Advanced Torque Controller

Exercise to Lecture #6
"Controller Design for Wind Turbines and Wind Farms"

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1 Design of a PI Torque controller

In a first step, the PI Torque controller is designed. The objective is to have a closed-loop transfer function with a damping of 0.7 and a natural angular frequency of 0.5 rad/s at the operation point 11 m/s (Region 2.5). The controller should also work at the operation point 5 m/s (Region 1.5). The PI torque controller is tested with wind steps of 0.1 m/s. Please perform the following tasks:

a) Please check, if the script Exercise06_AdvancedTorqueControllerTest.m is running. Here, the generator torque in initialized with the steady state value and then shifts to zero, since the implementation of the torque PI is still missing.
b) With the linearized model, the PI parameter can be calculated. You can use the function LinearizeSLOW1DOF_TC, the new steady states SteadyStatesNREL5MW_FBSWE_SLOW, and the files from the pitch PI exercise. Do the parameters differ significantly for the operation points from Region 1.5?
c) The controller parameter are loaded with NREL5MWDefaultParameter_FBSWE_Ex6_TPI.m. Please ignore the set-point fading for now (e.g. `Delta_Omega_g`) and implement the reference values and limits in the embedded Matlab function `LimitsAndReferenceValueTC` in the subsystem `FBSWE/Torque Controller/LimitsAndReferenceValueTC` of the simulink model NREL5MW_FBSWE_SLOW2DOF_Ex6_TPI.mdl.
d) Please test the implementation at 11 m/s. Is the reaction close enough to the designed reaction?
e) Please test the implementation at 5 m/s. Why the reaction is different at this operation point?

2 Implementation and Tuning of the Set-point-Fading

After the implementation and design of the torque PI controller, the set-point-fading needs to be implemented. The objective is to avoid to have the pitch controller interfering in Region 2.5 and the torque controller in Region 3. The controller should be tested with wind steps of 0.1 m/s at 11.2 and 11.6 m/s, since rated wind speed is 11.4 m/s. Please perform the following tasks:

a) Please check, if the script Exercise06_SetPointFadingTest.m is running. Here, the pitch controller is interfering, since the set-point-fading is still missing. What is the power at 11.3 m/s?
b) The controller parameters are loaded with NREL5MWDefaultParameter_FBSWE_Ex6_SPF.m. Please add the rule of thumb values for the set-point-fading variables `Parameter.VSC.Delta_Omega_g`, `Parameter.VSC.Delta_theta`, and `Parameter.VSC.P`.
c) Please implement the set-point-fading in the simulink model NREL5MW_FBSWE_SLOW2DOF_Ex6_SPF.mdl in the blocks `FBSWE/Pitch Controller`, `FBSWE/SwitchTransition`, and `FBSWE/Torque Controller/LimitsAndReferenceValueTC`.

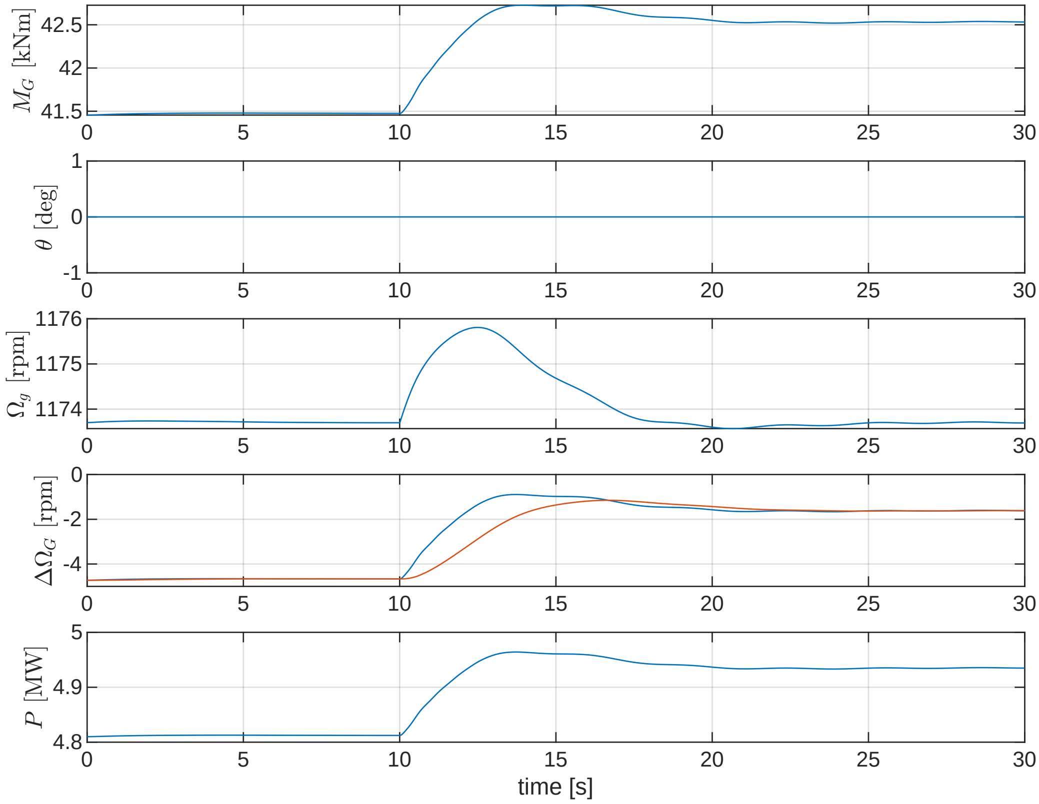

Figure 1: Reaction to a wind step at 11.2 m/s, close to rated. Due to the set-point fading, the set-point of the pitch controller is increased by subtracting the negative, low-pass filtered $\Delta\Omega_G$ (red) and thus is not interfering, since the resulting over speed is below this value.

d) Please test the implementation at 11.2 m/s. You should get results similar to Figure 1. Is the pitch controller still interfering? If not, what is the power at 11.3 m/s?

e) Please test the implementation at 11.6 m/s and set the controller mode to constant torque. Is the torque controller interfering?

3 Fine Tuning

Here, we will fine tune our controller by running several times a full Design Load Case (DLC) 1.2 with SLOW. Please perform the following steps:

a) Please run Exercise06_GenerateDisturbance.m. This should generate 11 files URef_??_Disturbance.mat files, where ?? is the mean wind field. Please describe briefly, how the time series of the rotor-effective wind speed is generated.

b) Please run Exercise06_SetPointFadingFineTuning.m. This script runs a full DLC 1.2 for different values for ΔP. Please add the equation in line 73 and 74 to calculate the AEP and the lifetime weighted Damage Equaivalent Load (DEL) and determine the optimal values for ΔP to stay below 43 MNm for the tower loads and have the highest Annual Energy Production (AEP).