SolarMill- Wind and Solar Energy

by

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Abstract

For this project, we are utilizing a combination of wind turbines and solar panels, a SolarMill, in order to feed a Level 2, 16 amps and 240 volts, electrical vehicle (EV) charging station. This will provide Cal Maritime with another form of renewable energy because Cal Maritime formerly only utilized solar panels. We designed a ballasting and electrical system to support the SolarMill and a data acquisition system to record how much green energy the charger uses. Our team collected data over a three-day period and compared that power production with power production data from the solar only grid. There were small spikes of power produced from the wind component of the SolarMill when comparing the data trends between the two systems.

ASSEMBLED CAD RENDERING

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1 INTRODUCTION

Wooster Engineering donated a SolarMill, a combination of wind turbines and solar panels, to Cal Maritime for senior projects. Our group was fortunate enough to decide how to integrate the SolarMill on campus. An older mechanical engineering senior project inspired our project. A group from 2013 designed, fabricated, and installed an electrical system that supports a 120-volt (slow charging) electrical vehicle (EV) charging station. This system draws power from an array of solar panels on top of the Engineering Technology Building roof. Figure 1.1 captures the solar grid and the EV charging station.

The solar panel array sends power down through an inverter, charge controller, and battery pack in order to deliver power at the correct specifications for the car charger. Figure 1.2 shows a one line with more detail regarding this system. The batteries store about twenty hours of power for the current charging station. The solar panels provide about 6.6 Kwh a day and over 31,000 Kwh in their lifetime on this campus.

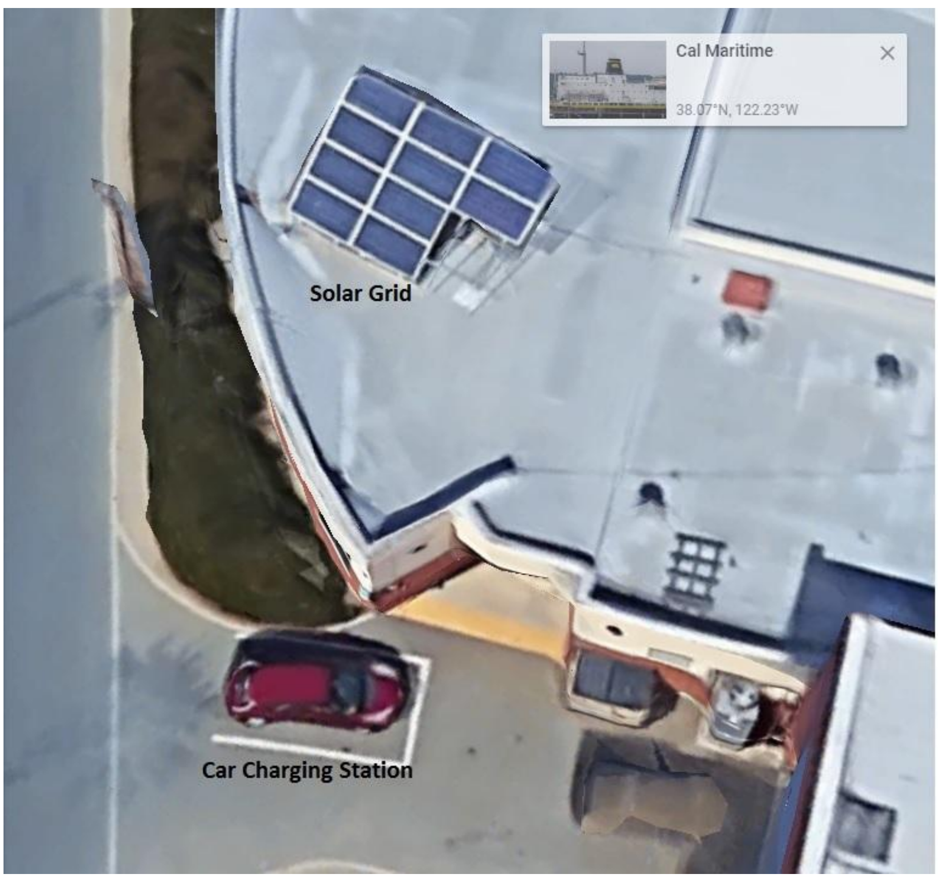


Figure 1.1 Current grid and car charging station

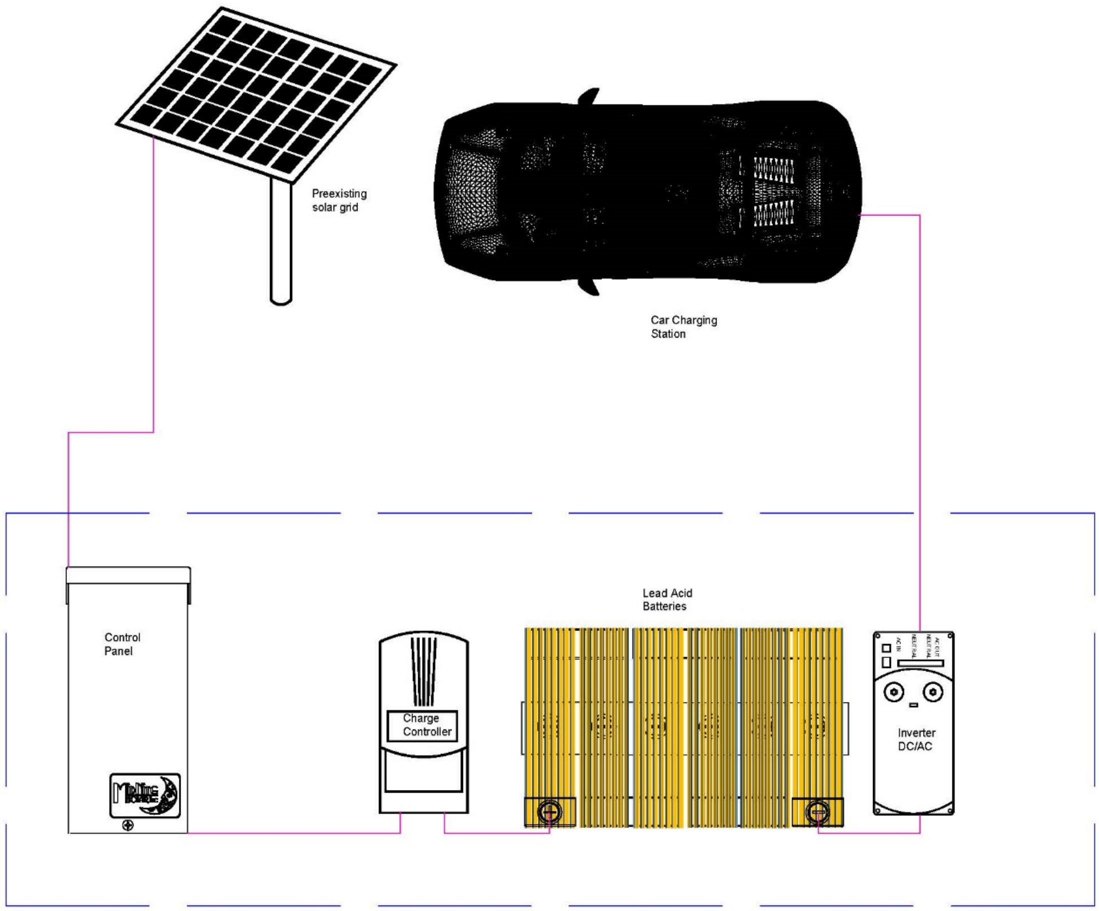


Figure 1.2 One line for pre-existing system

However, there is always room for improvement, and we believe that the SolarMill could be the improvement needed for this system. The new system will draw electricity generated by the SolarMill to a 240-volt (fast charging) EV charger.

2 Background, Literature Survey, and Benchmarking

2.1 Literature Review

"My SolarMill™ Store." *WindStream Technologies, Inc. (WSTI), www.windstrea-inc.com/my-solarmill*

This website provided all the specifications needed for the SolarMill SM1-3P that was used for this project. Specifications like weight, capacity for both the solar panels and the wind turbines, and speed cut-in for the turbines. All this information was important to know before ordering materials and during power calculations to best optimize that system.

Craig, R. R. (2011). *Mechanics of Materials.* Hoboken, NJ: John Wiley and Sons, Inc.

For this review, the author introduces the topic topic of Mechanics and Materials and how different materials ans structures act in different loading conditions. It goes throug the fundamental concepts of solid mechanics: equilibrum, Force-Temperatur, and Geometry of Deformation. It goes through the process of calcuating stresses, stains, and moments about beam. With the use of the book, it provided systematic problem-solving methods importants to anylizing how material and structures act under loading.

“NDBC – Station DPXC1 Recent Data.” NOAA – National Data Buoy Center. N.p., 2018. Web. 20 Apr. 2018. <http://www.ndbc.noaa.gov/station_page.php?station=pcoc1>

The National Oceanic and Atmospheric Administration (NOAA) records the wind in the different areas in the United States. Specifically, there is one station that is close to Cal Maritime, so we were able to obtain the wind data for Station DPXC1- Davis Point, San Pablo Bay, CA. NOAA was able to provide us with recent data on wind speed, wind direction, and wind gust that is recorded periodically throughout the day and can be used to calculate the power generation of the wind right before reaching the blades of the vertical wind turbine blades of the SolarMill.

Breeze, P. (2016). *Solar Power Generation.* London: Joe Hayton.

This book proved to be a valuable resource when evaluating the data acquired from both the solar only grid and the SolarMill grid. It also provided us with a greater understanding of how photovoltaic cells are converted into electrical energy.

DeVore, H., Higgins, M., MacLeod, C., Moss, N., & Velez, A. (2013). *Electric vehicle charging station*. Vallejo, Calif.: California Maritime Academy.

The information from the previous car charging station provided us with the information that we needed to assess how we could incorporate the SolarMill EV charging station with the Solar Panel ONLY EV charging station. We were also able to use their information to see how much more efficient the system can be with the batteries holding the charge before delivering it to the customer at the EV charging station. Gathering information from the 2013 Solar Panel EV charging station project was crucial to our original goal of integrating our SolarMill into their system.

Gipe, P. (2004). *Wind Power.* White River Junction: Chelsea Green Publishing Company.

This book answered our inquiries about wind power and converting the wind component of the SolarMill into energy. There is a great section in this book about the efficiency of wind and expected power generation from wind turbines.

California ISO – Todays Outlook, www.caiso.com/TodaysOutlook/Pages/default.aspx.

The California Independent System Operator provides a statewide average electricity generated by different renewable energy systems. The graphs used from this website provided information like peak sun hours and wind distribution throughout the day. This information was useful in making theoretical calculations of power that the SolarMill could potentially produce at specified ratings.

National Fire Protection Association. (2017). NFPA 70 National Electrical Code. Quincy, Massachusetts, USA.

NFPA 70 is the National Electrical Code, which specifies and provides requirements for all sorts of electrical stuff. Pertinent to this project was the requirements for local disconnects to be able to isolate the SolarMill from the rest of the system, as well as referencing NFPA 1: Ch 52 for battery space requirements.

California Building Standards Commission. (n.d.). 2016 California Building Code. *California Code of Regulations Title 24, Part 2, Volume 1 of 2*.

This portion of the California Building Code provides specifications for roof mounting photovoltaic panels, which we are using to design the mounting system for the SolarMill. In particular, this portion of the code describes that ballasting may be used to secure panels to a roof that has a maximum slope of 1 unit dropped per 12 units of length which the Power Lab roof does not exceed.

California Building Standards Commission. (n.d.). 2016 Title 24, Part 3, California Electrical Code. California.

In this portion of the California Building Code, we found rules to follow about wiring up and dealing with the electrical portions to supplement the rules laid out in NFPA 70. A majority of the electrical work done on this project was performed or supervised by the campus electrician Mr. Lee Bowen who made sure codes and regulations were adhered to.

2.2 Design Constraints

Our design has to acquiesce to constraints set upon it by the department of facilities on campus, PG&E, and the budget for the project. Department of facilities requires our system to be in a safe and accessible area. The SolarMill must be secured to the roof without making any protrusions in the roof. PG&E requires safe work practices, electrical setup, and equipment layout with appropriate clearances around panels. The budget requires that the total cost of the project to ring up to more than $900.

A major concern for safety is the mounting of the SolarMill. The SolarMill must remain stagnant in storm conditions (an upward wind speed of 100 MPH. If the SolarMill were to fall off the roof in the instance of a storm, this could compromise the safety of people residing below. The SolarMill cannot be bolted to the roof due to the constraint mentioned earlier. Facilities required that there be no protrusions made due to the costly process of having an engineer approve each hole we have to make.

The connections from the SolarMill to the control panel located in the Power Lab need to be safe connections landed by a licensed electrician. The conduit leading up to that panel needs to be weather proof because it will be outside with the SolarMill for the initial run, and it will proceed to travel back outside to connect to the battery system.

Requirements outlined by PG&E and OSHA affect how the SolarMill can be mounted, how we must conduct ourselves while working on the roof, and specifications for key components throughout the system like the batteries and the car charger.

The budget will encourage us to take more affordable paths and only make necessary purchases for the project. More affordable paths might include cheaper models of inverters and other key components. However, system safety paramount any budget restrictions.

3 PROBLEM DEFINITION PHASE

3.1 USER REQUIREMENTS AND DESIGN OBJECTIVES

3.1.1 Electrical

The electrical system we design must support a 240-volt EV charger, and utilize the power generated by the SolarMill.

3.1.2 Ballasting

We must ballast the SolarMill to the roof in order to ensure that the SolarMill is not lifted off the roof in storm conditions. Winds can reach speeds upwards of about 100 miles per hour in storm conditions.

3.1.3 Data Acquisition

A data acquisition system should record the power coming from the SolarMill and the power required to support the car charger. This will provide the means of comparing this system to the solar only grid. This data will also show how much the other charger is green energy, and how much power from the grid is required.

3.2 CONSTRAINTS

3.2.1 Electrical

Solar panels and wind turbines produce two different types of voltage. Wind turbines produce AC voltage (Gipe, 2004) and the solar panels produce DC voltage (Breeze, 2016). This power needs to be consolidated in 240 VAC and 16 amps to feed the car charger directly or 208 VAC to feed a panel connected to the grid. This requires a combination of inverters, combiners, and transformers.

3.2.2 Ballasting

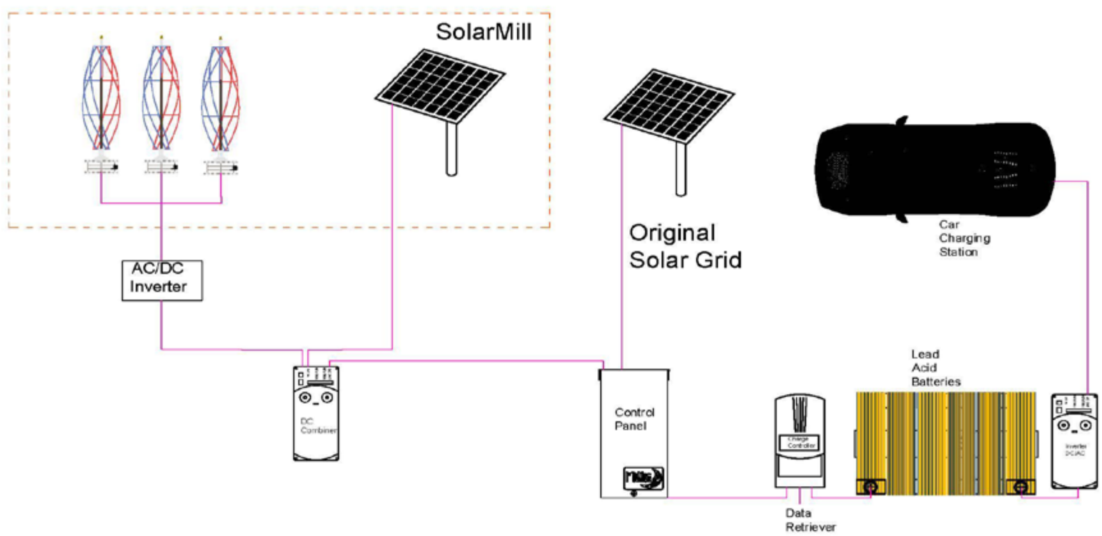
We will distribute ballast along the frame of the SolarMill. The ballasting cannot disintegrate under regular or storm condition weather. The ballasting must also have a long projected life span.

3.2.3 Data acquisition

The data acquisition system must remain inside a weatherproof enclosure, but also send data to an accessible location.

4 PROPOSED DESIGN

We must design a new system in order to utilize the power generated by the wind turbine and power the car charger. Wind turbines generate AC power unlike solar panels that generate DC power, so the first step from the wind turbine is an AC to DC converter. Following the AC to DC inverter, the energy has to be regulated between charging that batteries and a dump load in the event that the batteries are fully charged. Then, from the batteries, the power needs to convert back to 240 VAC power in order to charge the cars. A general one line of this system can be seen below:



4.1 FIRST ITERATION

The following design is based off the original budget allocated to the project. Originally, the project was destined for a $10,000 budget comprised of grants to our advisor, Ryan Storz, and a grant from CSSA's Greenovation fund. The application can be found in Appendices.

4.1.1 SolarMill

In order to provide the SolarMill with adequate exposure to wind, we have planned our design around placing the SolarMill on the roof of the power lab building on campus with the blades facing the water. This combination will also provide the panels that accompany the wind turbine with adequate sun exposure in order to generate power of their own. Figure 4.1 shows the exact location.

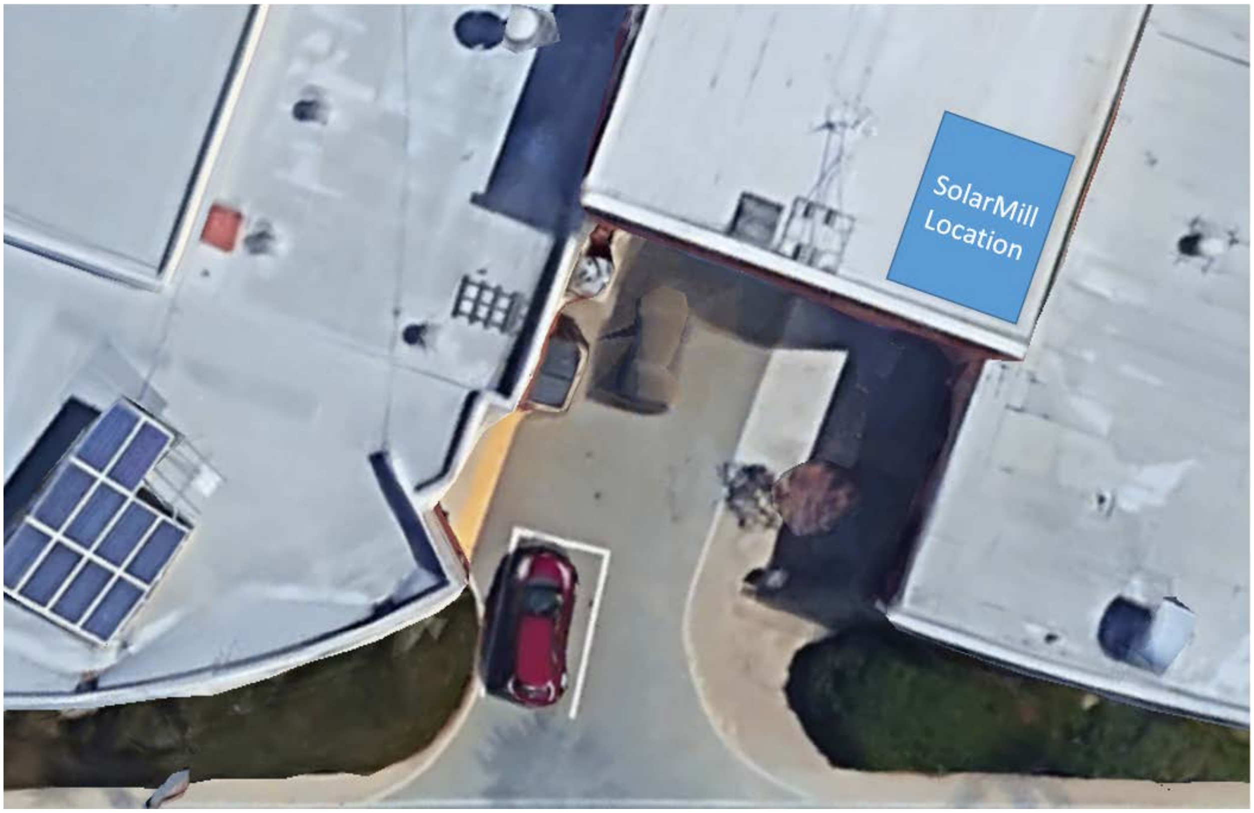


Figure 4.1 Proposed location for SolarMill

The SolarMill will experience a combination of shear stresses and forces coming from the wind (Figure 4.2). Given the constraint that there will be no holes put into the roof by facilities, the SolarMill, fastened to a bracket, will be ballasted with sandbags. This is the same method used to weigh down the current solar array located on the roof of the technology building. A proposed design for the bracket can be seen below in Figure 4.2.

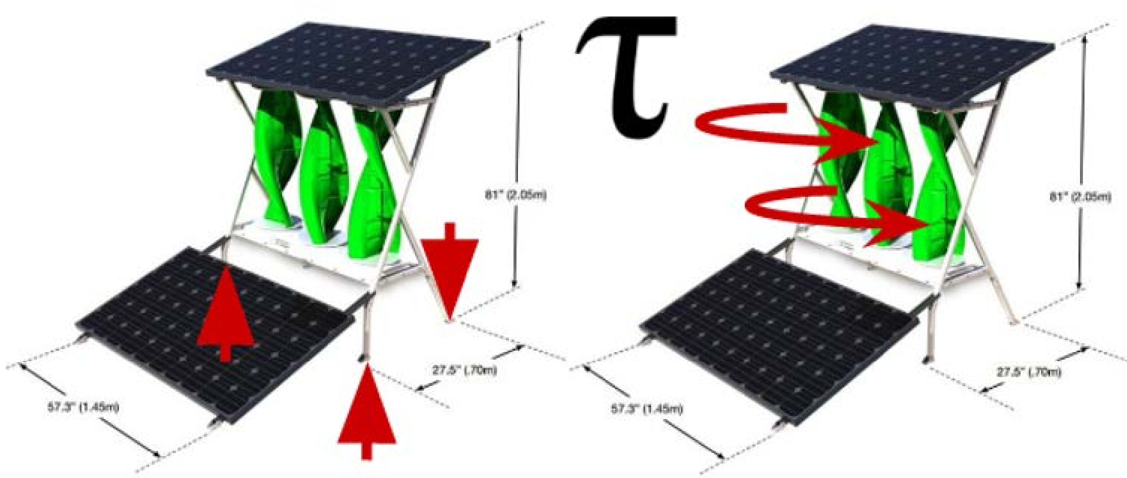


Figure 4.2 Forces experienced by SolarMill

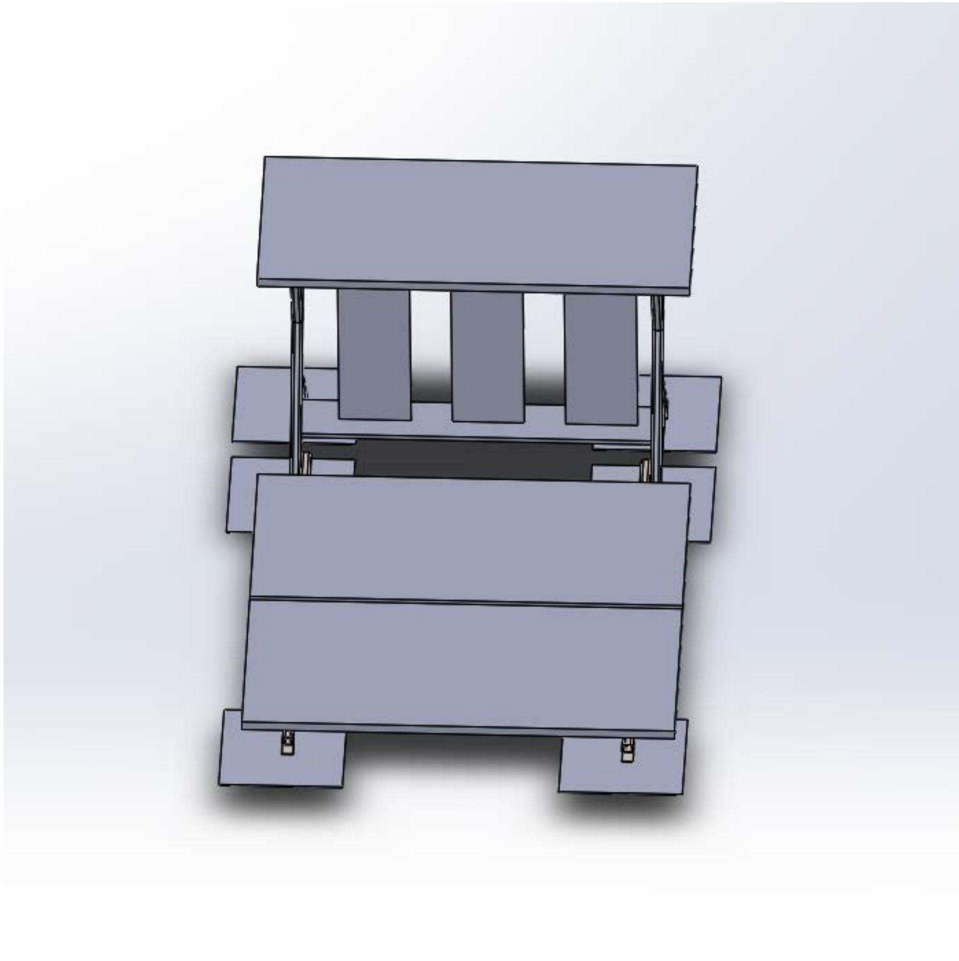


Figure 4.3 First iteration of ballasting design

Our first design iteration for connecting the solar mill to the roof was mounting it to one big flat plate and then ballasting the plate with sand bags. This turned out to not be the best method for ballasting. Bolting to the plate would lead to extrusions and uneven surfaces of the plate between the bolt head and the roof. In addition, sandbags are not ideal for ballasting because over time the bag enclosing them will break down.

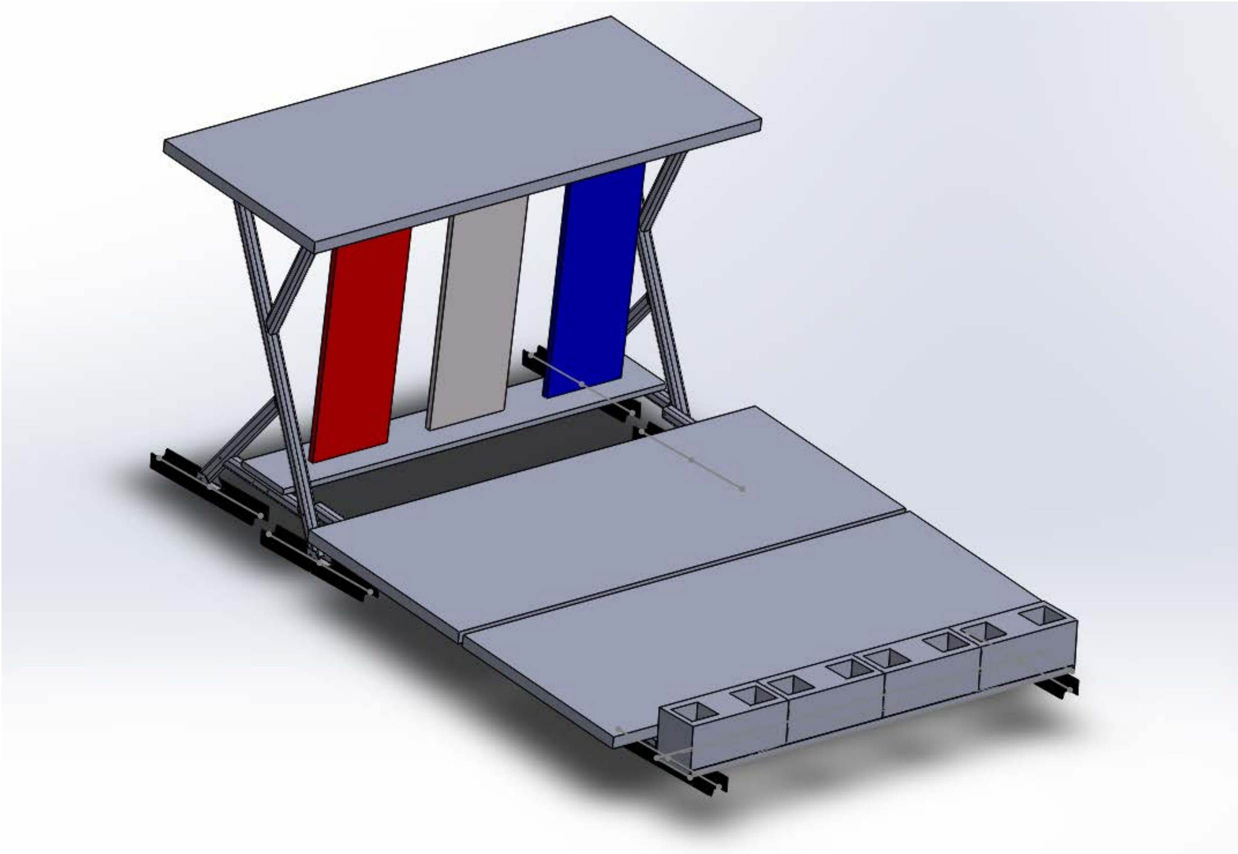


Figure 4.4 Second iteration ballasting design

This lead us to our second mounting design iteration. Using I beams as the feet we are able to mount the SolarMill feet brackets to the I beams with out the bolts contacting the roof. Instead of using sandbags for the ballasting method, we used cinderblocks as a more structurally sound ballasting method. Cinder blocks are also more weather resistant and have a longer life span than sand bags. To secure the cinder blocks to the solar mill we made an angle iron racks that were tack welded to the I-Beam frame seen in Figure 4.5.

Figure 4.5 Actual Ballast Design

4.1.2 Batteries

After the inverter inverts the power from the SolarMill from AC power to DC power, it will travel down weatherproof conduit to a charge controller. The charge controller will decide whether the batteries have space for the power coming in. If the batteries are full, the power dumps to a resistor bank. The capacity of the batteries will be enough power to support the car charger up to 10 hours.

The batteries will be located outside the power lab, against the wall of the technology building in a weatherproof container. The current location of the batteries will not work because they are releasing hydrogen into a not very well ventilated closet in the technology building. However, by placing the batteries outdoors, we will have to design a barrier to prevent cars from driving into the batteries. Figure 4.6 shows the new location for the batteries.

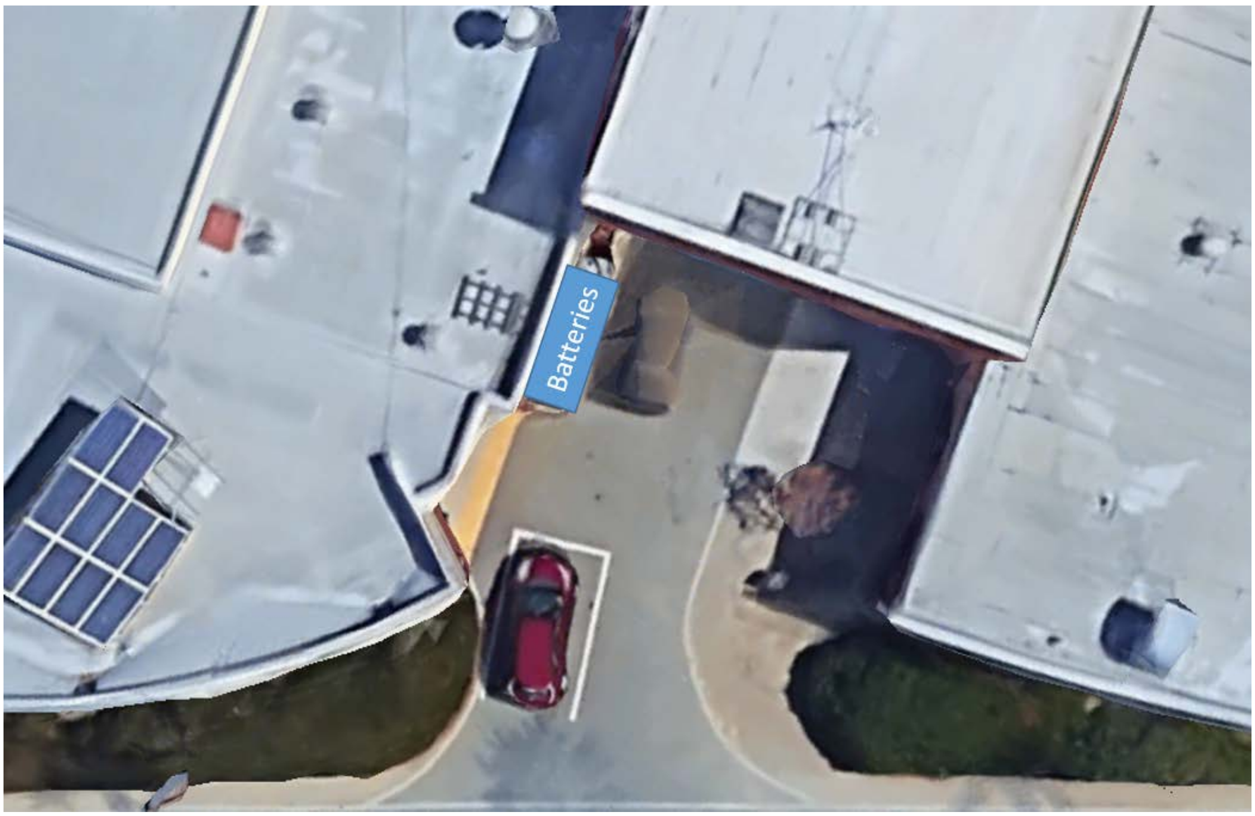


Figure 4.6 Potential battery location

4.1.3 Car Charger

The new 240V fast charging station will require a new charger that compliments 240 volts. In case the batteries contain now power and there is not enough power coming from the grid, it would also be suitable for the old charger to still be present as a slow charging station coming off of the technology building. The new charging station will have an LED configuration telling the user of the charging station that there is power available to charge their vehicle. There will also have to be a new inverter installed from the batteries to the new 240-volt car charger because the current inverter only inverts power to 120-volt AC.

4.2 SECOND ITERATION

The second iteration, geared towards the new budget presented to us at the end of the spring semester, focused on affordability and outreach. This iteration utilized a grid tied inverter that supplemented power from the SolarMill with power from the grid to support the large load that the car charger requires which nulled the need for a battery bank. In this new iteration, there was also a larger emphasis on data acquisition. Ballasting remained the same and so did the force analysis for the SolarMill in this iteration.

4.2.1 Electrical Design

The wind turbines of the SolarMill feed into an AC to DC converter, and that DC voltage combines with the DC voltage coming from the solar panels. The combined DC voltage feeds an inverter that inverts the power to 240 VAC. The power from the grid is 208 VAC. In order for the inverter to feed the grid, a transformer was required between the grid and the inverter. All of the energy generated at the SolarMill feeds the same panel that is feeding the car charger. The campus grid supplies any power required for charging that does not come from the SolarMill. Figure 4.7 shows this one line.

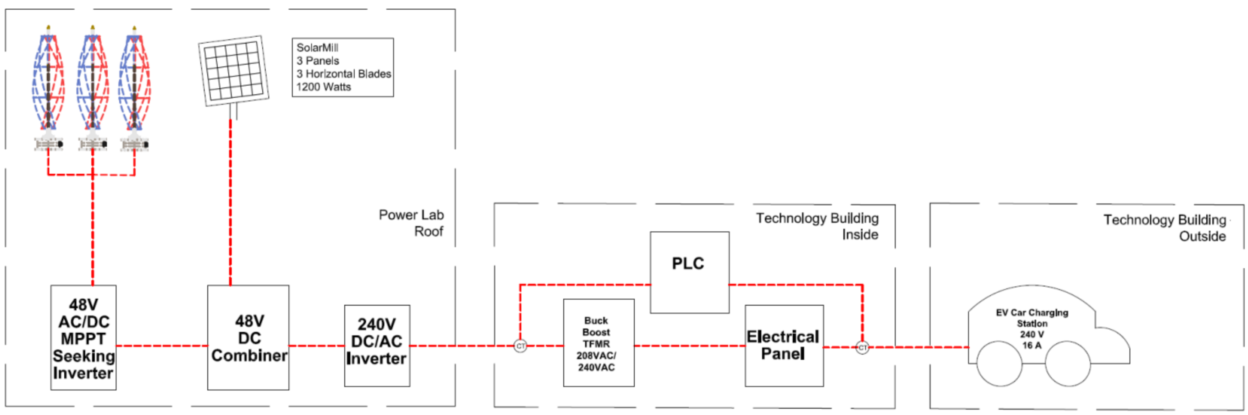


Figure 4.7 Final One Line

5 ANALYSIS

The major components in the design of this power grid is the SolarMill, the batteries, the inverter from the batteries to the car charger, and the car charger itself. This analysis will pertain to specifications of the products and will take into account cost and reputation.

5.1 SOLARMILL ANALYSIS

The analysis of the solar mill included an analysis of the stresses we can expect to see in regular and storm conditions. We calculated the expected power output from the SolarMill in order to estimate its contribution to the grid of the car charger.

The theoretical power output of turbines and solar panels are very different from the expected power output of turbines and solar panels. This is due to the efficiencies of these power generating devices as well as the weather conditions surrounding them. A solar panel can expect a maximum efficiency of about 40%, and a wind turbine will see a maximum efficiency of 30% at the highest wind speed that can be accommodated. Given those setbacks, the following theoretical power calculations were made for analysis of the efficiency of the power generating devices.

The theoretical power that the turbine could produce disregarding the efficiency of the wind turbine and assuming that it is operating under the maximum wind velocity is 1,739.93 watts. This was using the equation where

$$Max\ Power = \frac{1}{2}\rho A v^3 C_p$$

However, referring to the technical specifications of the turbine as well as the technical specifications of the panels, we can expect a maximum of 500 watts out of the wind turbine portion of the SolarMill if the wind blowing on the turbine was anywhere between 15 and 18 m/s at all times (about 40 mph). This is not likely because the average wind speed of Vallejo is anywhere between 4 and 6 m/s. Using the technical specifications, the monthly output would be anywhere between 100 and 150 kWh (

Figure 5.1 Expected power output

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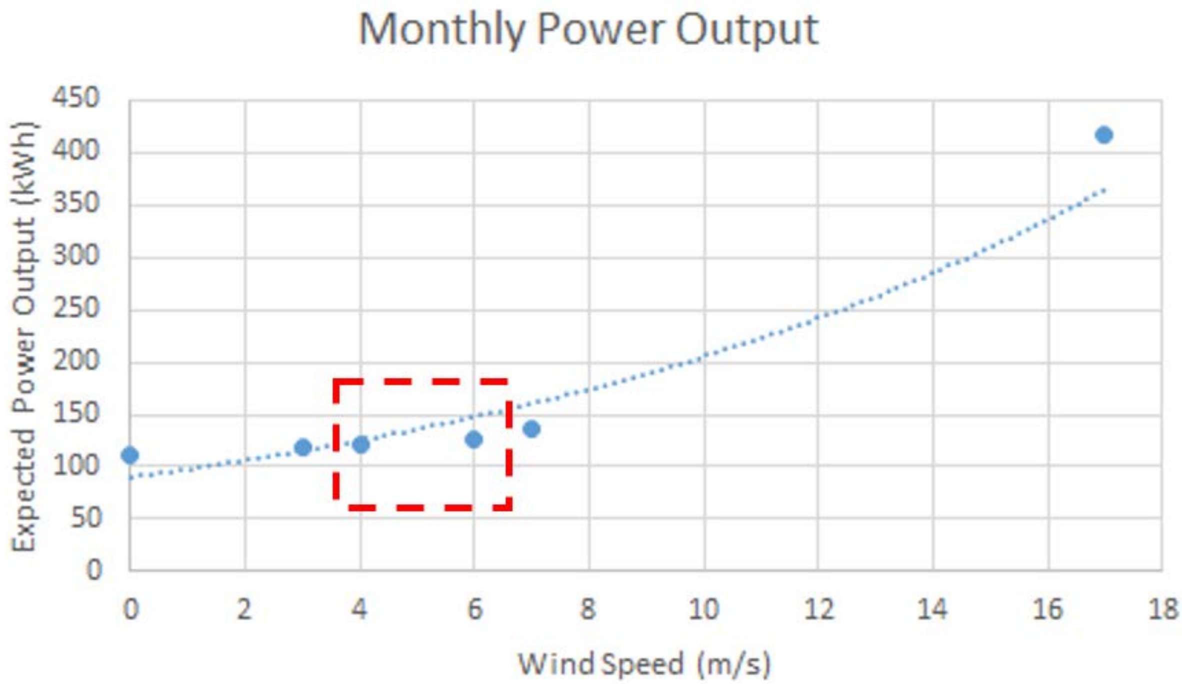


Figure 5.1 Expected power output

The solar panels are rated for a maximum output of 200 watts per panel at peak sun, which would generate a maximum of 36 kWh a month each or 108 kWh total, but the solar panels given trends in Vallejo will probably generate about 30% percent of that figure. If the SolarMill was able to produce the amount of power issued by the technical specifications under perfect conditions, the grid would produce up to 50% more power than it is currently providing.

We installed our donated solar mill onto the Power lab building in order to integrate it into or renewable energy car charging station. An important part of this installation was the mounting of the actual solar mill to the building itself. In order to figure out the forces that will be caused by the wind passing through the blades we did a force and stress analysis. We calculated stress with two different method. The first method was our hand calculations modeling the turbine blades as a fixed beams to a flat plate seen in the Appendix A. From this we figured out the max moment that would occur due to the wind speed. This max moment was used to calculate the moment diagram seen in the Appendix. From this moment diagram we got the Max stress Von Mises stress seen at the mounting surfaces. The plot below is the max stress at the blade base for beam 1 and the max stress on the mounting surface. For these calculations we expected to get much higher values than for the static analysis with flow simulation loading. This hand calc showed the worst case where the contact area was modeled as a flat plate with no gaps instead of having the spaces we would see on the actual turbine. looking at the appendix for this plotted data in table form, we see the max stress on the mounts is $1.7E6\ \frac{N}{m^2}$ at 45 m/s wind speed. When physically mounting the turbine to the roof we will have to take in account these stresses acting on the mounting system to know what forces we have to counteract in order to keep the turbine safely on the roof.

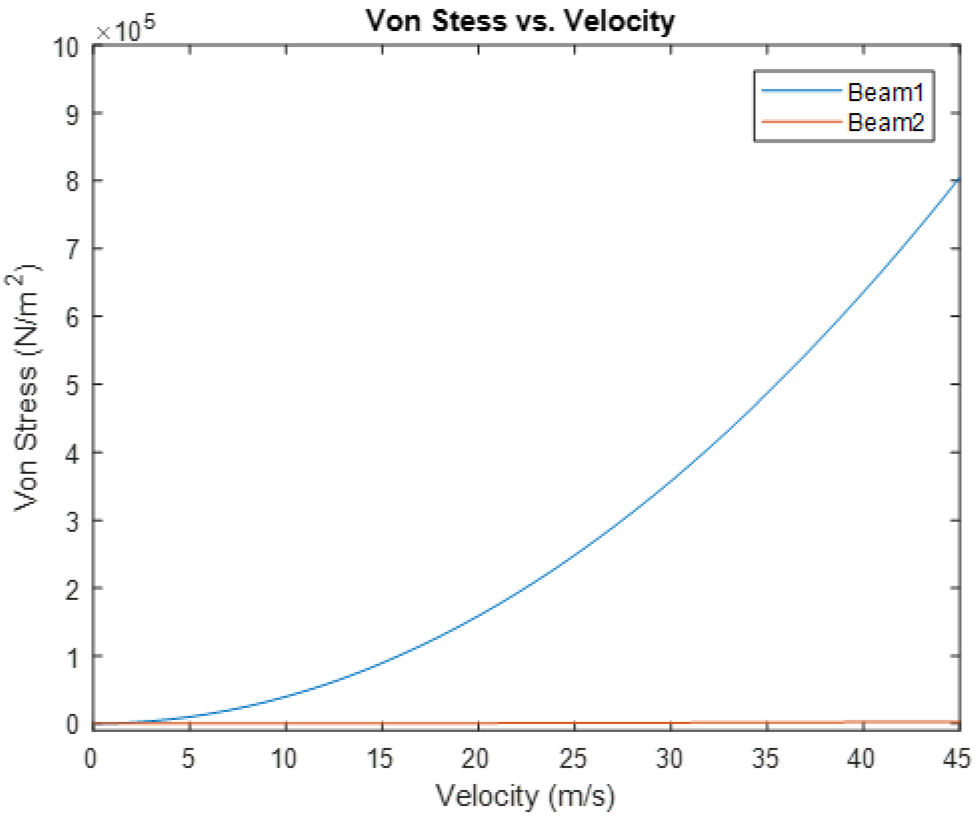


Figure 5.2

The second analysis we did was a flow simulation in solid works in order to get the force acting on the mounts of our turbine. We ran a flow for both 18 (m/s) which is the rated speed for our turbine, and a storm case at 45 (m/s). Looking at the figures below we see for 18 (m/s) wind speed we only got a stress of 242 (N/m^2) compared to the worst case hand calc we did which had about double the contact area due to the way we modeled it. The stress seen from the wind for the test is well below the yield strength of steel itself, so we don't need to worry about the material failing.

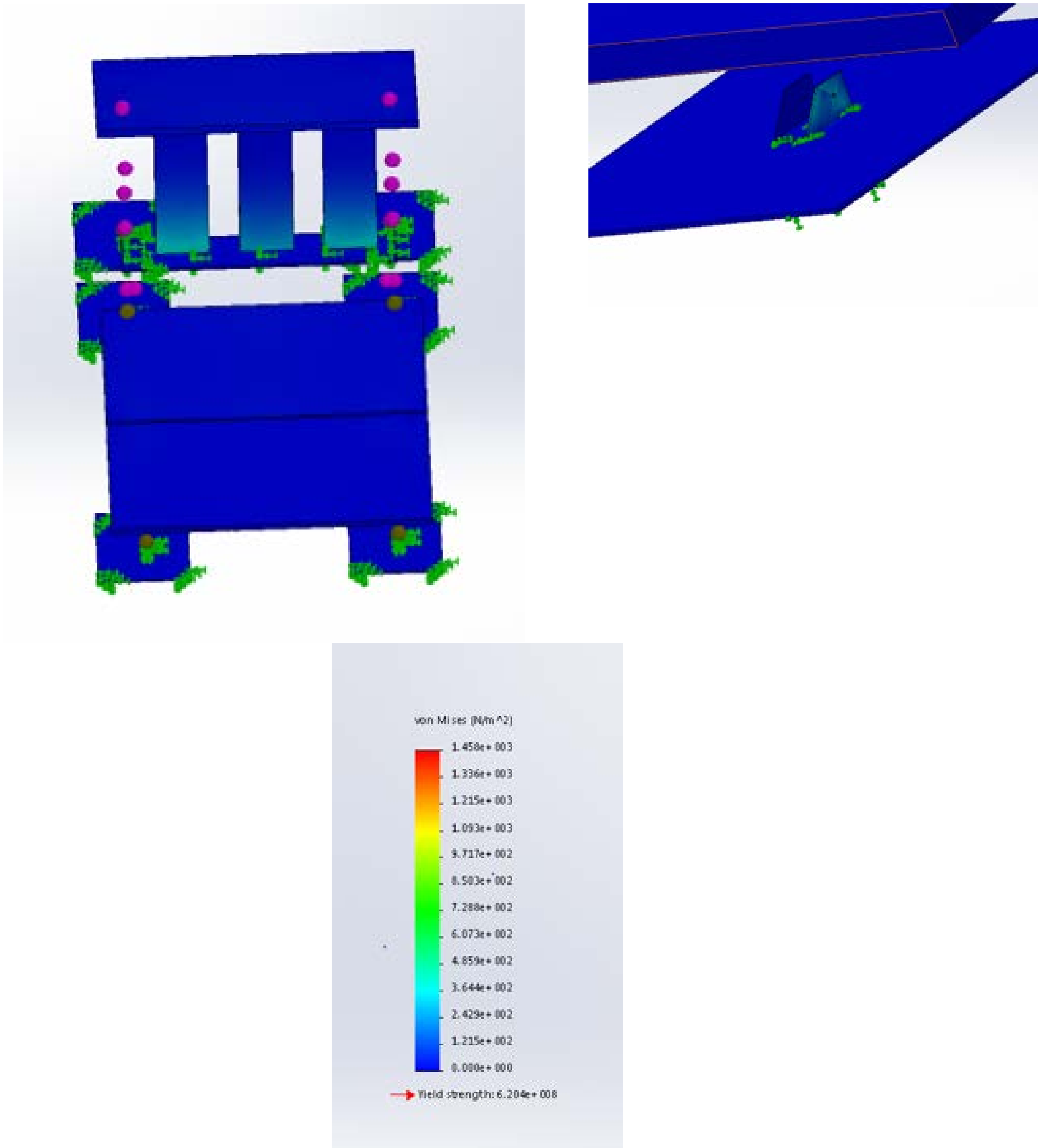

von Mises (N/m^2)
1.458e+003
1.336e+003
1.215e+003
1.093e+003
9.717e+002
8.503e+002
7.288e+002
6.073e+002
4.859e+002
3.644e+002
2.429e+002
1.215e+002
0.000e+000
Yield strength: 6.204e+008

Figure 5.3

Below we did a static analysis of the wind loading at unlikely storm conditions just to make sure the turbine material would not fail. It is the duty of an engineer to make sure there is a safety factor in their design for unpredictable conditions that might occur. Below we can see the results due to the flow analysis in solid works from the 45 m/s wind speed. We see that the stresses on the mounts and blades are still below the yield strength of steel. These plots of stress analysis caused by the wind force are imperative to making a safe system. By following the data collected from our flow simulated that we proved with the hand calculations found in the Appendix A we will be able to design a safe mounting system for our solar mill assembly.

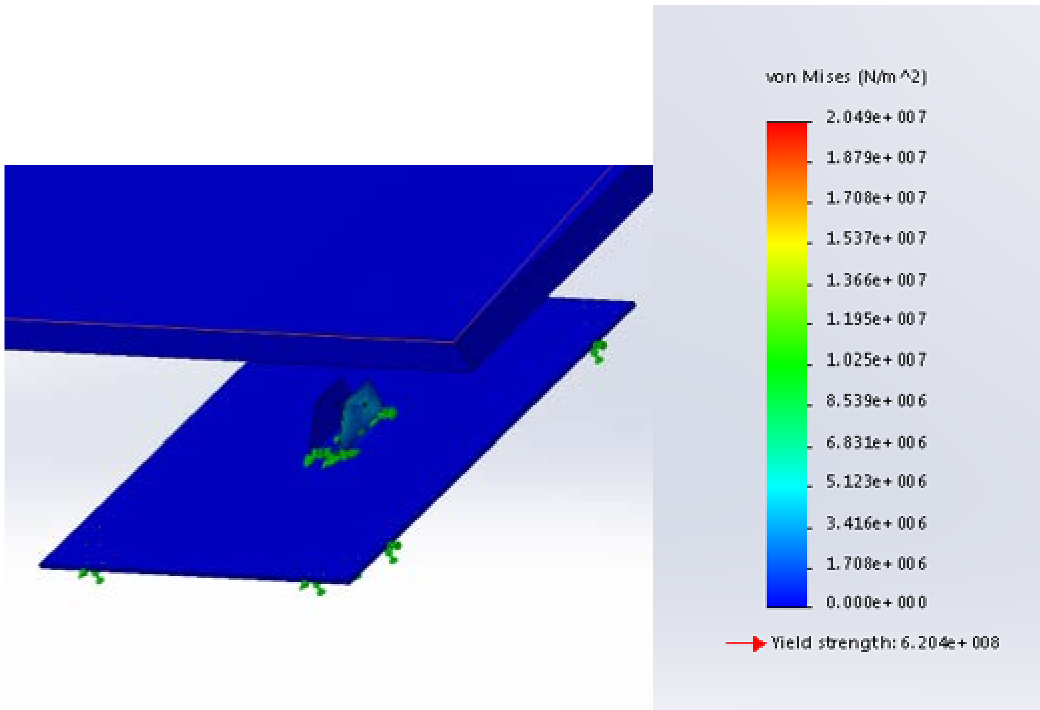


Figure 5.4

With the stress analysis above we proved that the material would not fail due to loading. What we needed to do know was figure out the reactive forces needed to keep the SolarMill on the roof. Along with the static analyse we did a check with hand calculations to see what the reaction forces would be acting on each end of the solar mill mounts. Modeling the SolarMill as a simply supported beam and using equations from (Craig, 2011), we were able to use the moment caused by the blades to figure out the stresses and reactive forces. We did hand calculations for both the 18 m/s and 45 m/s case.

Wind Simulation of 18m/s Max operational Speed of Turbine

$$Force = \frac{1}{2} * \rho * v^2 * A$$

$$Force = \frac{1}{2} * 1.225 \left(\frac{kg}{m^2}\right) * 18 \frac{m^2}{s} * (1.62 * 1.98)m$$

$$Force = 636.5\ N$$

$$q(x) = \frac{Force}{Height\ Of\ Blade\ Plate(y)}$$

$$q(x) = \frac{636.5\ N}{1.62\ m}$$

$$q(x) = 392.9\ \frac{N}{m}$$

$$M_{Max} = \frac{q(x) * y}{2}$$

$$M_{Max} = \frac{392.9\ \frac{N}{m} * 1.62m^2}{2}$$

$$M_{Max} = 515.6\ N * m$$

$$\sigma_{v.m} = \frac{M_{max} * y}{I}$$

$$\sigma_{v.m} = \frac{515.6N * m * 1.62m}{\frac{1.98m * .34m^3}{12}}$$

$$\sigma_{v.m} = 397.52\ \frac{N}{m^2}$$

$$\sum_M = R_1 * 2.8m + 515.6\ N * m$$

$$R_1 = \frac{184.8N * .2248\ lbf}{1N}$$

$$R_1 = R_2 = 41.54\ lbf$$

Wind Simulation of 45m/s Worst Case Storm Conditions:

$$Force = \frac{1}{2} * \rho * v^2 * A$$

$$Force = \frac{1}{2} * 1.225 \left(\frac{kg}{m^2}\right) * 45 \frac{m^2}{s} * (1.62 * 1.98)m$$

$$Force = 636.5\ N$$

$$q(x) = \frac{Force}{Height\ Of\ Blade\ Plate(y)}$$

$$q(x) = \frac{3978.426\ N}{1.62\ m}$$

$$q(x) = 2455.818\ \frac{N}{m}$$

$$M_{Max} = \frac{q(x) * y}{2}$$

$$M_{Max} = \frac{2455.818\ \frac{N}{m} * 1.62m^2}{2}$$

$$M_{Max} = 3222.5\ N * m$$

$$\sigma_{v.m} = \frac{M_{max} * y}{I}$$

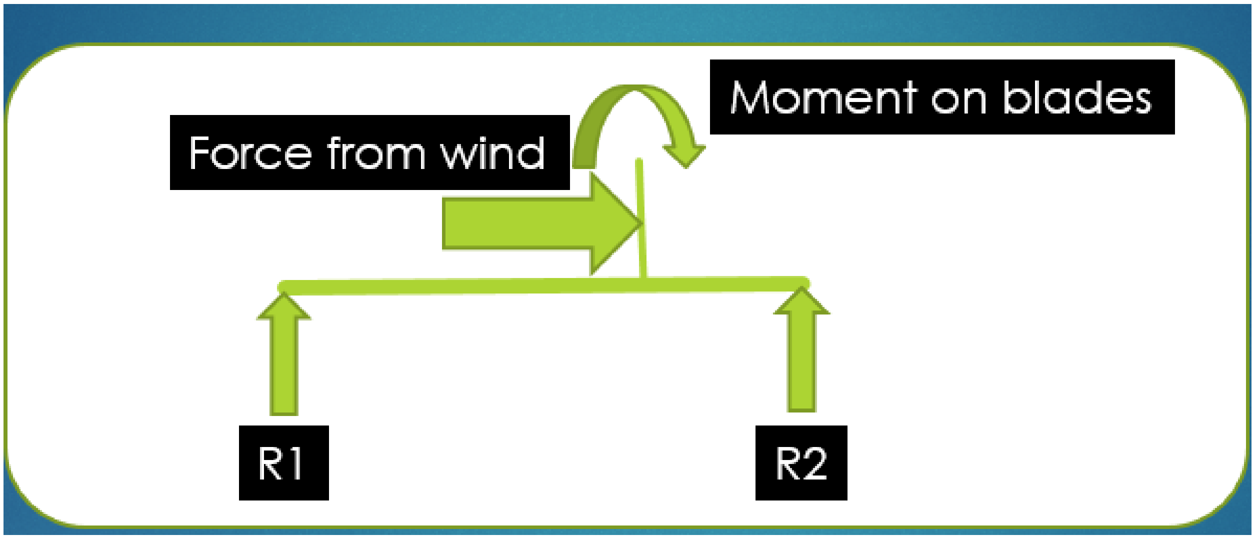
$$\sigma_{v.m} = \frac{322.5 * m * 1.62m}{\frac{1.98m * .34m^3}{12}}$$

$$\sigma_{v.m} = 1.7E6\ \frac{N}{m^2}$$

$$\sum_M = R_1 * 2.8m + 3222.5M * m$$

$$R_1 = \frac{1150.892N * .2248\ lbf}{1N}$$

$$R_1 = R_2 = 256.72\ lbf$$



Knowing the reactive forces, we were able to figure out the forces needed at the supports of the Solar mill to secure it to the roof. At the worst case wind loading case we would need a total of 500 pounds of ballasting to properly secure the solar mill to the room. At the max rated speed for the wind turbine we needed only 41 lbs at each support or 82 pounds of total ballast. Being that the solar mill assembly is already 375 pounds with out any ballasting we took this weight into account. Each I beam support was 15 pounds for a total of 90 pounds, and each cinder block is 30 pounds for a total of 120 pounds. Together the added weight of the mounting systems was 210 pounds. With the solar mill system and the mounting system ballasting weights we got a total of 585 pounds of ballast, which theoretically should be enough to keep the solar mill on the roof in case of storm wind conditions.

5.2 Batteries

In order to store the 1422 Ahr required for our 6hr max charging amount we will need to upgrade our battery storage capacity. The equations used to find the required capacity can be found in Appendices. The current capacity is just over 700 Ahr, but these batteries are almost 5 years old and will need replacing soon. Due to the need to replace the current batteries, we looked for new batteries that will cover the entire storage needs rather than just the difference between the current system and our projected needs.

There are many battery options that are available on the market, with a wide variety of cost and quality. Cost varies depending on the battery capacity and the voltage of the battery, increasing in cost as either goes up. After evaluating many battery types, we have narrowed it down to two possible setups.

Battery	Voltage	Rating	Type	Size	Needed In string x strings	cost/unit	total cost

Rolls S-1660	2 VDC	1284 Ah	Flooded lead acid	13.13 × 7.13 × 16.75 in 125 lbs	12x1	$405	$4,860
Crown CR430	6 VDC	430 Ah	Flooded lead acid	12.38 × 7.19 × 15.29 in 122 lbs	8x4	$320	$10,240

Table 5.1 Battery options

1

For battery storage setups, increasing the number of batteries in series will add the voltages together while adding multiple strings in parallel will add the Ahr of each string together. Adding batteries in series does not affect the Ahr of the setup.

From our selection, the cheaper option leaves us short of our 1422 Ahr target, but will overall take up less space, and a lower total weight. The Crown battery option would provide us with our desired capacity, however.

In order to keep costs down, we could limit the capacity of the setup to only account for 4-5 hours of max charging rate, or design it so the batteries act as a supplement to the wind and solar power where if that is not enough then the system switches to building power to charge the electric vehicle.

5.3 Inverter

Currently the system in place is running off of an Outback Power Pack inverter. This inverter is designed to take a DC voltage input and convert it to AC voltage. The inverter can have an input of: 12, 24, or 48VDC. This single inverter will then output a voltage of 120VAC. The max output power on the one inverter is 3500VA.

In order to bring the charging station to 240VAC we will need an output from our inverter of 240VAC. To get this 240VAC output we will purchase a new Outback Power Pack inverter and wire it so that we have 240V split phase. Both inverters will supply one hot wire with the third wire being a neutral. The maximum output power of the two inverters together will be 7000VA. With the stacking of the inverters we will achieve the 240VAC needed to support the level 2 charging station.

5.4 Car Charger

The current car charger being used is a ClipperCreek 120V charger. In order to update the system to a level 2, 240V charging station we would need to get a new car charger that is rated for 240V. There are many options available for a 240V electric vehicle charger, but we decided to narrow it down to ClipperCreek chargers since they have the widest range of options as well as they may be willing to help out with cost or donation since they helped with the previous project.

Clipper Creek LCS-15	$379	15A
Clipper Creek LCS-30	$499	30A
Clipper Creek LCS-40R	$665	32A
Clipper Creek LCS-20	$379	16A

Table 5.2 Car Charger options

The table above lists several options from ClipperCreek, which we looked at. The LCS-20 is the charger we are likely to go with due to its power draw being roughly our systems output so the batteries do not get drawn down too much, as well as it's one of the cheaper options. If we are able to get more funding, the LCS-40R would be a great choice to allow for the system power to be expanded, as well as its more rugged to handle being outside better.

6 FABRICATION PROCESS AND DESIGN PERFORMANCE

6.1 ELECTRICAL DESIGN

The electrical design duplicated the theoretical design stated in iteration two. Figure 4.7 shows the final one line that was materialized along the outside of the Engineering Technology Building and atop the Power Lab building. Figure 6.1shows the grid in actuality.

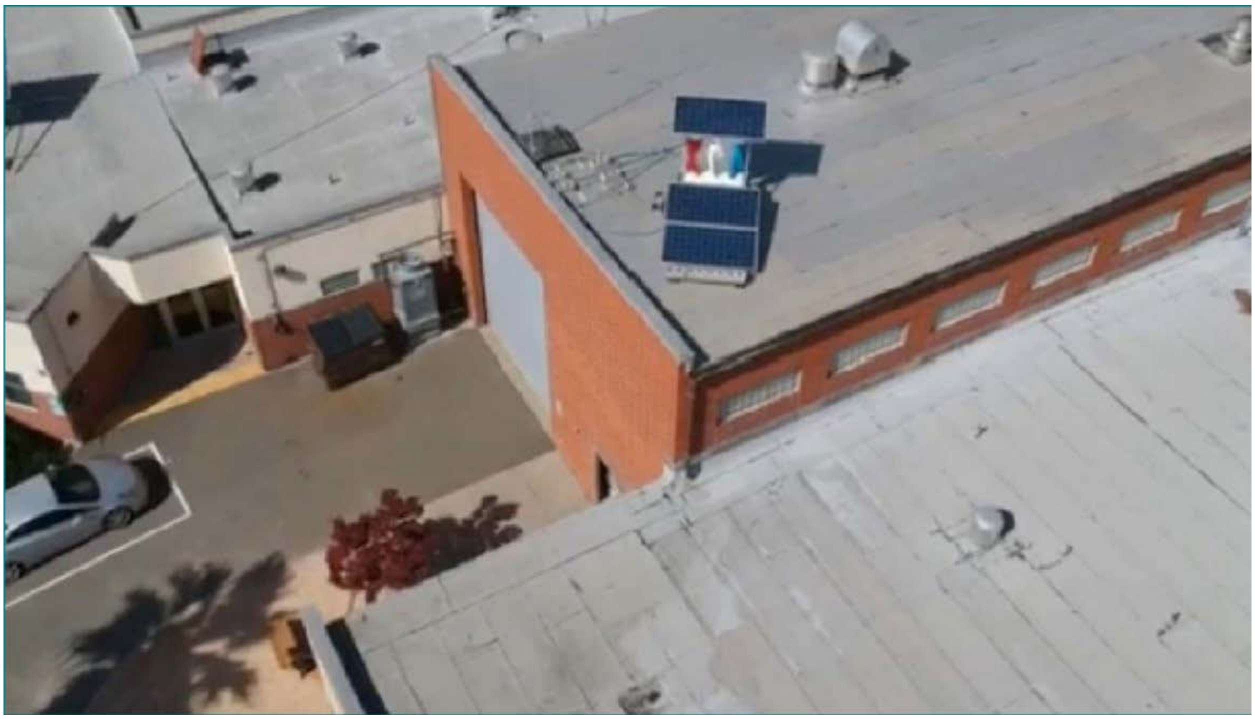


Figure 6.1 Bird's eye view of actual layout

6.2 BALLASTING DESIGN

Looking at the Design evolutions above we can see how we changed our ballasting design to best suit our needs. For Storm Conditions we needed to have 500 pounds of ballasting, but for max normal conditions, we needed only 80 pounds of ballasting. Looking at

6.3 DATA ACQUISITION DESIGN

For data acquisition we used a programmable logic controller (PLC) with an open source program. The PLC is an EasyIO 32FG+. The PLC is connected to two Magnelab current transformers. These current transformers transform the current running through the cable into a 0-5V control signal. Knowing the current and the constant voltage coming from the SolarMill we use the power law to find how much power we are producing. This data is then collected on the micro SD within the PLC which can be retrieved on the dashboard that we produced to be viewed anywhere on campus via the school's network.

6.4 BILL OF MATERIALS

Item #	Item	Quantity
1	SolarMill	1
2	Mill2Grid Inverter	1
3	DC/AC inverter	1
4	Local Disconnect	1
5	Buck/Boost Transformer	1
6	Current Transformer	2
7	PLC	1
8	Cinder Blocks	20
9	ClipperCreek EV Charger	1

Table 6.1 Bill of Materials

7 CONCLUSION

After collecting data from both the old solar system and our new solar/wind system, we were able to compare how wind affected power generation. As expected, solar made most of the power generation during the day while the solar rays are strong and during peak hours. After sunset hours, we saw a small quantity of power generation from the SolarMill where there was no power generation before from the old solar panel system. Even though the power generation from the SolarMill was minimal compared to the max solar output, the wind showed consistent power generation into the night and early morning when solar rays were not present. Solar produces more energy for smaller scale grids, but wind is not limited to eight hours a day.

The data acquisition system established by Kevin Kelly allows the users to log into a secure IP address and track the data remotely. There is also a private website that graphs and tables the data live from the SolarMill for interested parties. This openly accessible data can be educational as well as useful for research regarding wind and solar availability for the campus. The graphs below were provided from the website and present data from 04/16/2018-04/18/2018.

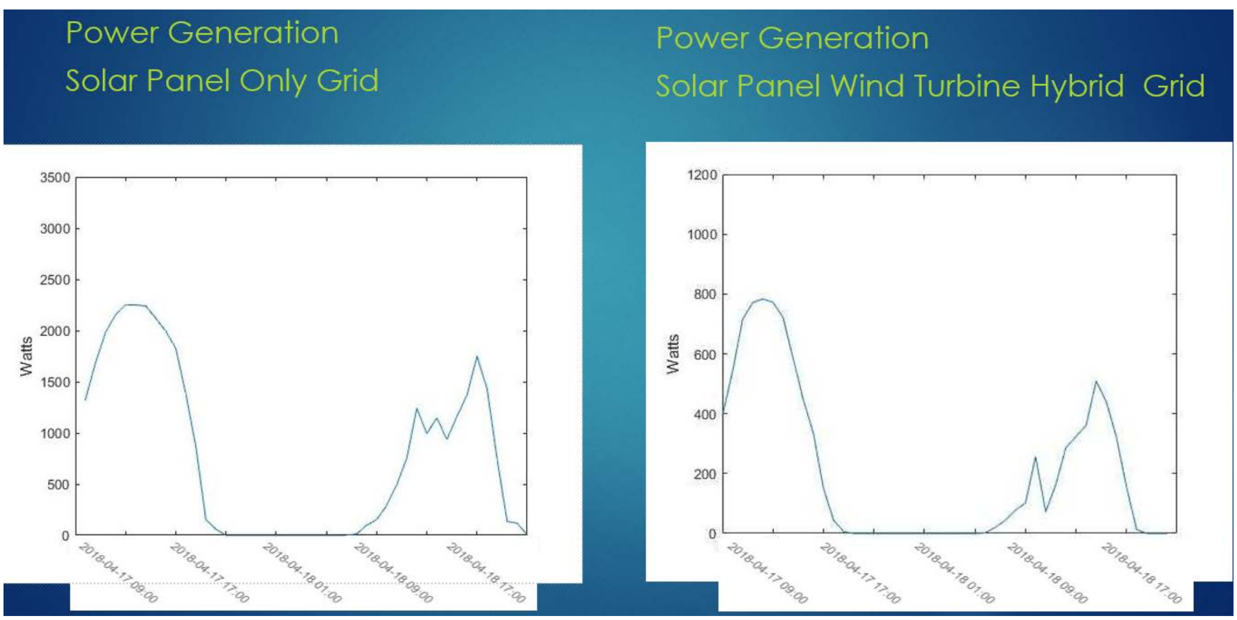


Figure 7.1 Power Generation from each grid over two days

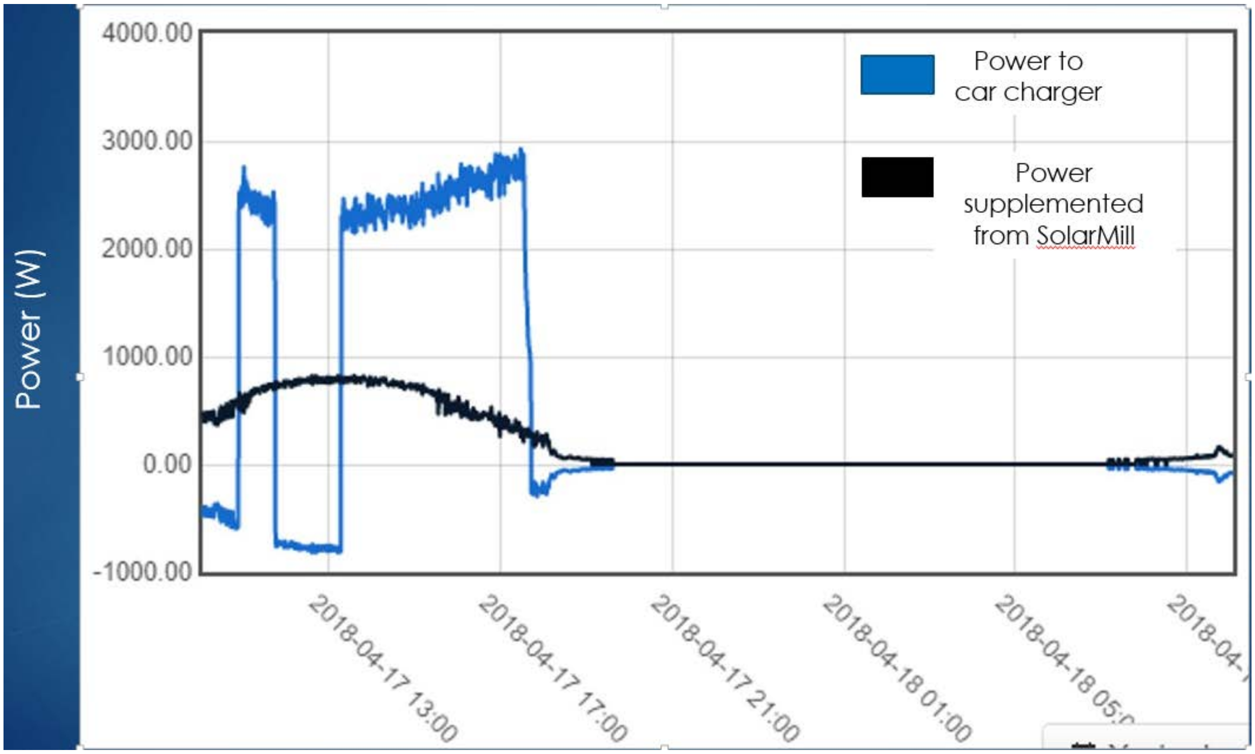


Figure 7.2 Power generated from SolarMill compared to power utilized for car charger

8 RECOMMENDATIONS

8.1 DATA ACQUISITION SUGGESTIONS

An option to make more sense out of the data coming from the SolarMill would be to place current transformers on the outlet of the wind turbines to get a better idea of the power production from the wind turbine.

8.2 DESIGN SUGGESTIONS

Separate solar and wind from the same frame, to better position each for maximum effect. Now, the configuration favors solar at the der

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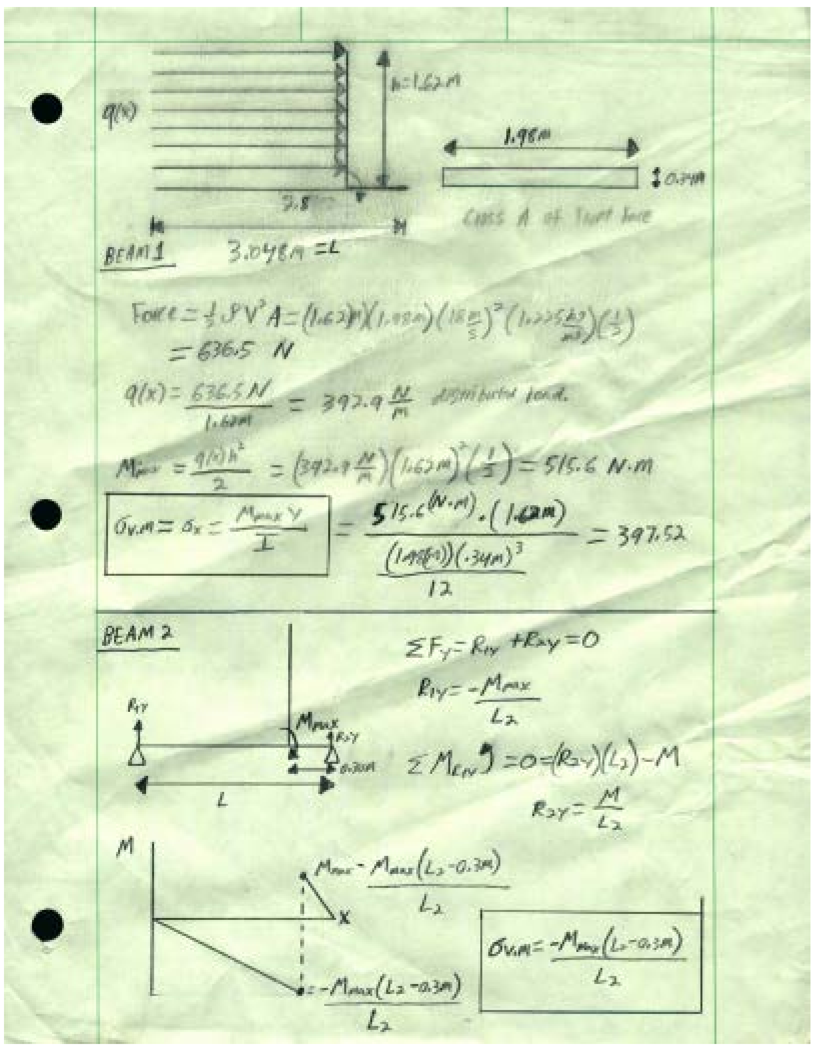
(California Building Standards Commission)

APPENDICES

A.1 Stress Calculations with Two Beam Model



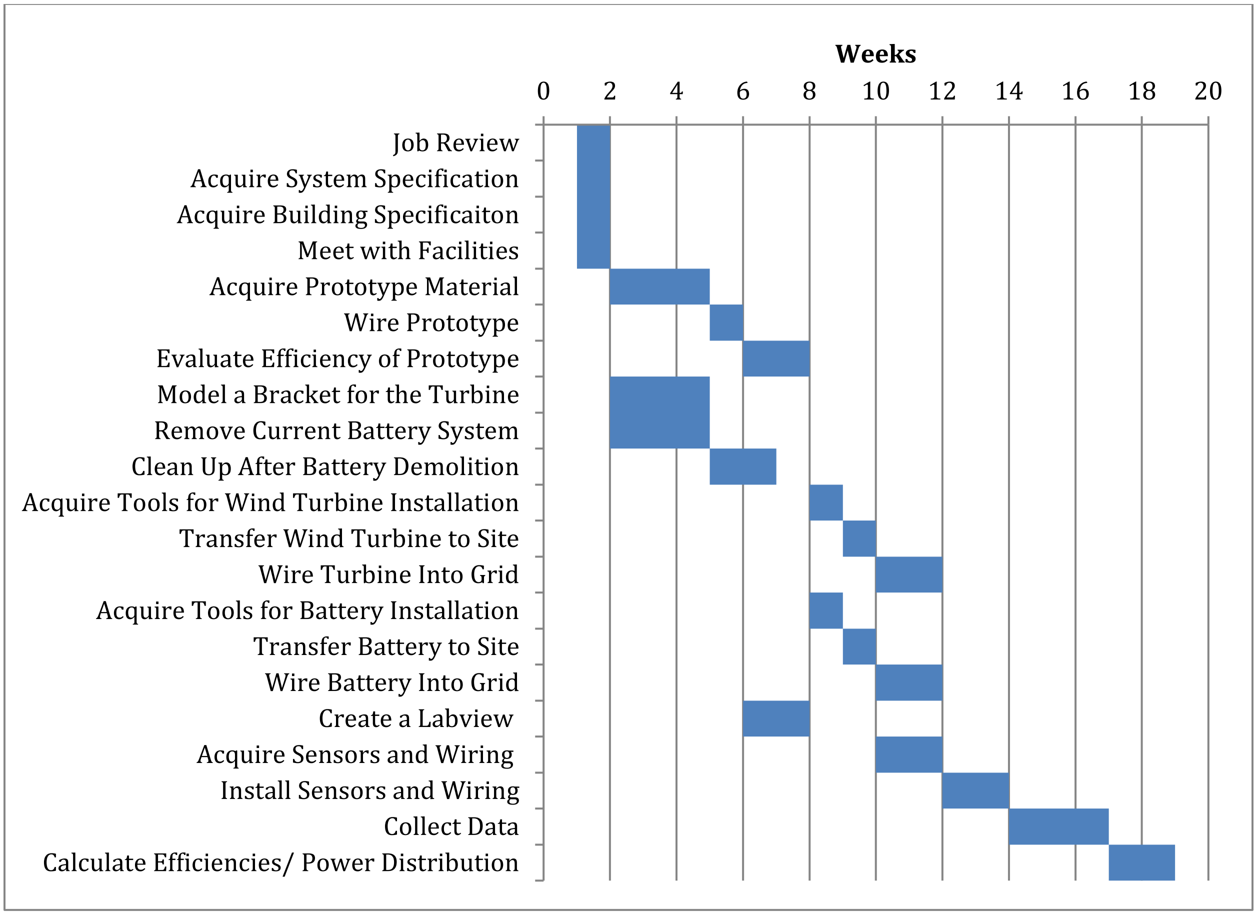
Stress on Mount	Stress on Turbine blade	Velocity	M max
(N/m^2)	(N/m^2)	(m/s)	(N.M)
0	0	0	0
1.43473959	397.5260889	1	1.591371
5.738958361	1590.104356	2	6.365482
12.91265631	3577.734801	3	14.32233
22.95583345	6360.417423	4	25.46193
35.86848976	9938.152224	5	39.78426
51.65062525	14310.9392	6	57.28934
70.30223993	19478.77836	7	77.97716
91.82333378	25441.66969	8	101.8477
116.2139068	32199.6132	9	128.901
143.473959	39752.60889	10	159.1371
173.6034904	48100.65676	11	192.5558
206.602501	57243.75681	12	229.1574
242.4709908	67181.90903	13	268.9416
281.2089597	77915.11343	14	311.9086

322.8164078	89443.37001	15	358.0584
367.2933351	101766.6788	16	407.3909
414.6397416	114885.0397	17	459.9061
464.8556273	128798.4528	18	515.6041
517.9409921	143506.9181	19	574.4848
573.8958361	159010.4356	20	636.5482
632.7201593	175309.0052	21	701.7944
694.4139617	192402.6271	22	770.2233
758.9772433	210291.3011	23	841.835
826.410004	228975.0272	24	916.6294
896.712244	248453.8056	25	994.6066
969.8839631	268727.6361	26	1075.766
1045.925161	289796.5188	27	1160.109
1124.835839	311660.4537	28	1247.635
1206.615995	334319.4408	29	1338.343
1291.265631	357773.4801	30	1432.233
1378.784746	382022.5715	31	1529.307
1469.173341	407066.7151	32	1629.563

1562.431414	432905.9109	33	1733.003
1658.558966	459540.1588	34	1839.624
1757.555998	486969.459	35	1949.429
1859.422509	515193.8113	36	2062.416
1964.158499	544213.2158	37	2178.586
2071.763968	574027.6724	38	2297.939
2182.238917	604637.1813	39	2420.475
2295.583345	636041.7423	40	2546.193
2411.797251	668241.3555	41	2675.094
2530.880637	701236.0209	42	2807.178
2652.833503	735025.7385	43	2942.444
2777.655847	769610.5082	44	3080.893
2905.34767	804990.3301	45	3222.525

$$\begin{aligned} Energy\ to\ EV &= AC\ Supply\ Voltage * I_{Max} * Design\ Hours \\ &= (240V)(16A)(6Hr) \\ &= 23040W * Hr \end{aligned}$$

A.2 Gannt Chart



A.2 Greenovation Fund Denied

4/25/2018 Mail - DMuqatash@csum.edu

Greenovation Update

Brandon Tsubaki <btsubaki@calstatestudents.org>

Mon 1/29/2018 6:16 PM

Dear Greenvation Fund Applicant,

On behalf of the Sustainability Officer and CSSA, I would like to thank you for your interest in the 2018 Greenovation Fund. This year the Greenovation Fund received nearly $200,000 in requests and was unable to fund your project this year.

We appreciate your commitment to sustainability in the CSU and encourage you to continue your efforts.

Thank you again,

--

Brandon Tsubaki, M.Ed.
Assistant Director of Student Engagement
Cal State Student Association
401 Golden Shore #135 | Long Beach, CA 90802
P (562) 951-4831 | F (562) 951-4860

https://outlook.office.com/owa/?realm=csum.edu&exsvurl=1&ll-cc=1033&modurl=0&path=/mail/search 1/1

2017/2018 Greenovation Fund Proposal (Part 2)

CSSA Greenovation Fund <no-reply@wufoo.com>

Mon 11/27/2017 1:50 PM

To:Muqatash, Dalal M <DMuqatash@csum.edu>;

Thank you for submitting a 2017/2018 Greenovation Fund Proposal. Don't forget, you must also submit the 2017/2018 Greenovation Authorization Form by April 30, 2017.

Please provide a copy of your 2017/2018 Greenovation Fund Proposal when meeting with your Associated Students President and Executive Director.

If you have any questions, please don't hesitate to reach out to me directly.

Brandon Tsubaki, M.Ed.
Assistant Director of Student Engagement
Cal State Student Association
401 Golden Shore #135 | Long Beach, CA 90802
P (562) 951-4831 | F (562) 951-4860

2017/2018 Greenovation Fund Proposal (Part 2)

Project Title: *	Solarmill Integration
Project Coordinator Name *	Dalal Muqatash
Project Coordinator's Title *	Project Manager
Project Coordinator's Email *	Dmuqatash@csum.edu
Project Coordinator's Phone Number	(707) 416-8603
Group/Organization Submitting Proposal *	California Maritime Academy Senior Design Project
Project Coordinator's Home Campus *	California State University Maritime Academy
Associated Students President's Name *	Anthony Zoller
Associated Students President's Email Address *	as.exec.pres@csum.edu
Associated Students Executive Director's (or designee) Name *	Josie Alexander
Associated Students Executive Director's (or designee) Name Email Address *	JAlexander@csum.edu
Total Cost of Project *	$7,894.20
Amount Requested by Greenovation *	$5,500.00