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WILDCAT
WIND POWER

WILDCAT WIND POWER

"All we do is Wind!"

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A&M	Agricultural and Mechanical
AC	Alternating Current
CA	California
CEO	Chief Executive Officer
CFM	Cubic Feet per Minute
CFO	Chief Financial Officer
COGS	Cost of Goods Sold
COO	Chief Operating Officer
CTO	Chief Technology Officer
DC	Direct Current
EMF	Electromotive Force
FL	Florida
HAWT	Horizontal-Axis Wind Turbine
IN	Indiana
KS	Kansas
KSU	Kansas State University
kWh	Kilowatt hour
NC	Normally Closed
NFL	National Football League
NH	New Hampshire
NO	Normally Open
NREL	National Renewable Energy Lab
OD	Outer Diameter
PO	Purchase Order
R&D	Research and Development
RPM	Revolutions per Minute
RV	Recreational Vehicle
TCU	Texas Christian University
TN	Tennessee
TSR	Tip Speed Ratio
UNL	University of Nebraska of Lincoln
UO	University of Oregon
UT	University of Texas
V	Volt
W	Watt
WWP	Wildcat Wind Power

1 Executive Summary

For years, people have been tailgating, camping, and attending music festivals. At such events, consumers look for a suitable power source to play their music, grill their hot dogs, or light up their campsite. Almost all of the aforementioned event attendees resort to gasoline or diesel generators. While this form of power is relatively inexpensive to purchase and easy to set up, it is not environmentally friendly. Generators use fossil fuels that emit toxic fumes, are noisy, and require gasoline or diesel to be readily available to continue producing electricity. For these reasons, Wildcat Wind Power has dedicated this year's Collegiate Wind Power Competition project to creating a portable, durable, and reliable wind turbine. Our turbine will not only power your tailgate or campsite, but it will also display your team spirit, while doing so in a manner that is efficient, quiet, and environmentally sound.

Wildcat Wind Power is a wind energy start-up company seeking to add an alternative option for powering the consumer's tailgating, camping or festival experience. We believe there is a need for an alternative energy option in the tailgating industry. The target market for this product includes but is not limited to; tailgaters, campers, and festival goers. Currently, there is not a product that caters specifically to these groups. The turbine will be able to fit inside an RV, or in the bed of a standard size pickup truck. Once the consumer has reached their destination, they will be able to set up the 30 foot turbine within minutes. A battery will power the consumer's tailgate until wind speeds have reached an ideal rate. The 400W turbine will be able to continue to charge the battery throughout the event, saving them the hassle of constantly refilling a gasoline generator. We, the members of Wildcat Wind Power, believe our sleek design will stand out at each event, drawing attention and turning more consumers on to the unique lifestyle alternative energy offers.

The following report depicts the financial support of the concept as well as a functioning design of the tested small-scale turbine. The business plan gives an in depth interpretation of the potential success in the market, a comparable representation of our turbine to others in the market (including internal combustion generators) and our future deployment strategies. Our functioning design is outlaid in the following report in two separate sections defined as the physical aspects of the turbine and the electrical circuit. Contained in the technical sections describing the functioning turbine, there is a detailed explanation of all turbine components and processes.

Our team has a diverse, yet cohesive group of individuals pulled from mechanical and electrical engineering, as well as marketing and entrepreneurship majors. The capabilities of this team have developed this concept to improve the consumer experience while enlightening them to the lifestyle associated with alternative energy. This turbine supplies a creative avenue for what may be a non-typical customer base to contribute to the betterment of the environment as a whole.

2 Business Plan

2.1 Business Overview

The business overview includes the mission statement, the existing problem and the solution as described below.

2.1.1 Mission Statement

Wildcat Wind Power's mission is to provide sports fans and campers alike with a compact, customizable, and durable source of renewable energy that can support their campsite or tailgate energy needs. We plan to do this by producing lightweight and efficient wind turbines that customers can match with the battery size that best fits their needs.

2.1.2 The Existing Problem

At Kansas State University (KSU), tailgating before football games is a huge part of our college culture. While we were barbecuing, we noticed the low hum of the gasoline generator and its distinct smell across the parking lot. With our turbine, we will seek to resolve:

- Noise disturbances caused by gas and diesel generators
- The smell of gasoline/diesel is unwanted in the tailgating/camping environment
- Unpredictable and upward trending cost of diesel fuel
- High emissions of greenhouse gasses by diesel and gasoline generators
- Negative health effects from production of carbon monoxide and other noxious gases by diesel and gasoline generators
- Safety concerns with flammability of fuel
- Decreased power capacity at generator's maximum load capability
- High potential for maintenance and/or damage costs if not stored and handled properly (diesel and gasoline generators)

2.1.3 The Solution

Our turbine will provide your basic tailgating and/or camping power needs and depending on the location can charge in as little as 24 hours, depending upon variable wind speed and power requirements. Set up is a breeze. All you have to do is attach it to your vehicle by driving onto the stabilizing plate. While you may not be able to hear Wildcat Wind Power's turbine at your tailgate, your team spirit and environmental consciousness will radiate across the entire stadium, with a customizable colored turbine and flag hook standing 30 feet high. Also, due to that fact that there is no diesel/gas, your space will smell cleaner.

2.2 Market Opportunity

Wildcat Wind Power is entering the market with a unique spin on an already existing product. Our plan is to touch into a niche market, eventually taking over sustainable wind energy. The product is a turbine consumers can set up at music festivals, tailgates, NASCAR, campgrounds and other RV outdoor adventures. The turbines currently in the market can do the same things ours will, but Wildcat Wind Power is driven on mobility and flair to set us apart in this already existing market. Our turbine has a unique base onto which the consumer drives his or her RV, ultimately holding up the turbine steady with the weight of the RV. There are a few turbines sold on the market right now that are powerful enough to power typical tailgate electrical loads, and do what we can do, but our turbine will set us apart in many ways.

The collapsible turbine will be easy to set up and take down, as well as be lightweight and color-specific to your favorite team, band, interests etc. Two hooks will be attached to the back of the shaft just below the tail for easy flag mounting. We are working diligently to come up with many ways for consumers to show their team pride. Easy setup will be ideal for tailgaters who intend to fully charge their batteries at their homes before venturing out. Due to unpredictable wind speeds, potential customers will greatly benefit from the option to charge their batteries beforehand.

Keeping a competitive price will be difficult due to the amount of wattage necessary for our turbine to power all the parts to a successful tailgate. These include but are not limited to: lights, pumping water for bathroom needs, a small electric grill, a mini fridge, as well as music or a television with cable and speakers. With all of these electrical loads, our pricing is not going to give us the edge we had hoped. However, a huge part of our campaign will not be based on the up-front cost you could save, but on the energy each turbine saves in the long run, ultimately targeting “green” consumers.

Fortunately for us, the tailgating industry is a massive one. Sports Business Daily reports 80% of Americans tailgate at least once a year, making the industry’s net worth a lump sum of $35 billion (Tailgating: Behind the Numbers, n.d.). Capital will initially come from private investors and will be paid back rapidly once our brand is out there. The market is too large for our signature turbines to not catch on.

2.2.1 Target Market

Our primary target markets are tailgaters and festival goers. Although they seem different on the surface, both have similar needs that Wildcat Wind Power’s turbine can solve.

For our tailgating market, we have chosen six large college universities and seven states that host NASCAR races. Table 1 provides a list of venues we are targeting and their seating capacity. This will more clearly show the size of our market. This table excludes our festival audience due to continuous relocation of such events, allowing for a fluctuation in attendance.

Venue	Seating Capacity
Bill Snyder Family Stadium- KSU	50,000
Darrell K. Royal Memorial Stadium- UT	100,119
Gaylord Family Memorial Stadium- UO	82,112
Memorial Stadium- UNL	85,000
Kyle Field- Texas A&M	83,002
Amon G. Carter Stadium- TCU	50,000
Kansas City Speedway- KS	74,000
Auto Club Speedway- CA	68,000
Daytona International Speedway- FL	101,000
Bristol Motor Speedway- TN	160,000
Indianapolis Motor Speedway- IN	235,000
New Hampshire Motor Speedway- NH	88,000

Table 1: Potential venue capacities.

Tailgaters spend $35 billion a year. The tailgating demographic spans across the entire United States and most tailgaters are supporting college sports, NFL, or NASCAR. Because of the wind speeds required for our product to be effective, we plan to target tailgaters whose teams are located in the Midwest, Southwest, and the Northeast. This includes huge events with massive fan bases such as the Texas Longhorns, and the Indianapolis 500.

The festival crowd is fairly new, seeing most of its growth and support come forward in the last 15 years. However, these events have taken the music industry by storm, and have grown exponentially. In 2015, there were over 800 festivals in North America alone. Although these music festivals are happening all around the world, “six of the top 10 grossing festivals in the world were American events, all established in the last 15 years” (Currin, 2014). Eighty percent of festival goers are below the age of 30 according to EventBrite’s festival demographic (Currin, 2014). This is great news for us, since majorities of millennials are supportive of green energy solutions to everyday problems (Koch, 2014).

2.3 Management Team

Wildcat Wind Power Tailgating Turbines are produced by a multidisciplinary group of students in the College of Engineering and the College of Business at KSU. The executive team includes the CEO, COO, CFO, CTO, and the Administrative Assistant.

CEO- Tanzila Ahmed

The Chief Executive Officer is in charge of overseeing the ins and outs of the company. Tanzila set goals throughout the semester and made sure deadlines were met, as well as delegated major projects to team leads throughout the group. The CEO is the final decision on any major decisions affecting the company or its products.

COO- Lawryn Edmonds

The Chief Operating Officer oversees deadlines set by the CEO. Lawryn was in charge of manufacturing the competition turbine in detail relating to the initial design. She focuses on maintaining the schedule set by the CEO. The COO is in charge of maintaining a safe workplace as well as overseeing quality control for the product and the employees.

CFO- Justin Currence

The Chief Financial Officer is in charge of anything relating to the budget. He restricts spending to stay under budget and project needed sales to produce profit. Justin is in charge of manufacturing costs, approving P.O.s, employee wages and work hours. He manages all of the money coming in and out of the business to make sure we stay afloat.

CTO- Lee Evans, Michael Banowetz, David Plenert & Alex Ackley

We had many Chief Technical Officers because there were many parts to initially get the company started. The CTOs are responsible for the design, communication and technical parts of the product. They oversee all movement of the design team and its processes. Lee, specifically, was in charge of the design and execution of the wind tunnel. The tunnel gave our company the ability to test our product before large manufacturing orders were placed. More information on the wind tunnel can be found in Appendix C.

Administrative Assistant- Jacob Meyer

The Administrative Assistant is in charge of all communication, meeting dates, conferences and facilitates a dialogue between teams and team members. Jacob was in charge of filing all reports, submission materials, release forms and travel arrangements to the competition and back.

2.4 Product Development and Operations

Wildcat Wind Power turbines will be high quality and long lasting. To ensure this, we have designed our wind turbines so that they are lightweight and easy to set up. This design allows us to ensure our customers they are getting a safe product that will not put them at any risk during their tailgates or camping trips. Each turbine will come with an instruction manual so that every customer will know how to properly set up the turbine.

In order to keep our costs competitive, it is imperative that we maintain an efficiently run supply chain. We will operate using just-in-time practices so that we can keep low inventory levels. This will significantly decrease any waste from manufacturing. We plan to order all of the parts through trustworthy and thoroughly researched wholesalers, and then we will assemble to turbines at our own facilities.

2.4.1 Barriers to Entry

We see four major barriers to our entry into this market, as detailed in Table 2.

Barrier to Entry	Plan to Address
Height limitations	Informing customers of potential height limitations and relieving any risk on our part by making this known.
Cost effectiveness	Rely on a "greener" customer base rather than one looking to initially save money.
Environmental indifference	Pitch to consumers with flashy, customizable options. Make our product more of a "want" than a "need" by promoting the uniqueness.
High startup costs	Private Investors benefit from renewable energy tax credits. Explore potential government subsidies.

Table 2: Barriers to entry.

2.4.2 Competitive Analysis

Wildcat Wind Power's competitive analysis incorporates a standard gasoline generator used at most tailgates, campsites, etc., as well as a competitor turbine already on the market, as detailed in Table 3.

	Gasoline Generator	Competitor Turbine	Wildcat Wind Power
Power (W)	1200	400	400
Average Fuel Consumption (gallons/hr)	.29	0	0
Average Cost	$249.99 +tax	$1,034.99 +tax	$1299.99 +tax
Assuming they operate 5hr/day			
No. Gallons Consumed in 1yr/ 365 days of use	529.25	-	-
Total Cost of Gasoline (5/hr a day for 365 days of use)	$1301.96	-	-
1 yr. Operating Expense	$1551.95	$1,034.99 +tax	$1299.99 +tax
Cost/kWh	$0.71		
Annual Savings	-	$266.97	$1.97

Table 3: Champion 1200W Gasoline Generator vs. PRIMUS Air 30-10-48 Turbine vs. WWP's Turbine.

2.4.2.1 Porter's Five Forces

Applying Porter's Five Forces reveals the competitiveness of the industry. There is a low threat of new entrants. It requires a large amount of capital in order to start a wind turbine business and researching, designing, and producing quality wind turbines all require many skilled employees. Additionally, the public has not been very receptive to personal wind turbines, which turns many capitalists away from the industry. The bargaining power of buyers is a relatively strong force because this is a commodity item and there are several alternatives. A personal wind turbine is not a necessary household item, and thus it is up to Wildcat Wind Power to convince buyers that this is a worthwhile purchase for camping and tailgating. There are several alternatives for buyers to choose from including gas generators, solar panels, and other wind turbines. Having so many other options coupled with the fact that this is a commodity item puts a lot of strength on the bargaining power of buyers.

The threat of substitute products is perhaps the strongest threat WWP will face. Gas generators that can produce just as much power as our wind turbines sell for much less money. This means the substitute products are very enticing to consumers who are strictly looking for a cheap source of energy. WWP hopes to target the niche market of forward-thinking tailgaters and campers who are looking for a quieter and more eco-friendly way to power their festivities. The bargaining power of suppliers is ranked as a moderate force because of how tight our current profit margins are. An increase in prices on any of the larger items such as the pole, generator, battery, or turbine blades would have a direct effect on our bottom lines. However, there are several potential suppliers of the raw materials, which give us a bit of bargaining power as well. Currently, there is little to no rivalry amongst competitors. Many of the personal wind turbines on the market aim to serve different niche markets, which allow the companies to focus on their target markets, and not worry about other companies trying to steal market share. An outline of Porter's Five Forces in detailed in Table 4.

Threat of New Entrants	Bargaining Power of Buyers	Threat of Substitute Products	Bargaining Power of Suppliers	Rivalry Amongst Existing Competitors
Low	Strong	Strong	Moderate	Low

Table 4: Porter's Five Forces.

2.4.3 Business Model Canvas

Table 5 lays out our business model in Canvas form.

<table>
<tr><td rowspan="2">Key Partners - Production contractors, street team (for in-person demonstrations), engineering and marketing specialists</td><td>Key Activities - R&D, turbine production, Sales & Marketing,</td><td rowspan="2">Value Proposition - a sustainably powered generator that is quiet, emission-free, and visually appealing</td><td>Customer Relationships - mutual caring for the environment, creative self-expression, consistent customer service/reliability/warranty</td><td rowspan="2">Customer Segments - tailgaters, campers, festival-goers</td></tr>
<tr><td>Key Resources - human capital, raw materials, knowledge of social media platforms and online forums</td><td>Channels - social media, online forums, outdoors and sports outlets, trade shows, direct (seeing it in person)</td></tr>
<tr><td colspan="3">Cost Structure - R&D, production, distribution, promotion, web-site creation</td><td colspan="2">Revenue Streams - Sales from referrals (direct sales from in-person demonstrations), Sales from online and in-store sports and outdoors outlets</td></tr>
</table>

Table 5: Business model canvas.

2.4.4 Product Development and Manufacturing Strategies

Wildcat Wind Power is dedicated to quality and craftsmanship to ensure safety and durability of our products. For this reason, WWP will strictly assemble in-house. Complete turbines and their accompanying batteries will be stored in a warehouse in dry and comfortable temperatures, to ensure lasting compatibility. Our main manufacturing strategy will be following just-in-time inventory management. This entails ordering the materials more often, but ordering smaller batches. By following this practice, we will have fewer materials to store, and negate the risk of damaging sitting inventory. Good inventory management can decrease overall manufacturing costs significantly, and we plan to pass those savings directly onto the consumer. Assembling turbines without a long distribution chain will keep costs down, and in turn, entice a larger market to try our product at a reasonable price.

2.4.5 Marketing Plan and Operations

We aim to market our wind turbines and custom battery size options through in-person demonstrations, social media, trade shows, and outdoors and sports outlets. Since our primary target market is tailgaters, we plan to put a majority of our marketing resources into the in-person demonstrations run by our “street team”. Members of the street team will go to sporting events and festivals and demonstrate the wind turbine and its effectiveness as a viable substitute for the currently popular gas and diesel generators. Our key marketable features are: our product provides quite, clean, environmentally friendly energy for your outdoor activities.

In the beginning, we plan to have a promotion opportunity for our customers as well. They can sign up to receive a Wildcat Wind Power wind turbine for the season, and if they refer over seven people to our company, they can keep their wind turbine at no cost. We believe this will be effective at the start since these customers will already have developed trust with the people they are referring to Wildcat Wind Power. We also plan to roll out our street team at trade shows near our target market locations. Tradeshows are an excellent source of publicity because we can give demonstrations of our product to people that are interested or invested in the industry. We hope that this will lead to an increase in online presence on forums about green energy solutions.

Our final marketing strategy will be through social media and our website. Having an active social media team will help give Wildcat Wind Power a personality that consumers can engage with. It is also a great way to get immediate information to our entire market, and gives us an easy way to gauge interest in our product. Using online analytics such as Google Analytics, we can track the demographics of people interested in our product. These data allow us to improve our marketing tactics to better fit the needs of our consumers. Table 6 is an easy-to-read chart depicting our plan.

Street Team	Eco-friendly tailgaters and festival attendants	In-Person demonstrations can prove product effectiveness	- 15 festivals per season - First four home games	High	$300K
Social Media	Millennials, sports teams/fans	Very environmentally conscious generation, majority are on some form of social media	Weekly	Moderate	$5K
Trade Shows	Individuals, campers	Create awareness, prove effectiveness	Quarterly	Moderate/ High	$70K
Outdoor Equipment stores	Camping/outdoorsy folk	People will be ready to purchase related items, create awareness	- Tailgating and camping seasons - Spring, summer, fall, NOT winter	Moderate/ High	$100K
Magazine Advertise ments	Camping/outdoorsy folk	Generate hype about sustainable energy on a personal level	Monthly	Moderate	$20K

Table 6: Marketing plan.

2.5 Financial Analysis

Table 7 is a breakdown of the costs of each individual part and the value it adds to the wind turbine.

Step	Area where it costs	Value Added Price per Part	Cumulative Value
Supplier	Extendable pole	$350	$1096
	Guy Wires	$49	
	Base Plate	$12	
	Steel Tube for Base & Support System	$21	
	Blades	$50	
	Electronics	$150	
	Generator	$60	
	Cast nacelle	$30	
	Battery 2400W	$374	
Manufacturer	Put the pieces together and cut steel	$50	$1146
Distributor	Distribution and Warehousing	$25	$1171
Retailer	Online retailer such as Amazon	$14	$1185
Consumer	Purchase	$114.99	$1299.99

Table 7: Cost analysis.

In order to break even, Wildcat Wind Power must sell 713 wind turbine generators to recuperate our projected fixed and variable costs before we can start making money. This will require sufficient upfront capital, mainly accumulated from investors interested in a sustainable energy marketable product. We calculated the raw materials cost based on the information found in Appendix A.

2.5.1 Risk

Table 8 details our risk analysis over 5 categories, and includes the associated estimated costs.

Cost Associated to Overcome Risks			
Risk Category	Specific Risk	Solution	Cost ($)
Product risk	Set up difficulty	Provide instruction manual	5/turbine
	Weight	Add carrying strap or wheels	5/turbine
Market	Uninformed consumers	Market efforts	10,000
	Skeptical consumers	Provide set up/ tear down demonstrations	2000
Business	Turbines don't sell b/c price	Lower price	100/turbine
	Turbines don't sell b/c lack of environmental empathy	Ad campaign	10,000
Financial	Lack of initial capital	Seek investors	12,000
	Slower than expected break-even		10,000
Execution	Miss a season	Store products	8,000
	Turbine fails, someone sues	Assume responsibility, Investigate failure	30,000
Total	Variable Costs = $110/turbine	Fixed Costs = $82,000	

Table 8: Risk analysis.

2.5.2 Operating Margin

Based on the calculations in Table 9, our business is scalable in the long run, but will take sufficient capital up front.

If WWP sold 200 turbines in one year.	
Revenue	$260,000
COGS	$234,000
Gross Profit	$26,000
Expenses	$10,000
Operating Income	$16,000
Operating Margin	16,000/260,000= 6.15%

Table 9: Operating margin.

3 Technical Design Overview

3.1 Mechanical Analysis

The major mechanical design components of our turbine include base and tower, generator mount, hub, blades, and nacelle. A horizontal-axis configuration has been chosen due to its greater theoretical power potential over a vertical-axis design. This year we are designing a five-blade turbine instead of the more conventional three-blade design to reduce our cut-in speed. One of the goals of our design was to eliminate mechanical losses that originate from a gearbox further optimizing the potential power output of our turbine. After testing various generators (outlined in the Electrical Analysis), one was chosen with the capabilities for a direct drivetrain eliminating mechanical losses from a gearbox. Figure 1 shows the completed design of the prototype turbine.

Figure 1: Prototype turbine.

3.1.1 Hub

Another key change between our current and previous design is to incorporate passive pitch control into the hub-blade system. Passive pitch is used to decrease our turbine’s cut-in speed while still maintaining the high-end revolutions per minute (RPM) necessary to achieve maximum power output. Using Qblade, a wind turbine modeling software, we were able to track peak torque output of our blade design over a range of different pitch angles and at different rotor RPM, shown in Figure 2.

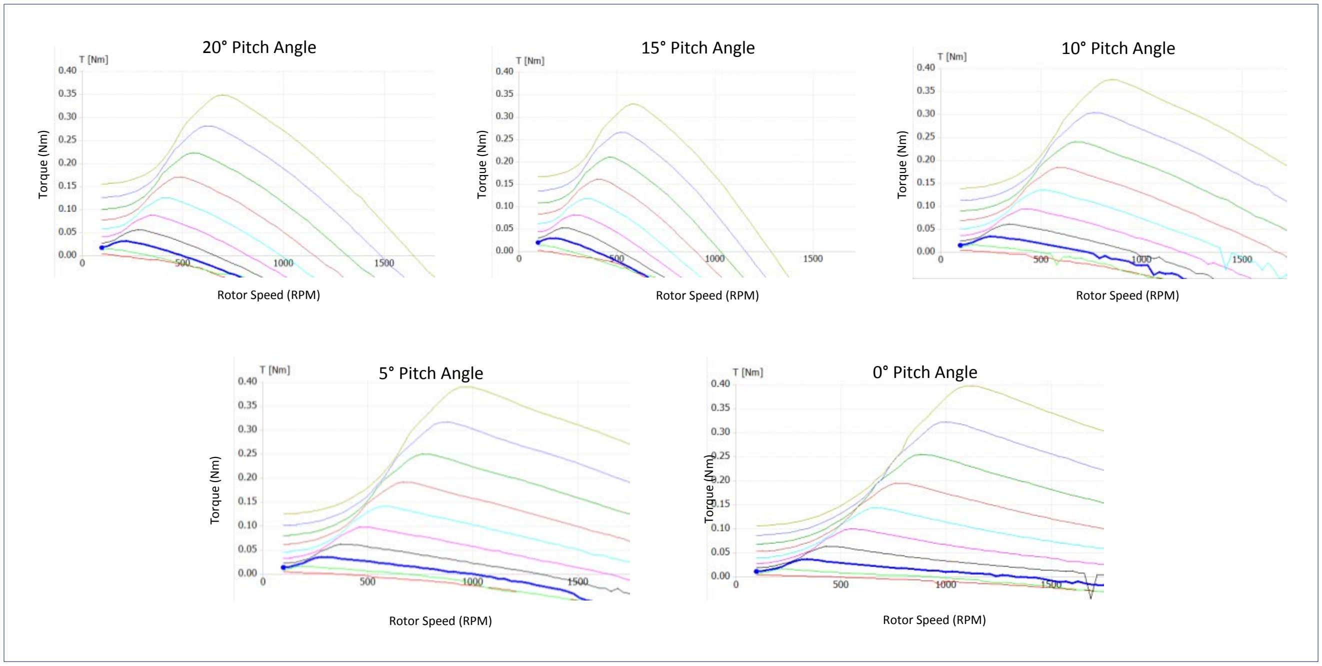

Figure 2: Variation of rotor torque at different pitch angles.

The goal is to adjust the pitch of the blades to achieve maximum torque over a wide range of rotor speeds. The main design constraint of the pitch control system is that it has to be entirely mechanical so no power from the generator is required. Another design constraint is that the pitching system must be capable of rapid and frequent adjustment in order to better handle the durability test. Our current design relies on the centripetal force of the rotor to produce a pitching moment on the blades causing a decrease in pitch angle. A compression spring maintains the blades in their maximum pitched position at low RPM. Once the desired wind speed, associated with a higher RPM, is reached, the blades will decrease their pitch angle thus providing maximum torque throughout a range of wind speeds.

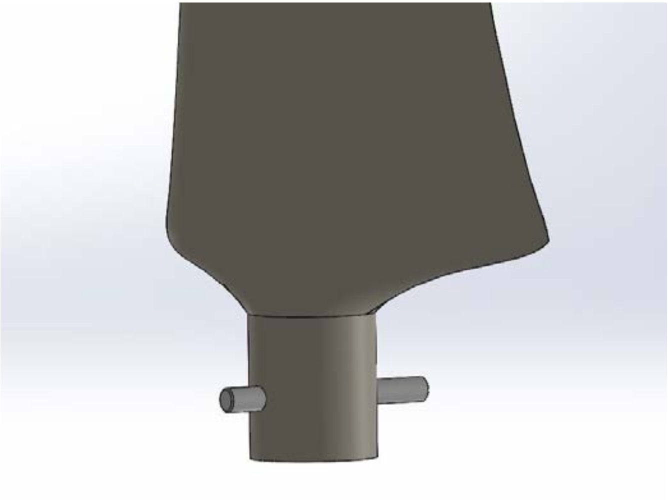

Figure 3: Blade root.

Each blade has a peg pressed into its root, as shown in Figure 3. The peg fits into a groove within the hub section which secures the blade to the hub as well as limits the range of blade pitch shown in Figure 4. This peg and groove system is what converts the outward displacement of the blade into rotational displacement.

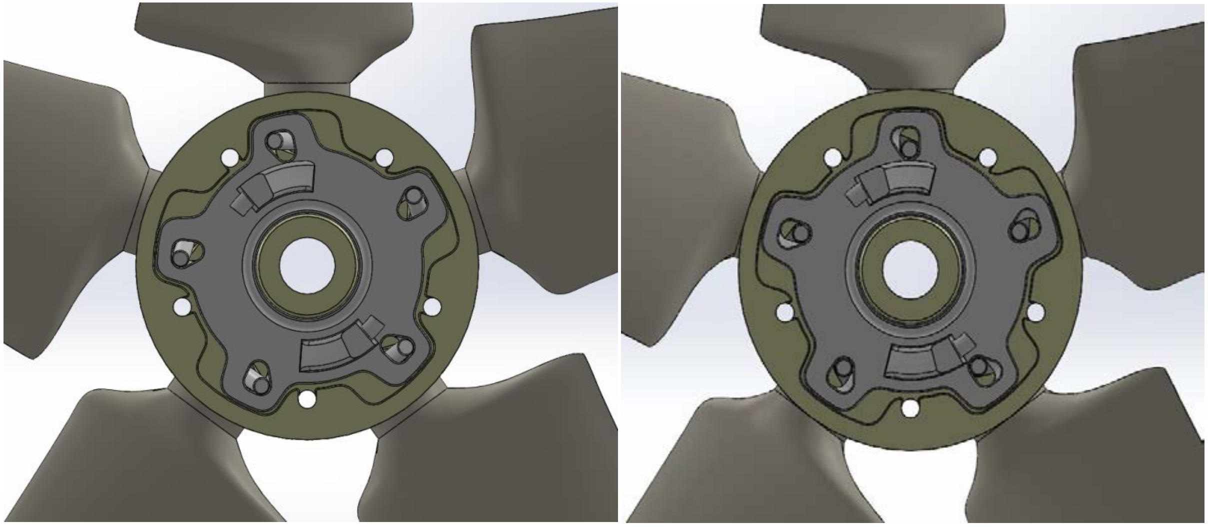

Figure 4: Inside of hub.

A ring gear connects each blade in the hub so that all the blades move in unison, as depicted in Figure 4. This is necessary to prevent any rotational imbalances which could lead to failure at sufficiently high RPM. The ring gear, rear hub, and retaining disk, all shown in Figure 5, have bearing races incorporated into their design to be used with 1/16 in. ball bearings. This ensures that the only point of contact between the ring gear and the rest of the hub are the bearings, shown in Figure 6. We have also created a fixed-pitch hub design which serves as a control for the variable pitch hub and can be used as an alternative in the event that we cannot get the variable pitch hub to work as desired.

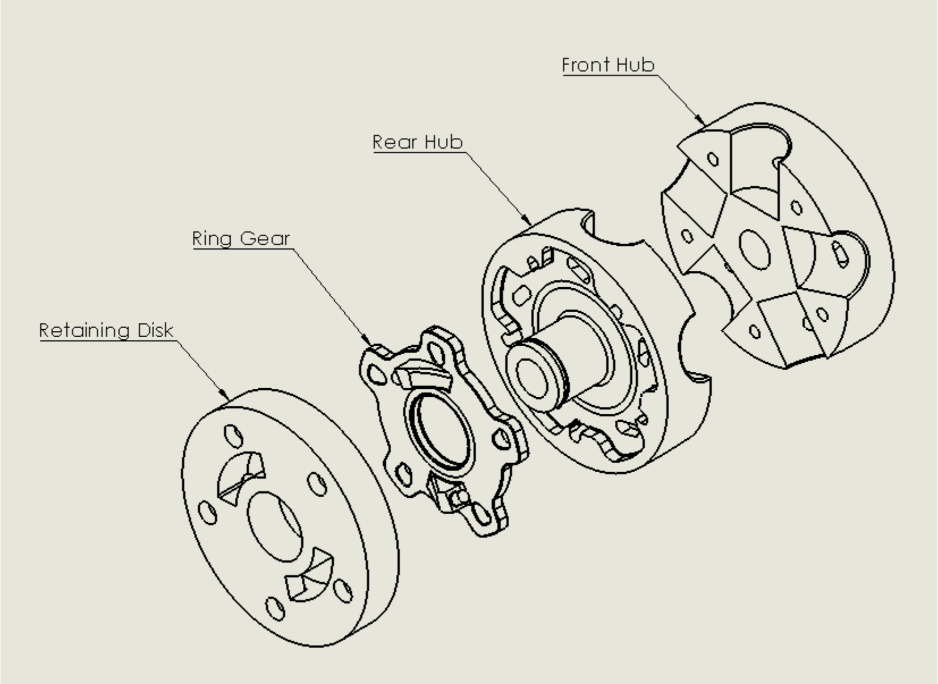

Figure 5: Simplified exploded view of hub.

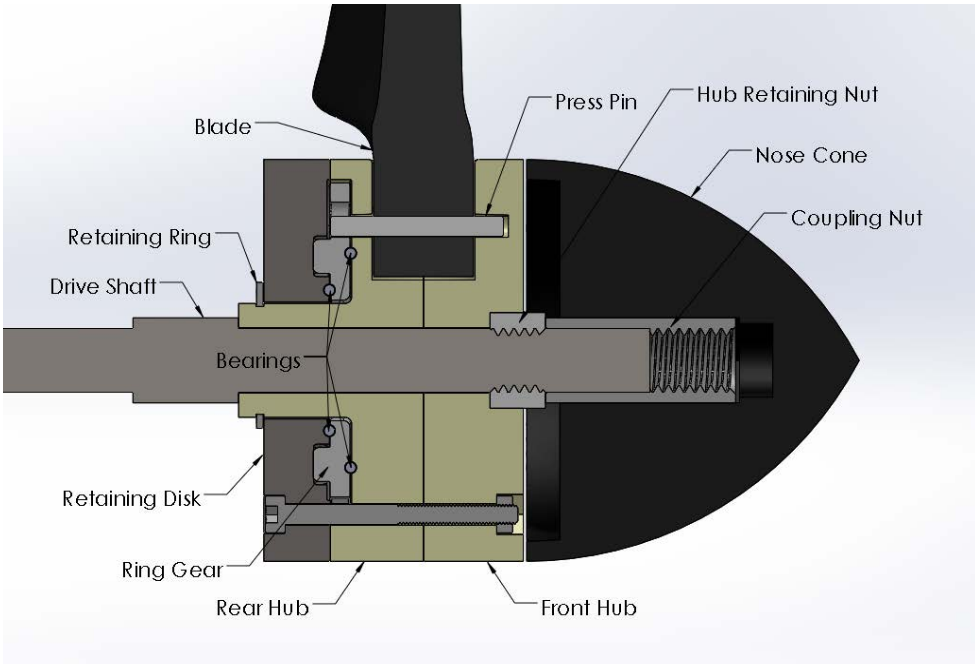

Figure 6: Annotated section view of hub.

3.1.2 Blades

We have designed our blades using the NREL s835 family of airfoils: the s835 for the root section, the s833 for the primary section and the s834 for the tip section. This family of airfoils was specifically designed for variable pitch, horizontal axis wind turbines with rotor diameters of 1-3 meters (Summers, 2005). The intended 1-3 meter rotor diameter of these airfoils is the smallest for which we were able to find data, and should scale well to the size constraints for this project. The chord length of each section was optimized for a tip speed ratio (TSR) of 4 providing a wider blade which produces higher torque at low speeds. Due to the passive pitch system the twist of each blade section was optimized for a TSR of 9. The airfoil data points were imported into Solidworks along with twist and chord length data from Qblade. This information was used to model the blades which were then 3-D printed on campus.

3.1.3 Generator Mount

The generator mounting bracket, shown in Figure 7 and Figure 8, is bolted to the upper flange which threads on to the top of the tower. The generator will connect to the raised mounting holes at the rear of the bracket. The bearing recesses house the two 3/8” bore bearings which are held in place by retaining rings. A shaft diameter of 3/8” was chosen because that diameter is large enough that threads could safely be machined on the end of the shaft. The threaded end of the shaft is used to retain the hub onto the shaft as well as transfer rotational energy of the rotor from the hub to the shaft via a nut. A coupling nut which is pressed into the nose cone is used not only to attach the nose cone to the drive shaft but also as a jam nut for the hub retaining nut, preventing the hub retaining nut from unthreading.

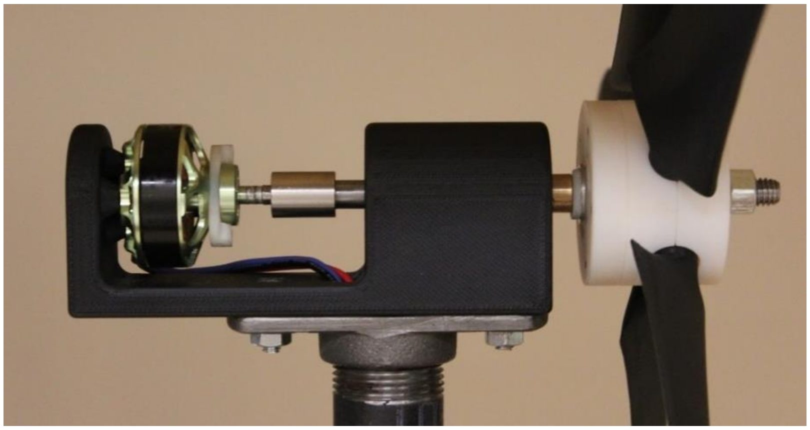

Figure 7: Picture of finished generator mount.

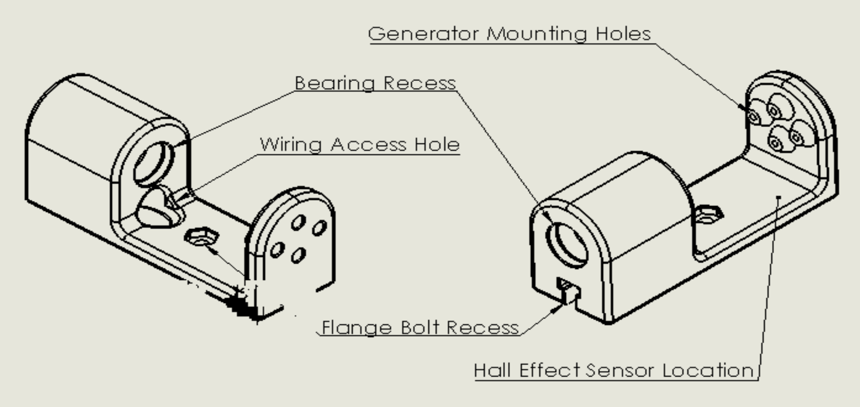

Figure 8: Generator mount.

3.1.4 Hall Effect Sensor and Magnets

Mounted to the front of the generator is a bracket containing 1/16” X 1/8” cylindrical magnets for the Hall effect sensor, as shown in Figure 9. As the generator rotates the bracket causes the magnets to pass near the Hall effect sensor which is mounted on the generator mounting bracket. All wiring from the generator and sensor will be guided down through the larger angled hole directed to the tower pipe.

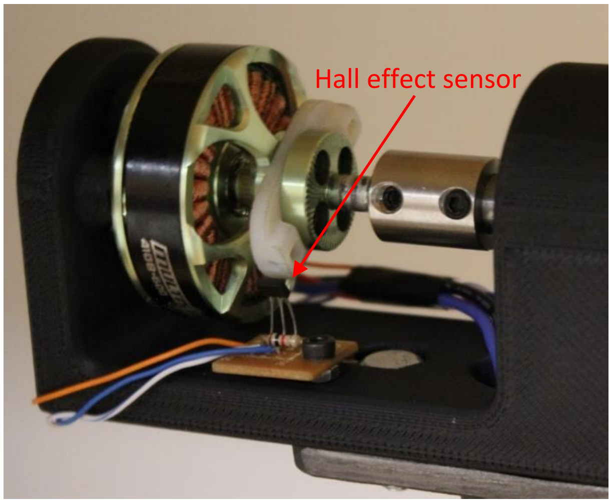

Figure 9: Displaying Hall effect magnet bracket.

3.1.5 Nacelle

Our nacelle has been designed to be a close fit to the generator mount, as shown in Figure 10. The nacelle is important to minimize disruptions in the air flow.

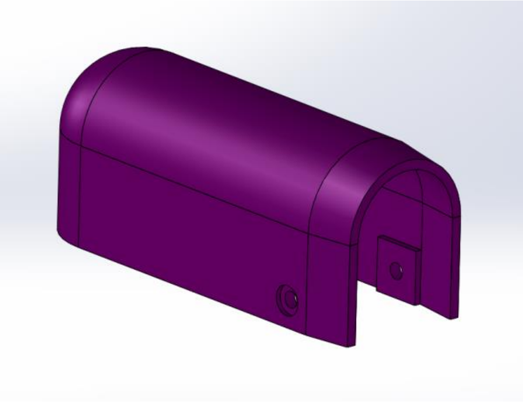

Figure 10: Current nacelle design.

3.1.6 Base and Tower

The base is a simple 20” x 12” rectangle of 0.5” steel with bolt holes that follow the given restrictions provided by the Department of Energy. The tower is 21” tall to ensure that the rotor and blades are in the center of the 4’ x 4’ tunnel cross section. The diameter of the pipe is 1” to ensure all oscillations or vibrations that could cause inefficiencies or inconsistencies are avoided. The tower will be screwed via a threaded pipe and flange onto the base plate. Figure 11 shows an isometric view of the base and tower with a previous nacelle design.

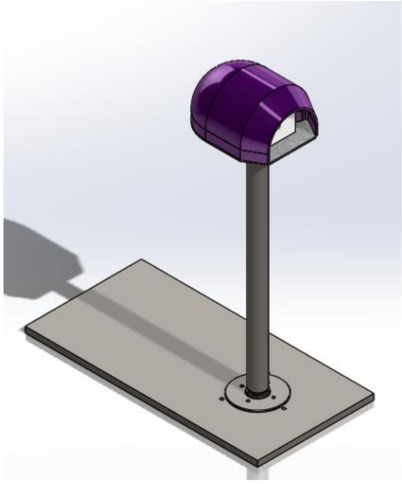

Figure 11: Isometric view of the tower and base.

Additional figures of the mechanical design can be found in Appendix B.

3.2 Electrical Analysis

The design for the electrical system includes seven main components: generator, speed detector, brake, rectifier, DC-DC converters, load, and microcontroller. From the generator, the rectifier converts the generated AC voltage into DC for use by the circuit and the load. The microcontroller monitors and automates several of the turbine’s processes. These include the brake, current sensor, voltage measurement, and generator RPM. The brake operates by tying the three leads of the generator together, utilizing the back Electromotive Force (EMF) of the generator to decrease the rotational speed of the shaft. Next, the microcontroller takes the input from the current sensor and the voltage measurement to calculate power. The low and high power DC-DC converters then regulate the voltage to 5V. The speed detector measures the RPM of the generator using a Hall effect sensor near the generator. Magnets pass the Hall effect sensor, producing a signal the microcontroller uses to calculate the RPM from the number of pulses. Finally, the load displays performance of the turbine by showing output values.

3.2.1 Electrical Diagram

Figure 12 and Figure 13 show diagrams detailing the makeup of our circuit. Figure 12 is a simplified block diagram of the power flow through the circuit as well as the general placement of each component relative to the others. Figure 13 is the circuit schematic made using PSpice that shows how all the components are connected. The schematic also shows more specific components such as the two sets of relays (shown as Brake and DC/DC Selector) and protection diode (shown as DIODE). A larger version of Figure 13 is located in Appendix D.

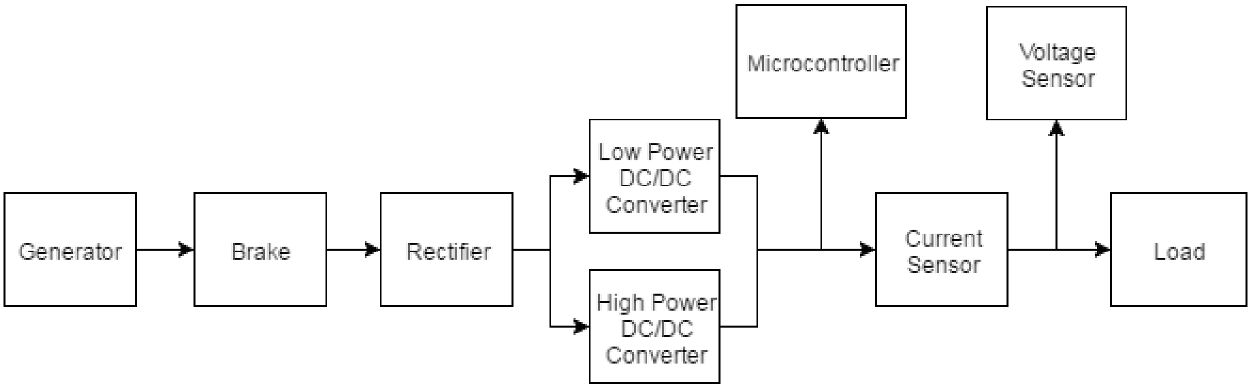

Figure 12: Block Diagram showing power flow.

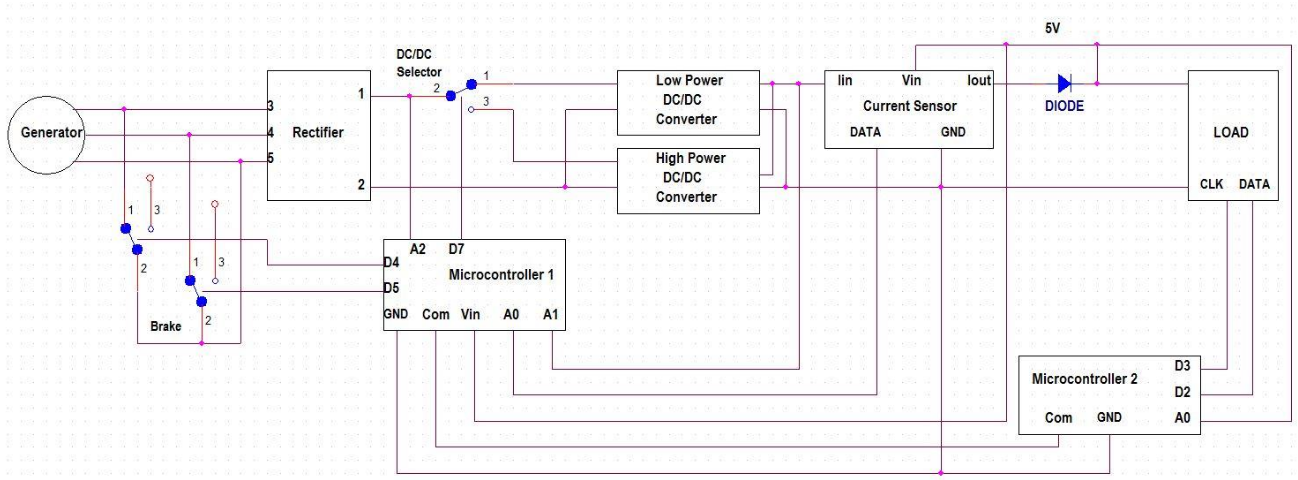

Figure 13: Electrical circuit schematic.

3.2.2 Generator

One of our main goals was to select a more efficient generator in comparison to the generators we have used in previous years. Our design team started by selecting four different generators to test: 2 inrunners and 2 out-runners. These terms apply to brushless motors typically used in model vehicles (cars, airplanes, or quadcopters). The brushless in-runner and out-runner generators are built with magnets on the inside or the outside of the stator coils, respectively. After testing, our team selected a 600Kv rated out-runner, shown in Figure 14. We selected this generator because it produced a higher power output and voltage level at RPMs that would allow us to use direct drive instead of a gear box. The direct drive will cut down on mechanical losses and will allow for a smaller overall mechanical design. Testing results showed that with a load of 1.09 Ohms, we could produce a little over 17W with a voltage around 4.4V. These measurements were found when the generator was spinning at 4200 RPM. Figure 15 and Figure 16 show the data of the power versus RPM and torque, respectively, during our testing of the 600Kv out-runner generator.

Figure 14: Generator selected for the turbine.

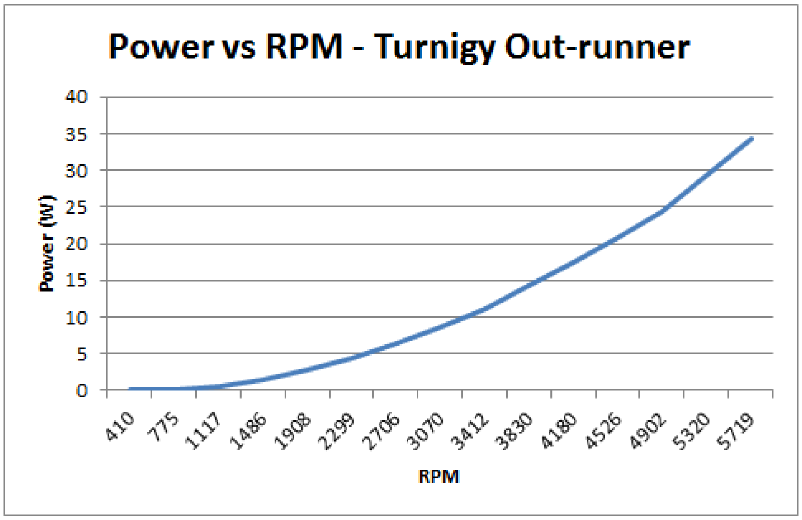

Figure 15: Power vs RPM.

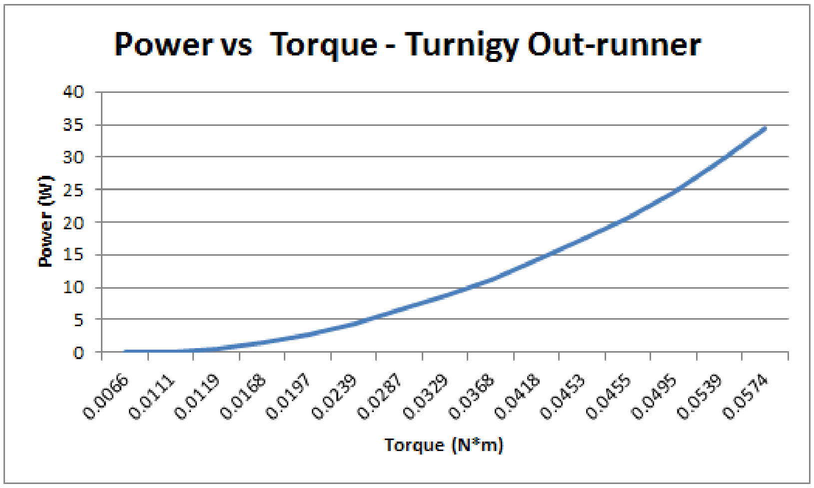

Figure 16: Power vs Torque.

3.2.3 Speed Detector

The speed detector will use a Hall effect sensor to detect the passing magnetic fields of magnets mounted on the generator. The sensor will be placed close to the generator inside the hub of the turbine and will send a digital pulse to the microcontroller when a magnet passes by. The microcontroller counts the number of pulses over one second and calculates the rotations per minute.

3.2.4 Rectifier

The three phase rectifier is located after the generator. We chose an IXYS FUS-45-0045B three-phase Schottky bridge rectifier. This rectifier provides us with low power losses and a steady DC output with the help of an appropriately sized capacitor. The rectifier has a low voltage drop: approximately 0.55V. This is ideal for our low-voltage, low-power circuit because it reduces the cut-in wind speed. Furthermore, the Schottky three-phase rectifier allows fast switching speeds and low coupling capacity between pins.

3.2.5 Brake

Our braking system involves taking advantage of the back EMF in the generator. Decreasing the rotational speed of the shaft occurs when the three leads from the generator are tied together. The brake consists of two Normally Closed (NC) relays being used as switches controlled by the microcontroller. There are two situations in which the brake is activated. When the microcontroller detects a manual button press, power is lost, allowing the relays to close. The other situation simulates a loss of load. This occurs when the point of common coupling is disconnected. When this happens, the turbine control circuit loses power and the NC relays return to their normal state, braking the generator.

3.2.6 DC-DC Converter

We chose a combination of boost and buck-boost DC/DC converters to regulate the voltage output. The voltage will be boosted at low RPMs and bucked down at higher RPMs to maintain a consistent voltage output and increase power transfers. The DC/DC converters will be switched by a three-pin relay. The smaller boost converter will be positioned on the NC pin of the relay so less power is consumed by the circuit on startup. Once the generator starts producing power, the microcontroller will switch the relay to the NO relay state that the larger buck-boost converter is connected to. This will allow for a regulated output voltage of 5V as the rectified generator output varies with wind speed.

3.2.7 Simulated Load

A physical load, based on our business plan, shows the power and energy produced by our prototype turbine. The power must be shown visually, through electricity or other applications of energy, and the power must also be shown numerically. Our simulated load is a 10x12 grid of Neopixel LED lights housed in a frame and shown behind frosted glass. The lights will show a pixelated wind turbine with three blades and two bars that would show the power generated at that moment and the total energy produced. On low power, the turbine blades spin slowly and our power bar will not illuminate many lights. As the turbine produces more power, the blades will speed up and our power bar will light up more lights. The current and voltage sensors are used to calculate power and energy to display on the LED grid as well as on an LCD screen. Figure 17 shows a mock-up design of our competition load.

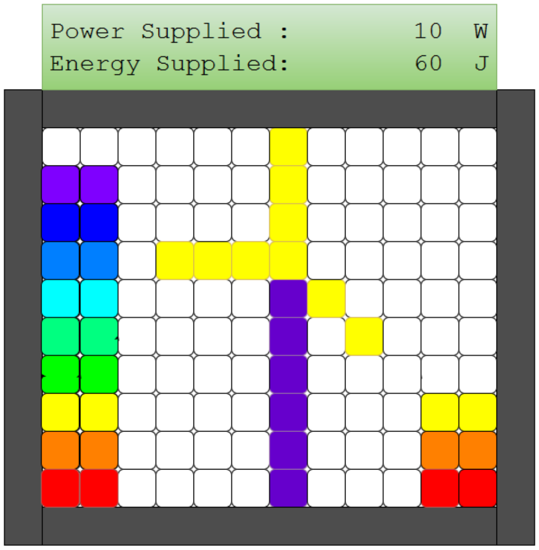

Figure 17: Mock design of competition load.

3.2.8 Microcontroller

The microcontroller monitors and automates several of the circuit’s processes. An Arduino Uno was selected for both the turbine and the load display controls. The turbine Arduino receives input signals from the current sensor, voltage sensor, and the Hall effect sensor. The Arduino calculates the generator’s RPM from the data signal sent by the Hall effect sensor. From the current sensor and voltage sensor the turbine Arduino calculates power. If the power is above its rated value, the turbine Arduino will pulse the brake on and off to regulate power output. If the turbine Arduino detects a manual button press, the brake is initiated. The turbine Arduino sends the voltage and current information to the load Arduino in order to control our display. Our full-scale turbine’s application, presented in the Business Plan, is to charge a battery for energy use at tailgating and festival events. The simulated load for the competition consists of a five volt power supply acting as a battery. The control state diagram for this process is depicted in Figure 18.

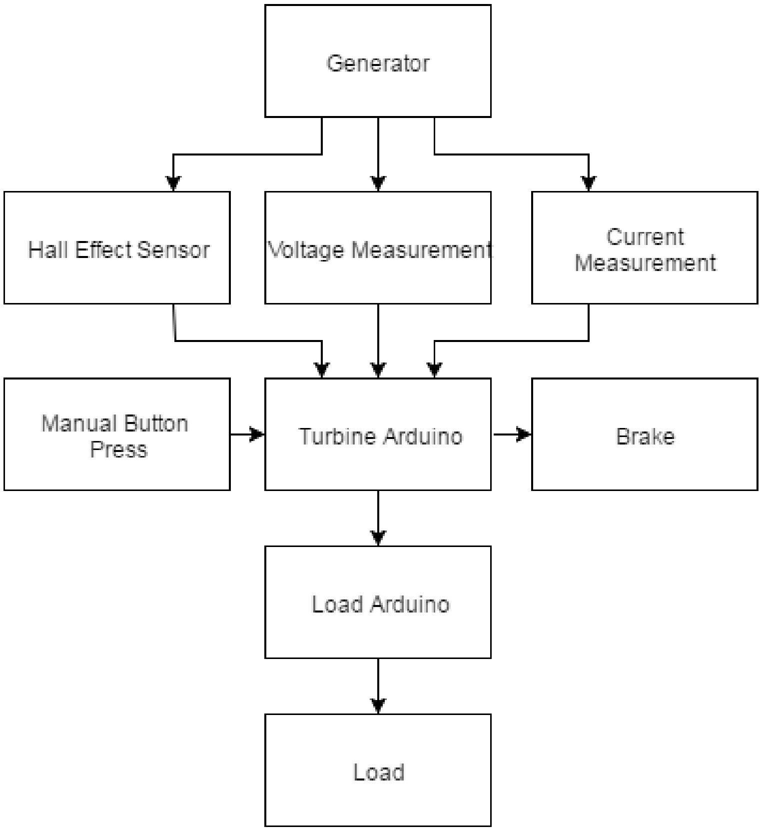

Figure 18: Control state diagram of the electrical circuit.

4 Deployment Strategies

The most convenient way for a consumer to reach a product is through a website. We will create a website; however, we believe that we can generate significant interest in our turbine by allowing the consumer to see it in practice. Our deployment marketing strategy is to have “street teams” at events using the turbine in the situations for which it was designed. Events include RV shows, sporting events, renaissance festivals, and music festivals. By having teams at these events we show potential consumers a new addition to their outdoor social experience. For a visual representation of our deployable turbine, refer to Figure 19 at the end of this section.

4.1 Project site evaluation and selection

When choosing a site for our tailgating turbines, we looked at a wind map of the United States. After getting an overview of what places would be good to target, we narrowed in on a few select locations that had venues with capacities 50,000 and up, see Table 1.

4.2 Stakeholder identification and communication

By going through all steps in the value chain, we identified our stakeholders as:

1. Raw materials suppliers
2. Manufacturers
3. Consumers
4. Surrounding tailgaters
5. The public (because of air quality)
6. Our business & engineering employees

As far as communication goes, we will order what we need from our raw materials suppliers. This will require only a basic level of communication. We will work with our manufacturers to come up with a plan for the most efficient way to mass-produce our turbines. This will require two-way communication between the engineers and manufacturers. We need to make sure that the true value of our turbine is communicated to our consumers. This will be through various marketing and promotional efforts which will include how our wind turbine generator will benefit them in ways that their gasoline generators cannot. Our consumers also need to be able to contact us concerning all of our wind turbine generators, thus we will include easy-to-access links to our website and customer service phone numbers. We will indirectly communicate with tailgaters surrounding our consumers, informing them of the safety guidelines of the turbine as well as team spirit. In order to communicate to the public, we will hold a press conference unveiling our wind turbines and their impact on the environment. Lastly, we will be in constant communication with our employees to continuously make our product and operations better.

4.3 Deployment timeline and project life cycle

We estimate that our turbine will take 4 weeks from ordering raw materials to the end of manufacturing when the product is ready to sell. The turbine will be sold in a compact and easy-to-store container with instructions on how to set up the turbine safely. We estimate that it will take 25 minutes to set up and 20 minutes to tear down. We expect the Wildcat Wind Power turbines to last at least 10 years if properly maintained.

Currently we are in the planning (development) stage of the product. Initial designs for the product have been sketched, and it has been determined as a feasible product. Our next step is building a full-scale prototype so that we can run tests and see how we can make it lighter and more efficient. Based on our financial projections, there is potential to build and sell the product while turning our profit. After a prototype has been designed and perfected, we will move into the execution phase where we will manufacture and sell the turbines.

4.4 Installation and maintenance

Due to the temporary nature of this design, the only requirements for installation are a solid surface (i.e. pavement) and a vehicle that is able to secure the plate to the ground. To assemble the wind turbine (to go from trunk of a vehicle to generating electricity) the process is as follows:

1. Place the base plate where desired. Drive over the base in the marked area. Put vehicle in park.
2. Place collapsed pole inside base pipe.
3. Line up holes in base pipe and fiberglass pole for the lock pin. Put in the lock pin prior to extending pole.
4. Attach wind turbine blades and tail fin to hub, fasten hub together.
5. Attach hub with blades to collapsed pole.
6. Start raising sections of pole one section at a time. (A friend might be helpful for this part.)
7. After you have raised two sections, unfold feet of tripod.
8. Attach guy cables provided to the ends of each foot of the tripod and the corresponding i-hook after the second extension on pole.
9. Keep raising sections one at a time, making sure they fully lock in place.
10. Tighten cables using turnbuckles until taut. (The turnbuckle is the rotating cylinder towards the bottom of the guy wire.)

4.5 Reliability

Due to the lack of moving parts inside the turbine's hub design, no maintenance will be required for 10 years after purchase. A majority of the maintenance after the 10-year period will be circuit-related.

Reliability of power generation is dependent upon the location of the turbine geographically. Less obstructed areas will yield better turbine performance, and local weather conditions will have an effect on wind speeds.

4.6 Risk Management

Risks involved with the physical turbine are: loss of stability in extreme wind speeds, improper assembly leading to failure of structure, and insufficient stabilization of the turbine from the weight of the car.

Other risks are onset from the weight of the portable turbine for the physical health of the consumer.

Figure 19: Full scale turbine at KSU's Bill Snyder Family Stadium. Supporting vehicle not shown.

5 Conclusion

Our prototype turbine displays the concepts utilized for the full-scale turbine presented in the business plan. The focus of the mechanical design of the turbine was to lower the cut-in wind speed so that sufficient power can be produced over a wider range of wind speeds. This design will allow our turbine to be competitive with a generator driven by an internal combustion. Our circuit converts the mechanical wind energy into a constant output of 5V, which will scale up to 12V for our full-scale turbine. The turbine's braking system models industry safety standards to protect the turbine as well as our consumers. Designed to power a tailgating event at full-scale, our prototype turbine proves to safely and sufficiently deliver this need. With the help of eager investors who believe in our mission, we will be able to successfully deploy a marketing strategy that will increase the desire to use renewable energy.

Appendix A: Raw Material Costs

Extendable Pole: At a 20% wholesale discount when we order 100 = $350
http://fiberglasstubingsupply.com
The extendable pole is made up of 5’ fiberglass pieces each with varying outer diameters (OD) and thickness of 0.5”. They will fit inside each other and then telescope up, like a Russian nesting doll. The sizes and pricing we found are as follows: 4.5” OD = $98, 4” OD = $88, 3.5 OD = $78, 3” OD = $68, 2.5” OD = $58, and 2” OD = $48, for a total of $438.

Steel Plate for Base: $11.91 per sheet
http://www.discountsteel.com
The steel plate comes in a stock size of 4’ x 8’ ¼” thick so that would be able to create 16 2’ x 1’ plates if we cut them ourselves. $190.48/16 = $11.91 per sheet before manufacturing costs to cut them ourselves.

Steel Tube for Base Plate & Support System: $21.05 per turbine
The steel tube comes in a stock length of 20’ and we need 2’ per base plate pole and 62” per support system, of which there are three.

2’ base support pole that has a 6” outer diameter
http://www.discountsteel.com/items/Electric_Welded_ERW_Round_Steel_Tube.cfm?item_id=201&size_no=158&pieceLength=cut&len_ft=0&len_in=0&len_fraction=0&itemComments=&qty=1
20’ is $138.44 so 2’ is $13.84 per turbine

62” x 3 legs / 12” per foot = 15.5 feet of the supports at ½” thickness
http://www.discountsteel.com/items/Electric_Welded_ERW_Round_Steel_Tube.cfm?item_id=201&size_no=11&pieceLength=cut&len_ft=0&len_in=0&len_fraction=0&itemComments=&qty=1
20’ at $9.30 so for 15.5’ it would cost $7.21 per turbine

Guy Wires (need 75 ft per turbine): $49
http://www.lowes.com
At $0.65 per foot, we need 75’ of guy wires to use as support attaching from the top of the extendable pole to the base of the steel support poles. $0.65/ft x 75ft = $49

Generator: $59.99
http://www.amazon.com/Sunwin-Electric-Control-Bicycle-Brushless/dp/B00DBLIJNA
A 500W, 72V generator costs $59.99.

Bridge Rectifier: $9.00
http://www.amazon.com/BRIDGE-RECTIFIER-SINGLE-PHASE-PROFILE/dp/B007Z7LXVQ

DC/DC Power Converter for 500 W 72+V to 48V DC: $128.80 per module in bulk
http://www.mouser.com/ProductDetail/Mean-Well/SD-500L-48/?qs=umBTOZqEewis66%252betk6pyQ%3D%3D

15 A Max Wiring: 50’ for $11.20

https://www.grainger.com/product/SOUTHWIRE-COMPANY-14-AWG-Building-Wire-WP5288802/_/N-qs4?s_pp=false&picUrl=//static.grainger.com/rp/s/is/image/Grainger/2W286_AS01?$smthumb$webparentimage$

Battery: $374
A 200 Amp-hour, 2400W, 12V battery is $374. The model number is UPG UB-4D AGM Battery. It is an absorbent-glass-mat type and has a 1-year warranty.

Appendix B: Generator Bracket

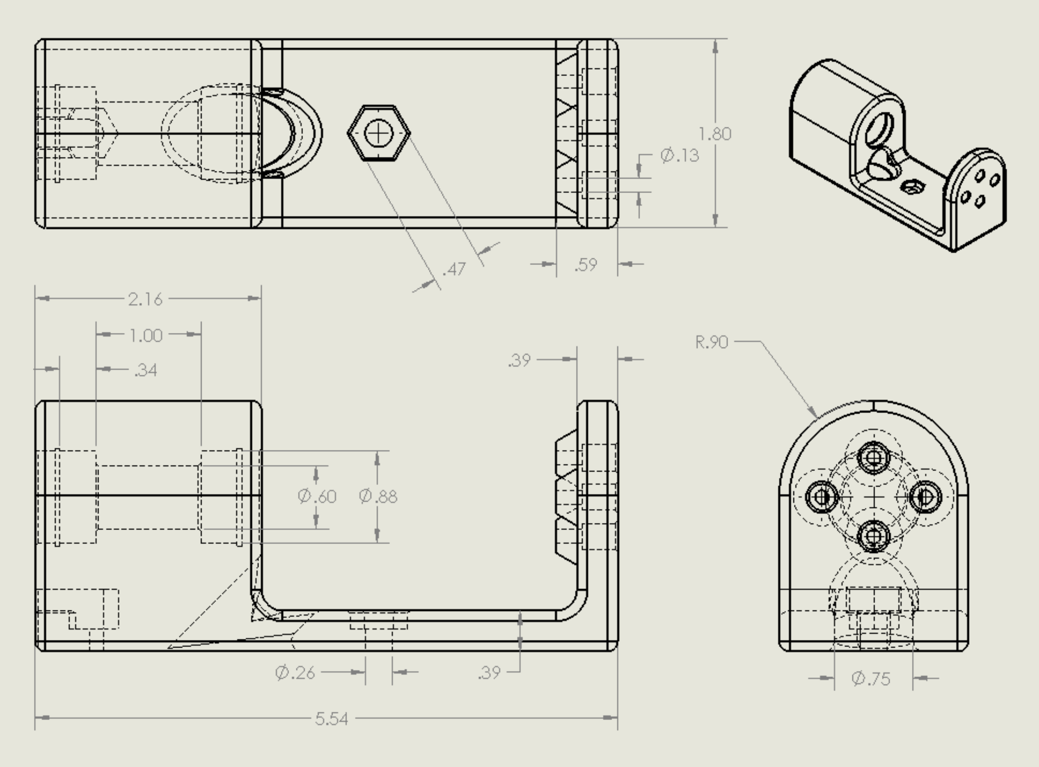

Figure 20: Generator bracket.

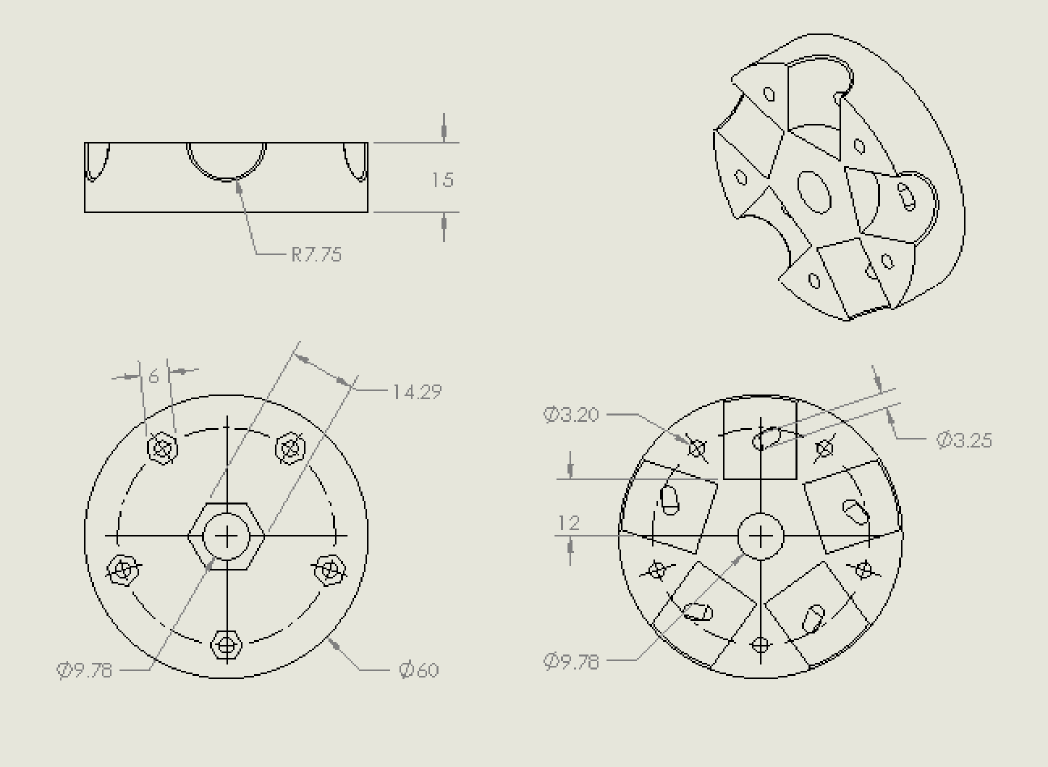

Figure 21: Front hub section.

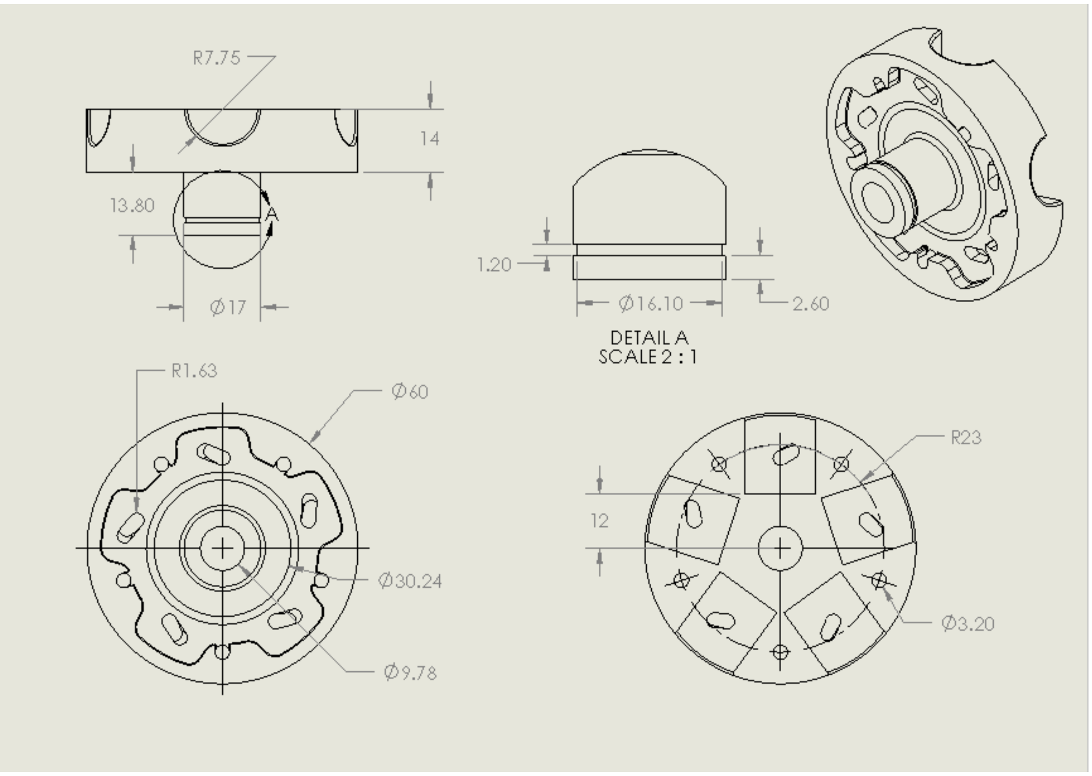

Figure 22: Rear hub section.

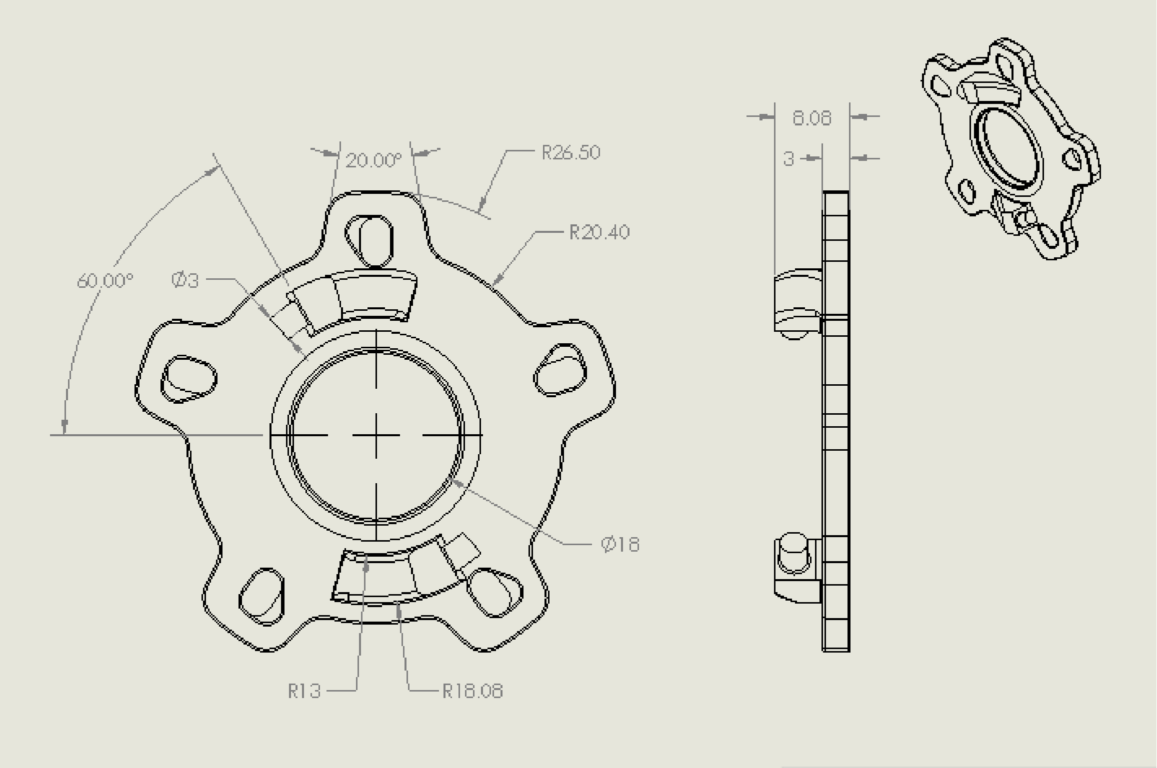

Figure 23: Ring gear.

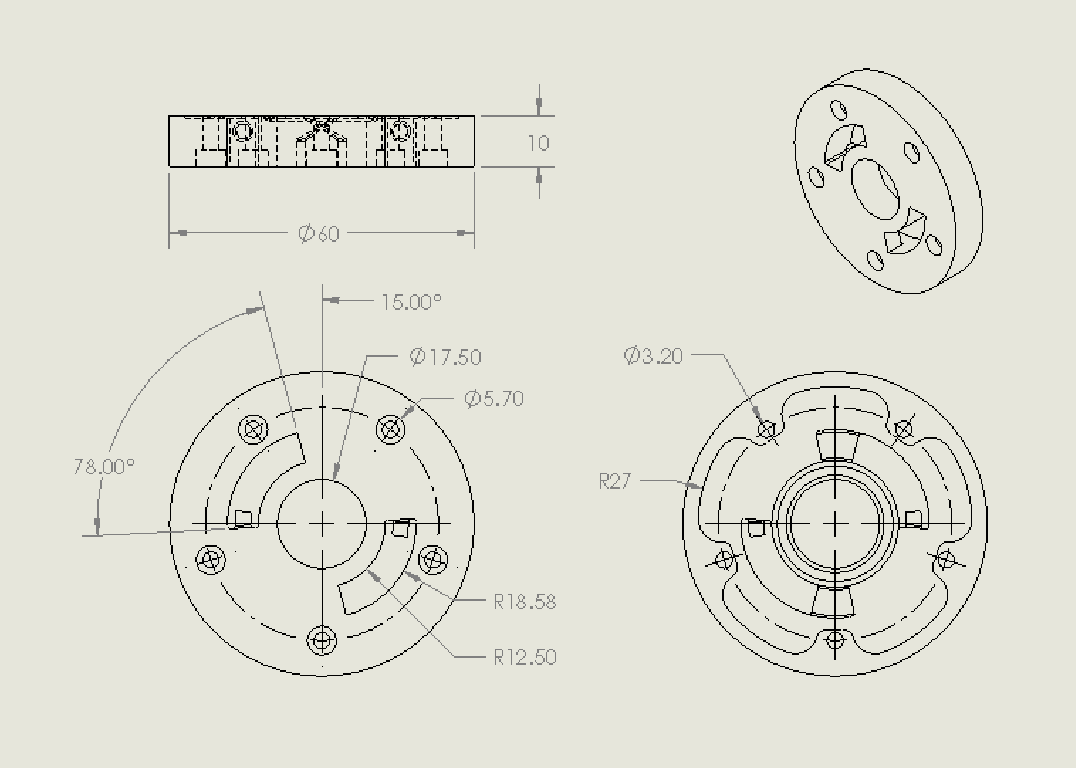

Figure 24: Ring gear retaining disk.

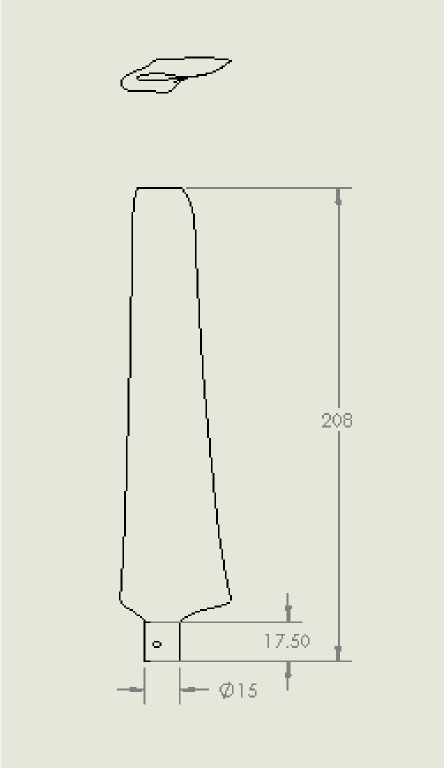

Figure 25: Blade.

Appendix C: Wind Tunnel

Introduction

One of our goals from last competition was to build a wind tunnel to allow our team to test designs more conveniently. Calculations and research on the design were started last summer by the team members that were still in the area. Design restrictions included the power required to operate the wind tunnel fans, the space required to operate the wind tunnel, and remaining under our budget of $3500. Our design goals consisted of laminar flow up to 18 m/s with easy access to the testing section, easy disassembly in case we needed to relocate the wind tunnel, and safety of operators and equipment around the wind tunnel.

Calculations and Design

We started by defining a tunnel size and then calculating the needed CFM flow at our desired velocity. This number was then used to research fans to find out what was feasible for us to accomplish. While one team member iterated on that process, others worked on calculating loss factors for the diffuser, test section, and flow straightener for the wind tunnel. This was done to make sure that when we specified the fans they would give us the wind speed we desired in the final assembly. The completed wind tunnel model can be seen in Figure 26.

The flow straightener proved to be the hardest section to design and calculate the loss factor for. After several iterations we decided on drinking straws as a cheaper option than extruded honeycomb. We were concerned that with that small a diameter the loss factor might be higher than our calculations showed due to boundary layer effects, so we used a higher friction factor for the plastic in our calculations to try and account for that.

The diffuser was another source of losses. We did not have the tools to make it out of an optimal set of curves as our research showed, so we went with a simple angled design and used the corresponding loss factors.

The design we came up with made use of our budget and tools we had available to maximize the performance we could achieve. We chose a pull configuration for the fans, which were placed inside a 4’ square box connected to the 3’ square test section by our angled diffuser. The flow straightener was placed on the other side of the test section, with doors on both sides of the test section to allow easy access, Figure 25. For disassembly, we designed the tunnel to come apart in three sections: the test section, the flow straightener, and the fan box and diffuser.

During the design process it was very important to us to consider safety. We chose impact resistant Lexan for the windows of our test section in case of turbine failure inside of the wind tunnel. Both the flow straightener and the fans were protected from foreign objects by screening of various sizes to give rigidity and protection against finer particles.

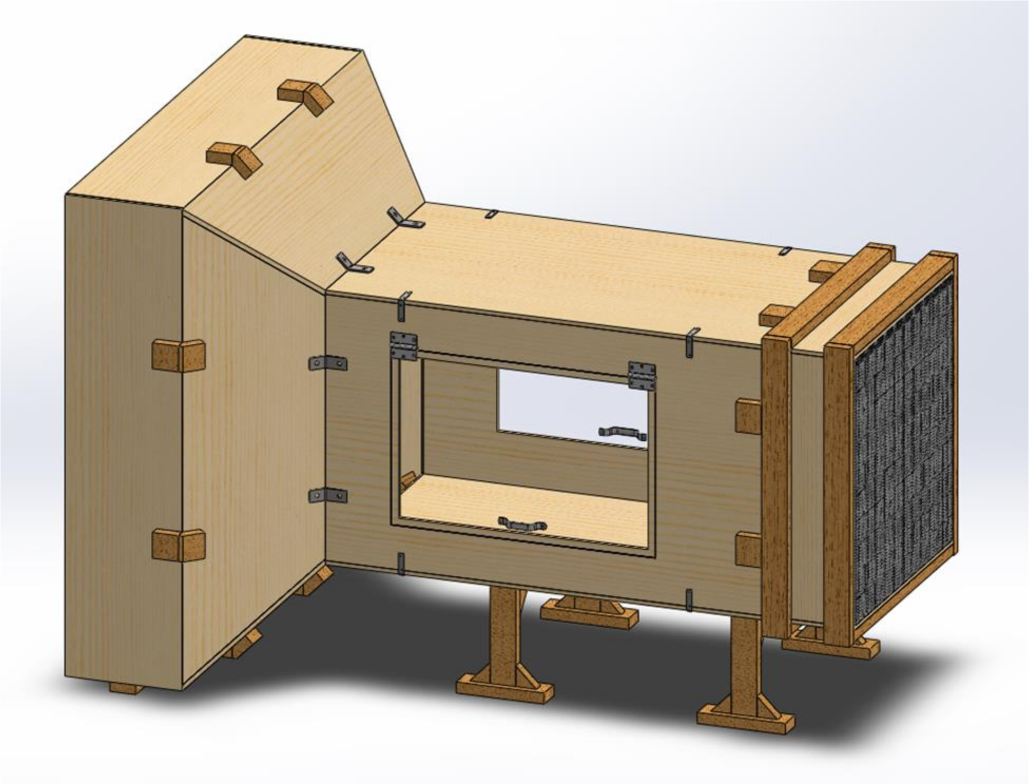

Figure 26: Wind tunnel model.

Construction

One of the main difficulties we came across during construction was the delay of one of the four fans we ordered. We decided to modify the design temporarily to use only 3 fans to allow testing while we waited for the fourth fan to arrive. The diffuser also gave us some difficulties making the assembly square and having the appropriate angles between all the boards.

Thankfully the electronics to control the motors were more straightforward. A variable-frequency drive, which was donated to us by a faculty member, is used to control the speed of the fans. The three-phase line from the drive is routed through an emergency stop switch before the junction box where all the fans are connected in parallel.

Results

Once construction was complete we found that we had underestimated our loss factors for the flow. Our calculations for the CFM with 3 fans gave us a theoretical maximum wind speed (ignoring losses) of 13 m/s. When we tested the wind speed with our thermo-anemometer we only observed 7 m/s. We removed our flow straightener and tested again and we got around 13 m/s, although the values were inconsistent due to the turbulent flow. Once the fourth fan is installed, we expect to get closer to our design goal of 18 m/s. In the future, we plan on redoing the flow straightener to use longer, wider diameter tubes such as small PVC pipes to attempt to reduce our loss factors.

Appendix D: Electrical Circuit Schematic

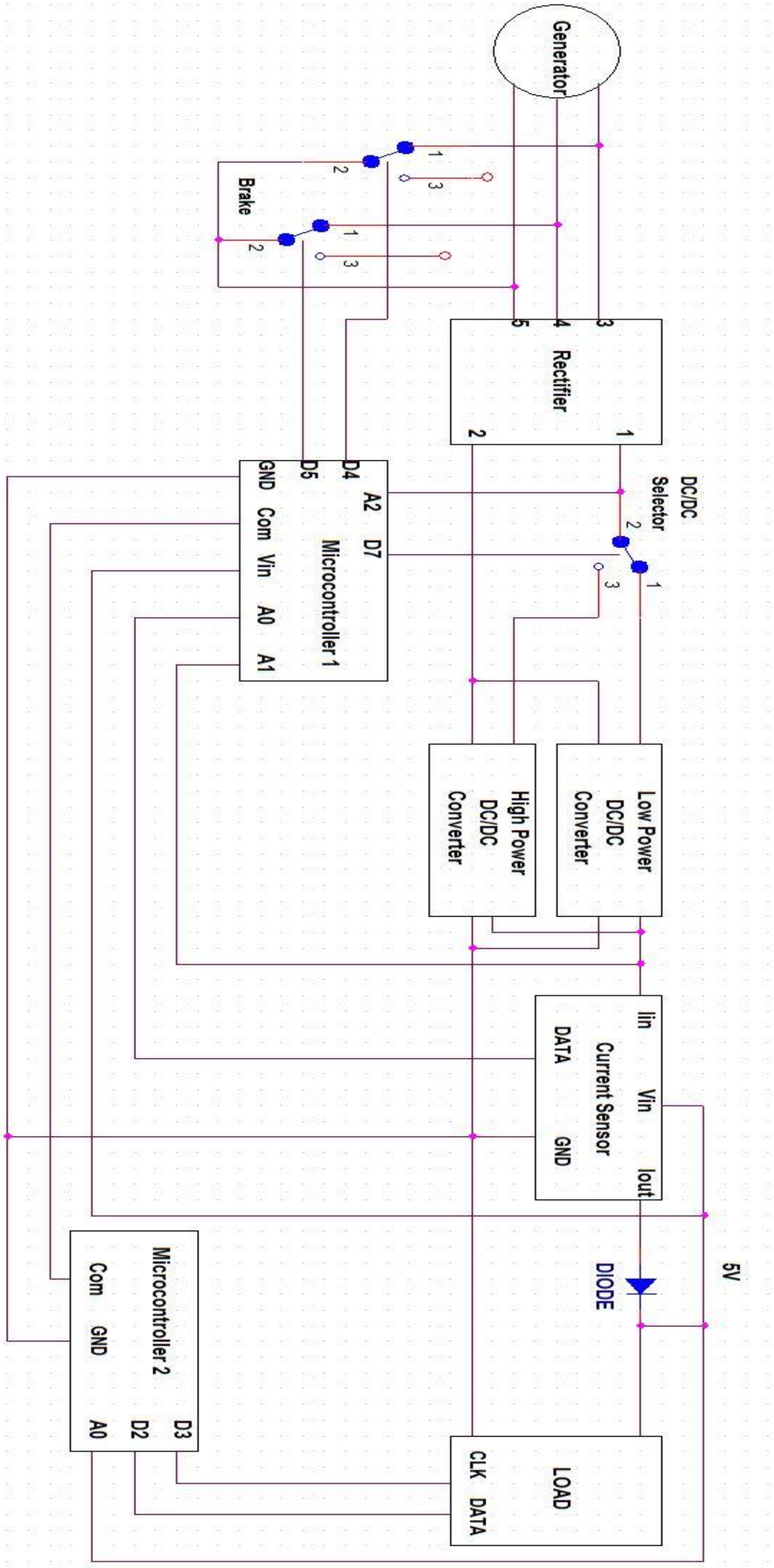

Figure 27: Larger version of the electrical circuit schematic.

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