**Project (with possible extension to Master thesis) for Sigurd Skogestad 2024-25.**

For additional information see here:

https://folk.ntnu.no/skoge/diplom/prosjekt24/

The proposed projects are part of an effort to improve the theoretical basis for "advanced regulatory control" solutions. The topics will also be covered in the module "Advanced process control". The project may also be extended to a Master thesis on this or a related topic. For more details about the problem and motivation behind the project, please see the following paper:

**S. Skogestad "Advanced control using simple elements - An important and challenging research area". Annual Reviews in Control (2023).**

https://folk.ntnu.no/skoge/publications/2023/skogestad-advanced-regulatory-control\_arc/

This paper ends with the following conclusion: *In summary, it is proposed that a lot more academic research is focused on developing theory for the advanced regulatory control solutions described in this paper. Indeed, the problems are very challenging. For example, the mathematical problems related to the optimal decomposed and decentralized control solutions are in general non-convex, and the stability analysis of switched systems (for example, with selectors, anti-windup and split range control) is very difficult and may result in limit cycles and chaotic behavior. This, in addition to an unclear problem definition, may scare academic researchers away, but hopefully the importance of the problem and the prospect of seeing the solutions being used in practice and thus benefiting humanity, may provide motivation to consider these challenging problems.*

For all projects: Simulations may be with Matlab, Simulink, Hysys or Aspen.

In many projects, examples will be used from the Perstorp Company (Professor Krister Forsman),

**1. Control of distribution networks (manifolds)**

Project SiS-1.

Cooperation with: Krister Forsman, Perstorp co

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Manifolds (distribution of gas or liquid to many customers) are very common in industry for example, for steam and water distribution. A possible control structure using SISO controller sis shown above but also multivariable control (MPC) may be considered.

For the above SISO control system some issues are:

* How should the controllers be tuned to reduce interactions and sensitivity to disturbances? In what order?
* Can VPC be used instead (to control the valve to be almost fully open)? (see figure below). With many flows one may use a max-selector on the valve openings. A gas-lift problem may be relevant here.

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Description automatically generated with medium confidence

* For gas distribution it is important to reduce pressure drops so save energy (compression power). What happens if the pressure controller is eliminated? And how can we always then keep one FC valve fully open? Maybe VPC?

The project will involve modelling (probably in Matlab), simulation and initial controller tuning. The master thesis will look at more advanced topics, for example, comparison with MPC and schemes that save energy.

**2. Bidirectional control of reactor-distillation recycle process**

Project SiS-2

A diagram of a machine

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Bidirectional inventory control can be extended to recycle systems as illustrated in the flowsheet of a reactor-distillation recycle process. In the project, the main objective is to simulate the process, both at steady-state and dynamically (using Aspen). In the Master thesis, the objective is to design, tune and simulate the control system for various disturbances, including temporary stops in all flows.

**3. Modelling, simulation and control of process for salt production**

Project SiS-3

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The project is based on an industrial process, but the anion X has been replaced by Cl (HCl).

The project aims at modelling a neutralization process for salt production and developing a control scheme. The following units are included:

* Feed tank of NaOH with pump (constant speed) and recycle valve.
* Bleed valve of NaOH (to buffer),
* Valve for NaOh to reactor loop, reactor loop with pump (constant speed), mixer, cooler and “reactor”
* Feed tank with valve for HCl
* Product draw for salt (NaCl).

Some data:

* The production rate of NaCL Is 1 t/h and the recycle around the reactor is 10 t/h
* The NaOH bleed to the buffer is on for 10 minutes (at about 10t/h) and then off for 50 minutes
* It is desirable to keep NaCl production going all the time.
* Pressures before the the pump runs at constant speed (you need to get a pump curve)
* The pressure in the feed line should be between 4 and 2 bar.

In the project, you should first design the process equipment, including selecting pumps and heat exchangers and simulate it with Aspen (steady state).

In the master thesis you should develop a dynamic model and look at the control.

**4. Control scheme for optimal operation of silver-catalyzed formaldehyde process (Dynea)**

Project SiS-4

A diagram of a factory

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With summer job (Nils Arne Susort). See details here:

https://folk.ntnu.no/skoge/diplom/prosjekt24/dynea/

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**5. Default tuning of PID controllers (including scaling of variables) based on limited information.**

Project SiS-5.

It is important to have simple rules for default tuning in order to avoid spending too much time on PID tuning during startup. The first part of the project is to search the literature for such rules. Next to propose possible new rules. Finally, to simulate the rules.

**6. Comparison of selector on input or setpoint (cascade) for CV-CV switching**

Project SiS-6.

The objective is to compare the two options by simulating some industrial cases.

**7. Comparison of alternative schemes for MV-MV switching**

Project SiS-7.

There are (at least) three alternative schemes. These should be compared on typical industrial case studies.

**8. Floating pressure or temperature control.**

Project SiS-8.

It may be possible (and desirable) to have the same variable being controlled twice in the same cascade hierarchy.

For example, one may have two pressure controllers on top of each other (one fast for stabilization and one slow for optimization with sets the setpoint to the fast controller), or there may be a VPC in between so that pressure is “floating" (uncontrolled) on an intermediate time scale. Another case may be stabilizing control of a reactor, with PD-control in the inner loop, with setpoint set by a slow PI-controller.

**9. Linear decoupling with reverse (feedback) implementation**

Project SiS-9

The task is to compare the performance of the reverse implementation of Shinskey with the more common implementation. In particular, compare the two for cases with input saturation and switch between manual and auto. Also consider the case where the RGA is close to 0.9 and there may be internal stability problems with the reverse implementation.

**10. Tuning of anti-windup schemes**

Project SiS-10.

There exists many approaches to anti-windup, and the first task is to compare the three most common schemes on some case studies

1. Limiting the bias

2. Anti-windup based on positive feedback implementation of I-action

3. "Back-calculation" scheme with extra tracking time parameter.

The next step is to make recommendation of how to choose the tracking time, for example, when we need anti-windup for CV-Cv switching, decoupling or cascade control.

**11. Structure and simulation of selector logic**

Project SiS-11.

Selectors are used for steady-state CV-CV switching and in a few cases for dynamic reasons (e.g., cross-limiting control). In the project, the aim is to simulate some typical process examples (see the paper). Anti-windup using back-calculation should also be included.

**12. Simple schemes for nonlinear decoupling and feedforward control.**

Project SiS-12.

The objective is to propose and simulate some simple schemes for nonlinear decoupling and feedforward control om industrially relevant case studies.

**13. Modelling, optimization and control of combined cycle power plants**

Project SiS-13.

The steam cycle uses a once-through boiler. This is a cooperation with SINTEF and the project is reserved for Ruben Montanes.

**X. Also other topics are possible.**

Please contact Sigurd Skogestad [skoge@ntnu.no]