Solar Tracking Structure Design

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Team 18

Project Progress

REPORT

Submitted towards partial fulfillment of the requirements for

Mechanical Engineering Design I – Spring 2014

Department of Mechanical Engineering

Northern Arizona University

Contents

1.0 Introduction

Solar energy is increasing in popularity throughout the world. Germany continues to lead the world in solar power production while breaking its own records year after year [1], despite the nation's perpetual cloud cover, and Saudi Arabia has pledged to reach a solar energy capacity of 41 gigawatts within the next 20 years [2].There is an excellent potential for solar power production in many locations throughout the United States, and there are a number of means of application.

Solar power production is usually accomplished using one of two methods. The first method utilizes Photovoltaic (PV) cells to convert sunlight into an electric current by the means of the photoelectric effect, in which a material absorbs electrons after receiving energy from a light source. A photovoltaic cell takes advantage of this effect by harnessing the electron flow in the form of direct current electricity. The second method of solar energy power production is the Concentrated Solar Power (CSP) method. CSP generation uses mirrors to concentrate sunlight into a specific spot. Unlike the PV method, the goal of the CSP method is to produce heat in order to drive a heat engine. Electricity is produced via a generator connected to the heat engine. This project will be focusing on the use of PV cells.

2.0 Goal Statement

Northern Arizona University offers several classes on renewable energies, and has its own area behind the Engineering building where several solar panels and wind turbines are stored. This project is going to be given access to four photovoltaic panels to fit the tracking system to. Along with the tracking station, this project also incorporates an educational component. The tracking system should have a manual override so the instructor can direct the solar panels in whichever direction they desire. The system should also display the power output of each individual photovoltaic cell, to show the efficiency at each angle.

Moreover, our clients informed us that our team will participate in a competition against other universities designs. This competition will take place in New Mexico State University. Therefore, our team has made it one of the primary goals to participate and win the event.The creativity and efficiency of the design will also be major evaluation criteria. Furthermore, our team has been and will continue working alongside the Electrical Engineering (EE) team. Our team works on the structural design and the EE team will provide us with the tracking mechanism and the programing needed to operate the

3.0 Design

The base structure design has been dramatically altered from the original design. Instead of the single poles to be cemented into the ground, this new system relies on a free standing, box structure, for easy mobility. This allows the solar panel to be moved to a different location, or even stored if needed. Shown in Figure 1, the base is made of square steel tubing on the bottom to prevent slippage, with the rest of the structure out of circular cross sectional steel pipes and connected with bought brackets to hold the base together.

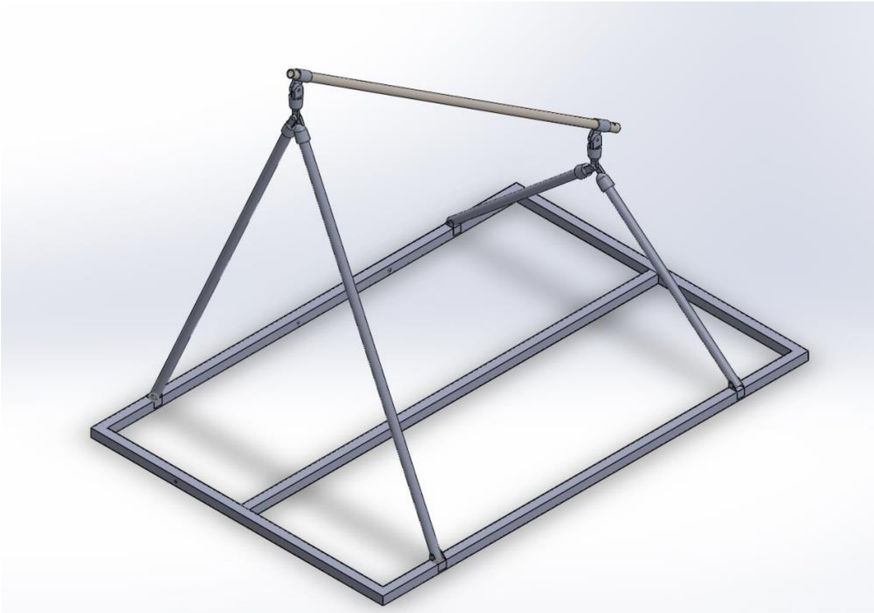

Figure 1: Solar Tracking Frame

The support pole is connected to the triangle frame via adjustable pipe fixtures, shown in Figure 2 and 3. Because this tracker does not use the traditional cemented in pole structure, attaching the support pole to the frame could only be achieved by using these pre-made fixtures.

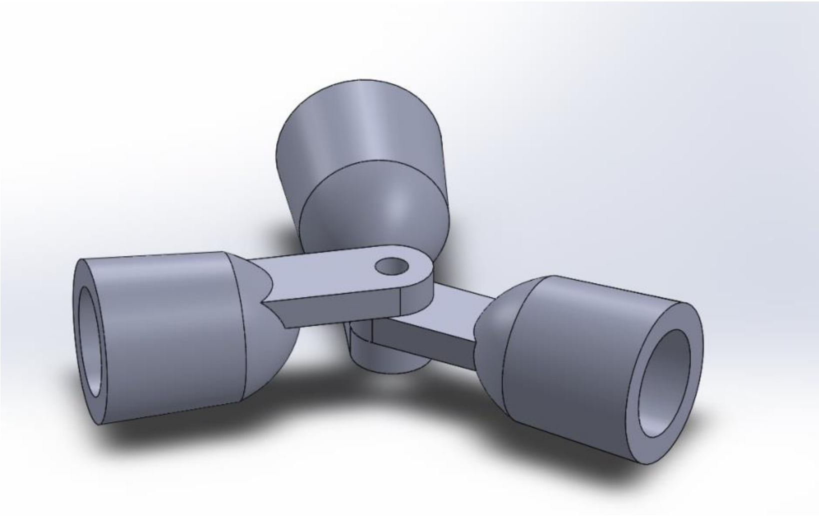

Figure 2: Bracket 1

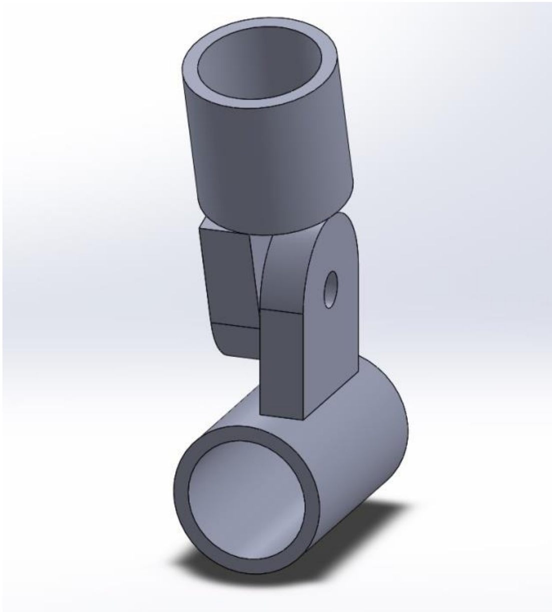

Figure 3: Bracket 2

With one of these at each end, the exact angles of the frame can be adjusted to allow for a bigger tolerance when setting up. If a pipe is made too short, changing the adjustable tee (Figure 2) is very easy to do. Changing the adjustable elbow (Figure 3) allows for different sun angles to be used.

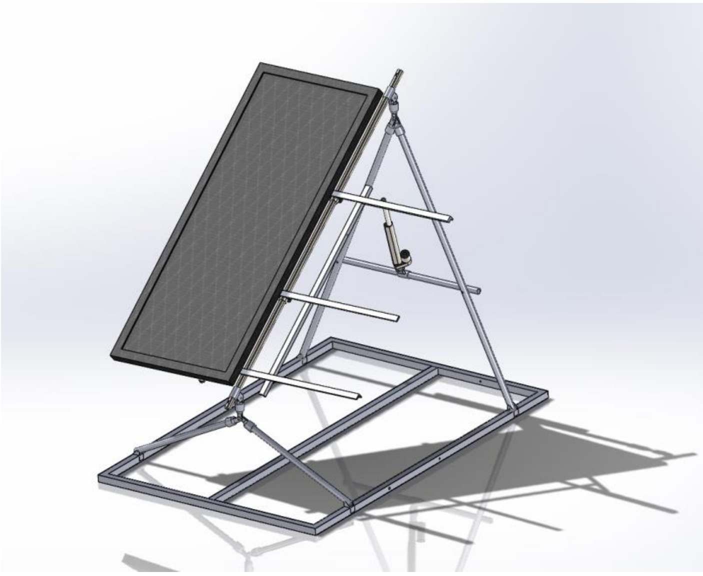

Figure 4: Final Design

The frame to hold the solar panels is made of stock aluminum to reduce weight. Because the solar panels only weigh 24 pounds each, the aluminum should have no problem holding them. The panels are fixed to the frame with the use of small brackets that bolt into the frame and go over the sides of the solar panel. By using these brackets, any size panels can be put onto the structure with minimal adjustments. Two of the panels being used in the New Mexico competition will fit on the mount using three brackets. Two pillow bearings are bolted to the back of the mount and are situated along the fixed axis of the base frame. The mount is kept from turning by the linear actuator connected to the back of the frame. The mount connected to the frame is shown in Figure 4 with one of the competition panels already situated on it.

The actuator being used is the Eco-Worthy 12 volt, 18” stroke linear actuator. It is connected to a cross bar across the back of the structure and held in place with one of the adjustable elbows shown in Figure 3 to allow it to move freely. This actuator was chosen to allow the most freedom with adjusting the size of the frame. By having the extra couple inches of stroke, the actuator does not have to be adjusted if the angle of attack is changed. The actuator can exert upwards of 1500 Newtons of force, more than enough for the mount and solar panels, and enough to withstand a couple feet of snow.

4.0 Structural Analysis

A structural analysis was done at several key points of the structure. These include the bolts holding the adjustable fixtures in place, bending in the support rod, and connections between the square steel base frame. Assuming a total weight on the structure of 200 pounds, 75 from the solar panels and frame plus 125 for a maximum snow load, the factors of safety were calculated with yield strength of 50 kpsi. If in shear, the yield was assumed to be 24 kpsi. Figure 5 shows the resultant factors of safety.

Location	Yield (kpsi)	Max Stress (kpsi)	F.O.S.
3/8" Bolt in Elbow	25	0.905	27
Support Bar	50	25.8	1.94
Bottom Brackets	50	0.226	221

Figure 5: Calculated Factors of Safety for Key Stress Areas

The minimum factor of safety is seen in the middle of the support bar. Because it has a long length and is the main structure that holds all of the weight, this makes sense that it would be the lowest. At 1.94 the factor of safety is still acceptable, especially because there is very little chance 125 pounds of snow would accumulate on the solar panel at any possible time. The next lowest factor of safety is 27, much higher than needed.

5.0 Cost Analysis

Table 1, located below, is a breakdown of the materials selected for the modified design. The total cost for the modified solar tracker is \$312.26, which is \$43.87 more than the final cost of our previous design. However, the cost per panel has been reduced significantly. Prior to altering the design, the cost per panel was equivalent to the total cost per unit at \$268.39. The current cost per panel now sits at \$156.13. The overall cost of implementing this design for all four solar panels is well under budget while also providing the benefits of a dual axis system. The majority of the cost is dedicated to the actuator and the main shaft. Additionally, a majority of the materials can be purchased locally at Home Depot or other vendors.

Table 1: Cost Analysis

	Price ($)	Count	Total ($)	Source
1" Pillow Bearing	11.25	2	22.5	VXB.com
18" Linear Actuator	99	1	99	EBay - In Route
1" Adjustable Elbow	11.99	2	23.98	EBay
1" Adjustable T	33.1	2	66.2	EBay
3/4"x48" galv. Steel pipe	16.98	3	50.94	Home Depot
36"x1.25"x1/8" Flat Steel	5.74	3	17.22	Home Depot
Square Steel Tube	16.21	2	32.42	Home Depot
Σ			312.26	

6.0 Electrical Engineering Team

The Solar Tracking Structure Mechanical Engineering (ME) Team is being assisted by a team of Electrical Engineers (EE). This EE team is tasked with the design and implementation of all tracking software, the implementation of a manual override, an output display, the collective energy management, and the storage of that collected energy.

Currently, the solar tracking structure will use chronological tracking software to track the sun's movements. The software's primary routine will adjust the panel every fifteen to twenty minutes throughout the day. For the purpose of flexibility, this code will adjust after the user has provided their latitude and longitude. Since the WERC competition is being held at New Mexico State University, but the customer requires a system that is tailored for Northern Arizona University, this design decision will allow the system to operate at maximum efficiency at both locations. Allowing the user to input their own location, when combined with the manual override and output display, will provide additional educational functionality to the overall system.

In order to meet the educational requirements set forth by the client, the tracking system will feature a manual override option along with an output display. Users will be able to stop the automatic tracking and move the panels themselves with the panel efficiency shown on the display. Currently, the EE team has not reached a conclusion as to the type of display that will be used.

At this time, the EE team is unsure about the means of storing the collected energy. Although the current, fixed panels are located near a battery bank, it is not known if the new system will be using the same bank and how the stored energy will be used. Therefore, the EE team is considering adding an inverter to the tracking structure. The inverter will convert the current generated by the panels from direct to alternating in order to store the electricity in the existing battery banks.

7.0 Competition Updates

Consortium for Environmental Education and Technology Development known as (WERC) holds a competition annually since 1991 at New Mexico State University in Las Cruces, New Mexico, the contest draws hundreds of college students from throughout the United States and around the world. Our team is going to be competing in the third task which is Power Point Tracking for Solar Energy

Table 2: Important Dates

Important Dates:	
Contest Registration	January 6, 2014
Entry Fee	January 14, 2014
Safety Summary, MSDS Sheets, and Flow Sheet	March 19, 2014
Written Report	March 21, 2014
Equipment Transportation Form	March 28, 2014
Opening Ceremonies/Safety Meeting (mandatory)	April 6, 2014 – 6:30 pm

The problem statement of the competition is our team will develop a novel system for maximum power point tracking and demonstrate its cost effectiveness by measuring the additional power generation vs. the cost of the components and power required for operation. Our team must quantify the difference in power generation with and without the solar tracking device and conduct a lifecycle cost analysis of the solar system with and without the tracking device.

The team performance will be based on those criteria that the team will be evaluated on are the effectiveness of increased power generation, cost, performance, maintenance requirements, ease of implementation, and safety issues

8.0 Current Progress

Figure 6, located below, is the teams Gantt Chart. The Gantt Chart outlines the time allocated for each task. Main tasks include ordering parts, construction, testing, and competition reports. Important dates are marked in red. Additional tasks not included in the Gantt Chart are the teams weekly meetings with the electrical engineering team and Dr. Srinivas Kosaraju. Electrical team meetings are Tuesdays from 3:30pm to 4:30pm and Dr. Srinivas Kosaraju meetings are Fridays from 3:00pm-3:30pm. For each of the meetings the team discusses progress reports and solutions to problems we've encountered. Team leads for each particular task is as follows:

- Roger Guiel is in charge of purchasing materials and testing the device.
- Hashem Bukhamsin and Dan Verne are in charge of construction.
- Angelo Edge is in charge competition reports.

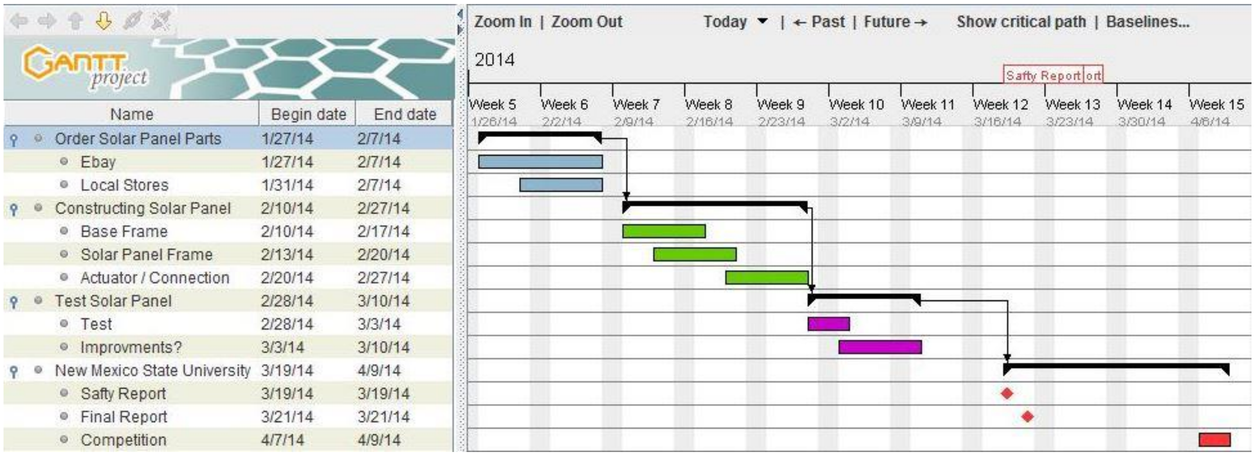

Figure 6: Spring Semester Gantt Chart

The team is currently ordering parts from online distributers and local stores. During the ordering phase, team members will continue to analyze the design and contribute to the electrical engineering teams needs.

9.0 Conclusion

The Solar Tracking Structure team is tasked with providing an effective, inexpensive design solution for Dr. Tom Acker of Northern Arizona University. Between December 11th, 2013 and January 31st, 2014, a number of changes were made to the Rotisserie design in order to reduce cost while increasing functionality. The antenna motor has been replaced with an 18 inch, 340 pound linear actuator which will allow the structure to move two panels at once. This change has reduced the cost per panel by 42 percent. A manually adjustable North-South axis has also been incorporated. Structural analyses performed on the updated design reveal that the factor of safety at the likely point of failure is 1.94. The current design cost is $312.26.

The EE team will be assisting the ME team by providing the tracking software, output display, and manual override functionality. The tracker will use a chronological tracking system that can be adapted to any point of longitude and latitude that the user requires. The EE team is also considering adding an inverter in order to store the collected energy using the battery bank located at the solar energy shed. A conclusion has not been reached regarding this addition.

The WERC competition will take place from April 6th, 2014 to April 9th, 2014. At this point in time, registration has been completed and the entry fee has been paid. The safety summary, MSDS sheets, and Flow Sheet comprise the next task that will need to be completed.

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