Light-Guide Solar Concentrator with Single Axis Tracking System

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Possible Sponsor: Duke Energy

Group C

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Introduction

This project includes the design and fabrication of a light guide solar concentrator (LGC), single axis tracking system and a companion mobile application. The motivation for any photovoltaic solar concentrator is to reduce the surface area of solar cells required to capture a given amount of solar energy. When the surface area is reduced, more expensive solar cells, such as multijunction solar cells, can be used while staying within a given budget. These more expensive solar cells have higher efficiency percentages of up to 46% which represents a significant improvement over the 20% efficiencies of silicon solar cells.

The advantage of a LGC over traditional solar concentrators is that the former is more compact and easier to install. Traditional solar concentrators use large parabolic mirrors to focus the light to a point that is above the mirror where the solar cells are positioned. On the other hand, LGCs require no large curved surfaces to concentrate light and the solar cells are not positioned above the mirror. Instead, the LGC redirects light to either side (see Figure 1.) This removes the need to create an additional mounting system for the solar cells. When considering the scale of a solar farm, this simplicity offers a substantial reduction in cost.

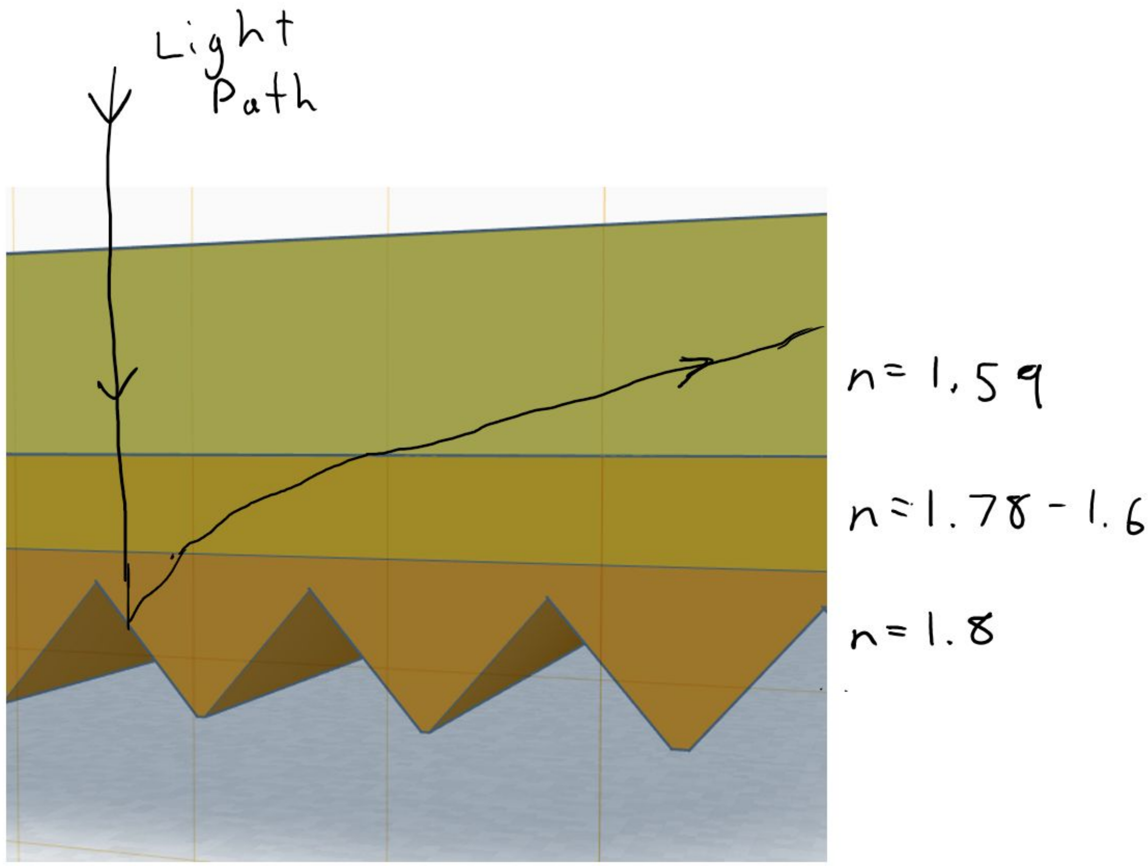


Figure 1: Geometry of Light-Guide Solar Concentrator

Displaying vital technical information regarding the efficiency and status of the solar concentrator is essential to understanding the system as a whole. A companion mobile application is the best platform to communicate the energy production and financial return of the system. For the average consumer, accessing data of the solar system in a mobile context aligns with the general move toward mobile technology in today's consumer market. This detailed display of efficiency can prevent the common phenomenon found in high end electronics known as buyers remorse.

For a solar farm technician, reading solar cell lifetime statistics in a mobile context allows them to identify and service problems more easily without having to individually assess each device. The mobile application will have the ability to display the solar cell efficiency history as well as remotely override rotation control of the linear actuators to give the user full control over their system. This allows the user to feel more comfortable and in touch with their product while having a full understanding of its capabilities.

Project Requirement Specifications

Concentrator Requirements

1.00	The solar concentrator will have a concentration value above C = 7.
1.01	The solar concentrator will have a planar shape. Light will enter from a large flat plane and exit along 2 sides.
1.02	The concentrator will have dimensions of 90 cm x 45 cm x 4 cm
1.03	The concentrator will consist of 3 layers, a textured layer, a gradient index layer and a polycarbonate layer.
1.04	The textured layer will have a silver mirror deposited onto it.
1.05	The textured layer will be bonded to the gradient index layer via a indexed matched resin
1.06	The polycarbonate layer will be fused directly to the gradient index layer.

Tracking System Requirements

2.00	Smaller support beam will be attached 10 cm from the edge of the concentrator and have a height of 29cm
2.01	The larger support beam will be attached 10 cm from the edge of the concentrator and have a height of 86 cm
2.02	The system will track from east to west automatically from -60 degrees to 60 degrees.
2.03	The north to south angle will be adjustable manually from 0 degrees to 55 degrees.
2.04	The linear actuators to rotate the panel will be controlled using a microcontroller.

Electrical System Requirements

3.00	The a maximum power point tracking system will control the operation voltage of the solar cells.
3.01	The maximum power point tracking system will be controlled with a custom PCB.
3.02	The solar cells will charge a battery bank.
3.03	The power supply will serve the microcontroller, linear actuators, and PCB

Microcontroller Requirements

4.00	The system software will be able to move the linear actuators.
4.01	The system software will have a hard-coded tracking pattern to default to.
4.02	The system software will be able to read online weather patterns.
4.03	The system software shall read data from solar censors and follow the sun.
4.04	The system software will be able to interface with the mobile application to accept user driven panel movement input.
4.05	The system software shall read and translate energy output from the MPPT PCB to the mobile application.
4.06	The system software will be able to monitor the energy stored into the battery.

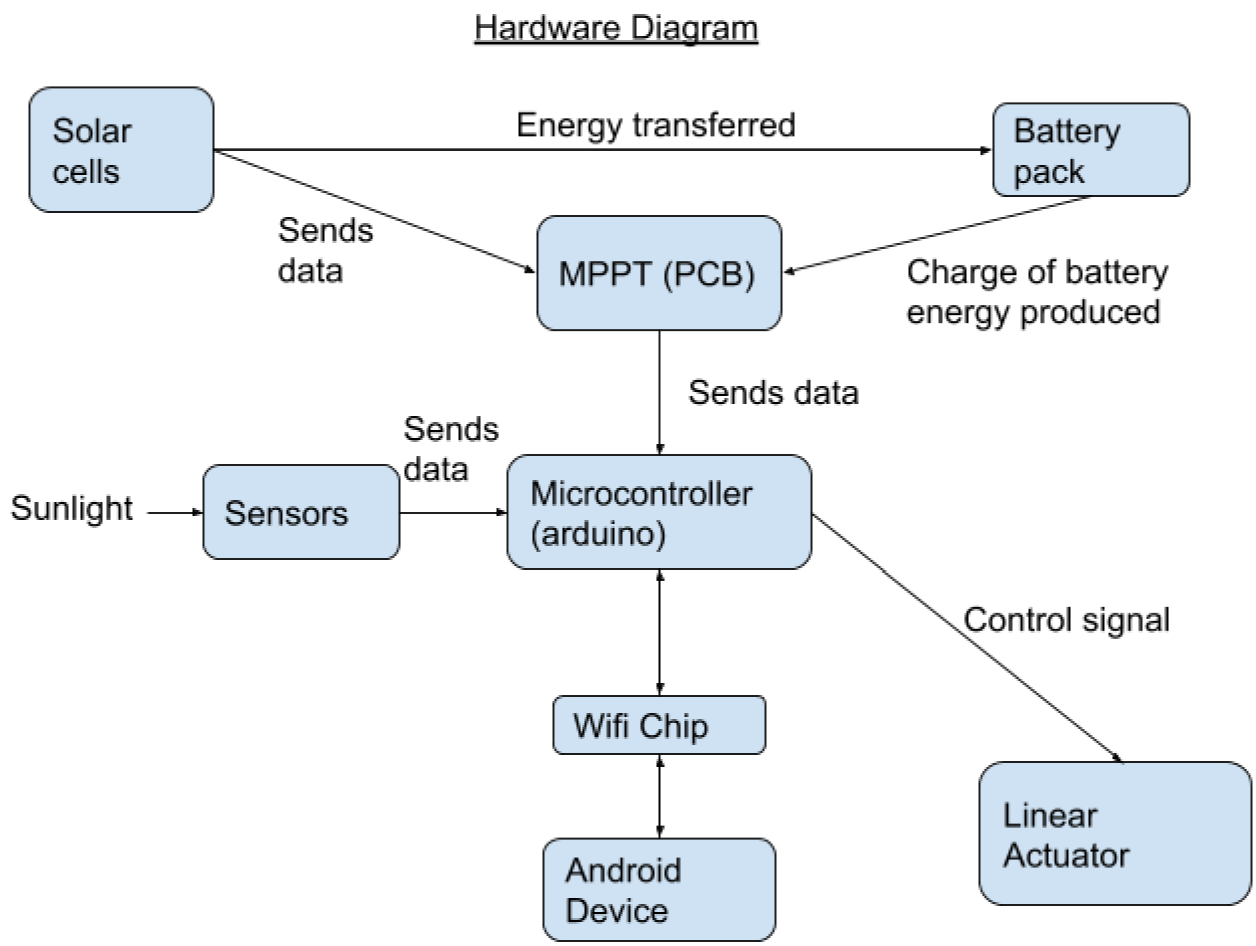
Mobile Application Requirements

5.00	The system will ship with a mobile application.
5.01	The application shall be supported on most Android devices.
5.02	The application will have the ability to remotely rotate the solar concentrator.
5.03	The application shall display important energy statistics from the solar cells.
5.04	The application will be able to communicate to the microcontroller via a wireless network.

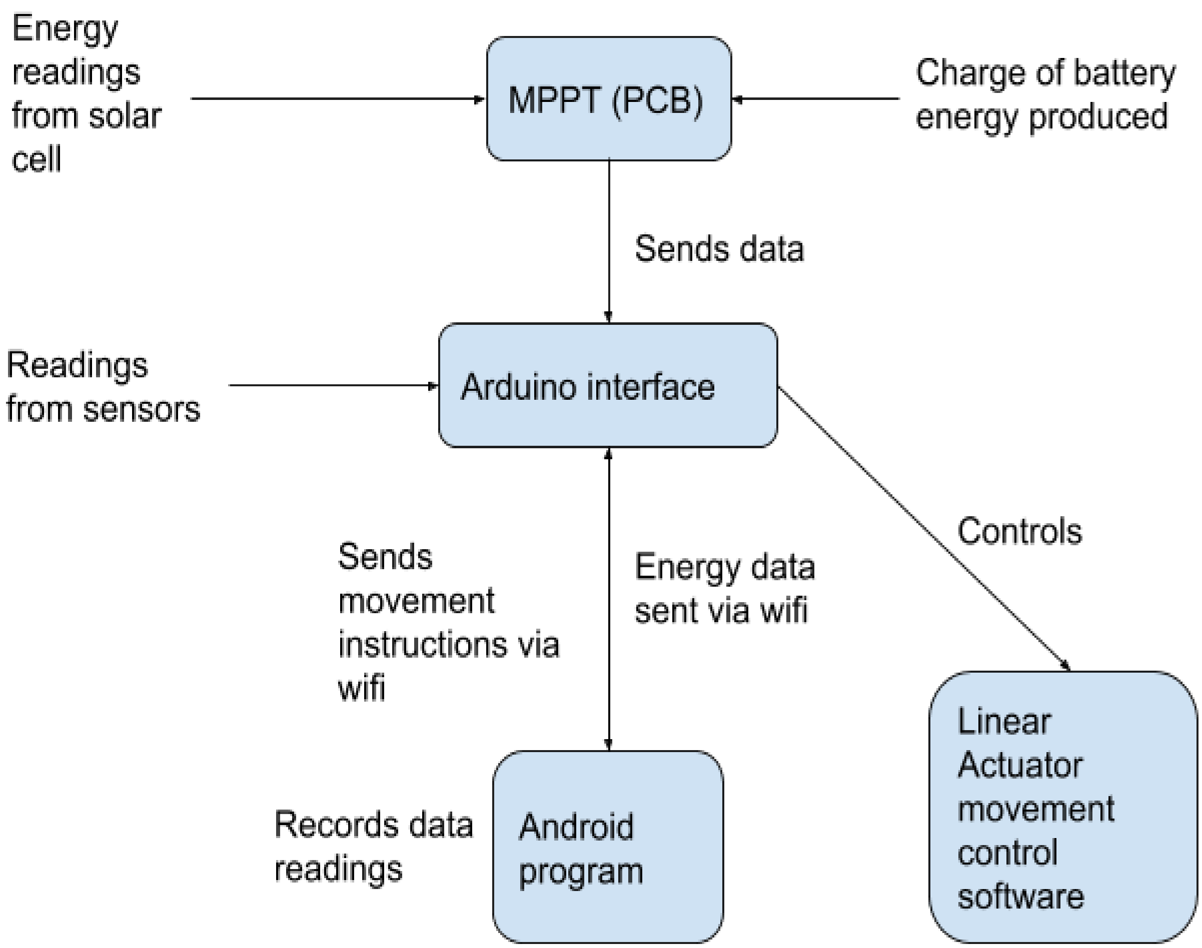
Project Constraints

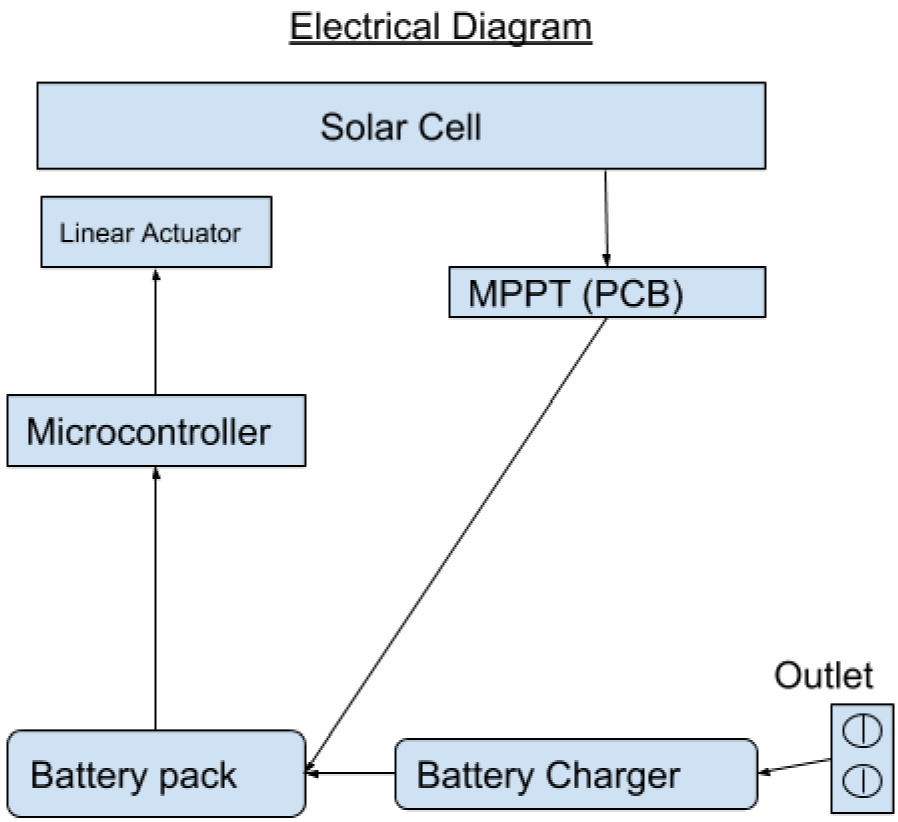
One key issue we have found lies in our ability to accurately track the sun. The accuracy of the solar sensors could greatly impact the solar system's ability to maintain a high C value. Another issue is that the cost of melting the elements to create the glass to refract the sunlight would be cost effective. The solar tracker would not be able to function during the night, and also during overcast days and storms the energy readings would be lower. This would cause a constraint on the location that the design can be utilized. Regarding health regulations, possible high power/voltage of battery pack could cause shock those who interact with it; looking into the side where the light is being concentrated to could cause a risk of blindness. Based on the recent political climate, solar hardware has become slightly more difficult to buy at a large scale. A 30% tariff will be placed on imported solar cells and modules from China after 2.5 Gigawatts have been purchased. This provides constraints on a larger scale deployment of our design, rather than a simple prototype.

Block Diagrams



Software Diagram





Budget
This project will be self-funded, pending energy company sponsorships.

Item	Quantity	Price Estimate
Metal framing material	1	$45
Metal support material	1	$20
Light sensor	2	$60
Linear actuator	2	$120
Battery bank	1	$100
Custom PCB	1	$30-$100
MPPT components	1	$20
Microcontroller	1	$10
Microcontroller wifi chip	1	$5

Voltage regulators	2	$10-$30
Kiln access	1	$200
High index glass samples (~3cm^2)	5	$30
Large high index glass sheet	2	$50
Zig-zag mold	1	$60
Silver nitrate salt	100g	$60
	TOTAL	~$820-$910

Project Milestones

<u>Concentrator Milestones</u>

#	Milestone	Week of Completion	✔
1	Design and build apparatus for testing planar gradient index material	2/18	
2	Begin testing ion exchange process on 5 - 10 small samples of glass	2/25	
3	Finalize choice of gradient index glass materials	3/11	
4	Bond 2 samples with resin and test optical properties under varying temperatures	3/25	
5	Fabricate a molded glass slump of zig-zag pattern	4/1	
6	Deposit mirror onto zig-zag size of glass	4/8	
7	Bond polycarbonate directly to glass	4/15	
8	Assemble a working mini prototype	4/29	
9	Order materials for full scale prototype	8/19	
10	Fabricate a full size gradient index sheet and fuse polycarbonate layer to it	8/26	
11	Fabricate a full size zig-zag glass piece	9/16	
12	Deposit Mirror onto full size zig-zag piece	9/23	

13	Attach mirrored zig-zag piece to assembly	9/30	
14	Attach solar cells to concentrator	10/14	
15	Integrate concentrator assembly with tracking system	10/31	

Tracker Milestones

#	Milestone	Week of Completion	✔
1	Complete and finalize tracker design	2/11	✔
2	Complete design of MPPT circuit	2/25	
3	Place order for parts that will interface with microcontroller (for testing)	3/11	
4	Complete design of battery bank and converter circuits	3/18	
5	Test moving parts by connecting them to microcontroller and purchase remaining parts including sample solar cells	3/25	
6	Test solar cell efficiency	4/4	
7	Review parts received and confirm that they wIll work as expected	4/11	
8	Assemble MPPT circuit and test with a solar cell	8/23	
9	Assemble frame for concentrator	9/9	
10	Test a solar cell, MPPT circuit and battery bank system	9/16	
11	Assemble support frame and linear actuators	9/30	
12	Integrate electronics with microcontroller	10/7	
13	Test movement of entire tracking system with microcontroller	10/14	
14	Integrate with concentrator	10/31	
15	Test manually with concentrator attached	11/7	
16	Test fully integrated system	11/14	

Software Milestones

#	Milestone	Week of Completion	✔
1	Define the problem the mobile application is trying to solve	2/4	✔
2	Define the feature set of the application	2/11	✔
3	Choose mobile platform, framework, and libraries, choose ~~and order microcontroller~~ (how to get info via wifi, start dummy app), charting, wifi, github sharing	2/25	
4	Design mobile application user experience	3/4	
5	Stub out mobile application	3/11	
6	Implement connection between microcontroller and mobile application	3/25	
7	Test interface with moving parts by controlling them with microcontroller	3/25	
8	Design microcontroller application	4/8	
9	Finalize design & test with mock data	4/22	
10	Implement microcontroller control of tracking system	8/23	
11	Implement microcontroller wifi endpoints	9/9	
12	Implement mobile app part 1 and integrate implementation with microcontroller app	9/16	
13	Implement mobile app part 2 and	9/23	
14	Implement mobile app part 3 (scope depends on user experience design)	9/30	
15	Complete mobile app implementation	10/14	
16	Test fully integrated system	11/14	

Decision Discussion

Due to pending funding from sponsors such as Duke Energy, our team has decided to generalize our project to suit both a solar farm product and a consumer grade product. Luckily, both of these scenarios require the same hardware and software components of our design, however some specifications may change based on this sponsorship. If the sponsorship were to be approved and we were given more funding, changes would include an increased concentrator size, a reduction of automation specifically on the second axis, the removal of an enclosure, and a change in data and UI served in the mobile application.

An increased budget would easily allow us access to a bigger kiln and access to higher grade materials to produce a larger concentrator. If an energy company wanted to place our device on their solar farm, we would most likely remove the automation of the second axis tracking system and linear actuator. After researching the effectiveness of dual-axis tracking, we found it most efficient to only track one axis, notably because of repair costs since servicing a broken axis tracker is not worth the money that the system would make back by tracking that second axis. However, the consumer grade model of this system would most likely require a second axis tracking system and actuator to reduce the labor that the consumer must exert to have a functional product.

The solar farm version of our system would likely require the removal of any idea of enclosure, since the energy company would find it most effective to pack many of our systems close together to maximize land use, while the consumer grade product would want full autonomy and protection against the elements.

Another vital change is the user experience and design of our android application. If our target market is for a consumer, the application will be more focused on ROI data and metrics to reduce buyer’s remorse. On the other hand, if we are building a system for a solar farm, our application will be built to suit the needs of a solar technician, who would also want efficiency metrics, but with more of a focus on underperforming areas that can be serviced.