The Wind Power Potential in Confronting the World's Escalating Energy Demand

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Objectives

The main objective of this proposal is to implement an in-depth analysis of the flow around the rotor and in the wake of a single Horizontal Axis Wind Turbine (HAWT) model and then study its effect on power production at different free stream velocities and Tip Speed Ratios (TSRs) which will be beneficial for large wind farm projects.

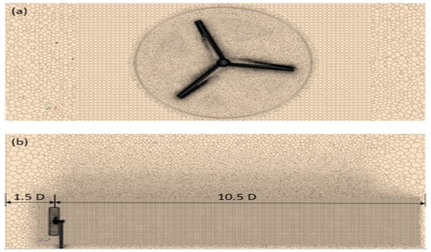
Approach

This experiment uses Miniature Constant Temperature Anemometer (CTA) measuring chain. The principle in this method is to maintain the temperature and resistance of the sensing wire at a constant level. The wires resistance will reduce due to heat transfer to the air. This change in resistance of the wire enables to measure air velocity.

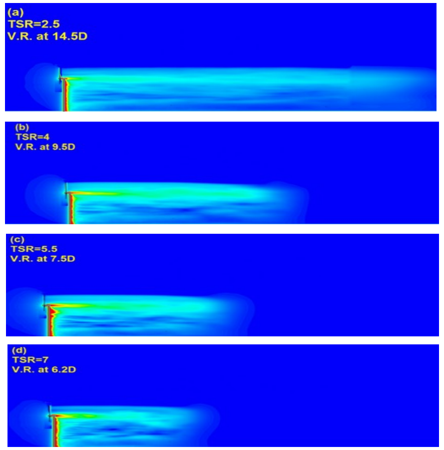
- For this work, the software STAR CCM+ was used to build a 3D model with inlet wind velocity of 5.2 m/s.
- Large Eddy Simulation or LES is used as the turbulence model to deal with both large-scale and small-scale eddies. It solves large scales of the turbulence by N-S equations and model the small-scale motions by one of subgrid scale model.
- The segregated flow model is used since it is an incompressible flow.
- The transient rigid body motion was used to model the rotor since it considers the periodic interactions of the rotating blades with the nacelle, tower, and even the wake.
- Unsteady conditions were used with total simulation time of 0.54 seconds.

CFD Simulation

- Figure (a) shows the rotating sub-domain represented by the circle that bounds the rotor, which can capture the extreme velocity and pressure gradients caused by rotor blades. figure (b) shows that the length of the wind tunnel test section is about 12D. An upstream distance of 1.5D and a downstream distance of 10.5D.

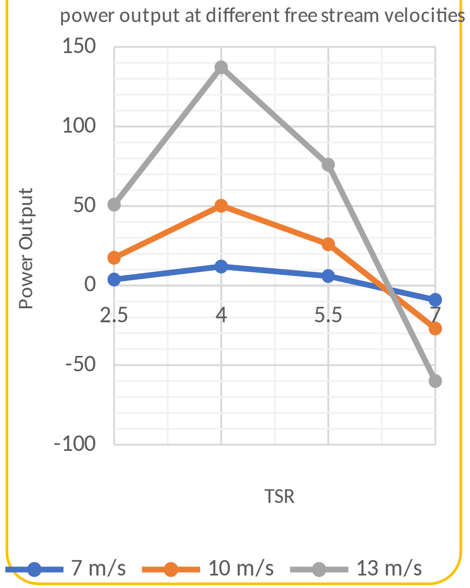


- While TSR is increasing it was noted that the resulted downstream distance decreased.



Results

- The following shows the effect of TSR & free stream velocity variations on power production.
- For fixed free stream, increasing the TSR increases the numerically predicted power production and the Power Coefficient (Cp), to an optimum value at TSR range between 4 to 5.5 then the power falls.
- The negative power at TSR = 7 means that the turbine can't respond to this high TSR, it no longer produces power at this high rotation, it needs some power from an external source to rotate at this high TSR. Therefore, it is an impossible case.
- While for running at constant TSR, the generated power and Cp slightly increase as the free stream velocity increases.



Conclusions

- For fixed free stream velocity, increasing TSR values between 4 and 5.5 for this particular blade design reduces the distance of complete velocity recovery, hence the separation distance between two turbines in a wind farm, while both the generated power and associated Cp increase to a maximum value then falls.
- For fixed TSR, increasing the free stream velocity almost does not affect the distance of complete velocity recovery (the separation distance), but the generated power increases significantly.
- For fixed TSR, increasing the free stream velocity results in an increase for the associated Cp.

Bibliography

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