Efficiency of Propeller Design on Wind Turbines

A Science Paper

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By
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Abstract

This project studied the effects of propeller design on the amount of energy produced. A wind turbine was fitted with a turbine vane with 2 scoops, 4 scoops, and 6 scoops. The amount of voltage produced by each design was then measured and recorded. The average amount of volts produced by the turbine with 2 scoops was .0439 volts. The average amount of energy produced by the turbine with 4 scoops was .0514 volts. The average amount of energy produced by the turbine with 6 scoops was .1319 volts. The probability of the results, assuming the null hypothesis was 0.000. The hypothesis stated that if the design of propeller on wind turbines changes, then the amount of energy produced changes. Based on the observations, the data, and the statistical analysis applied, the hypothesis was accepted.
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Introduction to Statement of Problem

Electricity is a major source of power in the United States. This major source of power is used for powering houses and businesses. Electricity is produced in many different ways. One way electricity can be produced is by electromagnetism which is using magnets that rotate over solenoids to produce electricity (History of Modern Math and Science, 2007). Electromagnetism can be produced by wind turbines.

Wind power is spreading across North America and the Middle East. This is the process in which wind is used to rotate propellers. The power from the wind rotates the yaw drive and causes magnets to circle over solenoids and this process produces an electric current (Wind Turbines: How Many Blades, 2003). Wind power is a very efficient way to produce energy because it doesn’t damage the environment or use any fossil fuels. This information and an interest in physics led to the following problem statement:

**Does the propeller design on wind turbines affect the amount of energy produced?**
Review of Literature

The world is running out of fossil fuels and fast. If people do not find another source of energy the world could change completely. There would not be any television, phones, or cars. People would have to find other things to do, such as play outside and ride bikes to work. The human race needs to find another source of energy, wind power. One way wind can be turned into mechanical power is by the use of wind turbines.

Wind turbines are machines that do not need any fossil fuels to produce electricity. The only thing wind turbines need to produce electricity is wind. Wind is caused by uneven heating of the atmosphere, irregularities of the Earth’s surface, and the rotation of the Earth (Wind and Hydropower Technologies Program, 2006). All wind turbines use this movement to drive the propellers on the wind turbines. Wind turbines can be made with a horizontal or a vertical axis. A horizontal axis wind turbines are the most common. These forms of wind turbines are also known as H.A.W.T.’s. H.A.W.T.’s are wind turbines that look like windmills. Another form of wind turbines are vertical axis wind turbines, or V.A.W.T.’s. V.A.W.T.’s look like giant scoops (Wind Turbines: Horizontal or Vertical Axis, 2003). A Savonius wind turbine has two scoops and is a vertical axis wind turbine. A Darrieus wind turbine is always facing the wind and never needs to be turned because they are horizontal axis. One thing that all wind turbines have in common is that all wind turbines have scoops or propellers used to catch wind.

There are many different styles of propellers, all of which are used for the same purpose. The propellers catch wind to rotate the yaw drive and the solenoids, which are tightly wound wires to produce electricity. Some propeller designs are one propeller, two propeller, three propeller, and scoops on vertical axis wind turbines. One propeller turbines aren’t very wide
spread commercially. One propeller turbines also require a counterweight on the opposite side of
the propeller to balance out the weight of the single propeller (Wind Turbines: How Many
Blades, 2003). Two propeller turbines are also not very wide spread on a commercial basis. The
reason being is because of a higher rotational speed and the higher speed also causes more noise
than three propellers or scoops. Three propeller designs are the most commercially wide spread.
This design is quieter because of an object called a yaw mechanism. The yaw mechanism is used
to keep the propellers at an idle no matter how fast the wind speed is. The scoop design allows
the wind turbine to attain wind from any direction. The scoops are also called vertical axis
propellers. The scoops have an opening in the center to allow wind to flow through and help the
scoop spin around the rest of the way so the other scoop can catch wind. All of these propeller
designs help the wind turbines catch wind to produce electricity (Clifford, 2008).

Electricity is used in many ways such as powering homes and businesses (McGrath,
2007). Transportation is also using electricity such as subways and now in the twenty-first
century, cars are also becoming hybrid and using electricity to power their motors. Electricity
can be produced in many ways as well. One way to produce electricity is by using steam (Parker,
2005). Another way to produce electricity is by electromagnetism. Electromagnetism is the
process in which electricity is produced by magnetism (Eagen, 2008). This occurs when magnets
spin over solenoids to produce an electric current. Electromagnetism is the way wind turbines
produce electricity (Baigerie, 2008).

The first step in creating energy from wind is by transforming the wind’s kinetic energy
into mechanical energy (Argrow, 2008). This step happens inside of a wind turbine. Inside of a
wind turbine is a mechanism called a yaw drive. This drive is like an axle in a car, the wind is
like the engine which makes the drive turn, in turn makes the magnets in the wind turbine turn.

The yaw drive is attached to the propeller or scoops (Clifford, 2007). When the wind blows against the propellers, the yaw drive rotates and spins over the top of the solenoids to produce an electric current. The electric current is then sent into the generator to produce an alternating current. This current is then retrified into a direct current to be able to work in transformers and homes (Hertz, 2007). So after all of the steps it takes for a wind turbine to produce electricity the energy can finally be used in people’s homes and business offices.
Hypothesis

If the design of propellers on wind turbines changes, then the amount of energy produced changes. According to the Danish Wind Industry Association, an industry that researches wind turbine designs, says that if turbine designers add or increase the size of wind turbine propellers or scoops the wind turbine will catch more wind and turn more easily and maintain top maximum speed more constantly. The wind turbine with six scoops should produce more energy. The null hypothesis is that the design of wind turbine propellers will not affect the amount of energy produced.
Experimental Design

Problem Statement: Does propeller design on wind turbines affect the amount of energy produced?

Independent Variable: Propeller design on wind turbines

Dependent Variable: Amount of energy produced

Control Group: None defined, true comparison

Retests: Ten retests for each propeller design on the wind turbines

Constants: The same wind speed

The same method of measuring electricity

The same time exposed to wind

The same height of propellers

The same temperature of air

The same materials used to build propeller

Quantitative Measure: The amount of energy produced in volts
Materials

- Wood glue
- Corrugated cardboard
- Plywood
- Three 30 centimeter X 6 millimeter dowel rod
- Wood screws
- Voltmeter with probes
- Magnet wire
- Screwdriver
- Hot glue gun
- Scissors
- Utility knife
- Electrical tape
- Ruler
- Sand paper
- Four rare earth magnets
- Push pins
- Anemometer
- Regular house fan
- Four 1.5 liter bottles
Procedure

1. Cut two circles out of plywood with a 10.5 centimeter diameter.
2. Cut a strip of cardboard that measures 11 centimeters by 1.5 centimeters.
3. Cut two separate triangles with bases of 11 centimeters and a height of 15 centimeters.
4. Attach the strip of cardboard to the top of each triangle with hot glue.
5. Attach this base to a square cardboard platform that measures .4 meters on all sides.
6. Cut a cardboard strip that measures 8 centimeters by 4 centimeters and fold it in half and tape it together tightly, then wrap 24 gauge magnet wire around it 200 times leaving 5 centimeter leads, forming a solenoid.
7. Apply electrical tape, but just enough to hold the solenoid together leaving the 5 centimeter leads open.
8. Repeat steps seven and eight until there are four completed solenoids.
9. Glue the solenoids to one of the 10.5 centimeter discs as evenly as possible.
10. Take one of the 1.5 liter bottles and cut it in half height wise from top to bottom.
11. Position them so that the halves are shifted a quarter of the bottle out forming an “S” shape and place the “S” on a piece of cardboard and trace it twice.
12. Cut the traced pieces out and hot glue it to the bottom and top of the “S”.
13. Stick a dowel rod through the exact center of your wind turbine vane.
14. Attach the 10.5 centimeter disc without the solenoids on it to the dowel rod.
15. Run the dowel rod directly through the center of the turbine vane and wooden
disc.

16. Glue four rare earth magnets to the disc using hot glue and place the magnets to where the magnets rotate over the top of the solenoids.

17. Place the wind turbine vane onto the base platform but do not attach it with anything or the turbine will not spin properly.

18. Plug the house fan into an outlet and sit it next to the wind turbine and turn the fan on.

19. Attach the voltmeter to the 5 centimeter leads off of the solenoids.

20. Take measurements for the amount of volts produced.

21. Repeat steps 11 to 17 except cutting the bottle into fourths and for the last time, sixthths.

22. Form a “+” shape with the fourths and a “*” shape with the sixthths.

23. Then run a dowel rod through the center of each vane and attach the disc already with the magnets glued to the wood.

24. Repeat steps 17 to 20 for each test group and take measurements.
Results

The average amount of energy produced for the two scoop wind turbines was .0439 volts. The average amount of energy produced for the four scoop wind turbines was .0514 volts. The average amount of energy produced for the six scoop wind turbines was .1319 volts.

The median for the two scoop wind turbine was .0385 volts. The median for the four scoop wind turbine was .0495 volts. The median for the six scoop wind turbine was .1195 volts.

The range for the wind turbine with two scoops was .054 volts. The range for the wind turbine with two scoops was .034 volts. The range for the wind turbine with six scoops was .158 volts.

It was observed that the wind turbine with six scoops rotated nearly twice as fast as the wind turbine with two scoops. It was also observed that the wind turbine with two scoops rotated under control and stayed moving very smoothly and fluidly.
Figure 1: Data Table
The Effects of Propeller Design on the Amount of Energy Produced in Volts

<table>
<thead>
<tr>
<th>Retests</th>
<th>Number of Scoops</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Two Scoops</td>
<td>Four Scoops</td>
<td>Six Scoops</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>.085</td>
<td>.062</td>
<td>.126</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>.059</td>
<td>.064</td>
<td>.249</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>.031</td>
<td>.040</td>
<td>.113</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>.037</td>
<td>.069</td>
<td>.140</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>.032</td>
<td>.065</td>
<td>.171</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>.042</td>
<td>.056</td>
<td>.091</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>.038</td>
<td>.039</td>
<td>.104</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>.035</td>
<td>.041</td>
<td>.095</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>.039</td>
<td>.035</td>
<td>.136</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>.041</td>
<td>.043</td>
<td>.094</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>.0439</td>
<td>.0514</td>
<td>.1319</td>
<td></td>
</tr>
<tr>
<td>Median</td>
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<td></td>
</tr>
<tr>
<td>Range</td>
<td>.0540</td>
<td>.0340</td>
<td>.1580</td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>.0164</td>
<td>.0129</td>
<td>.0482</td>
<td></td>
</tr>
</tbody>
</table>
Figure 2: Individual Graph
The Effect of Propeller Design on the Amount of Energy Produced
Figure 3: Mean Graph for the Effect of Propeller Design on the Amount of Energy Produced
Figure 4: Median Graph
The Effect of Propeller Design on the Amount of Energy Produced
Statistical Analysis

The statistical analysis applied to the data was A.N.O.V.A. This was chosen since more than two test groups were used. The probability assuming the null hypothesis is 0.000. The value indicates the design of propellers on wind turbines did have a significant effect on the amount of energy produced.
Conclusion

The hypothesis stated that if the design of propellers changed, the amount of energy produced would change. The hypothesis was accepted. The data collected showed that the wind turbine with six scoops produced more electricity. This indicates that the design of propellers on wind turbines does affect the amount of energy produced.

A possible explanation could be that the greater the area the scoops have, the more wind the scoops will catch and the magnets will turn rotate quicker and pass over the solenoids more often. Implying this information, the six scoop turbine had more surface area and did in fact rotate quicker.

This information, along with further study could lead to a greater expanse of wind turbines with six scoops instead of the original, and more common, two scoops. Due to the need for alternative energy being such a large priority people believe this study should be more closely studied. Other things like temperature, the Earth’s rotation, and wind speed also may affect the energy production of six scoop wind turbines. Six scoop wind turbines have not been produced in great numbers and still remain in an experimental stage. The research performed in this project could show engineers that six scoop turbines should be seriously considered for production.
Future Study

Some ideas for furthering this study:

1. Does the direction of the axis on a wind turbine affect the amount of energy produced?
2. Does the speed of wind affect the amount of energy produced?
3. Does the amount of coils in a solenoid affect the amount of energy produced?
4. Does the gauge of wire used to make solenoids on a wind turbine affect the amount of energy produced?
Acknowledgements

This science fair project wouldn’t have been possible without help from Ms. Schumacher and my parents. I’d like to say thanks. This project wouldn’t have been able to come together without my mom’s help and proofreading. Thank you to the judges for judging this project.
Appendix A

**Electromagnetism**: Form of producing electricity by rotating magnets over solenoids

**H.A.W.T.**: Horizontal axis wind turbine

**Kinetic Energy**: The energy of a body resulting from its motion

**Mechanical Energy**: The sum of kinetic energy and potential energy of large scale objects in a system

**Potential Energy**: Energy that is stored in matter because of its position or because of the arrangement of its parts

**Solenoids**: Tightly wound magnet wire in which the electricity is produced

**V.A.W.T.**: Vertical axis wind turbine

**Volt**: One joule per coulomb

**Wind Turbine**: A machine that catches wind to rotate propellers and use the kinetic energy from the wind to inertia of the propellers to create mechanical energy (volts)
Appendix B: Pictures/Illustrations
Appendix C: Statistical Printout

The results of an ANOVA statistical test performed at 10:33 on 19-NOV-2008

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>d.f.</th>
<th>Mean Squares</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>between</td>
<td>4.7602E-02</td>
<td>2</td>
<td>2.3801E-02</td>
<td>25.80</td>
</tr>
<tr>
<td>error</td>
<td>2.4906E-02</td>
<td>27</td>
<td>9.2245E-04</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>7.2508E-02</td>
<td>29</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The probability of this result, assuming the null hypothesis, is 0.000

**Two Scoops:** Number of items= 10

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3.100E-02</td>
<td>3.200E-02</td>
<td>3.500E-02</td>
</tr>
<tr>
<td>3.700E-02</td>
<td>3.800E-02</td>
<td>4.100E-02</td>
</tr>
<tr>
<td>4.200E-02</td>
<td>5.900E-02</td>
<td>8.500E-02</td>
</tr>
</tbody>
</table>

Mean = 4.390E-02
95% confidence interval for Mean: 2.4193E-02 thru 6.3607E-02
Standard Deviation = 1.641E-02
Hi = 8.500E-02 Low = 3.100E-02
Median = 3.850E-02
Average Absolute Deviation from Median = 9.300E-03

**Four Scoops:** Number of items= 10

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3.500E-02</td>
<td>3.900E-02</td>
<td>4.000E-02</td>
</tr>
<tr>
<td>4.100E-02</td>
<td>4.300E-02</td>
<td>5.600E-02</td>
</tr>
<tr>
<td>6.200E-02</td>
<td>6.400E-02</td>
<td>6.500E-02</td>
</tr>
<tr>
<td>6.900E-02</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean = 5.140E-02
95% confidence interval for Mean: 3.1693E-02 thru 7.1107E-02
Standard Deviation = 1.299E-02
Hi = 6.900E-02 Low = 3.500E-02
Median = 4.950E-02
Average Absolute Deviation from Median = 1.180E-02

**Six Scoops:** Number of items= 10

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9.100E-02</td>
<td>9.400E-02</td>
<td>9.500E-02</td>
</tr>
<tr>
<td>0.104</td>
<td>0.113</td>
<td>0.126</td>
</tr>
<tr>
<td>0.136</td>
<td>0.140</td>
<td>0.171</td>
</tr>
<tr>
<td>0.249</td>
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<td></td>
</tr>
</tbody>
</table>

Mean = 0.132
95% confidence interval for Mean: 0.1122 thru 0.1516
Standard Deviation = 4.826E-02
Hi = 0.249 Low = 9.100E-02
Median = 0.119
Average Absolute Deviation from Median = 3.250E-02
Works Cited Page


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Eagen, Kent. Personal Interview. 4 Oct 2008.


