Name:……………………………………………………

Emnemodul: Advanced process control

Exam Dec. 2012. Time: 0915 – 1200. Answer as carefully as possible, preferably using the available space. You may answer in Norwegian

Problem 1 (30%).

(a) Define self-optimizing control:

(b) What should you select as primary CVs? How can you identify good primary controlled variable (in words)?

(c) What is back-off and how can it be reduced?

(d) What can you say about the purity specification (constraint) of a ”valuable” and ”cheap” product? Which is expected to be active?

(e) Consider controlling (CV) a measurement combination, $\Delta c = H \Delta y$.
Explain under which conditions it is optimal to choose H such that HF=0 (nullspace method). Define F and derive the condition HF=0.

(f) Consider a process with one steady-state degree of freedom (u), two disturbances (d1, d2) and three measurements (y1, y2, y3). Use the nullspace method to derive the optimal measurement combination when F = (3 1 ; 3 0.6; 0 1).

(g) Why may we sometimes get more then one optimal combination when we use the nullspace method (for example, for the blending example in one of the exercises) ?

(h) Explain briefly the advantages of the "exact local method"

Problem 2 (10%).

(a) State the steps of the plantwide control procedure of Skogestad, and give a *short* explanation of the main issues in each step.

(b) Is it correct that we like choosing constrained variables as CVs in the ”supervisory” layer and avoid choosing variables that may reach constraints as CVs in the “stabilizing” layer? What about MVs; does the same apply?

Problem 3 (RGA and pairing). **(15%)**

You want to control 2 outputs (CVs) and have available 3 inputs.

$$y_1 = [0.9/(5s+1)]\,u_1 \quad + \quad [0.8/(5s+1)(3s+1)]\,u_2 \quad + \quad [-1/(5s+1)]\,u_3$$
$$y_2 = [0.4\,e^{-2s}/(5s+1)]\,u_1 \quad + \quad [0.3/(5s+1)(3s+1)]\,u_2 \quad + \quad [-0.2/(5s+1)]\,u_3$$

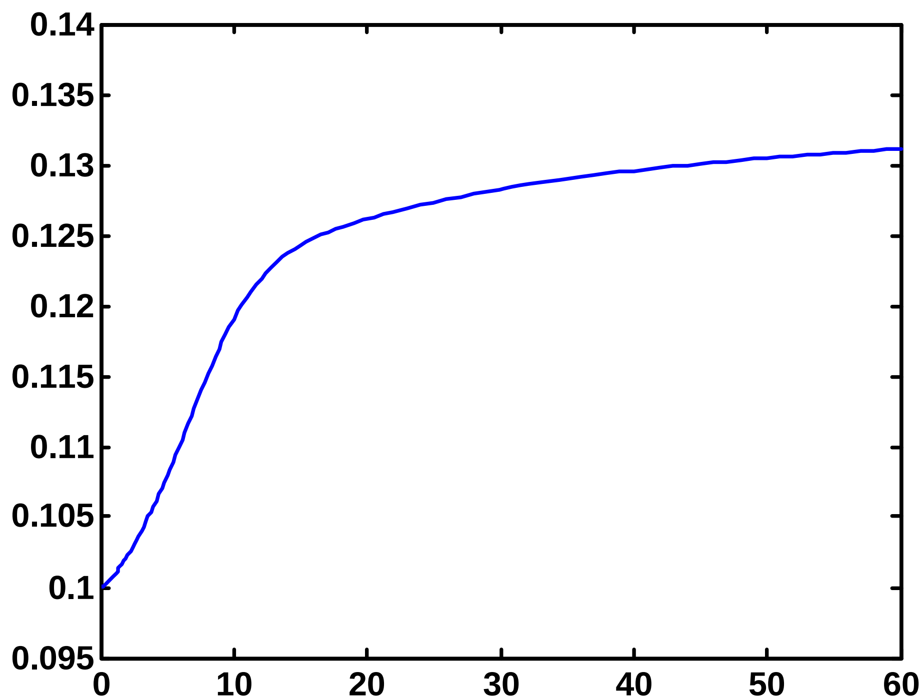
The task is to make a simple control structure with two single loops (using only 2 of the inputs).

(a) Compute the steady-state RGA for the three alternative input combinations.

(b) Which input combination do you recommend and what pairing?

Problem **4**. (15%)

We have performed an open-loop step response experiment. The figure shows the response in y to a change in the input (u) = 0.1 at t=0. The system is at steady-state before we make this change. Suggest PI-tunings for (1) Smooth control: τ_c=10,. (2) Tight control: τ_c=effective time delay.



Problem 5 (30%)

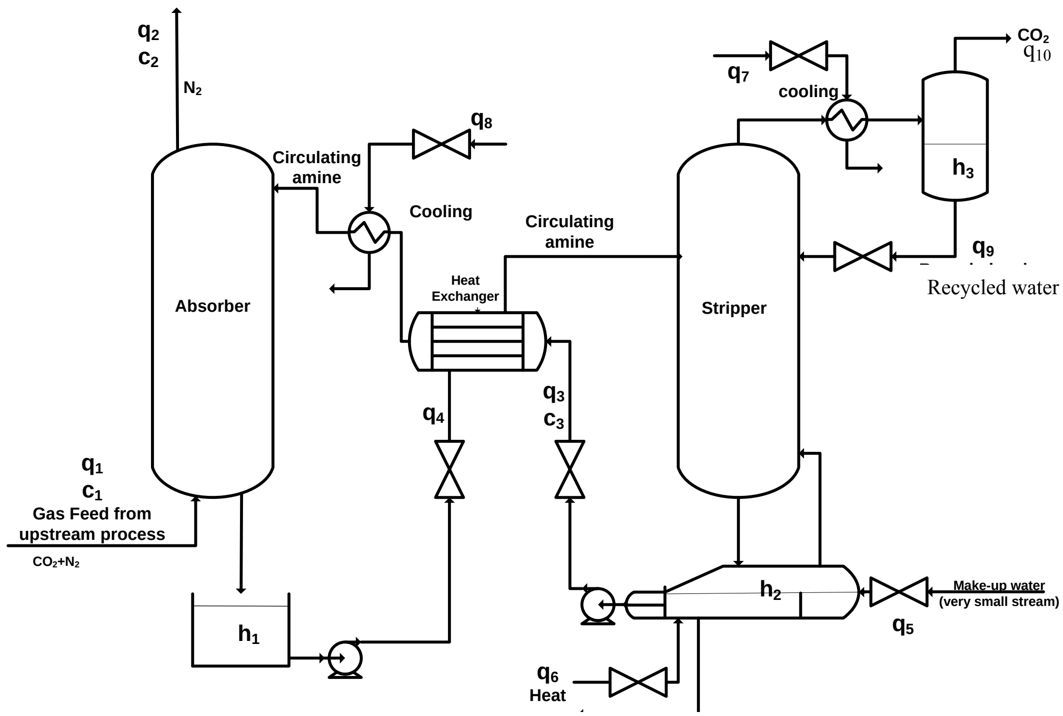


Figure 1. CO_2 Capture unit

The flowsheet of an absorber-stripper process for removing CO_2 from flue gas is shown in Figure 1. In the "cold" absorber (left), CO_2 (which has feed concentration c_1) is absorbed into the amine solution and it is released in the "hot" stripper column (right). The stripper column reboiler is heated with steam (q_6) and and the column is cooled with cooling water (q_7). The circulating amine q_3 is cooled to $40°C$ by cooling water (q_8) before entering the top of absorber. The pressure at the top of the stripper should be 1 bar. The concentration (c_2) of CO_2 that is released to the air should be less than 1%. Loss of water is compensated by the stream q_5.

(a) Define an economic objective for the process when you get paid for the amount of CO2 leaving the stripper.

(b) What are the degrees of freedom (dynamically, at steady-state)?

(c) What are the steady-state controlled variables? Suggest possible self-optimizing variable(s).

(d) What is meant by "consistency" of and "local-consistency" of inventory control? Discuss the inventory control loops for liquid and gas inventory.

(e) Suggest a control structure involving feedback loops and draw them on the flow sheet. (Hint: They should involve LC, TC, XC (where X denotes composition) and PC.)

(f) Assume that we want maximum throughput (of gas feed). What are possible expected active constraints when the gas load in the absorber is not the problem? Describe a typical control structure that may result. Could MPC be used?