Lidar-Assisted Control for Wind Turbines II

Exercise to Lecture #11
"Controller Design for Wind Turbines and Wind Farms"

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10.09.2024

1 Feedforward Controller with Perfect Wind Preview

In a first step, the feedforward controller needs to be designed assuming perfect wind preview of 5 s. Here, a 3DOF wind turbine model is used including a 2nd order pitch actuator.

Instead of adding the pitch angle θ_{FF} to the output θ_{FB} of the feedback controller, a feedforward pitch rate $\dot{\theta}_{\mathrm{FF}}$ is added to the input of the integrator included in the feedback controller [1].

Please perform the following tasks:

a) Please implement the collective pitch feedforward controller in the block `FF/Collective Pitch Feedforward Controller` of the simulink model NREL5MW_FBNREL_SLOW3DOF.mdl and adjust the block `FBNREL/FBSWE Pitch Controller` correctly as described above. The feedforward controller should be disabled/enabled by `Parameter.CPC.FF.Mode` and the static pitch curve is already loaded into `Parameter.CPC.FF`.
b) Which prediction time is expected to overcome the pitch actuator dynamics? Use the command `step` and a second order transfer function of the pitch actuator.
c) What is the expected optimal buffer time considering the preview time of 5 s and the expected prediction time
d) Please adjust in the script TestCollectivePitchFeedforwardPerfectWind.m the calculation of the ultimate load of the tower base bending moment M_{yT} and useful values for the buffer time. A discretization of 0.1 s is sufficient.
e) Run the brute-force-optimization to obtain the results displaced in Figure 1 with the best load reduction. How much is the ultimate load on the tower reduced?

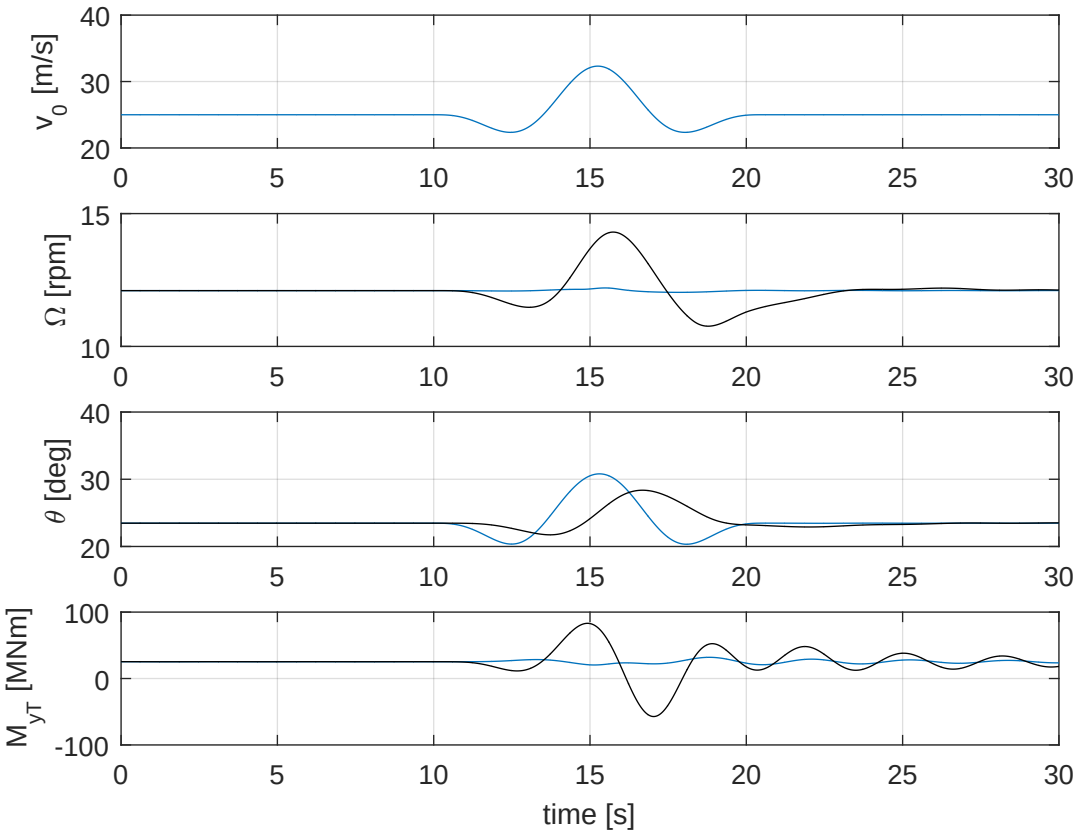

Figure 1: Reaction to an EOG. Feedback only (black), feedback combined with feedforward (blue).

2 Feedforward Controller with Realistic Wind Preview

In a second step, the adaptive filter needs to be designed assuming realistic wind preview from a scanning lidar ([1]) at 63 m with a mean wind speed of 20 m/s. The cut-off wave number (−3 dB) for the lidar scan has been identified to be 0.07 rad/m.

Please perform the following tasks:

a) What is the cut-off frequency for the first order low pass filter?
b) What is the time delay of the first order low pass filter at 0.1 Hz?
c) What is the expected optimal buffer time considering the preview distance, mean wind speed, the prediction time, and filter delay?
d) Please adjust in the script TestCollectivePitchFeedforwardRealisticWind.m the calculation of the fatigue load of the tower base bending moment M_{yT} (see e.g. Equation 2.13 in [1]) and useful values for the expected buffer time. A discretization of 0.2 s is sufficient. How much is the fatigue load on the tower reduced?

References

[1] D. Schlipf. "Lidar-Assisted Control Concepts for Wind Turbines". PhD thesis. University of Stuttgart, 2015. DOI: 10.18419/opus-8796.