

# The Robust Heliotropic Servo Design for Concentrated Photovoltaic Systems (HCPVS)

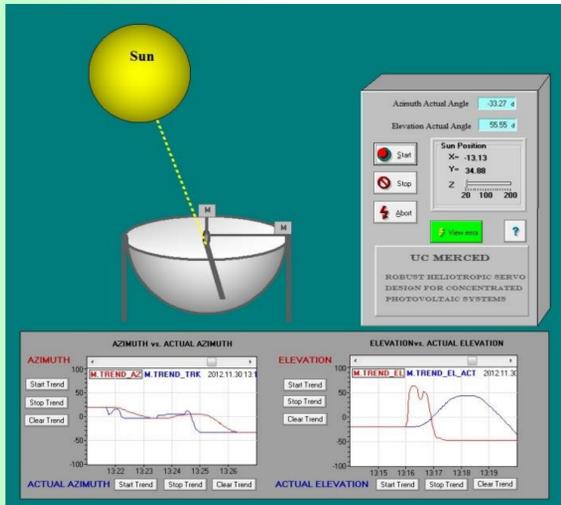
## Authors:

Brandon Stark, Brennan Stevenson, Trevor Murdock, Kelsey Nze, Grant McGregor, Jesan Morales-Holguin with YangQuan Chen

Mechatronics, Embedded Systems and Automation (MESA) Lab  
University California Merced, Merced, CA, USA

Web: <http://mechatronics.ucmerced.edu/>

## Simulation



A simulation of the Robust Heliotropic Servo Design for Concentrated Photovoltaic Systems was created using Advanced Motion Controls Click&Move® software. The simulation tracks the "Sun", by moving the rod along the inside of the dish, so as to maintain 2/5 of the hemisphere's radius and a parallel orientation to the Sun's rays. This is accomplished by using two separate servos to adjust the azimuth and elevation of the rod, controlled by AX1 and AX2 respectively. The equivalent ratio of both these axes to real coordinates is 10,000 counts to one revolution, and one degree of movement. The actual elevation and azimuth are compared with the corresponding orientation of the target via trend graphs, which show the transient response of the system in terms of system input and output.

## Prototype Construction

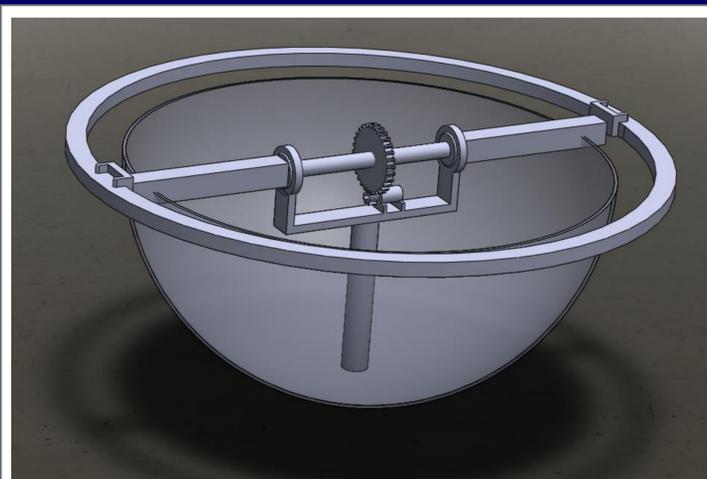


- 16"x16" Aluminum cover with a 12" diameter hole cut in the center.
- 12" diameter reflective bowl.
- 10" height base constructed of pine.
- Arduino Uno-R3
- 2- 5v DC Motors
- Flexible gear track and gears
- Not Pictured
  - Rotating base for 14" diameter track.
  - Rod and gear system.
  - Photodiodes

## Abstract

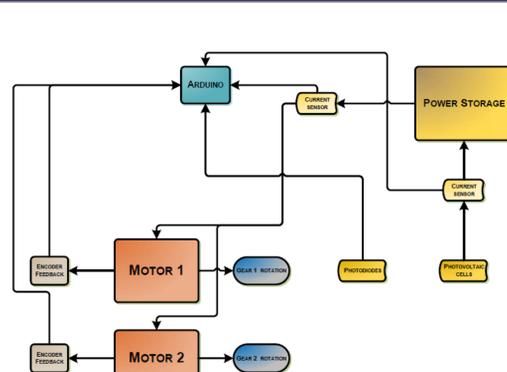
The Robust Heliotropic Servo Design for Concentrated Photovoltaic Systems, or HCPVS, is an advanced solar energy collector. The HCPVS will implement a control system to move a solar cell to the fulcrum point of the sun's concentrated rays. Accomplishing this will enable a less expensive, lower footprint, lightweight, and highly efficient solar energy collection system compared to traditional solar collection systems. The reduction in area utilized to generate power will enable green energy to be collected on a smaller scale suitable for modular application in traditional urban landscapes less isolated from direct human use. Lower volumes of photovoltaic material will reduce the waste materials from cell replacement over a standard lifespan significantly. Implementation of this device will advance solar technologies to be more efficient and robust in applications.

## 3D Model of the System



The latest model of the system. Each component is being built in small sections to be 3D printed for testing and calibration. Here you can see a motor that rotates the photovoltaic rod around the center axis. The outer circle will also rotate although this is not shown here.

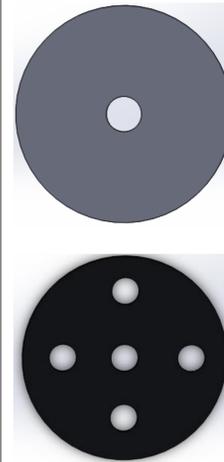
## System Model



This is the system model of the HCPVS encoder feedback combined with the photodiodes allows the Arduino to calculate the position of the rod move it accurately to be parallel with the sun.

- [1] "Solar Panel Efficiency and the Factors That Affect It." *One Block Off the Grid: The Smart New Way to Go Solar*. N.p., 2012. Web. 23 Apr. 2013.
- [2] "Getting the Best Solar Panel Efficiency and the Factors That Affect It." *Www.pursolaraz.com*. Pur Solar Inc., 2012. Web. 23 Apr. 2013.
- [3] Thompson, Caroline. "The Effects of the Angle of Sunlight on a Solar Panel." *LIVESTRONG.COM*. Ed. JPC. N.p., 8 Aug. 2010. Web. 23 Apr. 2013.
- [4] Wiltz, Jenni. "How do Solar Panels Work at Night?" *LIVESTRONG.COM*. Ed. Glenn K. N.p., 22 Aug. 2010. Web. 23 Apr. 2013.
- [5] Jewell, Eleanor. "How Do Solar Panels Work in Winter?" *LIVESTRONG.COM*. Ed. Glenn K. N.p., 25 July 2010. Web. 23 Apr. 2013.
- [6] "Solar Tracking." *Www.solarpanelsplus.com*. Solar Panels Plus, 2013. Web. 23 Apr. 2013.
- [7] <http://images.wisegeek.com/solar-panels-in-sun.jpg>
- [8] Winston, R. "Low Cost High Efficiency Solar Concentrator with Tracking Receivers", Atty. Dkt. No: 060933-5050.

## Photodiode System



- The Arduino and Simulink program will be used for the photodiode system
- The photocells on our Arduino and circuit board have the ability to convert the sunlight that the solar tracker collected and transform it into voltage
- When the sunlight shines onto the photodiodes, which will be located underneath the rod of the solar tracker, there will be a shadow around the 4 photodiodes on the exterior of the rod shown on the bottom left
- The middle photodiode on the rod will not have a shadow and it will have a higher voltage than the exterior photodiodes
- The upper left hand diagram represents the top view of the rod and the light will go through the pinhole

## The Usage of Arduino and Simulink

- With the Arduino program we can calculate how much light the photodiodes are absorbing and the accuracy of the sun's position with the solar tracker's rods as its moving.
- For the Arduino program, we will also program the solar tracker to readjust its positioning with the sun if it is unable to become parallel and aligned with the sun by using various algorithms that will account for the displacement
- By using Simulink, we can graph the energy consumption of the solar tracker and the position of the sunlight shining onto our solar tracker

## Concept of the HCPVS

It has been shown that a rod with its pivot-point at the hemisphere's center, and kept in parallel with the sun's rays, should always have light concentrated at approximately 2/5 of the hemisphere's radius<sup>[8]</sup> Maximum solar collection efficiency is achieved only within a small range of the rod's positional accuracy. Since the system only moves the rod (~0.02-.025m x .2m) with a small cluster of photovoltaic cells at the tip, it takes a fraction of the energy to keep the system at optimal positioning; in comparison, a standard solar collector must move an array of solar cells (typically 1m x 2m), in order to achieve comparable results. The HCPVS is designed to be easily moved without the need of elaborate setup, essentially "out-of-the-box" technology. With a high resolution, low latency tracking system, the collector's position has the potential to be dynamic, while maintaining maximum efficiency.

## Solar Panel Efficiency

- Solar Panel efficiency depends on <sup>[1]</sup>:
  - Manufacturers of the solar panels
  - Panel orientation
  - Roof and panel pitch
  - Temperature
  - Shade
  - Azimuth and other variables
- According to PurSolar and Electrical resource, most of the solar panels have an efficiency of 14-18%<sup>[2]</sup>

## Solar Panel Efficiency of Days and Angle of Sun

- Most of the sunlight during a clear day will be gathered from the solar panel around the noontime<sup>[3]</sup>
- During the nighttime, solar panels do not produce any electricity. <sup>[4]</sup>
- Solar panel's efficiency is less than 18% during the winter months <sup>[5]</sup>
- Solar Panel Plus's evacuated tubes increase in efficiency in the morning and afternoon when the sun's angle is within the range of 40 and 80 degrees from perpendicular <sup>[6]</sup>

