NORTHERN ARIZONA UNIVERSITY

Department of Mechanical Engineering

ME 476C

Solar Tracking System

Project Background and Needs

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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.

Client Information

The Solar Tracking Structure is being sponsored by Dr. Thomas Acker. Dr. Acker is a professor of Mechanical Engineering at Northern Arizona University (NAU), as well as the Director of the University's Institute of Sustainable Energy Solutions (ISES). He is the author of numerous published papers on wind energy engineering as well as an editorial board member and reviewer for the ASME Journal of Wind Energy, ASME Journal of Heat Transfer, and

ASME Journal of Solar Energy Engineering [3].Dr. Acker has also worked at the National Renewable Energy Lab from 2003 to 2004.

The ISES focuses on influencing public and private sector decision-making in regards to sustainable energies while also advancing research and educating the public about sustainable energy. They are responsible for the implementation of multiple sustainable energy courses at NAU, the establishment of the Arizona Wind Working Group and Arizona Geothermal Wind Working Group, the establishment of the Southwest Renewable Energy Conference and Southwest Renewable Energy Institute, and the creation of the wind energy companies Windfinders, LLC and TecVerde, LLC [4]. ISES has also sponsored numerous senior capstone projects for NAU students.

Background

It has been estimated that the earth receives about 174 petawatts of solar radiation with about 70% being absorbed by land masses and oceans. In 2002, it was calculated that the earth absorbed 3,850,000 exajoules of solar energy, which was more energy than the entire world used in the entire year. Since the sun is projected to be around for at least 4.3 billion more years, investments and techniques for collecting solar energy is a reliable solution to the rapidly decreasing quantity of fossil fuels. Carefully constructed assemblies of photovoltaic cells, called solar panels, provide an effective means of collecting solar radiation and converting it into electricity. When correctly designed and attached to a well-engineered mechanical tracker, solar panels are able to provide power for commercial businesses and homeowners in a way that helps preserve the low supply of natural fossil fuels while drastically reducing the required cost. Renewable energy now provides 19% of electricity generation worldwide with a 15% increase projected by the year 2035.

A simple explanation of solar tracking systems is a device used for orienting a photovoltaic panel towards the sun by using both mechanical components and light sensors to collect more energy than a fixed panel. Before proceeding, it is important to note that the amount of energy produced during solar collection is more productive and efficient when the sun is directed at the PV on a clear day.

Tracking System Types and How They Function

The major types of tracking systems that the team is considering are either a single axis solar tracker or a dual axis solar tracker and described as follows:

- The single axis system usually made depending on a single horizontal or vertical axis. The direction of the axis is decided based on the location where system is going to be placed, the location plays a role in the sun position during the day along with how much daylight there is.
- The dual axis is a system that includes both a horizontal and vertical axle. This type of tracking system can track the sun motion exactly in any location around the world.

As of tracking the sunlight, there are three common methods that could be used and applied to the system which varies depending on the need:

1- Passive trackers: Moving the panels across the sky using sun's radiation to heat a compressed gas/fluid driving the panel to one side or the other based on the amount of fluid accumulating in the colder side.

2- Active trackers: Moving the panels across the sky using motors, hydraulic drives, and gear trains that react to the sunlight intensity measured by a light sensors that are positioned at various locations in specially shaped holder.

3- Chronological tracker: Moving the panels across the sky using prerecorded data and counteracts the Earth's rotation by turning in distance increments the opposite direction.

Northern Arizona University has a solar field that is located on south campus, the panels in the center of the field are facing the opposite direction of the rest of the panels. This due to a mechanical failure in the tracking system. This demonstrates that the tracking system reliability factor is low. The client stated that the cost of fixing the trackers it is relatively high. The cost range of commercial tracking systems are an average of $2000 - $3000 dollar. The Department of engineering has a renewable energy shed that is located behind the building. This shed is where the solar panels that the team is building a tracking system for are located. This shed contains a battery bank where it stores the collected energy.

Need Statement

While solar panels are an effective means of collecting energy, their efficiency at doing so is directly related to their angle with the sun. Because PV cells get the most energy from facing the sun, a stationary solar panel collects less sunlight one that follows the sun across the sky. The problem that this project addresses is the inefficiency associated with fixed solar panels. Meaning, panels that do not track the sun across the sky. Two axis, as well as single axis solar panels allow for a better output from the PV cells, but they can be very expensive and require a lot of maintenance.

Goals

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.

Project Objectives

The objectives for the solar tracker are as follows: Track the sun across the sky within a 5º margin of error. Ability to manually rotate the tracker with the use of a controller along the full ecliptic. The apparatus should also be able to display the power output of each cell. While the tracking is required for daylight hours, after sunset it should reset to the sunrise location and not follow the solar path when there is no sunlight to collect. The manual override only applies when the solar panels are being used for informative purposes. Also, the design needs to be reliable, needing little maintenance.

Constraints

There are several constraints that apply to the project. There is a $2000 dollar budget applied to the systems for the four photovoltaic cells. This applies to the machinery and controls, as well as any mounting or construction. The entire system needs to fit under the overhang of the photovoltaic cells, allowing for minimal space usage. This means that the mounting should not come out from under the surface area projection of the solar cells. The entire system, all four cells, should require under $100 in basic upkeep every two years, replacing basic parts that may break like coverings or electronics.

Because the system is based in Flagstaff, there are several environmental constraints to consider. The system should be able to handle gusts of up to 65 Mph, while receiving no visible movement in the tracking with a constant 40 Mph wind. There should be no visible damage from hail or snow, and the tracking should continue to operate with two feet of snow on top. Flagstaff can have dramatic changes in temperatures over a 24 hour period, so the system should be able to operate within the temperature range of -10º to 100º Fahrenheit. Finally, after being exposed to all of these elements, the system should show little to no visible oxidation after 15 years, the average life of most photovoltaic cells.

Analysis and Schedule

The quality function deployment is a method that transforms the user demands into engineering design quality. This comparison helps establish what engineering design requirements are most important. Figure 1, located below, is the solar tracking design quality function deployment.

	Engineering Requirements					
Customer Requirements	Supported Weight	Structure Weight	Cost	Programming	Efficiency	Area
1. Tracking	•	•	•	•	•	
2. Manual Override			•	•		
3. Inexpensive	•		•		•	•
4. Display			•	•		
5. Weather Resistant	•	•	•			•
Units	lbs.	lbs	$	C/C++	%	ft.^2
Engineering Target	100	250	2k	yes/no	95	100

Figure 1: Quality Function Deployment

Figure 2 outlines the schedule for the solar tracking design project. Each sub task is labeled under a specific design step. Arrows signify the next subtask to be accomplished after the finishing the previous sub-task. The black bar located in the middle of subtasks show the team's current progress. Milestones are labeled as diamonds and signify project due dates. The milestones are located at the bottom of the gantt chart.

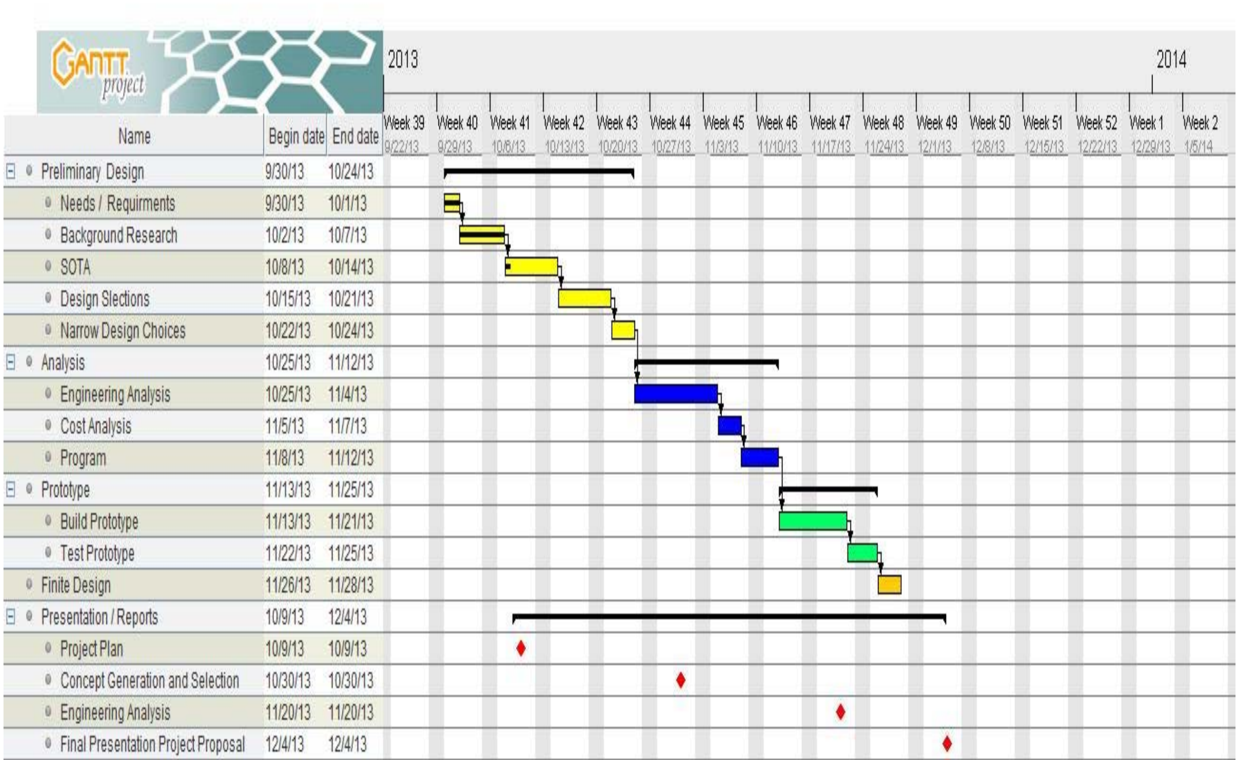

Figure 2: Gantt Chart

The house of quality, Figure 3, is a method that relates each engineering design choices from the quality function deployment. A “+” dictates that as one engineering design choice increases/decreases, the other engineering design choice increases/decreases. A “-“dictates that as one engineering design choice decreases/increases, the other engineering design choice increases/decreases.

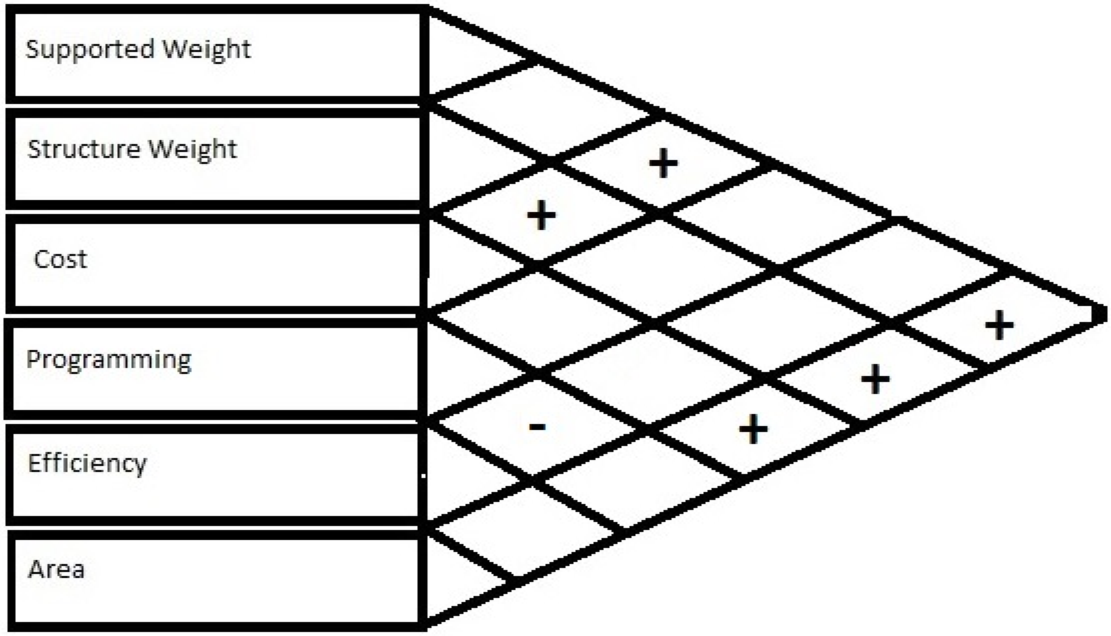

Figure 3: House of Quality

Conclusion

Solar power plays an increasingly important role in our search for more efficient and sustainable energy sources. In order to fully utilize this energy source, PV cells must be able to follow the sun throughout the year. Solar tracking systems are expensive, and the more precise the system is, the higher the cost. At the request of Dr. Acker, the Solar Tracking Team will design an inexpensive and accurate tracking system that is suitable for the climate of Flagstaff, AZ. The tracking system will also function as an educational tool via a controller that allows for manual manipulation of the PV cells accompanied by a readout of the cells' efficiencies at different degrees of tilt.

References

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