The Development of a Small-Scale Vertical Axis Wind Turbine

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Introduction

Wind is an unstoppable force that can be harnessed to produce electricity and to harness this energy a wind turbine is the leading technology. Today, wind energy is one of the fastest growing renewable technologies and one of the most intriguing. With this technology, the team decided to make a vertical axis wind turbine (VAWT) for the production of electricity. This turbine has many advantages and disadvantages to horizontal axis wind turbines (HAWT). Although a VAWT is less efficient in theory with producing power per pound of wind force to a HAWT, it makes up for this disadvantage with being able to produce power at lower wind speeds, being multi directional in harnessing wind force, and being more efficient in the manufacturing of the turbine itself. An integrated alternator was chosen as the primary means of generating power because this design begins generating electricity at much lower rpm than a geared dc generator.

Figure 1: Completed Wind Turbine

Approach

To conceptualize, improve, and produce a simple and affordable home wind turbine while utilizing fresh ideas for producing electricity. When building a wind turbine, there are a wide range of options to pick from in the wind turbine industry concerning various blade, generator, and gearing designs. Different blade designs achieve varying drag and lift forces. Geared generator designs can improve power output or hinder it, and depending on the configuration, gearing losses can be avoided altogether.

With a simple rectangular blade design, the turbine has an easily manufactured frame that does not incur rotational losses due to inadequate drag force capacity. These blades follow a Darrieus design which focuses on generating drag instead of lift to rotate the turbine.

An improved integrated alternator is the most innovative design characteristic of this turbine. It consists of 24 N-42 grade rare-earth (Neodymium) magnets, 9 magnetic copper wire coils for harnessing power, and a star wiring configuration pattern for power output management. The magnets induce am electrical current in the wire coils based on Faraday's Law and the concept of magnetic induction.

Mechanical Fabrication

The turbine consists of eight 4' x 1 ½' blades which are composed of 1/8" aluminum sheeting and a 10" radius curvature. Each blade has three, 4-inch protruding flaps that align to pre-cut slots on the center rotating shaft, and is anchored to the rotating shaft by 3 set screws per flap. This blade assembly is then connected to a 2" cold-rolled steel shaft, supported by two pre-loaded tapered roller bearings.

Figure 2: Blade and Center Rotating Shaft Assembly

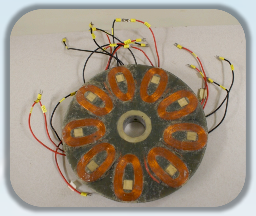

Figure 3: 16 Gauge Coil Plate

Figure 4: Dual Magnet Plates

Electrical Fabrication

Several wire coil designs were built and tested individually to compare the voltage output potential of various wire gauges and coil orientations. From these results, 25 gauge wire was deemed adequate and a coil plate was made using a resin mold for protection and stability. After more testing, a second coil plate of 16 gauge wire was created for comparison. These and any new coil plates can be interchanged on the turbine for testing new configuration ideas at various wind speeds.

Through extensive research & testing, it was found that a dual magnet configuration would be the most efficient for this design. This configuration consists of two plates (identical in size, shape and magnet layout) facing each other, with the coil assembly sandwiched in-between so that it receives the effects of two sets of magnets. The magnets have a north-south-north configuration on one plate while the other plate has a south-north-south configuration causing an attraction and realignment of the magnetic fields between the plates.

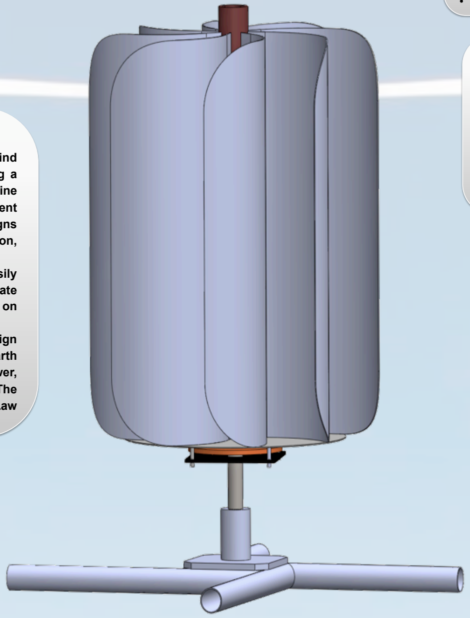

Figure 5: SolidWorks Model of the Turbine

Conceptual Modeling

In figure 6, the factor of safety was taken into account for the final turbine blade at 55 mph. This is important to check, to ensure the blade could withstand high winds.

In figures 7 & 8, the velocity profile of a 20 mph wind flowing into and against the blade is shown. The average force for this wind speed produced 10.25 lb and 4.22 lb into and against the blade with drag coefficients at 1.54 & 0.64.

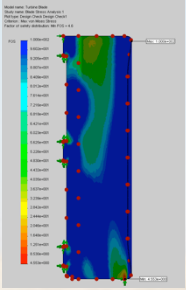

Figure 6: Factor of Safety of the Turbine at 55 MPH In CosmosWorks

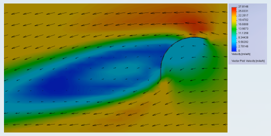

Figure 7: CFD Results For A 20 MPH Wind Into The Blade In CosmosFloWorks

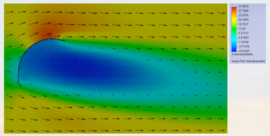

Figure 8: CFD Results For A 20 MPH Wind Against The Blade In CosmosFloWorks

Objectives

- Produce a working, scalable model of an efficient and durable home wind turbine
- Design and build an easy to manufacture turbine blade for the limited resources at hand
- Perfect an improvised integrated alternator that circumvents energy losses associated with direct gearing to an external generator.
- Generate 250 W at a average wind speed of 20 mph.

Results

The finished turbine stood 6'6" tall with a 3'4" blade diameter. The turbine was tested in the lab as well as in the field to determine a superior wiring configuration and quantify the effects of electrical loading. The turbine blade design was investigated independently using the Computational Fluid Dynamics analysis tools available in COSMOSFloworks, and the Factor Of Safety distribution was plotted using COSMOSWorks. The pressure distribution plot aids in visualizing air pressure deviations surrounding the blades.

The team designed an alternator that could be tested with multiple three phase configurations. Ultimately, a star configuration was chosen to achieve higher voltage production at low rpm. Both coil plates sustained consistent voltage output at several rpm, but the 16 gauge plate was utilized for further testing due to a lower back-emf and increased current capacity. Data is provided below in summarized form for clear interpretation.

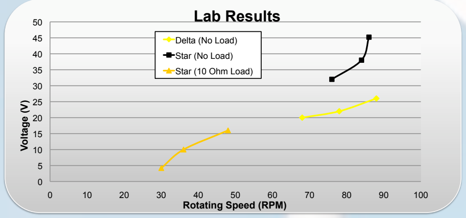

Figure 9: Investigation of Delta, Star Configurations and Loading Effects

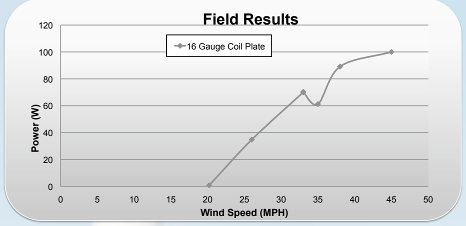

Figure 10: Field Results at Varying Wind Speeds

Conclusion

As evidenced above, the star no-load wiring configuration is superior to delta at low rpm. It can also be seen that the attachment of a ten Ohm load greatly reduced the rpm of the turbine. This was expected due to the back-emf present in the alternator and therefore increased rotational resistance. In the field, power output increased greatly with air velocity, and seems to reach a maximum near 45 mph. Continued high-velocity testing would clarify this hypothesis.

The FOS distribution is very good, with a maximum of 100 at the outermost tip of the blade, and a minimum of 4.6 at the bottom, outside edge of the blade where a small aluminum L-bracket is located for stability purposes. During field testing, briefly after the turbine produced an output of 100 Watts, this small bracket fractured—supporting the FOS prediction.

The pressure distribution results clearly evidence the presence of large low-pressure regions behind the blades, and high-pressure regions near the tip. Air flow direction vectors plainly identify the path of travel of the air moving around the blade.

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