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Synchronisation behaviour of paired VAWT rotors

Greeshma B Shivamallegowda[a] and Mark Runacres[a]

[a]Vrije Universiteit Brussel (VUB), Department of Engineering Technology (INDI), Pleinlaan 2, 1050 Brussels, Belgium

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E-mail: greeshma.boohalli.shivamallegowda@vub.be

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1 Introduction

Recent research on vertical axis wind turbines (VAWT) has shown that they may be considered as viable alternatives to their horizontal-axis counterparts for offshore applications and small-scale urban power generation[1],[2]. When used in a paired configuration with two rotors in close proximity, VAWTs show an enhanced efficiency [3]. An improvement of 13-16% in the power production was observed in an experimental study with two closely-spaced counter-rotating VAWTs [4]. Spontaneous synchronisation was also observed between the rotors in specific instances during the experimental campaign. In particular, when the rotational velocity of one rotor was varied up to about 10%, the rotational velocity of the second rotor automatically synchronised. After several runs, it was determined that this synchronisation is repeatable. This work deals with understanding the dynamics of paired VAWTs and establishing a computational fluid dynamics framework to analyse the synchronisation of the paired rotors.

2 Synchronisation

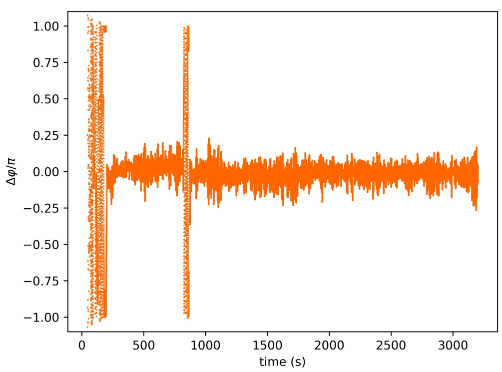

Figure 1: Phase difference between the rotors at 1250 rpm. [4]

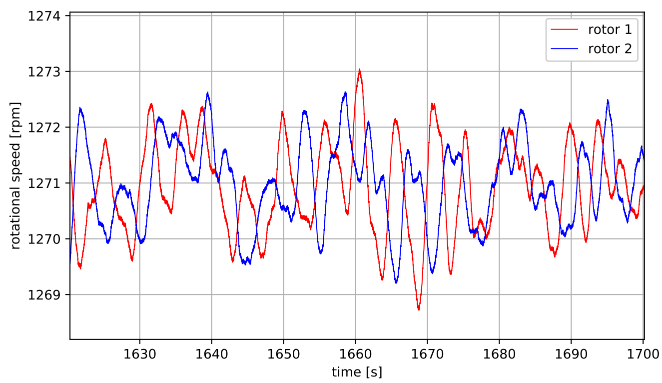

Figure 2: Oscillation of rotational velocities over a small period.

When the rotors are individually started from a stationary state to a certain rotational velocity, it is observed that the rotational velocities of the rotors tend to oscillate around a mean value. As a result, an oscillation in the phase difference is also observed as shown in the Figure 1. The rotors appear to desynchronise at a few instances. The oscillation of the phase differences in the synchronised part is observed to be between $\frac{\Delta\Phi}{\pi} \approxeq 0.1$ and $\frac{\Delta\Phi}{\pi} \approxeq -0.1$ radians. It can also be observed that the synchronisation is present for a considerable part of the experimental test. Figure 2 shows the fluctuation of the rotational velocities of the rotors for a small period of time when they are synchronised.

3 Computational fluid dynamics study of the rotors

A computational study of the coupled rotor configuration will shed more light on the aerodynamic aspect of this synchronisation process and aid to characterise the oscillations present in the experimental data. Before moving on to the coupled rotor studies, a set of validation studies are carried out on a single rotor configuration. The computational domain is generated using the mesh generator Pointwise. Computations were performed using the open-source solver, OpenFOAM using a transient solver called PIMPLE. An unsteady Reynolds-averaged Navier Stokes study is carried out using the Spalart Allmaras turbulence model as it provides a way to economically model the boundary layer problems involving adverse pressure gradients. The domain is made up of unstructured grids throughout except in the region in the close proximity of the blades. To account for the boundary layer, finer cells consisting of quad elements are employed near the surface of the blade. The unstructured grid around the rotors is finer in the proximity of the rotors and grows coarser towards the farfield. This can be seen on Figure 3 and Figure 4.

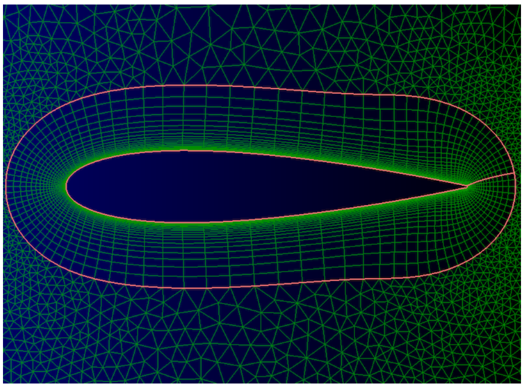

Figure 3: Structured grid around a blade

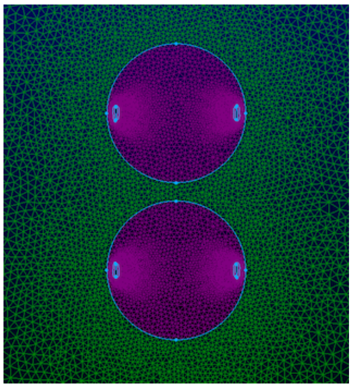

Figure 4: Unstructured grid around the rotors

The final computational setup will be chosen by carrying out a few comparative studies on the single rotor setup. To validate the results obtained from the single rotor simulations, they are compared to the results from the double multiple stream tube model (DMST) and an incompressible actuator cylinder model (ACM) as shown in Figure 5. The incompressible ACM overpredicts the performance of the rotor compared to the other two methods as the effect of drag is not taken into account while determining the forces on the rotor. The results from the DMST model and CFD are comparable for the lower tip speed ratios. However, the DMST model tends to overestimate the tip speed ratio for maximum C_p [5]. The quantiative comparison of the results from the CFD simulations with the results from the analytical models is not made as the grid independence study is still in progress.

4 Conclusion

The synchronisation of the two rotors are studied and the initial CFD simulation setup for the one rotor case has compared with several models. Further studies on the effect of the size of the computational domain, turbulence models, and usage of wall functions on the prediction of the performance of the rotors

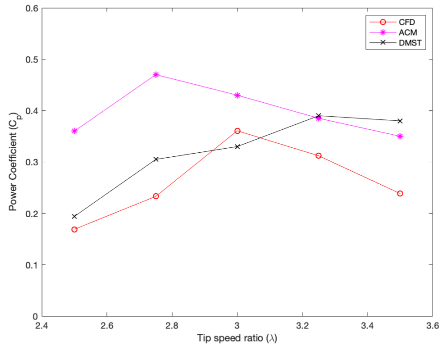

Figure 5: Cp from CFD simulations, ACM and DMST models

will be carried out. The long term planning includes imposing the varying rotational velocities on each of the paired rotors and studying the physical phenomena.

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