Restated Project Specifications and Plan

Taller Wind Turbine for Low Wind Speed Regions

Team Number: 25

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Table of Contents

Table of Tables

Table of Figures

I. Abstract

This project is focused on developing the blades and tower of a wind turbine that would be cost effective to operate in the southeastern United States. This report outlines the work that was done during the Fall 2014 semester and where the team currently is in the design process of the turbine. The team has come up with a final design for both the blades and tower of the wind turbine and has started the process to purchase materials for the small-scale prototype that will be constructed before the end of the semester. The team is also finishing cost analysis on the tower to ensure it is economically feasible to construct. The next report will go into much greater depth on the materials purchased and show the finished cost analysis.

II. Project Overview

Our project is sponsored by the FAMU-FSU College of Engineering. The project leader/sponsor is Dr. Sungmoon Jung and he wants the group to focus on using new turbine blade and structural materials that will allow for a new, cost-effective wind turbine to be built in Florida. Currently there are no major wind farms in Florida due to low wind speeds at 80 meters. By introducing a wind turbine that is effective in Florida a new market could exist. There is a need to develop and produce a new type of wind turbine that is larger to utilize wind power in areas like Florida.

The design that the team has come up with is a 160 meter tall horizontal wind turbine with 61 meter length blades. The civil engineering students have developed a tapered heptagonal lattice steel structure. This design was chosen to reduce weight and material to allow the taller structure to still be lightweight relative to other wind turbine towers. The mechanical engineering students have designed the turbine blades that will be used. The blades were designed to be lighter and similar in strength to current blades used. The team is finishing the final cost analysis and transitioning into purchasing materials for the prototype.

III. Objectives and Constraints

The objectives of the project remain the same as the Fall semester. The sponsor wants the students to utilize new technologies and ideas in their design of the wind turbine. The new structural/mechanical designs have to be structurally sound at the height of 150 to 200 meters. In order for the turbine to be a realistic option for the southeast the design must be cost competitive with current wind turbines in the market today. Along with being financially competitive, the turbine must be able to generate at least the same electrical power as current turbines. The final design and prototyping by the team must be accomplished before the end of the spring semester within a budget of $2,000.

The design specifications for this project are as follows:

- The wind turbine will be 150-200% taller than current wind turbines
- Must withstand stress of wind at 150-200m in SE United States
- The structure must support its own weight
- Blades will be lighter than average current turbine blades
- Turbine must be profitable within a reasonable amount of time

The performance specifications for this project are as follows:

- Operating in all weather conditions with exception of winds >16 m/s
- The wind turbine will have a net positive energy production.
- The efficiency will be within a range of 30-35%

IV. Current Progress

The team is currently preparing for the production of the wind turbine prototype. Last semester the team focused on the design of the tower and the blades. The basic tower design has been chosen. The material that has been selected is steel due to its high strength-to-weight ratio. The most efficient shape of the tower was found to be a seven-sided space frame with a widened base for extra support. Furthermore, the connections within the tower have been designed using plugs which minimize the number of bolts needed thus increasing the ease of construction. The tower has been tested using stress and modal analyses, both of which yielded passing results.

Currently, slight modifications are being made to decrease the weight of the tower while maintaining strength at high stress locations. Lateral supports are being added to several sections in order to prevent excess bending. After the modifications are made, modal analysis and stress analysis will be performed again using Structural Analysis and Design (STAAD) software. In addition, the connections will be reassessed to ensure that they provide the most efficient design. The cost of tower construction will be interpolated from data sheets from the National Renewable Energy Laboratory (NREL). The construction process will include equipment, labor, and transportation costs.

The team designed four turbine blades all with different interior bracing beams. Analysis (including shape factor analysis and overall weight analysis) was performed in order to select the best design. After analysis was complete, a turbine blade with a triple I-beam bracing beam was selected. In addition to selecting the interior bracing beam design for the wind turbine, materials for the blade were also selected. The team decided that the bracing beam will be made of aluminum 6061, the outer fabric will be made of E-glass and carbon fiber, the resin used will be epoxy, and the core will be made of SAN foam.

Having the wind turbine design complete, the team is now focused on the production of the prototype. The prototype the design will not be an exact scaled model of the actual design. However, the model will represent the main features of the tower including the connections and tapered width. The model will have 3-4 sections unlike the actual tower design which consists of 20 sections. This modification to the model was made since it would be unrealistic for a 6-ft tower to contain 20 sections. The materials for the tower will be ordered as soon as possible so that the fabrication may begin.

Once more, it is not realistic to construct wind turbine blades for the prototype that are identical to the actual design in terms of interior structure and materials used. This is due to the limited manufacturing capabilities as well as budget constraints the team is faced with. Therefore, the team will be constructing small scaled prototype blades made of Styrofoam and fabric. The team will purchase Styrofoam blocks and hand cut out the blades airfoil shape. Rather than having a hollow interior with a bracing beam the prototype blades will be solid Styrofoam. The Styrofoam will be wrapped in fabric, to protect the foam during testing. The prototype design will continue to be developed to ensure that the tower and blades and all their connections fit together well.

V. Final Design

The final design for the turbine tower and turbine blades have been completed. The tower will be roughly 160 meters tall and the blades will be lighter than but just as strong as current turbine blades. For the tower it will be produces in 20 separate sections and connected via male-female connections between each section. These sections can be easily assembled on site, and only one application of field welding is required where the wider base meets the skinnier top section. The design is a lattice structure that allows the tower to maintain the strength needed, but the lattice design decreases the amount of material needed, making the tower lighter. The blades are 61.5 meters long and made out of fiberglass and epoxy. The blade will be reinforced with a triple-I beam bracing beam that runs the length of the blade. Figure 1 shows a representation of the final design of the wind turbine.

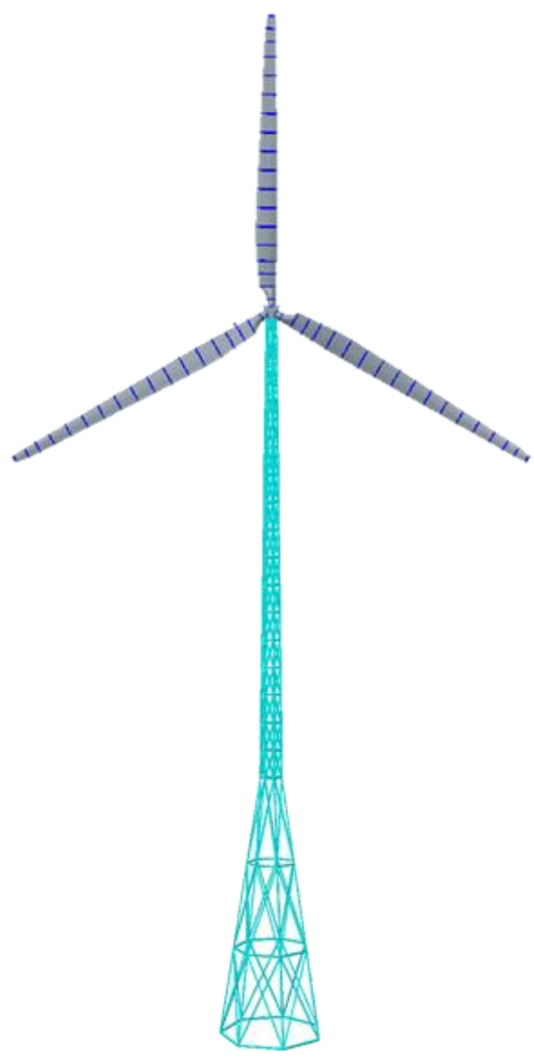

Figure 1: Wind Turbine Design

VI. Challenges

Throughout the fall semester we encountered several challenges to overcome. One of the first challenges we encountered was the team had to do significant research into wind turbine before work on the project started. Another challenge encountered was that there is a lack of data on wind speeds at different elevations and no available wind speeds at a height of 140 meters, which is the height of the proposed turbine. This problem was solved by extrapolating available wind speeds at 80 meters to 140 meters. Initial designs of the turbine tower failed when placed under a simulated load in STAAD modeling software. A new design was created in order to prevent failure of the tower. The current tower does not fail under expected wind loads but the sponsor has told us it is too heavy so the design must be reproached.

The design of the turbine blade encountered several issues, the biggest issue being that there is no data available to the students for dimensions of the turbine blades because the data is proprietary. Without knowing the thickness of the blade walls or the dimensions of the bracing spar of the blade the weight and amount of material needed for the blade is an assumption. The team is working on making the best assumptions possible for an accurate blade design. Because of the unique shape of the turbine blade, creating a model of the blade in Creo was very difficult. With help from Dr. Hollis the team was able to finish the blade design using the corresponding assumptions. Due to the complexity of the blade design also makes fatigue analysis of the blade a complicated process. Creo is currently unable to finish analysis on the turbine blade so the team is working on optimizing the blade design so Creo is able to complete the analysis.

The team is currently using the FAST program provided by the sponsor from the National Renewable Energy Laboratory to calculate the power output of the turbine based upon the chosen location. The program has errors that is outputting a power output of zero, this issue will be fixed in the coming week.

VII. Procurement Updates

No materials have been ordered for the project currently, but the group plans to begin ordering materials in the coming weeks. The civil students in the team are planning to obtain donated steel from Cives Steel Company, a company located in Thomasville, Georgia. They will use the machine shop in the college of engineering to construct the tower. The mechanical students are planning to build larger scale models of the turbine blades out of Styrofoam blocks from StyroShapes located in Hunt Valley, Maryland. The Styrofoam blades will be wrapped in a high performance fabric simulating the material that will be in our final design. This is a cost effective method to produce a large model of the blades. The blades will be cut by hand by the team members. Because this will not produce the most accurate blade models, the team will contact the High Performance Materials Institute to see if a small scale exact replica of our design can be produced by a 3D printer.

VIII. Methodology & Resource Allocation

The general strategy of the team is to split up the various tasks into distinct sections to make the workload more manageable. Although everyone has individual tasks the team will still meet weekly to ensure that progress is being maintained throughout the semester. The team will also meet every other week with the sponsor and faculty advisor to keep them updated and inquire about any issues encountered. The following schedule describes how the project will be broken down.

As aforementioned, tasks needed to complete this project before the end of spring 2015 semester will be divided up amongst the team. The Mechanical Engineering students are beginning to do the analysis of power output in the FAST program from NREL, which will last for approximately two and a half weeks. When this is finished the team will begin to run an iterative process to improve the design and its output. During this period fatigue analysis on the tower and blades will be commencing. After the fatigue analysis of the individual sections of the turbine is completed, the combined fatigue analysis will begin for two weeks. During this time period the students will also be working on the construction process for the design, which entails the amount of workers, Equipment, and Transportation needed. Since the end of the Fall 2014 semester, the students have been working vigorously on the cost analysis of the turbine. The cost analysis also includes the prices of additional parts, labor, transportation, and land. While cost analysis is being calculated, other students are working to calculate the amount of revenue produced by the team's turbine, as well as an average turbine in the mid-west US. Once the cost and revenue have been calculated, the profit of the wind turbine can be calculated. Currently the students are also working on choosing a construction method and ordering materials for the prototype. Once the materials have been received, the team will begin constructing the turbine. All of these tasks will be completed before the end of the spring 2015 semester. Table 1 provides information on the main tasks that each team member will focus on.

Table 1: Allocation of Resources

Task	Team Member(s) Responsible
• FAST Analysis • Analysis of Power Output	• Jeremiah McCallister • Stevie Blanchette
• FAST Analysis • Iterate on Design to Improve Output	• Jeremiah McCallister
• Fatigue Analysis • Blades	• Stevie Blanchette
• Fatigue Analysis • Tower	• Theo Meros
• Fatigue Analysis • Combined	• Stevie Blanchette • Theo Meros

• Construction Process of Design
  • Amount of Workers
  • Equipment
  • Transportation
	• Kim Martinson
	• Theo Meros

• Cost Analysis
  • Cost of Blades
  • Cost of Tower
  • Additional Parts
  • Cost of Labor
  • Cost of Transportation
  • Cost of Land
	• David Delie
	• Kim Martinson
	• Abigail McCool

• Revenue
  • Revenue at Selected Location
  • Revenue at Various Locations
	• David Delie

• Profits	• David Delie • Theo Meros • Abigail McCool

• Prototyping
  • Choose Method
  • Order Materials
	• Abigail McCool
	• Jeremiah McCallister

• Prototyping • Construct Blades	• All ME Team Members
• Prototyping • Construct Tower	• All CE Team Members
• Prototyping • Combine Parts	• All Team Members

IX. Gantt Chart

Each task and benchmark will be tracked using a Gantt Chart, which can be seen below in Fig. 1.

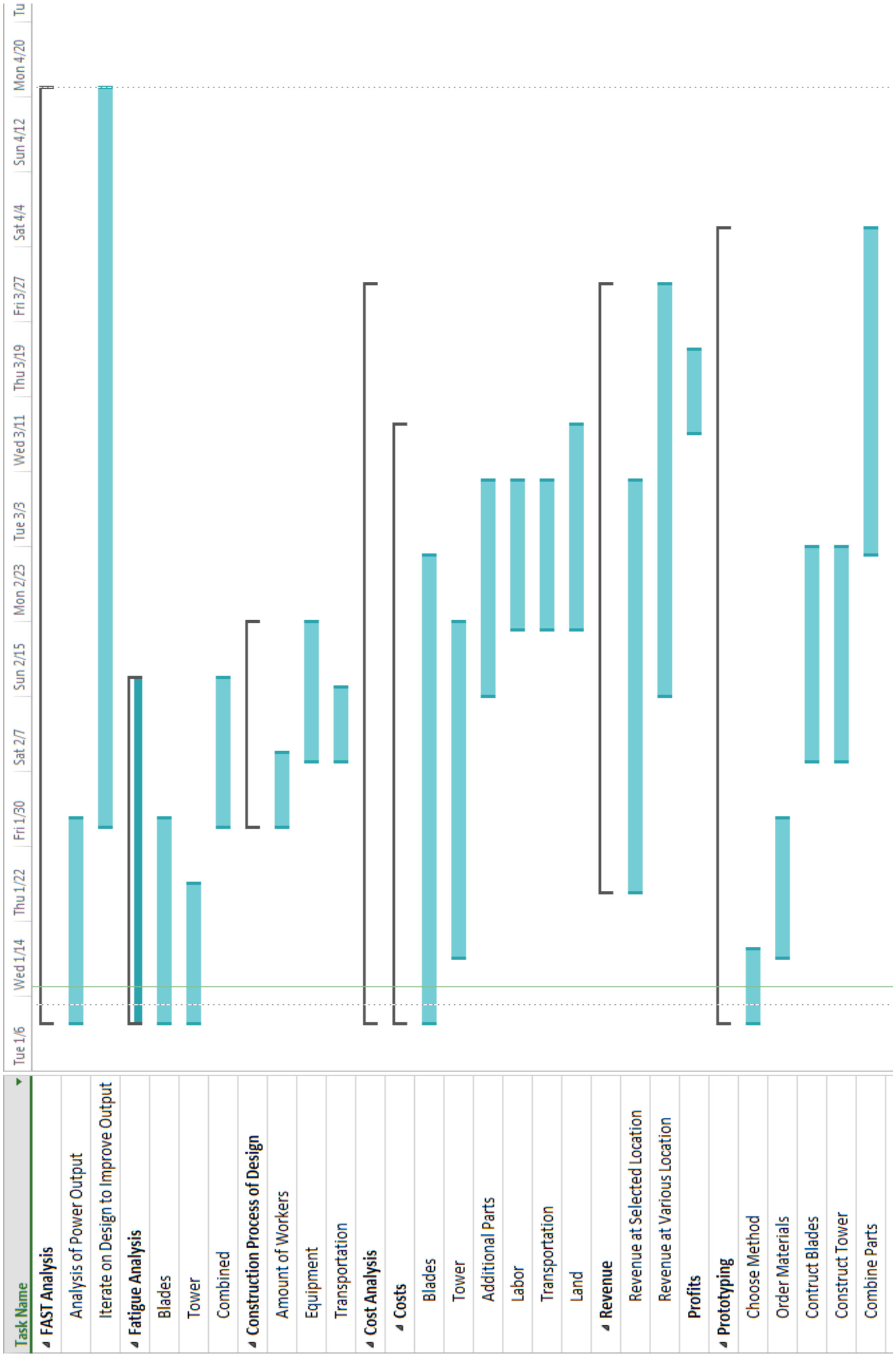

Figure 2: Updated Gantt Chart