**Assignment 1**

The goal of this assignment is to explore some of the concepts that we learned in the lectures in more depth. At the end of the course **(Day 4)**, you as a group will prepare a presentation based on the questions in this assignment. Each group will be given a unique turbine model.

**Day 1**

*Question 1: Examples of open-loop and closed-loop system*

Show one real-life example of open-loop control AND one example of closed-loop control. Justify why you think the examples you provided are open-loop and closed-loop.

*Question 2: Calculate the optimal gain (K\_opt) for your turbine model and implement the generator torque controller in Region 2*

First, calculate the optimal gain (K\_opt) for your turbine model. The turbine parameter can be found in ‘InitWT\_NREL5MW.m’ and ‘InitWT\_DTU850k.m’.

Step wind test

Second, open ‘Q2\_NREL5MW.m’. Input your calculated K\_opt values. Then, perform a step wind test (wind\_no = 1) and see if you achieve the maximum Cp and lambda. (Tip: you can find maximum Cp and lambda values in the structure called ‘turbine’)

Turbulent wind test

Third, open ‘Q2\_NREL5MW.m’. Change the wind file to turbulent wind speed around 8 m/s (wind\_no = 2), Calculate the AEP (annual energy production) for 10 min between 100s and 700s (sim.Tend = 700).

Now, let’s investigate other K\_opt values. Multiply your calculated K\_opt value with 0.99 or 1.01. Do you see a bigger value for the AEP? Why is that? Can you find a better K\_opt that produces higher AEP? How about the loads on the tower fore-aft motion (mode = 'omega+tower')?

**Day 2**

*Q3: Calculate the aerodynamic gain, the Kp and Ki for the blade pitch controller in Region 2.5 and 3*

1. Calculate the Kp and Ki for Region 2.5, assuming . Remember the turbine parameters can be found in ‘InitWT\_NREL5MW.m’ and ‘InitWT\_DTU850k.m’.
2. Calculate the following Kp and Ki for Region 3. Perform ‘Q3\_NREL5MW.m’ or ‘Q3\_DTU850k.m’ for the aerodynamic gain .

Consider the following three controller configurations:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Controller |  |  | GenTorq |  |  |
| C1 | 0.05 Hz | 0.7 | Const Torq | ? | ? |
| C2 | 0.05 Hz | 0.7 | Const Pow | ? | ? |
| C3 | 0.03 Hz | 0.7 | Const Pow | ? | ? |
| C4 | 0.05 Hz | 0.6 | Const Pow | ? | ? |
| C5 | ? | ? | ? | ? | ? |

1. Perform a step wind test and which controller is better and why? Think in terms of the pitch and generator torque activities, tower and rotor speed and power quality. Try different tuning parameters () and see if you can find a better controller C5.
2. Open ‘Q3b\_NREL5MW.m’ or ‘Q3b\_DTU850k.m’. Repeat the experiment with the turbulent wind. You might quantify the performance using the standard deviation of the time series using only 600s (100s to 700s) of the simulations. Do the results agree with your earliest findings? Find the two controllers that performed well and proceed to the next step.

*Q4: Simplified version of DLC 1.2*

1. Now, we will run a ‘simplified’ version of DLC 1.2 (design load case). The turbulent wind cases are 8, 12, 15 and 18 m/s and we assume that the site has a uniform distribution of the wind speed cases.
2. Compute the AEP and loads and input activities of all cases. Which controller is better? Why? Remember to check the maximum tower loads.
3. [Optional] You can try to quantify the tower damage using 1-Hz DEL (Damage Equivalent Loads) assuming m = 4 for steel materials. See `calc\_DEL.m`. Let’s use tower fore-aft displacement channel. See <https://toolbox.pages.windenergy.dtu.dk/WindEnergyToolbox/fatigue_tools/fatigue_nb.html>

**Day 3**

*Q5: Peak shaving*

1. Steady wind experiment
   1. Now, you should have your best controller C5. Open ‘Q4\_NREL5MW.m’ or ‘Q4\_DTU850k.m’. Input your controller parameters.
   2. Run the code and generate the steady-state plots.
   3. Open ‘Q4b\_NREL5MW.m’ or ‘Q4b\_DTU850k.m’. Can you find the minimum pitch setting that can reduce the peak thrust by 10%? Change the minimum pitch at ‘wpdata\_NREL5MW\_PeakShaving.100’ or ‘wpdata\_DTU850k\_PeakShaving.100’.
2. Turbulent wind experiment
   1. With the new minimum pitch setting, run a turbulent wind comparison case in ‘Q4c\_NREL5MW.m’ or ‘Q4c\_DTU850k.m’. Do you see a reduction in tower loads by sacrificing the power?

*Q6: Torque Limit*

1. In ‘Q5\_NREL5MW.m’ or ‘Q5\_DTU850k.m’, you can make a comparison between the baseline case and a case with different torque limits.
   1. Input your controller parameters.
   2. Increase the opening of the torque limit to see the behaviour of your turbine.
   3. Similarly, you can perform a turbulent wind case by changing the line 13 wind\_no to 3 (v=12m/s).

*[Optional] Q7: Peak shaving & Torque Limit*

1. Run a simplified ‘DLC1.2’. Based on your best design C5 from Q3 and Q4, can you improve your design further with peak shaving and torque limit?
   1. A comparison file is in ‘Q6\_NREL5MW.m’ or ‘Q6\_DTU850k.m’.
   2. Input your controller parameters.
   3. Change the minimum pitch setting at ‘wpdata\_NREL5MW\_PeakShaving.100’ or ‘wpdata\_DTU850k\_PeakShaving.100’.
   4. Change the torque limit at line 52.
   5. Run the turbulent wind cases 8, 12, 15 and 18 m/s and we assume that the site has a uniform distribution of the wind speed cases.
   6. Compute the AEP and loads and input activities of all cases. Can peak shaving or changing the torque limit improve your design in terms of power AND tower loads?