**NTNU Fakultet for naturvitenskap og teknologi**

**Norges teknisk-naturvitenskapelige Institutt for kjemisk prosessteknologi**

**universitet**



**5th year research projects, autumn 2013**

**Project proposals from: Sigurd Skogestad + Krister Forsman**

1. **Proposals from Sigurd Skogestad**
2. **Validation of PID tuning rules**

**Co-supervisor: Chriss Grimholt**

Grimholt and Skogestad (2012) have recently proposed a new way analyzing the optimality of tuning rules. This involves using Pareto-optimal curves portraying the optimal performance versus robustness for a given process. This has been done for the SIMC rules for several different processes. In the continuation of this project it is interesting to compare with other tuning rules (e.g. Ziegler-Nichols, Astrom, Tyreius-Luyben, and more). It is also interesting to take a deeper look at our criteria for optimality. That is, if it sufficiently covers the criteria of a "good" tuning. The work will be conducted with simulations in Matlab and Simulink.

1. **Energy storage in a domestic water heater**

**Co-supervisor: Chriss Grimholt**

In order to discourage energy usage during periods of high consumption in the energy grid, it is easy to envision that the energy companies will increase the energy price during these times. In this project, we want to investigate the storing of energy in a domestic water heater such that we avoid energy usage during the high price period. As a solution, we want to find simple strategies (e.g. with simple feedback), and avoid complicated controllers as MPC. The work will be conducted with simulations in Matlab and Simulink.

1. **Oil Production Optimization using Self-Optimizing Control**

Cosupervisor: Chriss Grimholt

The petroleum fields are usually optimized on several time horizons. On the long time horizon, typically ranging from one year to the reservoirs lifetime, decisions are related to the physical development of the field.

That is, which production units should be commissioned, where should they be placed, and when should they be operational.

On the medium time horizon, the planning revolves around maximizing the oil and gas extraction from the field within the bounds of the long time scale strategies.

On this horizon, commissioning of new wells and their location, as well as the use of artificial lift technology, are important topics.

Operational production planning occurs on the short time horizon, ranging from weeks to days, and is also known as real-time production optimization (RTPO).

The objective is to maximize the daily production rates considering down-hole effects like coning, and production limitations like pipeline and downstream water handling capacity.

Usually the RTPO problem is solved once a day under the assumption that the well conditions remains fairly constant. However, between each iteration of RTPO, the down-hole condition may change resulting in a suboptimal operation.

In this project we will use a simple steady state model that consists of a four well cluster connected to a separator with one pipeline. The objective is to maximize oil production while satisfying the production constraints.

The goal of this project is to find good control variables (CV) such that, by using feedback, we can keep the production close-to optimum despite disturbances in down-hole conditions (e.g. gas oil ratio).

We will find different CV by using well know methods like the null space method and exact local method, but we will also use newer concepts J\"aschke's optimal split of parallel units (by using marginal cost).

We will also investigate changes in active constraints and how the control structure changes between the different constraint regions.

1. **Economic plantwide control using commercial process simulation software**

Co-supervisor: Vladimiros Minasidis

A systematic top-down procedure for the design of economic plantwide control system was developed by Skogestad in 2000. The word economic is used here to distinguish the Skogestad’s plantwide design procedure which is based on the steady state plant’s economic performance. The main objective of Skogestad’s procedure is to design a control structure for the complete plant that achieves safe and close to optimal economic performance based on simple control strategies e.g. constant setpoint policies.

In this project we want to explore the possibility of automating the economic plantwide design procedure for various process flowsheets developed using commercial process simulators like Hysis or Unisim. The main focus of the project is to formulate an algorithmic procedure that will facilitate the control structure design for the engineers that use these process simulators for this purpose.

A successful completion of the project requires: the development of the steady state and dynamic model of a generic chemical process (could be a process which consists of reactor, separator and recycle stream), design of the economic plantwide control (the steady state model is used here) and the evaluation of the performance of the designed control structure (the dynamic model is used here).

1. Dynamic optimization and control of batch crystallization processes

Co-supervisor: Vinicius de Oliveira

Batch crystallization is well established in the industry for the small-scale

production of fine chemicals and pharmaceuticals industries as a purification and

separation technique. Generally, chemical reaction steps take place in liquids

while the final product is, in many cases, solids. Often, the solid product is ob-

tained by crystallization. Many physical properties of the products are strongly

linked to their size and shape. For instance, surface structure and reactivity

varies with crystallography orientation. The production of crystalline material

with a desired size distribution is a big challenge in industrial crystallization.

In batch cooling crystallizers the fact that solubility depends on temperature is

exploited to reach given specifications.

The goal of this project is to use dynamic optimization techniques to obtain

temperature profiles that minimizes the mass of nucleated (undesired) crystal in

a batch cooling crystallization process. For this purpose we will use population

balance models available on the literature and we propose applying simple single

and multiple shooting methods for dynamic optimization.

Once the optimal temperature profile is available an important question still

remains: How do we implement it in practice in a simple and reliable way?

For this we will seek simple feedback control structures that yield near op-

timal batches despite disturbances and implementation errors. To deal with

disturbances, the main idea will be to find a combination of variables whose

optimal trajectory is insensitive to the (defined) disturbance (optimally invariant

trajectory). Therefore, tracking this trajectory by a feedback controller will

automatically produce optimal inputs for any sufficiently small disturbance.

A crucial requirement in batch processes operation is to be able to meet all

the constraints despite disturbances and model uncertainties. Thus, we would

like to employ a model predictive controller (MPC) to track the optimally invari-

ant trajectory. The motivation behind MPC is that it can intrinsically handle

constraints and it is, therefore, well suited for batch operation. Furthermore,

apart from feasibility, it also is important to be near the optimal solution even

in face of unforeseen disturbances. For that matter, we will add an economical

term in the MPC cost function which should automatically drive the system

towards the optimal solution.

1. **Expected problems when pairing on negative RGA-elements**

The basis for this project is that it is not clear what happens if one pairs on a negative RGA. This will be a mix between simulation (in Simulink) and theory.

Background: Pairing on a negative steady-state RGA-element may give good decentralized control performance, but there are potential risks.

First, note that if one pairs on a negative RGA, then one cannot tune the controllers

using independent designs (where each loop is tuned separately with the other loops in manual), because one would get instability when all loops are closed.

Second, consider sequential loop closing, which is probably more common practise. In this case, pairing on a negative RGA is claimed to result in instability, and the objective of this work is to study this in more detail.

1. **Optimalisering og regulering av CO2-stripper (samarbeid med Statoil Kårstø)**

Medveileder: Marius Govatsmark, Statoil Kårstø

CO2-stripperen er en destillasjonskolonne der CO2 strippes fra etan. Bunnproduktet er rent etan, mens topp-produktet er en blanding av etan og CO2. Topp-produktet brukes som fyrgass i dampproduksjon noe som gir betydelig frihet i valg av toppsammensetning. Optimal toppsammensetning vil avhenge sterkt av føden. Betydelig variasjon i toppsammensetningen og potensiell nær azeotropisk blanding av etan og CO2 i toppen gjør prosessen ulineær og utfordrende å regulere.

Oppgaven består i:

1. Lage en dynamisk modell av en CO2-stripper

2. Finne optimal drift for ulike føder

3. Foreslå en reguleringsstruktur som muliggjør optimal drift (både basis- og overordnet regulering)

4. Implementere regulering ved bruk av PID-regulering og / eller MPC.

1. **Modellering, estimering, optimalisering og regulering av NPK-prosessen**

Medveileder: Knut Wiig Mathisen, Yara

NB. Studenten som velger denne oppgaven bør ha kunnskap om NPK-prosessen.

1. **Project proposals from prof. II Krister Forsman, process control specialist at Perstorp**

For more details about these projects see here:

<http://www.nt.ntnu.no/users/skoge/diplom/prosjekt13/>

# Cascade control

In a traditional cascade loop, a disturbance in the slave control loop leads to a disturbance in the master loop which has an ”unnecessary” undershoot.

This type of behavior is impossible to achieve without modifying the structure. Is there a modification of the structure that does not have this effect?

A different question: Is it possible to quantify when cascade control should be used?

# 2. Implementation of ratio control

Ratio control can be implemented in several different ways and the objective is to compare these. One issue is how we handle saturation, and another issue is how to handle nonlinearity caused by changes in the operating point.

# 3. Variance minimizing control

In applications, occasionally the control valve will saturate, i.e. go to 0% or 100%, in which case the controller is not active any more. Normally, this just means that we are facing a process design problem, and there is nothing to be done about the situation from a control point of view. However, in some applications it may be as important to reduce variations in the process variable as it is to keep its value close to the setpoint.

To solve this compromise we may consider modifying the working setpoint slightly so that we get back into a controllable situation, but also monitor when we can start going back to the target setpoint.

**4. Industrial control case at Perstorp**

There are several possible cases, including distillation processes.

**5. Training simulator for formalin process**

**Co-supervisor: Oleg Pajalic, Perstorp**