SMART INDIA HACKATHON 2024

TEAM HELIOTROPES

Problem Statement ID- SIH1545

Problem Statement Title- Development of a non-electrical device for tracking the movement of the sun for movement of the solar panels, increasing their efficiency.

Theme- Renewable / Sustainable Energy

PS Category- Hardware

Team ID- 45282

Team Name- Team Heliotropes

TEAM HELIOTROPES

PROPOSED NON-ELECTRICAL SOLAR TRACKING SYSTEM

SMART INDIA HACKATHON 2024

EXPLANATION OF THE PROPOSED SOLUTION

⚠ PROBLEM ⚠

- **Fixed solar panels** miss out on optimal sun exposure, reducing efficiency.
- **Electrical tracking systems**, though effective, are costly and energy-consuming, undermining sustainability

✔ SOLUTION

A passive, non-electrical tracking system inspired by **sunflower heliotropism**. This system uses **thermal-responsive materials** to adjust the solar panel's angle, following the sun's movement throughout the day without the need for electricity.

HOW IT ADDRESSES THE PROBLEM

BOOSTS SOLAR PANEL EFFICIENCY

Tracks the sun throughout the day, increasing energy production by **30-40%** compared to fixed panels.

COST-EFFECTIVE

LCE and CNT solar panels cut installation and maintenance costs by **20-30%** compared to fixed systems.

ENERGY SAVING AND SUSTAINABLE

Operates passively using thermal-responsive materials, requiring no electricity, aligning with sustainability goals by reducing energy consumption

INNOVATION AND UNIQUENESS OF THE SOLUTION

BIOMIMICRY-INSPIRED DESIGN

- **Concept**: Mimics sunflower heliotropism.
- **Innovation**: Applies nature's evolutionary solutions to technology.
- **Uniqueness**: Bridges biology with engineering

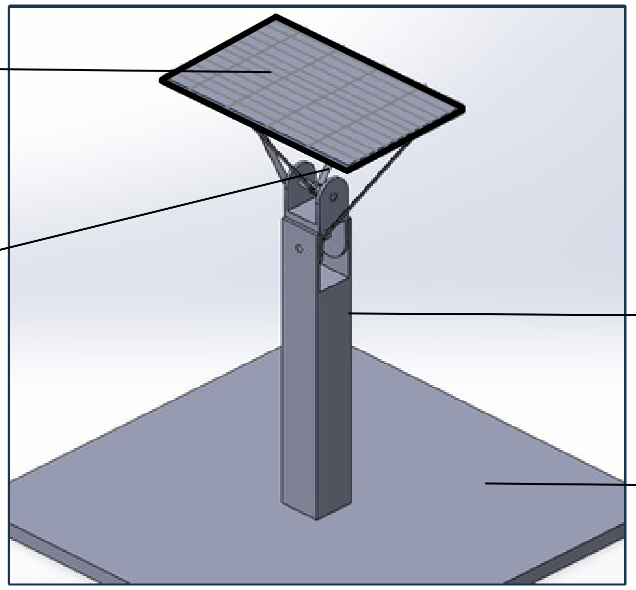
NON-ELECTRICAL OPERATION

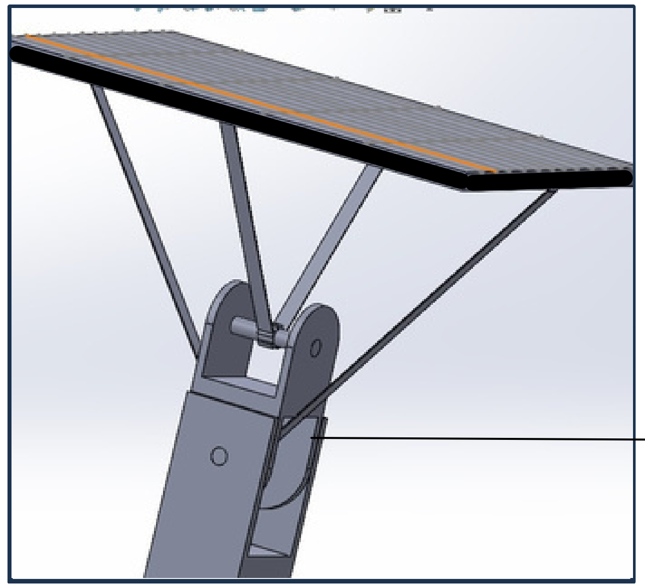
- **Concept**: Tracks the sun without electricity.
- **Innovation**: Eliminates reliance on electrical systems.
- **Uniqueness**: Differentiates from conventional motor-driven systems

THERMAL-RESPONSIVE MATERIAL

- **Concept**: Temperature-responsive materials enable movement.
- **Innovation**: Harnesses ambient temperature for tracking.
- **Uniqueness**: Replaces complex systems with smart materials

EARLY STAGE PROTOTYPE





TEAM HELIOTROPES

TECHNICAL APPROACH

SMART INDIA HACKATHON 2024

Our solution will include an integration of **two methods**, each effective at different scenarios.

THERMAL ACTUATORS

MATERIAL PREPARATION

Direct Actuation Materials:

- Bimetallic Strips: Expand and contract with temperature changes to rotate solar panels.
- Shape Memory Alloys: Return to their original shape when heated, driving panel movement.

Indirect Actuation Materials:

- Thermal Fluid: Expands when heated, actuating mechanical systems like gears to move the panels.

PROCESS

Thermal actuators work by converting temperature changes into mechanical movement. When cold, the wax inside the actuator is solid, and the piston remains retracted. As the temperature rises to a set range, the wax melts, expands, and pushes the piston into its "hot position," enabling it to act on mechanical components like valve stems or levers. This phase change occurs over a narrow temperature range (typically 10-15°F) but can be customized. The non-compressible nature of the wax allows for the generation of significant mechanical force.

LCE NANOCOMPOSITES

MATERIAL PREPARATION

Combination of liquid crystalline elastomer (LCE), which goes through a phase change and contracts in the presence of heat, with carbon nanotubes, which can absorb a wide range of light wavelengths.

PROCESS

1)The carbon nanotubes heat up as they absorb light, and the heat differential between the environment and inside the actuator causes the LCE to shrink.
2)This causes the entire assembly to bow in the direction of the strongest sunlight.
3)As the sun moves across the sky, the actuators will cool and re-expand.

MECHANICAL OUTPUT CALCULATIONS FOR SOLAR PANEL SYSTEM

1. Weight of the Solar Panel

Assuming the weight of the solar panel is given as:

Weight of Solar Panel = 20 kg

2. Torque Calculations

To find the force exerted by the weight of the solar panel:

Force (F) = Weight (W) x Gravity (g)

Where g = 9.81 m/s^2

F = 20 kg x 9.81 m/s^2 = 196.2 N

3. Counterweight Calculation

Assuming a counterweight is needed to balance the torque:

Let the required counterweight be F_{cw} kg, located at a distance r = 0.5 m from the pivot.

Torque due to counterweight = Torque due to solar panel

$$F_{cw} \times d_{cw} = F_{Bimetallic} \times d_{Bimetallic}$$

$$F_{cw} = \frac{F_{Bimetallic} \times d_{Bimetallic}}{d_{cw}}$$

Assuming the distance from the pivot to the solar panel's center of mass is 0.75 m

$$F_{cw} = \frac{15\ N \times 0.75\ m}{0.5\ m} = 22.5\ N$$

Thus, the counterweight force needs to generate around 22.5 N of force, translating into a mass of approximately:

$$m_{cw} = \frac{F_{cw}}{g} = \frac{22.5}{9.81} \approx 2.3\ kg$$

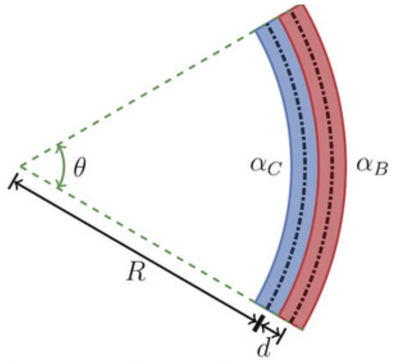
4. Radius of Curvature Calculation

Assuming a radius of curvature for the pivot mechanism to be determined:

Let's assume the radius of curvature (R) is related to the bending of the bimetallic strip:

R = 0.5 m (assumed based on design requirement

$$R = \frac{L}{\alpha_{brass} - \alpha_{steel}} \times \Delta T$$



Where:

L= Length of strip = 0.5 m, $\Delta T = 30^0 C$

$$R \approx \frac{0.5}{(19\times10^{-6})-(11\times10^{-6})} \times 30 = 20833\ m$$

This suggests that the bending curvature is small, but enough to induce movement, given proper mechanical advantage via the gear system.

TEAM HELIOTROPES

FEASIBILITY AND VIABILITY

SMART INDIA HACKATHON 2024

FEASIBILITY

ECONOMIC FEASIBILITY

The price of CNTs has dropped from ₹45,00,000/kg in 2010 to ₹4,15,000/kg in 2022, indicating a trend towards more affordable material costs.

MANUFACTURING COSTS

Advances in manufacturing techniques, such as roll-to-roll processing for LCEs, can reduce costs

APPLICATION FEASIBILITY

CNT-LCE composites are being explored for applications in robotics and smart materials.

RISKS AND CHALLENGES

MATERIAL COMPATIBILITY

Compatibility issues can lead to a 20% reduction in mechanical performance if CNTs are not properly integrated.

UNIFORM DISPERSION

Achieving a uniform distribution of CNT's within the LCE matrix is challenging and crucial for consistent performance

PERFORMANCE ISSUES

Excessive CNT content can reduce elasticity by up to 25%.

SOLUTION

ADDRESSING INTEGRATION CHALLENGES

Improved formulations can boost CNT-LCE compatibility and performance by 30%

IMPROVING PERFORMANCE

- Optimize CNT concentration and type for balanced properties.
- Use advanced thermal conductors and actuators for uniform heat distribution.

ENSURING DURABILITY AND RELIABILITY

Implement rigorous testing and quality control to assess long-term performance.Comprehensive testing can mitigate performance degradation by 10% after 1000 cycles.

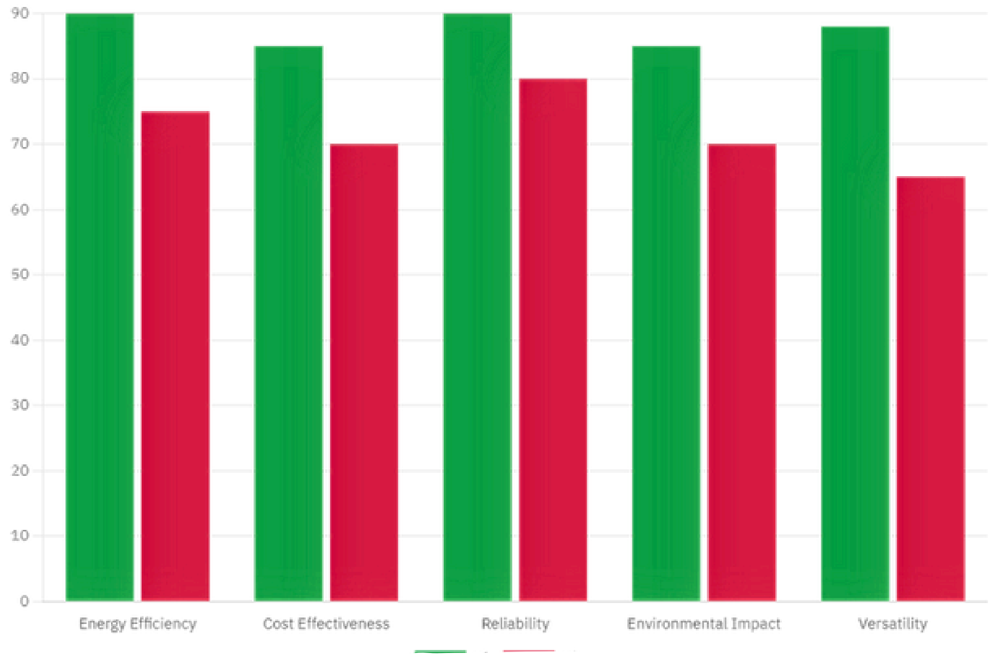
IMPACT AND BENEFITS

TEAM HELIOTROPES

SMART INDIA HACKATHON 2024

BENEFITS

1. Increase solar panel output by 25-30%.
2. Reduced number of panels needed.
3. Fewer points of failure during outages.
4. Improves efficiency without additional panels.
5. Suitable for remote location.



HELIOTROPISM-INSPIRED VS ELECTRICAL-MODEL COMPARISON

REDUCED CARBON FOOTPRINT

By increasing the efficiency of solar panels, this tracking system can contribute to reducing greenhouse gas emissions.

REDUCED WASTE

As a non-electric solution, it minimizes electronic waste associated with traditional tracking systems.

MARKET EXPANSION

Improved efficiency can drive the expansion of the solar energy market, creating new business opportunities and jobs.

TECHNOLOGICAL ADVANCEMENT

The development of LCE nanocomposite-based actuators can contribute to advancements in materials science and robotics.

ENERGY OUTPUT CALCULATIONS FOR SOLAR PANEL SYSTEM

1. Conventional Electrical Solar Panel

- Power Rating: **400 W (0.4 kW).**
- Average Sunlight Hours in India: **5.5 hours/day.**
- Panel Efficiency**: 20% (stationary).**
- Daily Energy Output = Power Rating x Sunlight Hours.
- Daily Energy Output = 0.4 kW x 5.5 hours/day = **2.2 kWh/day**.
- Annual Energy Output = Daily Energy Output x 365 days.
- Annual Energy Output = 2.2 kWh/day x 365 days **= 803 kWh/year.**

2. Electrical Self-Rotating Solar Panel

- Efficiency Boost due to Tracking**: 30%.**
- Increased Daily Energy Output = Daily Energy Output (conventional) x (1 + 0.30).
- Increased Daily Energy Output = 2.2 kWh/day x 1.30 **= 2.86 kWh/day**.
- Annual Energy Output (with tracking) = Increased Daily Energy Output x 365 days.
- Annual Energy Output = 2.86 kWh/day x 365 days = **1,044.9 kWh/year.**
- Energy Consumption by Tracking System = Annual Energy Output x 0.05.
- Energy Consumption by Tracking System = 1,044.9 kWh/year x 0.05 = **52.25 kWh/year.**
- Net Energy Output (electrical tracking) = Annual Energy Output - Energy Consumption.
- Net Energy Output = 1,044.9 kWh/year - 52.25 kWh/year **= 992.65 kWh/year.**

3. Non-Electrical Self-Rotating Solar Panel

- Increased Daily Energy Output = 2.2 kWh/day x 1.30 **= 2.86 kWh/day.**
- Annual Energy Output (non-electrical tracking) = Increased Daily Energy Output x 365 days.
- Annual Energy Output = 2.86 kWh/day x 365 days = **1,044.9 kWh/year**.
- Net Energy Output = Annual Energy Output = **1,044.9 kWh/year**.
- Percentage Increase (Non-Electrical vs Electrical) = (Net Energy Output - Net Energy Output (electrical)) / Net Energy Output (electrical) x 100.
- Percentage Increase = (1,044.9 kWh/year - 992.65 kWh/year) / 992.65 kWh/year x 100 = 5.26%

= 5.26% increase in energy production.

TEAM HELIOTROPES

RESEARCH AND REFERENCES

SMART INDIA HACKATHON 2024

- https://www.sciencedaily.com/releases/2012/08/120816100927.htm
- https://www.researchgate.net/publication/264603617_Direct_Sun-Driven_Artificial_Heliotropism_for_Solar_Energy_Harvesting_Based_on_a_Photo-Thermomechanical_Liquid-Crystal_Elastomer_Nanocomposite
- https://youtu.be/9b0ffb1ipC4?si=ovBTV91y1HjBAcld
- "Actuation and Sensing in Liquid Crystal Elastomers: A Review" by J. P. White, M. R. Buckley, and D. J. Crossland
- ScienceDaily - Sunflowers inspire more efficient solar power system (university of Wisconsin - Madison)
- www.elsevier.com/locate/solmat
- www.elsevier.com/locate/jallcom
- http://www.elsevier.com/locate/compscitech
- www.elsevier.com/locate/matdes