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A Review Paper on Solar Tracking System

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ABSTRACT

In today's era the biggest problem World is facing is energy crises and we know that fossil fuels are available in very limited amount. Also there overuse in last 30-40 years has reduced them further. So, now to meet our energy demands the only option we are left is to utilize the Renewable resources of energy that is available in abundance. There are various sources of renewable energy like wind, sun and geothermal but most cost effective among them is Solar Energy. Solar energy can not only meet our existing energy demands but can also provide us clean and cheap energy. Solar Panels once installed can give energy for several years without having any maintenance cost. Solar photovoltaic systems are such systems which are used for harnessing solar energy but we since the earth is rotating around the sun due to which solar energy in existing Solar panels is available only for a limited time throughout the day. To overcome this problem solar trackers are used. Authors in this study have tried to explore the possibility of solar trackers and their cost effectiveness in solar photovoltaic.

KEYWORDS

Photovoltaic, solar Tracker, Renewable Energy Sources (RES), STS (Solar Tracker System)

1. INTRODUCTION

The shift from conventional fossil-based resources several solar power resources are a available in like geothermal energy, wind energy, bio-energy as well as solar power. Solar energy is among the most significant attempting to solve the issue of world wide heating in addition noisa source of fresh energy. it may also assist in provided that an alternative so sensational fossil-based energy resources in addition to as a cost-effective source of energy besides. Consumption is actually tined enclosed by photovoltaic and thermal energy, making use of solar panels as well as solar collectors, respectively. There will be numerous applications given that photovoltaic thermal sporting goods. At low-temperature ranges, space conditioning and domestic hot water by-product tend to bethe overall most typical use. at medium temperature ranges, solar temperature reduction, desalinisation furthermore post industrial process high temperature tend to purpose which can deed alternative energy. At high-temperature stages, concentrating solar power plants are going to be sensational programs that catch the overall most attention of worldwide. furthermore, for very high-temperature ranges up to 1000 °c, processes specified hydrogen production in addition to methanol-reforming can use sun irradiation [1].

Accompanied by all of the anticipated res, solar energy(SPV) systems experience has taken major toleration in addition to investment funds wondering its around the world potential in addition to its to set off-world power very little time. so, within the coming years, SPV techniques will experience the highest participation in energy production among all of the areas. moreover, the SPV module is really a dc source, something that often sets off powerful dc whose amplitude is dependent on the availability containing daytime sunlight as well as the temperature at standard test condition (STC)consistingof25°calongwithSolarConstantof1kW/m^2 [2]. Significantly, the SPV module indicates the overall unidirectional characteristic. Hence, the power output of the SPV module is usually withstanding broadens along with atmospheric temperature along with room temperature. Also, the SPV generator indicates only one MPPT under full exposure to sunlight.

On this context, the main objective consisting of utilising the MPPT tracking method is to exactly track and distinguish the overall global MPPT, as well as there by gathering the overall maximum power. Additionally, MPPT techniques are compared in order to as an organised set of rules that is normally needed in order to operate on the system with efficiency .This signified ,multiple MPPT tracking algorithms have already been published in the scientific literature, which is, actually, the heterogeneous ways in order to match the source and load impedances [3]. The correct geographical orientation of such devices would possibly raise the light intensity of the incident solar radiation flux, and that depends upon azimuth and inclination angles.

1.1 Solar energy

The overall energy that's harnessed using sun radiation is known as solar energy. Radiant light and heat from the powerful sun have a tendency to harnessed exploitation various kinds of technologies like solar heating, solar cell, solar thermal thermoelectric, solar architecture and artificial photosynthesis. It’s estimated that earth gets approx1kW/m^2 at high noon but also direct changeover from photon energy to electricity already done and solar power plants are now setting up on considerable Scale. Nevertheless, solar energy production competencies not satisfactory. Therefore it really is preferable to extract the maximum amount of energy as feasible by means of lowering losses. Solar energy seems to have benefits over all other sources of energy. The most important fact is, except the overall a lot of installation cost and zero maintenance cost it truly is quite free of cost and with no energy restriction. it does not reject heat and carbon dioxide or radioactive particles, as well as solar energy, does no longer produce any noise. As a result, it’s totally most environment-friendly. Solar energy serves as a reliable source of energy in the hilly parts of the world along with isolated lands where transmission via power line are often costly or very unlikely. Photovoltaic panels have a tendency to be used in the backcountry for electrification [4]. In addition, urbanised electrification with the aid of street lights by a photovoltaic panel is becoming popular. Modern electrical gadgets also have the facility to run along with solar power. These days’ electric vehicles, the building-integrated solar system as well as smart grid system have begun implementing solar energy broadly. Spacecraft, as well as satellites that are sent to space for a long time, have no other alternative energy other than solar.

1.2 Photovoltaic Technology

Solar Cells are the best-known technique for producing electrical power through Silicon Cells swaddle in photovoltaic modules. to elucidate the photovoltaic solar panel more easily ,photons from sunlight energies electrons in an upper state of energy and coming to the lower state to release one electron so that creating electricity. The term photovoltaic defines the general unbiased working condition of a photodiode in which current through the appliance is due to the transduced light energy [5]. Solar cells generate direct current electricity from light, which can be used to recharge a battery for electric devices.

1.3 Solar Module

1.3.1 In the Field of Photovoltaics

A photovoltaic module or photovoltaic panel is a packaged, interconnected assembly of photovoltaic cells, also known as solar cells. An installation of photovoltaic modules or panels is referred to as a photovoltaic array. Photovoltaic cells typically require protection from the environment.

For cost and practicality, several cells are connected electrically and packaged into a photovoltaic module. A collection of these modules, mechanically fastened together, wired, and designed to be field-installable units (sometimes with a glass covering and a frame and backing made of metal, plastic, or fiberglass), is known as a photovoltaic panel or simply a solar panel.

The foremost application of photo voltaics was to power satellites and spacecraft. Nowadays, most solar modules are used for grid-connected power generation. Therefore, an **inverter** is required to transform direct current (DC) into alternating current (AC).

There is also a smaller market for off-grid power applications for inaccessible outbuildings, wayside communication challenges, meteorological stations, and cathodic protection in pipelines.

1.3.2 Solar Tracker Fundamentals

A solar tracker is a device that aligns a day lighting reflector, solar photovoltaic panel, or concentrating solar reflector or lens toward the sun. The sun's position in the sky varies with the seasons (elevation) and the time of day as it moves across the sky. Solar-powered devices function best when consistently pointed at the sun, so a solar tracker increases the efficiency of these devices compared to a fixed position, albeit at the cost of added system complexity.

There are several types of solar trackers with varying costs, quality, and performance. One of the most well-known types is the **heliostat**, a movable mirror that reflects sunlight to a fixed position. Other techniques can also be employed. The efficiency of a solar tracker depends on its application.

Concentrators, particularly in solar cell processes, require a high degree of precision to ensure that concentrated sunlight is directed accurately to the device, typically at or near the focal point of the reflector. Usually, concentrator systems cannot function without tracking, making at least single-axis tracking essential.

Large-scale power plants or high-temperature research facilities that use multiple ground-mounted mirrors along with an absorptive focal point require high accuracy, similar to that used for solar telescopes.

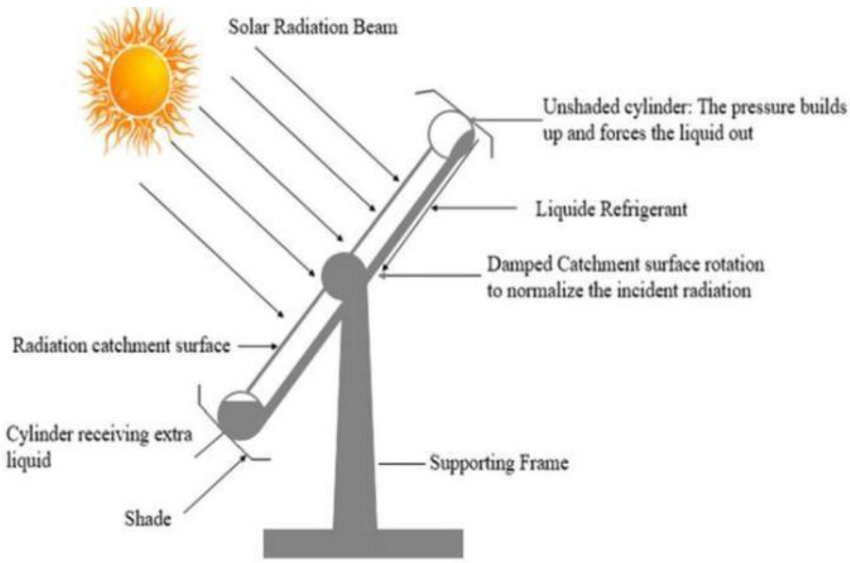

Figure1: Basic design of solar tracker

1.4 Sun path, Azimuth& Altitude Angle

The change of position of moving sun varies at different time and season to season due to earth's continuous and periodic rotation and revolution. As a result it has become necessary to locate theorientation of sun for a particular moment. The locations are placed on a special type of chart named Sun Path Diagram .A Sun Path Diagram shows the azimuth angle, elevation angle, sun paths throughout the years, sunrise and sunset time etc.

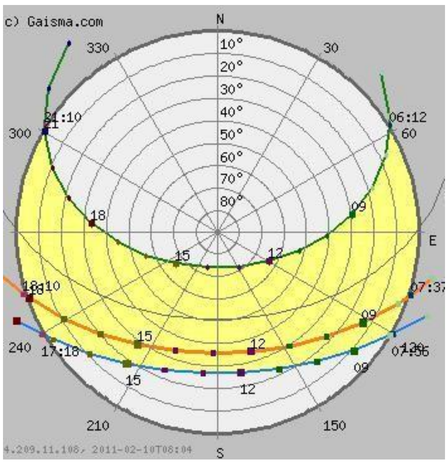

Figure2: Sun path diagram

1.4.1 Solar azimuth, ψ, is the direction of the sun from the observer, expressed because of the hour angle from the north point of the line to the point at which a vertical circle passing through the sun intersects the horizon.

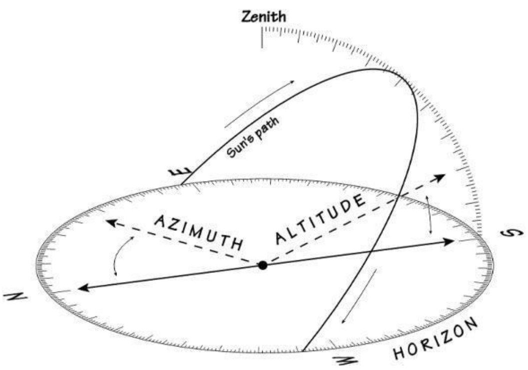

Figure3: Azimuth and altitude angles

1.4.2 Solar altitude, α, is the angular height of the sun measuredfrom the horizon. Above the horizon is positive, below is negative. The sun directly in the centre of the sky has a Solar Altitude of 90 degrees.

1.4.3The declination angle, δ, is the angle of deviation of the sun from directly above the equator.This angle can be mathematically calculated by the following equation:

(1) $$\delta = 23.45Sin(360(n - 180)/365)$$

Here, n is the number specified for the days within the year and δ is positive for the angles north to the equator and negative for the angles south to the equator.

1.4.4 The zenith angle, υz, is the angle between the sun anda line perpendicular to the earth's surface. It is the complement of solar altitude. The zenith angle is given bythe following equation:
Here ,ϕis the latitude in degree

1.5 Solar Irradiance

Solar irradiance is the measure of the power density of sunlight. Its unit is W/m^2 and is an instantaneous quantity. The irradiance received by the earth from solar radiation is 1367 W/m^2. After getting absorbed by atmosphere, as it passes through it, the radiation becomes1000W/m^2at surface. Solar radiation is affects the solar cell output performance and so it is a very important factor in this field. Sunlight consist energy which has wavelengths with in a wide range of electromagnetic wave spectrum. But no solar cell can absorb energy from the whole spectrum [8]. A solar cell is mainly designed for absorption of a portion of the total radiation spectrum. Photovoltaic solar cells are designed for the absorption of the visible spectrumonly. The direct normal solar irradiance is given by,

It,n=Ib,ncosυz+Id,n **(3)**

Here,
It,n=the irradiance coming directly from the sun Id ,n= the diffuse radiation

Solar irradiance is a parameter directly related to solar energy received by solar panel and maximum when rays are perpendicular to panel plane. To achieve maximum solar energy it is necessary to rotate the panel face towards the sun. The device that is used for this purpose is called Solar Tracker.

1.6 Various Type of Tracking

Solar tracking system is classified by its degrees of rotation. According to degrees of rotation trackers can be grouped into two primary categories
1. Single Axis Solar Tracker
2. Dual Axis Solar Tracker

1.6.1 Single Axis Solar Tracker

A single-axis solar tracker continues to follow the movement of the sun either horizontally or vertically. As the name recommends, this sort of tracker seems to have just one axis for rotary motion. The horizontal variety of solar tracker is utilized in tropical regions where the sun will receive very way up at midday, except the days are going to be short. On the other hand, the upright kind of solar tracker is employed in regions with elevations where the sun doesn't have to get high, but summer days are often lengthy. In concentratedsolar power processes, single-axis trackers are going to be used with flat surface solar module [9].

$v_z=\Phi-\delta$ **(2)**

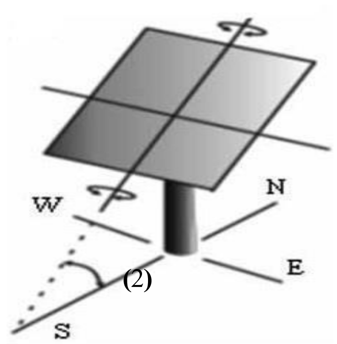

Figure4: Single Axis Solar Tracker

1.6.2 Dual Axis Solar Tracker

A dual-axis solar tracker seems to have two degrees of rotary motion. it could possibly track the sun either horizontally and vertically. This type of tracker maybe employed at anyplace in the world as well as guarantees maximum efficiency in exerting solar energy. Concentrated solar power (CSP) processes using dual axis tracking include solar power structures and dish systems. Dual-axis tracking is incredibly significant in solar power tower processes because the angle error is important for longer distances between the mirrors in addition to the central receiver situated in the tower structure. Design for dual-axis tracking system is complex compared to single-axis tracking and operation is demanding [10]. Nevertheless, for large scale solar energy production dual- axis tracking is more fiscal.

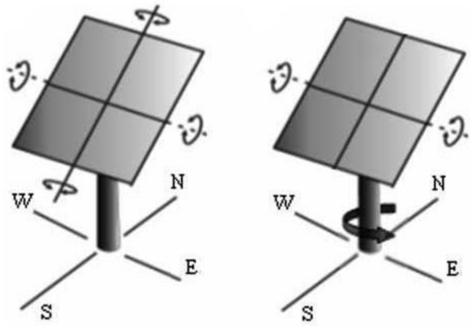

Figure5: Dual Axis Solar Tracker

1.7 Methods of Solar Tracking

There are three methods of solar tracking.
- ActiveTracking
- PassiveTracking
- ChronologicalTracking

1.7.1 Active tracking

The position of the sun is continuously determined by sensors throughout the day. The sensors trigger the motion of a motor or actuator to ensure that the solar panel always faces the sun. Active tracking is highly accurate with the help of sensors. However, a significant challenge arises when sensors fail to discriminate between measurements, resulting in false triggers or missed triggers during cloudy days

1.7.2 PassiveTracking

Passive tracking method does not use sensors like active tracking. Instead of using sensors, a passive tracker moves in response to imbalance in pressure between two points at the ends ofthetracker.This pressureimbalanceis caused byheat from sun that creates gas pressure from compressed pressure moves the structure. This method does not have to rely on electrical sensors andrequires negligible amount of power to operate. However, the mechanical design has to be very crucial to maintain accuracy.

1.7.3 ChronologicalTracking

A chronological trackerisatimer-basedtrackingsystem. The structureismoved at a fixedratethroughout thedaysincethe sun moves across the sky at a fixed rate of about 15 degree per hour. This method is better suitable for single axis tracking without sensors. For dual axis tracking a modified version can be implemented. The position of sun throughout the day can be calculated and set by the programimplemented on the controller module. The solar tracker rotates according to data sent from control unit’s memory of pre-stored data or calculated from given formula. Thismethod of sun-tracking is accurate and reliable [11]. However, data storage, calculation continuous data transmission is power consuming and unnecessary rotation when sun light istoo low can never be avoided. All the three methods are applicable with single axis an dual axis tracking system. Which method is best suitable, is determined by the location of installation, purpose of generation and demand of solar power. Modern trackers combines both the sensor controlledmethod and sensor less controlmethod atthesame time to increase efficiency.

2.BASIC COMPONENT OF SOLAR TRACKING SYSTEM

A Solar tracker has a overall basic components. The major components are described here-

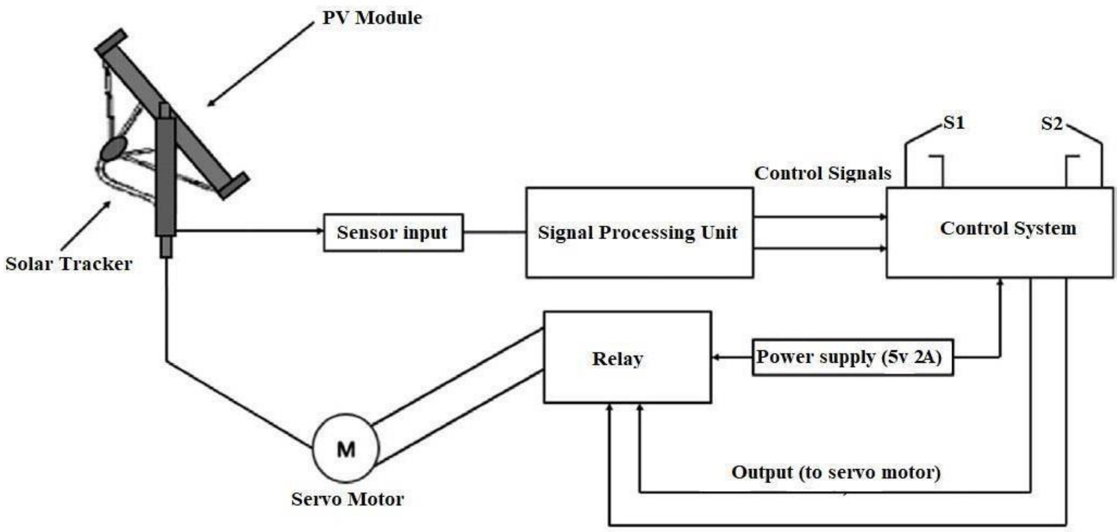

Figure6: Solar Tracker Layout

2.1 Sun Tracking Algorithm:

Solar tracking can have open- Loop control algorithm more closed-loop control algorithm. Open-loop control algorithm involves calculation of azimuth And altitude angle of sun on a purely mathematical platform based on astronomical references.The open-loop component isneededbecause the sun can be obscured by clouds, eliminating or distorting the feedback signals.Closed-loop control algorithm includes detection of the position of sun by real-time light-sensing method and is needed to eliminate errors due to variability in installation,assembly,calibration,and encoder mounting.These two methods can be combined Together to keep balance between economic design and increasedefficiency [12].

2.2 Tracker Control Unit:

The control unit executes the suntracking algorithm and necessary calculations.It can also coordinate the movement of the positioning system.AMicroprocessor or a computer can be used as the centre of control unit. It normally has command input and data output mechanism for interfacing.For the trackers placed in remote region automatic tracking control mechanism is best suitable.

2.3 Positioning System and Drive Mechanism:

Positioning System moves the solar tracker according to the preference of control unit.It can be either electronic or hydraulic.Electrical Systems utilize encoders and variable frequency drives or linear actuators to monitor the current position of the panel and move to desired positions.The drive mechanism includes and move to desired positions.The drive mechanism includes mechanical devices-rotary motors, linear actuators, linear mechanical devices-rotary motors, linear actuators, linear drives, hydraulic cylinders, swivel drives, planetary gears, and threaded spindles.[13].

3. RESULT

Solar trackers are instruments which will be used to increase the amount of solar energy collected via PV systems via constant tracking of the position of the sun across the sky throughout the day. These methods are aesthetically attractive, environmentally friendly and are progressively becoming cost-efficient with the growth of the computer systems as well as control systems technologies. The integrated features bring these techniques appropriate as green and enormous scale domestic and industrial power generation processes [16]. In this article, different types of STS are summarized on their designs, thermal and electrical performances as well as the factors influencing the heat loss during operation.

Based on ideas of energy collection and the sun tracking techniques, ST can be divided into two categories viz. active types and passive types. These two major types of STS can,in turn, be divided into many other different categories based on a number of parameters such as the number of axes, the tracking directions and methods among others. Inactive STS, single/double-tracking modes are used. Each of these systems presents their own advantages; the double-axis STS provide better power stratifications while single axis processes are cheaper and less complex. the comparison between the energy returns of both tracking methods (single and double) with the fixed traditional PV systems open that the sun tracking system's energy return is always higher than that of the traditional fixed PV panels [17]. Although the double- axis tracking systems give better energy return when compared to other types of systems; the literature indicates that they suffer from high energy losses during their operation due to auxiliary units and moving joints. Serious problems occur when any of the sensors is shaded up since this phenomenon can cause an asymmetrical control signal leading of the malfunction of the entire system. Solar trackers are instruments which will be used to increase the amount of solar energy collected via PV systems via constant tracking of the position of the sun across the sky throughout the day. These methods are aesthetically attractive, environmentally friendly and are progressively becoming cost-efficient with the growth of the computer systems as well as control systems technologies. The integrated features bring these techniques appropriate as green and enormous scale domestic and industrial power generation processes. In this article, different types of STS are summarized on their designs, thermal and electrical performances as well as the factors influencing the heat loss during operation.

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3.1 Conclusions

It is evident from the above study the use of solar trackers will certainly increase the efficiency of SPV systems but proper care is required while installing solar trackers with these systems. Problems such as failure of solar tracker also need equal attention while installing them. Whether to install active or passive solar trackers is also a question which needs to be explored further. This study also tried to analyze all the important factors which are required for the optimization of solar trackers.

4.Future Directions

The development and adoption of solar tracking systems have significantly enhanced the efficiency of solar energy generation. However, to further optimize their performance and adoption, research and innovation are focusing on the following future directions:

4.1 Integration with Artificial Intelligence and IoT

The integration of AI and IoT in solar tracking systems can enable real-time monitoring, predictive maintenance, and dynamic adjustment of panels based on weather patterns and energy demand. Smart algorithms could improve tracking accuracy and minimize downtime.

4.2 Advanced Materials and Design

Future solar trackers may incorporate lightweight, durable, and cost-effective materials that reduce mechanical wear and tear. Innovations in design, such as flexible or adaptive structures, could improve reliability and adaptability to diverse environments.

4.3 Energy Storage and Hybrid Systems

Combining solar tracking systems with advanced energy storage solutions and hybrid energy systems could improve energy reliability, allowing for continuous power supply even during low sunlight periods.

4.4 Decentralized and Off-Grid Applications

Developing compact and cost-effective solar tracking systems for decentralized and off-grid applications could help bring solar energy to remote or underserved regions, fostering energy equity.

4.5 Enhanced Efficiency through Multidimensional Tracking

Research is ongoing to develop multidimensional tracking systems that optimize energy capture not only based on the sun's movement but also by considering reflected and diffused sunlight, further maximizing energy generation.

4.6 Cost Reduction through Scalability

Innovations aimed at simplifying manufacturing and reducing the cost of components could make solar tracking systems more accessible. Modular and scalable designs could enhance their adaptability for various installation sizes.

4.7 Integration with Renewable Ecosystems

Solar tracking systems could be integrated into larger renewable energy ecosystems, working in synergy with wind turbines, battery systems, and smart grids to optimize overall energy production and distribution.

4.8 Automation and Robotics

Automation and robotics could enable self-cleaning mechanisms, automated maintenance, and faster installation, reducing operational costs and improving long-term performance.

4.9 Climate-Resilient Designs

Future systems will likely incorporate features to withstand extreme weather conditions, such as high winds, heavy snow, or intense heat, ensuring reliable performance in diverse climates.

4.10 Policy and Incentive Alignment

Aligning future solar tracking innovations with supportive policies and incentives could accelerate adoption. Collaboration with governments and industry stakeholders will be key to overcoming barriers to implementation.

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