Physics and Math of Energy
Spring 2010

Wind Power Lab

Part 1: Blades

Background:
The Betz Limit says that 59% of the power in the wind can be harnessed with a wind turbine. However, in reality, turbines have other imperfections that render their actual performance much lower (25-45%). Every turbine comes with a Power curve, which shows the power output verse the wind speed. Below is the power curve for the Skystream 3.7 turbine that is at Beech Hill Farm. Blade design has a huge impact on a turbine's performance. In this lab we will explore some of the variables that affect how much energy the blades can "capture". These variables include: Length, Number, Weight/material, Pitch/Angle, Shape, Material, and Wind Speed. In addition to testing variations with wind speed, you will design your blades to test one of other of these variables.

Purpose: To investigate how the blade design impacts the power output

Procedure:
1. Build the turbine housing unit using the largest gear.
2. Decide which variable that you are going to test with your blade design.

   Material: two duplicate sets of different materials
   Shape: two sets that are shaped differently but have the same length
   Size: two different sized sets of the same material

3. Design your first set of blades.
4. Test Blades according to blade experiment sheet
5. Design your second set of blades.
6. Test Blades according to blade experiment sheet

Name ________________________ **Blade Experiment Sheet**

Partners' names ____

What variable will you test for your experiment? __________________________

Describe how you will perform this experiment. BE SPECIFIC! What materials will you use, how many times will you test, how will you change your variable, how will you record output. **Use another sheet if necessary!**

Important!! What things do you have to keep the same (constant) as you perform this experiment?

Make a prediction! What do you think will happen as you change your variable?

Testing:

1. Measure maximum wind speed
2. Set up turbine and measure Voltage – note polarity, a negative reading on your meter means that the positive and negative terminals are swapped.
3. Attach light bulb or LED (polarity matters)
4. Measure maximum Current – be sure to put the meter in-line with the bulb NOT across it.
5. Measure maximum Voltage
6. Reduce wind speed and measure it
7. Repeat steps 4-6 until turbine stops spinning (try to get 5 readings if possible).
8. Replace turbine blades with second set.
9. Repeat 1-7

Data Tally Sheets

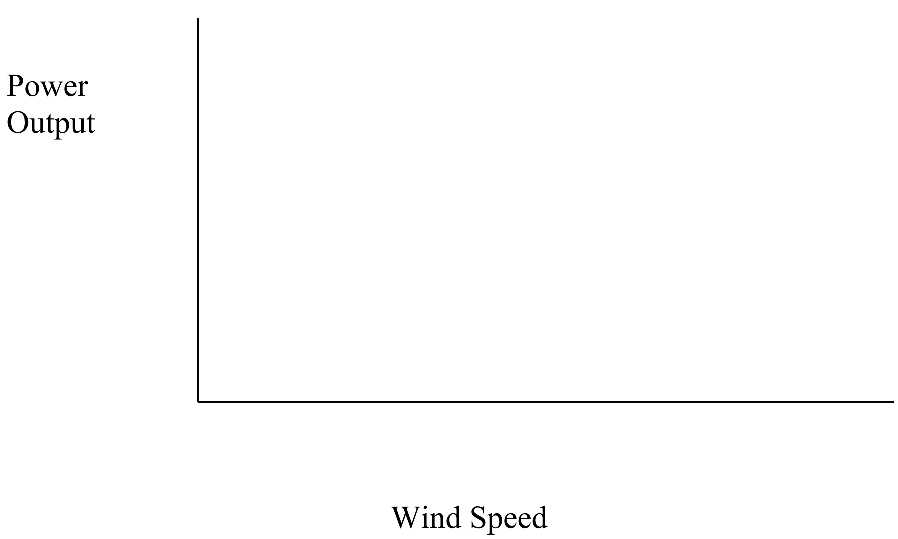
Variable One = _____________

Trial #	Wind Speed	Voltage (V)	Amperage (A)	Power (VxI)
1				
2				
3				
4				
5				

Variable Two = _______________

Trial #	Wind Speed	Voltage (V)	Amperage (A)	Power (VxI)
1				
2				
3				
4				
5				

Make a quick graph of your data for one of the data sets:



Questions for Part 1:

How did the voltage/amperage/wattage change as a result of manipulating your variable?

Do you think that your variable has a large or small effect on power production?

What was the optimal setting for the variable that you tested?

If you were a lead design engineer what would you recommend your company do to their turbine blades? Why?

What problems did you encounter as you performed your experiments? What other variable was it hard to hold constant?

Part 2: **Gear Ratio Experiment (from Kid-wind documentation)**

Background

Last week you learned about the way an electric generator works: A coil of wire is rotated in a magnetic field to create a flow of electrons. This is the basis of how a wind turbine makes electricity. The blades spin, causing a driveshaft to spin, which in turn rotates the coils in the generator.

The problem is that to make the type of electricity we use every day, the generator has to spin VERY fast. To simplify, the faster the coils rotate near the magnet, the more electrons will be pushed along.

If you've seen a real utility-scale wind turbine, you probably noticed that the blades spin pretty slowly. So how do they get the generators to spin fast enough? They do this by using gears. You have probably used gears on a bicycle before, so you know how they work. Gears give a wind turbine a *mechanical advantage.* This means that they multiply the mechanical force of the turning blades. This is done by using gears with different numbers of teeth. When the larger gear makes one full revolution, the smaller gear has to spin faster to keep up.

A "Gear ratio" is the relationship between the number of teeth on two or more gears that are meshed. So when you ride your bicycle, the gear in front might have 48 teeth, while the gear in back has 16 teeth. That would mean every time your pedals spin around once, the back wheel spins three revolutions (48/16 = 3). This is called a 3 to 1 (3:1) gear ratio. Wind turbines work the same way except that they have much larger gear ratios. A modern wind turbine may have a gear ratio of 100:1 or more. So every time the blades make one revolution, the generator shaft spins 100 times!

Purpose:

To test how the gear ratio impacts the turbine performance.

Procedure:

Make a prediction! What do you think will happen when you change to a smaller gear?

Testing:

1. Replace turbine gear with 2nd largest gear.
2. Choose the your best set of blades.
3. Set up turbine and measure Voltage – note polarity, a negative reading on your meter means that the positive and negative terminals are swapped.
4. Attach light bulb or LED (polarity matters)
5. Measure maximum wind speed
6. Measure maximum Current – be sure to put the meter in-line with the bulb NOT across it.
7. Measure maximum Voltage
8. Reduce wind speed and measure it
9. Repeat steps 3-8 until turbine stops spinning (try to get 5 readings if possible).
10. Remove light and try attaching a water pump to the output and/or other loads (ask me about this)

Data:

Variable ____________ Medium Gear

Trial #	Wind Speed	Voltage (V)	Amperage (A)	Power (VxI)
1				
2				
3				
4				
5				

Questions for part 2:

How did the voltage/amperage/wattage change as a result of the smaller gear?

Do you think that the gear ratio has a large or small effect on power production?

What are the pros and cons of different gear ratios?

What happened when you attached the water pump or other load? Did it pump work? Did it change the performance of the turbine? If so how? Why ?

What problems did you encounter as you performed your experiments?

Part 3: Resistive Load

Background

When a load is placed on a generator it slows down. This relates to electromagnetic phenomena. When the rotor turns, it cuts through the magnetic field generated by the stator, producing a current running through the rotor and the electrical device. The current in turn causes the rotor to produce a magnetic field that contrasts that of the stator, inhibiting rotation. The more intensive the current, the larger the inhibition. When the load increases, the current also increases, making it harder to turn the alternator. This phenomenon is consistent with the law of energy conservation: you have to work more to produce more electricity. Power can be measured by dividing the resistance of the load into the square of the voltage.

$P = VI$ $V=IR$ $P = V^2/R$

Purpose:

To test how a turbine reacts to various loads

Procedure:

Make a prediction! What do you think will happen when you put a large load (high resistance) on the turbine? What about a small load (low resistance)?

1. Measure each of your three resistors.
2. Remove the light bulb
3. Start the fan on the highest setting and measure the wind.
4. Measure the voltage.
5. While turbine is still running attach the highest resistor.
6. Record your observations and the voltage
7. Remove resistor – let the turbine free-run again
8. Repeat 5-7 for the other resistor values.

Data:

Wind Speed =

Trial #	Resistor (ohms)	Voltage (V)	Power (V^2/R)	Observations
1				
2				
3				
4				

How did the voltage/wattage change as a result of different resistive loads?

Can you explain in your own words why you saw these results? How do they apply to real world applications?

What problems did you encounter as you performed your experiments? What other variable was it hard to hold constant?

Make a graph of Power vs. Resistance.

Part 4: **Wind Turbine Blade Competition**

Design Team ______________

Details: The ***WindNRG Corporation*** needs a team of wind engineers to design and build a set of blades for their new wind generator. These blades must be durable, quiet and effective at converting the energy of the wind into electrical energy.

Competition
Each blade set will be tested at high and low wind speeds for 30 seconds. Power output will be calculated and averaged. The team with the highest average output will be the winner.

Design Questions
How many blades do you plan to place on your hub? __________________

How long are you going to make these blades? __________________

Which Gear Ration will you use? ____________________

After your first test what modifications did you make to the blades? Why did you make these modifications?

Final design

How many blades ________

Length of Blades ________ (cm)

Width of Blades ________ (cm)

What materials did you use to make your blades?

Individual Power Data
Average Power Output (High & Low) _________________________

High Wind Speed	Voltage =	Current =	Power Output =
Low Wind Speed	Voltage =	Current =	Power Output=

QuickTimeø and a
decompressor
are needed to see this picture.

Class Data

Which blades seemed to perform the best?

Why do you think that they did well?

How would you change your blades to perform better?

NICE JOB! You are done with your work!

QuickTime□ and a
decompressor
are needed to see this picture.

High Wind Speed Voltage ______ Amperage ______ Power Output ________
Low Wind Speed Voltage ______ Amperage ______ Power Output ________