Development of Safe and Efficient Operation for Airborne Wind Energy (AWE) Systems – A Rotary Kite Design

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Introduction

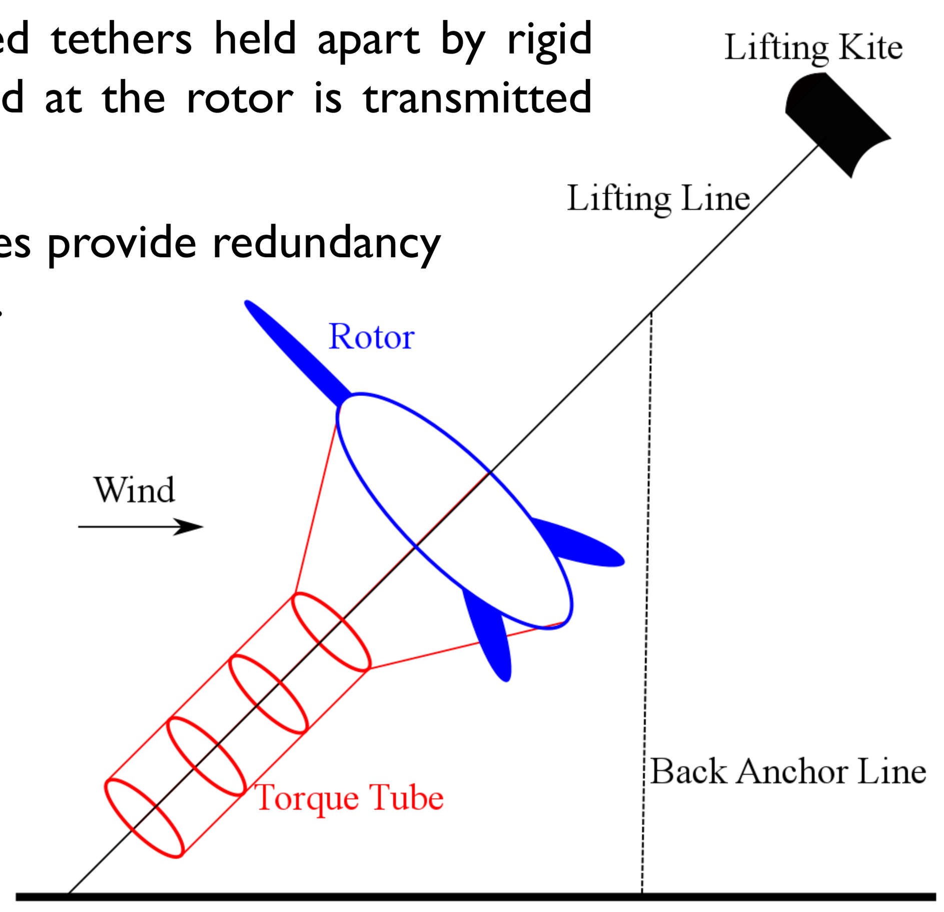
- Airborne wind energy (AWE) is the term used to describe an energy system that uses a wing or kite anchored to the Earth's surface via tensioned tethers.
- By using lightweight materials AWE systems are able to reach higher altitudes compared to horizontal axis wind turbines (HAWT) where stronger more consistent wind can be found.
- AWE devices have the potential to achieve lower costs of energy compared to HAWT of equal power rating.
- This PhD is to research a networked rotary AWE system – the Daisy Kite.

The most recent Daisy Kite prototype undergoing tests on the Isle of Lewis

- Windswept and Interesting Ltd have been developing the Daisy Kite for several years. Over this time a series of prototypes have been manufactured and tested.
- The aim of this PhD is to produce a mathematical representation of the current Daisy Kite design. It is envisaged that this will then be used to improve the design and investigate possible control strategies.

The Daisy Kite System

- A diagram of the Daisy Kite's main components can be seen below.
- The lifter kite and line are launched first and used to pull the rest of the system into the air.
- The rotor consists of a series of kites equally spaced around a flexible ring.
- Using a cylinder of tensioned tethers held apart by rigid rings the rotation established at the rotor is transmitted to the ground station.
- The networked kites and lines provide redundancy and limit single point failures.
- The Daisy Kite is the only passively autonomous AWE device as it does not require active control to remain airborne and generate power.
- The current prototype has achieved a maximum power output of 616W.



A diagram of the Daisy Kite's main components

Mathematical Representation

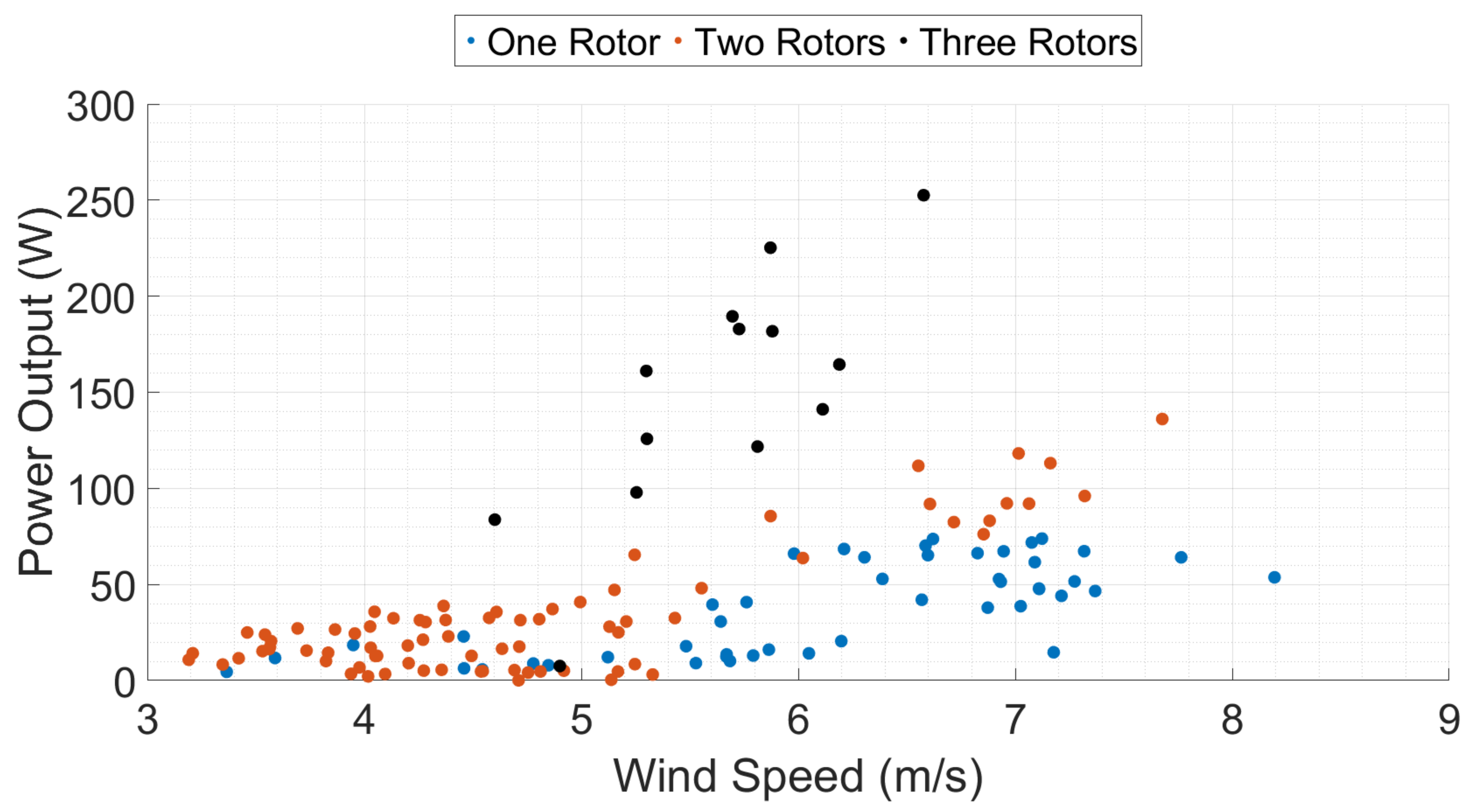
- An aerodynamic model that uses blade element momentum (BEM) theory predicts the rotor's power output for a given wind speed and rotational speed.
- A vortex lattice method (VLM) is used to estimate the kite's lift coefficient and induced drag.
- A simple model has been developed to analyse the torque tube. It has been used to investigate the relationships between line tension, torque and the system geometry.

Average Wind Speed (m/s)	Recorded Power (W)	Predicted Power (W)
6.9	56.2	84.3

Comparison of recorded data and predicted power for data from 27th June 2017

Experimental Field Tests

- This research has involved the manufacture of a new Daisy Kite prototype.
- This prototype will be used to validate the mathematical representation that is being developed.
- A key component of the Daisy Kite's design is the ability to have multiple rotor's on the same shaft.
- The graph below compares the experimental results obtained for different numbers of rotors.



Results obtained for different numbers of rotors. The points shown are 10-minute averages.

Conclusions & Future Work

- The results have shown that the aerodynamic model must be improved. This will be achieved my improving upon the assumptions made, primarily the kites aerodynamic properties.
- The torque tube analysis has highlighted the importance of line tension. To keep the line drag low a small diameter must be used which requires a large line tension or shorter spacing between the rings within the torque tube.
- A series of tests will be conducted on a single rotor prototype to provide a comprehensive datum which the mathematical representation can be compared to. This data will also be used to confirm the advantages that any future design alterations provide.