A
Project Report
On

DESIGN AND DEVELOPMENT OF SOLAR TRACKING DEVICE FOR SOLAR PANEL WITHOUT POWER CONSUMPTION

submitted to

Sant Gadge Baba Amravati University,
Amravati (M.S.) 444 602

in partial fulfillment of the requirement

for the degree of

BACHELOR OF ENGINEERING
in
MECHANICAL ENGINEERING

by

Ms. Sakshi Mokashi
Mr. Shubham Nikalje
Mr. Akash Thote
Mr. Vikram Nage
Ms. Komal Tayde

under the guidance of
Prof. K. V. Chandan

Department of Mechanical Engineering
Shri Sant Gajanan Maharaj College of Engineering
Shegaon-444203 (M.S.)
(Recognised by AICTE, accredited by NBA, New Delhi, NAAC, Banglore & ISO 9001:2000)
www.ssgmce.ac.in

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Certificate

This is to certify that the project report entitled **"Design and Development of Solar Tracking Device for solar panel without Power Consumption"** is hereby approved as a creditable study carried out and presented by

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– Projectees

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Abstract

This project aims to design and manufacture a passive solar tracking system to enhance the performance and efficiency of solar power systems. The proposed tracking system utilizes passive techniques that do not rely on active control mechanisms or external power sources, reducing complexity and energy consumption. The project involves the conceptualization, design, prototyping, and testing of the passive solar tracking system to optimize the incident angle of sunlight on solar panels.

The design process begins with a comprehensive study of solar tracking principles, including the movement of the Sun, geographical location considerations, and the effects of incident angle on energy capture. Various passive tracking mechanisms, such as bimetallic strips, compressed gas systems, and shape memory alloys, are evaluated to determine the most suitable approach for the project.

Based on the analysis, a novel passive tracking mechanism is developed, taking into account factors such as simplicity, reliability, cost-effectiveness, and adaptability to different solar panel configurations. The design includes mechanical components, such as linkages, gears, and pivots, that enable the tracking system to follow the Sun's path autonomously throughout the day.

The outcome of this project is expected to demonstrate the feasibility and benefits of a passive solar tracking system in improving energy production and maximizing the utilization of solar resources. The findings can contribute to the development of more efficient and cost-effective solar power systems, particularly in applications where active tracking systems may not be practical or economically viable.

Keywords: passive solar tracking system, solar power systems, incident angle optimization, mechanical design, manufacturing, energy efficiency.

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CHAPTER 01

INTRODUCTION

Introduction

1.1 Overview

Solar energy is popular due to its renewable nature, widespread availability, and decreasing costs, making it a sustainable, accessible, and cost-effective source of power with minimal environmental impact. Solar power is becoming increasingly popular as a source of renewable energy due to its numerous benefits such as cost-effectiveness, reliability, and sustainability. The use of solar energy for agricultural purposes has been gaining attention as it provides farmers with a reliable and sustainable source of energy for irrigation, crop drying, and other activities. However, the efficiency and effectiveness of solar panels in agriculture can be improved by employing a single-axis sun-tracking mechanism.

In this project, we aim to design and manufacture a passive solar tracking system with single axis tracking, in this there is no use of any kind of electrical power required for the rotation for solar panel instead of electrical use we using mechanical source of power. In the spiral spring mechanical energy is stored and with the help of gear arrangement speed will reduce such a way that that can match the sun speed throughout the day.

The main goal of this project to design tracking system for the domestic and industrial purpose solar plate for increase the efficacy of panel.

1.2 Solar Energy

Solar energy is a renewable and sustainable energy source that is becoming increasingly popular in the world due to its many benefits. Solar energy is produced by the sun, which emits light and heat energy through a process called nuclear fusion. This energy is then captured and converted into usable electricity by solar panels. The use of solar energy has many advantages, including reduced environmental impact, reduced dependence on fossil fuels, and increased energy independence.

One of the main advantages of solar energy is that it is a clean and renewable energy source. Unlike fossil fuels, solar energy does not produce harmful emissions that can damage the environment and contribute to climate change. Solar panels also do not require any fuel to generate electricity, which means that they have zero fuel costs and produce no waste or pollution. Another advantage of solar energy is that it is a decentralized energy source.

This means that solar panels can be installed on rooftops, in remote areas, or in areas without access to a traditional power grid. This is particularly important in developing countries where access to electricity is limited and unreliable.

1.2.3 About Sun

Diameter: The Sun has an approximate diameter of about 1.39 million kilometers (864,000 miles). It is about 109 times larger than the Earth in diameter.

Mass: The Sun's mass is approximately 1.989 × 10^30 kilograms, which is about 333,000 times the mass of the Earth.

Surface Temperature: The temperature on the Sun's surface, known as the photosphere, is around 5,500 degrees Celsius (9,932 degrees Fahrenheit).

Core Temperature: The core of the Sun is incredibly hot, with temperatures reaching around 15 million degrees Celsius (27 million degrees Fahrenheit). This is where nuclear fusion occurs, converting hydrogen into helium and releasing tremendous amounts of energy.

Luminosity: The Sun's luminosity is a measure of the total amount of energy it emits per unit of time. It is approximately 3.8 x 10^26 watts, which is equivalent to the energy output of about 3.8 trillion billion 100-watt light bulbs.

Distance from Earth: The average distance between the Sun and the Earth, known as an astronomical unit (AU), is approximately 149.6 million kilometers (93 million miles). This distance is used as a standard to measure distances within the solar system.

Solar Irradiance: The solar irradiance, which represents the power per unit area of sunlight reaching the Earth's outer atmosphere, is approximately 1361 watts per square meter (W/m^2). However, by the time sunlight reaches the Earth's surface, it is affected by various factors and can vary depending on location, time of day, season, and atmospheric conditions.

Age: The Sun is estimated to be around 4.6 billion years old and is considered middle-aged. It is currently in the main sequence phase of its life cycle, where it fuses hydrogen into helium in its core.

1.2.1 Solar Radiation

Solar radiation, also known as solar energy or sunlight, is the electromagnetic radiation emitted by the Sun. It is the primary source of energy for our planet and plays a crucial role in various natural processes and human activities. In this brief overview, we will explore the characteristics, components, measurement, and significance of solar radiation.

Solar radiation consists of a broad spectrum of electromagnetic waves, ranging from high-energy gamma rays and X-rays to lower-energy ultraviolet (UV) rays, visible light, and infrared (IR) radiation. However, only a small portion of this spectrum is relevant for solar power generation and biological processes on Earth.

The intensity of solar radiation varies based on several factors, including time of day, season, geographic location, and atmospheric conditions. The angle at which sunlight reaches the Earth's surface influences the amount of energy received. Sunlight is most intense when it strikes the Earth perpendicular to the surface, which occurs at noon when the Sun is directly overhead. Conversely, during sunrise or sunset, sunlight travels through a thicker portion of the atmosphere, leading to lower intensity and a longer path for the radiation to reach the surface.

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The Earth's atmosphere acts as a filter for solar radiation, allowing certain wavelengths to pass through while absorbing or scattering others. UV rays, for example, are mostly absorbed by the ozone layer in the Earth's stratosphere. This absorption helps protect living organisms from the harmful effects of excessive UV radiation. Visible light is the portion of solar radiation that our eyes can perceive. It consists of a range of colors, with each color corresponding to a specific wavelength.

When combined, these colors form white light. The Earth's atmosphere allows visible light to pass through with minimal absorption, enabling it to reach the Earth's surface. Infrared radiation, also known as heat radiation, has longer wavelengths than visible light. It accounts for a significant portion of solar radiation and plays a crucial role in the Earth's energy balance. Infrared radiation is responsible for warming the Earth's surface and plays a vital role in maintaining a suitable climate for life.

Measurement of solar radiation involves various instruments and units. The most commonly used instrument is a pyrometer, which measures the total amount of solar radiation received on a horizontal surface. Pyrometers measure solar irradiance, expressed in watts per square meter (W/m^2). Another important measurement is solar insolation, which represents the amount of solar radiation received over a specific period, typically in kilowatt-hours per square meter (kWh/m^2) or mega joules per square meter (MJ/m^2).

The intensity of solar radiation varies based on several factors, including time of day, season, geographic location, and atmospheric conditions. The angle at which sunlight reaches the Earth's surface influences the amount of energy received. Sunlight is most intense when it strikes the Earth perpendicular to the surface, which occurs at noon when the Sun is directly overhead. Conversely, during sunrise or sunset, sunlight travels through a thicker portion of the atmosphere, leading to lower intensity and a longer path for the radiation to reach the surface.

Geographic location plays a significant role in solar radiation. Regions near the equator receive more direct sunlight throughout the year, resulting in higher solar radiation levels. In contrast, areas farther from the equator, such as Polar Regions, experience lower solar radiation due to the inclined angle at which sunlight reaches the surface. The Earth's atmosphere also affects solar radiation. Cloud cover, aerosols, and pollutants can scatter or absorb solar radiation, reducing the amount that reaches the Earth's surface. This phenomenon is particularly notable during cloudy or hazy days when solar radiation levels are lower.

Solar radiation also plays a crucial role in agriculture and plant growth. Plants rely on solar energy for photosynthesis, the process by which they convert sunlight into chemical energy to fuel their growth and development. The availability of solar radiation influences plant productivity, flowering, and fruiting.

Solar radiation has implications for weather and climate as well. The distribution of solar radiation across the Earth's surface drives temperature gradients, air circulation patterns, and atmospheric dynamics, contributing to the formation of weather systems and climate patterns. Solar radiation is a key driver of the Earth's energy balance, affecting the distribution of heat and moisture on a global scale.

Solar radiation has numerous practical applications beyond power generation and agriculture. It is utilized in solar water heating systems, solar cooking, solar drying, and solar thermal technologies. Solar radiation is also harnessed for solar water desalination, providing freshwater in regions with limited access to clean water sources.

1.2.2 The Sun and Earth

The Sun and Earth are integral components of our solar system, with the Sun being the central star and the Earth being the third planet from the Sun. Here is a brief description of the Sun and its relationship with Earth:

The Sun is a massive ball of hot, glowing gas, primarily composed of hydrogen and helium. It is located at the center of our solar system and provides the primary source of light, heat, and energy for Earth and other planets. The Sun consists of several layers, including the core, radioactive zone, convective zone, photosphere, chromosphere, and corona. At its core, the Sun undergoes nuclear fusion, where hydrogen atoms combine to form helium, releasing tremendous amounts of energy in the process. This energy eventually reaches the Sun's surface and is radiated into space as sunlight.

The Sun emits electromagnetic radiation across a broad spectrum, including ultraviolet (UV), visible light, and infrared (IR) radiation. This solar radiation is essential for supporting life on Earth and drives various natural processes, including weather, climate, and the water cycle. Earth orbits the Sun in an elliptical path, completing one revolution around it approximately every 365 days, resulting in a year. This orbital path, combined with the tilt of Earth's axis, gives rise to the changing seasons. During the summer solstice, the hemisphere tilted towards the Sun experiences longer days and receives more direct sunlight, leading to warmer temperatures. Conversely, during the winter solstice, the hemisphere tilted away from the Sun experiences shorter days and receives less direct sunlight, resulting in colder temperatures. Sunlight is crucial for sustaining life on Earth. Through the process of photosynthesis, plants and some microorganisms convert sunlight into chemical energy, producing oxygen and forming the foundation of the food chain. Sunlight also plays a vital role in regulating Earth's climate, driving atmospheric circulation, and influencing weather patterns.

1.3 Photovoltaic System

A photovoltaic (PV) cell, also known as a solar cell, is a device that converts sunlight directly into electricity through the photovoltaic effect. PV cells are the building blocks of solar panels and play a crucial role in solar power generation. Here is an overview of PV cells, including their structure, working principle, types, and applications.

Structure: A PV cell typically consists of several layers of different semiconductor materials, most commonly silicon. The main components of a typical silicon-based PV cell are:

Absorber Layer: This layer is usually made of silicon and is responsible for absorbing sunlight. Silicon is a semiconductor material that can generate electricity when exposed to light.

P-N Junction: The absorber layer is doped with impurities to create a p-n junction, which is the boundary between the positively charged (p-type) and negatively charged (n-type) regions. This junction allows for the separation and flow of electrons and holes, enabling the generation of an electric current.

Contacts: Metal contacts are placed on the front and back surfaces of the cell to collect and carry the generated electricity. The front contact is usually a grid-like pattern, allowing sunlight to reach the absorber layer, while the back contact covers the entire back surface.

Working Principle: The functioning of a PV cell is based on the photovoltaic effect. When sunlight, consisting of photons, strikes the absorber layer of the PV cell, it transfers energy to the atoms in the material. This energy excites electrons in the material, creating electron-hole pairs. The p-n junction within the cell separates these electron-hole pairs, with the electrons flowing to the n-side and the holes to the p-side. The electric field created by the p-n junction causes the electrons to move towards the front surface of the cell, while the holes move towards the back surface. This flow of electrons and holes creates a voltage difference between the front and back contacts, generating an electric current. The metal contacts collect this current and transfer it to an external circuit for utilization.

1.3.2 Types of PV Cell

There are several types of photovoltaic (PV) cells, each employing different materials and technologies to convert sunlight into electricity. Here is a brief description of the most common types:

Crystalline Silicon (c-Si) Cells: These cells are made from slices of crystalline silicon, which can be either monocrystalline or multicrystalline. Monocrystalline cells are made from a single crystal structure, offering high efficiency and a uniform black appearance. Multicrystalline cells are composed of multiple crystal structures, resulting in a slightly lower efficiency but lower production costs. Crystalline silicon cells are widely used and known for their long-term reliability.

Thin-Film Cells: Thin-film cells utilize a thin semiconductor layer, which is typically deposited on a substrate material such as glass or metal. The most common thin-film materials include amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium gallium selenide (CIGS). Thin-film cells are less expensive to produce compared to crystalline silicon cells and can be flexible, allowing for more versatile applications.

Multijunction Cells: Multijunction cells consist of multiple semiconductor layers, each tuned to absorb different portions of the solar spectrum. By stacking different materials with varying band gaps, multijunction cells achieve higher efficiency than single-junction cells. They are often used in concentrated photovoltaic (CPV) systems and space applications where efficiency is crucial.

Organic Cells: Organic photovoltaic (OPV) cells utilize organic materials, such as polymers or small molecules, as the active layer. These cells have the potential for low-cost production and can be flexible. However, they currently have lower efficiencies compared to traditional PV technologies and are primarily used in niche applications.

Dye-Sensitized Cells: Dye-sensitized solar cells (DSSCs) use a layer of photosensitive dye to capture sunlight. The dye absorbs photons and transfers the energy to a semiconductor material, generating an electric current. DSSCs have lower production costs and perform well under low-light conditions, but their efficiency is typically lower compared to other PV cell types.

Perovskite Cells: Perovskite solar cells are an emerging technology that uses perovskite materials as the light-absorbing layer. These cells have rapidly improved in efficiency in recent years and have the potential for low-cost production. However, further research is still underway to address issues related to stability and scalability.

1.4 Solar Tracking

A solar tracking system is a mechanism or device used to orient solar panels or mirrors toward the Sun to maximize the absorption of solar radiation. The primary goal of a solar tracking system is to optimize the incident angle of sunlight on the solar panels, ensuring that they receive the highest possible solar irradiance throughout the day. This increased efficiency can significantly enhance the energy output of solar power systems. There are primarily two types of solar tracking systems: single-axis and dual-axis.

Single-Axis Tracking System: A single-axis tracking system adjusts the position of solar panels along one axis, typically either the horizontal (azimuth) or vertical (elevation) axis. Horizontal single-axis tracking systems rotate the solar panels from east to west, following the Sun's path throughout the day. This allows the panels to face the Sun directly as it moves across the sky. Vertical single-axis tracking systems tilt the panels to optimize the angle of incidence as the Sun's elevation changes throughout the day. Single-axis tracking systems are relatively simpler and more cost-effective than dual-axis systems.

Dual-Axis Tracking System: A dual-axis tracking system adjusts the position of solar panels along both the horizontal and vertical axes. These systems allow the solar panels to track the Sun's movement both horizontally and vertically, ensuring that they are always perpendicular to the incoming sunlight. Dual-axis tracking systems offer the highest level of accuracy and efficiency, as they can follow the Sun's position more precisely throughout the day. However, they are more complex and expensive compared to single-axis systems.

1.4.1 Effect of Tracking

Solar tracking systems offer several benefits and effects that can enhance the performance and efficiency of solar power systems. Here are some key effects of using a solar tracking system:

Increased Energy Production: Solar tracking systems allow solar panels to continuously face the Sun as it moves across the sky. By optimizing the incident angle of sunlight, the panels can capture more solar radiation throughout the day. This increased exposure to sunlight leads to higher energy production compared to fixed-tilt systems. Studies have shown that solar tracking systems can improve energy production by 20% to 40% or more, depending on the location and tracking accuracy.

Extended Peak Power Output: With solar tracking, the peak power output of solar panels is extended. Fixed-tilt systems have a relatively short period of optimal performance during the day when the Sun is directly facing the panels. In contrast, solar tracking systems continuously adjust the panels to face the Sun, maximizing power output over a more extended period. This can be particularly beneficial during mornings and evenings when the Sun is at lower angles.

Improved Efficiency: Solar tracking systems maximize the utilization of available solar irradiance by reducing the incidence angle mismatch between the solar panels and sunlight. By maintaining an optimal angle of incidence, the system reduces reflection and increases the amount of solar radiation absorbed by the panels. This leads to improved overall system efficiency and higher energy conversion rates.

Enhanced Return on Investment (ROI): Solar tracking systems can provide a higher return on investment over the lifespan of a solar power system. The increased energy production and improved efficiency result in higher electricity generation, which can lead to faster payback periods and greater financial benefits. While solar tracking systems have higher upfront costs compared to fixed-tilt systems, the additional energy generated can offset the initial investment.

Reduced Land Requirement: Solar tracking systems can generate more energy per unit area compared to fixed-tilt systems. By maximizing the energy output from a given area, solar tracking systems can help reduce the land requirement for solar power installations. This is particularly advantageous in situations where available land is limited or expensive.

CHAPTER 02

LITERATURE SURVEY

2.1 INTRODUCTION

The available renewable energy resources are solar, Wind, Hydro, Fuel Cell (FC) etc. Among these, the solar energy is a pollution free, promising and reliable green source to meet the growing demand. The increasing demand for energy with the concern of depletion in conventional fuels, and protecting the environment from pollution have made the researchers to develop a new solution of utilizing the renewable energy. Considering all these factors. The PV system converts sunlight into electrical power using the principle of photovoltaic effect. Whenever light falls on PV cell, the energy from photon is transferred to the charge carriers. Then the charge carriers split into positively charged holes and negatively charged electrons due to the electric field across the junction. This results in the flow of current if a closed path is provided to the circuit by connecting a load. The basic operation of a PV cell is shown in Fig.1. The total amount of solar energy that consumed worldwide increased exponentially the total capacity, generated, and consumed energy has increased exponentially, and the total growth of solar energy capacity and usage is 29.6%.

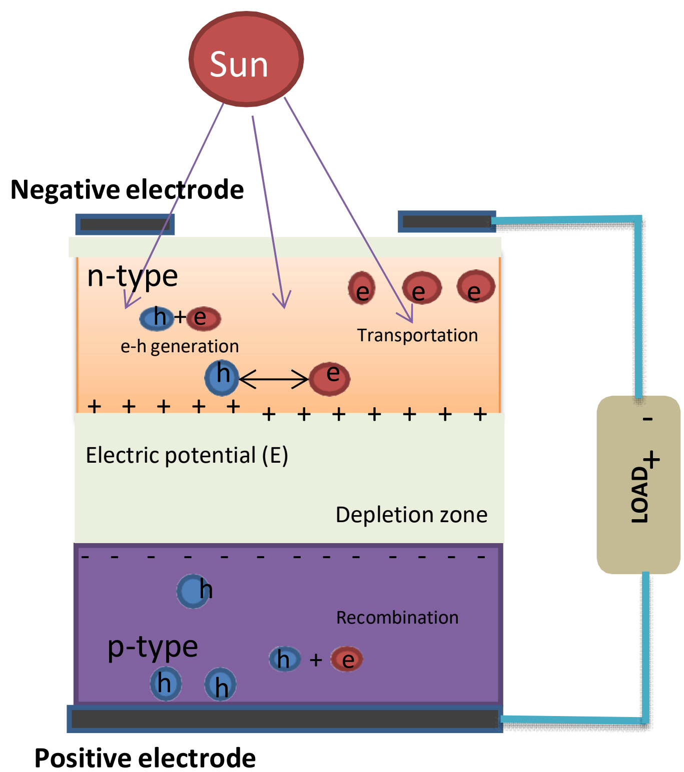


Fig 1: Solar Tracking System

A. Need: Sun irradiance varies with months, time of day, weather conditions, geographical area, and position of the sun in the sky. So to maintain the maximum irradiance the system called as solar tracker is generally used which can enhances power output by 25%. Solar tracker systems are designed and developed to increase the amount of solar radiation received by photovoltaic devices and thereby increasing the output of PV module. This process is carried out by maintaining the optimum angle of the solar panel to produce the best power output. Many solar tracking systems have been built and designed to achieve the optimal amount of solar energy, and many models have been proposed to enhance the efficiency of PV module.

A solar tracking system tracks the position of the sun and maintains the solar photovoltaic modules at an angle that produces the best power output. Several solar tracking principles and techniques have been proposed to track the sun efficiently. The idea behind designing a solar tracking system is to fix solar photovoltaic modules in a position that can track the motion of the sun across the sky to capture the maximum amount of sunlight. Tracker system should be placed in a position that can receive the best angle of incidence to maximize the electrical energy output.

2.2 Type of Tracking

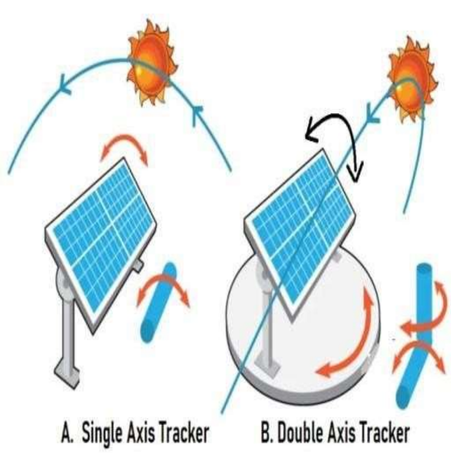
The complexity of a tracking system depends on the number of axes used to move the solar photovoltaic modules i.e. horizontally, vertically, or both. Two main types of solar tracking systems exist. The first one is single axis tracking, which can be used to move the solar photovoltaic horizontally or vertically. The second type is dual axis solar tracking systems, also known as two-axis tracking, which can be used to simultaneously change in both angles of azimuth and tilt angle. In other words the tracker which track sun in only one direction is single axis tracker while if it tracks in both direction the tracker will be called as double axis tracker system as shown in fig.2

Moving solar tracking systems from side to side is equally important as cost of doing so. Therefore solar tracking systems can be manually moved mechanically through the use of cantilevers, gears or motors. The most important point to assist the proposed solar tracking systems is calculating the gained energy compared with the consumed energy by the tracker components. Motors, hardware components, resistors, and the size of photovoltaic panels can affect the gained power. Solar tracking systems can be mainly divided into two main groups based on the techniques that control the photovoltaic module. These two main groups are active and passive tracking system. Active tracking systems use some form of electric energy to drive motors and gear trains to direct the panel toward the sun. Passive tracking systems uses the non-electric energy such as a low boiling point compressed gas fluid that expands due to energy gain from solar heat or any other phase change material.

2.2.1. Active Tracking

Active and passive solar tracking are the two main techniques utilized to efficiently track the sun. Active tracker accounts 75% usage in applications while the second most type is the passive solar tracker accounting 7.55%. [1] In general the tracker uses light detecting sensors like LDR, averages of the signals generated from four LDR's placed at the four corners of a photovoltaic cell. Based on the computed averages, the microcontroller gives instructions to servomotors for rotation of the PV cells towards the direction of maximum incident sun rays as shown in Fig. 2. Their result obtained show a 54.71% increase in the generated output power for the tracking system as opposed to the fixed solar panel [2].

Another Study of 5 PV cells as the input device to controller for photovoltaic performance of a dual-axis solar tracker based on photovoltaic cells with different inclination angles at high altitudes above 3800 m.a.s.l. A solar tracking system activated by two linear actuators was implemented to automatically follow the trajectory of the sun during the day. As shown in fig.3,



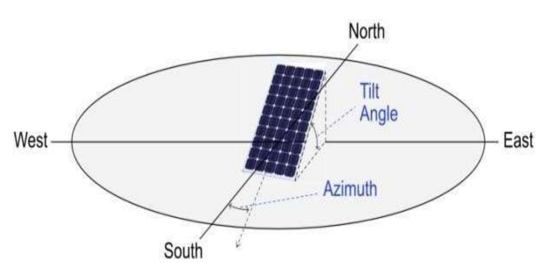


Fig 2: Magnetization as a function of applied field fig 3 : Solar Tracking

Each PV cell measures the solar irradiance independently connected to the PLC; within its programming, the PLC obtains the maximum reference solar irradiance value and compares it with the irradiance of the solar tracker to optimize the range of motion of the axes and find the point of maximum power. It reviles comparison of fixed, single and double tracking system. Tracking sun improves the efficiency of energy conversion up to 24% to 30 % like the dual-axis solar tracker had a maximum monthly photovoltaic yield of 37.63% more than the fixed photovoltaic system and the energy production of 10.66 kWh/m2 /d more than that in the fixed system[3], which produced 7.75 kWh/m2 /d as shown in fig.4. In contrast, on rainy days with partial cloudiness, the performance of both photovoltaic systems was reduced to 14.38%,[4] but this may not be true all the time considering the availability of sun rays region wise.

Efficiency of Fixed Photovoltaic module is 0.4% greater than single Sun Tracker Photovoltaic. In the dry season, Sun Tracker Photovoltaic has 0.5% greater interference than Photovoltaic Fixed Mounting. The maximum efficiency in Photovoltaic Fixed Installation is 12.4%, while the maximum efficiency of Sun Tracker photovoltaic is 13%.[5] Thus using solar trackers more solar radiation are allowed to capture by maintaining the surface of the module approximately perpendicular to the source for a longer period thereby producing more electric power. Another studies shows that, Active- single-axis and double-axis solar tracking systems maximize electricity production, increasing the capture of solar radiation and photovoltaic efficiency by between 15% and 45% compared to other fixed photovoltaic systems of equal power [6]; by 19.97% compared with dual-axis systems based on light dependent resistors (LDR) [7]; by up to 40% compared with other low-cost systems with four and 8 simulated LDRs [8] and by up to 54.39% compared to using a closed circuit control loop[9]. Currently, dual-axis solar trackers have greater photovoltaic efficiency in the production of electricity because they follow the trajectory of the sun in a synchronized movement across the horizontal as azimuth angle and vertical axes.

To control a solar trajectory tracking system, several control strategies are used, including open, closed or combined loops [9], Classic strategies such as ON-OFF, PI and PID controls, and control algorithms through a programmable logic controller (PLC). For entering information about the sensors, the sequence of the processes and the output of the actuators that automatically direct the solar tracker software can be used [10]. Therefore, some solar trackers use photo sensors or photodiodes as the main solar tracking device; however, the normal operation of these sensors depends on clear skies and favorable weather conditions [11].

Others have used low-cost LDRs [12] and photovoltaic panels [5, 13]. In addition, the performance of these solar trackers can be improved by MPPT strategies [14]. The performance of trackers is affected by several factors, such as irregular precipitation, partial cloud cover, seasonality and altitude. To correlate these variables in a scatter plot, performing principal component analysis is used to determine which factor influences the loss of performance [15]. This technique divides the variables into relevant blocks and is very effective for the monitoring and detection of faults.

The study also shows that performance of both type of tracker is function of types of actuators, mechanical components, materials and pay load of solar module and terrain of operation.

2.2.1. PASSIVE TRACKER

Other type of tracker system is passive which uses either the phase change material which changes physical properties of fluids as solar energy in tracking the sun or gravitational potential or through mounting spring or integration of wind energy. An early attempt for single axis passive solar tracker based on shape memory alloy (SMA) actuators tested and found useful than bimetallic actuators with higher efficiency [16].On other hand bimetallic laminates of Ni36/Mn75Ni15Cu10 strip for organic cell can be used as main actuator for tracking which changes the shape as it bend and deform due to the influence of temperature depending on the shadow area and the solar cell perpendicular to light as shown in fig.5 and 6.

Fig 3: Application of bimetallic and laminate for solar tracking

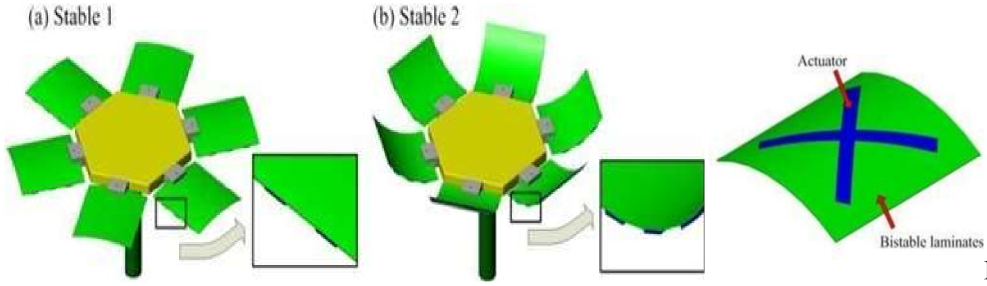


Fig.

Fig 4: Actuation effect of laminate and bimetal from stable 1 to 2 and position of actuator and laminate

The results hold good feasibility and reasonable in term of stability, deformation process of bistable laminates. The study reviles the deformation capability called as actuation effect which is directly related with tracking efficiency is function of the snap-through temperatures, arrangement of the bimetallic strip on the bistable laminates, thickness of the bimetallic strip tested numerically and experimentally and has reasonably good aggregate[17]. Clifford et. Al. designs a bimetallic strip tracker which consists of two bimetallic strips of aluminum and steel. The bimetallic strips are positioned on a wooden frame, symmetrically on either side of a central horizontal axis such that the strip which is way from the sun absorbs thermal radiation as shown in fig.7 while the other remains shaded.

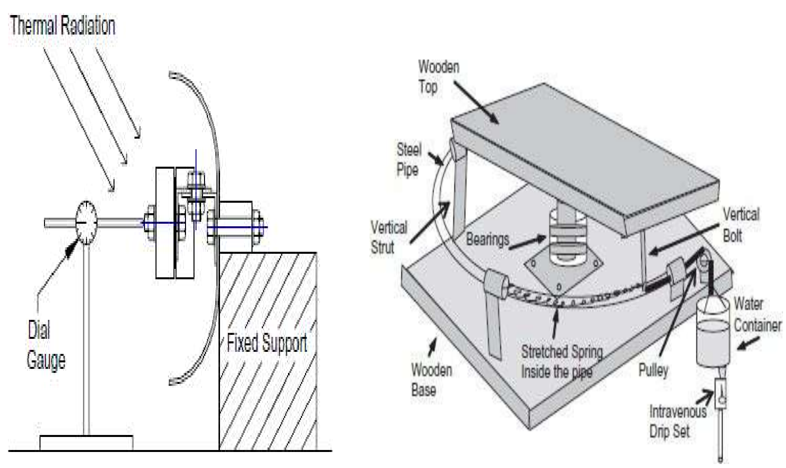


Fig. 5: Gravity based Passive Tracked

The exposed bimetallic strip gets hotter; the aluminum bends more than the steel due to its higher coefficient of thermal expansion. This bending causes a maximum deflection at the strip midpoint and with the attached mass an unbalanced moment results, which generating movement towards the sun rotates the solar panel along [18]. Another attempt by Suhail Zaki Farooqui et.al.[19] is of making gravity based solar tracker for specially solar cooker. It consists of actuation of stretch spring and mirror as shown in fig.8.

Initially Water stored inside a container is attached to a spring through a chord, thus an amount of potential energy stored in the stretched spring and water get discharged at a constant rate from the container, thus the spring slowly returns to its un-stretched position dragging the solar cooker along with it. Further, by increasing the height of the booster mirror attached to the solar cooker fulfills the requirement of tracking along changing solar elevation. The controlled discharge of water if matched with the rate of change of the solar azimuth, the solar tracking can be achieved. The whole system has been optimized for 6 h of cooking per day, without manual tracking resulted optimum angle of inclination of the booster mirror as 25 degree.

2.3 CONCIUSION

Solar tracking systems have very high efficiency and performance compared with fixed or stationary solar photovoltaic systems. The main advantage of solar tracking systems is the increased electricity generation depending on the geographical location of the solar tracker and other variables. However, solar tracking systems possess numerous limitations. Solar tracking systems are more expensive than fixed systems due to the complexity of the technology used and their use of expensive products for their complex operations. It is observed that active tracker using optical sensor and microcontroller based active drives offer the advantage of high precision tracking and are used widely and also frequently used in comparison with the auxiliary bifacial and time based active drives. However, they have a common disadvantage of low efficiency on cloudy days since the sensors require sunlight to function effectively. Passive drives rely on the changing physical properties of fluids rather than complex and complicated control circuits, motors, gears and sensors used in active drives. This makes them more viable than active drives. Also the factors that affect the energy output of such systems include the photovoltaic material, geographical location of solar irradiances, ambient temperature and weather, angle of sun incidence, and orientation of the panel.

CHAPTER 03

METHODOLOGY

Research and Literature Review:

Conduct a comprehensive literature review on solar tracking systems, focusing on both active and passive tracking mechanisms. Explore the principles, advantages, and limitations of different tracking approaches. Identify key design considerations, such as incident angle optimization, mechanical components, and system efficiency.

System Requirements and Design Specifications:

Define the specific requirements for the passive solar tracking system based on project goals and objectives. Determine the desired accuracy, tracking range, and adaptability to different solar panel configurations. Establish design specifications for the mechanical components, sensors, and actuators of the tracking system.

Conceptual Design:

Develop a conceptual design for the passive solar tracking system, considering simplicity, reliability, and cost-effectiveness. Determine the tracking mechanism based on selected passive tracking techniques, such as bimetallic strips, compressed gas systems, or shape memory alloys.

Create initial sketches, diagrams, and 3D models to visualize the overall system design and components.

Detailed Engineering Design:

Refine the conceptual design into a detailed engineering design, incorporating specific mechanical components and materials. Use computer-aided design (CAD) software to create precise 3D models of the tracking mechanism and related subsystems. Perform structural analysis and simulations to ensure the design's mechanical integrity and reliability.

Component Selection and Procurement:

Select mechanical components, such as linkages, gears, and pivots, based on design specifications and compatibility with the passive tracking mechanism. Source lightweight and durable materials suitable for the fabrication of the tracking system.

Procure necessary sensors, actuators, and other electronic components required for the autonomous operation of the system.

Prototype Development and Testing:

Fabricate a prototype of the passive solar tracking system, following the detailed engineering design. Assemble the mechanical components, integrate sensors and actuators, and ensure proper alignment and movement of the tracking mechanism.

Conduct extensive testing of the prototype under various environmental conditions, recording data on energy output, tracking accuracy, and system efficiency.

Performance Evaluation and Optimization:

Analyze the test data to evaluate the performance of the passive solar tracking system. Assess energy production improvements and compare them with fixed-tilt systems or simulations. Identify areas for optimization and refinement in the design and operation of the tracking system, addressing any limitations or challenges.

Manufacturing and Production:

Finalize the design based on the prototype evaluation and optimization results. Scale up the manufacturing process for mass production of the passive solar tracking system. Ensure quality control measures are in place during manufacturing to maintain consistency and reliability of the tracking systems produced.

Documentation and Reporting:

Prepare a comprehensive report documenting the entire project, including methodology, design specifications, testing procedures, results, and analysis. Present the findings in a clear and concise manner, supported by visuals such as diagrams, charts, and photographs. Include detailed documentation of the design, fabrication, and assembly processes for future reference.

Conclusion and Future Work:

Summarize the project's key findings, emphasizing the feasibility and benefits of the passive solar tracking system. Discuss potential future research and development opportunities for further improving the design, efficiency, and applicability of the passive tracking mechanism. Reflect on the project's relevance in promoting sustainable and efficient solar power systems.

Project Management:

Establish a project timeline, milestones, and task assignments to ensure effective project management. Monitor and track progress regularly, addressing any challenges or obstacles that arise. Allocate resources appropriately and ensure adherence to project goals and objectives. Maintain effective communication and collaboration among team members throughout the project lifecycle.

CHAPTER 04

DESIGN AND SIMULATION

4.1 Identifying the problem

The main problem is the eliminating power consumption required to solar tracking system. Design the pure mechanical solar tracker. The problem addressed by the proposed solar power system is the limited availability of sustainable and cost-effective power generation solutions for various settings, particularly in domestic as well as industrial. The problem addressed in this project is the suboptimal energy production and efficiency of conventional fixed-tilt solar power systems due to the inability to track the movement of the Sun. Fixed-tilt systems have a fixed angle, resulting in reduced exposure to direct sunlight and suboptimal incident angles throughout the day. This leads to lower energy output and missed opportunities to harness the full potential of solar radiation.

4.2 Selection of project

We conducted extensive research and evaluation of different methods and mechanisms that could be integrated into the solar power system. We considered various factors such as efficiency, cost, scalability, and ease of use, among others. We analyzed the strengths and limitations of each option, and weighed them against our requirements and design objectives. Through a collaborative process of brainstorming and analysis, we arrived at the final design that effectively addressed the challenges and needs of the project. The selected method and mechanism offered a well-balanced solution that met the performance, portability, and affordability requirements of the project.

4.3 Project planning

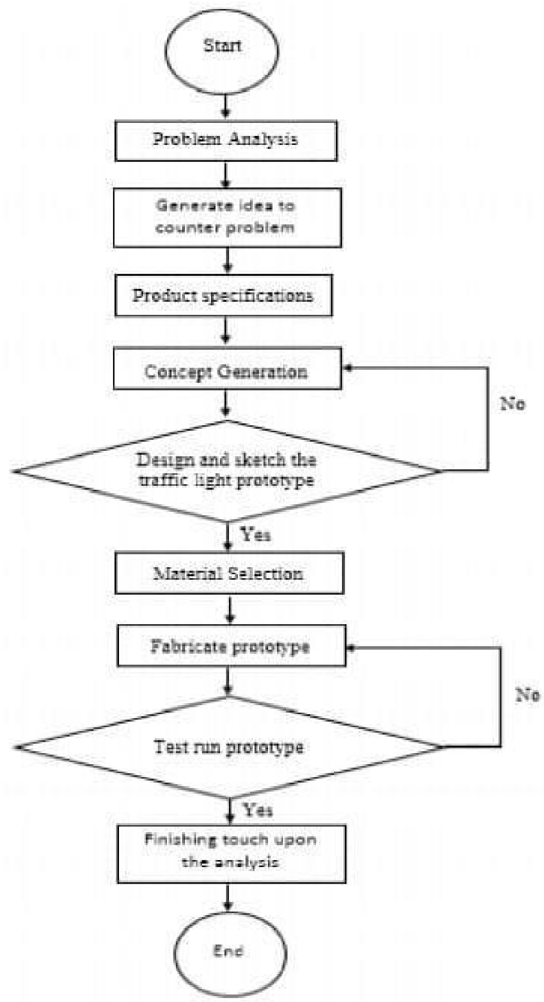


Fig. flow chart

4.4 Design Process

Design process for the proposed solar power system involves several key steps:

1. Defining the requirements: This involves identifying the power requirements of the system and the specific application of the system, such as water pumping or irrigation in agriculture and domestic.
2. Selecting components: Based on the power requirements, suitable solar panels, tracking mechanism, and portable power unit will be selected.

3. Designing the sliding mechanism: A sliding mechanism will be designed to facilitate the movement of the solar panel, ensuring optimal positioning for maximum energy generation.
4. Designing the tracking mechanism: The tracking mechanism will be designed to adjust the tilt angle of the solar panel automatically based on the position of the sun, maximizing the energy output.
5. Designing the portable power unit: The portable power unit will be designed to provide flexibility in power requirements and ease of transportation.
6. Integrating the components: All components will be integrated to form a cohesive solar power system that is efficient, portable, and suitable for various settings.
7. Testing and refinement: The system will be tested and refined to optimize its efficiency and performance, ensuring that it meets the power requirements of the application.

4.5 CAD Model

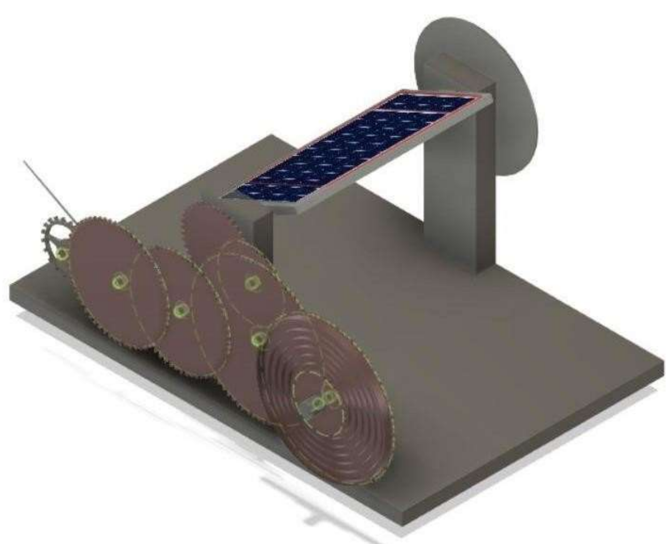


Fig 7: Isometric View

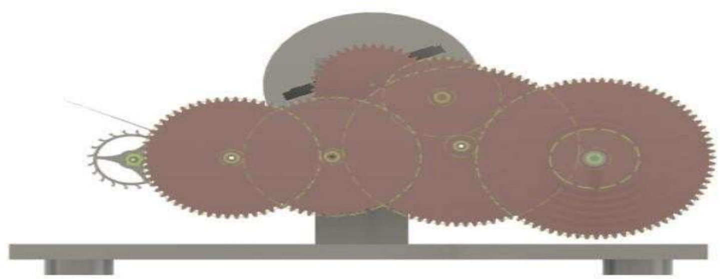
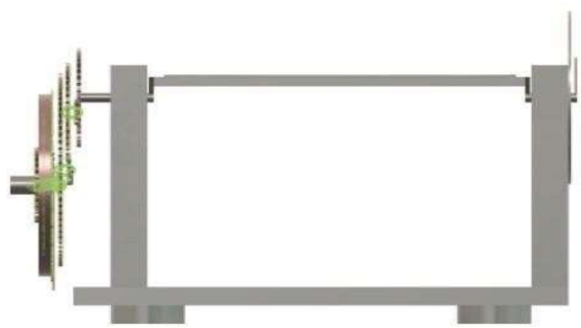
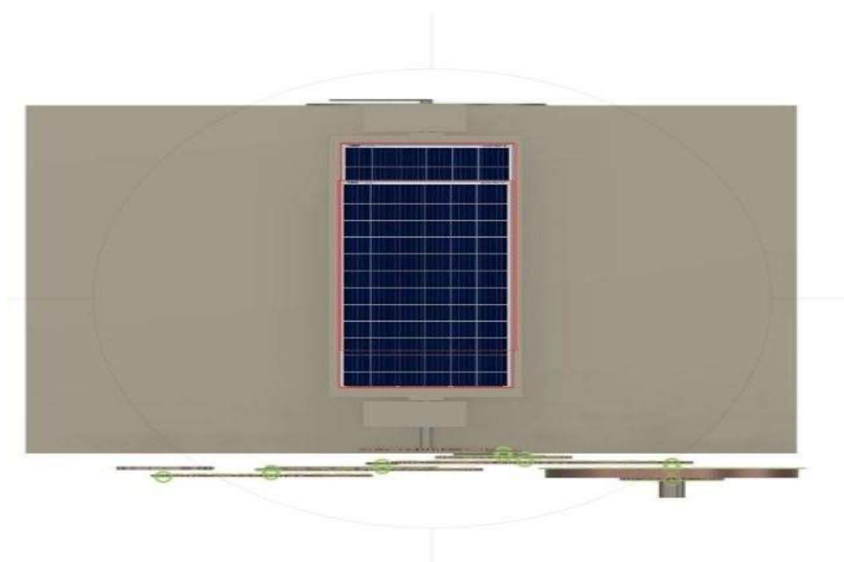


fig 8 Side View





Top View

CHAPTER 05

DESIGN CALCULATIONS

Design Calculation

5.1 Calculation

The project is design and manufacturing of passive solar tracking system, for the competition this we must calculate the design specification material. An average the sun is providing maximum intensity of the solar radiation in 8 hr. per day. For the tracking the maximum solar radiation we need to move the solar plate through the120 degree per day with the angular speed of the sun radiation.

We have a solar plate having mass of 3 kg and plate dimension are 340mm length 240mm width 20mm thickness is need to be revolve through 120 degree per 8 hr. in a single day for that following calculations:

Mass of the rectangular flat solar plate (m): 3 kgLength of the plate (l): 0.34 m

Width of the plate (w): 0.24 m Thickness of the plate (t): 0.02 m Angular displacement (θ): 120 degreesTime (t): 8 hours

Calculations:

Convert the given angular displacement from degrees to radians:θ_radians = 120 * (π/180)

θ_radians ≈ 2.094 radians Calculate the angular velocity (ω):

ω = θ_radians / t

ω ≈ 2.094 radians / (8 hours * 3600 seconds/hour)ω ≈ 7.3 x 10^(-5) radians/second

Calculate the moment of inertia (I) of the rectangular plate:I = (1/12) * m * (l^2 + w^2)

I = (1/12) * 3 kg * ((0.34 m)^2 + (0.24 m)^2)

I ≈ 0.118 kg * m^2

Calculate the angular acceleration (α):

α = ω / t

α = (7.3 x 10^(-5) radians/second) / (8 hours * 3600 seconds/hour)α ≈ 2.7 x 10^(-9) radians/second^2

Calculate the torque (τ):

$$\tau = I * \alpha$$

$$\tau = (0.118 \text{ kg} * m^2) * (2.7 \times 10^{-9} \text{ radians/second}^2)$$

$$\tau \approx 3.2 \times 10^{-11} \text{ Nm (Newton meters}$$

So, based on the given angular displacement and time, the calculated torque required to rotate the rectangular flat solar plate is approximately 3.2 x 10^(-11) Nm.

For achieving this torque we must design the spiral spring for the following calculations:

Material: Steel

Assumed material: Spring steel (commonly used for spring manufacturing)

Determine the spring constants:

Spring constant (k): This represents the stiffness of the spring and is typically measured in force per unit of displacement. It depends on the geometry of the spring and the material properties.

Assumed spring constant: k = 300 N/m (suitable for this example)

Determine the maximum stress and deflection:

Maximum allowable stress (σ_{max}): This is the maximum stress that the material can withstand without permanent deformation or failure. It depends on the material properties. Assumed maximum allowable stress: σ_{max} = 800 MPa Maximum deflections (δ_{max}): This is the maximum displacement of the spring under load. Assumed maximum deflection: δ_{max} = 10 Calculate the dimensions:

Inner diameter (D): Determine the desired inner diameter of the spring. For this example, let's assume D = 25 mm.

Outer diameter (d): Calculate the outer diameter based on the inner diameter and the thickness of the spring. d = D + 2 * thickness = 25 mm + 2 * 0.5 mm = 26 mm

Number of coils (n): Determine the number of coils based on the desired length, maximum deflection, and coil pitch (distance between successive coils). For this example, let's assume a pitch of 5 mm. n = length / pitch = 2000 mm / 5 mm = 400 coils

Width (w): The width of the spring is given as 3 mm.

Calculate the moment of inertia:

Moment of inertia (I): This parameter represents the resistance of the spring to bending and twisting.

Assumed moment of inertia: I = (d^4 - D^4) / 64 = (26^4 - 25^4) / 64 = 1288.4 mm^4

Check the maximum stress:

Calculate the maximum stress in the spring using the maximum deflection and the spring constant. σ = k * δ_max = 300 N/m * 10 mm = 3000 N/mm^2 (MPa)Ensure that the calculated maximum stress (σ) is lower than the maximum allowable stress (σ_max). If σ > σ_max, adjust the spring dimensions or material properties accordingly.

Manufacturing considerations:

The flat spiral spring can be manufactured by winding the spring steel strip into the desired shape and then heat treating it to improve its mechanical properties. Additional considerations such as end configurations, mounting options, and surface finish should be taken into account based on the specific application requirements.

Material: Steel

Thickness: 0.5 mm

Length: 2 m

Width: 3 mm

Assuming a suitable data, we can determine the spring dimensions as follows:

Wire diameter (d): The wire diameter can be calculated by subtracting the double thickness from the width of the material:

d = Width - 2 * Thickness d = 3 mm - 2 * 0.5 mm d = 2 mm

Mean coil diameter (D): The mean coil diameter is calculated by adding the wire diameter to the thickness:

D = Wire diameter + Thickness D = 2 mm + 0.5 mm D = 2.5 mm

Number of active coils (n): The number of active coils is determined based on the desired spring rate and available space. Since the specific requirements are not provided, we'll assume a suitable number of coils based on typical spring designs:

n = 10

End configurations: For simplicity, we'll assume open ends for the spring design.

With the above parameters, we have determined the following dimensions for the spiral spring:

Wire diameter (d): 2 mm

Mean coil diameter (D): 25 mm

Number of active coils (n): 10

End configurations: Open ends

This spiral spring provide the angular speed is 2 rad per min to the gear attached to the spiral spring this speed match with the sun radiation speed for that the gear and pinion assembly for that calculation:

Angular Velocity

$\alpha = \omega/T$

$= 2.525*10^{-9}$

Now,

Torque = Moment of inertia * angular velocity

$T = I* \alpha$

$=0.0403 *2.525*10^{-9}$

$= 1.093*10^{-10}$

Here,

The force required to produce this torque

$T = F*r*\text{Gear ratio}$

$F = T/r* \text{Gear ratio}$

$F = 1.093*10^{-10} /0.041*0.02$

$F = 1.332*10^{-7}$

The spring attached to the gear is providing the angular speed at 1 rad/sec

For 1 gear,

$W_{out} = W_{in} * \text{Gear ratio}$

$= 1*1/24$

$= 0.041$ rad/sec

For 2 gear,

$W_{out} = W_{in} * \text{Gear ratio}$

$= 0.041 * 1/24$

$= 1.736*10^{-3}$ rad/sec

For 3 gear,

$W_{out} = W_{in} *\text{Gear ratio}$

$= 1.736 * 10^{-3}*1/24$

$= 7.23 *10^{-5}$ rad/sec

This is the required angular speed for rotation at the solar panel through 120 Degree in 8 hours per day

CHAPTER 06

WORKING AND COMPONENT

Working and Component

6.1 Working

The solar tracking system work on the Energy provided by the spiral spring, with the help of gear assembly. In this solar traker system the electrical power consumption devices are totally eliminated. In this system the key is provided for supplying the mechanical power by manually at once spring is fully charged. If the spiral spring is fully charged there are one escape mechanism is attached from that the spiral spring reduces their energy with regulated speed.

Fig 9 working model

The spiral spring is attached to the gear with the help of shift on that one sided bearing are fitted. This gear will attach to another compound gear for speed reduction and increasing the torque. For matching the speed of the solar plate we must provide suitable torque and the force to lift the plate according that design gear and pinion assembly. With the help of this torque is supply to the rotation shaft of the panel and rotate the solar panel.

6.2 Component

The manufacturing the solar tracking system there is following component is required. In which some are the energy storage and the speed reducing element.

Spiral Spring: A spiral spring, also known as a helical spring, is a type of mechanical spring that is formed by coiling a wire in a helical or spiral shape. It is one of the most commonly used types of springs due to its flexibility, compactness, and ability to store and release mechanical energy.in this tracker steel material spring is used having thickness is 0.5 mm length is 2m width is 3mm.

Escape mechanism: An escape mechanism, also known as an escapement, is a crucial component in mechanical timekeeping devices such as clocks and watches. It regulates the release of energy from the power source (such as a mainspring or weight) to drive the timekeeping mechanism in a controlled and precise manner. The escape mechanism consists of several interacting components that work together to control the movement of the gear train and the display of time. The main function of the escape mechanism is to convert the continuous rotational energy of the power source into intermittent, controlled movements

The basic operation of an escape mechanism involves the following components:

Escape Wheel: The escape wheel is a gear with specially shaped teeth. It receives power from the mainspring or weight and rotates in small, regular increments.

Pallet Fork: The pallet fork is a lever-like component that interacts with the escape wheel. It has two pallets that engage with the teeth of the escape wheel, allowing the wheel to rotate incrementally. Balance Wheel or Pendulum: In mechanical watches or clocks, an oscillating component like a balance wheel or pendulum is usually present. It provides a periodic back-and-forth motion that helps regulate the timing of the escape mechanism.

Pallet Jewels: The pallet jewels are small, precisely shaped gemstones or synthetic jewels that serve as bearings for the pallet fork, reducing friction and ensuring smooth movement.

Balance Spring: In mechanical watches, a balance spring (also known as a hairspring) is used in conjunction with the balance wheel. It provides a restoring force that keeps the oscillation of the balance wheel controlled and regular Gear And pinion assembly: Gear and pinion assembly is a mechanical system that involves the coupling of a gear and a pinion to transmit rotational motion and torque between two or more components.: A driving shaft, also known as a drive shaft or propeller shaft, is a mechanical component used to transmit torque and rotational motion between two or more rotating parts. It is commonly used in various applications, including automotive vehicles, industrial machinery, and power transmission systems. The driving shaft typically consists of a solid or hollow cylindrical shaft with universal joints or constant velocity (CV) joints at each end. These joints allow for flexibility and compensation of misalignment between the driving and driven components while maintaining a constant rotational velocity. In this the driving shaft for the mounting the solar panels well as gear assembly.

Ball bearing: Bearings are mechanical components that facilitate smooth and controlled movement between two or more parts. They reduce friction and provide support, allowing for relative motion while minimizing wear and energy loss. Bearings are used in a wide range of applications, including machinery, vehicles, and industrial equipment.

Supporting body: Standing supporting bodies are utilized in various applications, including architectural structures, furniture design, industrial equipment, and infrastructure. The design and engineering considerations for a standing supporting body depend on the specific requirements of the object being supported, including its weight, shape, anticipated loads, and environmental conditions. In this the standing body for the supporting the solar panel.

Holding box: A holding box, also known as a storage box or container, is a versatile and practical solution for storing and organizing various items. It provides a secure and enclosed space to hold objects, keeping them protected, easily accessible, and free from dust or damage. Holding boxes come in various shapes, sizes, and materials, catering to different storage needs and preferences. In this project the gear arrangement are fitted into the holding box

.

6.3 Specification of material

Component	Material	Speciation
Spiral Spring	Steel	0.5mm thichness,3mm width
Gear 1	Cast iron	35 teeth 40 mm dia
Gear 2	Plastic	75 teeth 61.5mm dia
Escaper	Cast iron	20 mm dia 36 teeth
Pinion	Plastic	20mm 30teeth

Table 1 : Material Specification

CHAPTER 07

FUTURE SCOPE

Future advancements can focus on improving the efficiency of solar tracking systems. This may involve incorporating advanced tracking algorithms, using more accurate Sensors and optimizing the control mechanism to maximize solar energy capture. Additionally, advancements in materials and manufacturing techniques can lead to the development of more efficient and lightweight tracking systems.

Integration with Renewable Energy Systems: Solar tracking systems can be integrated with other renewable energy systems to create hybrid setups. For example, combining solar tracking with wind turbines or incorporating energy storage technologies can enable the efficient utilization of multiple renewable energy sources, improving overall system performance and reliability.
Future developments can focus on reducing the cost of solar tracking systems, making them more affordable and accessible. This can be achieved through advancements in manufacturing processes, component optimization, and the use of cost-effective materials. Additionally, economies of scale and increased market demand can contribute to cost reductions.

Future solar tracking systems can be designed to be adaptable and flexible, capable of tracking the sun's position in various weather conditions and environments. This can involve incorporating intelligent control systems that can adjust tracking parameters based on weather data, cloud cover, or shading, ensuring optimal energy capture under different circumstances. Future solar tracking systems can be designed with scalability in mind, allowing for easy expansion or integration with existing solar installations. Modular designs can enable the addition of tracking units to increase capacity as required, making it adaptable to various project sizes and installations.

The future scope of solar tracking systems is wide-ranging, with opportunities for improving efficiency, integrating with other renewable energy systems, leveraging IoT technologies, reducing costs, enhancing adaptability, and incorporating advanced sensors. These advancements can contribute to the widespread adoption of solar tracking systems and further the development of sustainable and efficient solar energy generation.

CHAPTER 08
RESULT AND CONCLUSION

8.1 Result

From this tracker we can increase the solar panel efficiency of over the steady solar panel below are the observation taken from that we can identify easily.

We know that the angle between the sun's rays and the solar panel is crucial for achieving maximum efficiency. We can conduct an observation by changing the angle of the solar panel at the same time with the same load to determine how the output changes in relation to the position of the solar panel.

TIME	VOLTAGE (V)	CURRENT (A)
08:00 AM	8.5	0.681
10:00 AM	9.5	0.692
12:00 PM	9.8	0.705
02:00 PM	9.9	0.706
03:00 PM	10	0.705
04:00 PM	10.3	0.699
05:00 PM	9.4	0.698

Table 2 : Output of the steady 5 w solar panel with respect to time

TIME	ANGLE	VOLTAGE (V)	CURRENT(A)
08:00 AM	80	10.2	0.699
10:00 AM	75	10.1	0.702
12:00 PM	85	10.2	0.709
02:00 PM	90	10.3	0.710
04:00 PM	85	10.2	0.705
06:00 PM	80	10.1	0.698

Table 3: Output of the 5 watt solar panel with tracker with respect to time

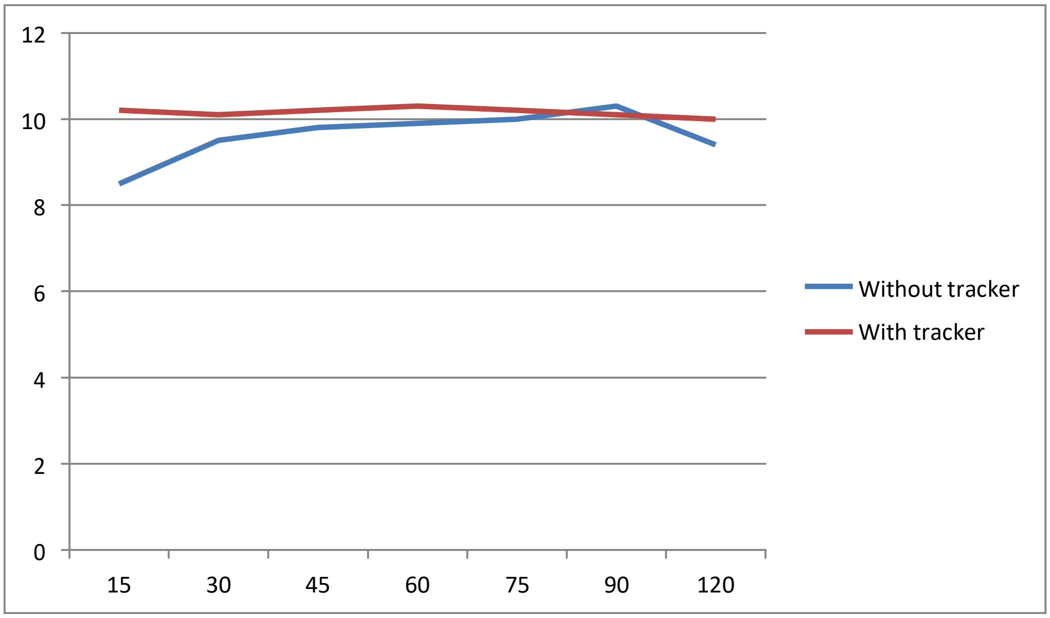


Fig. 10 Comparison of Tracking and without tracking output with Voltage on Y-axis

8.2 Conclusion

The project "Manufacturing of Passive Solar Tracking System" aims to develop an innovative and efficient solar tracking system that maximizes the capture of solar energy. The report has provided an overview of the project, starting with the identification of the problem of inefficient solar energy utilization and the need for a passive solar tracking solution.

The suggested solution of tracking system without any use of energy that developed from PV panel is a better aggregate which provides 15% more energy generation as predicted in review. Overall, the project offers a promising solution for optimizing solar energy capture through passive solar tracking. The report provides a comprehensive understanding of the project's design, manufacturing, and potential future developments. By implementing this passive solar tracking system and considering the future scope, it is expected that the designed and manufactured model will contribute to the advancement of solar energy utilization, promoting sustainable and efficient energy generation.

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Review of Solar Tracking Techniques

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Abstract— Solar tracking drives can be broadly classified as active or passive. Passive drives are mechanical and active drives are electrical or electronics. In this paper, a review of the some recent published techniques for photovoltaic tracking drives is presented. Based on functionality, the published techniques are compared. Active drives are shown to be more efficient when compared with the passive drives but they required power. However, in terms of flexibility and cost, passive drives are more viable than active drives. The merits and demerits of each drives are concluded.

Keywords: Solar Tracking Techniques, Solar, Wind, Hydro, Fuel Cell (FC)

I. INTRODUCTION

The available renewable energy resources are solar, Wind, Hydro, Fuel Cell (FC) etc. Among these, the solar energy is a pollution free, promising and reliable green source to meet the growing demand. The increasing demand for energy with the concern of depletion in conventional fuels, and protecting the environment from pollution have made the researchers to develop a new solution of utilizing the renewable energy. Further, the consumption of fossil fuels results in the emission of greenhouse gases that increases the global warming. Considering all these factors, the renewable energy is one of the best solutions that will provide sufficient and also a clean energy. It also lessens the greenhouse effect. Power can be extracted from the solar irradiation using the photovoltaic (PV) system. The PV system converts sunlight into electrical power using the principle of photovoltaic effect. Whenever light falls on PV cell, the energy from photon is transferred to the charge carriers. Then the charge carriers split into positively charged holes and negatively charged electrons due to the electric field across the junction. This results in the flow of current if a closed path is provided to the circuit by connecting a load. The basic operation of a PV cell is shown in Fig.1. the total amount of solar energy that consumed worldwide increased exponentially the total capacity, generated, and consumed energy has increased exponentially, and the total growth of solar energy capacity and usage is 29.6%.

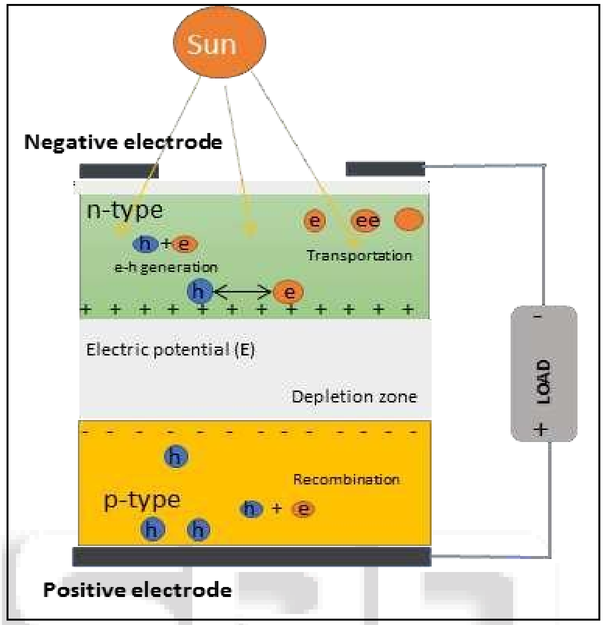

Fig. 1: Solar Tracking System

A. Need:

Sun irradiance varies with months, time of day, weather conditions, geographical area, and position of the sun in the sky. So to maintain the maximum irradiance the system called as solar tracker is generally used which can enhances power output by 25%.

Solar tracker systems are designed and developed to increase the amount of solar radiation received by photovoltaic devices and thereby increasing the output of PV module. This process is carried out by maintaining the optimum angle of the solar panel to produce the best power output. Many solar tracking systems have been built and designed to achieve the optimal amount of solar energy, and many models have been proposed to enhance the efficiency of PV module. A solar tracking system tracks the position of the sun and maintains the solar photovoltaic modules at an angle that produces the best power output. Several solar tracking principles and techniques have been proposed to track the sun efficiently. The idea behind designing a solar tracking system is to fix solar photovoltaic modules in a position that can track the motion of the sun across the sky to capture the maximum amount of sunlight. Tracker system should be placed in a position that can receive the best angle of incidence to maximize the electrical energy output.

B. Type:

The complexity of a tracking system depends on the number of axes used to move the solar photovoltaic modules i.e. horizontally, vertically, or both. Two main types of solar tracking systems exist. The first one is single axis tracking, which can be used to move the solar photovoltaic horizontally or vertically. The second type is dual axis solar tracking systems, also known as two-axis tracking, which can be used to simultaneously change in both angles of azimuth and tilt angle. In other words the tracker which track sun in only one direction is single axis tracker while if it tracks in both direction the tracker will be called as double axis tracker system as shown in fig.2

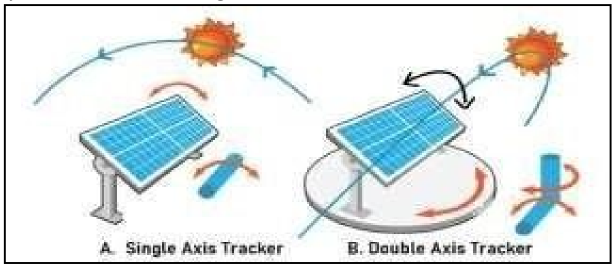

Fig. 2: Magnetization as a function of applied field.

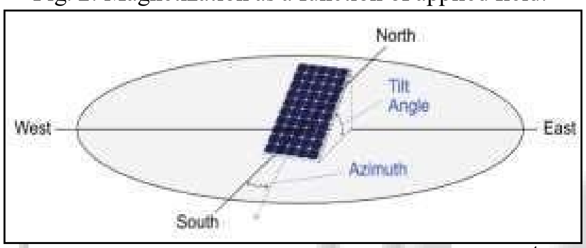

Fig. 3: Solar Tracking Systems Applied Field (10^4 A/m)

Moving solar tracking systems from side to side is equally important as cost of doing so. Therefore solar tracking systems can be manually moved mechanically through the use of cantilevers, gears or motors. The most important point to assist the proposed solar tracking systems is calculating the gained energy compared with the consumed energy by the tracker components. Motors, hardware components, resistors, and the size of photovoltaic panels can affect the gained power.

Solar tracking systems can be mainly divided into two main groups based on the techniques that control the photovoltaic module. These two main groups are active and passive tracking system.

Active tracking systems use some form of electric energy to drive motors and gear trains to direct the panel toward the sun. Passive tracking systems uses the non electric energy such as a low boiling point compressed gas fluid that expands due to energy gain from solar heat or any other phase change material.

C. Active Tracking

Active and passive solar tracking are the two main techniques utilized to efficiently track the sun. Active tracker accounts 75% usage in applications while the second most type is the passive solar tracker accounting 7.55%. [1]

In general the tracker uses light detecting sensors like LDR, averages of the signals generated from four LDR's placed at the four corners of a photovoltaic cell. Based on the computed averages, the microcontroller gives instructions to servomotors for rotation of the PV cells towards the direction of maximum incident sun rays as shown in Fig. 2. Their result obtained show a 54.71% increase in the generated output power for the tracking system as opposed to the fixed solar panel [2].

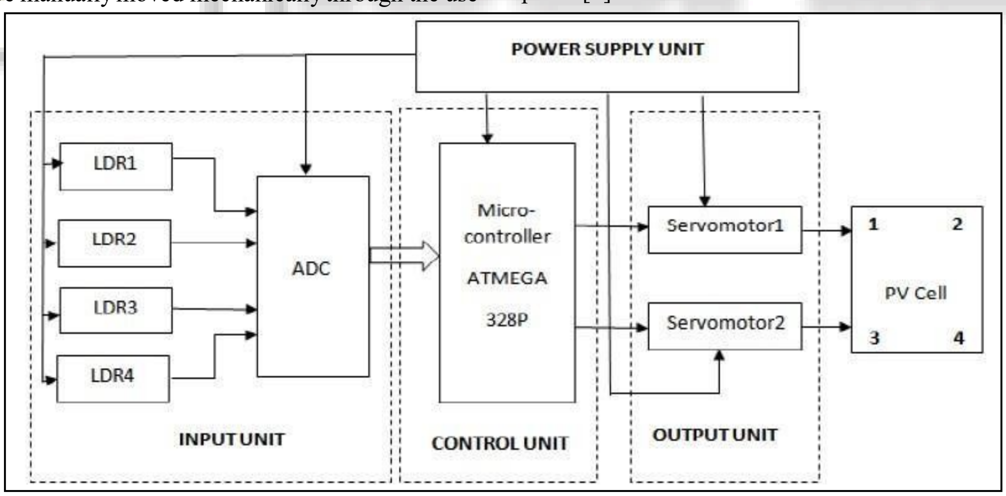

Fig. 4: Controlling configuration block diagram of Active Tracking system

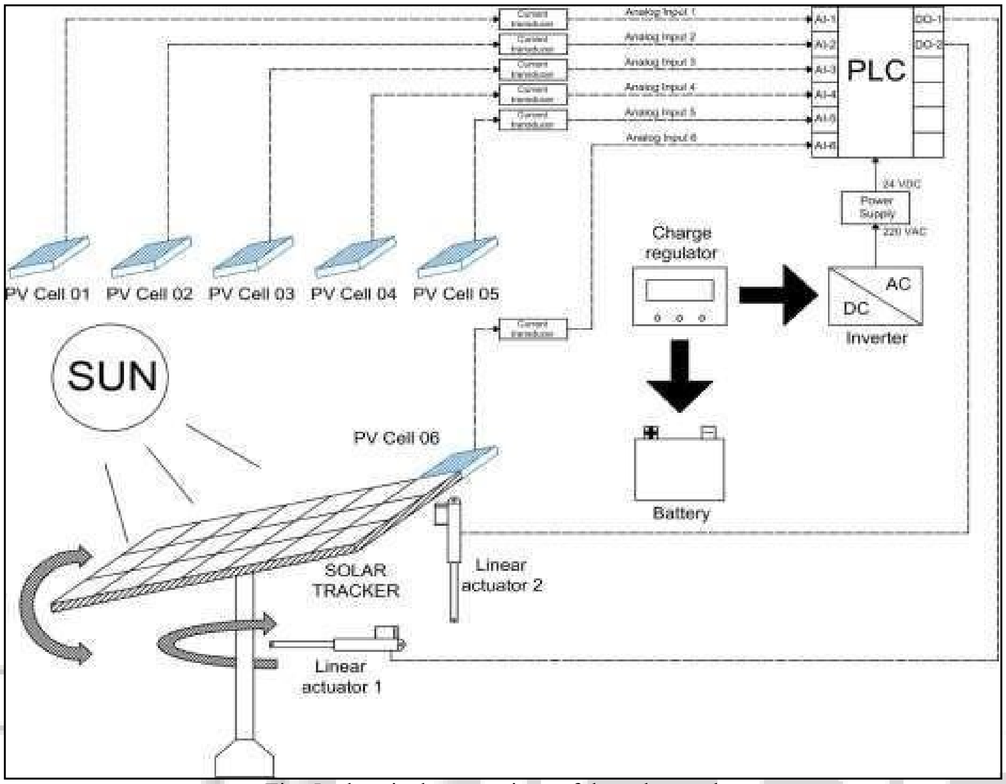

Fig. 5: electrical connections of the solar tracker

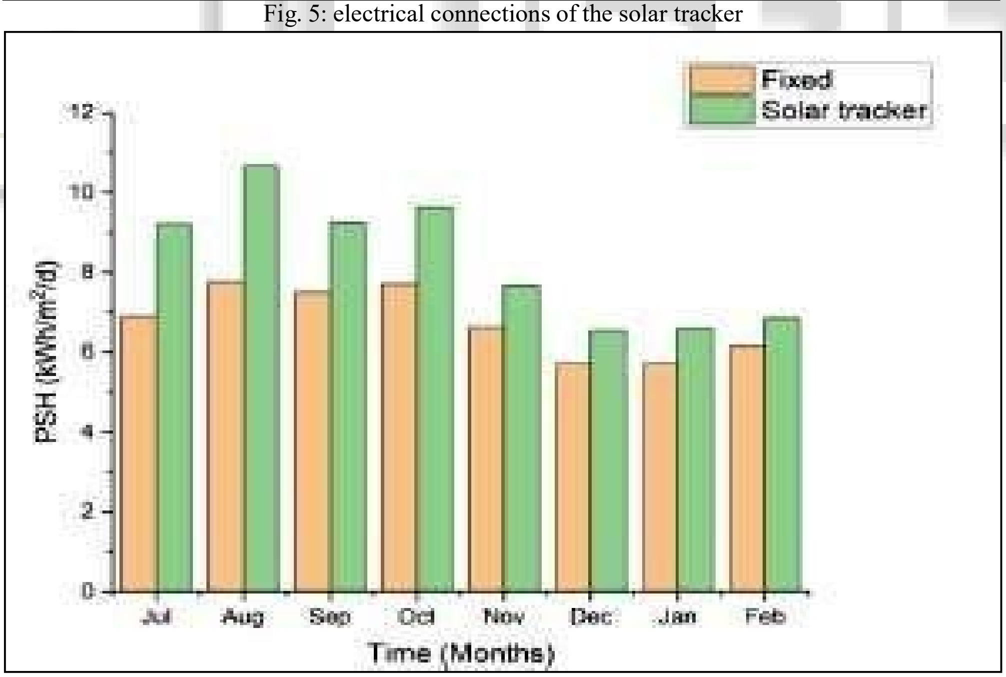

Fig. 6: Monthly energy production of the solar tracker compared to the fixed photovoltaic system

Another Study of 5 PV cells as the input device to controller for photovoltaic performance of a dual-axis solar tracker based on photovoltaic cells with different inclination angles at high altitudes above 3800 m.a.s.l.

A solar tracking system activated by two linear actuators was implemented to automatically follow the trajectory of the sun during the day. As shown in fig.3, Each PV cell measures the solar irradiance independently connected to the PLC; within its programming, the PLC obtains the maximum reference solar irradiance value and compares it with the irradiance of the solar tracker to optimize the range of motion of the axes and find the point of maximum power. It reviles comparison of fixed, single and double tracking system. Tracking sun improves the efficiency of energy conversion up to 24% to 30

% like the dual-axis solar tracker had a maximum monthly photovoltaic yield of 37.63% more than the fixed photovoltaic system and the energy production of 10.66 kWh/m^2/d more than that in the fixed system[3], which produced 7.75 kWh/m^2/d as shown in fig.4.

In contrast, on rainy days with partial cloudiness, the performance of both photovoltaic systems was reduced to 14.38%,[4] but this may not be true all the time considering the availability of sun rays region wise. Efficiency of Fixed Photovoltaics module is 0.4% greater than single Sun Tracker Photovoltaic. In the dry season, Sun Tracker Photovoltaic has 0.5% greater interference than Photovoltaic Fixed Mounting. The maximum efficiency in Photovoltaic Fixed Installation is 12.4%, while the maximum efficiency of Sun Tracker photovoltaic is 13%.[5]

Thus using solar trackers more solar radiation are allowed to capture by maintaining the surface of the module approximately perpendicular to the source for a longer period thereby producing more electric power.

Another studies shows that, Active- single-axis and double-axis solar tracking systems maximize electricity production, increasing the capture of solar radiation and photovoltaic efficiency by between 15% and 45% compared to other fixed photovoltaic systems of equal power [6]; by 19.97% compared with dual-axis systems based on lightdependent resistors (LDR) [7]; by up to 40% compared with other low-cost systems with four and 8 simulated LDRs [8] and by up to 54.39% compared to using a closed circuit control loop[9]. Currently, dual-axis solar trackers have greater photovoltaic efficiency in the production of electricity because they follow the trajectory of the sun in a synchronized movement across the horizontal as azimuth angle and vertical axes.

To control a solar trajectory tracking system, several control strategies are used, including open, closed or combined loops [9], Classic strategies such as ON-OFF, PI and PID controls, control algorithms through a programmable logic controller (PLC). For entering information about the sensors, the sequence of the processes and the output of the actuators that automatically direct the solar tracker software can be used [10]. Therefore, some solar trackers use photosensors or photodiodes as the main solar tracking device; however, the normal operation of these sensors depends on clear skies and favorable weather conditions [11]. Others have used low-cost LDRs [12] and photovoltaic panels [5, 13]. In addition, the performance of these solar trackers can be improved by MPPT strategies [14].

The performance of trackers is affected by several factors, such as irregular precipitation, partial cloud cover, seasonality and altitude. To correlate these variables in a scatter plot, performing principal component analysis is used to determine which factor influences the loss of performance [15]. This technique divides the variables into relevant blocks and is very effective for the monitoring and detection of faults.

The study also shows that performance of both type of tracker is function of types of actuators, mechanical components, materials and pay load of solar module and terrain of operation.

II. Passive Tracker

Other type of tracker system is passive which uses either the phase change material which changes physical properties of fluids as solar energy in tracking the sun or gravitational potential or through mounting spring or integration of wind energy. An early attempt for single axis passive solar tracker based on shape memory alloy (SMA) actuators tested and found useful than bimetallic actuators with higher efficiency [16].On other hand bimetallic laminates of Ni36/Mn75Ni15Cu10 strip for organic cell can be used as main actuator for tracking which changes the shape as it bend and deform due to the influence of temperature depending on the shadow area and the solar cell perpendicular to light as shown in fig.5 and 6. The results hold good feasibility and reasonable in term of stability, deformation process of bistable laminates. The study reviles the deformation capability called as actuation effect which is directly related with tracking efficiency is function of the snap-through temperatures, arrangement of the bimetallic strip on the bistable laminates, thickness of the bimetallic strip tested numerically and experimentally and has reasonably good aggregate[17].

Fig. 7: Application of bimetallic and laminate for solar tracking

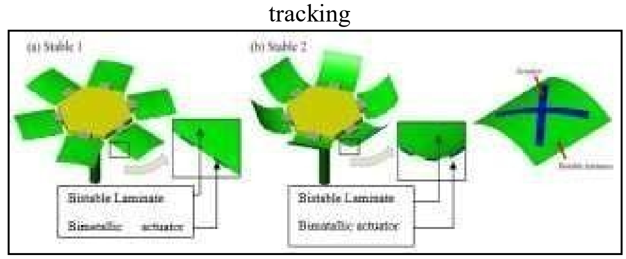

Fig. 8: Actuation effect of laminate and bimetal from stable 1 to 2 and position of actuator and laminate

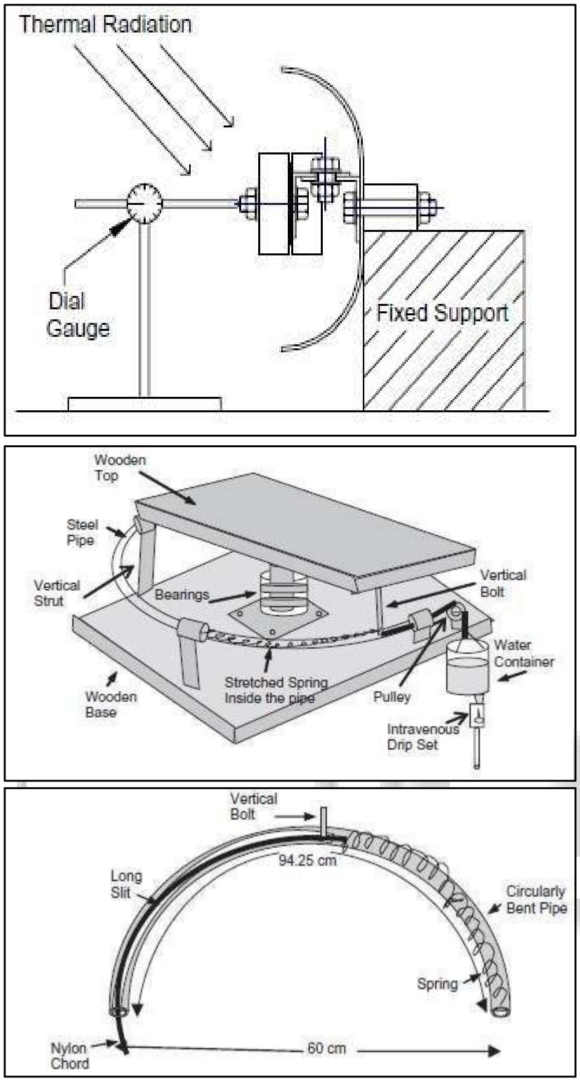

Fig. 8: Gravity based Passive Tracker

Clifford et. al. design a bimetallic strip tracker which consists of two bimetallic strips of aluminium and steel. The bimetallic strips are positioned on a wooden frame, symmetrically on either side of a central horizontal axis such that the strip which is way from the sun absorbs thermal radiation as shown in fig.7 while the other remains shaded. The exposed bimetallic strip gets hotter, the aluminium bends more than the steel due to its higher coefficient of thermal expansion. This bending causes a maximum deflection at the strip midpoint and with the attached mass an unbalanced moment results, which generating movement towards the sun rotates the solar panel along [18].

Another attempt by Suhail Zaki Farooqui et.al.[19] is of making gravity based solar tracker for specially solar cooker. It consists of actuation of stretch spring and mirror as shown in fig.8. Initially Water stored inside a container is attached to a spring through a chord, thus an amount of potential energy stored in the stretched spring and water get discharged at a constant rate from the container, thus the spring slowly returns to its un-stretched position dragging the solar cooker along with it. Further, by increasing the height of the booster mirror attached to the solar cooker fulfills the requirement of tracking along changing solar elevation. The controlled discharge of water if matched with the rate of change of the solar azimuth, the solar tracking can be achieved. The whole system has been optimized for 6 h of cooking per day, without manual tracking resulted optimum angle of inclination of the booster mirror as 25 degree.

III. Conclusion

Solar tracking systems have very high efficiency and performance compared with fixed or stationary solar photovoltaic systems. The main advantage of solar tracking systems is the increased electricity generation depending on the geographical location of the solar tracker and other variables. However, solar tracking systems possess numerous limitations. Solar tracking systems are more expensive than fixed systems due to the complexity of the technology used and their use of expensive products for their complex operations.

It is observed that active tracker using optical sensor and microcontroller based active drives offer the advantage of high precision tracking and are used widely and also frequently used in comparison with the auxiliary bifacial and time based active drives. However, they have a common disadvantage of low efficiency on cloudy days since the sensors require sunlight to function effectively. Passive drives rely on the changing physical properties of fluids rather than complex and complicated control circuits, motors, gears and sensors used in active drives. This makes them more viable than active drives. Also the factors that affect the energy output of such systems include the photovoltaic material, geographical location of solar irradiances, ambient temperature and weather, angle of sun incidence, and orientation of the panel.

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