Impedance matching for Darrieus type vertical axis wind turbines through the application of fluid dynamics

Jon Love

Mentored by Dr. Robert Lieb

Introduction

Vertical axis wind turbines (VAWTs) are a type of power generating wind turbine that are typically smaller scale and more stable than their horizontal axis counterparts. Rather than being found in large, open fields, vertical axis wind turbines can be effectively built on city rooftops or placed between buildings (Castelli & Benini, 2011). There are two main types of vertical axis turbines: Darrieus type, which are lift-driven, and Savonius, which are drag-driven. By their very nature, both turbines are limited to operating effectively in high-wind areas. Savonius types are better suited to lower wind speeds, generating more electricity than Darrieus types with the same wind velocity, but Darrieus types are typically more efficient at higher speeds. This study aims to reduce the minimum wind speed needed to practically operate small scale Darrieus VAWTs, widening the range of locations they can be used and offering the advantages of both Savonius and Darrieus types. To do this Bernoulli’s Principle will be applied by forcing the air through a funnel before it crosses the turbine. The Bernoulli’s Principle states that as the speed of a fluid increases, the pressure of that fluid decreases, and that this can be done by forcing the fluid from an area with a relatively high cross-sectional area to an area with a lower cross-sectional area.

Materials and Methods

In this study, researchers used 40 ft² of quarter-inch plywood as well as 16 ft² of quarter-inch particle board to construct the funnel (Figure 1). The Darrieus type VAWT used was a GudCraft® WGV15 Vertical Wind Turbine Generator 15W 12V (Figure 2), and the anemometer was an Ambient Weather® WM-2 Handheld Weather Meter. A barn fan 18 inches in diameter was used as an analog for wind, and a Variac was used to vary the speed at which the fan turned. Data was originally to be collected at 30, 60, 90, and 120 volts to simulate various wind speeds. The speed of the air leaving the fan was recorded in meters per second with the anemometer, as well as the turbine’s rotational speed in RPMs with a tachometer. The funnel was then placed between the fan and the turbine. In this test, the speed of the air as it both enters and leaves the funnel was recorded, as well as the turbine’s rotational speed. The intent of the funnel was to collect a large area of wind and condense it down, capitalizing on the Bernoulli Principle. If this was achieved, the air speed as the funnel became larger would increase and therefore drive the turbine faster.

Results

The equation used to calculate the change in velocity of the air as it passes through the funnel was $v_2 = \sqrt{\frac{a_1}{a_2}} v_1$, where $a$ is the cross-sectional area of the funnel at a given point and $v$ is the velocity of the air at the same point. Taking $a_1$ as the opening of the funnel and $a_2$ as the exit end of the funnel yields the ratio $v_2 = \sqrt{\frac{a_1}{a_2}} v_1$, where $v_1$ is the velocity of the air before entering the funnel and $v_2$ is the velocity of the air as it leaves the funnel. Using a Chi-Squared Goodness of Fit test, the observed data was found not to follow this model at the 95% confidence level. Graph 2 shows the expected and observed values of the velocity of air exiting the funnel at the voltages at which the fan was run. As shown by Graph 2, the existing apparatus apparently decreases the velocity of the air flowing through it rather than increasing it. This suggests that the design does not properly make use of the Bernoulli principle, and does not increase the velocity of the air. Therefore a redesign is required.

Conclusions

The data collected shows that the velocity of the air passing across the turbine was less than the speed of the air originating at the fan. Because the velocity of the air exiting the funnel did not increase, the funnel did not properly apply the Bernoulli Principle. One potential explanation for why this funnel was ineffective is that the collimator placed at the exit end of the funnel caused too much drag, decreasing the velocity of the air more than the funnel increased the velocity. Another possible cause of the funnel not producing the desired effect is that the design of the funnel was flawed. The funnel may have allowed air to escape, thus making the Bernoulli Principle not applicable. Also, it is possible that air from the fan did not enter the funnel at all due to a misalignment, causing the velocity of the air to decrease. In the interest of time and affordability, the funnel was designed to shorten only one axis at a time, with the adjustable opening shortening the x-axis only, and the fixed midsection shortening only the y-axis. It is possible that because of this, the flow of air was disrupted. After reviewing the data it is apparent that this study had some flaws in the protocol and therefore should be reevaluated to reduce the number and effect of these issues.

References