Solar Tracking Structure Design

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Team 07

Progress Report

Document

Submitted towards partial fulfillment of the requirements for
Mechanical Engineering Design I – Fall 2013

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Introduction

Our team has been tasked with designing a solar tracking system. Over the winter break, there had been some changes that were made to our original design. Our need, objective and overall design all endured changes. Currently, solar panels available on the market are not the best systems for teaching the basics of solar tracking to students. Due to this problem, the team will embark on a new design objective. Our new objective is to design a solar tracking system that enables students to experience the fundamentals of solar tracking systems. In order to facilitate this, the solar panels need to be mechanically operable and must also be operated manually, if the system should fail. Since students will be conducting hands on learning exercises, the system needs to be relatively simple and user friendly. The system will accommodate an input panel which will allow users to input certain information and will operate the system.

Design Changes

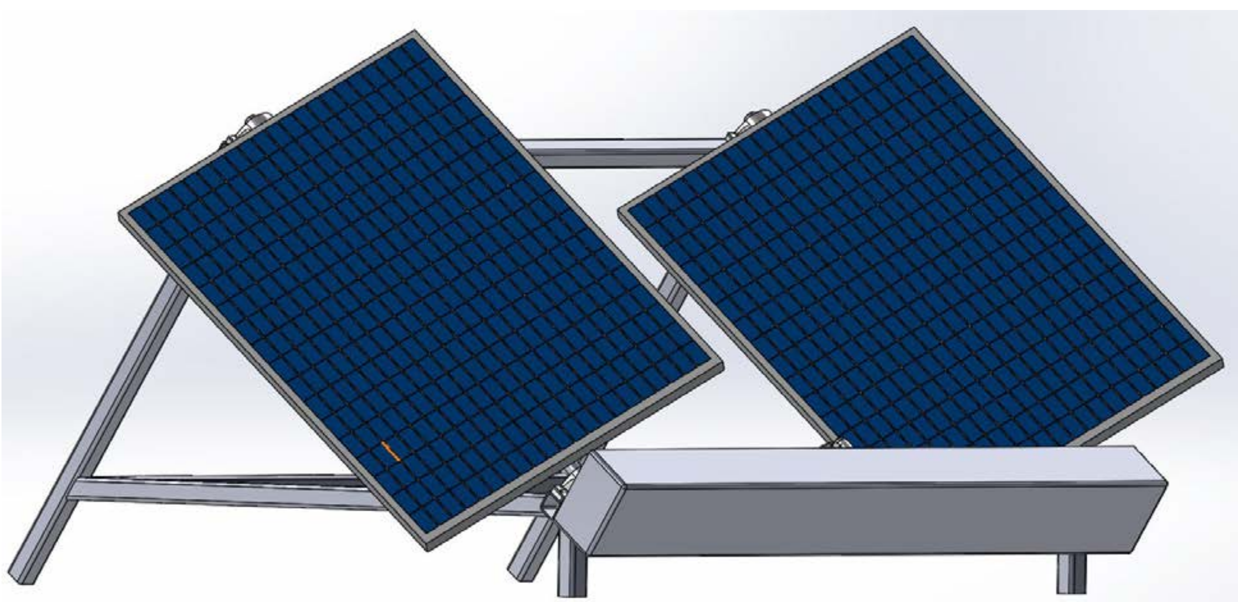

Figure 1: Fall 2013 design

Our old design, as seen above, was designed around being the most efficient at tracking the sun using active tracking methods which incorporates the use of sensors that detect the sun. We also decided last semester that north- south tracking was not necessary, because the Sun's North-south position does not change that much in Flagstaff. To save money we also had only one motor to power both solar panels rotation through a chain and sprocket system. We also had the solar panels being supported by a single shaft of steel which was 2in diameter. The steel structure of the design was also made of 2”x2”x2” square tubing which made for a very high price on the design.

Figure 2: Spring 2013 design

The design was updated according to the client’s new requirements. As seen in figure 2 the major changes were made on the frame and the rotation system. The frame is now built with 1”x1”x1/16” square tubing and 1.5”x1.5” angled bar in-between the two solar panels.

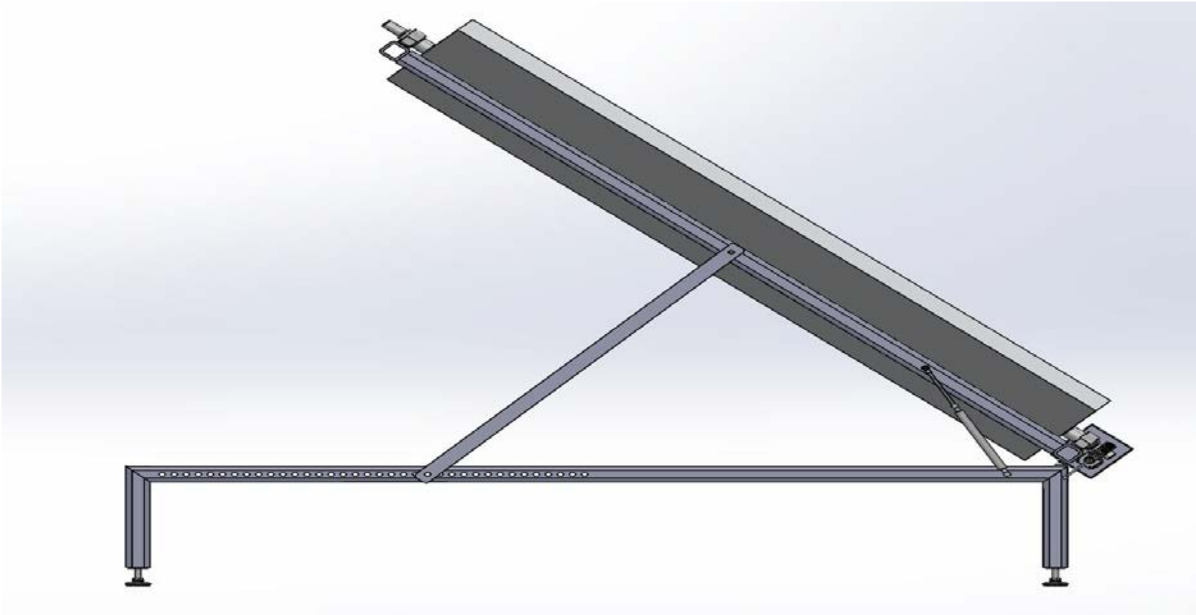

Figure 3: Side view of new design

Dr. Acker requested north-south adjustment for solar tracking so we designed a base frame to support the solar panels and provide the adjustment range. To adjust in the North-South axis two steel beams are secured to the solar panel beam and bottom frame. The bottom frame has 19 holes drilled into to allow for adjustment of the North-South axis of the system every 20 days. Since the tracking system will be used for educational purposes, the top frame which originally held two solar panels was split into two separate frames to provide ability to compare different rates and angles of solar tracking. The leveling pads were added to the bottom frame to deal with different ground conditions.

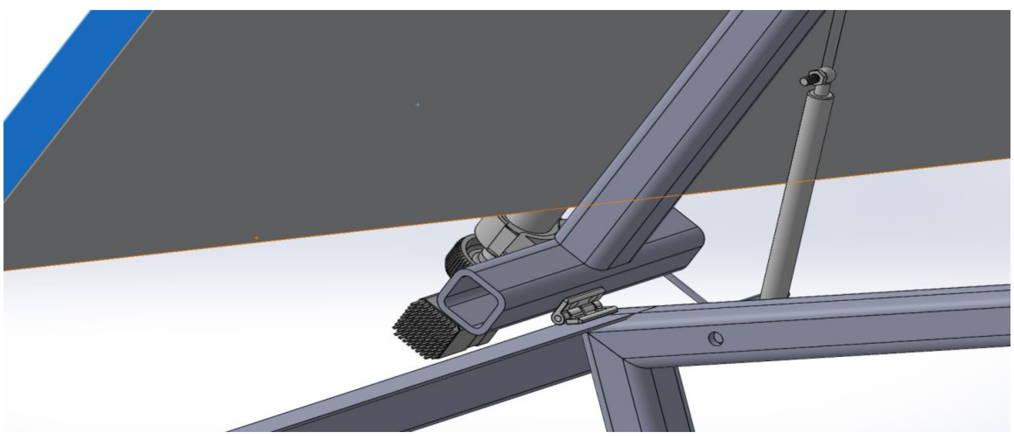

Figure 4: Hydraulic stabilizers

Hydraulic stabilizers have also been added to allow for a smooth adjustment of the North-South axis of the solar panel system on each solar panel.

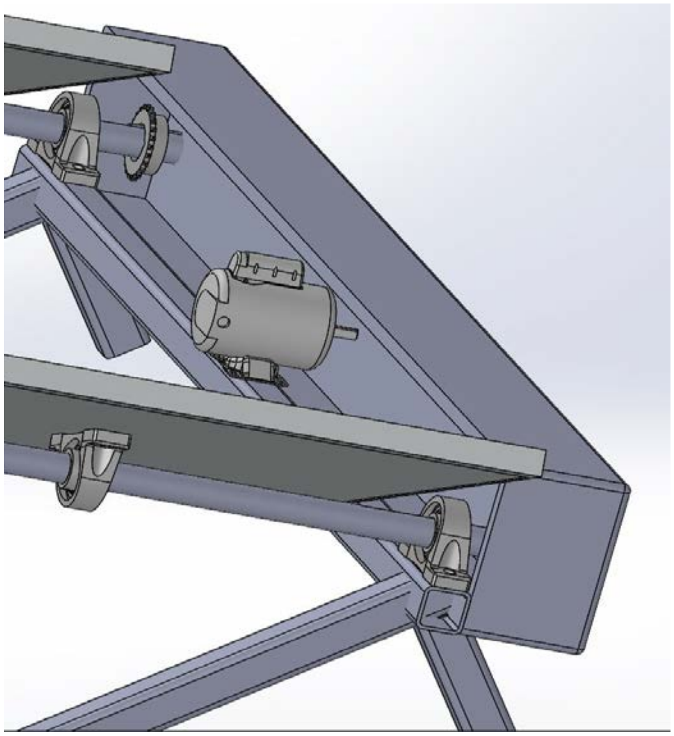

Figure 5: Old motor design

The old motor system was designed around having one motor in-between the two solar panels that would be connected to each shaft by a gear and chain. This design required a rather large motor for the design which would have been very costly.

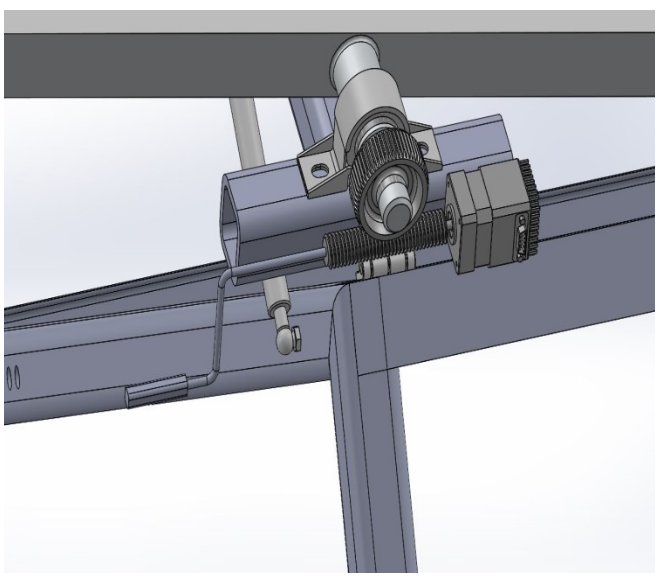

Figure 6: New drive system

The new rotating system uses two stepper motors to rotate two solar panels separately. Worm drives are used to increase the torque and stop the panel at any given angle required by the user.

The hand crank is on the other side of the worm gear for users to operate the tracking system manually. The new design has the shaft welded on the solar panel frame to reduce the torque caused by the weight of the solar panel. By welding the shaft on the frame, this also saves the money from purchasing long shafts.

Support Beam analysis

The team decided that there needed to be structural analysis performed on the frame of the system because that will ultimately support the entire panel configuration. The team utilized Solidworks to perform this analysis.

The first thing that was to be done was to make a part in the program. Originally, the team decided to have 36 holes horizontally through the beam, but after reviewing the design, the team decided to move to 19 holes. It was changed from 36 to 19 holes because the tracking system only needed to be moved every 20 days instead of 10 days. This design change helps with keeping the strength of the material and ultimately making a safer design. In doing this, it will also help cut down on maintenance time, since it will be moved every 20 days instead of every 10 days.

Before the analysis was even started, the team needed to make some assumptions. The assumptions required a collaboration of the main components weight's with the other team members. After consulting with the team, the component weights were used as forces. The weights of the components are as follows:

- Solar panel – 50 lbf (each)
- Frame of solar panel, motor and bracing steel – 10 lbf

Another parameter that needed to be predetermined was to choose what material to use for our design. Since this design is to be made with materials that not need to be special ordered, we chose to use AISI 1020 Steel. We chose this material due to the fact that this material is readily available, inexpensive and relatively strong. So with this, the team will use this material in the construction phase.

The following steps were used to input the parameters and complete the structural analysis of our support beams using Solidworks:

1. Open up *Solidworks* program.
    a. Locate and open the part that is to be analyzed.
2. At the top menu, go to *Tool* tab, select Add-ins.
    a. Check left box of Solidworks Simulation, then select ok.
    b. Accept license agreement.
3. At the top menu, select *Simulation* tab.
4. Select drop down menu from Study Advisor and select New Study
    a. In the left column, select Static then the green check mark.
5. In the top menu, click Apply Material.
    a. In left column, select material (AISI 1020 Steel), click Apply, and then close.
6. In left column, right click Fixtures.
    a. Select Fixed Geometry, highlight face box, and then using the part; select face 1 and 2 to be fixed (meaning where the part will be supported). Click green check mark.
7. In the left column, right click External Loads and select Force.
    a. Now, locate Selection tab in left column, but force placements on beams or joints must be predetermined. For this project, I chose to set forces directly in the center of the beam because that is where the biggest load is at. Select Beams box and using the 3-D model, select the small square at the center and on top of the beam.
    b. Under Units tab, choose English Units.
    c. Under Force tab, select Normal to button, and input value of the force to be used. Finally, select green check mark at top.
8. In left column right click Study and select Run. A series of plots will appear in the window.
    a. In left column, right click Stress 1 and select Edit Definition.
        i. Stress Plot appears; under Display tab, select psi. Then select green check mark.
    b. In left column, right click Displacement 1 and select Edit Definition.
        i. Displacement Plot appears, then under Display tab, select URES Resultant Displacement and set measurements to mm. After setting these parameters, select green check mark.

9. After making these changes, the maximum stresses and deflections could be found by associating the colors from the scale to the members/joints to the color scale on the right hand side of the part.
10. After running the program, the team found these results:
    a. Maximum Stress – 33,158.8 psi (**Fig. 1**)
    b. Maximum Displacement – 7.9 mm (**Fig. 2**)

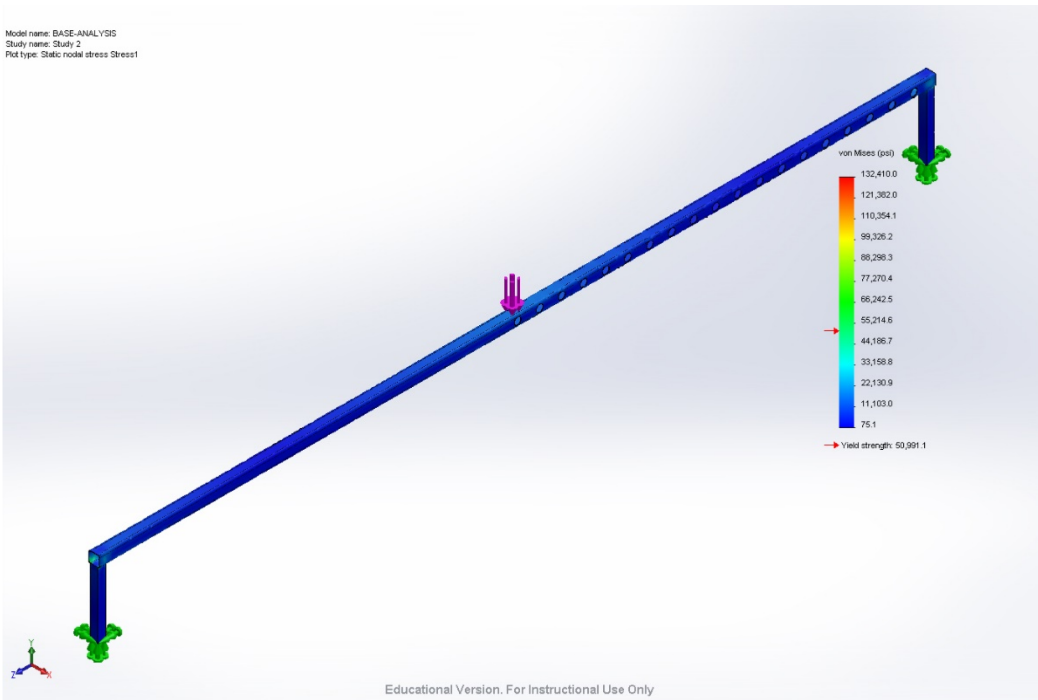

Figure 7: Stress plot of base frame

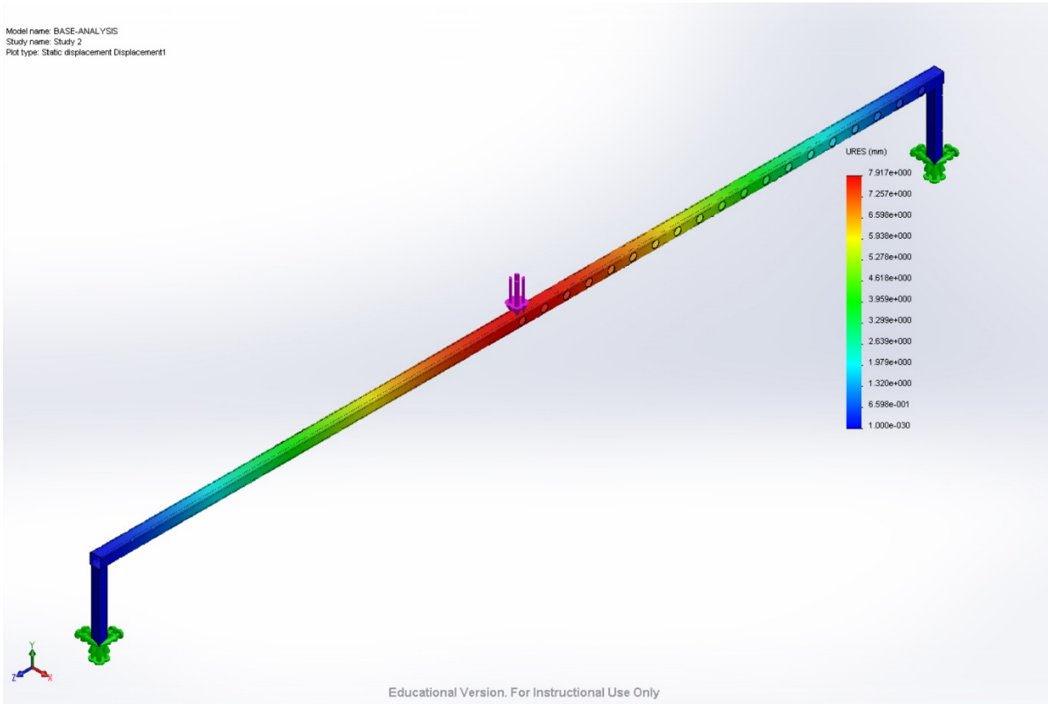

Figure 8: Displacement plot of base frame

The above analyses are only two completed out of a number of analysis carried out by the entire team. The requirement that I am addressing is that the frame is safe, reliable and able to hold the load. I found that the base frame would be safe because after using *Solidworks* to analyze it, we found that there is very little deformation and none of the structural members will fail during the loading of the solar panel system. We know that the frame is also cost efficient as well due to the fact that we are using steel that is locally and readily available.

Torque Analysis for the new design

The new design incorporates a motor for each solar panel thus requiring a new torque analysis. Given that each 4' x 6' solar panel weighed approximately 50lbs and that distance from the frame to the shaft is estimated to be 0.92 inches the torque is calculated below.

$$\tau = r \times F = 0.92in \times 50lbs = 46\ lb - in$$

This gives us a maximum bending torque of 46 lb-in experienced by the shaft. Choosing a motor that is incorporates that torque requires an analysis of the gear reduction caused by the worm gear seen in figure 9 below.

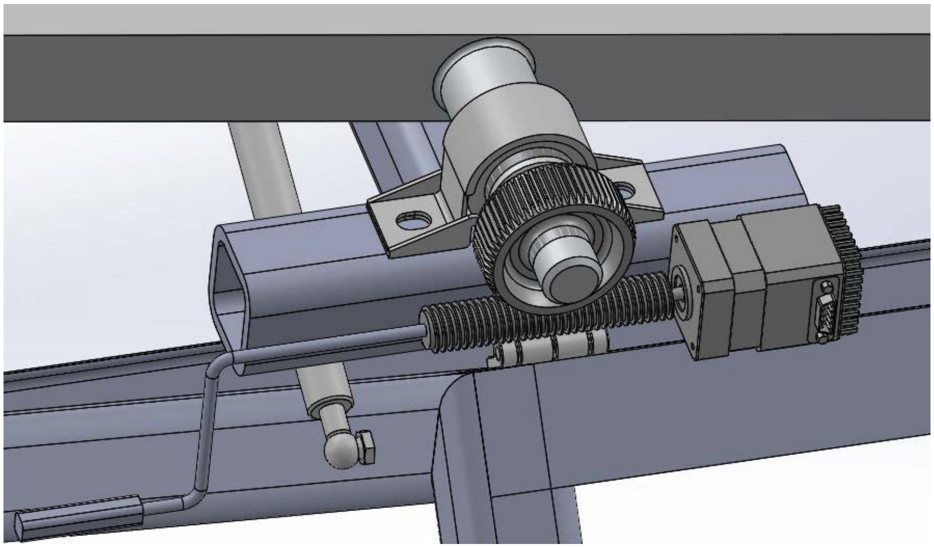

Figure 9: Worm gear assembly

The worm gear has a pitch of 6 and an outside diameter of 3.71inches, the worm that is attached to the motor has an outside diameter of 2.33 inches. So the gear reduction from the motor to the shaft is roughly 1.5922. Using the gear reduction the motor requires a torque of 73.3 lb-in.

Calculating the shear force experienced on the bolt

The new design incorporates an adjustable north to south direction using a series of holes in the frame and a pin to lock in the position seen in Figure 10 below.

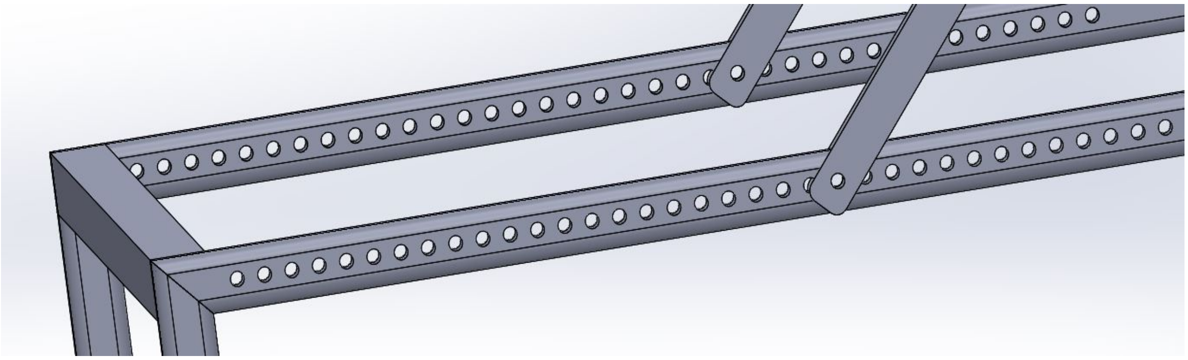

Figure 10: North to south pivot points

This pin expected to experience a shear force caused by the weight of the solar panel. Shear force was calculated by taking the maximum amount of force the bolt could experience roughly 50lbs then dividing it by the area.

$$Area = \pi D^2 = \pi \times 0.25^2 = 0.19635\ in^2$$

Then the bolt experiences the force along four points along the pin. Then the equation for shear force, ν, is shown below.

$$\nu = \frac{4 \times 50lbs}{0.19635\ in^2} = 1018.59\ {}^{lbs}/_{in^2}$$

From the shear force calculated 1020 ANSI steal would be an appropriate material for the pin to be made out of.

Task Breakdown

Table 1: Project tasks breakdown

Task	**Lead Members of Task**
Purchasing materials for frame	Joshua, Jiayang
Bottom frame construction	Micah, Travis
Control system set up	Pengyan, Anthony
Purchase gears and motor	Jiayang, Travis
Tray and stand for panels	Joshua, Micah
Gear and motor assembly	Anthony, Travis
Test control system	Jiayang, Pengyan
Analysis return on investments	Anthony, Joshua
Analysis energy efficiency	Pengyan, Micah

These tasks are the steps that will lead to the completion of the solar tracker. Each group member is responsible for making sure these steps are completed. This is not individual work but group work. Joshua and Jiayang are accountable for the purchase of the materials because they did the most research on the material selection for the final design. Micah and Travis have the most experience in welding they are in charge of constructing and welding of the stand. Anthony and Pengyan will learn and set up the controls of the tracking system. The task of purchasing gears and motors will be the duties of Jiayang and Travis. Once again Micah will be in charge of the welding of the tray for the solar panels, Joshua will assist. The assembly of the gears and motors will be accomplished by Anthony and Travis. Testing the controls will be led by Pengyan because he is involved in the setup of the control system. Jiayang will aid Pengyan on the testing. The analysis of the return on investments will be done by Joshua and Anthony. The final analysis of energy efficiency will be done by Pengyan and Micah. With the all the tasks complete the group will meet their objective.

Gantt Chart

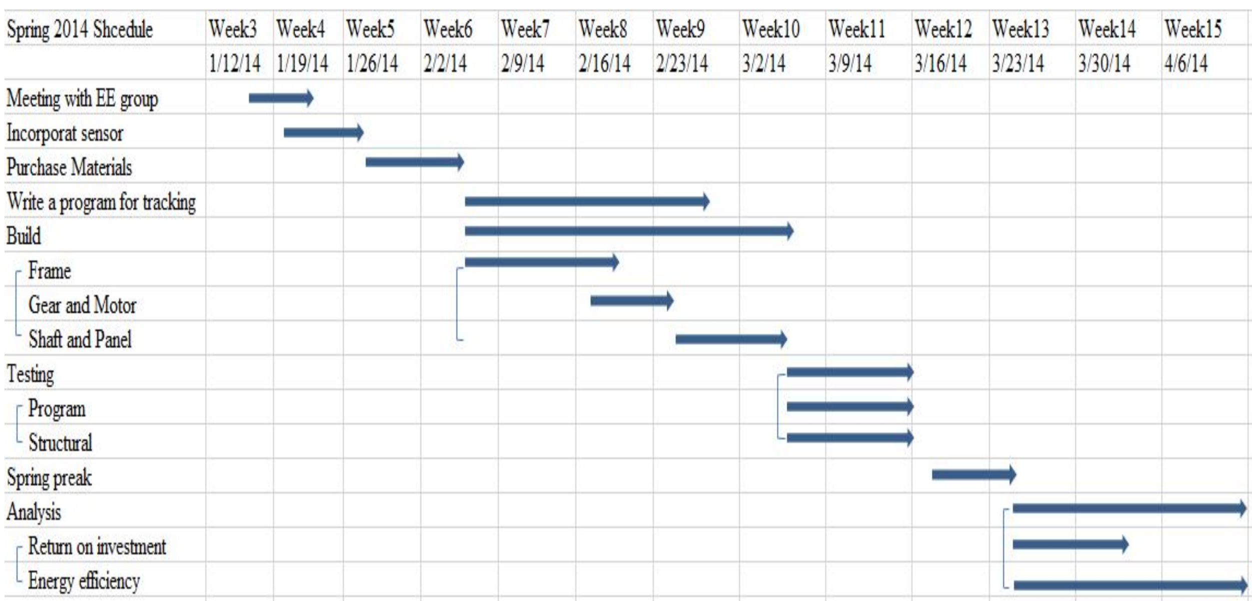

Figure 11: Gant Chart for spring 2014 from last semester

This is our previous gantt chart,which includes design modifications, materials purchasing, building,testing and analysis of the solar tracking system task for the 2014 Spring Semster.

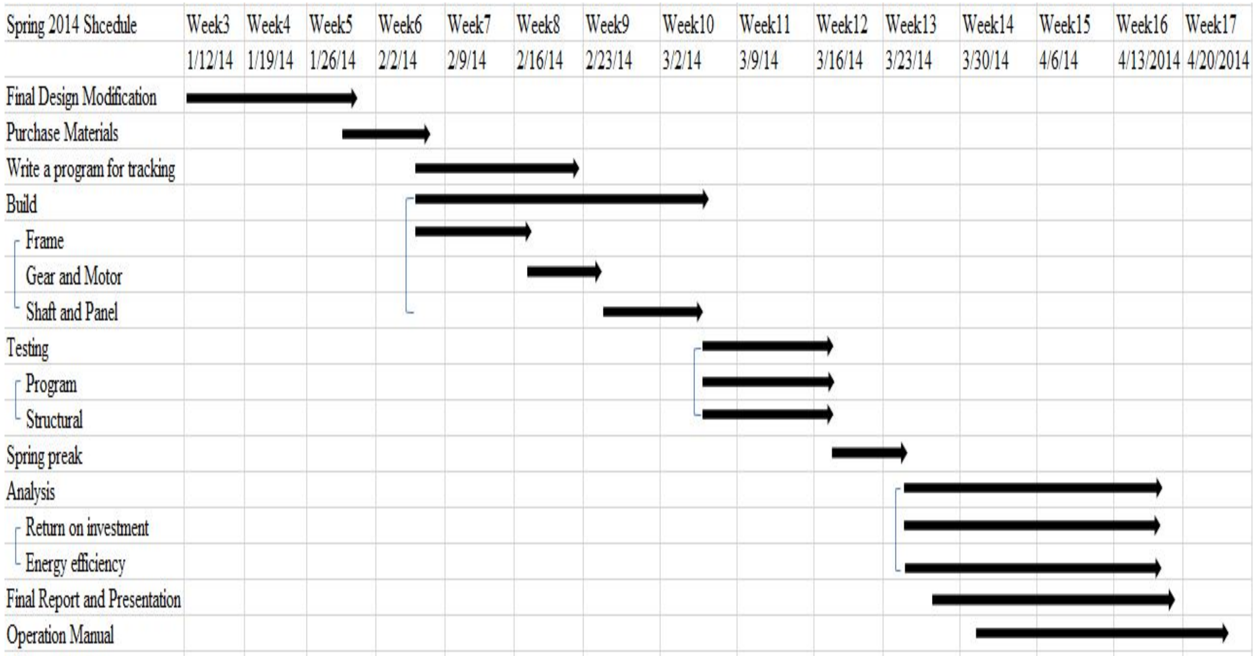

Figure 12: Updated spring 2014 Gantt Chart

There are few chages from the orginal Gantt chart based on the new semester schedule. After meeting with our client and class instructor, our team won't be meeting with the EE capstone group since our design uses a passive system to track the solar positon. The team will start writing the program for the tracking system on week 6 this task is projected to take 10 days to finish. Then the team will start work on building the frame while integrating the motors and gears, that is predictated to take 20 days. Then we are going to test the solar tracking system, the design will be completed before spring break. Upon return the analysis of the solar panel system will be initiated and analysizing for efficiency will begin. Then work on the final report, presntation and operations manuel will start.

Conclusion

The design changed, due to new needs by the sponsor Dr. Acker. The objective has become to design a system that enables students to experience the basics of the solar tracking system. This objective forced the team to modify the tracking system. The design changes include a motor to move each panel, a hydraulic stabilizer, North-South tracking, leveling pads and a worm gear. The design upgrades required new analysis before building. The sections the group analyzed were the motor, gears, base and stand. The group broke down the project in order to guarantee the tracking system will be complete by the end of the semester. The tasks include purchasing materials, construction, assembly, control system set up, test and analysis. The Gantt chart has been updated for Spring 2014. The team has projected the build to be finished by March 5th, and the testing to be finished by the 14th of March before spring break. The goal is to have the analysis of return of investment and energy efficiency completed by April 15th. The final report and presentation is due the 17th of April. Dr. Raju has requested an operation manual to assist people in using the tracking system which will be completed before the end of the school year. The team has upgraded the project and created a project plan for the rest of the year.