CALIFORNIA STATE SCIENCE FAIR
2009 PROJECT SUMMARY

Name(s)
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Project Number
S0209

Project Title
Efficient Low-Cost Wind Energy Using Passive Circulation Control

Abstract

Objectives/Goals

Circulation control is a way of changing the flow over a wing using a jet of air. By ducting air through a slot at the trailing edge of an airfoil it is possible to transform the shape of the flow, and change the lift, just as if the airfoil pitch were changed. At every wind speed there is an optimal lift distribution and pitch. Conventional variable pitch mechanisms are complex and expensive, but increase the efficiency of wind turbines significantly. This project shows how circulation control can provide the efficiency of variable pitch mechanisms without their complexity.

The rotational motion of wind turbine blades creates a pressure gradient spanwise along each blade. Instead of powering the trailing edge jet with pressurized gas, a wind turbine can utilize this pressure gradient, with an inlet near the root of the blade, and an outlet near the tip. As the wind speed increases, and the rotation rate of the rotor increases, so does the pressure gradient, therefore, so does the air coming out of the trailing edge. The flow then passively adapts with the wind speed. The effect of this kind of flow control is comparable to the effect of changing the pitch. So this project offers the possibly to replace a complex part of a wind turbine with a static system that has the same effect but requires no moving parts and is just a blade modification.

Methods/Materials

I started by experimentally testing different heights of flaps that mimic how a jet slot airfoil would perform at a single wind speed. I created a car-top testing apparatus to collect data on turbine performance. Additionally, I wrote a simulation code to predict the theoretical performance of a turbine with this passive jet slot modification.

Results

The data taken from the experiment (power, rpm, and wind speed) described the characteristics of the generator and the performance of the turbine with and without blade modifications. The data from the flapped blade tests and simulation of the jets suggest that passive jet slots would increase the efficiency of the turbine.

Conclusions/Discussion

The next step is to build new, hollow blades that were modeled in the simulation to experimentally verify that the slots create the same effect as the trailing edge flaps. This project has the potential to increase the efficiency, reliability, and affordability of wind turbines in a way that has not been patented or prototyped before.

Summary Statement

I designed a wind turbine blade modification that increases turbine efficiency over a range of speeds, tested a simplified prototype, and wrote a program that predicts how this modification affects turbine performance.

Help Received

Father helped with simulation and aided with data collection.