EMOMA – homework 2 (no. 3)

1. Make a model of a single–link manipulator for the following data:

   $J_m = 3.1e^{-4}$ kg·m^2;

   $K_b = 0.105$ V/(rad/s);

   $K_m = 0.105$ N·m/A;

   $L = 0.9$ e-3 H;

   $R = 0.76$ Ω;

   $B_m = 4e^{-4}$ N·m/(rad/s);

   gear ratio r=156;

   under saturation limits of the manipulator input signal: $V_{min} = -35$ V, $V_{max} = 35$ V.

2. Simplify the model neglecting the electrical time constant, simulate both accurate and simplified models using a rectangular pulse input signal (for the position) and make the comparison plotting outputs of both models in first figure and the difference in the second.

3. Assuming that both position and velocity are measured, design the PD control system satisfying the requirement: maximal control error (i.e, the difference between the reference trajectory and the manipulator output trajectory) should be between 0.01 and 0.005, for the polynomial cubic reference trajectory from $\theta_0 = 0$ [rad] to $\theta_f = 0.5$ [rad], with initial and final velocities equal to zero and time of movement $t_m = t_f = 1$ (starting at $t_0 = 0$).
   Check behavior of the control system for the step change of the constant reference trajectory from $\theta_0 = 0$ to $\theta_f = 0.5$ (modify the controller structure to P-D).

4. Calculate the LSPB trajectory from $\theta_0 = 0$ to $\theta_f = 0.5$, with the same time of movement t_m as for the cubic polynomial trajectory and with the blend time $t_b = 0.2t_m$, assuming initial and final velocities equal to zero. Test the behavior of the PD control system for this trajectory.

When doing the comparison in points 3 and 4, plot in the same figure desired and actual trajectories of the arm position (one figure) and of the arm velocity (second figure). Plot the position control error (third figure). The same applies to point 6.

5. Check influence of the constant load disturbance equal to $\tau_l/r = 2$ N·m, for cubic and LSPB reference trajectories.

6. Design the PID control system under the same control error accuracy requirement as in point 3, tuning PID by the choice of one triple pole -α. Test the behavior of the resulting feedback control system for both cubic and LSPB reference trajectories, for situations without and with load disturbance as in point 5. Check behavior of the PID control system for the step change of the constant reference trajectory from position $\theta_0 = 0$ [rad] to position $\theta_f = 0.5$ [rad] (modify the controller structure to PI-D, use anti-windup if needed).

7. Add the feedforward action to the PID feedback control system and test it for sinusoidal arm reference trajectory with amplitude $\theta_{max} = 0.25$ [rad] and angular frequency $\omega^{ref} = \alpha/4$ [rad/s] where α is the value chosen in point 6 for the PID tuning. Plot the output and reference trajectories in one figure and position control error in another one. Compare with the feedback only PID control (without feedforward) plotting analogous figures for the same sinusoidal reference trajectory.

The report should be concise (do not copy fragments of the lecture notes into the report) but containing comments to the results and all relevant design procedures (in particular, choice of ω and gains for PD, choice of α and gains for PID, design of LSPB trajectory). Please make sure all figures are readable, in particular the values on the axes.

The report should be submitted by 24th January, 2022, 11.59 a.m. at the latest, as a single "pdf" (or "doc") file, to the "Reports" module on the EMOMA course page on the server Studia III (the server will not accept transmission after the deadline).