

Advanced control for the future

using the magic of feedback and simple elements*

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Trondheim

17th Seminar on Power Electronics and Control (SEPOC) – November 9–12, 2025
"Applied Computing and Cutting-Edge Solutions in Power Electronics and Control for Industry 5.0"
Floranopolis

Part 1. Introduction

Advanced Control for the future - using simple elements (agents)

- **How can you control a complex process effectively using simple elements with a minimal amount of modelling? How can you put optimization into the control layer?**
- Industry has been using simple and effective “advanced regulatory control” (ARC) schemes for almost 100 years, yet they remain poorly understood and therefore underused. The objective of the workshop is to provide a systematic approach for designing such control systems. The target audience includes both practicing control engineers as well as PhD students and teachers from academia.
- The workshop explores the standard advanced control elements commonly used in industry for designing advanced control systems. These elements include cascade, ratio, feedforward, decoupling, selectors, split range, and more, collectively referred to as “advanced regulatory control” (ARC). Numerous examples are provided, with a particular focus on process control. I emphasize the shortcomings of model-based optimization methods, such as model predictive control (MPC), and challenge the view that MPC can solve all control problems, while ARC solutions are outdated, ad-hoc and difficult to understand. On the contrary, decomposing the control systems into simple ARC elements is very powerful and allows for designing control systems for complex processes with only limited information. With the knowledge of the control elements presented in the workshop, participants should be able to understand most industrial ARC solutions (which can be a challenge!) and propose alternatives and improvements.
- Link: <https://books.google.com.br/books?id=97iAEAAAQBAJ&lpg=PR11&ots=DxVsAkc52g&lr&hl=no&pg=PR12#v=onepage&q&f=false>
- Link: <https://www.wiley.com/en-us/Multivariable+Feedback+Control%3A+Analysis+and+Design%2C+2nd+Edition-p-9780470011683>

More bout ARC

Advanced control refers to any control strategy that goes beyond basic single-loop PID control. It becomes necessary for processes involving multiple inputs, changing objectives or constraints, additional measurements, or measured disturbances. Many engineers intuitively think, “This is getting complicated—we need a model and optimization (e.g., MPC).” However, model-based control is often expensive to implement and highly sensitive to model uncertainty. Fortunately, there is a more robust yet less appreciated alternative: **advanced PID architectures**. These rely primarily on measurements (data) and feedback and consist of smart combinations of PID controllers with simple elements such as cascade control, selectors, split-range control, and ratio control.

My prediction: The future of advanced control will continue to be built on these simple PID architectures—just as they are today—despite having been largely neglected by academia for the past 80 years. Model-based control (e.g., MPC) will be added on top in specific applications, such as for strongly coupled processes or when future disturbances are known. Machine learning and AI (including tools like ChatGPT) are unlikely to be used extensively for real-time control, except in soft sensor (estimation) tasks. However, they will become important tools for **offline tasks** such as model development, software generation, control architecture design, and controller tuning.

Before ChatGPT: «Advanced control» is anything that comes in addition to single-loop PID control. It is needed for processes with extra inputs, changing control objectives and constraints, extra measurements and measured disturbances. The intuition of most engineers is that «this becomes very difficult, so we will need a **model** and optimization (MPC)». However, model-based control is costly to implement and sensitive to uncertainty. Fortunately, there is another option, mainly based on **measurements** (data) and feedback, which is much more robust but much less understood: Advanced PID-architectures that interconnect in a smart way PID controllers and other simple elements (cascade, selectors, split range control, ratio control).

My prediction: Advanced control in the future will use simple PID-architectures as the basis (as they do today - in spite of being neglected by academics for 80 years). It will be complemented with model-based control (MPC) for certain applications, for example, for strongly coupled processes or for cases where future disturbances are known. ML/AI will not be much used for online control, except for estimation (soft sensors). However, ML/AI (chatGPT) will be used for offline purposes, including developing models, writing software, suggesting control architectures and tuning controllers.



Midnight or midday?



Geiranger fjord



Trondheim

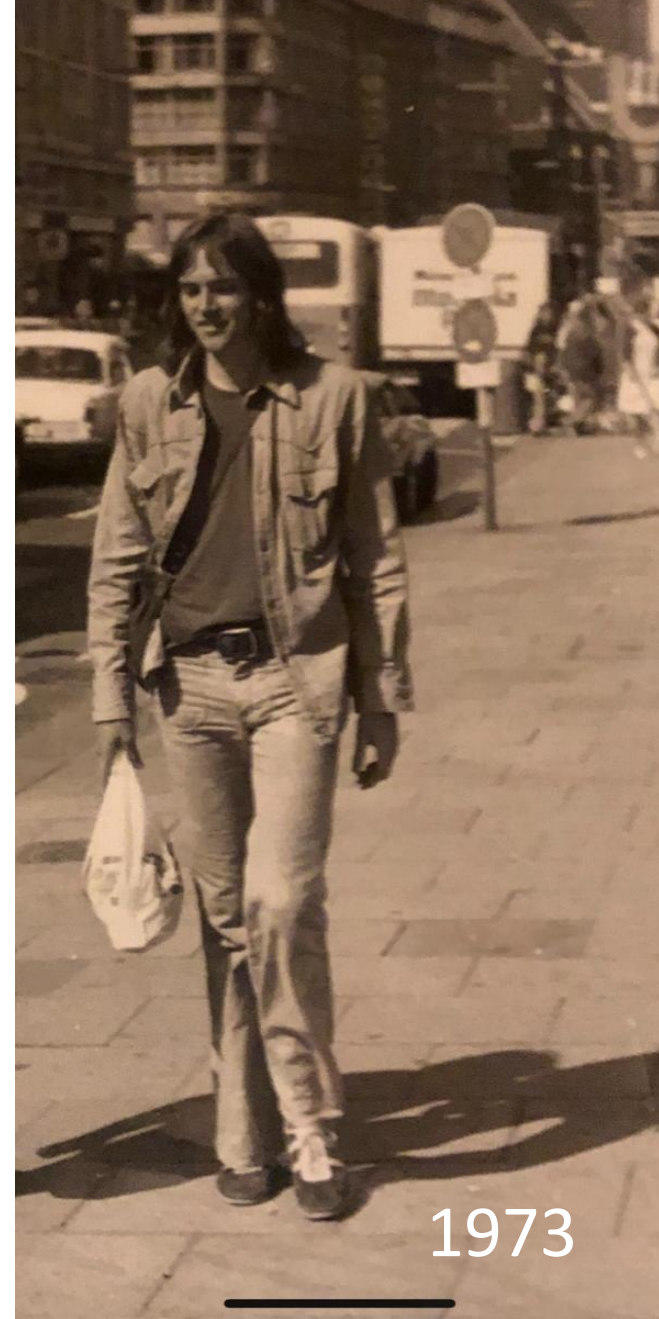


About Sigurd Skogestad

- 1955: Born in Flekkefjord, Norway
- 1974-1978: MS (Siv.ing.) studies in chemical engineering at NTNU
- 1979: Military service (FFI)
- 1980-1983: Worked at Norsk Hydro F-senter (process simulation)
- 1983-1987: PhD student at Caltech (supervisor: Manfred Morari)
- 1987-present: Professor of chemical engineering at NTNU
- 1994-95: Visiting Professor UC Berkeley
- 2001-02: Visiting Professor UC Santa Barbara
- 1999-2009: Head of ChE Department, NTNU
- 2015-.2023: Director SUBPRO (Subsea research center at NTNU)

Non-professional interests:

- **mountain skiing (cross country)**
- **orienteering (running around with a map)**
- **grouse hunting**



“The goal of my research is to develop simple yet rigorous methods to solve problems of engineering significance”



Sigurd Skogestad Professor

Department of [Chemical Engineering, Norwegian University of Science and Technology \(NTNU\), N7491 Trondheim, Norway](#)

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"The overall goal of my research is to develop simple yet rigorous methods to solve problems of engineering significance"

"We want to find a [self-optimizing control](#) structure where close-to-optimal operation under varying conditions is achieved with constant (or slowly varying) setpoints for the controlled variables (CVs). The aim is to move more of the burden of economic optimization from the slower time scale of the real-time optimization (RTO) layer to the faster setpoint control layer. More generally, the idea is to use the model (or sometimes data) off-line to find properties of the optimal solution suited for (simple) on-line feedback implementation"



"News"...

- 27 Nov. 2023: [Welcome to the SUBPRO Symposium at the Britannia Hotel in Trondheim](#)
- **Aug. 2023:** Tutorial review paper on "Advanced control using decomposition and simple elements". Published in [Annual reviews in Control \(2023\)](#). [\[paper\]](#) [\[tutorial workshop\]](#) [\[slides from Advanced process control course at NTNU\]](#)
- **05 Jan. 2023:** Tutorial paper on "Transformed inputs for linearization, decoupling and feedforward control" published in [JPC](#). [\[paper\]](#)
- 13 June 2022: Plenary talk on "Putting optimization into the control layer using the magic of feedback control", at ESCAPE-32 conference, Toulouse, France [\[slides\]](#)
- 08 Dec. 2021: Plenary talk on "Nonlinear input transformations for disturbance rejection, decoupling and linearization" at Control Conference of Africa (CCA 2021), Magaliesburg, South Africa (virtual) [\[video and slides\]](#)
- 27 Oct. 2021: Plenary talk on "Advanced process control - A new look at the old" at the Brazilian Chemical Engineering Conference, COBEQ 2021, Gramado, Brazil (virtual) [\[slides\]](#)
- 13 Oct. 2021: Plenary talk on "Advanced process control" at the Mexican Control Conference, CNCA 2021 (virtual) [\[video and slides\]](#)
- **Nov. 2019:** Sigurd receives the "Computing in chemical engineering award from the American Institute of Chemical Engineering (Orlando, 12 Nov. 2019)"
- **June 2019:** Best paper award at ESCAPE 2019 conference in Eindhoven, The Netherlands
- **July 2018:** PID-paper in JPC that verifies SIMC PI-rules and gives "Improved" SIMC PID-rules for processes with time delay ($\tau_d = \theta/3$)
- **June 2018:** Video of Sigurd giving lecture at ESCAPE-2018 in Graz on how to use classical advanced control for switching between active constraints
- **Feb. 2017:** Youtube videos of Sigurd giving lectures on PID control and Plantwide control (at University of Salamanca, Spain)
- **06-08 June 2016:** IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems (DYCOPS-2016), Trondheim, Norway.
 - [Videos and proceedings from DYCOPS-2016](#)
- **Aug 2014:** Sigurd receives [IFAC Fellow Award](#) in Cape Town
- **2014:** Overview papers on "control structure design and "economic plantwide control"
- [OLD NEWS](#)



Books...

- **Book:** S. Skogestad and I. Postlethwaite: [MULTIVARIABLE FEEDBACK CONTROL](#)-Analysis and design. Wiley (1996; 2005)
- **Book:** S. Skogestad: [CHEMICAL AND ENERGY PROCESS ENGINEERING](#) CRC Press (Taylor&Francis Group) (Aug. 2008)
- **Book:** S. Skogestad: [PROSESSTEKNIKK](#)- Masse- og energibalanser Tapir (2000; 2003; 2009).



More information ...

- [Publications](#) from my [Google scholar](#) site
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- [Proceedings from conferences](#) - some of these may be difficult to obtain elsewhere
- [Process control library](#) - We have an extensive library for which Ivar has made a nice [on-line search](#)
- [Photographs](#) that I have collected from various events (maybe you are included...)
- [International conferences](#) - updated with irregular intervals
- [SUBPRO \(NTNU center on subsea production and processing\)](#). [\[Annual reports\]](#) [\[Internal\]](#)
- [Nordic Process Control working group](#) - in which we participate
- [5-year Master program in Chemical and Biochemical Engineering at NTNU \(MTK\)](#) - Sigurd Skogestad is Program Leader 2019-2025.

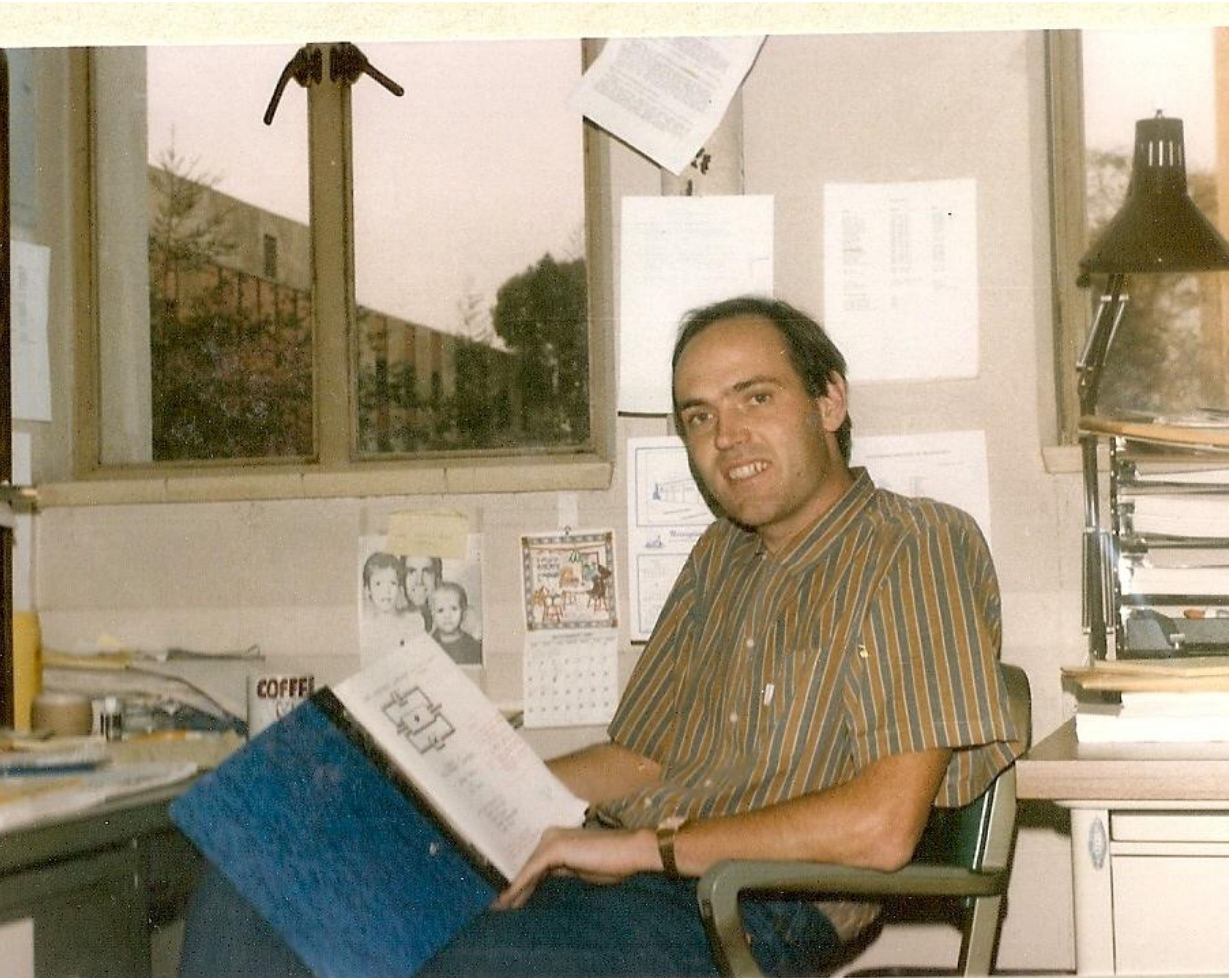


My research focus

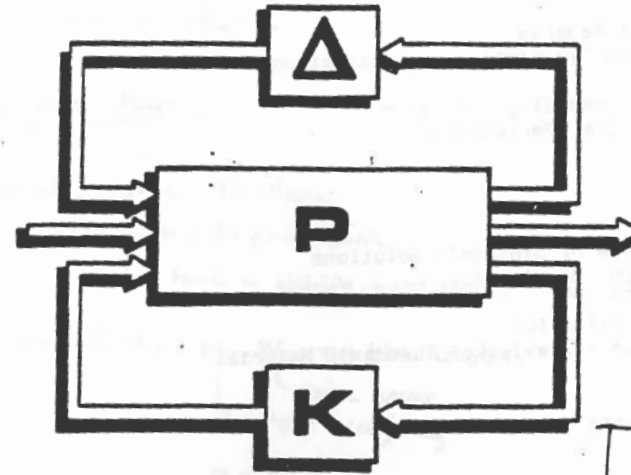
- Control for economic optimization
 - Control of changing active constraints
- Control for linearization, stabilization and robustness
- Keep it simple!
 - Make use of the magic of feedback

October 1984

Robust control takes off!



ONR / HONEYWELL WORKSHOP Oct. 8-10, 1984, Minneapolis, Minnesota



Advances in MULTIVARIABLE CONTROL

Lecture Notes
by
John Doyle

with contributions by
Cheng-Chih Chu
Bruce Francis
Pranod Kargonekar
Gunter Stein

Contents:

1. Own notes from Workshop
2. Gunter Stein's overview (Oct)
3. John Doyle's notes (Jan-May 85-version)
3. Some ~~own~~ own notes from Honeywell-stuff (April 85)
4. Chester's (Cheng-Chih Chu) paper on General Dist. P (April 85)
5. Bruce Francis' overval stabilization & H^∞ (Oct. 84)

Figures
P. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100

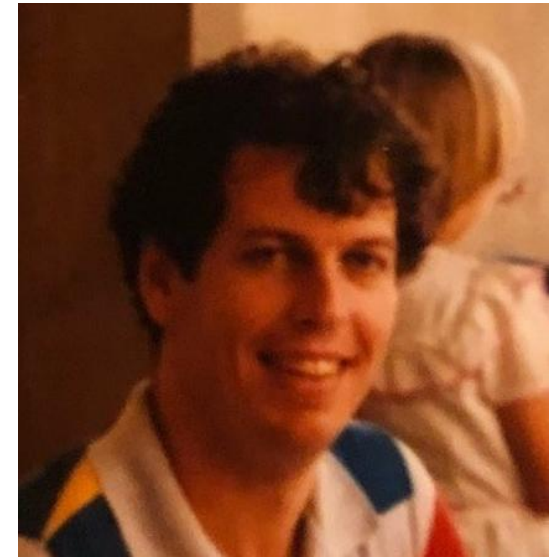
Guaranteed Margins for LQG Regulators

JOHN C. DOYLE

Abstract—There are none.

INTRODUCTION

Considerable attention has been given lately to the issue of robustness of linear–quadratic (LQ) regulators. The recent work by Safonov and Athans [1] has extended to the multivariable case the now well-known guarantee of 60° phase and 6 dB gain margin for such controllers.



Robust Control of Ill-Conditioned Plants: High-Purity Distillation

SIGURD SKOGESTAD, MANFRED MORARI, MEMBER, IEEE, AND JOHN C. DOYLE

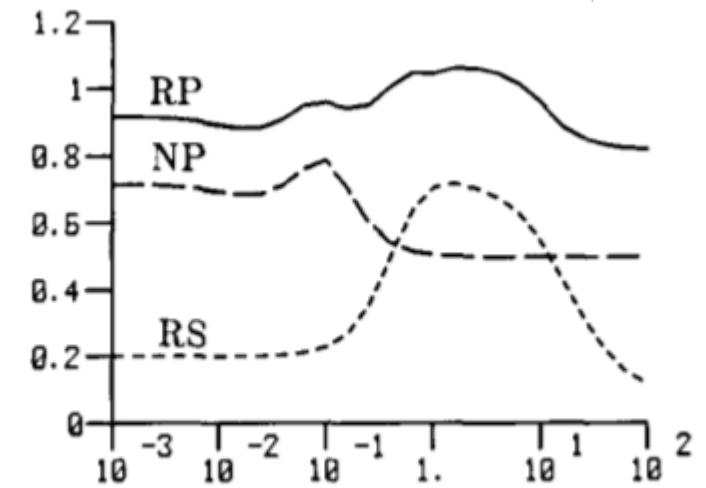
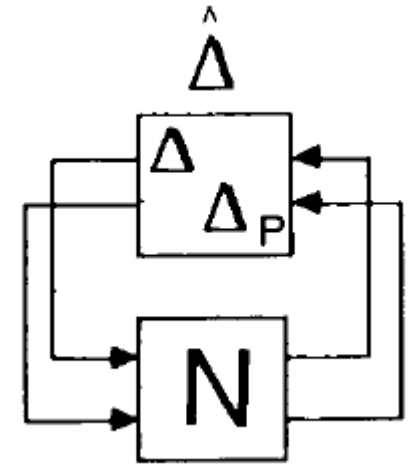
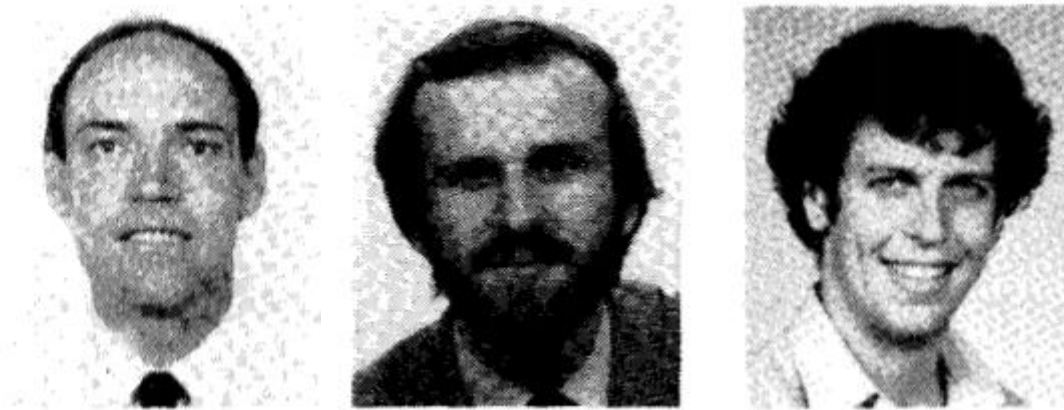
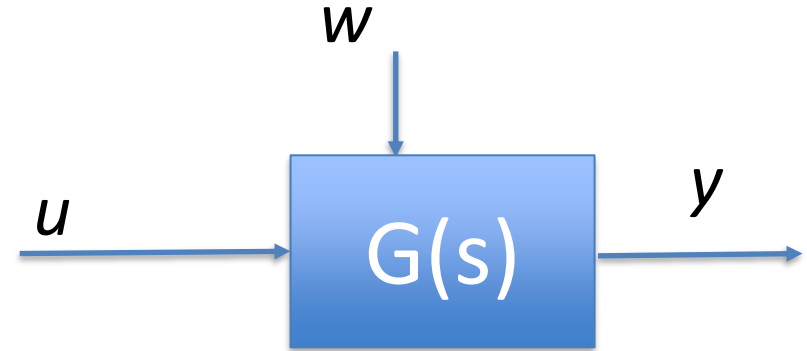


Fig. 13. *LV*-configuration. μ -plots for μ -optimal controller $C_\mu(s)$.

Doyle counterexample

$$y = \frac{1}{(s - 1)^2} u$$

	GML	GM	PM	wc	DM=PM/wc
LQG Doyle (w=1)	0.92	1.06	9	1.19	0.132
LQG Doyle (w=1e12)	0.904	1.0000007	18	3.97	0.252



%Process

```
A=[1 1; 0 1]; B=[0;1]; C=[1 0]; D=0;
SYS=ss(A,B,C,D), G=tf(SYS)
s=tf('s'); Gd=G*s;
```

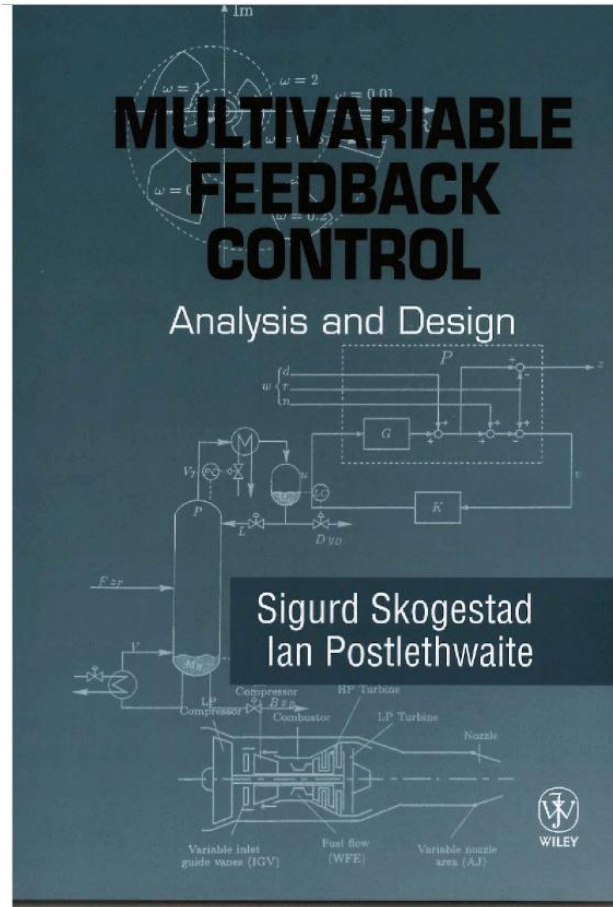
% LQG from Doyle with sw=1

```
q=1; Q=[1 1; 1 1]; QXU = blkdiag(q*Q,1);
sw=1; QW=[1 1;1 1]; QWV =
blkdiag(sw*QW,1);
KLQG = lqg(SYS,QXU,QWV); C=tf(KLQG)
```

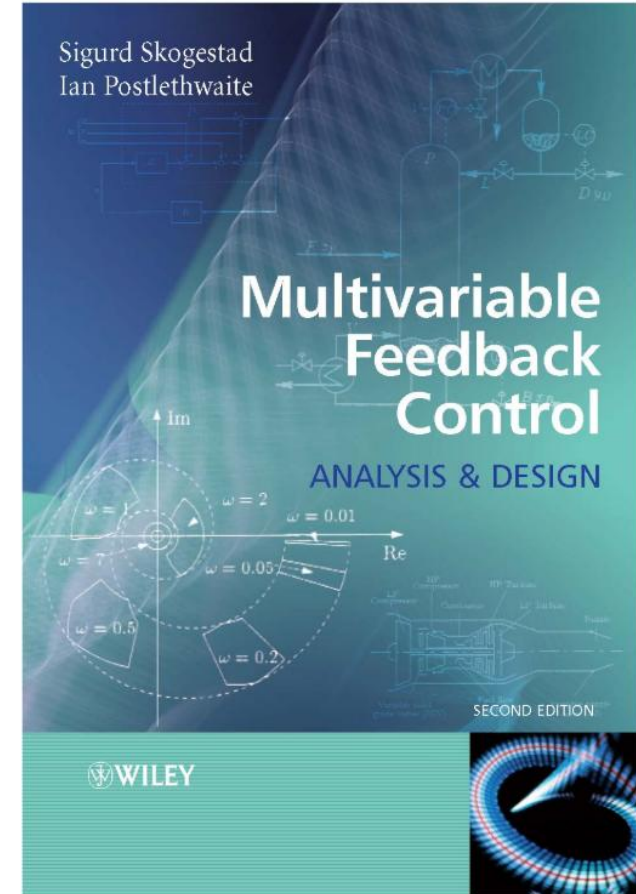
Robust control



Berkeley, Dec. 1994



1996



2005

IMC PID tuning rule (1984, 1986)

AMERICAN CONTROL CONFERENCE
San Diego, California
June 6-8, 1984

IMPLICATIONS OF INTERNAL MODEL CONTROL FOR PID CONTROLLERS

Manfred Morari
Sigurd Skogestad

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California Institute of Technology
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Pasadena, California 91125

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Department of Chemical Engineering
Madison, Wisconsin 53706

252

Ind. Eng. Chem. Process Des. Dev. 1986, 25, 252-265

Internal Model Control. 4. PID Controller Design

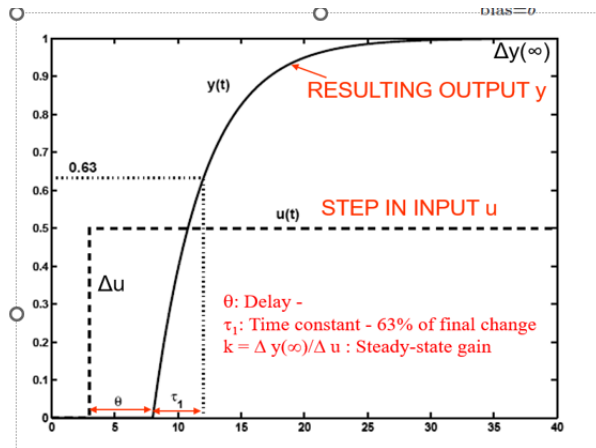
Daniel E. Rivera, Manfred Morari,* and Sigurd Skogestad

Chemical Engineering, 206-41, California Institute of Technology, Pasadena, California 91125

For a large number of single input-single output (SISO) models typically used in the process industries, the Internal Model Control (IMC) design procedure is shown to lead to PID controllers, occasionally augmented with a first-order lag. These PID controllers have as their only tuning parameter the closed-loop time constant or, equivalently, the closed-loop bandwidth. On-line adjustments are therefore much simpler than for general PID controllers. As a special case, PI- and PID-tuning rules for systems modeled by a first-order lag with dead time are derived analytically. The superiority of these rules in terms of both closed-loop performance and robustness is demonstrated.



SIMC* PID tuning rule (2001,2003)



$$g(s) = \frac{k}{(\tau_1 s + 1)(\tau_2 s + 1)} e^{-\theta s}$$

$$K_c = \frac{1}{k} \frac{\tau_1}{\tau_c + \theta}$$

$$\tau_I = \min\{\tau_1, 4(\tau_c + \theta)\}$$

$$\tau_D = \tau_2$$

Tuning parameter:

$$\tau_c \geq \theta$$

$$= \lambda$$

[19] S. Skogestad, Probably the best simple PID tuning rules in the world. AIChE Annual Meeting, Reno, Nevada, November 2001



Journal of Process Control 13 (2003) 291–309

JOURNAL OF
PROCESS
CONTROL

www.elsevier.com/locate/jprocont

Simple analytic rules for model reduction and PID controller tuning[☆]

Sigurd Skogestad*

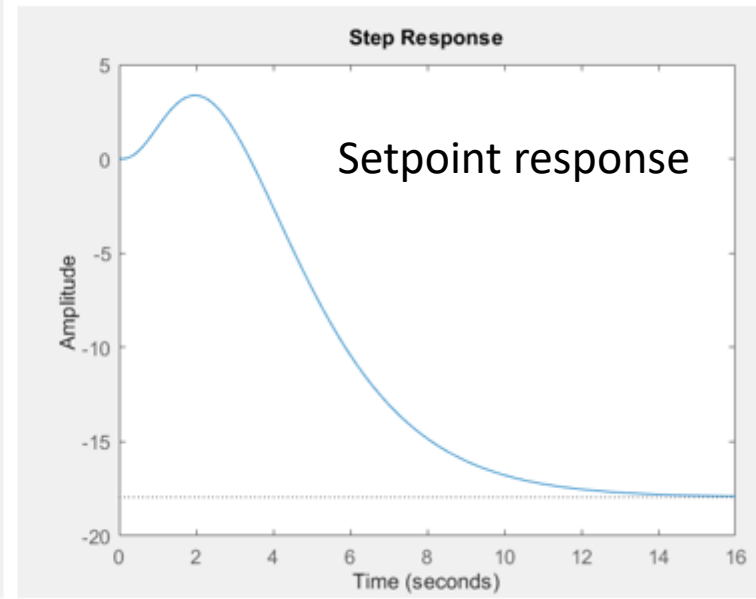
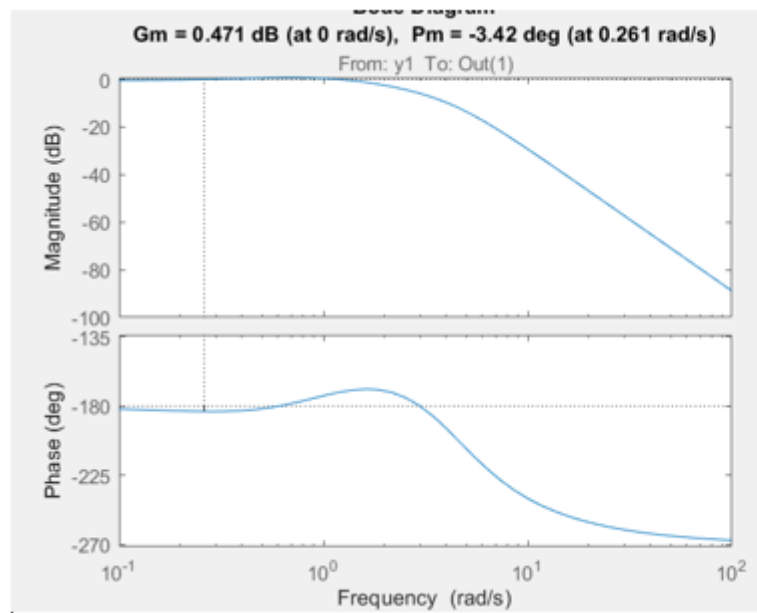
Department of Chemical Engineering, Norwegian University of Science and Technology, N-7491 Trondheim, Norway

Received 18 December 2001; received in revised form 25 June 2002; accepted 11 July 2002

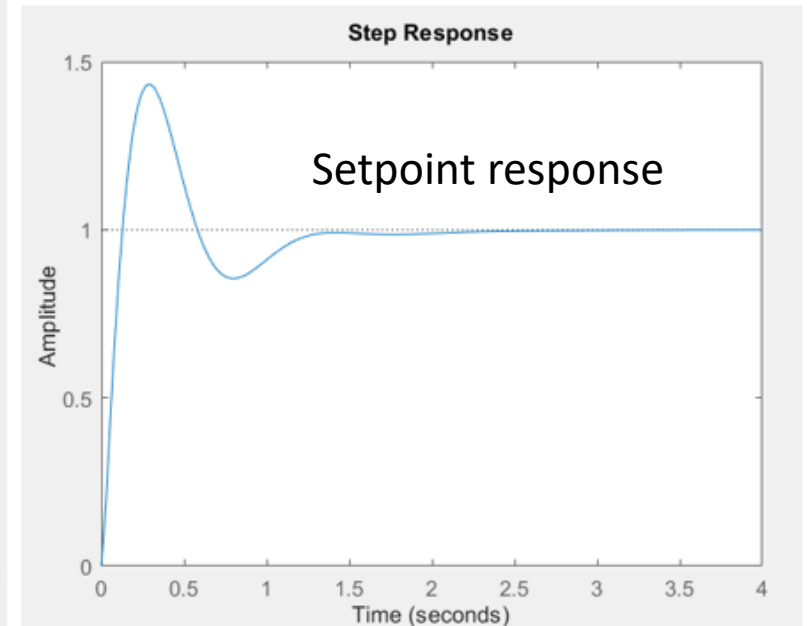
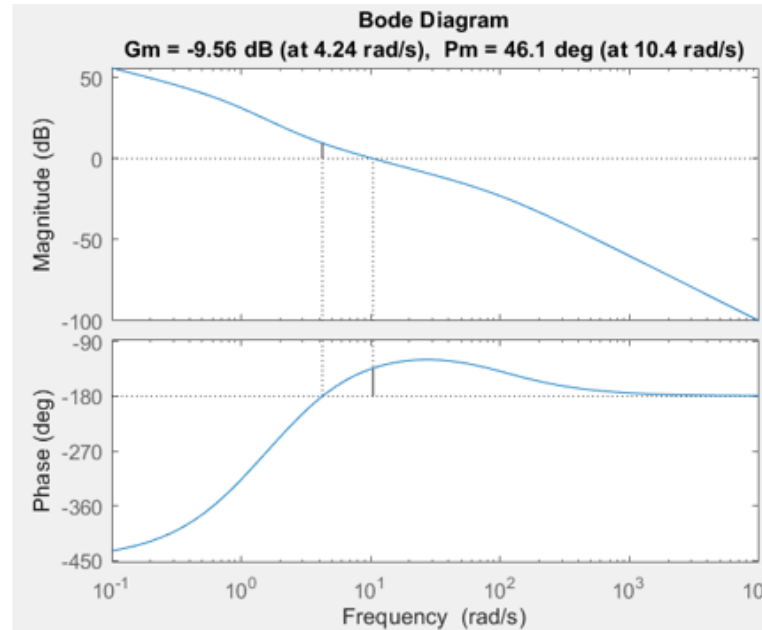
Abstract

The aim of this paper is to present analytic rules for PID controller tuning that are simple and still result in good closed-loop behavior. The starting point has been the IMC-PID tuning rules that have achieved widespread industrial acceptance. The rule for the integral term has been modified to improve disturbance rejection for integrating processes. Furthermore, rather than deriving separate rules for each transfer function model, there is just a single tuning rule for a first-order or second-order time delay model. Simple analytic rules for model reduction are presented to obtain a model in this form, including the “half rule” for obtaining the effective time delay.

LQG (w=1)

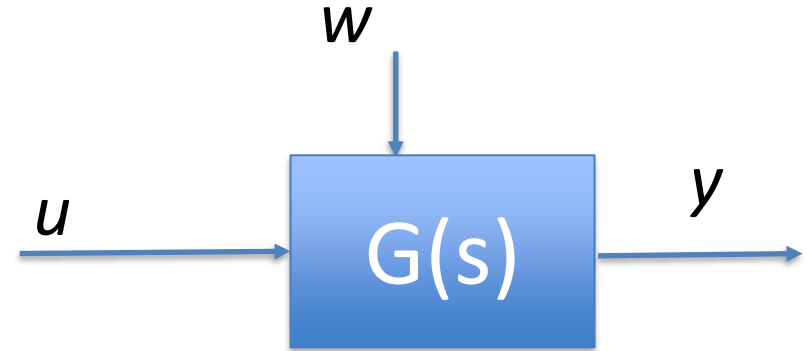


PID



Doyle counterexample

$$y = \frac{1}{(s - 1)^2} u$$



	GML	GM	PM	wc	DM=PM/wc
LQG Doyle (w=1)	0.92	1.06	9	1.19	0.132
LQG Doyle (w=1e12)	0.904	1.0000007	18	3.97	0.252
SIMC-PID (tauc=0.1)	0.333	infinity	46	10.4	0.0774

%Process

```
A=[1 1; 0 1]; B=[0;1]; C=[1 0]; D=0;
SYS=ss(A,B,C,D), G=tf(SYS)
s=tf('s'); Gd=G*s;
```

% LQG from Doyle with sw=1

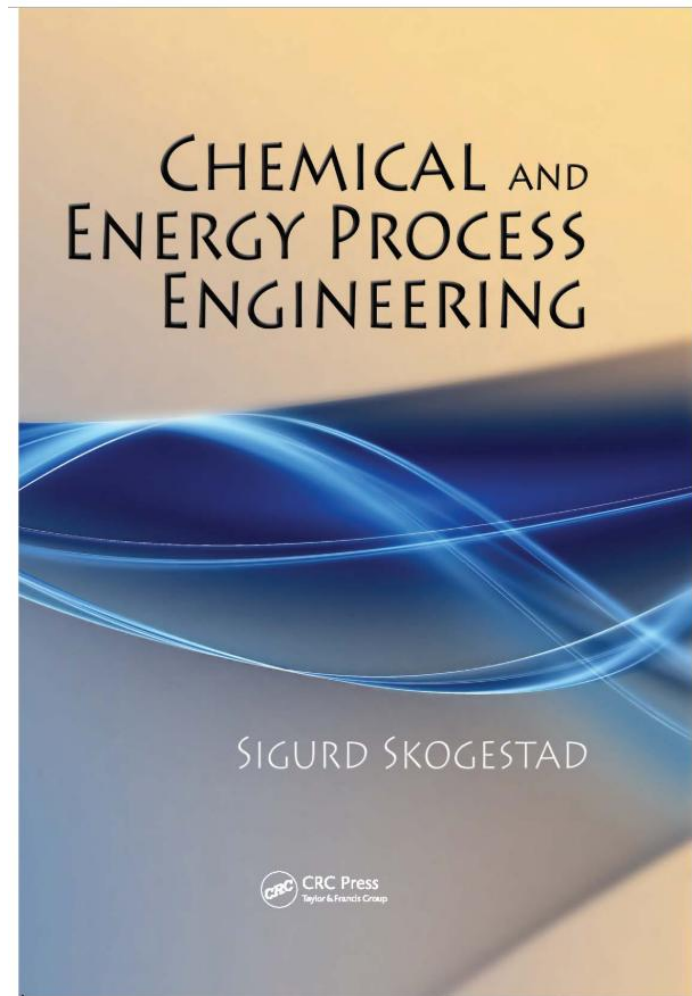
```
q=1; Q=[1 1; 1 1]; QXU = blkdiag(q*Q,1);
sw=1; QW=[1 1;1 1]; QWV =
blkdiag(sw*QW,1);
KLQG = lqg(SYS,QXU,QWV); C=tf(KLQG)
```

%Note: The SIMC-PID is tuned for double integrating process
 tauc=0.1; Kc=1/(4*tauc^2); tauI=4*tauc ; tauD=4*tauc ; tauF=tauc/10;
 cpid = Kc*(1+1/(tauI*s))*(tauD*s+1)/(tauF*s+1);

Process engineering



2000, 2003, 2009



2009

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Annual Reviews in Control

journal homepage: www.elsevier.com/locate/arcontrol

Review article

Advanced control using decomposition and simple elements

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ARTICLE INFO

Keywords:

Control structure design
 Feedforward control
 Cascade control
 PID control
 Selective control
 Override control
 Time scale separation
 Decentralized control
 Distributed control
 Horizontal decomposition
 Hierarchical decomposition
 Layered decomposition
 Vertical decomposition
 Network architectures

ABSTRACT

The paper explores the standard advanced control elements commonly used in industry for designing advanced control systems. These elements include cascade, ratio, feedforward, decoupling, selectors, split range, and more, collectively referred to as “advanced regulatory control” (ARC). Numerous examples are provided, with a particular focus on process control. The paper emphasizes the shortcomings of model-based optimization methods, such as model predictive control (MPC), and challenges the view that MPC can solve all control problems, while ARC solutions are outdated, ad-hoc and difficult to understand. On the contrary, decomposing the control systems into simple ARC elements is very powerful and allows for designing control systems for complex processes with only limited information. With the knowledge of the control elements presented in the paper, readers should be able to understand most industrial ARC solutions and propose alternatives and improvements. Furthermore, the paper calls for the academic community to enhance the teaching of ARC methods and prioritize research efforts in developing theory and improving design method.

Paper (2023) is open access and is also available on my home page (search for “skogestad”)

Participants

Part 2.

Plantwide process control «Control architectures»

Sigurd Skogestad

Plantwide control (Control architecture)

- Objective: Put controllers on flow sheet (make P&ID)
- Two main objectives for control: Longer-term economics (CV1) and shorter-term stability (CV2)
- Regulatory (basic) control layer for CV2 and supervisory (advanced) control layer for CV1

How can we design a control system for a complete chemical plant?

Where do we start?

What should we control? And why?

TENNESSEE EASTMAN CHALLENGE PROBLEM (1993)

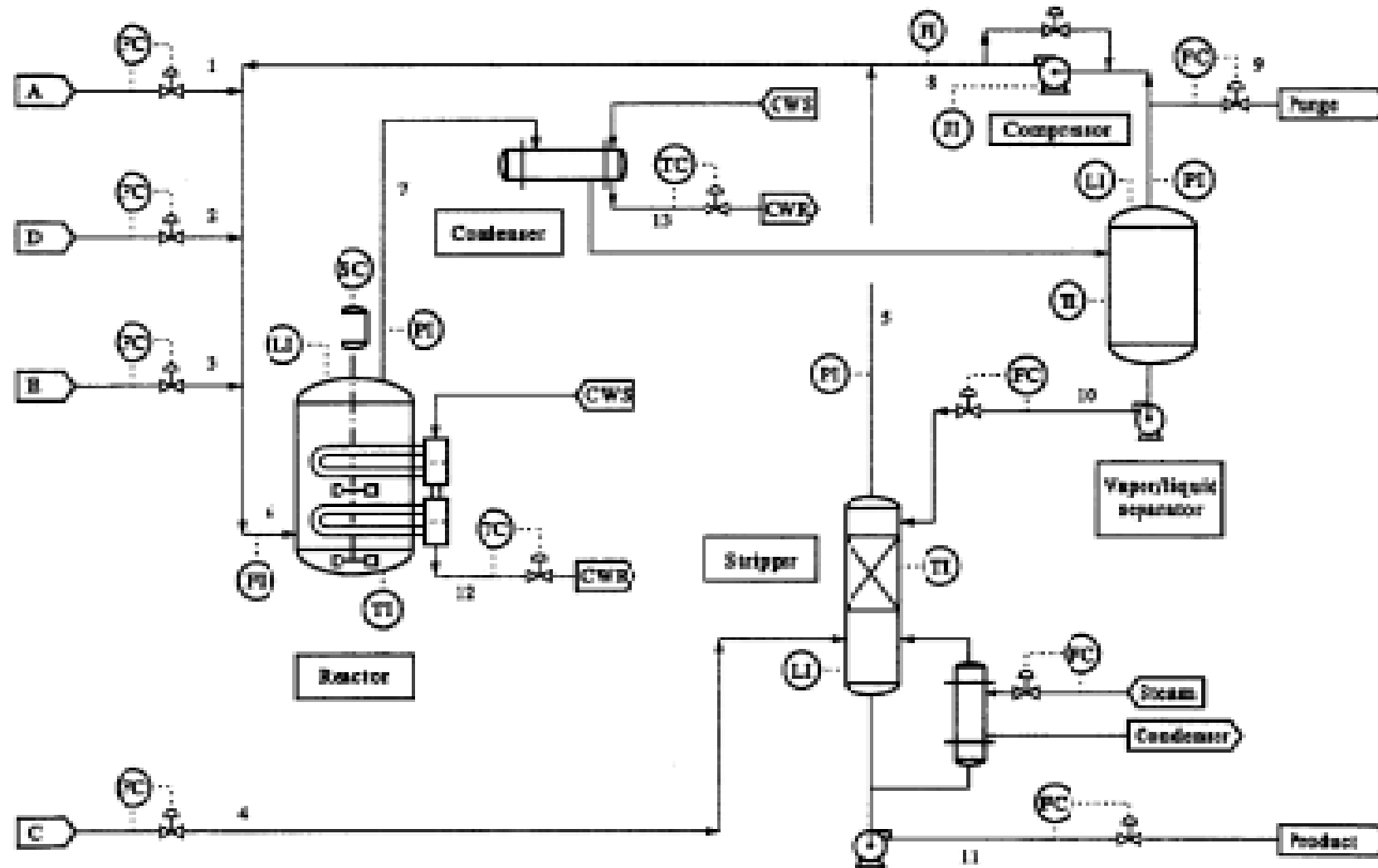


Fig. 2

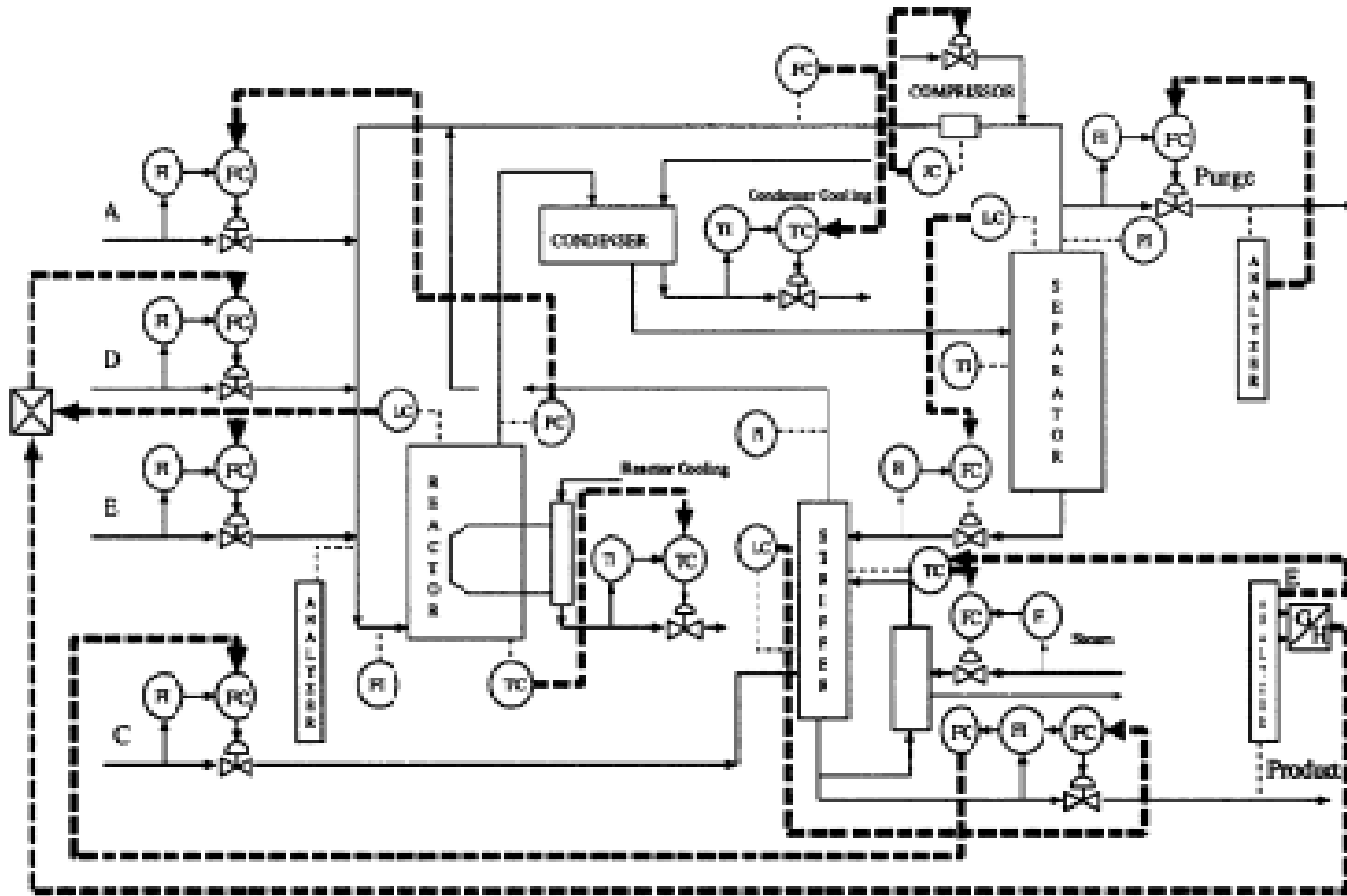


Fig. 10. Base control system of the Tennessee Eastman process.



Sigurd at Caltech (1984)

How we design a control system for a complete chemical plant?

- Where do we start?
- What should we control? and why?
- etc.
- etc.

Control system structure*

Alan Foss (“Critique of chemical process control theory”,
AIChE Journal, 1973):

*The central issue to be resolved ... is the determination of **control system structure***.
**Which variables should be measured, which inputs should be manipulated
and which links should be made between the two sets?***



*Current terminology: **Control system architecture**

Plantwide control = Control structure (**architecture**) design

- *Not* the tuning and behavior of each control loop...
- But rather the *control philosophy* of the overall plant with emphasis on the ***structural decisions***:
 - Selection of controlled variables (“outputs”)
 - Selection of manipulated variables (“inputs”)
 - Selection of (extra) measurements
 - Selection of control **configuration** (structure of overall controller that interconnects the controlled, manipulated and measured variables)
 - Selection of controller type (LQG, H-infinity, PID, decoupler, MPC etc.)

Main objectives of a control system

1. Economics: Implementation of acceptable (near-optimal) operation
2. Regulation: Stable operation

ARE THESE OBJECTIVES CONFLICTING?

- Usually NOT
 - Different time scales
 - Stabilization → fast time scale
 - Stabilization doesn't "use up" any degrees of freedom
 - Reference value (setpoint) available for layer above
 - But it "uses up" part of the time window (frequency range)

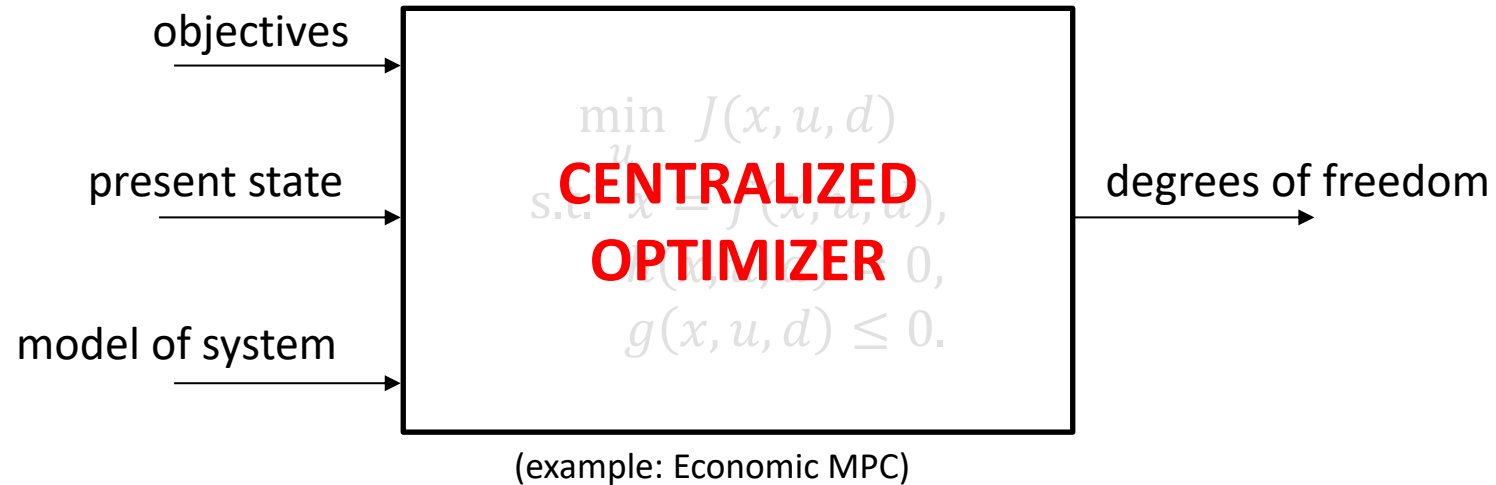
Optimal operation

General approach: minimize cost / maximize profit, subject to satisfying constraints (product quality, environment, resources)

Mathematically,

$$\begin{aligned} \min_u \quad & J(x, u, d) \\ \text{s.t.} \quad & \dot{x} = f(x, u, d), \\ & h(x, u, d) = 0, \\ & g(x, u, d) \leq 0. \end{aligned}$$

Optimal operation (in theory)



Procedure:

- Obtain model of overall system
- Estimate present state
- Optimize all degrees of freedom

Problems:

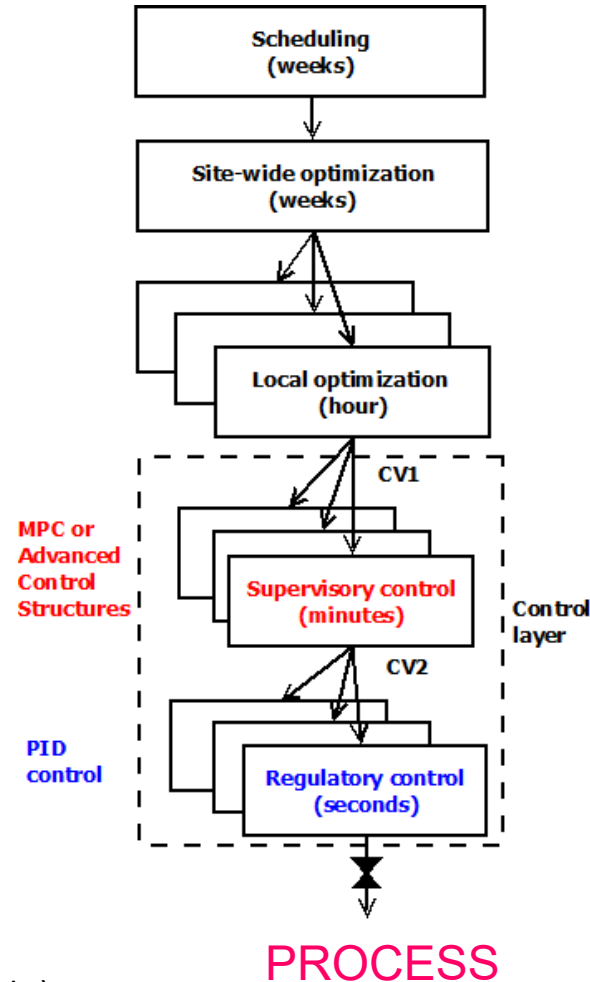
- Model not available
- Optimization is complex
- Not robust (difficult to handle uncertainty)
- Slow response time

Engineering systems

- Most (all?) large-scale engineering systems are controlled using hierarchies of quite simple controllers
 - Large-scale chemical plant (refinery)
 - Commercial aircraft
- 100's of loops
- Simple components:
 - on-off + PI-control + nonlinear fixes + some feedforward

Two fundamental ways of decomposing the controller

- Vertical (hierarchical; cascade)
- Based on **time scale separation**
- Decision: Selection of CVs that connect layers



- Horizontal (**decentralized**)
- Usually based on distance
- Decision: Pairing of MVs and CVs within layers

In addition: Decomposition of controller into smaller elements (blocks):
Feedforward element, nonlinear element, estimators (soft sensors), switching elements

Time scale separation: Control* layers

Two objectives for control: Stabilization and economics

- **Supervisory (“advanced”) control layer**

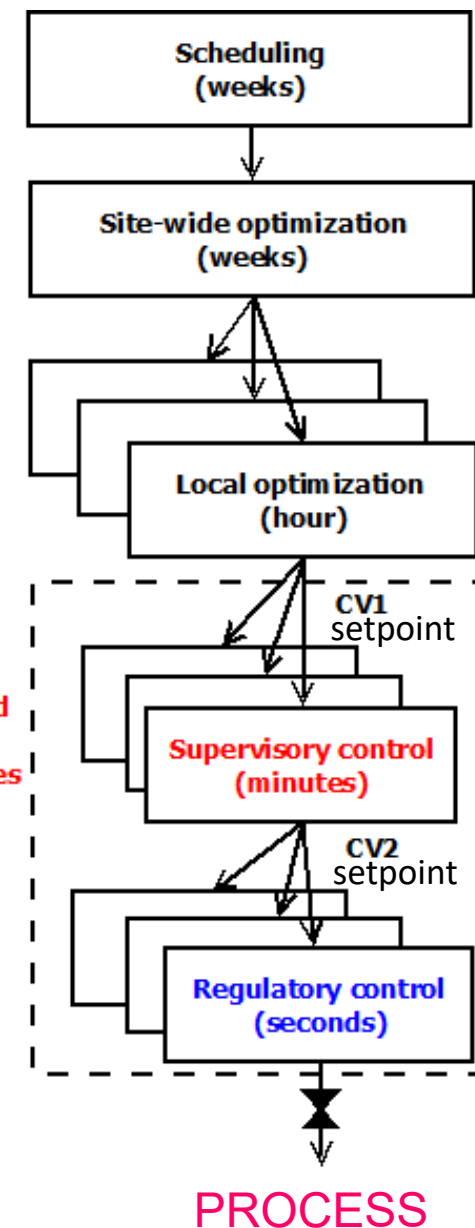
Tasks:

- Follow set points for CV1 from economic optimization layer
- Switch between active constraints (change CV1)
- Look after regulatory layer (avoid that MVs saturate, etc.)

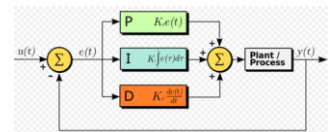
- **Regulatory control (PID layer):**

- Stable operation (CV2)

*My definition of «control» is that the objective is to track setpoints

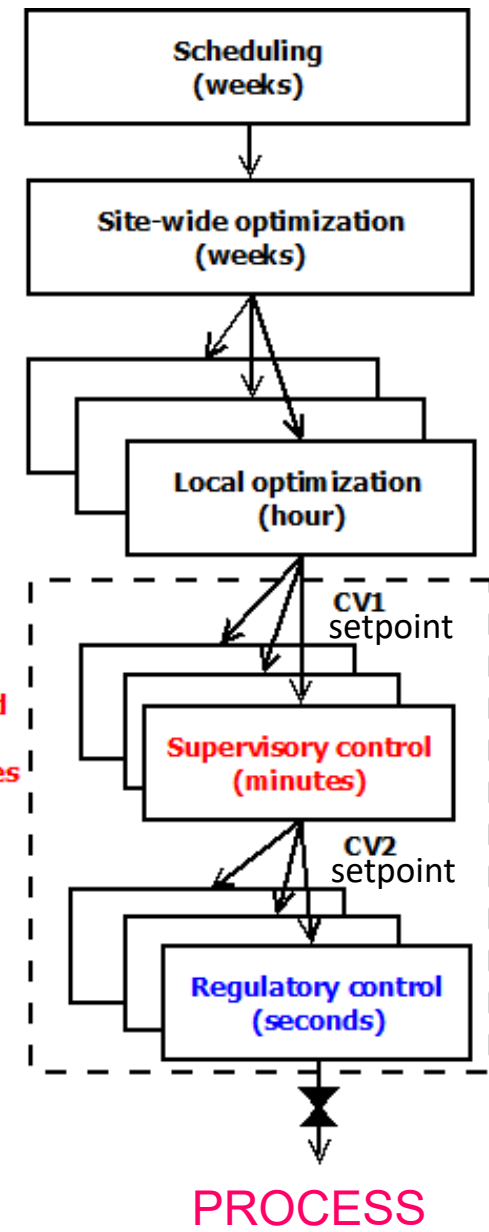


Control layer

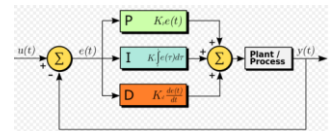


«Advanced» control

- Advanced: This is a relative term
- Usually used for anything than comes in addition to (or in top of) basic PID loops
- Mainly used in the «supervisory» control layer
- Two main options
 - **Standard «Advanced regulatory control» (ARC) elements**
 - Based on decomposing the control system
 - Cascade, feedforward, selectors, etc.
 - This option is preferred if it gives acceptable performance
 - **Model predictive control (MPC)**
 - Requires a lot more effort to implement and maintain
 - Use for interactive processes
 - Use with known information about future (use predictive capabilities)



Control layer



Combine control and optimization into one layer?

EMPC: Economic model predictive “control”

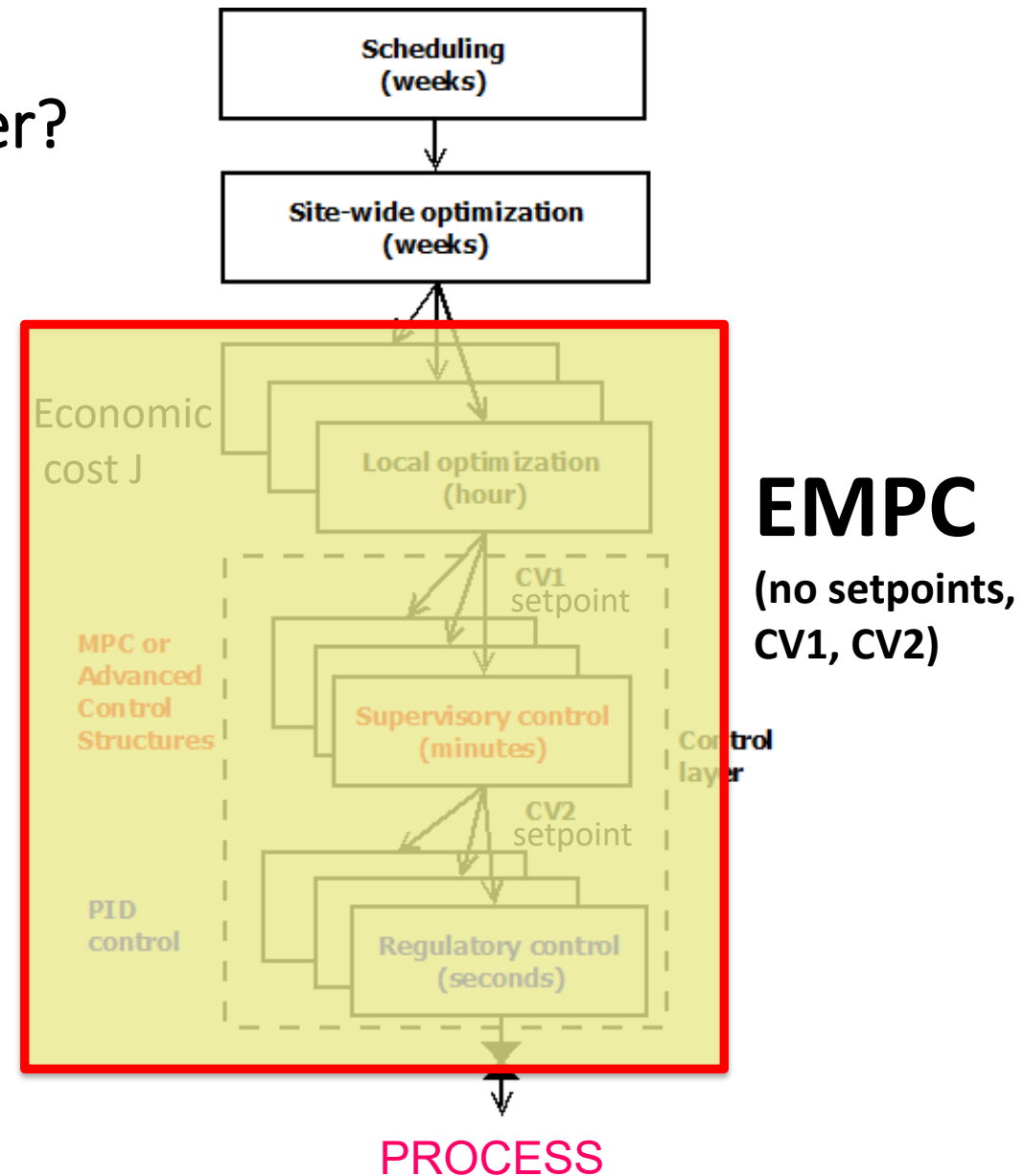
$$J_{EMPC} = J + J_{control}$$

- $J [\$/s] = J_{economic}$ = cost feed + cost energy – value products
- $J_{control} = \sum \Delta u_i^2$ (typical) - Penalize input usage

**NO, combining layers is generally not a good idea!
(the good idea is to separate them!)**

One layer (EMPC) is optimal theoretically, but

- Need detailed dynamic model of everything
- Tuning difficult and indirect
- Slow! (or at least difficult to speed up parts of the control)
- Robustness poor
- Implementation and maintenance costly and time consuming



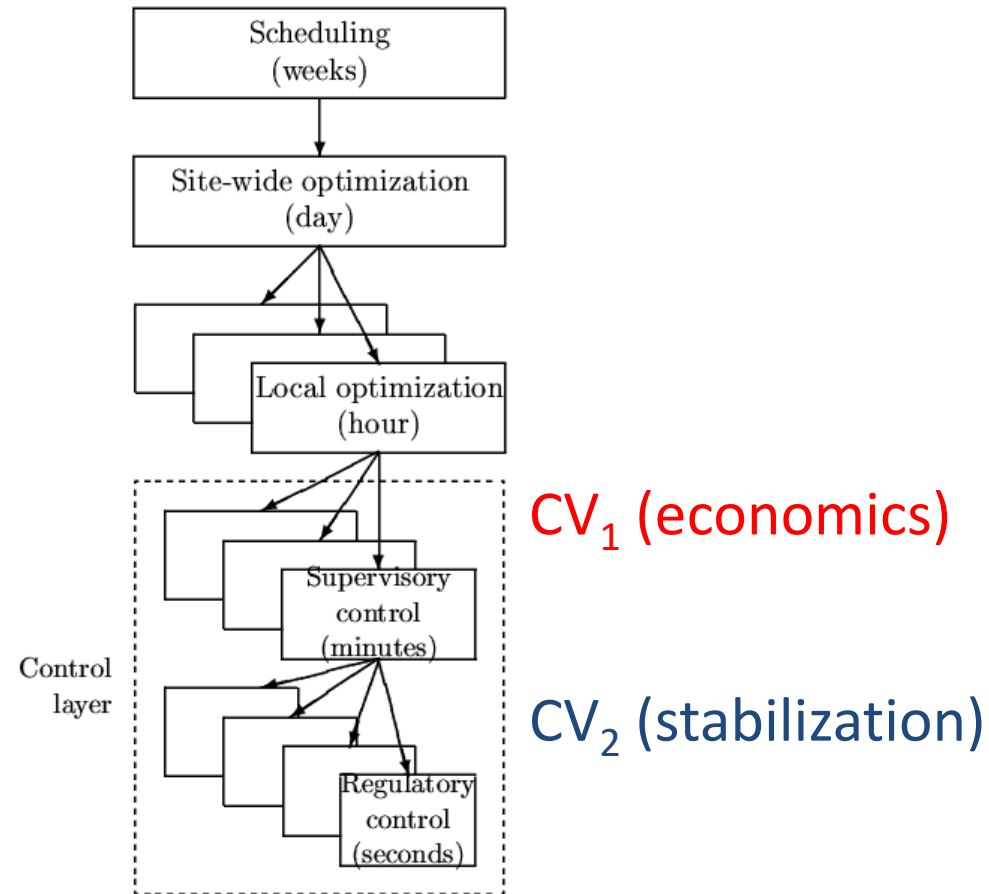
What about «conventional» RTO and MPC?

- Yes, it's OK
- Both has been around for more than 50 years (since 1970s)
 - but the expected growth never came
- MPC is still used mostly in large-scale plants (petrochemical and refineries).
- MPC is far from replacing PID as some expected in the 1990s.

Alternative solutions for advanced control

- **Machine learning?**
 - Requires a lot of data, not realistic for process control
 - And: Can only be implemented after the process has been in operation
- **“Classical advanced regulatory control” (ARC) based on single-loop PIDs?**
 - **YES!**
 - Extensively used by industry
 - Problem for engineers: Lack of design methods
 - Has been around since 1930's
 - But almost completely neglected by academic researchers
 - Main fundamental limitation: Based on single-loop (need to choose pairing)

Optimal operation and control objectives: What should we control?



Skogestad procedure for control structure design:

- I. Top Down (analysis)
 - Step S1: Define operational objective (cost) and constraints
 - Step S2: Identify degrees of freedom and optimize operation for disturbances
 - Step S3: Implementation of optimal operation
 - What to control? (CV1) (self-optimizing control)
 - Step S4: Where set the production rate (TPM)? (Inventory control)
- II. Bottom Up (design)
 - Step S5: Regulatory control: What more to control (CV2)?
 - Step S6: Supervisory control
 - Step S7: Real-time optimization

TPM = Throughput manipulator

S. Skogestad, "[Control structure design for complete chemical plants](#)", *Computers and Chemical Engineering*, **28** (1-2), 219-234 (2004)

What should we focus on?

See ABB for slides

- Part 3. TPM and inventory control. Bidirectional control
- Part 4. PID tuning using the SIMC rule
- Part 5. <none>
- Part 6. Advanced control elements
- Part 7. More on switching (Cow Example) and more control elements