12-6-2018

Concentric Contra-Rotating Dual Shaft Vertical Axis Wind Turbine

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UNDergraduate SHOWCASE

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Introduction

The demand for low cost renewable energies grows with the global energy crisis. This study aims to improve the efficiency and energy production of the typical vertical axis wind turbine (VAWT) by introducing a second counter-rotating set of blades. VAWT's are ideal for small scale and urban applications, where wind speed are lower and air space is limited. CFD analysis and wind tunnel model testing we will determine the viability of a dual rotor design for off-grid and disaster relief energy production.

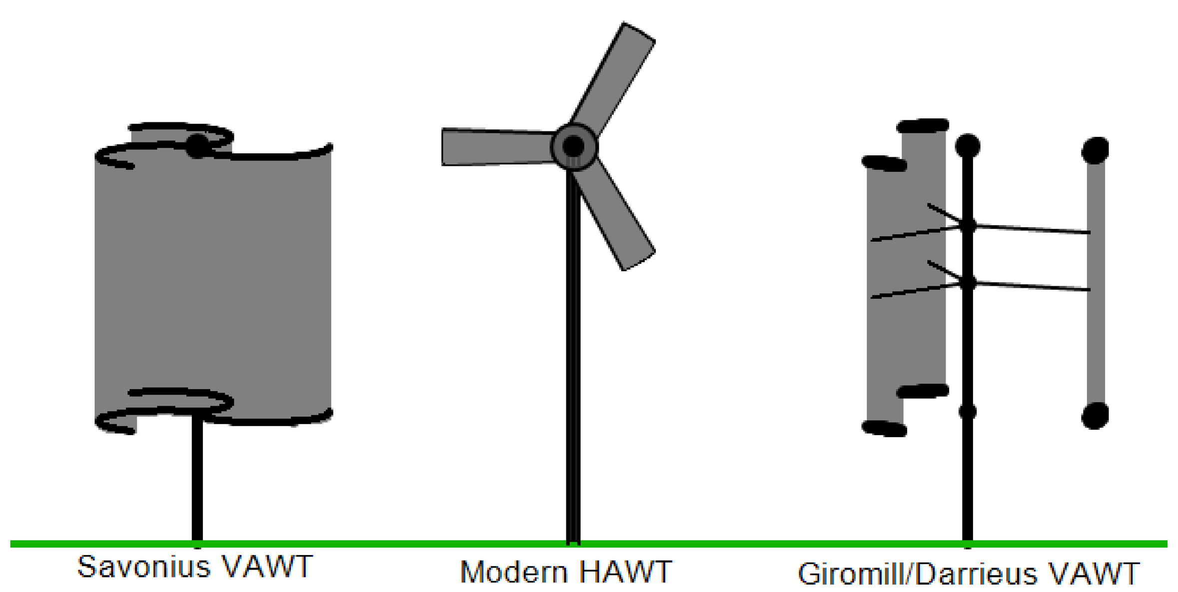


Figure 1: Turbine type comparison

Objective

This study aims to design and build a scale model dual rotor VAWT for wind tunnel validation in addition to developing a simulation model for CFD analysis. The study seeks to mitigate global climate change by making wind power more accessible and efficient.

Methodology

Assumed turbulent flow with Viscous SST k-ω Model solver. Air domain with inner and outer rotating domains. The inlet air velocity is set to 35 mph to simulate the wind tunnel conditions. The method applied is an entirely 2nd Order SIMPLE Green-Gauss Node. The solution is initialized from the Inlet and run on Steady for 1000 iterations before running on Transient for 288 time steps with a time step size of 0.00238 seconds and 30 max iterations per step.

Hypothesis

1. The addition of a counter-rotating set of blades in a modified H-style vertical axis wind turbine will improve the energy production at lower wind speeds.
2. The counter-rotation of two concentric modified blades will produce constructive interactions that will improve the lift and rotation of each set and improve the overall efficiency.

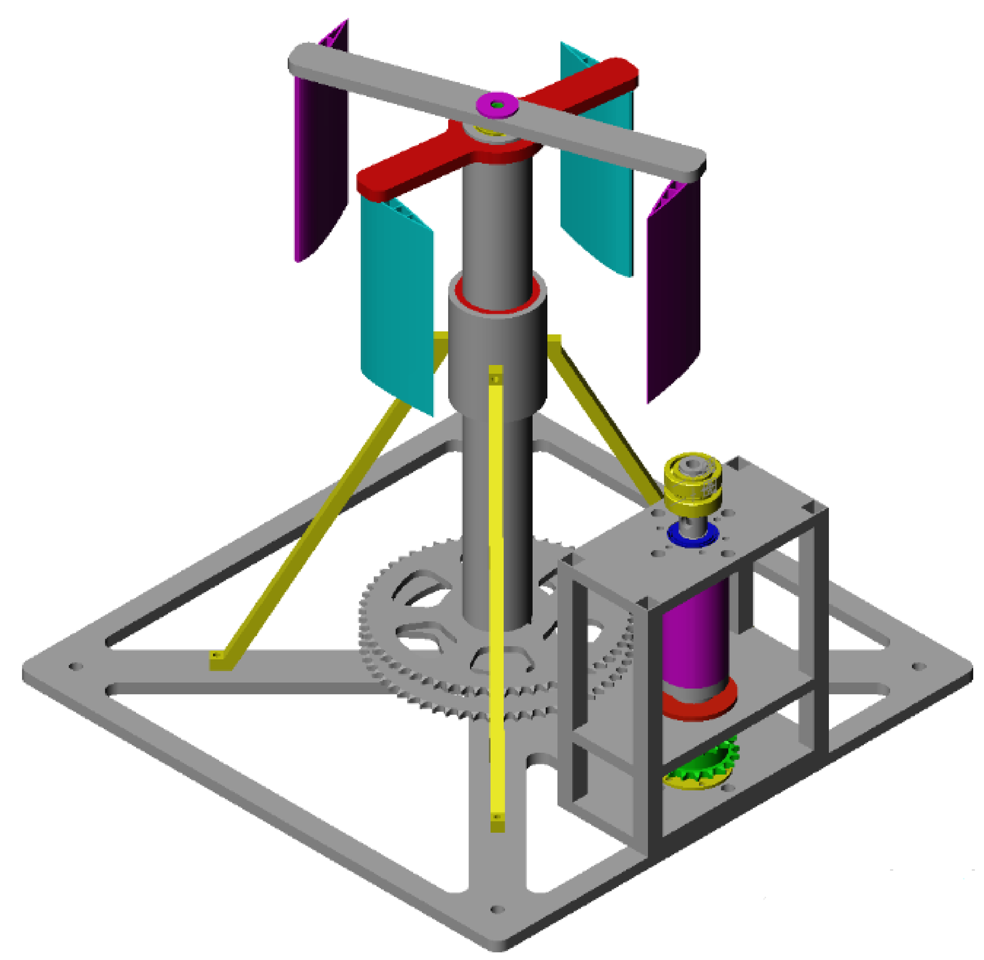


Figure 2: Proposed VAWT design

Design

The proposed design consists of two sets of symmetrical NACA0015 airfoils with a 0 degree angle of attack. The second set of foils is attached to a second shaft that connects independently to the electric motor. Each set of foils is oriented in opposite directions to facilitate the counter-rotating aspect of the design. For the simulation, the geometry is simplified to a top view two-dimensional arrangement with the effects of the inner shafts assumed negligible. Additionally the simulation initial conditions for inlet wind speed and rotating domain speed are based values observed in the wind tunnel.

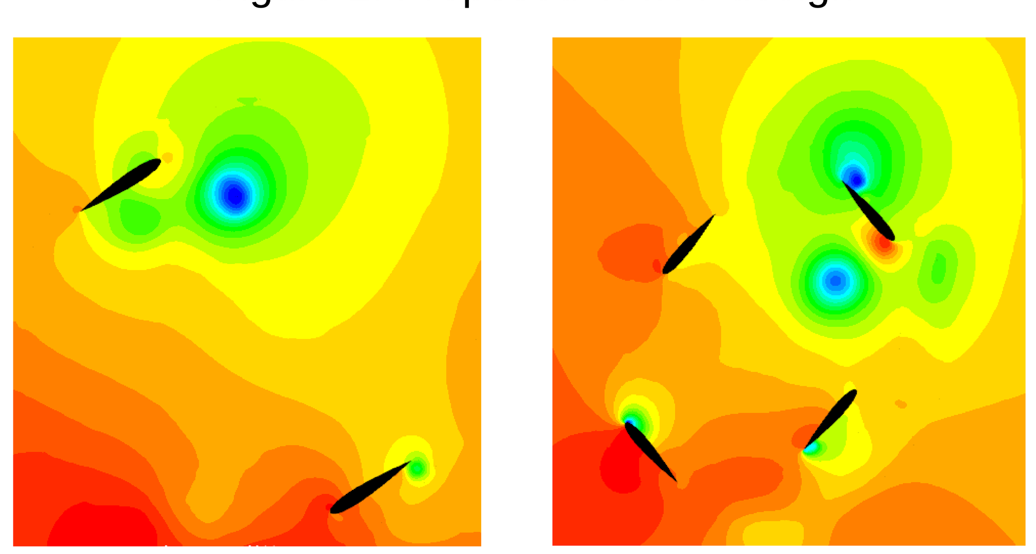
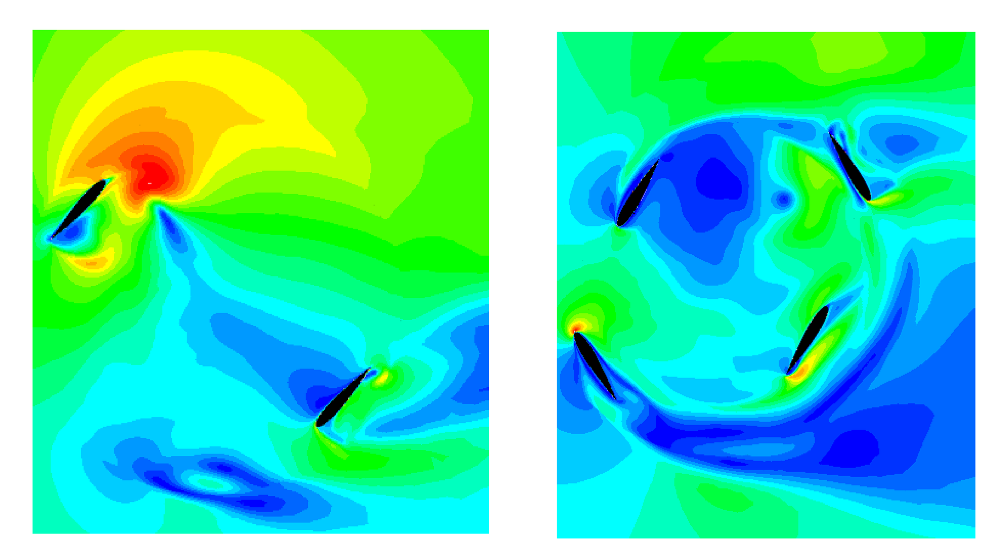


Figure 4: Pressure and velocity contours of single and double systems at 350 rpms



Simulation

Single Set Validation: The complex geometry required significant testing to generate an accurate and functioning simulation. Several iterations of a single rotating set of foils were conducted to generate a mesh independence study which would be used to determine the meshing of the double set testing. Lift and drag force data was gathered to approximate the power generation of a single set of foils in turbulent conditions. This approximation was averaged across three mesh sizes at three different rotational speeds.

Double Set Testing: Once the simulation was proven to be functioning properly, similar steps were taken to introduce a second rotating domain containing the counter-rotating set of foils. Again several iterations were run of the geometry at three different angular velocities to compare against the values found from the single set. This was done to theoretically determine if the interactions between each of the foil sets would be constructive.

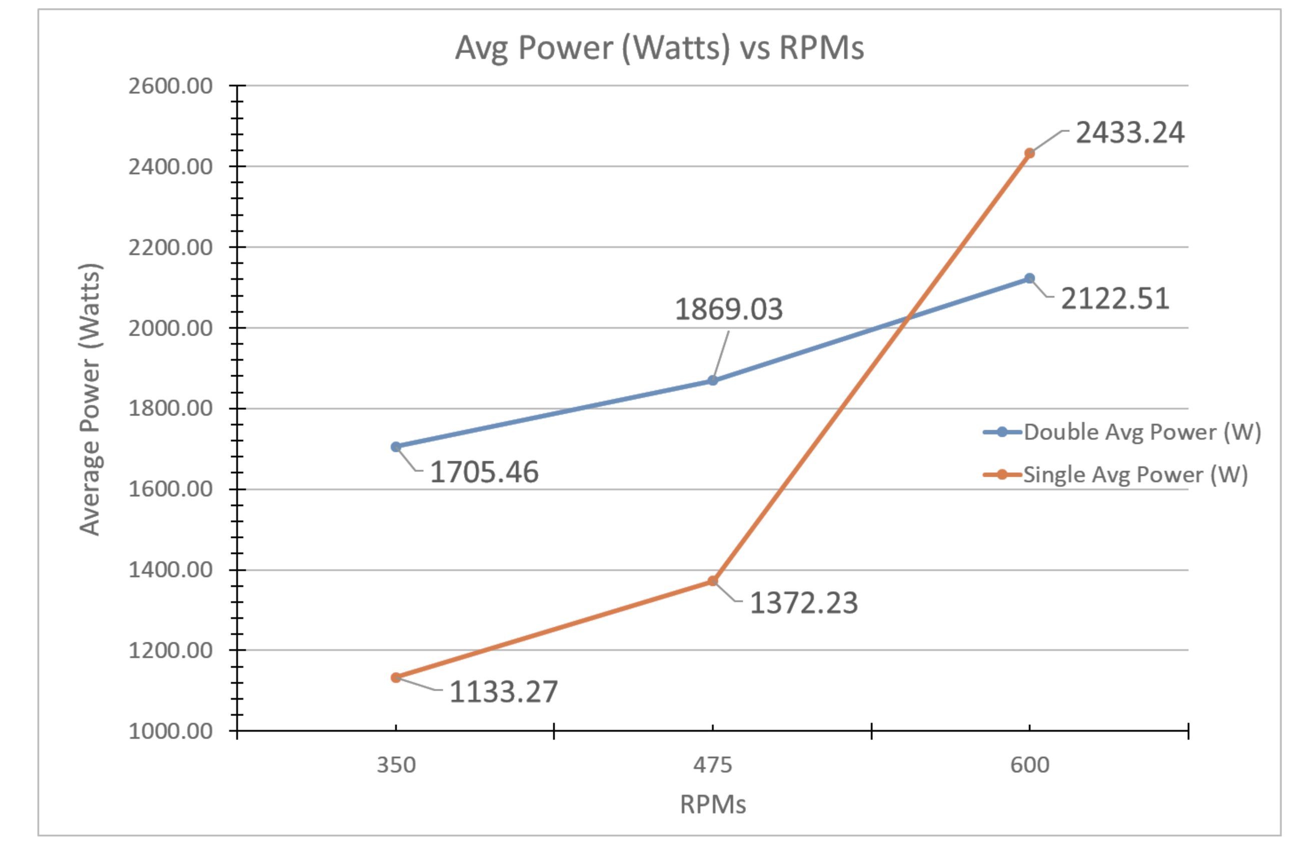


Figure 3: Average power data gathered for the two arrangements at three angular velocities

Conclusions

The low pressure vortices shed by each set of foils appear to improve the flow of the adjacent foil. Initial simulations point to the concentric geometry being less sensitive to the turbulence experienced by the system than expected. The addition of the second counter-rotating foils does indeed improve the theoretical energy production under ideal conditions. There was also positive interactions observed between the shed low pressure vortices.

Future Work

Additional modifications to the physical model will be required to conduct wind tunnel verification of the values gathered during the simulation. Thanks to the international collaborative nature of this study, the work will likely be continued by a research fellow at the University of Leeds in England.

Acknowledgement

This study is conducted thanks to the International Research Experience for Students (IRES) program made possible by the research grant (1458962) provided by the National Science Foundation (NSF).