Flow Physics Investigation of VAWTs for Harvesting Wind Energy in the Urban Environment
zEPHYR Marie Skłodowska-Curie project: towards a more efficient exploitation of on-shore and urban wind energy resources

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CONTEXT

The last 2 decades saw a rapid development of Vertical Axis Wind Turbines for small-scale standalone applications. The major reasons were increasing need to develop wind turbines for the urban environment and availability of higher computing resources which allowed improvement in VAWT performance at a faster rate. In the urban environment, wind flow is more chaotic and turbulent in nature. VAWTs perform better than HAWTs in such wind conditions, and thus are more suitable for installment on rooftop environment. The purpose of the current work is to understand the flow physics of VAWTs in more detail, important aerodynamic interactions taking place in the flowfield and how does it affect the performance and acoustics of such rotors. At the end of the project, the aim will be to produce a cluster configuration of such wind turbines which can provide a high-power density for an urban locality.

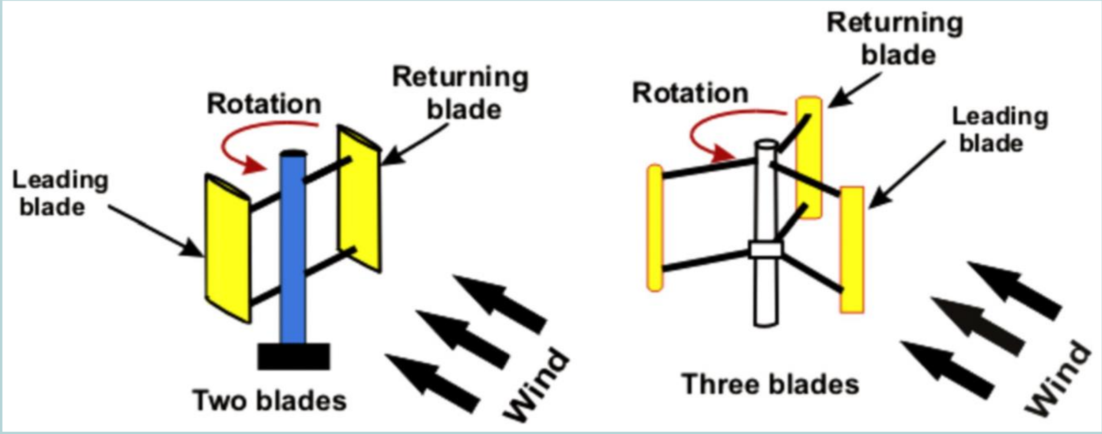

Figure 1: Lift type Darrieus VAWT rotor [1]

VERTICAL AXIS WIND TURBINES

VAWTs perform better than HAWTs in the urban environment for reasons such as:

- Greater compact and simple design, thus, lowering costs
- Absence of yaw-control: unidirectional in nature
- Possibility of higher power density in urban wind farms
- Mechanical and electrical components at ground level, providing easier maintenance

There are a few disadvantages of a VAWT design, such as:

- Low efficiency (in a clean flow)
- Poor self-starting characteristics
- Resonance and fatigue issues

There are 2 major types of VAWTs: **Savonius** and **Darrieus**. **Savonius** is a drag-based wind turbine and has been in use traditionally by humans for agricultural and electricity production purposes. **Darrieus** turbine was first proposed in 1925 and the design is a lift-based system using airfoil-shaped blades. During the current project, a major focus will be given towards Darrieus turbine as it is a more promising concept for the urban applications. [2]

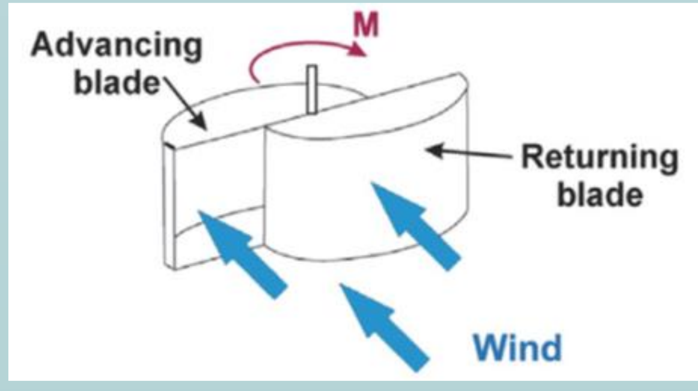

Figure 2: Drag type Savonius VAWT rotor [2]

COMPUTATIONAL METHODOLOGY

The research project is divided into 2 phases. The first phase will focus on *standalone wind turbines* to understand its performance and acoustic behavior. After deciding on a few configurations, design of *cluster configuration of VAWTs* will be taken up in the 2nd phase. In each phase, there will be 2 sub-phases:

- **Low-fidelity analysis**: The task will be to analyze multiple configurations of Darrieus turbines in a relatively short time and finalize a few configurations based on aerodynamic performance. For the purpose, QBLADE software will be used which employs Double Multiple Streamtube (DMS) method.
- **High-fidelity analysis**: A few selected configurations will be simulated on Dassault Systemes PowerFLOW software, which employs Lattice-Boltzmann Method to solve the rotor flowfield. Additionally, far-field aeroacoustic analysis will be performed using Ffowcs-Williams and Hawkings (FWH) methodology implemented in PowerFLOW.

RESEARCH QUESTIONS

The research objectives falls into 2 major categories:

Aerodynamics

- What are important aerodynamic interactions taking place in the rotor flowfield?
- What is the most suitable choice of VAWT parameters, such as number of blades, airfoil profile, aspect ratio, solidity, etc. for a particular wind condition?
- What is the best suitable configuration of a VAWT cluster? Can we employ biomimicry, such as a school of swimming fishes?

Aeroacoustics

- What is noise signature of Darrieus VAWT as compared to Savonius VAWT, and which one is more suitable for rooftop conditions?
- What are important fluid interactions that contribute to noise and can it be avoided by employing an innovative design?

INITIAL RESULTS

The initial simulations on QBLADE produced a comparison between different NACA airfoil profiles and their overall aerodynamic performance (power coefficient). As thickness of airfoil increases, low speed behavior of turbine improves and solves a key issue of Darrieus turbine - self-starting behavior. On the other hand, high speed characteristics are reversed. A turbine with thicker blade will produce less performance and thus, is a major concern at a speed where the turbine operates for most of its lifecycle.

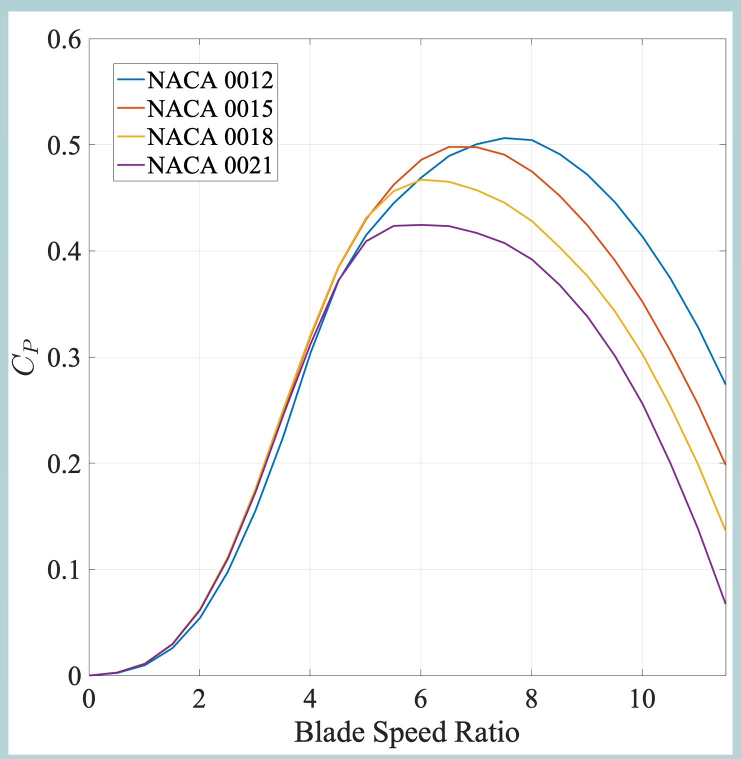

Figure 3: Darrieus VAWT performance

[1] Ref 1. Performance investigation of H-rotor Darrieus turbine with new airfoil shapes, 2012

[2] Ref 2 . Impacts of solidity and hybrid system in small wind turbines performance, 2013

The project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 860101

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