Report #1: (Due: Sun 26-sep-2021 23:00) Aerodynamic rotor design for Class IIIB

Note! Only one person in each group should submit the report on Learn.

Report format

Prepare a slide deck using the provided PowerPoint template with two parts:

1. A 4-minute presentation to be delivered orally, as a group, to the class;
2. Other plots or tables that either (a) were requested in this assignment prompt or (b) you deemed relevant to the material requested in the report.

On Wednesday 29 September in class, you will **orally present the report for 4 minutes** as a group, followed by **8 minutes of questions from the instructors**. You are not expected to be able to present the entire report orally; you must decide as a group what is most important to present. Not everyone in the group needs to present during the 4 minutes, but everyone should be ready to answer questions afterwards.

Please be ready to explain any trends in the plots, the reasons behind values in tables, etc. At the end of the day, the instructors will provide written feedback along with a pass/fail grade for your report. You must pass all group reports in order to be able to attend the final exam. **For your group to pass**, your report should not only contain the requested tables/figures but you should also orally demonstrate an adequate understanding of the reported turbine behaviour.

Report content

This report is designed to do the following:

- Present your aerodynamic redesign of the DTU 10MW RWT rotor optimized for the Class IIIB of the IEC 61400-1 (Ed. 3).
- The presentation should show how you did the design and as a minimum the figures and tables listed below.
- The purpose of the report is to show that you are able to carry out an aerodynamic rotor design and give you the possibility to explain the different choices you made before continuing with the design of the rest of the turbine.
- You should apply the step-by-step method presented in the class.

The report should be divided into two parts: A design process part and a design evaluation part, where you evaluate the design with HAWC2S:

- The expected content of the two parts are described below.
- **For a report to pass,** it should not only contain the requested information but you should also be able to explain the presented results.
- Examples of similar plots for another wind turbine can be found in [1].

Part 1: Design process and final result

Concerning the design process you should be able to explain:

- determination of tip radius (*not* blade length!) for your new rotor and an argumentation of why this radius is chosen.
- argue for your choices of
  - design angle of attack (AoA) for each airfoil,
  - tip speed ratio (TSR),
  - absolute thickness distribution and
  - other issues influencing the design such as tip speed, maximum chord, number of blades etc.
- final chord, twist, and relative thickness distributions and compare these curves to the original DTU 10MW rotor.

Your handed-in slide deck must contain, at a **minimum**, the following plots for Part 1. This is because this is needed for others to judge your design. Other plots/tables may also be included at your discretion. You are welcome annotate the slides if you think it will improve your report; be as creative as you like.

- Side-by-side plots of lift-versus-drag (left) and lift-versus-AoA (right) for each airfoil used. You must indicate the design point that you have selected for each airfoil on the plots.
- Plots of the values for your selected design lift coefficient, design lift-drag ratio and design AoA versus the relative thickness for all selected airfoils and the curve that you have chosen to describe this relationship.
- Plot of your chosen absolute thickness distribution (versus blade length or rotor radius). You should plot the original thickness distribution of the DTU 10MW rotor for comparison.
- Plots of the final chord, twist, and relative thickness distributions of your rotor design. You should plot the original distributions of the DTU 10MW rotor for comparison in each of these plots. **Please be aware that the sign of the twist in the design code is opposite to HAWC2.**

Part 2: Design evaluation

Concerning the design evaluation that should be carried out with HAWC2S, you should be able to explain:

- your choice of design TSR. Here, you must compute the power coefficient and thrust coefficient of your rotor at design pitch (pitch=0 deg) as function of TSR.
- the actual operational conditions of the blade at the design TSR from the BEM computation to check that they are the same as your chosen design conditions. You might experience that the actual operational conditions is not in complete agreement with the design conditions because the aerodynamic model is not exactly the same, but they should be in fairly good agreement.
- the performance of your rotor, where you must compute the aerodynamic power, thrust, power coefficient, and thrust coefficient versus wind speed using the operational rotor speed and pitch angles.
  - The operational rotor speed is given by the design TSR and the rated rotor speed, and the pitch angles should be the design minimum pitch angle (pitch=0deg) until rated aerodynamic power. You are not expected to set the pitch angle for wind speeds at rated power. Therefore, focus the evaluation for power up to rated power. You can use 7% electromechanical drivetrain losses for the rated aerodynamic power.

Your handed-in slide deck must contain, at a **minimum**, the following plots for Part 2. As for Part 1 other plots/tables may also be included at your discretion. You are welcome annotate the slides if you think it will improve your report; be as creative as you like.

- Side-by-side plots of the power and thrust coefficients at design pitch versus TSR
- Side-by-side plots of the actual lift coefficient and the design lift coefficient versus relative thickness (left plot) and versus radius (right plot) for design pitch and TSR. The same should be done for the lift-drag ratio and AoA. Thus, curves plotted in Part 1 are repeated in the plots for the relative thickness.
- Plots of the actual lift coefficient, lift-drag ratio, AoA, axial induction (*a*), local *CT* and local *CP* versus radius at design TSR.
- Side-by-side plots of the operational rotor speed (left plot) and pitch angles (right plot) versus wind speed
- Side-by-side plots of the aerodynamic power (left plot) and its coefficient (right plot), and the thrust (left plot) and its coefficient (right plot) versus wind speed

Please make a sanity check of the plotted data. Do your results match each other and make sense? E.g. CP and CT values should correspond to the shown power and thrust curves. If plots or values are unexpected, please explain which plots and values are unexpected and try to explain why these unexpected values appear.

References

[1] Bak C. Aerodynamic design of wind turbine rotors. In Brøndsted P, Nijssen R, editors, Advances in wind turbine blade design and materials. Woodhead Publishing. 2013. (Woodhead Publishing Series in Energy; No. 47).