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SOLAR POWER GENERATION WITH AUTO TRACKING

BY:
ADITYA R(19BEC004)

SUBMITTED TO:
Mr. VISHAL VAIDYA

Electronics & Communication Engineering Department
Institute of Technology, Ahmedabad

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ABSTRACT

Energy crisis has become a very big issue in today's world. With a lot of green energy sources coming up, renewable energy sources are reducing the dependency on the conventional resources. Solar energy has to play an important role in the growth of renewable energy resources.

In the past few years, many people have started using solar system as a back-up power at their houses. It is because solar energy is an unlimited energy resource. Even in the upcoming future, solar energy has the potential, and will become the major energy supply at every place.

Due to the continuous revolution of earth the sun does not face towards the solar panel always. As we have to maximize the use of the resources, the energy panel should face the sun at least, till it is present in the daytime.

INTRODUCTION

Solar power is basically the conversion of the sun radiation or the energy from sun into electricity using the solar photovoltaic cells. Research says that the solar energy that reaches the sun is about more than 10000 times the current energy consumption of the mankind.

Another research says that the power created by solar is sufficient for one year for the entire planet if there is hundred percent efficiency in the conversion of solar energy into power in 1 hour.

In today's world solar cells that convert sun’s energy into electrical energy are very costly and also inefficient for its cost. This is the point where tracking system comes in. A tracking mechanism in solar power generation is basically used to increase the energy generation efficiency of solar cells.

As the sunlight strikes the panel the tracker will navigate, to get the best sunlight. This is completely automatic and the mechanism keeps the panel in such a way that the sunlight strikes the panel till the sun is visible.

SOLAR ENERGY POWER GENERATION

The two ways to use solar power are:

1. Solar energy is simply used as a source of heat i.e., the solar thermal power generation
2. Converting into electricity using PV cells as mentioned.

In today's technological front, solar panel are highly inefficient. Solar trackers provide a way to increase this efficiency. It is cost effective too

The sunlight is composed of two components, the direct beam and the diffused sunlight. The direct beam composes 90% of the total solar energy. On cloudy days the ratio of direct vs diffuse is about 60:40 or sometimes even less than that.

The energy from the beam is directly proportional to the cosine of the angle between the panel and the incoming beam.

Previously the solar panel were fixed at a particular waiting angle for the largest illumination in the daytime. As the fixed solar panel cannot provide the optimal for maximum solar energy, the transformation efficiency is less or limited and hence the need for solar tracker arises.

PHOTOVOLTAIC TECHNOLOGY AND SOLAR CELL FOR POWER GENERATION

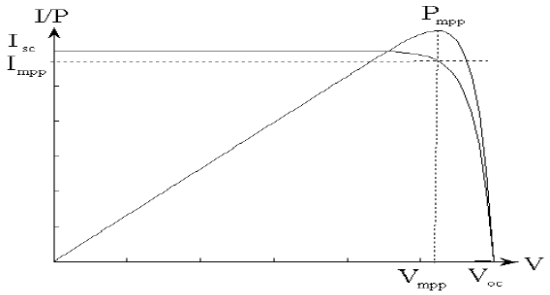
The most abundant source of renewable energy, the solar energy can be harnessed using photovoltaic cells. The word photovoltaic arises from two words photo and voltaic. Photo means light and voltaic means electricity production, which combines to make the term photovoltaic meaning producing electricity from sunlight.

The output energy from the photovoltaic cell is directly proportional to the amount of light striking the photovoltaic panel. Other factors that affect the output energy from the photovoltaic panel are season, the position of the panel, orientation and the time of the day. Maximum power is obtained when the sunlight is directly aligned with the panel.

The solar cells are made with silicon semiconductor and further treated with phosphorus and boron to make the silicon wafer. They align together to make the solar cells after the doping process.

In any case of any technology and the material, cell has two terminals to draw current. A typical solar cell consists of a front contact at the top, back contact at the bottom and PN junction in the middle.

The amount of power is directly proportional to the sunlight falling on it. More the power generated, if light intensity is high. Also, power generation is high if the area of the cell is more. The angle at which the sunlight falls also alters the power generation.



I-V and *P-V* characteristics of photovoltaic cell.

WORKING

The sunlight has bundles of photon, each photon carrying a finite amount of energy. To generate electricity from solar cell the photons have to be absorbed. The energy of photon and the band gap energy of the semiconductor decides the absorption of photon and further the proportion of electricity generated.

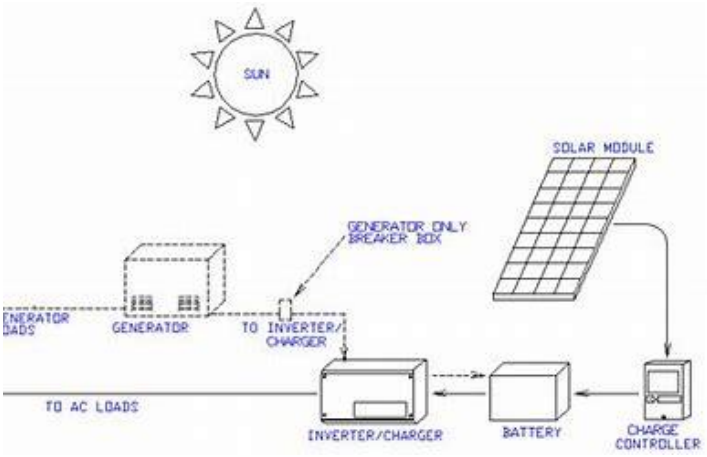
This is the point where the term electron-volt (eV) arises, which is the unit of energy which can be split into photon energy and band gap energy of semiconductor.

The semiconductor material of solar panel absorbs the photons induction light giving rise to the electron-hole pairs at the junction. This solar cell is connected to the load, be it of any kind, the electrons and holes generated at the junction are separated such that the electrons are collected at the negative terminal and the holes are collected at the positive terminal.

This creates an electric potential between the terminals developing voltage across it. It further gives rise to drawing current by the DC load, inverter and the charging circuit of the battery.

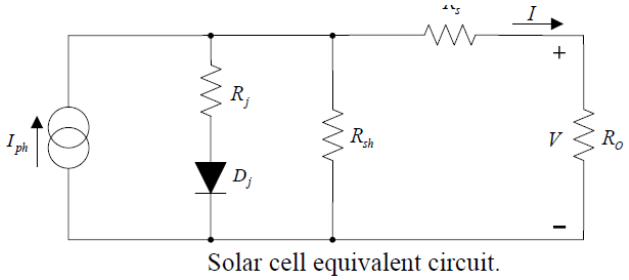
As earlier said number of photons is directly proportional to the current generated. Not much solar radiation falling on the solar cell is converted into electricity. This is due to the light that is composed of photons of different wavelengths, some of these photons gets reflected after hitting the solar cell, hence prevented from entering the cell. In some cases, the generated electrons combine with the other molecules present, even before being drawn into current by the load.

There are even more reasons for the low conversion rate or efficiency. The conversion efficiency rate of the stationary solar panel at individual residences is mere 6 to 10%. When it comes to large scale installation at the solar power plants, designing is such that high conversion efficiency rates have to be achieved. It ranges around 40 to 60% but it pays the cost too.



The components required for the solar energy generation are:

Solar panels



Solar cell equivalent circuit.

The solar panels convert the solar energy into electrical power. It is placed in a manner such that maximum energy from the sun is collected. Most of the solar panels are rated to 12 volts, generally half volt PV cells connected in series inside the panel to produce a high voltage, in this case 12 volt.

If the panels are connected in parallel, then the current that is drawn by the load will be more and hence an increase in the power while maintaining the same amount of voltage. Be it series or parallel connection, the power rating of the system increases when multiple solar panels are connected in any manner.

For high potential difference various solar cells are connected together, some in series and some in parallel. In case of PV module, several PV modules are connected together how to make a PV array, for small power usage as well as high power generation.

Batteries

Most of the solar energy power generation systems use battery to store the energy obtained from the solar panels. The battery provides a constant source of power supply only when it is fully charged, as the amount of solar power generated depends upon the strength of the sunlight.

Mostly lead acid batteries are used in solar energy systems. As the solar panels can be connected in any manner to create a solar array, only batteries can be connected together to form a battery bank. Adding to the desired voltage, current, power requirements these batteries can be connected in series or parallel.

Controller

Solar Charge Controller

This device is used to regulate the flow of current in and out of the battery. The mechanism works as follows, if the battery is completely discharged it will destroy the battery, hence the controller prevents batteries from these kinds of conditions.

The controller module balance is the amount of electricity used by the various appliances. It also prevents the damage of the battery from over charging or deep discharging. Some controllers have the alarm, showcasing the non-functioning of the module.

Inverter

The power generated from the solar panels is DC, most of the requirements for various appliances on AC. The converter that converts the direct current to alternating current is an inverter. This inverter also converts the DC voltage to AC and also to the grid or appliance rating voltage. Recent innovation states that various solar panels are connected with micro inverters to provide a very high AC voltage.

TECHNOLOGY TO ENHANCE POWER OUTPUT FROM SOLAR PANEL

There are three ways to increase the overall efficiency of the solar panel namely,

1. Increasing the cell efficiency
2. Maximizing the power output
3. Employing a tracking system.

There is a lot of research work going on improvement of solar cell efficiency. The entire world is actively waiting for this research to reach success.

The other two ways, that is maximizing the output power and employing a solar tracking system are the practical possibilities as of now.

Maximum power point tracking (MPPT)

Maximum power point tracking is the best possible process to maximize the output power from the solar panel. It keeps the operation point of solar panel on the knee point of the PV characteristics shown above.

There are various algorithms to implement this process. This process or this technology has a limitation.

It offers maximum power from a stationary array of solar panel at a particular time and position. This process fails when the sun is not aligned with the solar power generation system.

Automatic solar tracking system

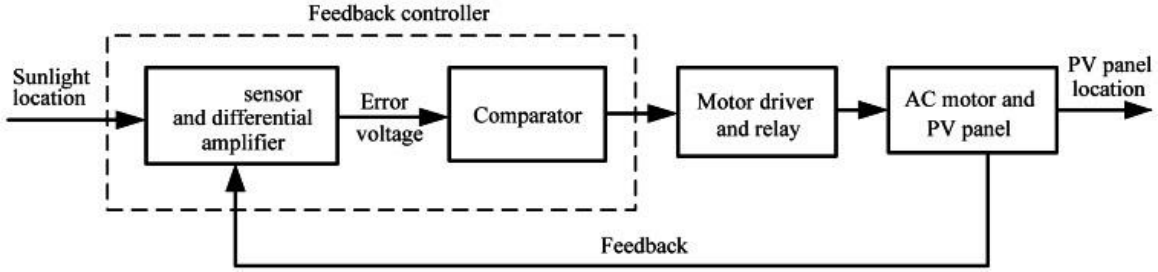
The automatic solar tracking system increases the efficiency of the power generation by keeping the solar panel aligned with the rotating sun. It increases the output power 30 to 60% then the stationary system. This is the technology that is currently used widely. The major challenges in the solar tracking system are, sensing the sunlight, calculating the initial position of the solar panel, the power consumption of the motor of tracker.

In the upcoming pages of the report, we will be studying this concept in deep.

Diffused Reflection

Diffused reflection is another way to increase the efficiency of solar panel. Maximum number of rays that reach the solar panel from the sun pass through clouds, dust and water. These are the diffused rays, which tend to reduce the efficiency of the solar cell. If these diffused rays are reflected on the solar panel through any means like reflectors, output of the panel will be increased.

SOLAR SENSOR FOR AUTOMATIC TRACKING



In technical terms a solar tracker is basically a device on which the solar panels are fitted. This tracks the motion of the sun ensuring that maximum amount of the sunlight faces the panel for the maximum amount of time.

The general components of automatic solar tracker are:

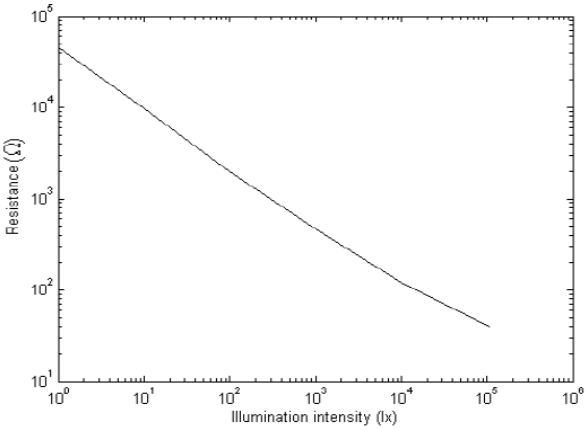
1. Solar sensor
2. Controller
3. Rotor or any kind of motor fixed in the panel.
4. Fault detector

In the field of solar power generation, sensor system usually follows the astronomic formula-based equation to locate the exact position of the sun.

Both photovoltaic tracking controller and dish type tracking controller can be used as four quadrant solar sensor to correct the tracking difference. The functionality of the solar sensor is temporarily lost during the cloudy period.

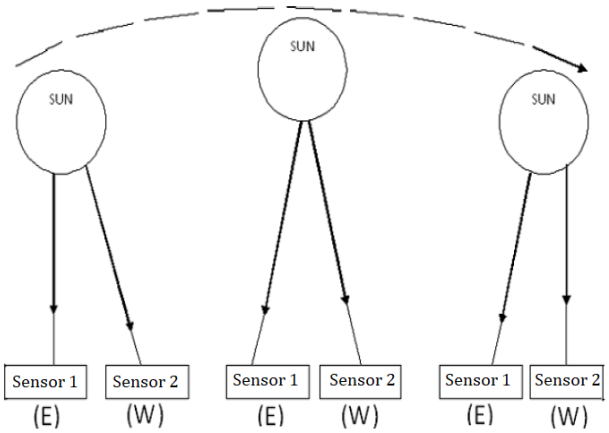
When a MPU or microprocessor unit is used to find the sun's position, it is better to use solar sensor to make it a closed loop system as it increases the process speed and also the precision.

Generally, the difference or bias for the calculated sun position is 1% when the system clock of the tracker is precisely set. A closed loop solar sensor is always recommended in the power generation systems.



Resistance of typical sensor at various illumination level of light

WORKING OF AUTOMATIC SOLAR TRACKING SYSTEM (ASTS)



(A) After Sunrise (B) Equal light on the sensors (C) Tracker Works

The basic principle is as follows, when a fixed number of sensors are used, the trackers reposition the panel, repositioning occurs towards the sensor that receives the maximum sunlight.

The data of amount of sunlight that hits the sensor is sent to the controller. The comparison of the light illumination at the different sensors is also done by the controller. It analyses the data and sends signal according to the fixed algorithm to the rotor placed.

As the earth rotates, the amount of light striking the panel and the sensor changes, so the values of the signal from sensor also changes, so the controller then sends new instruction to the rotor at the panel and the solar panel gets repositioned.

For e.g., If the sun is at extreme east during sunrise, then the amount of light falling on the sensor set for the east-west movement is maximum. So, the panel will reposition itself such that maximum rays fall on the panel.

The computer-based control unit serially communicates with the ASTS. If some fault occurs and the solar panel stops rotating, this computer unit can rotate the solar panel manually or stop all operations of ASTS in case of emergency.

MECHANISM OF ASTS

The tracking device is composed of several sensors that detect the light intensity from the directions northern, southern, eastern and western. In every direction there is a sensor with a particular elevation angle (45 degree) facing the light source.

Sensors are separated into two groups. One group is used for the east-west direction that compares the light intensity in the eastward and westward directions. The other group of sensors for comparing light intensity in the northern-southern direction. This kind of designing is best, as it facilitates repositioning all the direction

When the east-west direction sensor receives a different intensity of light, system will receive the signal with respect to the output voltage of the east-west direction sensor.

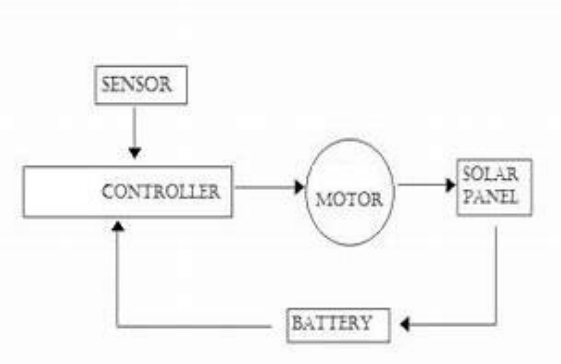
An analog to digital converter of voltage type is required to convert the output voltage of the sensor to digital data and decide the direction that has the larger light intensity over the other.

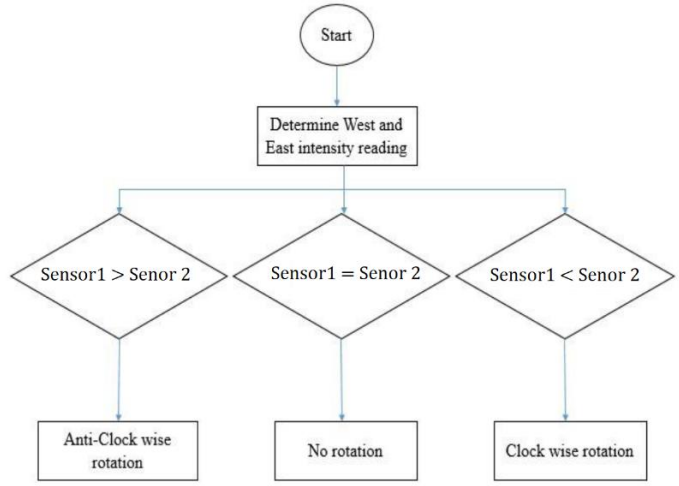
The output signal from the controller, that is input to the rotor is a PWM signal, which can be achieved by a timer program set in the working algorithm.

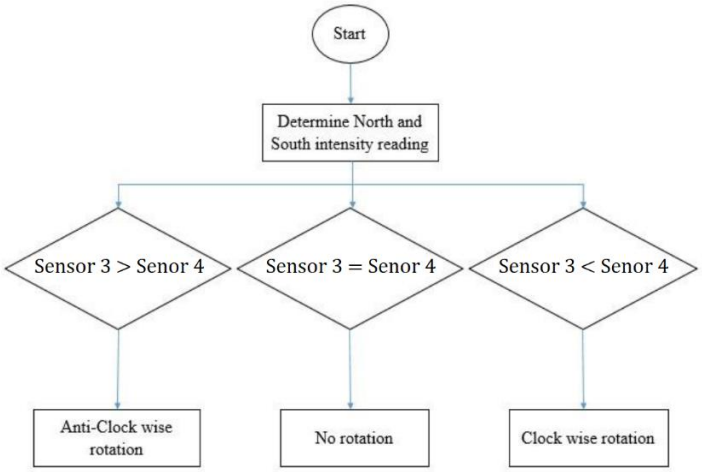
On analysis the system will drive the motor, to turn the solar panel in the decided or required direction. If all the output voltages from the sensors placed in the east-west direction are same, it indicates that the tracking is complete in the particular direction.

The same methodology is applied for the southern and northern direction sensors to analyse and track the movement of sun in the southern northern direction.

The difference in the current position and the calculated position is the error over here. This is fed as input to the controller or system. To improvise the process, it is better to improvise the algorithm that is pre-set in the system or the controller that takes into account all the parameters like error, fault detector etc.



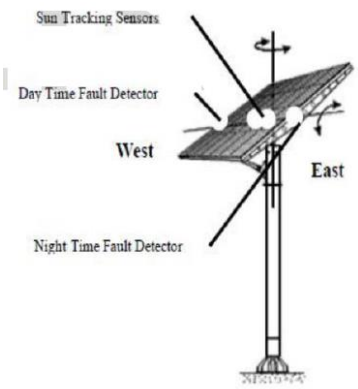




There are some modifications in the system that allows it to work even more efficiently. During the cloudy time or bad weather condition, there will be less striking of light rays on all sensors. The difference between the values of the voltages from the trackers will not be greater than the threshold set in the system. This can cause a failure in the system. To solve this problem, a short delay is placed in the algorithm, and the controller checks for the values each time after the delay.

Night time fault detector (NTFD) is one such mechanism that is present nowadays in solar tracker. The sensor detects if the solar panel is ready for tracking at the next sunrise. Generally, the NTFD is mounted in the east of the solar panel, designing it in a way that it won't work if there is lesser intensity light, as compared to the middle census.

DTFD or Daytime fault detector protects the fault when ASTS stops tracking or rotation in the day time when sun is present, except for some exceptions like cloudy weather etc. Both NTFD and DTFD have same mounting properties.

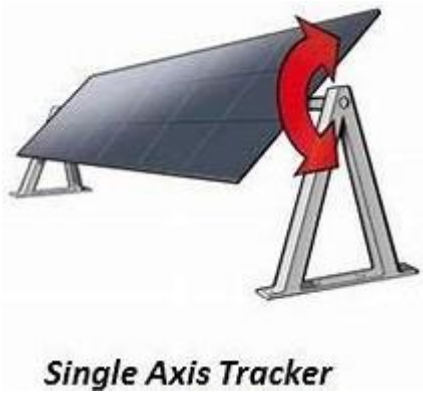


Sensor mounting assembly on solar panel

TYPES OF SOLAR TRACKERS

The Solar trackers can be basically classified by the axis of rotation into, single axis trackers and dual axis trackers.

Single Axis Tracker



In the single axis trackers, the mechanism has only one degree of freedom that acts as the axis of rotation. It is possible to align the trackers in any Cardinal direction with the available advanced tracking algorithms.

Several common implementations of single axis trackers are horizontal single axis trackers, vertical single-axis crackers, tilted single axis trackers and polar aligned single axis trackers.

Horizontal single axis tracker (HSAT)

Horizontal single axis tracker has the axis of rotation, horizontal with respect to the ground. This tracker is best suitable for low latitude regions. In this simple geometry, all the axis of rotation are parallel to one another.

To increase the ratio of energy production to cost, the spacing can be increased, subject to local terrain, time of the day and shading conditions. These trackers have the face of the module oriented parallel to the axis of rotation. As the module starts to track, the mechanism suites a cylinder and is rotationally symmetric around the axis of rotation.

Vertical single axis tracker (VSAT)

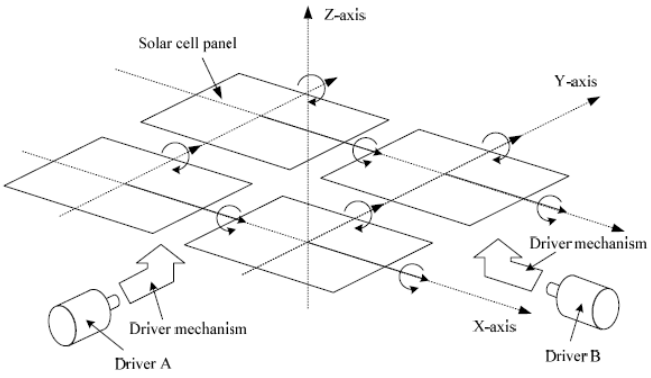
Vertical single axis tracker has the axis of rotation vertical with respect to the ground. These vertical single axis trackers rotate from east to west in the course of the day. These crackers are most effective and suitable at high latitude regions.

These trackers have the face of module oriented at a particular angle with respect to the axis of rotation. As the module starts to track the mechanism, suites a cone that is rotationally symmetric around the axis of rotation.

Tilted single axis tracker (TSAT)

Tilted single axis tracker have axis of rotation between horizontal and vertical. These crackers are basically used to reduce the wind profile and the elevated end height. These structures are the face of module oriented parallel to the axis of rotation and sweeps a cylinder that is rotationally symmetric around the axis of rotation.

Dual axis trackers

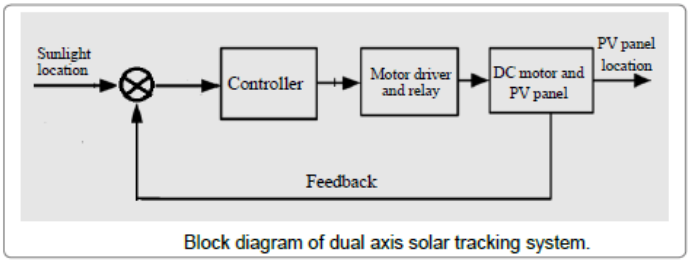


Sketch of the two-axis array solar cells.

Dual axis trackers have 2 degrees of freedom that acts as the axis of rotation. The axis is normal to each other. The axis that is fixed with respect to ground is named as primary axis. The other axis that is referenced to the primary axis is named secondary axis.

The several implementations of the dual-axis crackers are tip tilt dual axis tracker and azimuth altitude dual axis tracker.

In the dual axis solar tracker, the models are oriented parallel to the secondary axis of rotation. These trackers are meant for optimum solar energy levels because of their ability to follow the sun in both the directions, vertically and horizontally.



Block diagram of dual axis solar tracking system.

Tip tilt dual axis tracker (TTDAT)

The trackers that have the panel mounted on the top of the pole is named tip tilt dual axis tracker. The rotating array at the top of the pole drives the east-west moment. At the top of the bearing, T or H shaped mechanism allows the vertical rotation of the panels. The unique abilities of tip tilt configuration allow a fully automatic tracking possible, subject to the ability of the controller.

Azimuth altitude dual axis tracker (AADAT)

The azimuth altitude dual axis tracker has its primary axis also known as the azimuth axis, vertical to the ground. The secondary axis or the elevation axis is normal to the azimuth axis. The difference in the operation of AADAT differs from TTDAT, as this uses a ring mounted on the ground along with a series of rollers to rotate the array.

ADVANTAGES OF SOLAR TRACKER

The solar tracking systems are used to continuously orient the PV panels towards the sun such that maximum return is available from the investment in the PV system. This is beneficial as the sun's position in the sky will gradually change over the course of the day and over the seasons, throughout the year.

The most effective use of the solar tracker is in the areas of low horizons and locations that are shade free from dawn to dusk. Throughout the entire period, the trackers will utilise the wide-open access to gain every possible or available photon from the sun.

Advantages to the tracking system will depend on its placement, it determines how well it increases the effectiveness of the panel. This becomes significant throughout the summer period with long time of sunlight available to capture and store energy, when at Northern latitudes, where sun rises in the north east and sets in the Northwest.

DISADVANTAGES OF SOLAR TRACKER

Some primary disadvantages of solar power generation are, high cost during development, difficult to control motor speed and difficult to design. As we are adding a solar tracking system to the solar panels, we are adding a lot of moving parts and gears which will require continuous maintenance. Also, we need replacement of broken parts.

If the electronically controlled solar tracker stops working and if the manual control is not an available option, we have to physically position array to solar south to ensure that it will continue to capture as much solar energy as possible.

If the system is composed of a little array, like a 3-Watt capacity, the customer will get less overall cost benefit than somebody else with a bigger array of a 4–5-Watt size capacity, on the condition your energy production works out above the person employing a bigger array, because of the increased sun exposure in the area.

Application of Solar tracker

Factors have to be considered while determining the usage or application of the solar tracker. Some of the factors are the solar technology that is being used, the amount of direct solar radiation, feed-in tariffs in the region, cost to install and to maintain the mechanism.

CONCLUSION

With the increasing energy crisis, renewable sources of energy, especially solar power generation has come to active use in recent times. This paper demonstrates the importance, structure, working and applications of the solar power generation and the automatic tracker system to enhance the efficiency of the solar power generation unit. The efficiency of stationary solar panel has become an increasing concern for the users. The best advantage of the Automatic solar tracking system is that, it can track the sunlight automatically. The solar tracker provides profitable solution for the poor countries to integrate their solar system with lower cost, compared to the general power generation. Though the system has its limitations, it is lucrative and also provides an opportunity for improvement in future.

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