ABSTRACT

With the continuously increasing population, their raised household comforts, and the growing industrialization, there has been a significant rise in energy demands. These rising energy demands, coupled with the rapid depletion of fossil fuels and the resulting increase in CO2 emissions, have highlighted the urgent need for the transition towards clean and renewable energy sources like solar and wind power. Among these alternatives, our focus has been on harnessing wind power.

Wind power is captured through the use of wind turbines, which are broadly classified into two categories: Horizontal Axis Wind Turbines (HAWTs) and Vertical Axis Wind Turbines (VAWTs). In the past decade, the resurgence of interest among researchers in lift-type VAWTs due to their demonstrated potential for higher power density compared to their HAWT counterparts, as the operation of these turbines in closer proximity to each other in a counter-rotating configuration would produce more power in a farm. In alignment with the same, this thesis presents the computational study conducted to investigate the effect of aerodynamic interference between rotors in a non-overlapping twin-rotor configuration (having center-to-center relative inter-turbine spacing (S) ($\frac{S}{D} > 1$) and overlapping twin-rotor ($\frac{S}{D} \leq 1$), where D represents the rotor diameter) on the performance and wake recovery. The relevance of this piece of work lies in understanding the performance characteristics and interaction dynamics of twin-rotor VAWTs, which will allow for their successful incorporation into a wind farm (onshore or offshore).

The work commenced with a two-dimensional study using Unsteady Reynolds Averaged Navier Stokes (URANS) Equations, employing the commercial solver ANSYS Fluent 19.2. The selection of a numerical modeling technique for an isolated rotor involved the comparison of two different dynamic meshing techniques: sliding mesh and overset mesh. Both techniques produced similar results but deviated from the experimental findings. However, due to the limitations of the sliding mesh technique in handling overlapping rotors, the overset mesh technique was chosen for further investigations. The subsequent phase focused on the performance and wake validation study of both single rotors and counter-rotating pairs of rotors at a $\frac{S}{D} = 1.65$. By building upon established criteria, the modeling process was extended to include paired and twin-rotor configurations with different relative spacings.

A systematic simulation campaign was carried out for overlapping twin-rotor ($\frac{S}{D} \leq 1$) and non-overlapping twin-rotor ($\frac{S}{D} > 1$) for varied tip speed ratios. The key results indicate that overlapping rotors exhibit unique interaction effects, influencing the performance and wake characteristics of each rotor. Analysis of the obtained data indicates that the overlapping twin-rotor with $\frac{S}{D} = 0.9875$ demonstrates approximately 25% better performance compared to a single-rotor. Furthermore, the twin-rotor with $\frac{S}{D} = 0.89$ exhibits a remarkably smooth power output (nearly independent of the azimuthal position) with an enhancement of approximately 8% over the single rotor. This has significant practical implications from the point of view of power generation and transmission. Additionally, the wake recovery is observed to be faster for the $\frac{S}{D} = 0.89$ case in comparison to other configurations.

Further, the thesis provides details of several attempts made to conduct experimental studies, which are outlined in the appendix. The reasons for the lack of success in these attempts are thoroughly discussed, shedding light on the challenges encountered during the research process. In conclusion, this thesis encompasses the numerical investigation of overlapping and non-overlapping twin-rotor VAWTs, focusing on their performance, wake validation, numerical modeling techniques, and the insights gained. The study contributes to our understanding of the resulting interaction effects between twin-rotor VAWTs and offers valuable insights into their optimal design and performance. The findings and analysis presented in this work serve as a foundation for the development of efficient and reliable twin-rotor VAWTs.