Master study
Systems and Control Engineering
Department of Technology
Telemark University College
DDiR, November 29, 2006

SCE1106 Control Theory

Exercise 11

Task 1: Smith predictor

a) What type of processes can with advantage be controlled by a Smith predictor?

b) Assume that a process is to be controlled by a Smith predictor. Use the following expressions and symbols.

$$\begin{aligned} y(s) &= h_p(s)u(s) + h_d(s)v(s), \quad \text{real process} \quad (1)\\ h_m(s) &= h_m^-(s)h_m^+(s), \quad \text{model of } h_p(s) \quad (2)\\ h_c(s) &= \quad \text{regulator in the Smith predictor} \quad (3) \end{aligned}$$

Sketch a block diagram for the process controlled by a Smith predictor. Mark the estimated output $\hat{y}$ in the block diagram.

c) Give a description of the particular elements in the Smith predictor, i.e., $h_m^-(s)$, $h_m^+(s)$, and so on.

d) Find the transfer functions $h_r(s)$ and $h_v(s)$ in the relationship

$$y(s) = h_r(s)r(s) + h_v(s)v(s). \quad (4)$$

which describes the closed loop of the process controlled by the Smith predictor.

e) mention some advantages and disadvantages with the Smith predictor compared with conventional PID control.

f) Assume that the process is described by

$$h_p(s) = \frac{k}{(1+T_1 s)(1+T_2 s)} e^{-\tau s} \quad (5)$$

where $k = 0.5$, $T_1 = 1$, $T_2 = 0.5$ and $\tau = 2$. You can desire if you will put $h_d(s) = h_p(s)$ or $h_d(s) = 1$. We are to use a Smith predictor in which $h_c(s)$ is chosen as a PI controller with parameters as found in Exercise 6. Simulate the system controlled with a Smith predictor after a unit step change in the reference r.

In order to do the experiment more realistic you can with advantage include some modelling errors in the process model, and thereafter study the response from the disturbance v to the output y, as well as the set-point response from the reference r to the output y.

Task 2: Interaction and pairing of variables in MIMO systems

Given a process modelled by

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} -2 & 2 \\ 1 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 4 & 0 \\ 0 & 2 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} \quad (6)$$

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \quad (7)$$

a) Find the steady state gain matrix from the control input, u, to the output, y.

b) Assume that we want set-point control such that the outputs y_1 and y_2 are to be controlled to follow specified references r_1 and r_2. Investigate if there is possible with perfect control in steady state, i.e., investigate if there exists steady state control input, u, such that $y = r$ in steady state.

c) Write down a formula for computing the RGA matrix and put numerical values into the expression. Compute numerical values for the RGA matrix. Use MATLAB.

d) We want to control the process with two single loop PID feedback control systems. Investigate from RGA analysis which pairing strategies which are to be used. Is the pairing suggested from the RGA analysis the only possible?

e) Comment the relationship between the RGA analysis and the Δ indices by Balchen.