UNIVERSITY OF PADOVA

Control Engineering Laboratory

Third Laboratory Challenge

SECOND SHIFT (Friday 10:30) GROUP NAME: F.1

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1 Challenge Description

The challenge requires the design of a control system for the QUANSER SRV-02 MOTOR with added resonant load, capable of asymptotic tracking of step references with an overshoot $M_p \leq 30$ % for a $r = 50°$ reference signal. The goal is to reach the fastest possible settling time. For the sake of comparability with other groups, the design was carried out solely in the form of Simulink simulations using the black-box model.

2 Control Strategy

To match all the performance specifications mentioned above, a robust state-space controller was used. Since the controller makes use of the whole state (the angular positions ϑ_h and ϑ_d and the angular velocities $\dot{\vartheta}_h$ and $\dot{\vartheta}_d$) rather than only the system output $[\vartheta_h, \vartheta_d]^T$, a simple state observer consisting of two real implementations of derivatives (with values as mentioned in the handout) was employed to estimate the missing states. To get an accurate measurement of the beam displacement with respect to the hub, a bias estimation is performed in the first 0.7 seconds of the simulation. During this time, the controller is not active, and the reference signal is 0. Figure 1 shows the Simulink implementation of the controller.

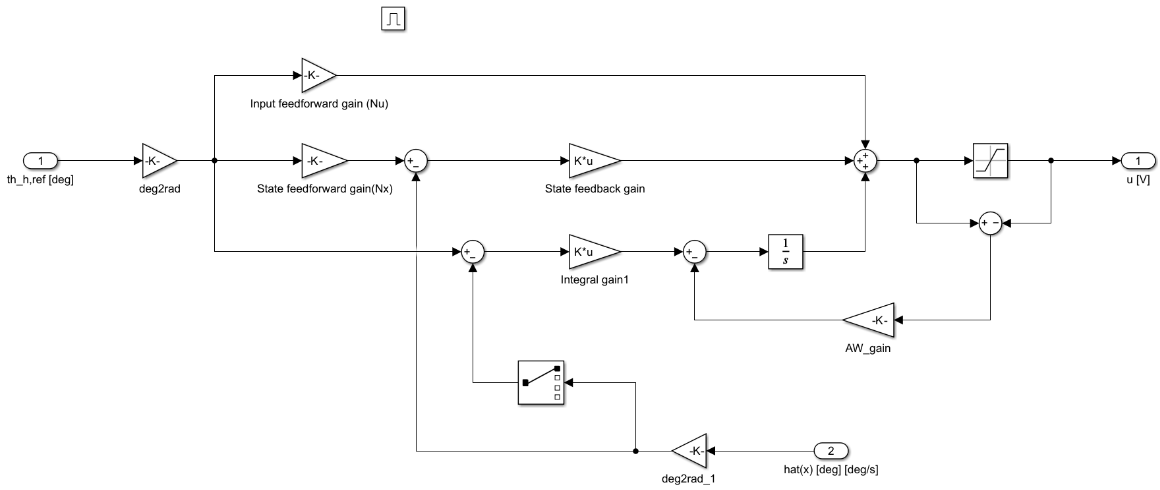

Figure 1: Robust state-space controller.

The controller gains were determined to place the eigenvalues of the closed-loop system in positions determined using the Bode method with the dominant pole approximation. Including the integrator with its anti-windup mechanism, this leads to five poles and six tunable parameters: the desired specifications as input to the Bode method, the relative positions of the other two plant poles with respect to these (i.e. the relative phase and magnitude), the integrator pole location, and the anti-windup gain. These were tuned carefully, keeping in mind the effects of pole positions on speed and aggressiveness. The resulting desired eigenvalues and feedback gains are:

$$\lambda_{1,2} = -27.2727 \pm 54.9002i$$
$$\lambda_{3,4} = -25.0083 \pm 10.1046i$$
$$\lambda_5 = -58.8491$$

$$\boldsymbol{K} = \begin{bmatrix} 1044.20 & 632.550 & 20.4151 & 14.7787 \end{bmatrix}$$
$$K_I = 11309.5$$
$$K_{\text{Anti-Windup}} = 33$$

2.1 Results

Figure 2 shows the resulting response of the controlled system to a 50° step reference signal for both the hub position and the relative beam displacement. The response has an overshoot of $\boldsymbol{M_p = 3.32}$ % and a settling time of $\boldsymbol{t_{s,5\%} = 0.191}$ **seconds**. The files of the challenge can be accessed here.

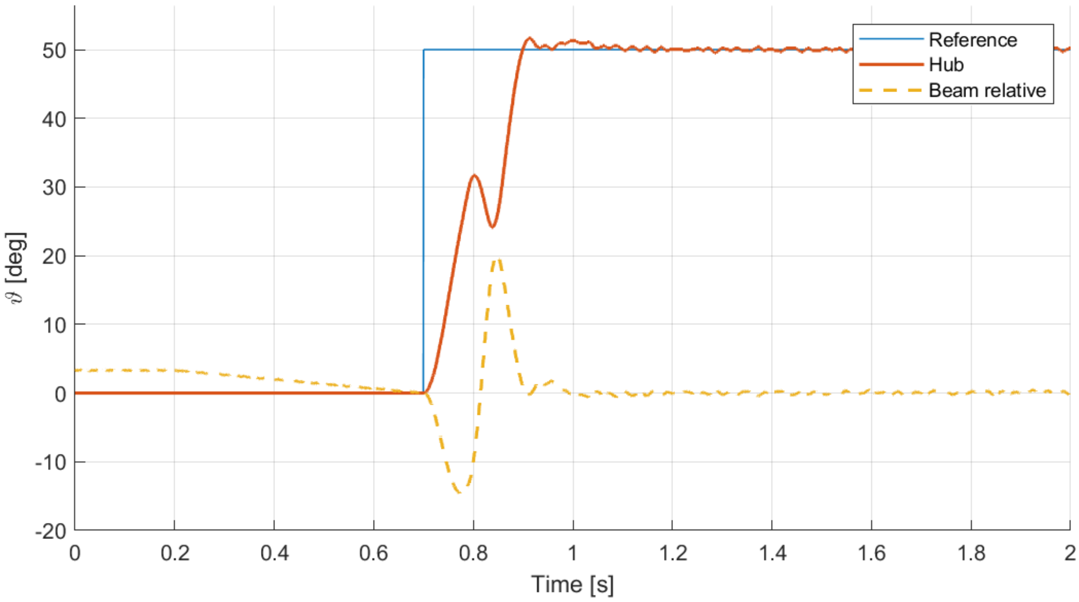

Figure 2: Transient of the step response to a reference value of 50°.