FLORIDA INTERNATIONAL UNIVERSITY

EML 4905 Senior Design Project

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PREPARED IN PARTIAL FULFILLMENT OF THE
REQUIREMENT FOR THE DEGREE OF
BACHELOR OF SCIENCE
IN
MECHANICAL ENGINEERING

Highway Wind Turbines

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This B.S. thesis is written in partial fulfillment of the requirements in EML 4905. The contents represent the opinion of the authors and not the Department of Mechanical and Materials Engineering.

Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of BRUCE CHAMPAGNIE, GEATJENS ALTENOR, and ANTONIA SIMONIS and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

Antonia Simonis	Bruce Champagnie	Geatjens Altenor
Team Leader	Team Member	Team Member

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Faculty Advisor

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

The objective of the project is to design a wind turbine to recapture wind energy from vehicles on the highway. Wind energy is considered the fastest growing clean energy source however; it is limited by variable natural wind. Highways can provide a considerable amount of wind to drive a turbine due to high vehicle traffic. This energy is unused.Extensive research on wind patterns is required to determine the average velocity of the wind created by oncoming vehicles. The wind turbines will be placed on the medians therefore fluid flow from both sides of the highway will be considered in the design. Using all of the collected data, existing streetlights on the medians can be fitted with these wind turbines. Additionally, since the wind source will fluctuate, a storage system for the power generated will be designed to distribute and maintain a constant source of power. Ideally, the turbine can be used globally as an unlimited power source for streetlights and other public amenities.

INTRODUCTION

Wind energy is the fastest growing source of clean energy worldwide. A major issue with the technology is fluctuation in the source of wind. There is a near constant source of wind power on the highways due to rapidly moving vehicles. The motivation for this project is to contribute to the global trend towards clean energy in a feasible way.

DESIGN CHALLENGES

The price of turbines is increasing in accordance with the rising cost of energy and commodities. The cost of designing the turbine, calculated in energy savings must be recovered in a reasonable time period.

Each vehicle on the highway offers an intermittent and uncontrolled source of wind power. The design of the wind turbine must include storage of power and a system to distribute the generated power effectively.

Operational noise level and space are other important design considerations. The wind turbines should have as little negative impact on the placement location as possible.

Wind turbines are traditionally used in remote locations. This offers the additional challenge of having to transport the power generated to the location wherein it will be utilized. Fortunately, the wind turbine in this project is designed for use in high traffic areas where the demand for power is high.

Safety is another major design consideration. The turbines must be placed in high traffic areas therefore several safety provisions are incorporated into the design. These safety measures include stationary highway guards surrounding the rotating turbine blades and warning labels.

Global Applications

The design can be used in any city around the world. It should be environmentally friendly. Labels in various languages and manuals will be provided for each specific city. Figure 1 shows a dramatic increase in the employment of wind energy globally. Wind power increased by nearly 20% in 2012 reaching a new peak of 282 GW. Various sources such as the Global Wind Energy Council show China as the leading country in the employment of Wind energy.

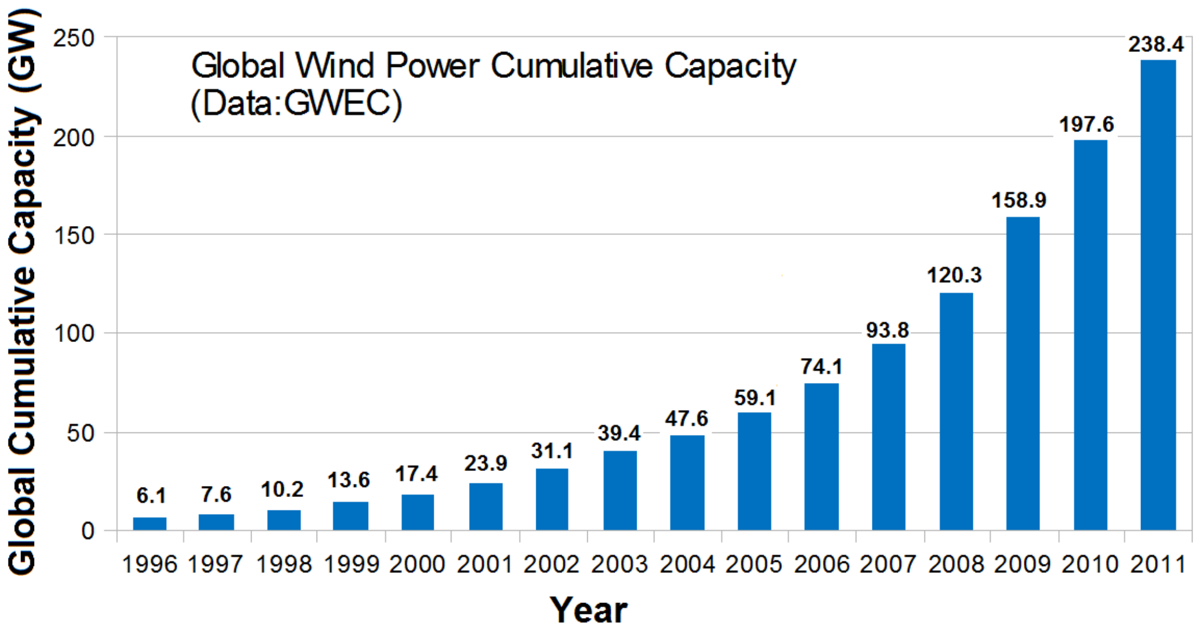

FIGURE 1: GLOBAL TREND IN WIND ENERGY, DATA FROM THE GLOBAL WIND ENERGY COUNCIL

PROBLEM STATEMENT

A major hindrance in the growth of wind energy is fluctuation in the sources of wind. Highways appear to be a sufficient source of potential wind energy. An in-depth analysis of fluid flow due to traffic on highways must be performed to acquire boundary limits for the wind turbine design. The turbine must be able to store energy for use when there is low traffic, bumper to bumper or stop and go traffic. The design must be sustainable and environmentally friendly.

MOTIVATION AND OBJECTIVE

The motivation for designing a highway wind turbine is to contribute towards the global trend in wind energy production in a feasible way. Wind turbines are traditionally employed in rural areas, the goal of this project is to design a wind turbine that can be used in cities. In particular, the turbines will use the wind draft created by vehicles on the highway to generate electricity. The idea is to offset the amount of pollution created by burning fossil fuels by introducing a potential source of clean energy.

PROJECT TIMELINE

The project is divided into several major tasks. Research is a significant portion of this project because collecting our own data requires special permissions and maybe a bit hazardous. Data is collected from the Department of Transportation and the Civil Engineering Department at FIU. All of the team members are expected to research the pros and cons of the different design options to ensure the most efficient design. The preliminary Solidworks design of the highway wind turbine is updated with new information.

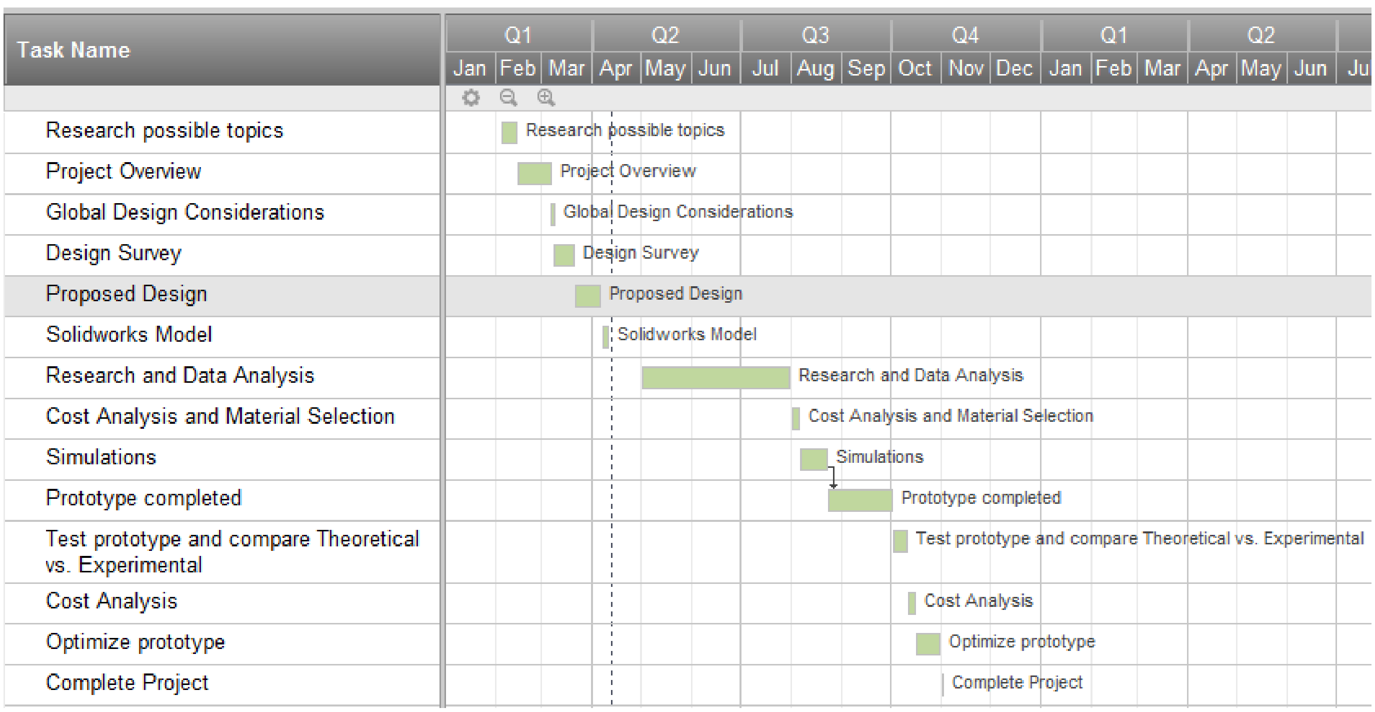

FIGURE 2 PROJECT TIMELINE

Task	Member (s)	Hours
Project Overview	All members	6
Proposed Design	Bruce Champagnie and Antonia Simonis	11
Design Survey	Bruce Champagnie	5
Preliminary Sketches	Bruce Champagnie	2
Solidworks Design	GeatjensAltenor	5
Research and Data Analysis	All members	50
Cost Analysis	GeatjensAltenor	5
Material Selection	Bruce Champagnie	5
SolidworksSimulations	Antonia Simonis	8
Design Prototype	All members	48
Testing Prototype	All members	48
Optimize Prototype	All members	24

FIGURE 3: BREAKDOWN OF TASKS

All team members are expected to participate in the research and design of the highway wind turbine. Team meetings are frequently held atleast once a week. Bruce Champagnie has the most influence in collecting and analyzing relevant data relating to the turbine design. GeatjensAltenor is charged primarily with the solidworks rendering of the turbine. Antonia Simonis is in charge of simulating the completed model on solidworks before production of the prototype. Much of the work is performed as a team but these are the areas where each individual made the most impact.

LITERATURE SURVEY

The idea to utilize wind turbines on the highway is not entirely unique. There have been attempts by several individuals and groups to recycle energy from highways. The most impressive is a design displayed on a YouTube video entitled "Highway Helical Wind Turbine Project (Next Generation Highway's Potential For Wind Power)." In the video a group of Mechanical Engineering Students from YCET Kollam, Kerala display a prototype of their highway wind turbine as seen in Figures 4 and 5.

FIGURE 4: COMPUTER SIMULATION OF HIGHWAY WIND TURBINE, INDIA

Figure 4 is a video still of a computer animated design of a highway wind turbine proposed by Mechanical Engineering Students in India. In Figure 5, the students Nabeel B, Firoz khan T S, Krishnaraj V, Kannan Raj, Arun S, Shaiju mon T K, and Akhil Ganesh demonstrate a working prototype of their design. (Highway Helical Wind Turbine Project (Next Generation Highway's Potential For, 2012)

FIGURE 5: MECHANICAL ENGINEERING STUDENTS IN INDIA DISPLAY HIGHWAY WIND TURBINE

CONCEPTUAL DESIGN (DESIGN ALTERNATIVES)

There are several ways to approach this particular design problem. Inliterature surveys, we discovered different features of wind turbines which were appealing for different reasons. For example, the gear turbines in China were very inexpensive and the modular sections could easily be snapped together to form a bigger system. That particular design did not seem as environmentally friendly as the designs with larger propellers. Other designs include turbines built into highway dividers or on overhead poles as seen in the design by the Arizona State Student Joe (last name not provided) (Joe, 2007). Joe calculated that with cars moving at 70 mph, 9,600 kilowatts of electricity could be produced per year using his design.

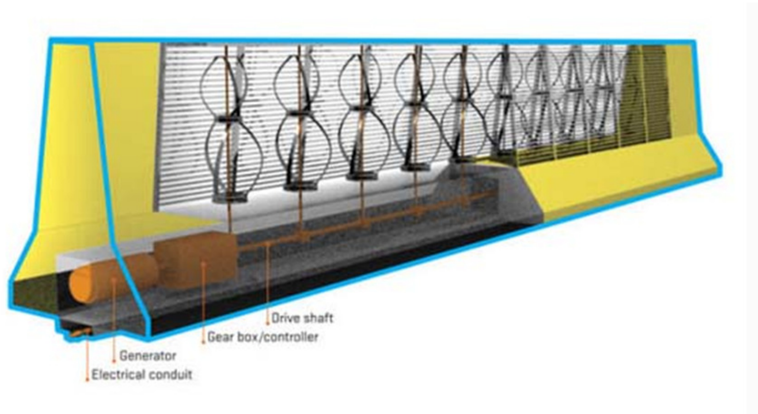

FIGURE 6: MARK OBERHOLZER, GUARDRAIL WIND TURBINE DESIGN

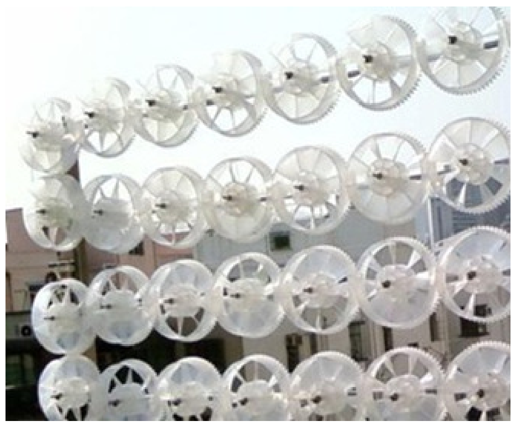

FIGURE 7: HONG KONG UNIVERSITY AND LUCIEN GAMBAROTA OF MOTORWAVE LTD.

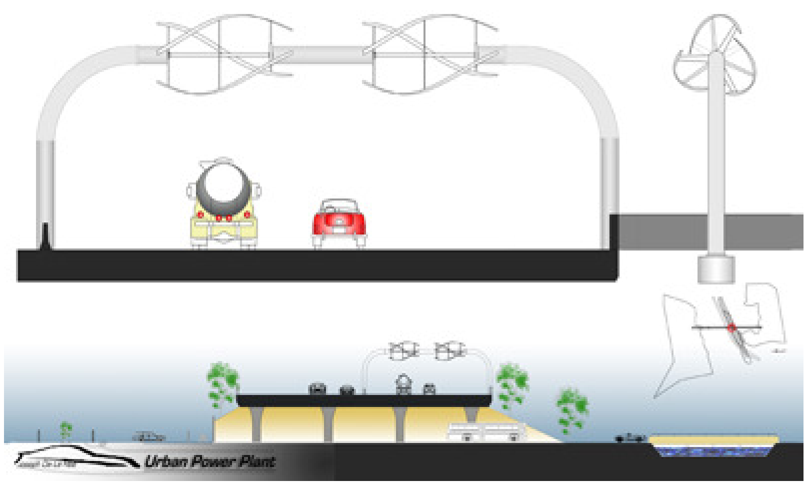

FIGURE 8: ARIZONA STATE UNIVERSITY STUDENT DESIGN

FIGURE 9: ARIZONA STATE UNIVERSITY STUDENT REALISTIC DESIGN

Figures 6-9show various designs for wind turbines on the highway. Each design has positive and negative aspects. For example, in figure 6, the turbines are built into guardrails. This design is particularly complex because the guardrails must be fitted with vanes in order for the wind produced by vehicles to reach the turbines inside. Figure 7 shows an inexpensive wind turbine design. This design was not selected due to safety considerations. The parts are small and can easily be snapped out of place. Figures 8 and 9 show wind turbines proposed by an Arizona State University student. This design is rejected because it requires the construction of custom support posts.

ANALYTICAL ANALYSIS

The following formulas are utilized to design the most efficient turbine.

$$\text{Power available} = 1/2\rho AV\text{^}3$$

The power coefficient (CP) is the power extracted divided by the power available

$$Cp = \frac{Power\ extracted}{1/2\rho AV\text{^}3}$$

The maximum value for the power coefficient is called the Betz limit

$$Cp\max = \frac{\frac{8}{27}\rho AV^3}{\frac{1}{2\rho C^3}} = \frac{16}{27} = 0.5926$$

Now the maximum m power that can be extracted from a given wind stream is defined by what is known as the Betz limit, therefore, the power extracted is calculated by the following equation.

$$Power\ extracted = 1/2\text{Cp}\rho AV\text{^}3$$

Where V is the wind velocity andρ is the fluid density. These equations show that velocity is the most significant factor in generating power. Power is directly proportional to the cubed velocity of the wind.

PROPOSED DESIGN

Our group is proposing to design a vertical axis wind turbine to utilize the wind produced by moving vehicles to generate electricity. These turbines will be placed along roadways that have high volume of fast moving traffic. The electricity generated will then be the stored in batteries. Since the electricity produced will be direct current (DC) it must be converted to alternating current (AC) before it can be used for lighting the street lamps, sold to the grid or any of the man ways we use electricity today. This means that the DC current must be pasted through an inverter first before it is usedFigure 8shows a sample vertical axis wind turbine with part labels however; the turbine we are designing will likely reflect the design in Figure9 by TAK studios.

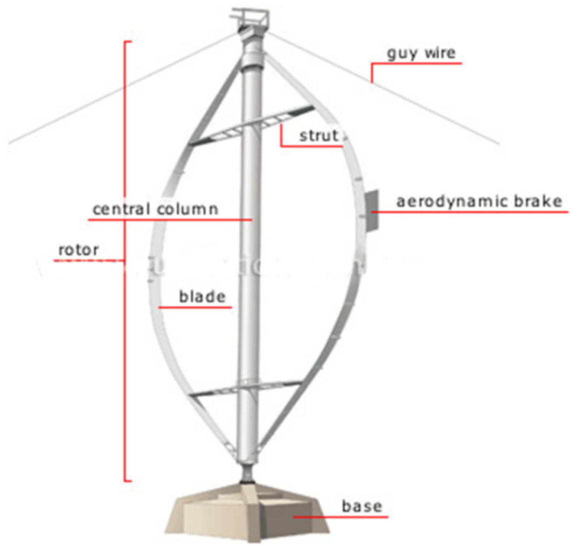

FIGURE 8: LABELED PARTS OF A VERTICAL WIND TURBINE

FIGURE 9: TAK STUDIO DESIGN

There are several advantages and disadvantages to using a vertical wind turbine design. A vertical wind turbine design is selected because vertical turbines are capable of capturing wind in any direction, whereas, horizontal turbines need to be pointed in the direction of the wind. Additionally, heavy parts such as the generator and battery can easily be placed at the base of the turbine.

MAJOR COMPONENTS

Figure 8 shows the major components of a vertical wind turbine. The blades are the most difficult part of the design because they must be propelled by wind in any direction. This necessitates that the blades are curved and angled so that as much surface area is exposed to the wind draft from oncoming vehicles as possible. The blades must also be lightweight. The central column design is relatively simple. It is a hollow tube whereon the blades will be attached. It should be large enough to accommodate the width of streetlights.

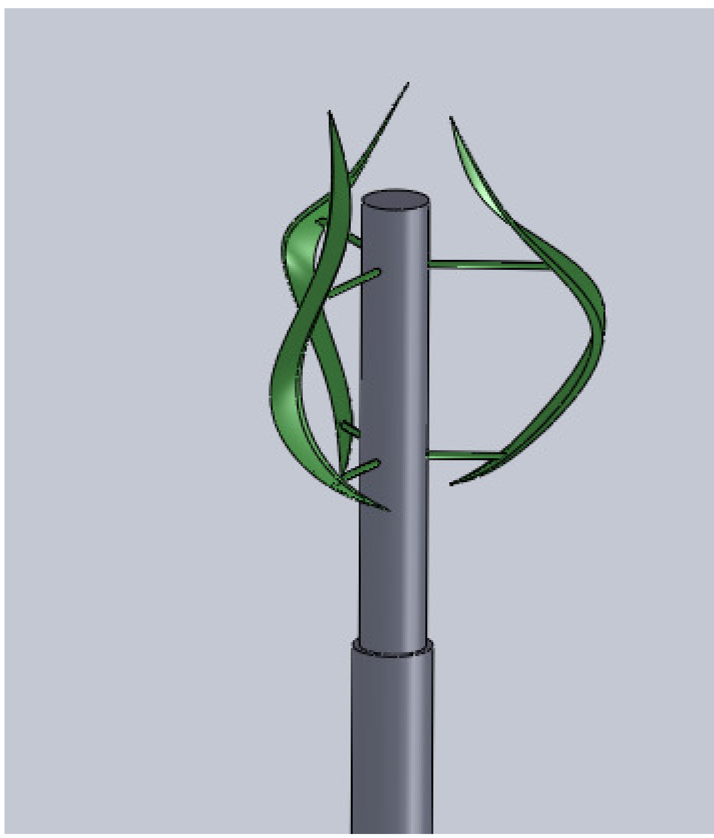

FIGURE 10: PRELIMINARY SOLIDWORKS DESIGN

Figure 10 shows the preliminary Solidworks rendering by GeatjensAltenor. The idea is to curve and angle the blades to capture the maximum amount of wind.

To produce this product we hope to find existing parts that fit within the design criteria and manufactureparts significant to the design. We will be doing a series of calculations in order to determine wind is needed to turn the turbines sufficient enough to generate an adequate amount of electricity. Data will be collected to determine the traffic patterns and energy storage requirements. Efficient placement is important so that they can harvest maximum energy from the wind draft created by automobiles.

COST ANALYSIS

We do not have a sponsor for this project therefore the costs is divided among group members. Average cost of some turbine parts are listed in Figure 11 shows average costs of several of the major components in a vertical wind turbine. To reduce costs, some of the components will be manufactured such as the wind turbine blades.

Quantity Elements	Element	Unit Price($)	Total Price ($)
1	Alternator	409.98	409.98
1	Generator	99.56	99.56
3	Pair of blades	279.95	839.85
1	Battery	267.95	267.95
6	feet pvc pipe (shaft)	8.5	51
Total			1668.34

FIGURE 11: BALLPARK COSTS OF VERTICAL WIND TURBINE COMPONENTS

PROTOTYPE DESIGN AND TESTING

Using the research and data collected, a scale solid works model is designed. Simulations are performed for different materials and loading conditions. From this analysis, the material for the prototype is selected.

The turbine blades are made of durable lightweight material. A mold is created and used to produce all 3 blades. The shaft is made from PVC pipe. The generator, alternator, batteries and other components are bought.

The model is exposed to wind created by a fan at the approximate speed of wind drafts created by vehicles for testing. Experimental data on the power generated is compared to theoretical data.

CONCLUSION

Conclusively, extensive data is collected on wind patterns produced by vehicles on both sides of the highway. Using the collected data, a wind turbine is designed to be placed on the medians of the highway. Although one turbine may not provide adequate power generation, a collective of turbines on a long strip of highway has potential to generate a large amount of energy that can be used to power streetlights, other public amenities or even generate profits by selling the power back to the grid. This design concept is meant to be sustainable and environmentally friendly. Additionally, a wind turbine powered by artificial wind has a myriad of applications. Theoretically any moving vehicle can power the turbine such as an amusement park ride. The highway wind turbine can be used to provide power in any city around the globe where there is high vehicle traffic.

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