Midterm Report 1

Offshore Wind Turbine

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1.0 Executive Summary

The main goal of the Offshore Wind Turbine Project is to reduce the cost of wind turbines located in "deep water". The primary cost components that drive increases are the foundation and overall construction costs. The objective of this report is to illustrate and elaborate upon several distinctly different Offshore Wind Turbine designs. The Offshore Wind Turbine is broken down to three sections, Horizontal versus Vertical Axis, Direct Drive versus Gear Box, and Foundation selection. The three proposed foundations include a Concrete Cone Spar Buoy, Kite, and Boat Shaped Barge. Each section will provide an analysis and proof of concept, which contributes to the overall selection process. The selection will be based on a weighted decision matrix. The decision matrix guarantees that an appropriate design will be picked based on weighted desired characteristics of each design. Based on the established criteria of the decision matrices, the proposed design will include a Horizontal Axis, Direct Drive, and a Boat Shaped Hull Barge. These individual components will be integrated to form a cost and performance efficient final design.

2.0 Project Overview

2.1 Sponsor Requirements

The energy potential of offshore wind farms is much greater than that of land based farms thanks to the reduced surface roughness of the sea. For some states the entire electricity could come from offshore wind farms. With such enormous energy potential, offshore wind turbines will contribute to the national energy security.

Although the floating offshore wind turbine has advantages, the cost is still prohibitive. The most important project objective is to reduce the cost compared to existing ideas. The approach is not limited to innovative design --you may come up with innovative construction method, logistics, or any other approach that you can think of. (1)

2.2 Scope

The scope for the offshore wind turbine is related to location and water depth. The location should be sufficiently far from shore such that surface effects from land are immaterial leaving only those from the ocean surface. Water depth should be deep enough to be considered “deep water” (i.e., greater than or equal to 60m).

2.3 Goal

The purpose of this project is to expand a future renewable resource in the hopes of making it available for the commercial market. The largest problem facing the current development is expense. If it were able to have grid parity, the benefits from offshore wind power would grow the renewable energy market tremendously. The largest cost components, of an offshore wind turbine system, are the foundation and overall construction. The primary goal is to modify existing designs to minimize cost, while maximizing output and sustainability with the goal of reaching a levelized cost of electricity with respect to total grid production.

2.4 Constraints

Time Management: The Floating Wind Turbine must be designed, built and tested before the last week of the spring semester (as of now April 25th 2014). Time management will be necessary in order to batch and cure the concrete foundation, build the steel structure and manufacture the blades and gears before the project deadline. Proper scheduling will be essential to the overall success of the Floating Wind Turbine.

Budget: As of now our budget is 2,000 dollars that is being supplied by Dr. Jung’s research grant. Supplies will also be donated from Florida Rock and Cives Steel which will alleviate some of the financial burden from acquiring materials. Blades, gears, motors and sensors will be restricted to the 2,000 dollar budget. The team will track expenditures in order to stay on budget and provide a quality product with a marginal cost.

Team members: The team consists of seven members from three disciplines of engineering. There are three mechanical, three civil and one electrical engineering majors assigned to this project. It is imperative that the three disciplines communicate and schedule effectively amongst each other to make the Floating Wind Turbine a reality. Due to differing schedules, the team must overcome scheduling conflicts and resolve a meeting time once a week that can accommodate the team. This is critical to meet objectives and benchmarks determined by faculty and the team members.

In order to overcome scheduling conflicts, much of the work will be broken into task that will completed remotely by the team members. Proper file organization will minimize confusion and ease collaboration of report writing. Drop box and the File Exchange in the EEL4911 Blackboard Course site will be utilized to share, retain and organize documents.

Task will be tracked and benchmarks will be set using a Gantt Chart created in Microsoft Project. The specified timeline will be utilized to track progress, goals, due dates. This timeline will govern the progression of the project.

3.0 Design and Analysis

3.1 Turbine

One of the very first concepts that was needed to take into consideration was analyzing the two main styles of turbines: horizontal or vertical axis rotation. For a horizontal turbines, the rotating axis is parallel to the water as seen in the Figure 3.1.1. The majority of industry uses this style, particularly for big wind applications. They are able to produce more electricity from a given amount of wind. Ideal for producing as much wind as possible at all times. However, these turbines are generally heavier and do not produce well in turbulent winds (2).

Vertical axis turbines, shown Figure 3.1.2, the rotating axis is perpendicular to the water. They are typically used in small wind projects and residential applications. The most convincing attribute about these designs is that they produce well where wind conditions are not consistent because it can take wind from any direction. Unfortunately, the biggest drawback of them is that they cannot be placed high enough altitude to benefit from steady wind (2).

Figure 3.1.1 – Horizontal Axis Wind Turbine

Figure 3.1.2 – Vertical Axis Wind Turbine

In order to evaluate and decide which design best applies to this project, a decision matrix needs to be formulated:

Table 3.1.1 – Decision Matrix: Horizontal Axis vs. Vertical Axis

Style:	Big Wind Applications (0.3)	Weight (0.2)	Cost (0.2)	Efficiency (0.3)	Totals
Horizontal Axis	8	4	6	8	6.8
Vertical Axis	3	7	4	5	4.6

$$Horizontal\ Axis = 8(0.3) + 4(0.2) + 6(0.2) + 8(0.3) = 6.8 \quad \textbf{(Equation 3.1.1)}$$

$$Vertical\ Axis = 3(0.3) + 7(0.2) + 4(0.2) + 5(0.3) = 4.6 \quad \textbf{(Equation 3.1.2)}$$

As you can see, a horizontal axis turbine is the most appropriate decision for an offshore wind turbine. All of the categories were weighted subjectively but were relatively distributed evenly. One of the biggest factor in this decision is the ability for the turbine to be able to perform in big wind applications. The turbine must be able to be able to hold up against strong winds and wave loadings so a vertical axis turbine would be difficult to construct. Also, it is important to understand that wind speeds become steadier as they move farther away from the sea level. A steady wind speed is crucial in order to have the turbine produce maximum output power. This value ranges between 9-11 meters per second. Therefore, in order to have a turbine that operates at the optimum power, the turbine must be able to be able to perform from a higher altitude to perform under steady wind conditions. Weight is the major drawback when choosing a horizontal axis but this design is necessary based on the climate conditions that this turbine needs to withstand (2).

Although costs is the single most important factor of this project, it does not play as much into a factor when choosing the axis design since both are very similar and comparable. The main difference when choosing cost is deciding which material will be used for construction. Vertical axis turbines are slightly less cost effective due to the fact they must be used at a lower altitude. This difference is very small so cost was considered not as significant. Finally, a lower altitude results in slower wind and therefore decreases the turbine's efficiency in the long run. As a result, the other categories were placed with a larger percentage in order for the team to have a better understanding which design better fits for the project scope. In the end, a horizontal axis offshore wind turbine is the design of choice (2).

3.2 Power Generation

When looking at today's wind turbine designs we see that there are two main concepts in generating power. In both concepts they consist of a generator, the difference being uses a gearbox or direct drive. When breaking down both concepts we see many fundamental differences.

In Gearbox design, we typically see a 6 phase, 6 pole induction generator that requires 1500+ rpm synchronous speed in 50 Hz, while it requires 1800+ rpm synchronous speed in 60 Hz. These gearbox, work well in on-shore application as they are easy accessible and maintenance is not too much of a burden, however when looking at off-shore applications we see that the task is a bit more of a challenge and in return presents a higher cost. On the other hand, using gearboxes in off-shore applications isn't all bad. We see that in today's technology most applications do use gearboxes because they can produce such high voltage potential, increase the rpm up to synchronous speeds, and allow a wider range of wind speeds. Typically in induction generator with a gearbox we see a range of 1800-1860 rpm before having to put the turbine into stall phase (3). Although this may sound like an ideal design there are many flaws in using gearboxes and an ideal induction generator. For example, with gearboxes weight becomes an important fact which was not a problem on land. Increase weight, impacts the structure of the base which in turn increases the cost. When looking at an induction generator another burden that plays a role is a needed external excitation. This excitation roughly consumes about 20% of the power before being able to synchronous and pump out power to the grid. Another factor as mentioned above is maintenance. It costs a significant amount to have a skilled professional go out on a boat and climb up to perform maintenance or fix a problem. In all, there are positives and negatives in gearboxes that do allow the creation of power back onto the grid (4).

In direct drive designs, we typically see an excitation static generator, induction generator or a permanent magnet generator. In floating offshore designs it is more efficient to use a permanent magnet generator for direct drive because of its size and reliability. A permanent magnet generator is roughly 4 meters, compared to an excitation static generator which is 8 meters. When comparing an induction generator and its need for multiple poles to use such lower rpms it is inefficient to use. For example, an induction generator would need to use 80+ poles resulting in a bigger, more expensive, and less efficient generator. Therefore with the purpose of reducing the load, permanent magnet would be the ideal option in direct drive. Permanent magnet generators are relatively easy to manufacture and assembly with the rotor is cheaper compared to induction generators. Using permanent magnets also eliminate the need for brushes and external excitation sources. In direct drive permanent magnet designs, there is a 20% energy savings because of its self-excitation and losses across the gearbox are now disregarded. Permanent magnet generators allows for size reduce on the base, which reduces the cost of materials, and also is more reliable and longer lasting than most generators of equal power output. Another added benefit of direct drive is now gearbox maintenance can be ignored, resulting in further saving in commissioning, erection, and contingency. Although there are many pros for direct drive permanent magnet generators there are some down sides as well. Permanent magnet generators are more costly due to the market and its rare earth metals that create the magnetic field. Due to new innovations in the past two years, including reducing the size and efficiency, prices are slowly beginning to drop. As innovation increases and more permanent magnets generators hit the market they will drastically reduce in price. Another problem that could arise is the rotor becoming demagnetized thus resulting in a shift of the poles and lack of the creation of power. Because this technology is rather new, there is no case where this has happened yet, but it is always a small possibility. In all, there are solutions and challenges that direct drive permanent magnet generators give to the creation of power in offshore wind applications (5).

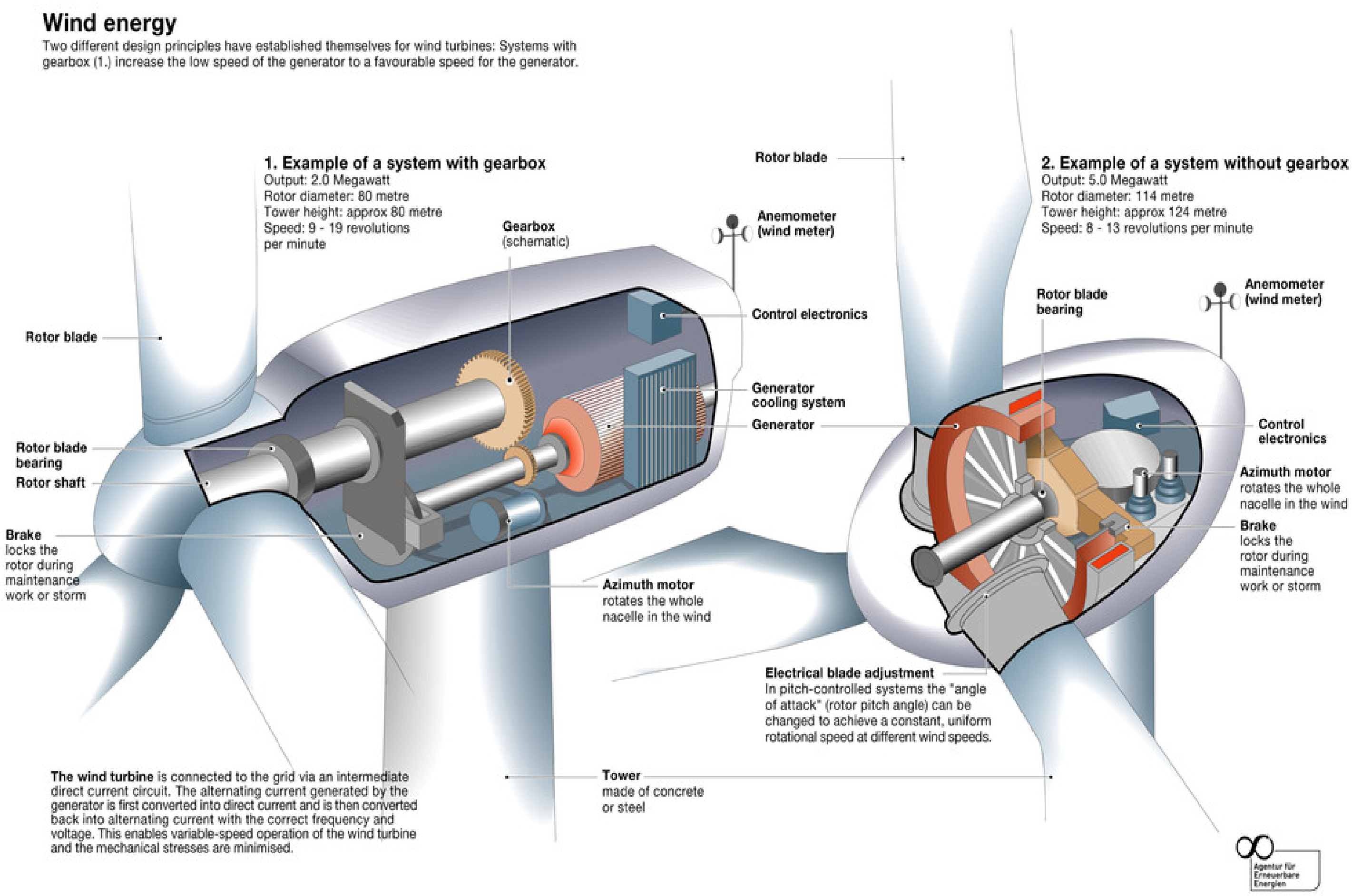


Figure 3.2.1 – Gearbox vs. Direct Drive Wind Turbines

Table 3.2.1 – Decision Matrix: Gearbox vs. Direct Drive

Power Generation	Maintenance (0.3)	Weight (0.3)	Initial Cost (0.2)	Efficiency (0.2)	Totals
Gearbox	5	4	6	6	5.1
Direct Drive	8	6	4	8	6.7

$$Gearbox = 5(0.3) + 4(0.3) + 6(0.2) + 6(0.2) = 5.1$$ (**Equation 3.2.1**)

$$Direct\ Drive = 8(0.3) + 6(0.3) + 4(0.2) + 8(0.2) = 6.7$$ (**Equation 3.2.2**)

After using the decision matrix, the answer between direct drive versus using a gearbox is to go with the direct drive design. Although the direct drive route is initially more expensive, looking at the long term picture it is cheaper with only requiring two services a year. Direct drive also provides more reliability and a greater life span up to 20 years, while offering easier assembly during the erection phase of the project. Looking at the comparison of a gearbox with induction generator versus a direct drive permanent magnet generator, it is seen that permanent magnet generators offer the best solution to bring down cost with improved efficiency in the future.

3.3 Foundation

3.3.1 Concrete Cone Spar Buoy

Offshore wind turbines are limited by their excessive construction costs. In order for Offshore Wind Turbines to be a viable option, the cost has to decrease significantly, either through the manufacturing process, construction, or radical designs. Since the budget is a large governing factor, preliminary designs have been used to estimate construction cost, material acquisition and manufacturing time. The estimates determined are based upon the preliminary design shown below. The design is subject to change.

Below are 3-D renderings, developed in AutoCAD 2013, of the preliminary design.

The base structure is represented in the image to the right. The 3-D model is composed of two dimensional wires. The green wires represent hidden lines. The cyan wires represent visible lines. This rendering shows the skeletal makeup of the concrete base structure.

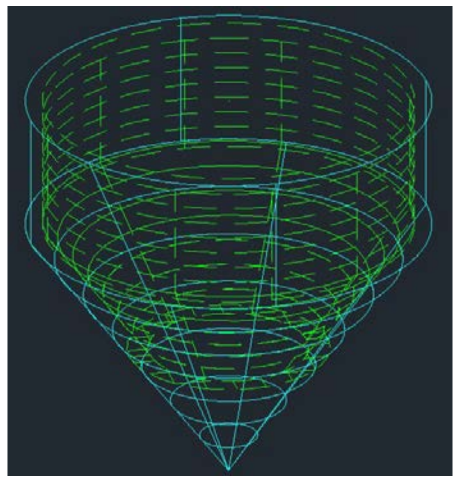


Figure 3.2.1

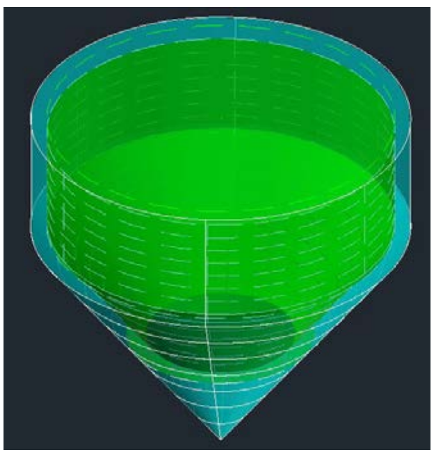


Figure 3.2.2

The base structure is shown in the X-Ray image to the left. The rendering shows the green cavity within the concrete structure. A structure with a cavity was chosen to reduce material cost and increase the buoyancy of the structure. The cyan portion represents the concrete and reinforcement. The X-Ray image to the right shows the designed dimensions. As you can see, there is a 1:1 ratio between the overall height and diameter of the base structure. It also can be seen that, the base of the structure is solid concrete. This feature increases stability of the structure by lowering its center of gravity.

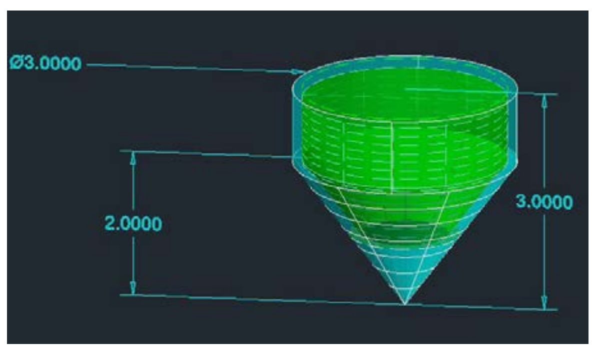
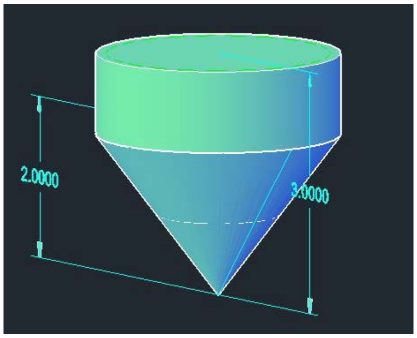


Figure 3.2.3

The structure shows a ratio of 2.25:0.75 feet comparing how much of the base structure is sitting below and above the waterline. Further testing is required to confirm this estimation.



The image to the left displays a conceptual rendering of the design. The image to the right displays the profile view of the conceptual 3-D model. It view displays the cavity, solid base and wall thickness.

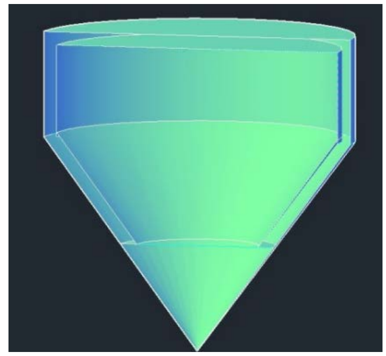


Figure 3.2.4

Figure 3.2.5

Properties of Base Structure:

Approximate Concrete Density: 58-60 LB/FT^3

Carbon fiber mesh reinforcement would be ideal but due to budget constraints, galvanized mesh can be utilized as reinforcement. The walls will be doubly reinforced to prevent both positive and negative bending moments caused by weather, waves and the point load.

Proposed Design Changes:

1. Corrugated Base:
    - In order to improve stability and reduce lateral movement, a corrugated base has been proposed. The corrugated base would allow water to flow through the structure and be rerouted in a way that decreases the effect of waves and tides. If rerouted correctly, an anchor system in theory would not be required to maintain the position of the floating wind turbine. This would significantly reduce the construction cost.

PROS VS CONS

PROS:

- Lightweight
- Parts can be manufactured in assembly line
- Reusable Concrete molds will reduce cost

CONS:

- Stability is reduced due to geometric design
- Wind Turbine Structure will have to be assembled in Ocean which increases construction Costs
- Mooring lines are required to stabilize base which increases costs.

3.3.2 Kite

This proposed design would consist of a glider wing moored down by cables with turbines distributed along its span length. The attached cables will be attached to a mounting surface along the sea floor. The overall kite is grounded by itself in the air. The idea would be to take advantage of high altitude wind speeds to have an immediate power source in remote areas. It was envisioned that this type of turbine would be useful as an emergency power source because it would be capable of producing large amounts of power, quickly, once it reached altitude.

Below lies the 3D rendering of the kite design developed in Pro-Engineer.

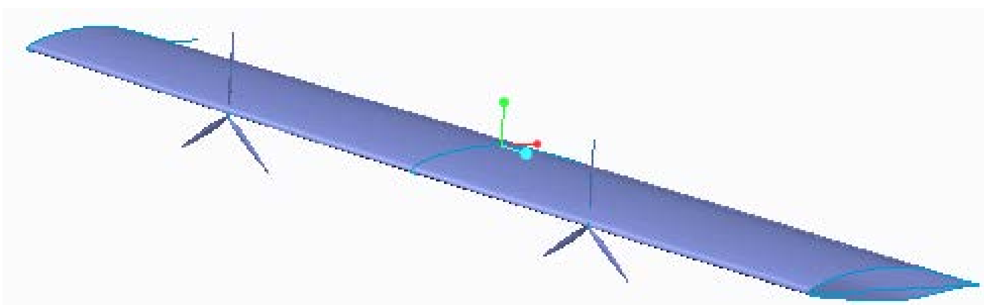


Figure 3.3.1

Properties of Kite Structure:

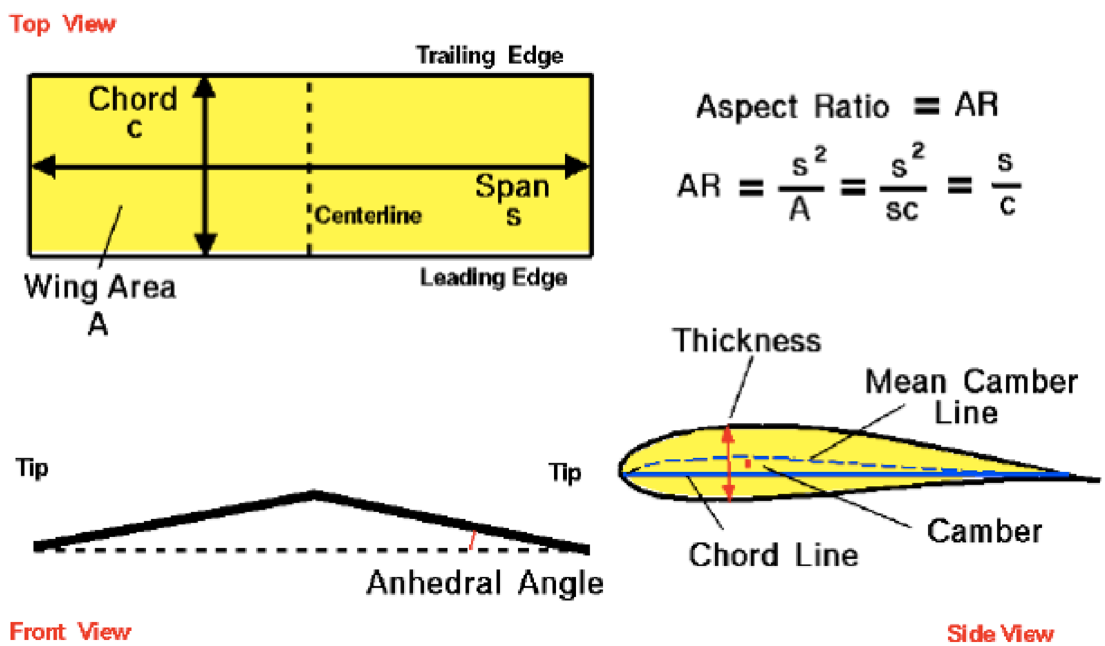


Figure 3.3.2

Since high aspect ratio wings have long spans (such as gliders), while low aspect ratio wings have either short spans or thick chords, our craft would need to have a long span in order to optimize the number of turbines along its span and thus maximize power generation. Gliders have a high aspect ratio because the drag of the aircraft depends on this parameter. A high aspect ratio will lead to lower drag and a higher lift to drag ratio. In addition a high AR will give a better glide angle.

Aeronautical aluminum, carbon fiber, or a nylon carbon fiber combination would be used as the kite's wing material, depending on the design type. The base structure will be designed to support the lift of the kite at high altitude wind speeds. The base would be either a drilled anchor or, at sea, ballast material such as concrete.

Proposed Design Changes:

1. Rigid wing vs. Packable wing:
    - In order to improve lift and durability it is proposed that a rigid wing material is used such as carbon fiber or steel. Since the wing will need to stand up to loads due to fluid forces, supporting its own weight, and supporting the weight of the turbines.
    - In order to maximize the usefulness of the design, it is proposed that a light weight packable material be used for the shell of the wing and carbon fiber skeleton used to support loads. This would be a more costly design and would not allow for very large turbines due to weight concerns. However, this design would make sense for its purpose as an emergency power source.

PROS VS CONS

PROS:

- Lightweight
- Mobile
- Parts can be manufactured in assembly line
- Useful in many locations
- Consistently high production

CONS:

- High cost of materials
- Extremely long mooring line required
- Complicated Aeronautical Engineering design

3.3.3 Boat-Shaped Barge

The idea behind this design is to combine autonomous/self-orientation technology with a V hulled barge. With this design, mooring lines would not be necessary as the boat shape design would orient the barge into the waves, thus into the wind. Additionally, autonomous capabilities would keep the boat in one location, making mooring lines optional. This approach would also transfer, possibly installation costs from the barge being able to take itself to its destination via its motorized onboard system or manual labor installation costs. The overall goal of this platform design would be to reduce or eliminate the costs due to mooring and installation.

Below lies a 3D rendering of the boat-shaped barge design developed in Pro Engineer.

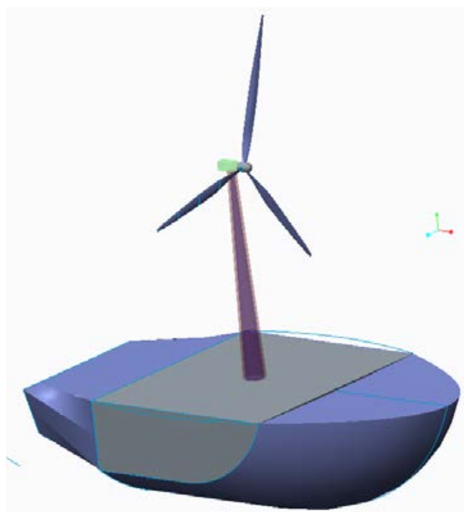


Figure 3.3.3

Properties of Base Structure:

Since most of the loads placed on the barge will be lateral loads due to the turbine tower the base of the tower will need to be very robust. The Dutch Barge shape will allow a large displacement while still maintaining a V shaped hull, for orientation purposes.

The barge will be constructed from either fiberglass or concrete with fiberglass reinforcement. The type of material used will depend upon cost and strength.

The autonomous features would include, global positioning systems, water jets propulsion or standard propeller system, orientation hardware and software, gyroscopes.

Proposed Design Changes:

1. Non autonomous barge:
    - In this case a barge would be launched with a self-propulsion system and motored out to its destination at which point automated systems would deploy its mooring system and raise the turbine tower. This system would reduce installation costs by making the barge self-launching as well as self-installing. The proposed system would utilize a standard motor prop in order to place the barge in position at which point the mooring system would be diploid via remote control. This would make the barge stationary and make self-orientation unnecessary.

PROS VS CONS

PROS:

- Manufactured onshore where infrastructure exists
- Allows for many design options
- Parts can be manufactured in assembly line
- Reusable Concrete/fiberglass molds will reduce cost
- Self-deployable
- Allows for the option to not use mooring lines, reducing cost
- Eliminates the need for installation crews

CONS:

- Maintenance (a lot of moving parts)
- Lengthy design process
- Would require extensive testing

Foundation Decision Matrix:

Style:	Installation Difficulty (0.25)	Weight Supported (0.10)	Cost (0.30)	Maintenance (0.10)	Innovation (0.25)	Totals
Concrete Cone Spar Buoy	6	7	6	7	4	5.7
Kite Design	4	2	8	3	6	5.4
Boat-Shaped Barge	7	8	6	8	8	7.2

$$Spar\ Buoy = 6(0.25) + 7(0.1) + 6(0.3) + 7(0.1) + 4(0.25) = 5.7$$ (**Equation 3.3.1**)

$$Kite\ Design = 4(0.25) + 2(0.1) + 8(0.3) + 3(0.1) + 6(0.25) = 5.4$$ (**Equation 3.3.2**)

$$Barge\ Design = 7(0.25) + 8(0.1) + 6(0.3) + 8(0.1) + 8(0.25) = 7.2$$ (**Equation 3.3.3**)

Based on the decision matrix, the Boat Shaped Barge design is the most suitable option for this project. The biggest deciding factor in the design choice was cost and innovation. Along with cost, one of the biggest objectives that have been asked by the Mechanical, Civil, and Electrical departments is to develop a completely new design against preexisting ideas. If innovation wasn't such a crucial factor, the concrete spar buoy would be a very promising design. Unfortunately, the kite design has too many questions and factors that need to be taken into consideration. The main concern is the amount of total output power. This design will produced far less power than the other options. In order to fly, the material would have to be very light and would not be able to support much weight. The installation process would be extremely difficult for initial construction. As a result, maintenance costs and well as initial costs would be extremely high in order to keep this design running efficiently for its typical 20 year life span.

4.0 Conclusions

As stated before, the main objective of this project is to reduce the cost of wind turbines located in “deep water”. The biggest driver of the work scope in order to achieve this goal is to focus on the foundation and overall construction costs of the design choice. This scope has been decided based on research on cost breakdown for every component and stages for preexisting ideas that are already out in the field. Reducing costs and striving for innovation and creating are the key components for a success project. When going through design concepts, the team broke the entire design into three main sections. These sections include choosing a Horizontal versus Vertical Axis turbine, a Direct Drive versus Gear Box generator, and a Foundation selection. Because of the scope of the project and where major improvement can be made, three different foundation design concepts have been developed, a Concrete Cone Spar Buoy, Kite, and Boat Shaped Barge design. After much research and analysis on each design, a selection has been made based on a weighted decision matrix. The design selection will include a Horizontal Axis, Direct Drive, and a Boat Shaped Hull Barge. In the end, all of the components and individual assets will play a significant factor in order to reduce cost while still performing effectively.

5.0 Future Follow-up on Design Concepts

Future Follow Up on Design Concepts

Listed below are some other innovative ideas that could ultimately drive down the cost of whichever design is chosen. Due to time constraints, all options will not analyzed and existing technologies selected will be made. One or more of the following could be utilized in the final designs of the offshore wind turbine.

1) **Autonomous boat-** A boat that is preprogrammed to navigate to its desired position would reduce costs of construction and maintenance by being its own transportation.

Existing Technology: "One Mega Arduino microcontroller board handles navigation and another handles sensors and communications via an Iridium satellite transceiver, but the boat is entirely pre-programmed, relying on sensor data to adjust to environmental conditions. For power, the boat relies on solar panels, which can be heavy and make the boat less efficient. To compensate, the team removed the aluminum frames from the panels and laminated them straight onto the deck, allowing them to cram more solar arrays onto the top of the robot. The deck itself is tilted south, which is a better angle for collecting sunlight." (6)

2) **Self-Erecting Tower-** A tower that stands itself up upon arrival of its desired location at sea. It could be telescoping or use hydraulics to raise itself in pivots.
    a. Existing Technology on Telescoping Towers: "Erecting the **Telescoping Mast** is made by simply connecting guys and brackets to the attached unique heavy duty rolled edge guy rings and clamps, extend the sections, insert the locking cotter pins, rotating the tubes to a locked position, and tightening the clamps. The unique ROHN **Telescoping Mast** design features interior tube flanging combined with a double crimped exterior tube to produce a stronger and more stable joint than most common masts. This exclusive design also prevents the sections from accidentally pulling apart and allows disassembly by pulling each section out through the lower end. Each section extends deeper in to the lower tubes than most other **Telescoping Mast** designs, adding still further to the stability of the structure (7)."
    b. Existing Technology on Fold Over Towers: "you can easily access the top mounted components, without ever having to climb the tower. In the time it takes to climb the tower, the top can be lowered down to ground level. Maintenance and replacements can be performed at a comfortable and safe working level in minutes, eliminating the need to work at dangerous heights. When the work is complete, the tower is easily returned to the upright position and locked into place. You never have to leave the ground (8)."

Figure 5.1.1 – Illustration of Self Erecting Tower

c. Self-Erecting Tower Existing Studies: “Although self-erection by itself may not achieve large savings on the overall cost of a wind turbine, it can reduce the cost of energy by allowing the use of taller towers. Taller towers place the wind turbine in higher wind speeds. This can be especially advantageous at sites with high wind shear. However, tower height is often limited by the availability of cranes for installing the turbine, and the costs of the larger cranes needed to erect taller machines are significantly higher. Therefore, self-erection schemes can eliminate the crane limitation, reduce costs, and allow a tall tower, which gets the rotor into the higher winds where it can capture more energy (7).”

3) Gyro

a. “Overcomes all these disadvantages”:
    i. Given that the input shaft is free to rotate at a different speed to that of the output connected to the generator, wind gusts will not be transmitted and hence overload the generating equipment. In addition, energy from wind gusts need not be lost but can be stored in the turbine, strength permitting, before being transferred to the output shaft. GVT units can be operated in parallel. This allows for any capacity to be catered for. Properly designed GVT transmissions are expected to have a long working life due to the smoothing effects of load shocks inherent in the GVT concept. GVT input can be either uni-directional or oscillating (8).”

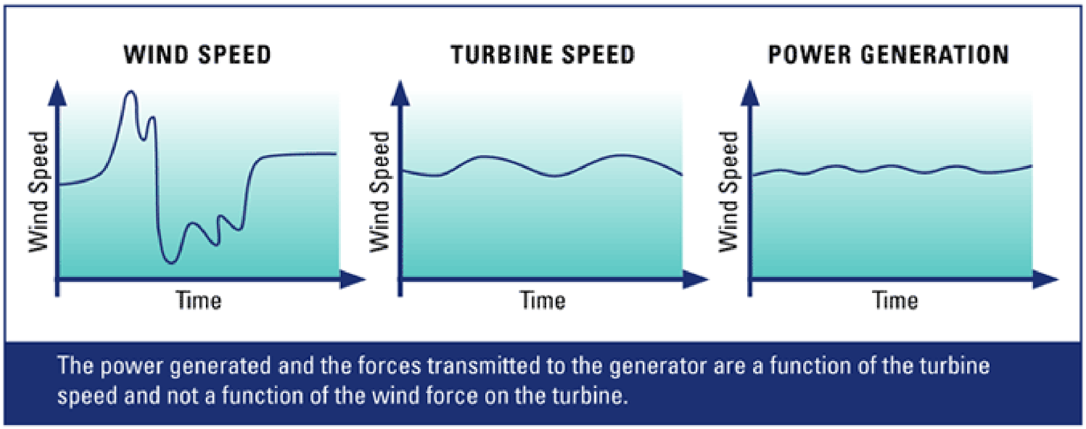


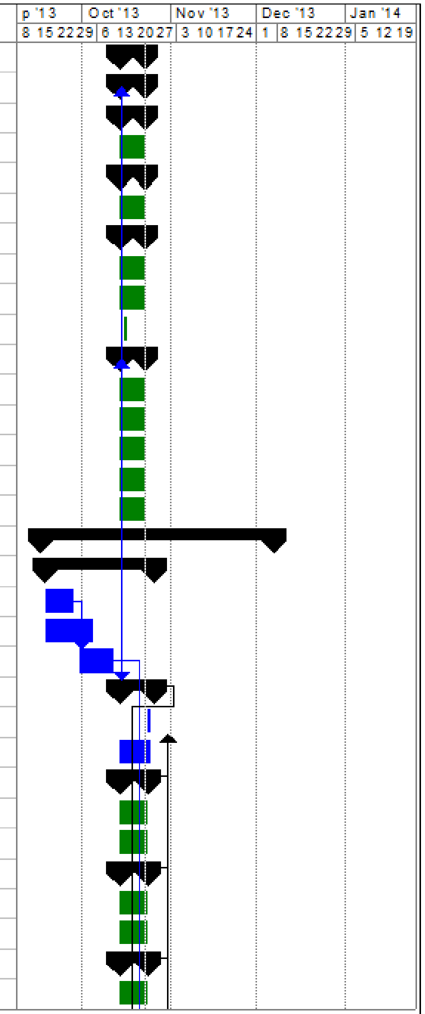
Figure 5.1.2 – Analysis of Gyro Technologies

4) Automatic mooring lines:

a. Existing technology: **"**MoorMaster™ is a vacuum-based automated mooring technology that eliminates the need for conventional mooring lines. Remote controlled vacuum pads recessed in, or mounted on, the quayside, moor and release vessels in seconds. The technology dramatically improves safety and operational efficiency, and also enables ports to make infrastructure savings. It has performed more than 54,500 mooring operations at ferry, bulk handling, Ro-Ro, container and lock applications around the world (9)."

6.0 Updated Gantt Chart

ID	Task Name	Duration	Start	Finish	Predecessors
1	**OWT Project**	**7 days**	**Mon 10/14/13**	**Tue 10/22/13**	
2	**Background Research**	**7 days**	**Mon 10/14/13**	**Tue 10/22/13**	**44**
3	**Cost Breakdown**	**7 days**	**Mon 10/14/13**	**Tue 10/22/13**	
4	Components, Construction, Logistics	7 days	Mon 10/14/13	Tue 10/22/13	
5	**Existing Technology**	**7 days**	**Mon 10/14/13**	**Tue 10/22/13**	
6	Blades, Gearbox, Generator, Tower, Foundation	7 days	Mon 10/14/13	Tue 10/22/13	
7	**Target Site**	**7 days**	**Mon 10/14/13**	**Tue 10/22/13**	
8	Expected Energy Production	7 days	Mon 10/14/13	Tue 10/22/13	
9	**Many Small (<= 2 MW) or Fewer Large (3+ MW)**	7 days	Mon 10/14/13	Tue 10/22/13	
10	**Goal Statement**	1 day	Wed 10/16/13	Wed 10/16/13	
11	**Ideation and Invention**	**7 days**	**Mon 10/14/13**	**Tue 10/22/13**	**44**
12	Floating Mechanisms	7 days	Mon 10/14/13	Tue 10/22/13	
13	Tower	7 days	Mon 10/14/13	Tue 10/22/13	
14	Blades	7 days	Mon 10/14/13	Tue 10/22/13	
15	Gearbox	7 days	Mon 10/14/13	Tue 10/22/13	
16	Generator	7 days	Mon 10/14/13	Tue 10/22/13	
17	**ME Deliverables**	**60 days**	**Mon 9/16/13**	**Fri 12/6/13**	
18	**Reports**	**28 days**	**Wed 9/18/13**	**Fri 10/25/13**	
42	Needs Assessment	8 days	Wed 9/18/13	Fri 9/27/13	
43	Code of Conduct	13 days	Wed 9/18/13	Fri 10/4/13	
44	Project Plan / Project Spec Report	10 days	Mon 9/30/13	Fri 10/11/13	42
22	**Midterm Report I**	**10 days**	**Mon 10/14/13**	**Fri 10/25/13**	**44**
23	Abstract	1 day	Thu 10/24/13	Thu 10/24/13	25,28,31,35
24	Overview	9 days	Mon 10/14/13	Thu 10/24/13	
25	**Turbine Concepts**	**8 days**	**Mon 10/14/13**	**Wed 10/23/13**	
26	Horizontal Axis	8 days	Mon 10/14/13	Wed 10/23/13	
27	Vertical Axis	8 days	Mon 10/14/13	Wed 10/23/13	
28	**Power Generation Concepts**	**8 days**	**Mon 10/14/13**	**Wed 10/23/13**	
29	Direct Drive	8 days	Mon 10/14/13	Wed 10/23/13	
30	Gearbox	8 days	Mon 10/14/13	Wed 10/23/13	
31	**Foundation Concepts**	**8 days**	**Mon 10/14/13**	**Wed 10/23/13**	
32	Concrete Cone Spare Buoy	8 days	Mon 10/14/13	Wed 10/23/13	



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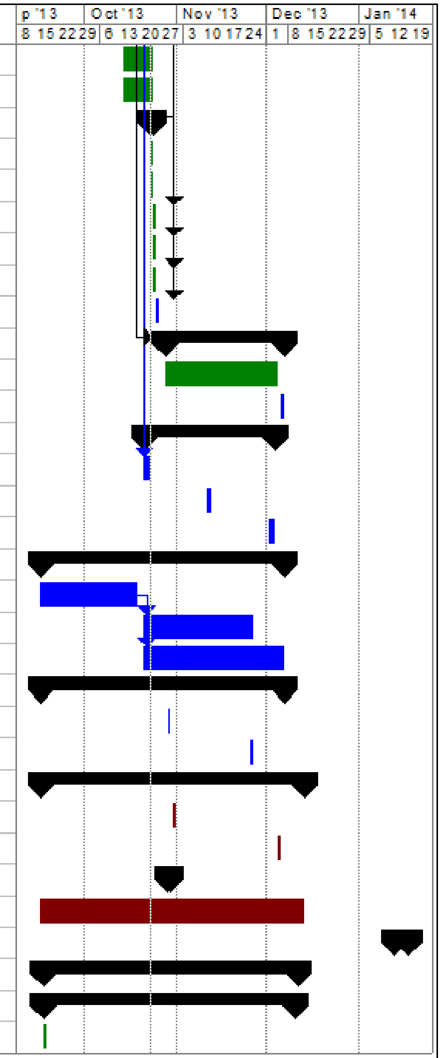
ID	Task Name	Duration	Start	Finish	Predecessors
33	Boat Barge	8 days	Mon 10/14/13	Wed 10/23/13	
34	Kite	8 days	Mon 10/14/13	Wed 10/23/13	
35	**Analysis and Selection**	**1 day**	**Wed 10/23/13**	**Wed 10/23/13**	
36	Pros and Cons	1 day	Wed 10/23/13	Wed 10/23/13	
37	Decision Matricies	1 day	Wed 10/23/13	Wed 10/23/13	
38	Conclusions	1 day	Thu 10/24/13	Thu 10/24/13	25,28,31,35
39	Future Follow-up Design Concepts	1 day	Thu 10/24/13	Thu 10/24/13	25,28,31,35
40	Updated Gantt Chart	1 day	Thu 10/24/13	Thu 10/24/13	25,28,31,35
41	Submit Report	1 day	Fri 10/25/13	Fri 10/25/13	25,28,31,35
122	**Final Report**	**30 days**	**Mon 10/28/13**	**Fri 12/6/13**	**22**
123	Detailed Design	28 days	Mon 10/28/13	Wed 12/4/13	
124	Submit Report	1 day	Fri 12/6/13	Fri 12/6/13	
45	**Presentations**	**32 days**	**Mon 10/21/13**	**Tue 12/3/13**	
46	Midterm Presentation I	2 days	Mon 10/21/13	Tue 10/22/13	44
47	Midterm Presentation II	2 days	Mon 11/11/13	Tue 11/12/13	
48	Final Design Presentations	2 days	Mon 12/2/13	Tue 12/3/13	
49	**Website**	**60 days**	**Mon 9/16/13**	**Fri 12/6/13**	
56	Initial Website Design	25 days	Mon 9/16/13	Fri 10/18/13	
57	Final Webpage Design	27 days	Mon 10/21/13	Tue 11/26/13	56
58	Website Maintenance	35 days	Mon 10/21/13	Fri 12/6/13	56
53	**Peer Evaluations**	**60 days**	**Mon 9/16/13**	**Fri 12/6/13**	
60	Peer Evaluation Report	1 day	Tue 10/29/13	Tue 10/29/13	
106	Peer Evaluation Report	1 day	Tue 11/26/13	Tue 11/26/13	
118	**ECE Deliverables**	**65 days**	**Mon 9/16/13**	**Fri 12/13/13**	
121	Professional Engineering Licensing Agreement	1 day	Thu 10/31/13	Thu 10/31/13	
120	HW on Engineering Ethics & Professional Responsibilities	1 day	Thu 12/5/13	Thu 12/5/13	
59	**Peer Evaluation**	**1 day**	**Tue 10/29/13**	**Tue 10/29/13**	
119	Individual Lab Notebook - covers every Fall & Spring week	65 days	Mon 9/16/13	Fri 12/13/13	
61	**Materials**	**5 days**	**Mon 1/13/14**	**Fri 1/17/14**	
83	**Meetings**	**62 days**	**Tue 9/17/13**	**Wed 12/11/13**	
84	**Staff, B210, 4-4:15p**	**61 days**	**Tue 9/17/13**	**Tue 12/10/13**	
85	1	1 day	Tue 9/17/13	Tue 9/17/13	



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ID		Task Name	Duration	Start	Finish	Predecessors
86		2	1 day	Tue 10/1/13	Tue 10/1/13	
87		3	1 day	Tue 10/15/13	Tue 10/15/13	
88		4	1 day	Tue 10/29/13	Tue 10/29/13	
89		5	1 day	Tue 11/12/13	Tue 11/12/13	
90		6	1 day	Tue 11/26/13	Tue 11/26/13	
91		7	1 day	Tue 12/10/13	Tue 12/10/13	
92		**Team, CE Lab, 7-8p**	**61 days**	**Wed 9/18/13**	**Wed 12/11/13**	
93		1	1 day	Wed 9/18/13	Wed 9/18/13	
94		2	1 day	Wed 9/25/13	Wed 9/25/13	
95		3	1 day	Wed 10/2/13	Wed 10/2/13	
96		4	1 day	Wed 10/9/13	Wed 10/9/13	
97		5	1 day	Wed 10/16/13	Wed 10/16/13	
98		6	1 day	Wed 10/23/13	Wed 10/23/13	
99		7	1 day	Wed 10/30/13	Wed 10/30/13	
100		8	1 day	Wed 11/6/13	Wed 11/6/13	
101		9	1 day	Wed 11/13/13	Wed 11/13/13	
102		10	1 day	Wed 11/20/13	Wed 11/20/13	
103		11	1 day	Wed 11/27/13	Wed 11/27/13	
104		12	1 day	Wed 12/4/13	Wed 12/4/13	
105		13	1 day	Wed 12/11/13	Wed 12/11/13	
107		**Mentor, B202, 4:15-5:00p**	**46 days**	**Tue 10/8/13**	**Tue 12/10/13**	
108		1	1 day	Tue 10/8/13	Tue 10/8/13	
109		2	1 day	Tue 10/15/13	Tue 10/15/13	
110		3	1 day	Tue 10/22/13	Tue 10/22/13	
111		4	1 day	Tue 10/29/13	Tue 10/29/13	
112		5	1 day	Tue 11/5/13	Tue 11/5/13	
113		6	1 day	Tue 11/12/13	Tue 11/12/13	
114		7	1 day	Tue 11/19/13	Tue 11/19/13	
115		8	1 day	Tue 11/26/13	Tue 11/26/13	
116		9	1 day	Tue 12/3/13	Tue 12/3/13	
117		10	1 day	Tue 12/10/13	Tue 12/10/13	

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Task		Milestone		External Tasks	
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References

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