WindPitch Wind Turbine Experiment-
Output Power and Efficiency

EXPERIMENT OVERVIEW

This experiment will determine the efficiency factor (E) of the WindPitch wind turbine based on wind speed and RPM using both a 100 ohm and 50 ohm load.

EXPERIMENT OBJECTIVES

- Students will use the Scientific Process to perform the experiment.
- Students will learn about how blade pitch alone produces different power outputs from the wind turbine.
- Students will come to understand that increasing blade pitch using only one fan speed and one resistive load may decrease the wind turbine's power output.

WIND POWER EQUATION PREREQUISITE

Students must be familiar with the Wind Power Equation that precedes this experiment.

SAFETY

Caution must be exercised when using the wind turbine and table fan. Spinning blades can pose a hazard and can cause injury if not careful. DO NOT PLACE YOUR FINGERS, HANDS, ARMS, FACE OR ANY OTHER PART OF YOUR BODY IN THE SPINNING WIND TURBINE OR FAN BLADES!

Wear safety glasses for all experiments

PREREQUISITES

- Read and understand the WindPitch Education Kit instructions including:
    - Component Parts
    - Assembly
    - Blade Installation
    - Blade Pitch Adjustment
    - Electrical Connections

EQUIPMENT

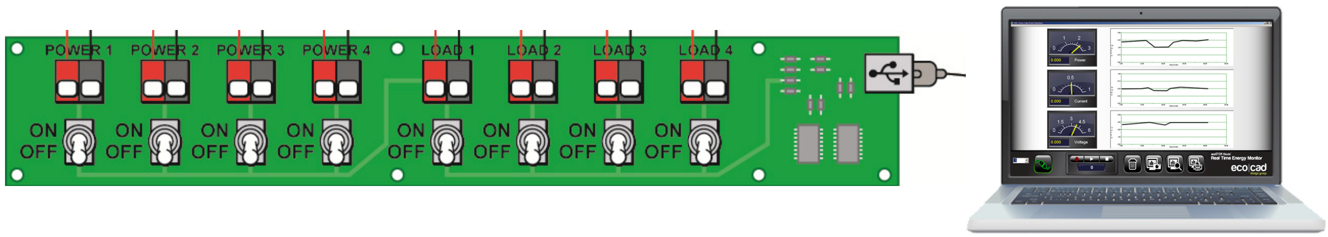
- Control Panel
- Computer running the ecoCAD Real Time Energy Monitoring software
- WindPitch wind turbine with 3 BP-28 profile blades
- Student built flat or profiled blades where available
- Large Table or Floor Fan (at least 16" in diameter with 3 speeds)
- General Technologies model TA105 infrared laser tachometer
- La Crosse model EA-3010U handheld anemometer.
- Two(2) 100 ohm fixed resistors
- Printer

EXPERIMENT SETUP

1. The Control Panel should be connected to the computer with the graphic software running to perform the experiment. All the switches should be OFF.

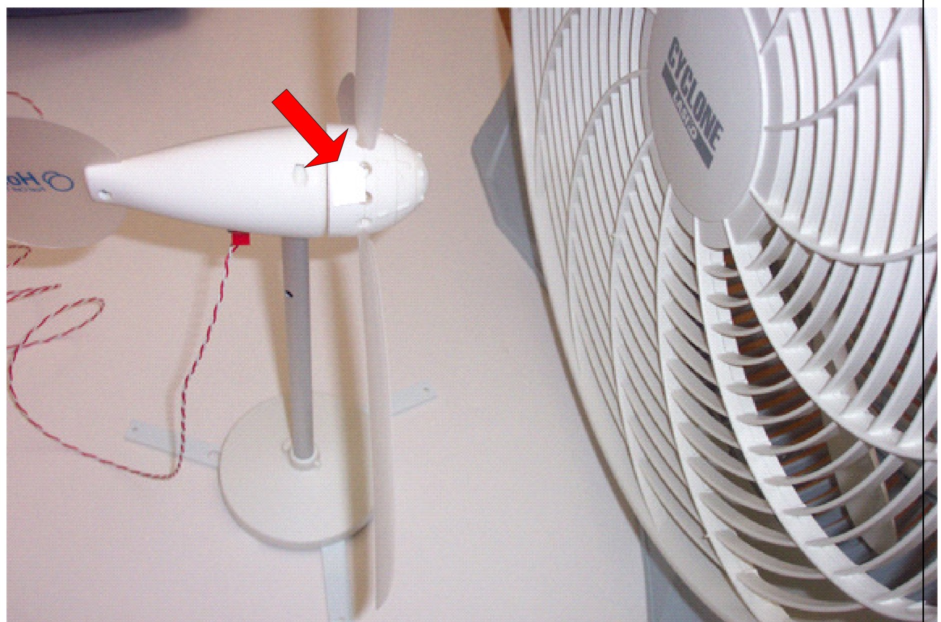
2. Insert a 100 ohm resistor into both the **Load 1** and **Load 2** terminals. Polarity does not matter.

3. Attach the WindPitch electrical output terminals to the **Power 1** terminals on the Control Panel. You will need to acquire a length of 2 conductor wire to make the connection between the WindPitch and the Control Panel. Wire the Red terminal on the WindPitch to the Gray or Red terminal on **Power 1** and the Black terminal on the WindPitch to the Black terminal on **Power 1**.



DOING THE EXPERIMENT

1. Set the table or floor fan as close as possible to the wind turbine blades. **MAKE SURE THAT THE WIND TURBINE BASE IS SECURE AND CAN'T MOVE. USE A BOOK OR OTHER OBJECT TO HOLD IT IN PLACE BEFORE TURNING THE FAN ON.**



2. Cut a ½" square section of reflective tape and apply it to the side of the WindPitch blade hub just behind the blades.

3. Setup the WindPitch wind turbine with two (3) BP-28 blades.

4. Adjust the blade pitch angle to $15^{o.}$

5. Switch ON the wind turbine (**Power 1**) and the first 100 resistor (**Load 1**).

6. Set the fan to its highest speed setting.

7. Measure and record the wind speed in meters/second.

8. On the tachometer set the RPM / TOT button to RPM.

9. Aim the tachometer at the reflective tape and push the Measurement Button on the side. A red dot will appear on the rotating hub and RPM reading should appear on the display.

10. Measure and record the RPM.

11. Clear the computer screen by clicking on the Trash can icon.

12. Click the Screen Capture icon to record the power being consumed by the 100 ohm resistor load.

13. Switch ON the second 100 ohm resistor (**Load2**). Now both resistors are in parallel and the total resistance is 50 ohms.

14. Measure and record the wind speed in meters/second.

15. On the tachometer set the RPM / TOT button to RPM.

16. Aim the tachometer at the reflective tape and push the Measurement Button on the side. A red dot will appear on the rotating hub and RPM reading should appear on the display.

17. Measure and record the RPM.

18. Clear the computer screen by clicking on the Trash can icon.

19. Click the Screen Capture icon to record the power being consumed by the 50 ohm resistor load.

20. Turn the fan OFF.

Analysis

The power is nearly the same for both the 100 ohm load and 50 ohm load. However, in our tests the speed of the wind turbine blades (not the wind speed generated by the fan, which remained the same) has decreased with the added load. This may reveal differences in the wind turbine's ability to generate power based on the fixed wind speed of the fan.

Power (watts)	RPM / load	Wind Speed (m/s)
0.094	1052 (100 ohms)	3.33
0.092	952 (50 ohms)	2.75

To determine the efficiency factors for the above two sample start with the following equation for wind turbine power:

$$P = 0.5*\rho*A*V^3*E$$

where:

P = Power in Watts
ρ= Air Density in Kg/m^3 (about $1.225 Kg/m^3$ at sea level, less higher up)
A = Rotor Swept Area in $m^2 = \pi r^2$ (r= radius of the rotor)
V = Wind Speed in m/s (cubed)
E = Efficiency in percent

Based on a blade length of 6 inches (radius = 0.1542 meters) it can be stated that the Rotor Swept Area equals 0.0073 m^2. It can also be stated that the measurements were taken exactly at sea level so the air density is $1.22 Kg/m^3$.

Solving for efficiency (E) we have:

$$E = P / (0.5*\rho*A*V^3)$$

<u>1052 RPM & 100 ohm load</u>

$E = 0.094 / (0.5 * 1.225 * 0.0073 * 3.33^3)$
$E = 0.094 / 0.165$
$E = 0.56\ \%$

<u>952 RPM & 50 ohm load</u>

$E = 0.092 / (0.5 * 1.225 * 0.0073 * 2.75^3)$
$E = 0.092 / 0.093$
$E = 0.98\ \%$

By the formula above, the power output is increased by the cube of the wind speed, so performing this and the other experiments with lower and higher wind speeds will result in different efficiencies.   You are encouraged to do so.

Another factor to be considered in terms of power generation is torque.

For a DC motor the torque is proportional to the magnetic field cut by the motor coils, and the strength of the magnetic field is proportional to the current passing through the coils. Thus the motor torque is proportional to the input current. However, the motor torque of the motor is inversely proportional to the rotational speed of the motor.

The same theories that apply to a motor also apply to the WindPitch 3-phase alternator. Thus, when more load (50 ohms versus 100 ohms) is applied to the alternator, the alternator's torque increases. With the wind force applied to the alternator being kept constant the rotation speed is reduced to compensate for the increased load.

More about torque can be found at the following websites:

http://www.physics.uoguelph.ca/tutorials/torque/Q.torque.intro.html

http://auto.howstuffworks.com/auto-parts/towing/towing-capacity/information/fpte4.htm