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CYLINDRICAL SOLAR CELL STUDY

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PROBLEM DESCRIPTION

Renewable energy solutions, such as solar are essential for the sustainability of human growth and technology. However current array designs suffer from 3 distinguishable shortcomings associated with operating efficiencies. They include:

1. While operating, every degree higher than 25 degrees celsius results in an efficiency loss of 0.5%. [1]
2. Maximizing direct radiance through solar tracking can only be done through additional auxiliary power systems
3. Snow shading presents obstruction issues on panels leading to electrical bypasses, greatly restricting the panels output power generation.

PROJECT SCOPE

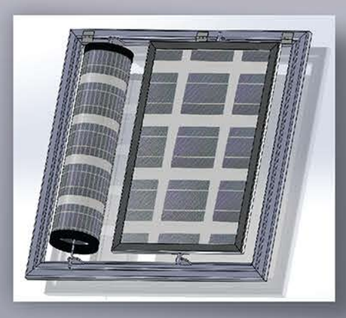
1. Design an innovative solar cell that:
   - Addresses the effects of snow shading
   - Provides a method of passive solar tracking
   - Regulates the operating temperature of the system
   - Operates more efficiently when compared to a standard control model
2. Construct a standard rectangular panel to act as a foundational product of comparison.
3. Design and produce a new solar cell with identical solar surface area and construction methodologies.
4. Compare the prototype solar cell to the traditional control model in performance studies.

TESTING METHODS

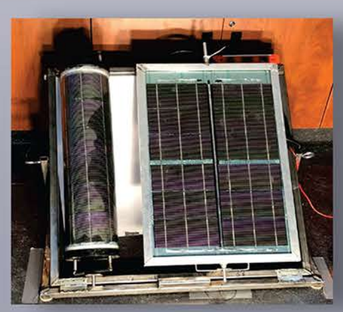
Performance testing was completed through 2 independent studies utilizing halogen heat lamps as the light source.

Study 1: Angle of Incidence
- Recording the voltage and current outputs of the cylindrical cell in comparison to the rectangular panel at incidence angles of 0, 15, 30, 45, 60, 75, 90

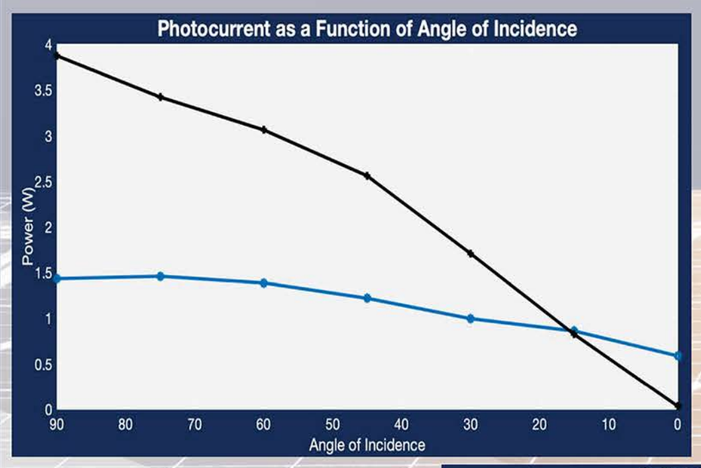
Study 2: PCM Thermal Comparison
- A study to evaluate the effects on the operating efficiency with and without the incorporation of the PCM core inside the cylindrical cell.



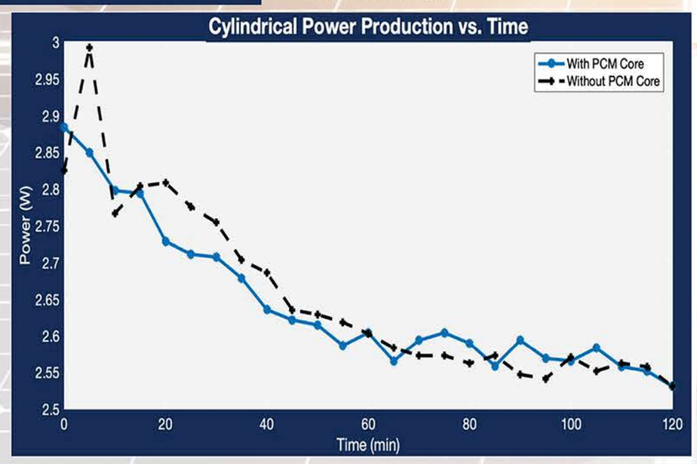
Solidworks rendering of testing configuration (Left) & Finished prototype model of solar units (right)



TESTING RESULTS

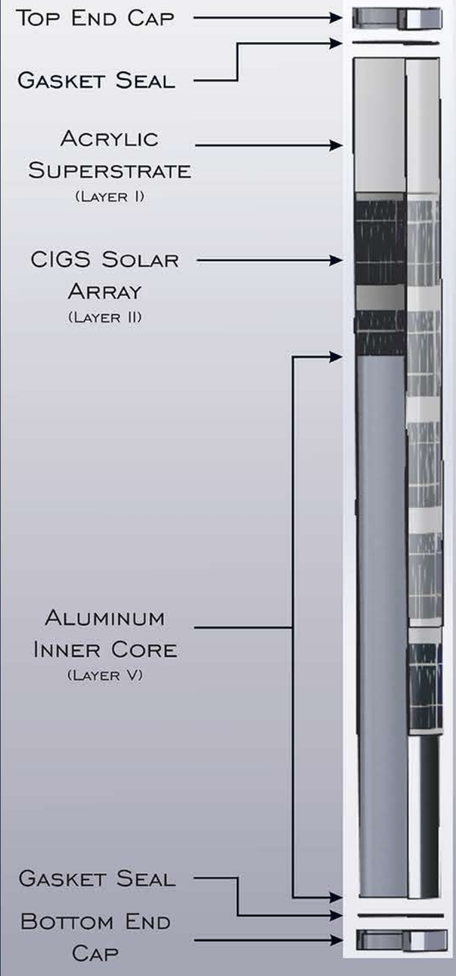


Study 1 findings:
- Results show that between an angle of incidence of 0 and 15 degrees that the cylindrical solar cell generates a greater output of power
- The total power output of the rectangular panel was 202 W, which is greater than the cylindrical cell's 103 W over the course of the entire half-day simulation



Study 2 findings:
- Until approximately the 60 min. mark of testing, the model operated better without the PCM core
- As the PCM core began to melt, it showed indications that it was providing the model with a greater power output

DESIGN SOLUTION



OVERVIEW
- A unique cylindrical solar cell that utilizes a removeable PCM core to help regulate its operating temperature
- The cylindrical geometry provides passive solar tracking abilities to further increase the systems performance efficiency
- The circular shape enhances the models ability to mitigate the effects of shading

TECHNICAL SPECIFICATIONS

CIGS Solar Cells
- Individual cells are rated at 0.5 Volts & 2 Amps (1.25 Watt)
- 12 (3.5 in x 7 in) flexible solar cells connected in series
- Soldered array results in 294 squared inch solar surface area

Layer Composition
I - 1/8 inch thick acrylic superstrate
II - Solar cell array
III - 1/8 inch polyurethane encapsulant epoxy
IV - Substrate layer of PET adhesive tape
V - 1/16 inch aluminum inner core

PCM Removable Core
- Paraffin wax rated at a melting point of 50 degrees celsius
- Total volume of 2.25 L
- Encapsulated between two concentric aluminum cylinders

ACRONYMS & ABBREVIATIONS
OD – Outer diameter
ID – Inner diameter
PET – Polyethylene Terephthalate
CIGS – Copper Indium Gallium Selenide
W.T. – Wall Thickness
IN – Inch

CONCLUSIONS

1. Study 1 suggests that the cylindrical model is capable of producing greater power outputs than the standard panel at certain angles of solar incidence.
2. At an incidence angle of 90 degrees, the panel provided almost double the power the cylindrical model was able to due to a lack of light being reflected onto the rear of the cell.
3. The PCM study showed suggestion that it could provide the model with a greater operating efficiency as time in the simulation increases.
4. Selecting a PCM material with a lower melting point could be advantageous for increasing the effects of the core itself.

FUTURE WORK

The following recommendations offer probable design approach alterations that would conceivably increase the efficiency of the cylindrical solar model.

1. Incorporating the PCM directly behind the inner aluminum cylinder (layer v) and not in a removable core. This would increase the rate of heat transfer to the wax thereby improving the operating efficiency.
2. Ensuring the solar array covers the entire surface area of the cylinder, thus maximizing the power-to-area ratio.
3. Implement a reflective "trough" behind the cylindrical cell to concentrate diffuse radiation on the solar array; enhancing the overall power output of the model.

Reference:
[1] Biwole, P., Eclache,P.,& Kuznik,F.(2011)Improving the Performance of solar panels by the use of phase-change materials. University of Nice Sophia-Antipolis and Univeristy of Lyon

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