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SUN TRACKING OF SOLAR PANEL WITH MECHANICAL GEAR BOX FOR MAXIMUM ENERGY UTILIZATION.

Mr.Himanshu Minotra
Assistant Professor Mechanical Engineering Department,SMS Institute of Technology, Lucknow, U.P , India

Mr. Varun Singh
Assistant Professor Mechanical Engineering Department,SMS Institute of Technology, Lucknow, U.P , India

Dr.Rohit Singh
Assistant Professor Mechanical Engineering Department ,SRMU Deva Road Lucknow U.P , India

Mr. Vivek Mishra
Assistant Professor Electrical Engineering Department, SMS Institute of Technology, Lucknow, U.P , India

Ms. Kiran Sharma
Lecturer Mechanical Engineering Department ,SRMU Deva Road Lucknow U.P , India

A B S T R A C T
Solar energy systems require optimal orientation of photovoltaic panels to achieve maximum efficiency. Fixed-position solar panels suffer from reduced energy output due to the dynamic movement of the sun. This paper presents the development of a sun tracking mechanism for a solar panel using a mechanical gear box to enhance energy utilization. The tracking system continuously aligns the panel with the sun's trajectory, thereby maximizing solar radiation absorption. The mechanical gear box provides precise control, improved torque transmission, and smooth rotational movement of the panel. Performance evaluation demonstrates a noticeable increase in energy generation compared to conventional fixed solar panel systems. The proposed approach offers a cost-effective and efficient solution for improving solar power generation in small-scale and standalone renewable energy systems.
Keywords: Gear box, Solar Panel , Battery, Gear Motor, Pilow Bearing

I. INTRODUCTION

Solar energy is one of the most abundant and clean source of renewable power available today. Maximizing output from solar system increases efficiency. Presently solar panel are fixed type which lower the efficiency as compare to movable. •By mechanical gear arrangement solar panel continuously absorb sunlight which convert solar energy into electrical energy. The growing global demand for energy, along with the depletion of conventional fossil fuel resources, has intensified the need for efficient and sustainable renewable energy solutions. Solar energy has emerged as one of the most promising renewable sources due to its abundance, cleanliness, and wide availability. Photovoltaic (PV) systems are widely used to convert solar radiation into electrical energy; however, their efficiency is highly dependent on the orientation of the solar panel relative to the sun. Conventional solar panels are generally installed in a fixed position, which limits their ability to capture maximum solar radiation throughout the day. As the sun's position continuously changes from east to west, fixed panels experience reduced exposure during morning and evening hours, leading to significant energy losses. To overcome this limitation, sun tracking systems have been developed to dynamically adjust the panel orientation, ensuring optimal alignment with the sun's trajectory.

This paper presents a sun tracking system for a solar panel incorporating a mechanical gear box to achieve maximum energy utilization. The mechanical gear box plays a crucial role in providing controlled motion, increased torque, and stable rotation of the solar panel, enabling precise tracking with minimal power consumption. By maintaining the panel perpendicular to incoming solar rays, the system significantly improves energy absorption compared to fixed installations.

The proposed sun tracking mechanism offers a cost-effective, reliable, and efficient solution for enhancing solar power generation. Such systems are particularly suitable for small-scale, standalone, and rural applications where maximizing energy output is essential. This study highlights the importance of mechanical integration in solar tracking systems to improve overall performance and energy efficiency.

2.REVIEW OF LITERATURE

1. Efficiency Gains through Sun Tracking

Numerous studies confirm that solar tracking systems substantially improve the efficiency of photovoltaic (PV) panels. Fixed panels can only capture peak sunlight for limited hours, whereas tracking systems follow the sun's trajectory throughout the day.

- Quantitative Improvements: Research indicates that single-axis trackers can increase power output by approximately 20-35%, while dual-axis trackers (DATs) can achieve even higher gains, often in the range of 25-45% compared to fixed systems, depending on the geographical location and climate. In specific studies, dual-axis systems demonstrated energy efficiency improvements ranging from 28.8% to 43.6% seasonally.
- Performance Metrics: The energy yield (kWh/kWp/year) is a crucial metric for long-term productivity. Studies using this metric found DATs generated more electricity (e.g., 30.79% more than a fixed-tilt system in one study).

2. Mechanical Gearbox Systems and Design

The mechanical aspects, particularly the gearboxes, are critical for the reliable and accurate operation of solar trackers. These systems convert the rotational motion from actuators (motors) into the precise angular movement needed to orient the panels perpendicularly to the sun's rays.

- Actuation Mechanisms: Active tracking systems typically use electric motors (like stepper or servo motors) coupled with gear trains to achieve movement in one or two axes.
- Types of Gears: Various gear types are employed (e.g., bevel gears, worm gears) to manage

torque requirements and control speed. The choice of gearbox and motor system depends on the required load capacity, precision, and cost constraints.

- Control Integration: Mechanical systems are usually integrated with control mechanisms, such as microcontrollers (e.g., Arduino, ATmega) using sensor-based (LDRs, encoders) or astronomical algorithms to determine the sun's position. Encoder-based systems offer superior reliability and performance in maintaining accurate alignment.

3. Challenges and Considerations

While effective, mechanical gear-based tracking systems present specific engineering challenges:

- Complexity and Cost: The primary drawbacks are the higher initial installation costs and mechanical complexity compared to fixed systems or simple single-axis trackers.
- Maintenance: Systems with rotating components and gearboxes require regular maintenance to ensure long-term reliability and performance.
- Energy Consumption: Active tracking systems consume a portion of the generated energy to power their motors and control circuitry. Optimizing the tracking strategy (e.g., using intermittent instead of continuous movement) can significantly reduce this internal energy consumption.
- Durability and Environmental Factors: Mechanical designs must withstand environmental conditions, including wind pressure and temperature variations.

4. Research Gaps and Future Directions

Future research focuses on enhancing the cost-effectiveness and reliability of tracking systems. Key areas include:

- Optimization: Developing more refined algorithms that balance energy gain with the energy consumed by the tracking mechanism itself.
- Hybrid Systems: Integrating semi-passive or hybrid mechanical systems that use minimal active components to optimize efficiency at lower cost.
- Predictive Analytics: Utilizing intelligent systems and machine learning to improve tracking accuracy and adapt to real-time weather conditions (e.g., cloud cover).

In conclusion, the literature widely supports the use of mechanical gear-driven solar tracking systems for significantly increasing energy utilization. The focus of recent research is on optimizing these systems to improve their cost-benefit ratio and long-term reliability for a broader range of applications.

A literature review on sun-tracking solar panel systems explores various advancements aimed at improving the efficiency of solar power collection. Traditional solar panels are typically fixed in place, which means they can only capture sunlight effectively at certain times of the day or seasons. To maximize energy production, sun- Tracking systems are created to monitor the path across the sky, ensuring that the panels are always positioned at the optimal angle. These system can be classify into two types: single-axis trackers, which rotate on one axis (usually east to west), and dual-axis trackers, which move on two axes (tracking both the sun’s azimuth and altitude).Research has demonstrated that sun-tracking panels can increase energy output by 20-40% same on fixed panel. However, challenges such as higher installation costs, mechanical complexity, and maintenance requirements remain. Studies also discuss various materials and designs that aim to reduce the mechanical load and increase the reliability of tracking systems. Furthermore, advancements in control algorithms, sensors, and automation have made tracking systems more efficient, reliable, and cost-effective. In addition to technical improvements, some studies have highlighted the environmental benefits, as these systems can help reduce the overall land area required for solar energy production. However, while the promise of higher energy yields is clear, the economic viability of sun-tracking systems depends on local conditions such as sunlight availability, terrain, and the cost of installation.

3.PROBLEM FORMULATION

Working mechanism

• The working mechanism of sun-tracking solar panel with mechanical gear arrangement is based on continuously aligning the solar panel.

• The mechanical gear arrangement plays a crucial role by translating the motor with small rotational movement into controlled and stable movement of solar panel.

• Gears use such as spur gear are reduces the speed, and ensure the smooth angular movement of the panel. As the motor rotate main gear, connected solar panel rotates either along single axis (East-West) direction.

• As the motor rotate 30rpm on input metallic gear which are 20 teeth meshing with 60 teeth on input shaft attached with 15 teeth of small nylon gear meshing with 75 teeth of large nylon gear.

• Further the six combinations of 15 teeth and 75 teeth are meshing with each other to rotate the solar panel of input speed 30rpm and output speed are 0.000649rpm which is approximate to 0.000696rpm.

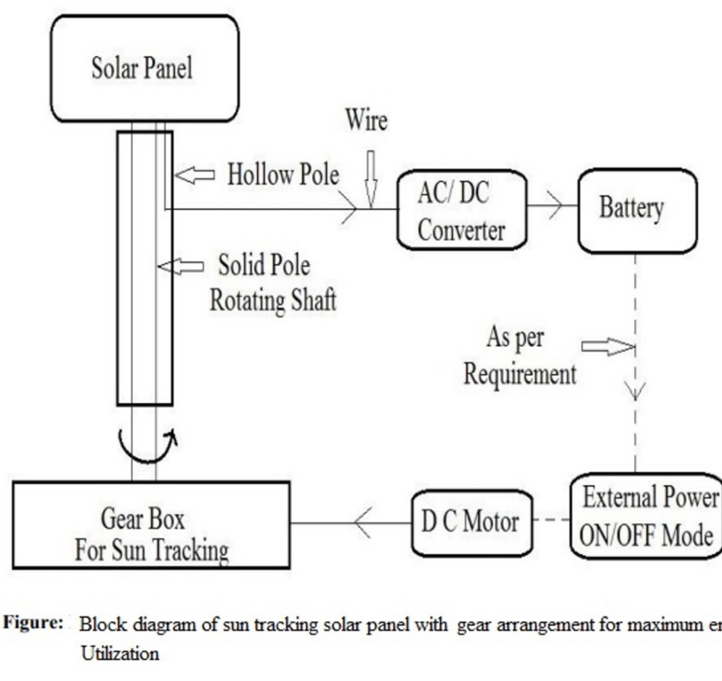
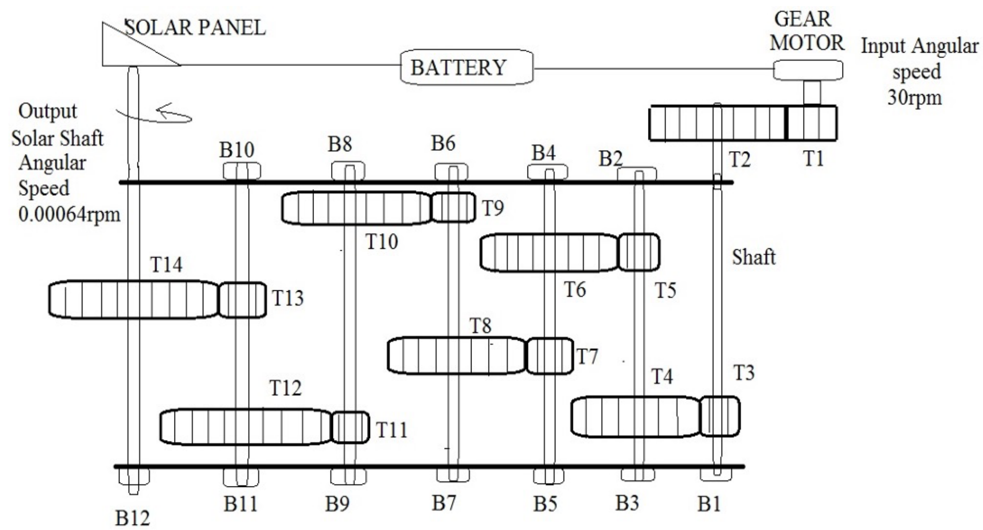
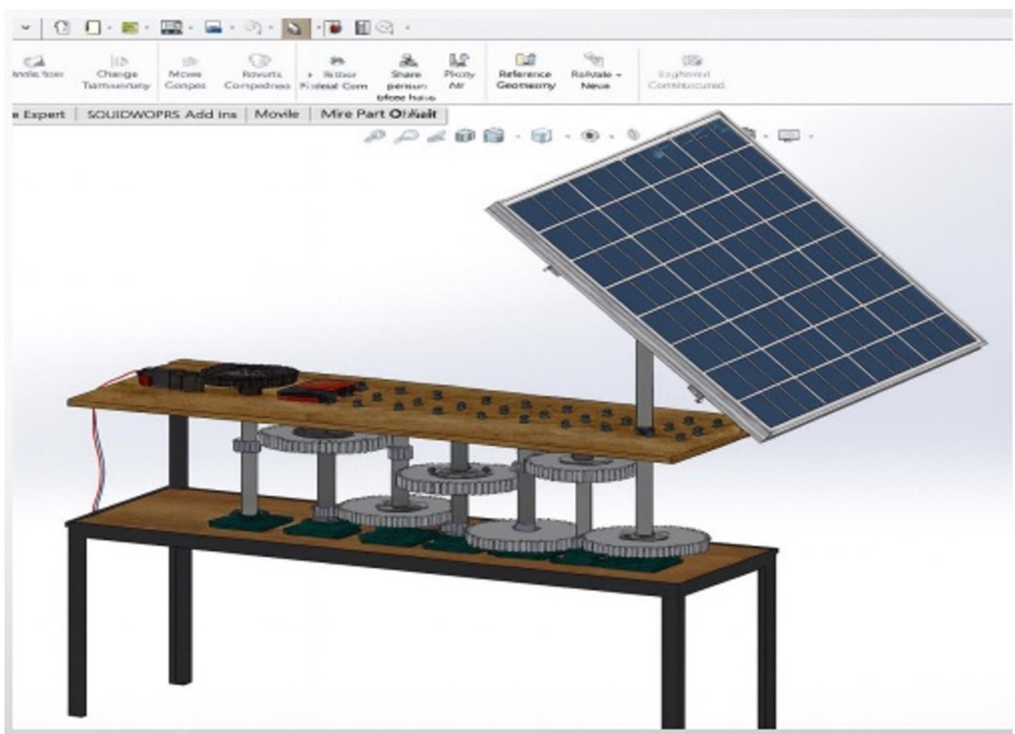


Figure: Block diagram of sun tracking solar panel with gear arrangement for maximum energy Utilization



Gear Box



Specifications:

Gear Material : Teflon

Pilow bearing : Toatal Number -12 , Hole in bearing -20mm

Shaft diameter- 20mm

Battery: Lead Acid Battery (12 V)

Solar Pannel: 55W,12 V   (Tilled at 450)

Gear motor: 30 rpm , 1HP

Spur Gears :

(i) 15 Teeth gear – Total Number -6, Diameter- 37.5mm,

Module-2.5mm, Face width-20mm, Tooth Thickness- 3.9mm
(ii) 75 teeth gear – Total Number -6 , Diameter-187.5mm,
Module- 2.5mm, Face width-20mm, Tooth Thickness- 3.9mm
(iii) 20 teeth Gear- Total Number-01, Diameter- 50mm,
Module-2.5mm, Face width-20mm, Tooth Thickness- 3.9mm
(iv) 60Teeth Gear- Total Number-01 Diameter- 150mm,
Module-2.5mm, Face width-20mm, Tooth Thickness- 3.9mm

4.Design Module & Calculations:

(i) Meshing of gear 1 &2

$$\frac{\omega 1}{\omega 2} = \frac{T2}{T1}$$

$$\omega 2 = \omega 1\left(\frac{T1}{T2}\right)$$

$$\omega 2 = 30\ (20/60)$$

$$\omega 2 = 10 \text{ rpm}$$

$$\omega 3 = 10 \text{ rpm}$$

- **Meshing of gear 3 &4**

$$\frac{\omega 3}{\omega 4} = \frac{T4}{T3}$$

$$\omega 4 = \omega 3\left(\frac{T3}{T4}\right)$$

$$\omega 4 = 10(15/75)$$

$$\omega 4 = 2 \text{ rpm}$$

$$\omega 5 = 2 \text{ rpm}$$

- **Meshing of gear 5 &6**

$$\frac{\omega 5}{\omega 6} = \frac{T6}{T5}$$

$$\omega 6 = \omega 5\left(\frac{T5}{T6}\right)$$

$$\omega 6 = 2(15/75)$$

$$\omega 6 = 0.4 \text{ rpm}$$
$$\omega 7 = 0.4 \text{ rpm}$$

- **Meshing of gear 7 &8**

$$\frac{\omega 7}{\omega 8} = \frac{T8}{T7}$$

$$\omega 8 = \omega 7(\frac{T7}{T8})$$
$$\omega 8 = 0.4\ (15/75)$$
$$\omega 8 = 0.08 \quad rpm$$
$$\omega 9 = 0.08 \quad rpm$$

1. **Meshing of gear 7 &8**

$$\frac{\omega 7}{\omega 8} = \frac{T8}{T7}$$

$$\omega 8 = \omega 7(\frac{T7}{T8})$$
$$\omega 8 = 0.4\ (15/75)$$
$$\omega 8 = 0.08 \quad rpm$$
$$\omega 9 = 0.08 \quad rpm$$

3 **Meshing of gear 7 &8**

$$\frac{\omega 7}{\omega 8} = \frac{T8}{T7}$$

$$\omega 8 = \omega 7(\frac{T7}{T8})$$
$$\omega 8 = 0.4\ (15/75)$$
$$\omega 8 = 0.08 \quad rpm$$
$$\omega 9 = 0.08 \quad rpm$$

1. **Meshing of gear 9 &10**

$$\frac{\omega 9}{\omega 10} = \frac{T10}{T9}$$

$$\omega 10 = \omega 9(\frac{T9}{T10})$$
$$\omega 10 = 0.08\ (15/75)$$

$$\omega 10 = 0.016 \quad rpm$$
$$\omega 11 = 0.016 \ rpm$$

A-Meshing of gear 11&12

$$\frac{\omega 11}{\omega 12} = \frac{T12}{T11}$$

$$\omega 12 = \omega 11(\frac{T11}{T12})$$

$$\omega 12 = 0.016\ (15/75)$$

$$\omega 12 = 0.0032\ rpm$$

$$\omega 13 = 0.0032\ \ rpm$$

A-<u>Meshing of gear 13&14</u>

$$\frac{\omega 13}{\omega 14} = \frac{T14}{T13}$$

$$\omega 14 = \omega 13(\frac{T13}{T14})$$

$$\omega 14 = 0.016\ (15/75)$$

$$\omega 14 = 0.00064 rpm$$

Input Angular speed from Gear motor- 30rpm
*Output Angular Speed of Solar tracking shaft-0.00064rpm
Fig.2 Top view with dimensions (in inch)

5. CONCLUSION

Thus with the help if this paper it is concluded that with the help of gear box sun tracking is possible which increases the efficiency of solar panel. By the constant output sources can be operated easily like irrigation, street lights, cctv camera , vertical farming and domestic flour mill etc which need power for a long time . this gear arrangement helps to increases the solar power upto 30% approx as per studied in a unit time as compared to the stationary solar panel in a unit time .

6.FUTURE SCOPE

1. In addition to it a light sensor will be used to make solar move to sun direction again during sunrise so as to save the time and power. It is done manually right now.
2.Difference in % increase of power will be calculated after gear box is installed in 24 hours
3.Single column stem will be used for sun tracking of solar panel of large size of 2-5 KW for huge power generation.
4. For cost reduction nylon gears can be used as per requirement of size of solar panel.
5. Cut off relay can be used automatically to disconnect solar with battery after sunset to restrict further rotation of solar panel.

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