Automated Modeling of 3D Solar Cell Concentrators

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Introduction/Background

Solar energy is an ever-emerging resource, valuable for its renewable nature and contribution to green efforts in industry and even home use. As such, it is in the best interest of society to maximize the output of solar cells. My group and I worked to achieve this through designing solar cell concentrators in addition to implementing solar tracking.

Research Objectives

The purpose of this study was to investigate the ideal construction of a solar cell concentrator in order to maximize solar panel output. Using an automated CAD to design the concentrators and Raspberry Pi system to implement solar tracking, we developed a way to refine solar power generation. Our hypothesis was that a revolved or circular parabolic concentrator would be most effective, as demonstrated is previous literature. The following questions guided our study:

1. What features of a solar cell concentrator correlate with improved concentration?
2. How does solar tracking work in conjunction with the concentrators to improve solar sell efficiency?

Method

Firstly, in order to develop the solar cell concentrator designs, we reviewed previously published literature, which guided us to various polygonal compound parabolic concentrators as having potential to be most optimal at concentrating incident light. Next, we wrote bash script in OpenSCAD to create a parameterized program to automate the CAD models of our concentrators with varying aperture radii and concentration ratios. After ray-tracing these models in Radiance, we determined the most effective models to print: we 3D printed 2.0X, 5.0X, and 10.0X concentrators of the square, pentagonal, octagonal, and circular compound parabolic shapes, which we then chemically smoothed using X2C 3D print coating. The concentrator surface also needed to be reflective, so we added a metal coating. To determine which metal to use, we tested aluminum, copper, chrome, and nickel on 3D printed test squares. Using a spectrometer and integrating sphere, we recorded the reflectivity of each metal and ultimately determined chrome to be most reflective within the solar spectrum. Consequently, we coated our concentrators with the chrome coating, and proceeded to test the efficiency of each shape and concentration using a solar simulator. Our data confirmed the trends seen in previous work, with the circular parabolic concentrator proving to have the highest efficiency with a pattern of increasing the number of sides resulting in improved performance. Lastly, we mounted our solar panels with a concentrator secured on top with two different models of solar tracking systems, one using photoresistor sensors and two servo motors to turn the solar panel towards the area of most sunlight, and the other, another dual axis platform instead utilizing sun position data to track and tilt towards the location of the sun in the sky.

Results

Our experimental results of measuring each solar cell concentrator's short-circuit current density aligned with our observed theoretical pattern with an increasing number of sides for a given concentration ratio achieving a higher value and thus better observed efficiency than the control (J_{SC} of 0.052 for the 10.0X circular parabolic concentrator vs. J_{SC} of 0.0345 for control).

Conclusions/Implications

Through my team's investigation of the ideal design for solar cell concentrators, we devised a way to automate the 3D modeling process of these concentrators with our OpenSCAD program. In this way, other researchers looking to easily and efficiently develop concentrator 3D models can use our program as a tool in their own research or applications.

References

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