Modelling and Simulation Studies of a Networked Rotary Kite System

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Introduction

- PhD researching a networked rotary airborne wind energy system – The Daisy Kite
- Windswept and Interesting Ltd. have been developing the Daisy Kite for several years. The system has undergone a number of design iterations, each developed through manufacturing and testing numerous prototypes.
- The aim of this PhD is to produce a mathematical model of the current Daisy Kite design. It is envisaged that this will help to improve the systems design and be used to investigate possible control strategies.

The Daisy Kite

- Figure 1 shows a diagram of the Daisy Kite's main components
- The system uses the effect of autorotation to create lift and usable shaft power
- The lifter kite is used to pull the system into the air, where the driver kites cause the entire system to rotate
- The device uses a cylinder of tensioned tethers held apart by several rigid rings to transmit the rotational motion down to the ground station

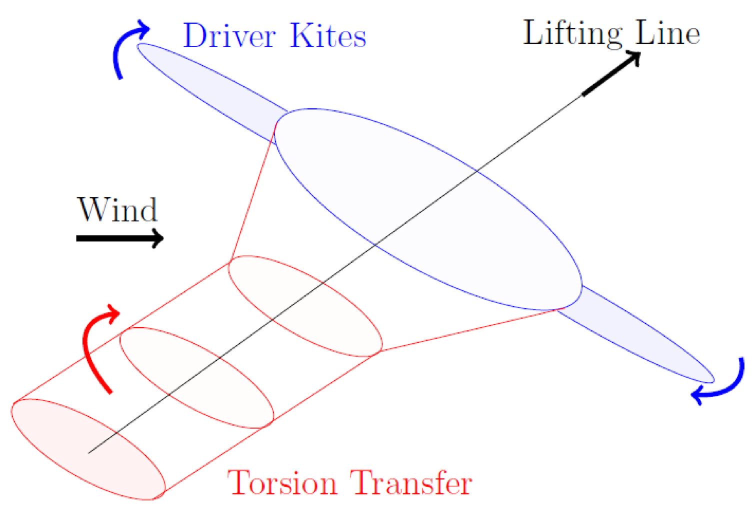

Figure 1 – Diagram of the Daisy Kite's main components

Figure 2 – The Daisy Kite undergoing testing (September 2017)

- Figure 2 shows the most recent prototype undergoing tests on the Isle of Lewis, Scotland
- The use of networked kites and lines provides enhanced safety by ensuring there is inbuilt redundancy
- Networked kites also ensure the device is inherently stable and able to produce continuous power
- The airborne components weigh under 2kg, making it a portable off grid solution
- So far the device development has relied on the results from experimental tests
- Experience through trail and error has driven most of the previous design changes

Experimental Results

- The results obtained from testing the most recent prototype can be seen in Figure 3
- There is a power meter on the ground station which records the power and rotational speed.
- A cup anemometer mounted on a near by mast records the wind speed
- A mechanical brake is used to control the rotational speed
- To develop the Daisy Kite design further an aerodynamic model has been produced

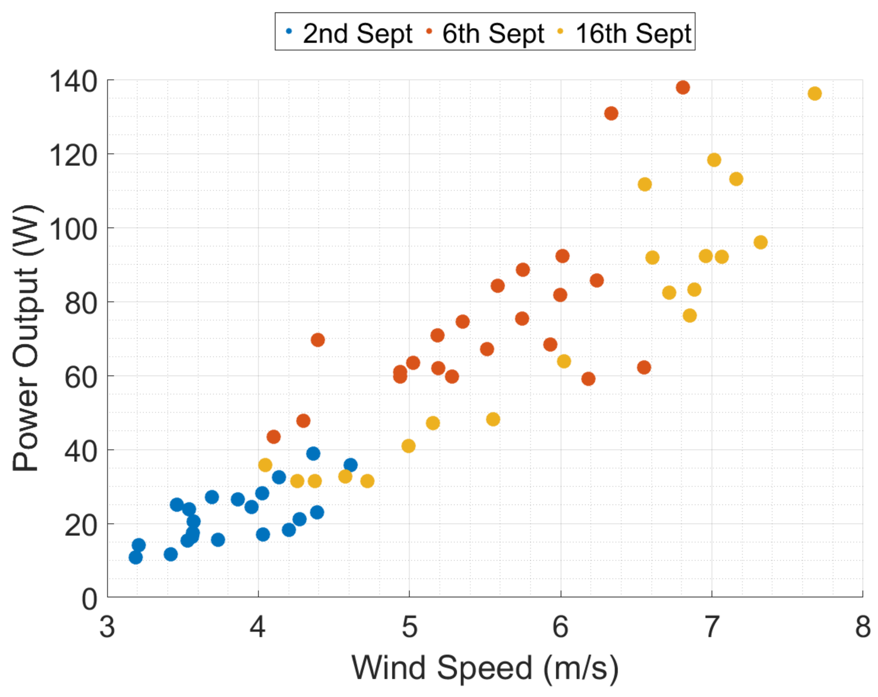

Figure 3 – The Daisy Kite's power output for the field tests completed in September 2017. The data points shown are ten minute means.

Aerodynamic Model

- The aerodynamic model uses blade element momentum (BEM) theory to predict the power output for a given wind speed and rotational speed
- The wind speed and rotational speed collected during field tests are used as inputs
- Recently a vortex lattice method (VLM) has been added to determine the driver kites lift coefficient and induced drag
- The model is used to predict the power output for a single rotor comprising of three driver kites
- The model results have been compared to the recorded power for a single rotor, shown in Table 1
- The model over predicts the power output by a factor of roughly 2

Average Wind Speed (m/s)	Recorded Power (W)	Predicted Power (W)
6.9	56.2	108.0

Table 1 – Comparison of recorded data and the models predicted power for data collected on 27th June 2017

Torsion Transfer System

- A laboratory rig has been developed to investigate the Daisy Kite's torsion transfer system
- The rig comprises of two motors facing each other with one section of the Daisy Kite's torque transfer system mounted in-between them. One motor is held stationary while the other is able to move axially towards the fixed motor.
- The results for the initial tests on the rig are shown in Figure 4. It can be seen that as the initial line tension increases the discrepancy between the predicted and measured values is reduced.
- This is due to the need to overcome the friction within the casters on the moving motor.

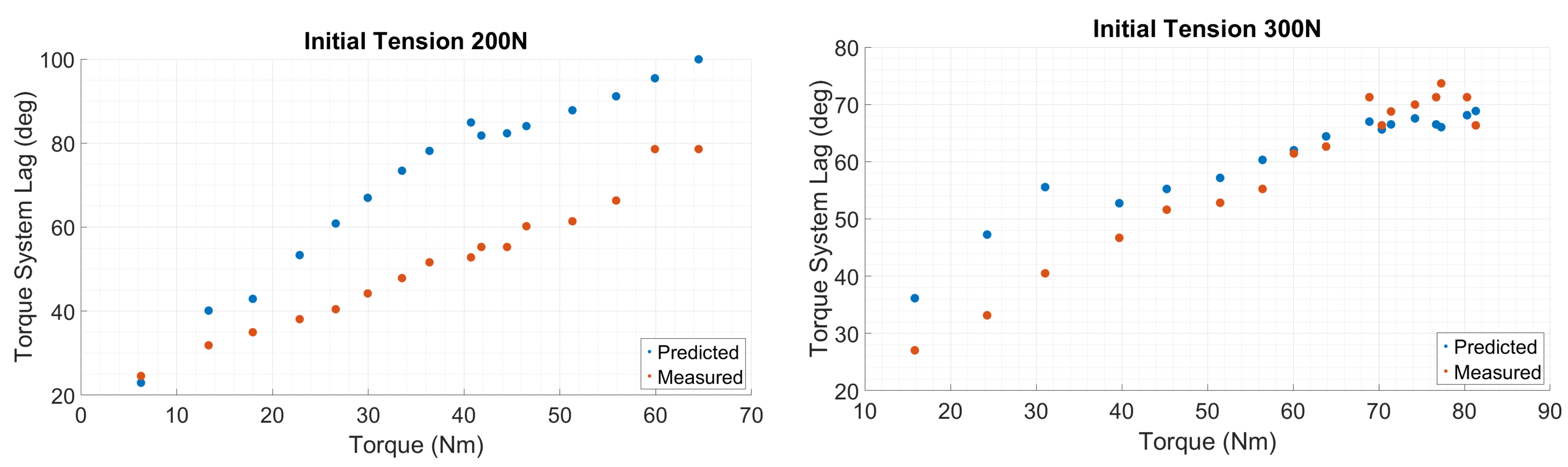

Figure 4 – Results for one section of the torque transfer system tested on the laboratory rig.

Conclusions & Future Work

- The field test data collected so far highlights the need for more accurate control over the systems power take off
- The next step is to incorporate a gearbox, generator and generator controller onto the Daisy Kite prototype
- Incorporating the VLM code into the aerodynamic model has reduced the error between the recorded and predicted power output
- The aerodynamic model will be improved by incorporating tether drag
- The discrepancy in the predicted and measured values from the torque transfer test is down to the mechanical friction within the test rig
- On future torque transfer laboratory tests greater initial line tension will be used to over come the friction within the test rig

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