drive but they need feed-back sensors to allow control of the speed. It is necessary to detect the rotation of the wheels, usually by means of sensors better controlled by pulling the motor supply that uses less battery power than the analogue/resistor methods. Low-inertia, efficient servo-motors bring advantages of fast response and efficiency, but add cost.

Fig: 1.5.4.e) 12 VOLT DC Motor

The advantages of the DC motor are the torque and their speed is easier to control. The drawbacks of DC motors are that they consumed huge amounts of power. They would consumed the battery power in no time and power saving techniques must be employed to ensure the mouse do not stop halfway while navigating. They are also prone to dust and harder to maintain.

B) SPECIFICATION OF DC MOTOR

Table: 1.5.4.a) specification of DC motor

Rated supply	12 VOLT DC
Length	80mm
Torque	1.5 kg .cm
Shaft diameter	6mm
Weight	130gm
Rated speed	10rpm

C) CONSTRUCTION OF DC MOTOR:

Gear box is made of white hard glass filled nylon, gears are made of metal rotating on Steel pins easy to mount by using a single M14 nut, hole required to insert the motor is 13.7mm ø Over-loading of motor may result in short life or damage to gearbox.

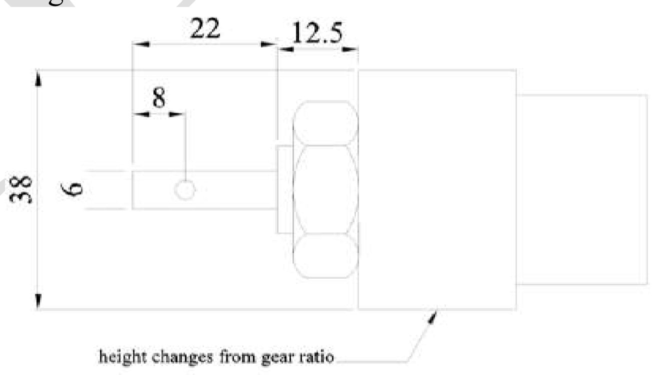


Fig:1.5.4.f) Dimension of DC motor

1.5.4.3 SMALL SOLAR CELLS:

A solar tracker is designed employing the new principle of using small solar cells to function as self-adjusting light sensors, providing a variable indication of their relative angle to the sun by detecting their voltage output & give the drive for motor. By using this method, the solar tracker was successful in maintaining a solar array at a sufficiently perpendicular angle to the sun. The power increase gained over a fixed horizontal array was in excess of 30%. Solar tracking is by far the easiest method to increase overall efficiency of a solar power system for use by domestic or commercial users.

5.5 V solar cells 9V solar cells
Fig: 1.5.4.g) Solar Cells

A) SPECIFICATION OF SOLAR CELLS:

Table: 1.5.4.b) Specification of Solar Cells

1) 5.5 V solar cells (Quantity 4)	2) 9 V solar cells (Quantity 2)
Polycrystalline solar cells	Polycrystalline solar cells
Dimensions: 66.9mm*39mm*2.5mm	Dimensions: 67mm*116mm*3mm
Max. working voltage: 5.5 V	Max. working voltage: 9.9 V
Max. working current: 170 mA	Max. working current: 110 mA
Power: 0.93 W	Power: 1.08 W
Life: 10-20 years	Life: 10-20 years

1.5.4.4 SOLAR TRACKER

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.

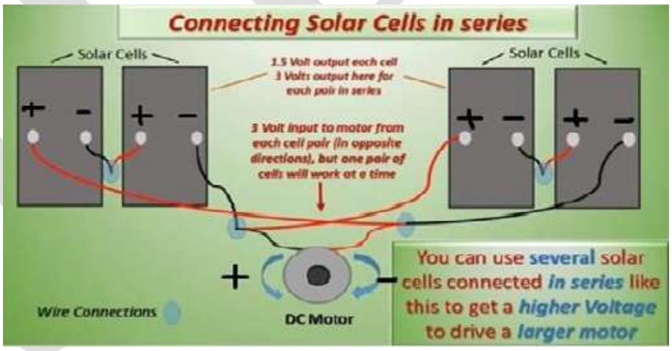


Fig: 1.5.4.h) Connection Of Solar Cells In Series

To track path of sun from azimuth rotation about the polar axis follows the sun during the day from east to west, by using solar cells we create voltage difference across them according the voltage difference, upper motor will run & main solar panel move according to sun position which is perpendicular to the sun rays.
Similarly, according to elevation (Tilt) angle follows seasonal changes in the tilt of the earth's axis by using another two solar cells the bottom motor rotate & main solar panel move according the earth position.

1.5.4.5 DRIVE

A) GEAR DRIVE

Gear drive is used for drive the shaft on main panels from the motor. Motor transmit the power to the main panel shaft through nylon gear pair. In order to increase the torque from motor shaft to panel shaft gear reduction ratio is used. Drive gear having 53 mm diameter and 23 no of teeth while driven gear having 78 mm diameter and 34 no of teeth. The motor driving the gear connected to small solar cells and according to the voltage difference across the cells motor rotate in clockwise and anticlockwise direction which drive the panel shaft so that shaft will attained the position perpendicular to sunrays

Fig: 1.5.4.i) Gear Pair

1) GEAR SPECIFICATION

Table: 1.5.4.c) Specification Of Gear

Gear Material	Nylon
Ultimate tensile strength(Sut)	75 N/mm
Yield strength (Syt)	45
Teeth on drive gear	23
Teeth on driven gear	34
Gear ratio	1.47
Diameter of drive gear	53 mm
Diameter of driven gear	78 mm
Module	2.3 mm

B) BELT–PULLEY DRIVE

According to elevation (Tilt) angle follows seasonal changes in the tilt of the earth's axis by using another two solar cells the bottom motor rotate & main solar panel move according the earth position. Pulley drive is used for this purpose. Motor is connected to the small solar cells voltage difference across the both solar cells causing rotation of motor. This rotation of motor transmitted to structure through the pulley drive. The rising position of sun change from 21st June to 21st December. In order to track the sun position during this period we have used belt & pulley drive.

1.6 MANUFACTURING OPERATIONS USED IN OUR PROJECT

1.6.1 CUTTING

The operation is used for cutting material with the help of different cutting tools. Shear force is acting to cut the material. Cutting operation is carried out on lathe machine. After cutting shaft of required length shaft is cut of required diameter 10mm.

1.6.2 GRINDING

Grinding operation is carried on shaft with closed grinding tolerances in order to fit bearing on shaft. Column material is removed by grinding so that bearings fit on column properly. Unnecessary burr & weld material removed by grinding.

1.6.3 DRILLING

Drilling is the operation of producing a cylindrical hole by removing metal by the rotating edge of cutting tool called drill. Drilling is one of the simplest methods of producing hole.

1.6.4 TURNING

Turning on a lathe is to remove excess material from the work piece to produce a cone shaped or cylindrical surface.

1.6.5 FACING

Facing is the operation of machining the ends of piece of work to produce flat Surface Square with the axis. This is also used to cut work to required length.

1.6.6 ARC WELDING

Here, the metal is heated by maintaining a very high voltage between the electrode and the metal. This results in dielectric breakdown of the air gap, causing a discharging arc. The temperature at the arc can reach up to 30,000°C (almost ten times oxy-fuel torches).The metal is used as one electrode, and the filler rod as the other electrode; either DC or AC can be used, with typical current ranging between 50A ~300A and typical power of 10kW or more. Typically, DC welders are used for sheet metal, while high power requirements of thick members need AC supply

1.6.7 ASSEMBLY

Component or end item comprising of a number of parts or subassemblies put together to perform a specific function, and capable of disassembly without destruction.

Fig: 1.6.g) Assembly Of Project

1.7 DESIGN PARAMETER OF PROJECT

1.7.1 PARAMETERS

Sut= ultimate tensile strength for gear material (nylon)=75 N/mm²
Syt= Yeild strength for gear material (nylon)= 45 N/mm²
Y= 0.484-(2.87/Z) Lewis form factor for 20° full depth involutes
Ft= Tangential force on gear (N)
Fr= Radial force on gear (N)
Dg= Diameter Of gear (mm)
Dp= Diameter Of pinion (mm)
b= Face width of gear tooth (mm)
m= Module (mm)
Zp and Zg= No. of teeth on pinion and No. of teeth on gear.

1.7.2 CALCULATIONS

A) TORQUE= Ft*(Dg/2)

Ft= 6t*b*m*Y
Ft= (75/3)*20*2.29*0.3995= 457.52 N
Torque= 457.52*(78/2) = 17.843 N-m

B) POWER REQUIRED TO DRIVE THE SHAFT:-

P= (2πNT)/60
= 18.68 W

C) SELECTION OF MOTOR

From above power requirement select motor of following specifications
Rated Voltage= 12.5 V
Rated Current= 1.5 amp
Speed of Motor= 10 rpm

D) DESIGN OF SHAFT

Fr= Radial force (N)
Ft= Tangential force (N)

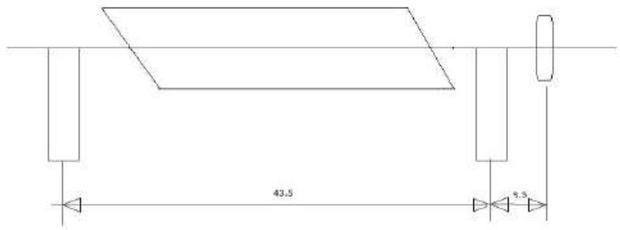


Fig: 1.7.a) Schematic diagram of main panel arrangement

1) VERTICAL LOADING DIAGRAM

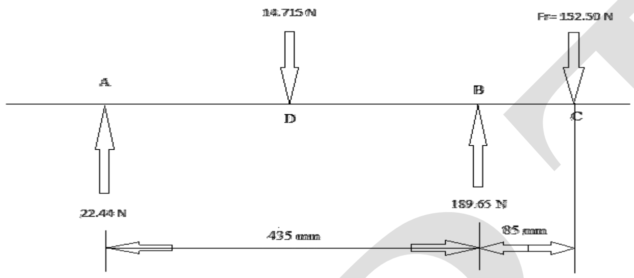


Fig: 1.7.b) Vertical loading diagram

Taking moment about A
(Fr * 52) - (Rbv * 43.5) + 14.715 * 21.75 = 0
Rbv= 189.65 N
Taking moment about B
(Fr * 8.5) – (Rav * 43.5) – (14.715) * 21.75 = 0
Rav= 22.44 N

2) VERTICAL BENDING MOMENT

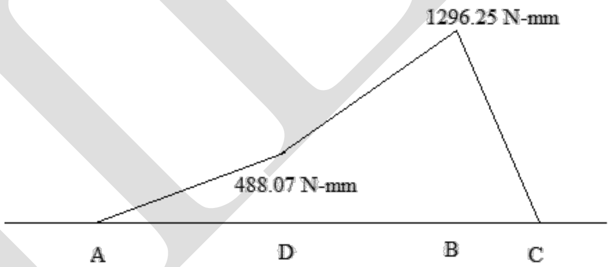


Fig: 1.7.c) Vertical Bending Moment

At B,
Mbv= (152.50 * 8.5) = 1296.25 N-mm
At D
Mdv=(22.44 * 43.5/2)=488.07 N-mm

3) HORIZONTAL LOADING DIAGRAM

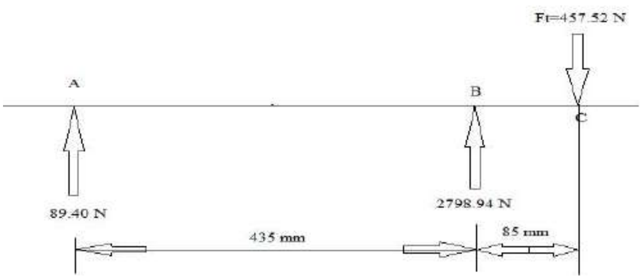


Fig: 1.7.d) Horizontal Loading Diagram

Taking moment about A
(Rbh*8.5)-(457.52*52)=0
Rbh=2798.94 N
Taking moment about B
(Rah*43.5)-(457.52*8.5)=0
Rah=89.40 N

4) HORIZONTAL BENDING MOMENT AT B

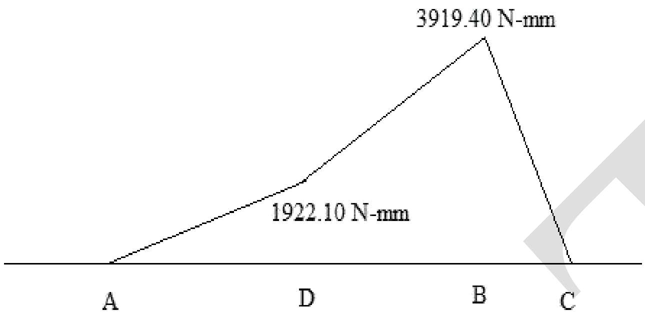


Fig: 1.7.e) Horizontal Bending Moment Diagram

Mbh=(89.40*43.5)=3888.9 N-mm
Mdh=(89.40*43.5/2)=1944.45 N-mm

5) RESULTANT BENDING MOMENT AT B

Mb= $\sqrt{(Mbv)^2 + (Mbh)^2}$
= 4099.24 N-mm

6) DESIGN OF SHAFT BASED ON ASME CODE

Kb= combined shock and fatigue factor for bending
Kt= combined shock and fatigue factor for torsion
Equivalent torque Te =$\sqrt{(Kb * Mb)^2 + (Kt * T)^2}$
Te= $\sqrt{(1.5 * 4099.24)^2 + (1 * T17.843)^2}$
Te= 6148.89
τ according to ASME Code The allowable shear stress for shaft
τ = 0.18 Sut = 0.18*280 = 50.4 N/mm²
τ = 0.3 Syt = 0.3*135 =40.5 N/mm²………………… (Select smaller of the above)
τ= (16*Te/πd³)
d= 9.178 mm
Diameter of shaft = 10 mm.
Length of shaft = 665 mm.

E) DESIGN OF GEAR PAIR:-

Gears are manufactured by hobbing operation
Gear cutting tool module= 2.30 mm

1) NO. OF TEETH ON PINION

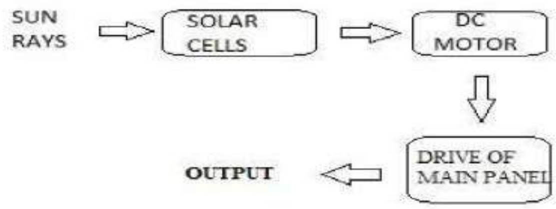
m= (diameter of pinion blank / no of teeth of pinion)
2.30= 53/Zp
No. of teeth on pinion Zp=23

2) NO OF TEETH ON GEAR

m= (diameter of Gear blank / no of teeth of Gear)
2.30= 78 / Zg
No of teeth on gear Zg = 34
Center distance (a) = (Dg + Dp) / 2
= (78+53) / 2 = 65.5 mm

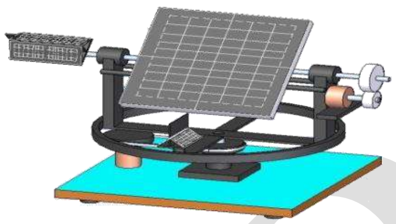
Face width= 20 mm

1.8 EXPERIMENTAL SETUP



a)Block diagram of tracking system

Fig: 1.8a) Experimental Setup



b) Solid edge model

To track path of sun from azimuth rotation about the polar axis follows the sun during the day from east to west, By using solar cells we create voltage difference across them according the voltage difference, upper motor will run & main solar panel move according to sun position which is perpendicular to the sun rays.

Similarly, according to elevation (Tilt) angle follows seasonal changes in the tilt of the earth's axis by using another two solar cells the bottom motor rotate & main solar panel move according the earth position.

1.9 OBSERVATION TABLES

A) FOR FIXED AXIS SOLAR PANEL DATE: 30/05/2014

Table:1.9.a) Observations For Fixed Axis Solar System

Time (hr)	Temp (° C)	Voltage (V)	Current (A)	Power (W)	Efficiency (%)
07.00	24	16.50	0.02	0.3300	0.47
07.30	26	16.80	0.02	0.3360	0.4786
08.00	26	17.25	0.03	0.5325	0.7585
08.30	27	18.20	0.06	1.0920	1.55
09.00	28	20.55	0.19	3.8950	5.54
09.30	29	20.80	0.20	4.1600	5.92
10.00	30	19.92	0.22	4.3824	6.24
10.30	31	19.91	0.24	4.7784	6.80
11.00	31	19.34	0.28	5.4152	7.71
11.30	31	19.48	0.3066	5.9704	8.51
12.00	32	19.91	0.41	8.2836	11.80
12.30	33	19.89	0.44	8.7516	12.46
13.00	34	20.05	0.48	9.6240	13.700
13.30	36	19.60	0.52	10.192	14.52
14.00	36	19.93	0.53	10.55	15.03
14.30	37	20.03	0.48	9.6144	13.69
15.00	36	19.60	0.24	4.7040	6.70
15.30	36	19.08	0.22	4.1976	5.97
16.00	34	18.49	0.10	1.849	2.63
16.30	34	18.57	0.09	1.6713	2.38
17.00	32	16.32	0.06	1.3056	1.85
17.30	31	16.10	0.06	0.9660	1.37
18.00	30	15.80	0.03	0.4740	0.679

B) FOR DUAL AXIS TRACKING SYSTEM: DATE: 28/01/2017

Table: 1.9.b) Observations For Dual Axis Solar Tracking System

Time (hr)	Temp (^oC)	Voltage (V)	Current (A)	Power (W)	Efficiency (%)
07.00	24	16.50	0.02	0.3300	0.47
07.30	26	16.80	0.02	0.3360	0.4786
08.00	26	17.25	0.03	0.5325	0.7585
08.30	27	18.20	0.06	1.0920	1.55
09.00	28	20.55	0.19	3.8950	5.54
09.30	29	20.80	0.20	4.1600	5.92
10.00	30	19.92	0.22	4.3824	6.24
10.30	31	19.91	0.24	4.7784	6.80
11.00	31	19.34	0.28	5.4152	7.71
11.30	31	19.48	0.3066	5.9704	8.51
12.00	32	19.91	0.41	8.2836	11.80
12.30	33	19.89	0.44	8.7516	12.46
13.00	34	20.05	0.48	9.6240	13.700
13.30	36	19.60	0.52	10.192	14.52
14.00	36	19.93	0.53	10.55	15.03
14.30	37	20.03	0.48	9.6144	13.69
15.00	36	19.60	0.24	4.7040	6.70
15.30	36	19.08	0.22	4.1976	5.97
16.00	34	18.49	0.10	1.849	2.63
16.30	34	18.57	0.09	1.6713	2.38
17.00	32	16.32	0.06	1.3056	1.85
17.30	31	16.10	0.06	0.9660	1.37
18.00	30	15.80	0.03	0.4740	0.679
Time (hr)	Temp(^oC)	Voltage (V)	Current (A)	Power (W)	Efficiency(%)
07.00	26	20.60	0.20	04.120	05.86
07.30	26	20.60	0.35	07.210	10.27
08.00	26	19.91	0.41	08.160	11.62
08.30	27	21.01	0.52	10.920	15.56
09.00	27	20.05	0.55	11.027	15.70
09.30	28	19.80	0.56	11.088	15.79
10.00	28	19.80	0.57	11.286	16.07
10.30	28.5	20.80	0.62	12.890	18.37
11.00	29	20.50	0.63	12.915	18.39
11.30	29	20.80	0.65	13.520	19.25
12.00	32	19.90	0.66	13.55	19.30
12.30	34	20.50	0.70	14.350	20.44
13.00	34	19.96	0.72	14.370	20.47
13.30	34	20.41	0.71	14.500	20.64
14.00	35	20.30	0.71	14.410	20.53
14.30	37	20.22	0.71	14.356	20.45
15.00	36	20.00	0.67	13.400	19.08
15.30	36	19.90	0.59	11.740	16.72
16.00	37	19.76	0.56	11.065	15.76
16.30	34	20.1	0.54	10.85	15.46
17.00	32	19.58	0.37	7.2446	10.31
17.30	31	19.19	0.25	4.79	6.83
18.00	30	17.99	0.12	3.4181	4.86

C) CALCULATION OF EFFICIENCY

1) ASSUMPTION

1. Time from 7:00 AM to 6:00 PM
2. Area of Cell= 0.078 * 0.025 = 0.00195m²
3. Number of Cell in Module = 36
4. Area of Module= 36 * 0.00195 = 0.0705 m²
5. Number of reading during full day = 23

2) FORMULAE

% η =P / ((1000 W/m^2)*Area of cell in m²)

Where, E=Percentage Efficiency

P =Power in **(**Watt)

Example 1) for fixed axis solar system

At time 11.00 a.m.

Input power = ((1000 W/m^2)*Area of cell in m²)
= 1000*0.0702
=70.2 W

Output voltage = 19.34 V
Output current =0.28 A
Output power = **5.4152 W**
Efficiency=output power / input power
=5.4152 / 70.2
η = 7.71%

2) Dual axis solar tracking system

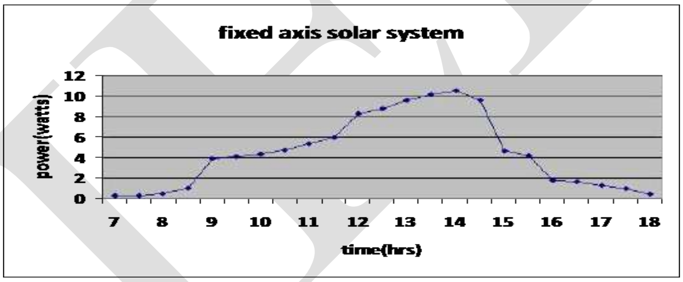
At time 11.00 a.m.

Input power =(1000 W/m²)*Area of cell in m²)
= 1000*0.0702
=70.2 W

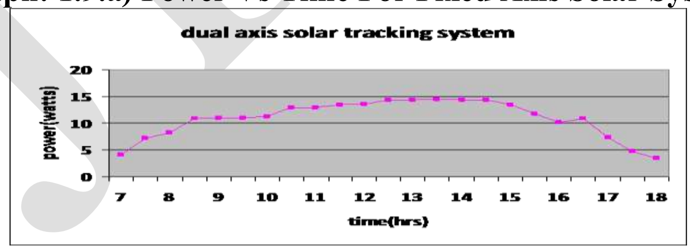
Output voltage = 20.50 V
Output current =0.63 A
Output power =**12.915 W**
Efficiency=output power / input power
=12.915 / 70.2
η = 18.39 %

D) GRAPHS

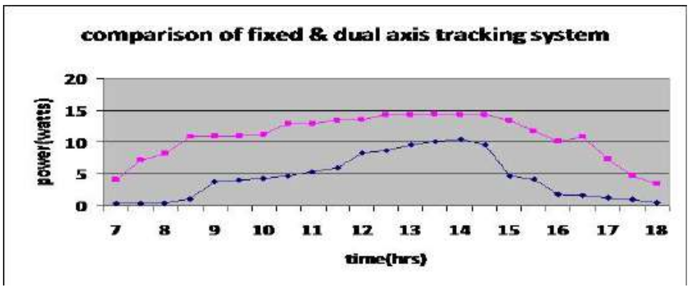
1) **GRAPHS OF POWER VS TIME:**



Graph: 1.9.a) Power Vs Time For Fixed Axis Solar System

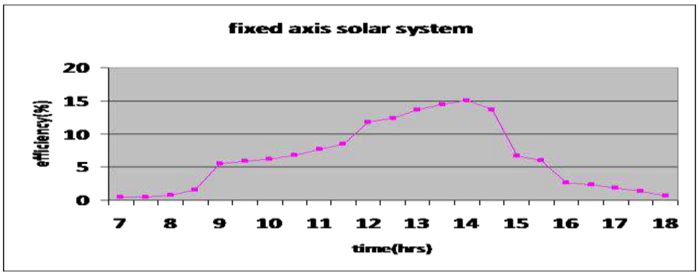


Graph: 1.9.b) Power Vs Time For Dual Axis Solar System

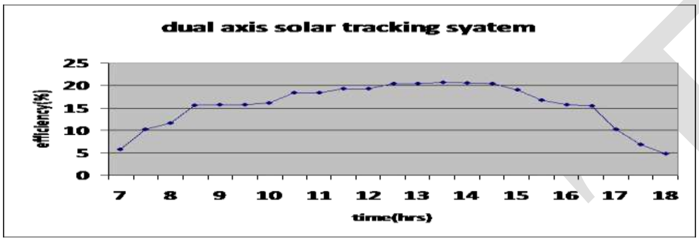


Graph: 1.9.c) Power Vs Time For Fixed & Dual Axis Solar tracking System

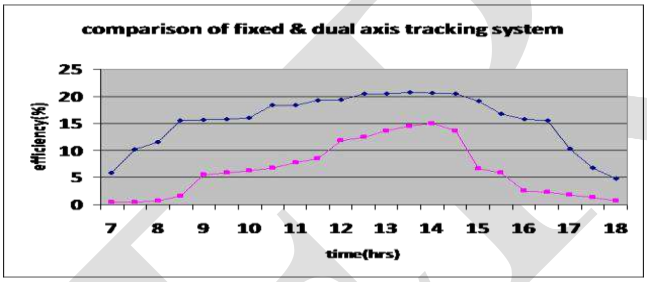
2) GRAPH OF EFFICIENCY VS TIME:



Graph: 1.9.d) Efficiency Vs Time For Fixed Axis Solar System



Graph 1.9.e) Efficiency Vs Time For Dual Axis Solar Tracking System



Graph: 1.9f) Efficiency Vs Time For Fixed & Dual Axis Solar Tracking System

1.10 ADVANTAGES & LIMITATIONS

1.10.1 ADVANTAGES

1) The conservation of non-renewable energy resources

Photovoltaic (PV) solar power eases the usage of diminishing natural resources such as oil, coal and gas. Today, we live in an exceptionally demanding environment where the use of energy is growing at an alarming rate. It is vital to preserve the earth's fossil fuels and other natural resources, not only for a healthier environment but also for the ability of future generations to meet their own needs.

2) Lower Rates of Waste and Pollution

PV solar power systems minimize the amount of waste production. For example, the entire process of converting coal to electricity produces a lot of dust, discarded solid waste, spillages of toxins and harmful emissions, as well as wasting energy, heat, land and water. Pollution from non renewable fuels is inevitable. Emissions such as Sulphur Dioxide, Nitrogen Oxide and Carbon Dioxide all can have a negative effect on farming, people's health and water. Ecosystems are also at risk of being destroyed. Furthermore, pollutants from kerosene used for lighting purposes is reduced with the use of solar power systems, as well as the decrease in use of diesel generators for the production of electricity.

3) Offsetting Green House Gases

PV Solar power systems produce electricity without giving off carbon dioxide. One PV Solar system can offset approximately six tons of CO_2 emissions over a twenty year life span

4) Reduction of Energy Usage

Solar power improves energy efficiency and is therefore very beneficial for Third World countries. Solar power electricity reduces the costs of conventional power for built up cities, and is cheaper for industrial and commercial purposes to run their operations. This leaves the use of PV systems to generate power for most of the developing world's population in rural areas.

5) Decrease in Disposing of Dry-Cell Batteries

Small dry cell batteries are used for appliances such as portable radios and flashlights, but are most commonly used in rural areas where there is lack of electricity .However, the lead from these disposed dry cell batteries can have damaging effects on soil and water. Solar power reduces the need of using disposable dry cell batteries and therefore decreases the risk of contamination.

- Simple low profile design with fewer parts.
- Requires minimal field leveling and site preparation.
- Easy rapid installation.
- Return to sun rise position automatically.

1.10.2 LIMITATIONS

1) Trackers add cost and maintenance to the system - if they add 25% to the cost, and improve the output by 25%, the same performance can be obtained by making the system 25% larger, eliminating associated maintenance.
2) When there is cloudy atmosphere it is difficult to tracking the sun.
3) Panel rotations require a extra power from outside of power used that produce by panel itself.
4) Fixing arrangement of LDR at perpendicular to sun light is somewhat problematic.

1.11 APPLICATIONS

1) Single axis tracking system for use with conventional solar modules, PV thermal models and concentrator.
2) Perfect for supplying power to remote radio and communication posts and water pumps.
3) Perform well as mounts for residential PV system.

CONCLUSION

In this proposed system, the sun tracking system was implemented which is based on concept of voltage difference by using small solar cells. After examining the information obtained in the data analysis section, it can be said that the proposed dual axis sun tracking is a feasible method of maximizing the energy received from solar radiation. The use of dc motors enables accurate tracking of the sun while keeping track of the array's current position in relation to its initial position with the help of solar cells. The solar cells are arranged for each axis.

The automatic solar radiation tracker is an efficient system for solar energy collection. It has been shown that the sun tracking systems can collect about 20.98 % more energy and proposed system collects 33.99 % than what a fixed panel system collects.

In most of the existing solar tracking system to run the drive the necessary power is given by the main panel with reduces the output power of main panels & thereby reducing efficiency of solar tracking system but in our project we have given input to driving system only by small cells. Thus small solar cell works two functions simultaneously. One is to sense the position of sun & another is to give input to the motor. Thus we are using whole available output energy of main panel for useful purpose.

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