Report #4: (Due: Sun 17-nov-2024 23:00) Design Loads and AEP

Assignment format

By 23:00 on Sunday, **one** person from your group submits a PDF of your report. The report excluding appendices with descriptions should be no more than 10 pages. Further information should be put in appendix. The format is up to you, but please list the names of who worked on the report.

The following Wednesday in class, about half of the groups will present their reports orally to the class. The presentation should last about 7 minutes, and you can scroll through your report – no need for a separate PowerPoint. After the presentation, there will be 8 minutes for questions.

Report objectives

Your report should accomplish the following objectives:

- Compare **max/mean/min** scatterplots of **operational data** for the DTU 10 MW and your turbine* and make connections to design choices and to expectations on the final design loads/AEP
- Compare **max/mean/min** scatterplots of **loads** for the DTU 10 MW and your turbine* and make connections to both design choices and to expectations on the final design loads
- Compare scatterplots of **10-minute DELs** for the DTU 10 MW and your turbine* and make connections to both design choices and to expectations on the final design loads/AEP
- Explain briefly how to set up turbulent-wind simulations and use them to calculate design loads and AEP
- Calculate and compare design loads for the DTU 10 MW and your turbine*
- Calculate and compare AEP for the DTU 10 MW and your turbine^
- Conclude whether your design successfully completed the design challenge: to have a higher AEP but equal or lower design loads
    - You may assume the shaft is overdesigned with a 30% margin on the torsional extreme design load.
- Evaluate what aspects of your design could be changed to improve its performance with respect to the design challenge

*Comparison should be IA for the DTU 10 MW and IIIB for your design.
^Comparison should be IIIB for both DTU 10 MW and your design.

Operational and load channels

If asked to analyse “operational data” or “load channels”, here are the channels you ***must*** consider:

- Operational data:
    - Rotor speed, pitch angle, generator torque, electrical power, and thrust
- Loads:
    - Tower base fore-aft, tower base side-side, shaft torsion, out-of-plane blade-root moment, in-plane blade-root moment

You are also encouraged to analyse yaw-bearing tilt and roll, blade flap/edge and/or tower clearance.

Required plots and tables

Your report must contain, at a minimum, the following plots and tables. It is fine to place some plots in the appendix if they are not relevant to your main narrative. Other plots/tables may also be included in the report at your discretion.

All loads analyses comparing DTU 10 MW with your design should use class IA for DTU 10 MW and class IIIB for your design. AEP should compare IIIB for both turbines.

- **Plot: operational data max/mean/min**. Min/mean/max scatterplot of operational data from turbulent simulations, DTU 10 MW vs. your design. Place channels in their own plot/subplots.
- **Plot: loads max/mean/min**. Min/mean/max scatterplot of turbulent loads, DTU 10 MW vs. your design. Place channels in their own plot/subplots.
- **Table: Wöhler exponents**. For each load channel analysed.
- **Plot: 10-minute DELs with turbulence**. Scatterplot of DELs (overlay with DTU 10 MW) versus wind speed for each requested channel.
- **Table: IIIB design loads and AEP for your design**. This should be of a similar format to Table 1.
- **Plot: Visualization of turbine design loads and AEP**. Format of figure is up to you.

You may optionally superimpose HAWC2S/theoretical line over the max/mean/min scatterplots if you want to add it to your analysis.

"Step-by-step" guide

This guide is intentionally less specific than previous assignments. Please contact Jenni/Taeseong if you have questions.

Generating turbulent htc files

Start from `make_turb_htc_files.py` and update all the lines with TODO. Check `make_steady_htc_files.py` to see if you can re-use code. Run the script with the DTU 10 MW master file. It should generate 240 files, with filenames like `dtu_10mw_turb_tca_05.0_3278.htc`. Compare one of your generated files with the files available on Learn under Miscellaneous / DTU 10 MW files and make sure all your settings are correct. (It's fine if the random seeds do not match.)

If your DTU 10 MW turbulent files look good, generate the files for your design. Run a single simulation locally and inspect it in pdap to make sure it looks fine. If it does, transfer your `htc_turb/` folder to gbar and run that bad boy. You're killin' it!

Calculating design loads, AEP and tower clearance

Use the debug files and the DTU 10 MW stats file available in Week 9 and Week 8, respectively, to check your code. The files are also linked under Miscellaneous / DTU 10 MW files.

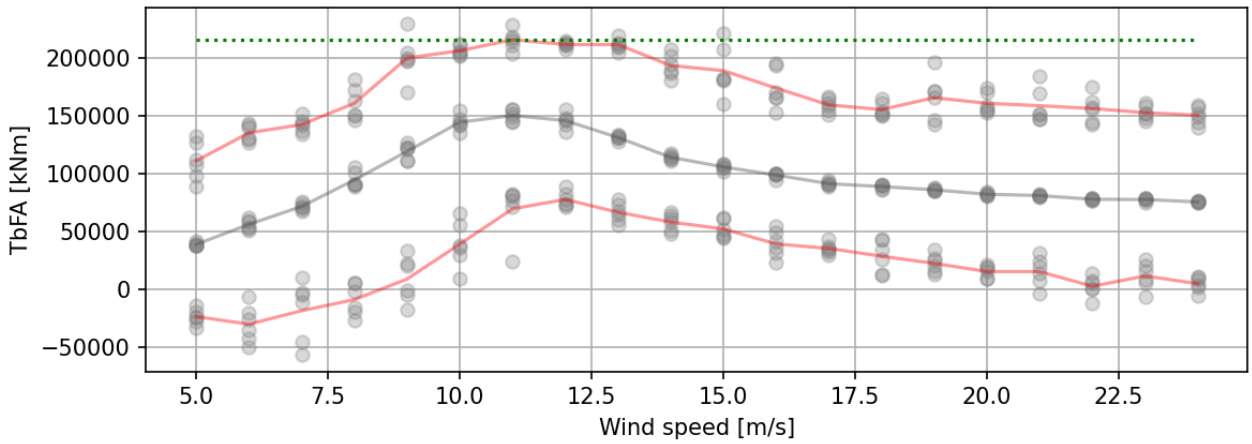
Once your code works for the DTU 10 MW stats file, replace it with the stats file for your turbine. You now have design loads and AEP for your turbine. NOICE.

Max/mean/min plots

Overlay the minimum, mean and maximum values for the DTU 10 MW with turbulence class A and your turbine with turbulence class B.

You can choose whether you want to plot 18 points per wind-speed bin (3 statistics and 6 turbulence seeds) 3 points per wind-speed bin (one representative point for each of the 3 statistics) or both. If you choose to only plot 3 points per bin, please plot the **mean** of each statistic. I.e., the **mean of the 6 mins**, the **mean of the 6 means**, and the **mean of the 6 maxes**.

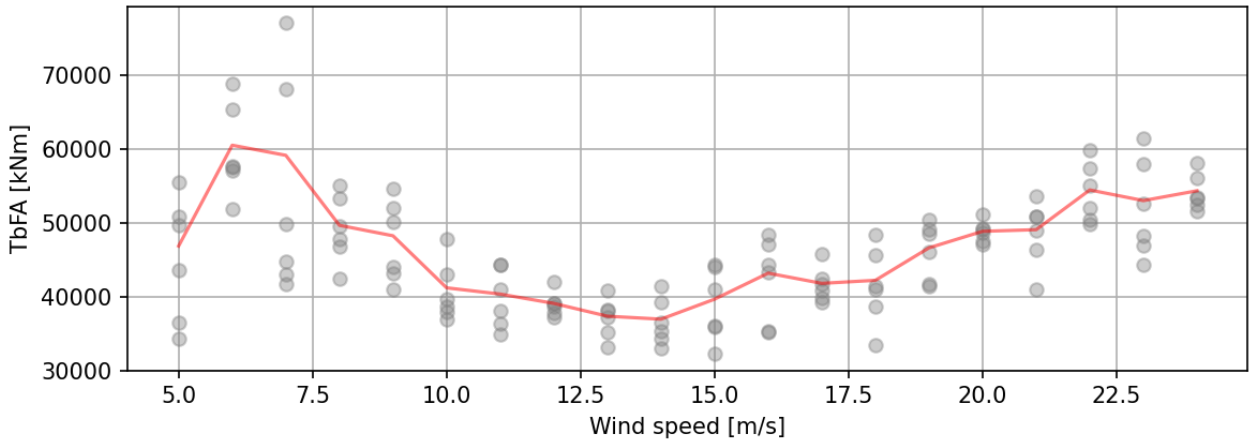
A plot is given below for inspiration. It has 18 transparent points per wind speed plus some lines indicating the bin-average of the extrema and the selected extreme value for the channel. NOTE it is not a pretty plot and it only has results from the DTU 10 MW. You are encouraged to make nicer plots. 🙃



Short-term DELs

An example plot with all 6 seeds per wind speed and a "bin-combined" line is given below. **NOTE THE RED LINE IS NOT THE MEAN OF THE SEEDS**. You should never, ever take the mean to combine DELs; they do not sum linearly.

Similar to the max/mean/min above, this is not a very great plot. You are encouraged to get a little more creative. 😉



Design loads and AEP

You may assume the shaft is overdesigned with a 30% margin on the torsional extreme design load.

Remember the debug files are available on Learn to help you write your code.

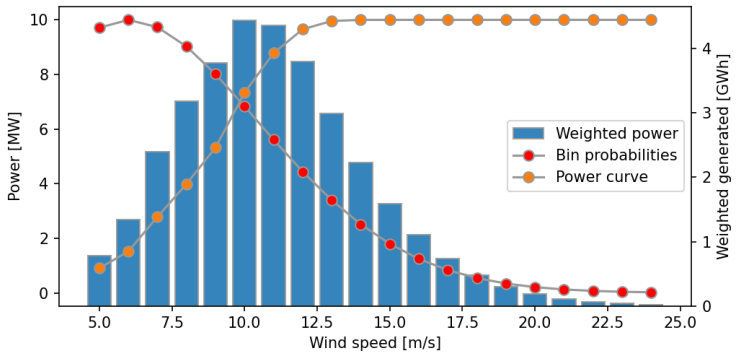
Table 1: Design loads/deflections for DTU 10 MW in wind class IA

	Extreme design load	Fatigue design load
Tower-base FA	364297.47 kNm	129826.23 kNm
Tower-base SS	117720.32 kNm	55207.15 kNm
Yaw bearing tilt	54987.89 kNm	32488.02 kNm
Yaw bearing roll	23907.46 kNm	4039.54 kNm
Shaft torsion	20365.17 kNm	2839.47 kNm
OoP BRM	72275.14 kNm	31335.80 kNm
IP BRM	40770.71 kNm	31017.46 kNm
Tower clearance	5.966 m	-

Table 2: AEP for DTU 10 MW.

	IA	IIIB
AEP	49.268 GWh	33.946 GWh

Example visualization of AEP calculation for 3B:



Optional: expansion packs

- Examine other load channels besides the minimum requirement. Discuss why they look like they do.
- Re-do the turbulence-class B simulations/calculations for your design with a different controller tuning. Evaluate which of the controller tuning parameters is better for your turbine.