Power Systems Analysis in an Induction Type Wind Turbine

Final Report

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Definitions

Induction Motor- An EC electric motor which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding.

Islanding - A condition in which a distributed generator continues to power a location even though the electrical grid power is no longer present.

NOTE: This template is a work in progress. When in doubt, please consult the project plan assignment document and associated grading rubric.

REC - Rural Electric Company. This is the utility that our group is dealing with that is located where the turbine will be built.

1 Introduction

1.1 Acknowledgement

A lot of the design came from Bob Zickefoose, a MSME teacher in Virginia who also has a similar ‘sister’ tower on his property in West Virginia. Much of the structure came from Ron Zickefoose, the client, and from Global Machine Company in Hampton, Iowa.

1.2 Problem and Project Statement

The client Ron Zickefoose designed and is building a wind turbine on his property to provide cheap and clean energy for his power consumption. In order to interconnect to the power grid and supply a small amount of power to the induction motor to start rotation, the power utility requires proof that the generator will not cause any islanding on the power grid. Which would cause voltage to flow back to the grid, causing a safety hazard for anyone working assuming that there is no voltage if the rest of the power grid is turned off. Once approval from the utility is established, the wind turbine should be able to supply enough power for our client’s needs, and enough to sell back to the utility.
Following the set parameters for the requirement documents of interconnecting on the power grid for a functional turbine. Establish a fully functional wind turbine adjusting the tail fin of the turbine and fully building the turbine is in order. Meeting all the interconnecting criteria will prove that the wind turbine will not cause any islanding issues with the utility tests will be done on the induction motor used. To run tests on the induction generator, a second motor can be hooked up to for maximum output, and what power is needed to start the induction generator. Showing the initial power is needed and a constant supply is there while outputting power will prove that voltage can’t be supplied by the motor without the reactive power from the grid.

Additionally, there will be a detailed research, analysis, description of the capabilities, limitations of the induction motor. This research will allow for the wind turbine to be hooked up to the grid and supply power and income to our client.

1.3 Operational Environment

The wind turbine will be open to the elements. The turbine stands at 110 ft. tall and will be subjected to any wind, rain, hail, snow and ice. During lightning storms, lightning will have a large percentage of hitting the tower. Since most of the turbine is made from metal the temperature outside will affect the structure and will be subjected to expansion and contraction.

1.4 Intended Users and uses

The intended users of the wind turbine are the owner of the property that it stands on. In this case our client Ron Zickefoose is the user. The nearby utility will also be an intended user of the wind turbine as they will get electrical energy from the turbine.
The property owner will get the most use out of the turbine. They will be able to offset how much money is spend on their electricity bill from their own consumption. In addition to that any extra electricity produced will be sold to the utility. Once the utility gets electricity they will be able to generate less power and use the wind turbine to sell electricity to their customers.

1.5 Assumptions and Limitations

Assumptions

The air density is a constant throughout the year
That the three phases of voltage are 120 degrees apart.

Limitations

The induction motor will turn into a generator after 1800 RPM
The system must operate at 230 volts and 60 Hertz
The current will run at 20.6 Amps

1.6 Expected Product and Deliverables

Blueprints of a one line, three line and control wiring. These blueprints will show exactly how the wind turbine is set up and how it functions.

Documentation for an interconnection agreement will be written for the local utility in the area. These documents will include some of the blueprints, and the different generation tests proving its capabilities. The turbine will stand at 110ft with a 4kW induction type motor.

2. Specifications and Analysis

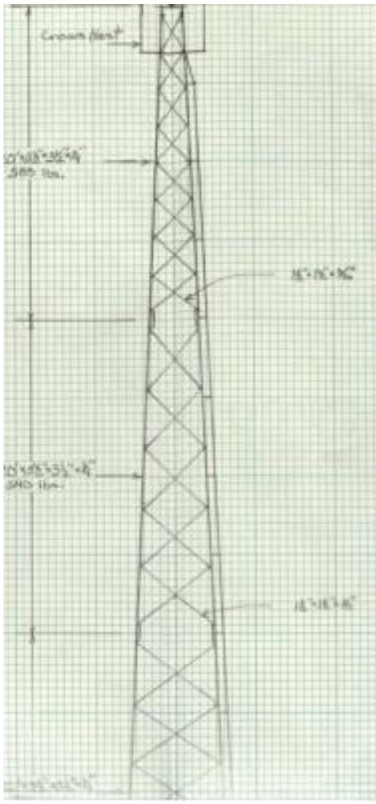
There are many methods of solving the problem of customers reducing energy costs to save money in the long term. The various solutions to this problem includes: Our group has used the solution for the wind turbine to produce cheaper electricity. In this solution there are different methods for problems while building a wind turbine. The problems from choosing a wind turbine is knowing what type of generator to use, how to verify electricity won't be supplied to the power grid if the grid is undergoing maintenance, and different ways to maximize the power output supplied from the turbine. Our team is using an induction generator based off the price point and how much power it supplies for what is needed for the customer's power consumption. Our group is testing the induction generator with a secondary motor will be the easiest option. An additional motor is available through Iowa State University wind lab so cost will be negligible. Another reason this method was picked was that if the power from the grid is off either way the turbine will not be able to supply power so we wanted to use was physics has already provided to our team. To improve the power output of the wind turbine there isn't one right solution and multiple solutions can be used at a time if our group finds that the solution is worth the costs. Our team decided to focus on the tail vane of the turbine. This was due to the fact the wind turbine wouldn't be able to produce any power if it is not facing a direction where is catches the wind. The controller will also be built because it has a low cost and will help improve the lifespan of the wind turbine.

2.1 PROPOSED DESIGN

The design includes using a 4kW induction generator. The tower is 110 feet fall with three legs and triangle supports up the leg of the tower shown in figure 1 and 2. Three turbine blades that are 10 feet tall. A tail vane pitching system has controller hooked up to a wind sensor that sends signals to the turbine telling what direction to go in. The design includes having blueprints of the entire turbine and grid layout as a package for anyone else interested in building a similar turbine.

A non-functional requirement includes a GUI to show the wind turbines power output along with the wind speed and direction.

Figure 1 - top half of tower.



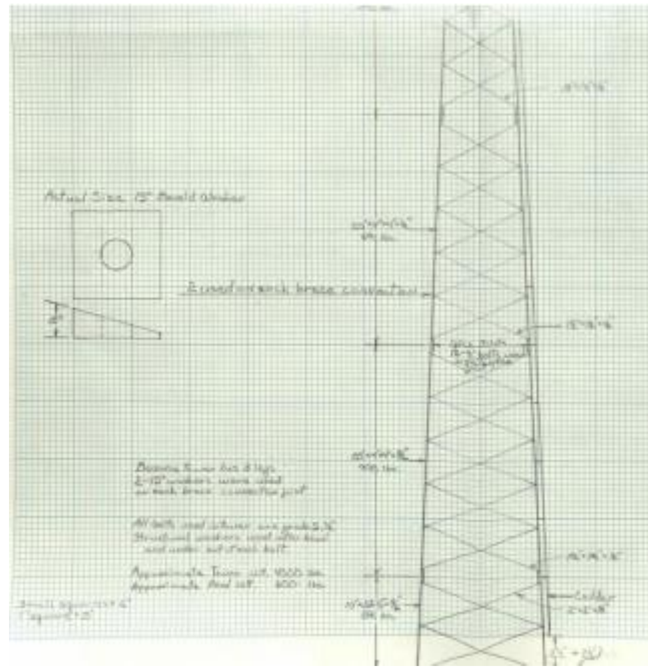


Figure 2 - Bottom half of tower.

2.2 DESIGN ANALYSIS

The turbine at 110 feet fall is built but not yet standing. The three-legged base will work for this application, in the future a four-legged based design would be preferred to add more stability.

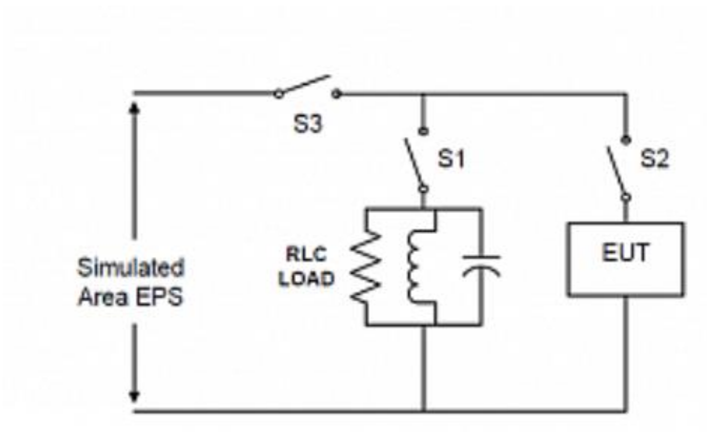
The present tail vane pitching system as a very simple circuit, though doesn’t allow for any fine tuning of the turbine. Compared to other turbines on the market, this turbine is a striped down, ‘bare-bones’ version that trades control for simplicity.

2.3 TESTING DESIGN

Different types of tests were available for our motor to interconnect with the power company.

Unintentional Islanding Test

Described in UL 1741 Section 46.3 is used to test if any power will backflow after power to the generator is turned off. To test our generator in this way it would have to be set up in a circuit described in *figure 3*.



IEEE 1547.1 Figure 2—Unintentional islanding test configuration

$$Q = R\left(\frac{C}{L}\right)^{0.5} = \frac{(P_{ql}P_{qc})^{0.5}}{P}$$

Figure 3 - Circuit for anti-islanding

The basics of the test is summarized in the following way:

1. Connect an LRC network in parallel with the inverter to the simulated grid
2. Run the inverter and tune the LRC load until the system has a small current
3. Open the circuit so the LRC load and inverter form an island
4. Time how long it takes the inverter to stop production
5. Repeat at 100%, 66% and 33%

Our group did not use this test for a variety of reasons. Even though the REC consultant was concerned about our generator not turning off when power stopped coming to our wind turbine we felt confident that we could do that through other tests. The downside of this more complicated test is that there were values for power inside the we were unsure of how to measure that were not given to use as parameters of the generator. Another downside is that there is little available documentation on how to proceed with the tests which cost around $1000 to purchase. Since the goal of this project is to save money on electricity we felt as though this purchase would be expensive compared to the cost of paying someone to getting our generator UL certified.

In-Rush Current Test

This test looks at the starting of the generator and looks for the maximum current drawn. With the maximum current drawn the starting voltage drop can be estimated. Our group used this test using a multimeter hooked up to the generator.

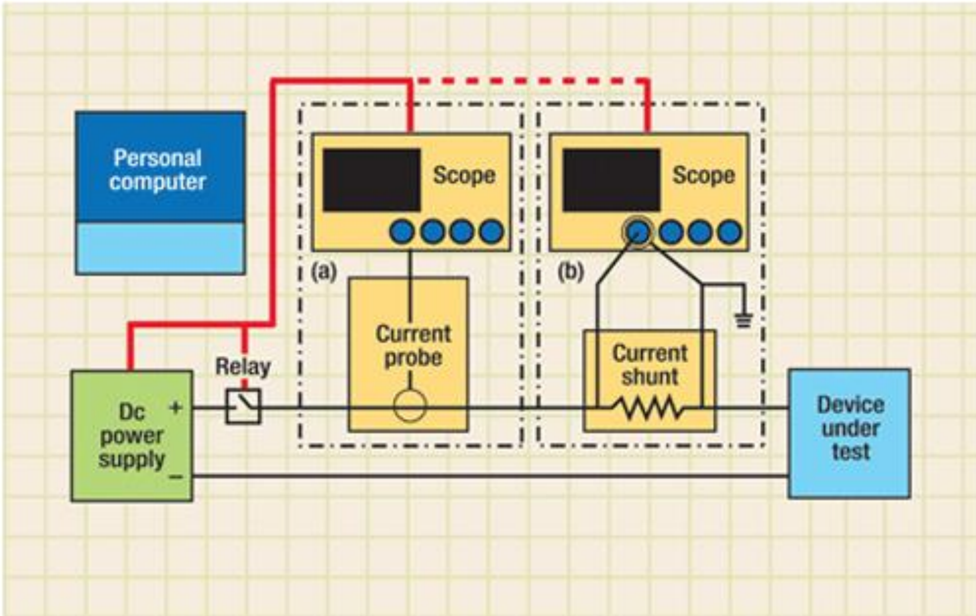


Figure 4 - Circuit for In-Rush current test

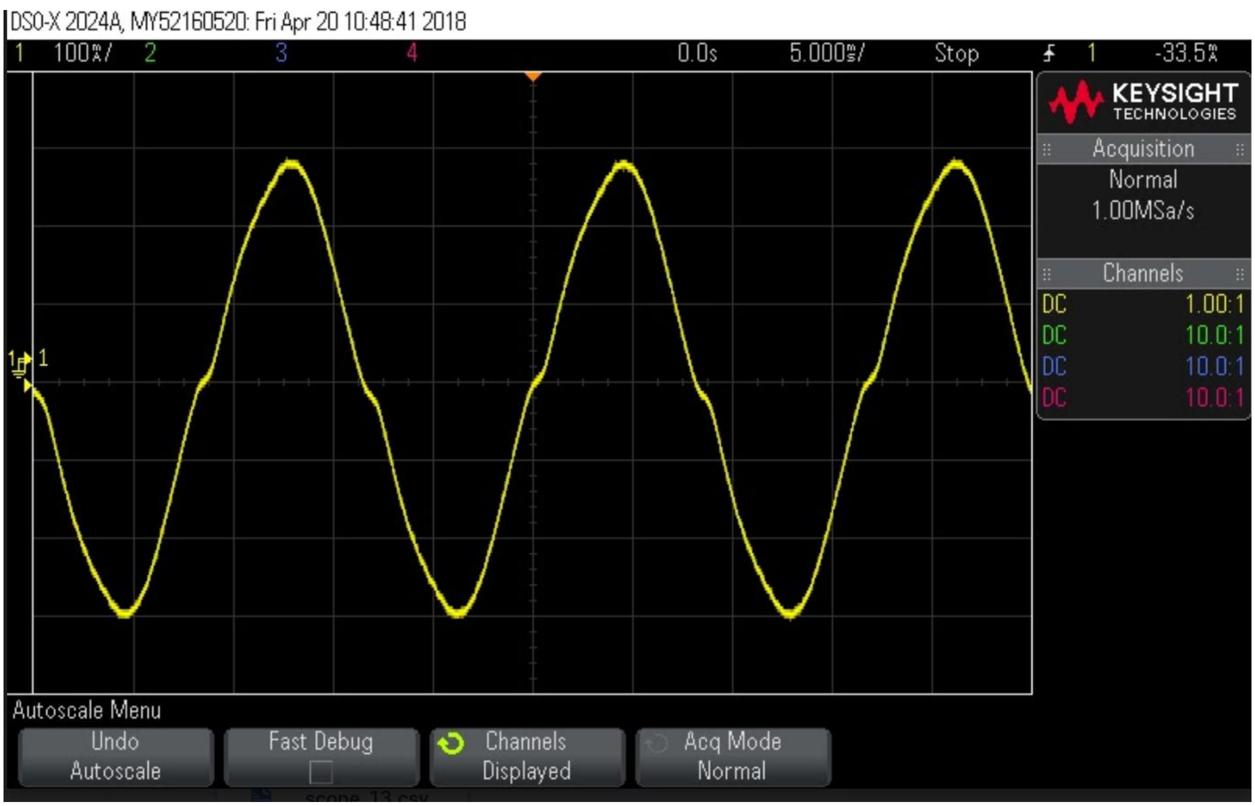
3 TESTING AND ANALYSIS

One of the largest obstacles to this project has been the objections of the local power utility, the REC. Their concern has been the possible scenario of having the electrical grid turned off and having one of their linemen hurt and electrocuted by our wind generator. We believe that most of this fear comes from the lack of understanding in the difference between synchronous generators and induction type generators. It is assumed that the majority of the wind generators that the REC engineers and the engineers at the design and consulting firm that the REC subcontracts out, Stanley Consulting, is the synchronous generators. All of the generators that one would drive by on Interstate 35 when driving through Iowa are synchronous type generators. The concerns of the REC and consulting engineers would be valid if our generator was a synchronous generator. It is not, it is an induction type generator. With an induction type generator, it would be impossible for the generator to generate power if the electrical grid it is connected to is shut down since it needs reactive power from the grid before it can generate power itself. Our testing reflected this.

3.1 TESTING IMPLEMENTED

To simulate the situation that the REC most feared we disconnected the generator motor and brought it into the wind lab for testing. We did not bring in gearbox. To simulate wind power, we mounted our motor next to another motor that we will refer to as the prime mover. Different sized gears were connected to the shafts of the generator motor and the prime mover with a gear ratio of 1:1.5 with the prime mover having the larger gear. The gears were then connected by a chain. A variac was then connected to the prime mover in order to simulate varying degrees of ‘wind power’. Each of the motor leads on the generator motor were then connected to 1.2 kOhm resistors and then connected to ground. As the prime mover was then brought up to its rated voltage and synchronous speed no voltage or current was observed on the generator's motor leads.

The second test implemented was similar. The only difference is that a variac was connected to the motor leads of the generator motor and the prime mover. To start with the voltage on the secondary variac connected to the generator motor was kept at zero voltage. The variac on the prime mover was gradually turned from zero volts to its rated voltage and speed. When the secondary voltage was kept at zero there was no current observed on the generator motor leads. Only when a voltage was applied to the generator motor leads would a there be any kind of power produced.



3.2 TESTING ANALYSIS

According to our test our original hypothesis was correct and the REC engineer's fears were unfounded. Our wind turbine will not be a risk to any workmen when the grid it is connected to is de-energized.

4 Closing Material

4.1 CONCLUSION

The client Ron Zickefoose designed and is building a wind turbine on his property. That will not cause any islanding on the power grid. The wind turbine should be able to supply enough power for our client's needs, and enough to sell back to the utility. Documentation for the local utility will be provided showing the needed information to allow the wind turbine to be on the power grid. Proving that the wind turbine will not cause any islanding issues with the utility tests will be done on the induction motor used. There will be detailed research, analysis, description of the capabilities and the limitations of the induction motor provided. This research will allow for the wind turbine to be hooked up to the grid and supply power and income to our client.

4.2 REFERENCES

[1] https://en.wikipedia.org/wiki/Induction_motor
[2] https://en.wikipedia.org/wiki/Islanding
[3] http://www.alternative-energy-tutorials.com/wind-energy/induction-generator.html
[4] https://www.electrical4u.com/torque-slip-characteristics-of-induction-motor/

Appendix I: How to Build Your Own Wind Turbine on Your Own Property

Step One: *Pick a space for the wind turbine*

[1] Wind farms will place the turbines anywhere from 7 rotor diameters apart to 15 diameter lengths apart. The larger difference increases the efficiency from the wind turbines due to the disturbed air flow from the other turbines.

Building one wind turbine on your own properties you can build where you want but should keep a few things in mind.

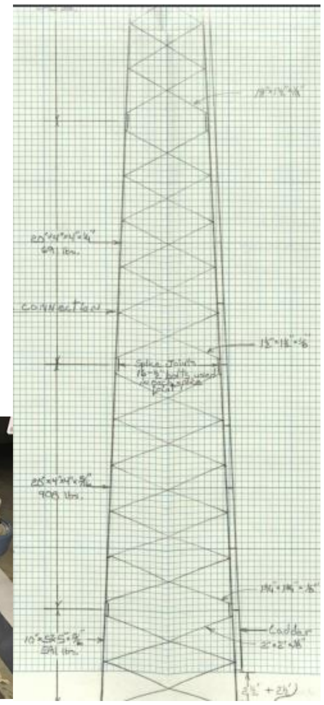
- How much noise do I mind?
    - Wind turbines do produce some sound and if your sensitive to sound you may want to place it further from your house.
- What is nearby the turbine?
    - If there are small trees nearby you may want to make sure they won't grow into the turbine
- Do I have enough room?
- How close do I want it to my house?
    - Close enough so you don't spend too much money on cabling to power the house
    - Far enough away for viewing pleasure

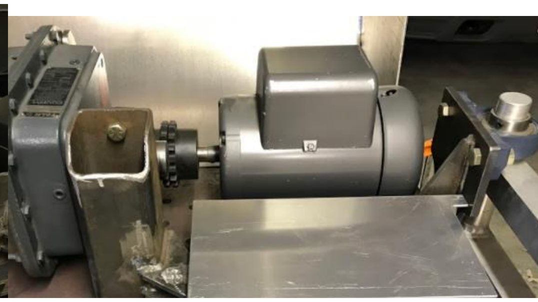
The wind turbine in our project is located 40 feet away from the nearest building. This is equivalent to

Step Two: *Design the wind turbine*

The design we used can be changed to fit the needs of the user. Our turbine is 120 ft. tall made of steel. There are three blades that at 10 feet long that are unable to pitch. The generator is a 5HP, 1PH at 60HZ motor that is created by Baldor. A gearbox with a 14.454

ratio. 





Step Three: *Buy a generator*

You want a generator that fits your needs.
Good qualities in a generator are that are helpful:

Being UL certified

This means that the generator you own is verified to do what it was made to do and is accepted by most companies as a usable product. This might be asked by the local utility company.

Think about how much energy that is wanted to be consumed.

An average home uses around 900 kW in a month.
Getting a generator that is able to produce enough to meet or exceed your demands.

Think about your budget

Make room for unforeseen expenses there will be some.
Shop around you may able to find a better deal.

Step Four: *Contact your local Utility Company*

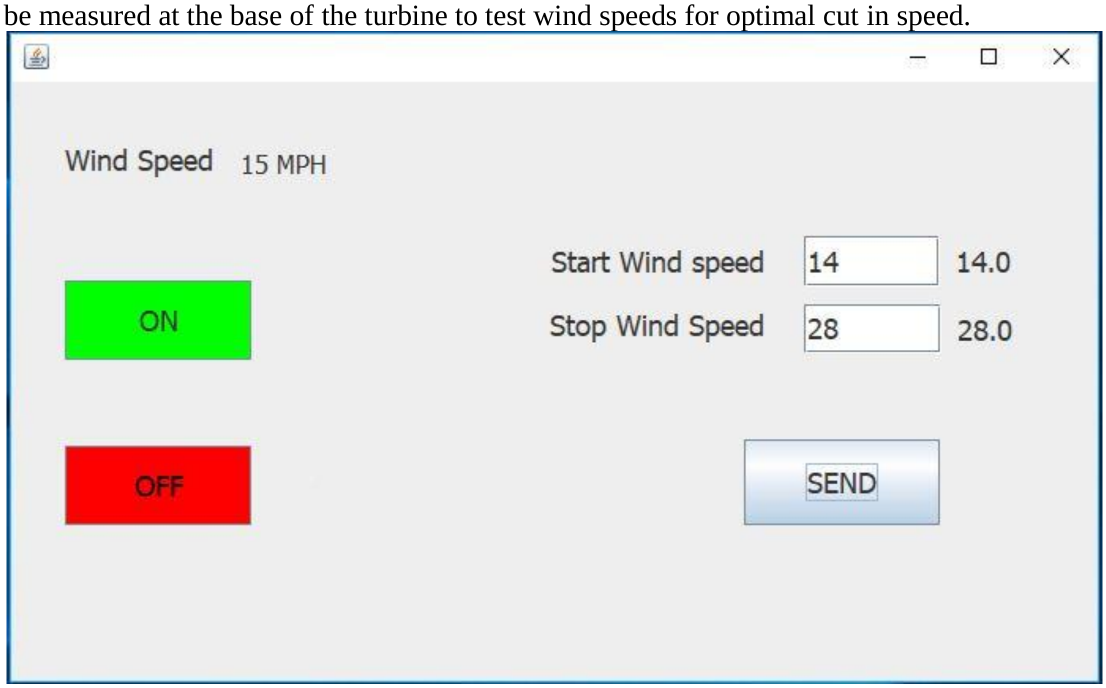
If one of your goals it to hook up to your local utility company to sell any extra energy back to the grid. There are some things to think about.

Time - The utility company will need you to prove that the system is safe to hook in to the grid.
Bureaucracy - depending on the location that is chosen. The more rural the area the more likely the checking of the system will be out source. It's best to start communication with them as soon as possible. They might have some special requirements need and find out who will be checking the system.

There is always a back-grid system if unable to get on the grid. Although you will have to make sure they system is contained and may want a power storage system as well.

Step Five: *Building a Controller Design*

When designing a controller think about what needs to be controlled. In this design we are taking in a wind and have an optimal power generation. The controls are setting a cut in and cut out wind speeds. Cut in is the lowest speed generation power more power than consumed. Where cut out is more to protect the system from damage. Spin to fast the generator or blades can be damaged. From this design power in will have to be measured at the base of the turbine to test wind speeds for optimal cut in speed.



Appendix II - Alternate Versions

Microcontroller

The current in use microcontroller is the Parallax BASIC Stamp II. As an alternate to the Parallax microcontroller board is a board designed around the ATMEGA 328-P by Microship Technology.

	Parallax	Atmega
Cost	$68	$12
Availability	1 source	Multiple Sources
Ease of Use	Complex	Easy
Programming Code	P-Basic	C Code
Size	4x3	3x2

Appendix IV: Code

The there are three languages were used in programing the microcontroller. Java was used for the GUI to set values using DIGI's XBee Java Library. Then Arduino we used the XBee-Arduino Library to communicate with the GUI and FreqMeasure was used to find wind speed. Most of the code was based off there examples of the libraries being used. The last language used is XCTU which is used to program the XBee settings.

Andrewrapp (2018) Xbee - arduino Library (Version 2) [Arduino] https://github.com/andrewrapp/xbee-arduino

DIGI (2018) XBee Java Library (Version 2) [Java] https://www.digi.com/resources/documentation/digidocs/90001438/

PJRC (2018) FreqMeasure Library [Arduino] https://www.pjrc.com/teensy/td_libs_FreqMeasure.html