**Name:…………………………………………………**

**Emnemodul: Advanced process control**

**03 Dec. 2014. Time: 0915 – 1200. Answer as carefully as possible, preferably using the available space.** You may answer in Norwegian

**Problem 1 (15%).**

Three of Sigurd’s rules for CV selection are:

1. Always control active constraints! (almost always)
2. Purity constraint on expensive product is always active (no overpurification)
3. Unconstrained optimum: NEVER try to control a variable that reaches max or min at the optimum

Give a short justification for each of the three rules.

**Problem 2 (20%)**



Comments. 1. Flow is to be kept at a given setpoint. 2. The “booster pump” runs at a constant speed (may be considered a disturbance). 3. “Cavitation” occurs when the pressure gets too low so the fluid starts boiling. This can occur at low flowrates because the booster pump then “sucks” more. To avoid cavitation you should make sure that the pressure before the booster pump is above a minimum value. 4. PT and FT indicate pressure and flow sensors (“transmitters”). 5. To minimize pumping energy (main pump) we would like the valve to be fully open whenever feasible.

1. State the “top-down” steps of the plantwide procedure of Skogestad
2. The figure shows the feed line to a process. Apply the top-down part of the procedure to this process. Note: Main disturbance is feedrate (Fs)

(c) Make a sketch of your proposed control strategy on the flow sheet (including at least a PC and a FC) and comment on how it achieves optimal operation.

**Problem 3 (30%).**

In Exercise 1 you considered optimal operation of the split α for a heat exchanger, where the objective was to maximize the temperature (J=T). We derived a simple analytical expression for the gradient, Ju = (T1-T0)2/(Th1-T0) - (T2-T0)2/(Th2-T0).

Th1, UA1

T0

m [kg/s]

Th2, UA2 A»

T2

T1

T

α

1-α

1. Briefly explain how the expression for Ju was obtained (just the main principles; not the details).
2. Explain why selecting c=Ju is a good self-optimizing variable.
3. Show a sketch on the flowsheet of how this self-optimizing strategy can be implemented. What should the setpoint for c be? What measurements are required to implement this control strategy?
4. Why is controlling c=T not a good self-optimizing variable?
5. In general, we cannot expect to find an analytical expression for Ju in terms of measureable quantities. A more general alternative is then to use “local” approaches and find linear measurement combinations. One approach is to use the nullspace method. Explain the idea behind the nullspace method. What is the sensitivity matrix (F)?
6. Assume that the disturbances (d) are T0, m, Th1, UA1, Th2, UA2, and available measurements (y) are T1, T2, T0, Th1 and Th2. What is the dimension of F is and how could it be obtained for this example? Can the nullspace method be used?
7. Explain briefly the “exact local method”. Can it be used for this example?

**Problem 4. Control of flow and pressure (8%)**

Which of the following control structures are workable (all involve gas flow)?



**Problem 5. Control of offshore process (12%)**



Typical data: pF=50 bar, p1 = 30 bar, p2 = 3 bar, pG=100 bar

In an offshore separation process, we are told that we should control the production flow (=well stream = feed flow), the oil product vapor pressure (p2=3 bar) and the gas product delivery pressure (pG=100 bar). Based on this, it is proposed to use the control system shown in the figure.

1. It this control system workable? If not, can it be made workable?
2. Propose a control system if we instead are told to control oil product vapor pressure (p2=3 bar), first stage pressure (p1=20 bar) and gas product delivery pressure (pG=100 bar).



1. Explain what a TPM is. Where is it located in the two above cases?

**Problem 6 (15%**)

1. The above figure illustrates the “squeeze and shift” rule. Explain the basis (theory) and practical significance of this rule.
2. We have given the following process: G(s) = 3 exp(-s)/[s(6.5s+1)]. What controller would you recommend for this process? PI or PID? Give tunings for your proposed controller.