Dynamics and Control of Processes

Topic 1: Introduction to process control

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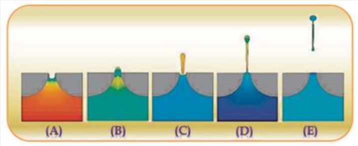
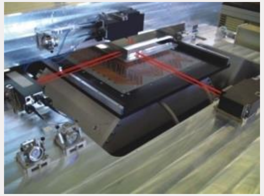
Course 6E8X0

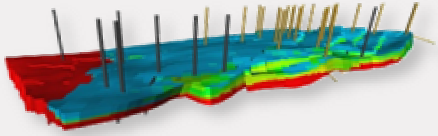
Introduction

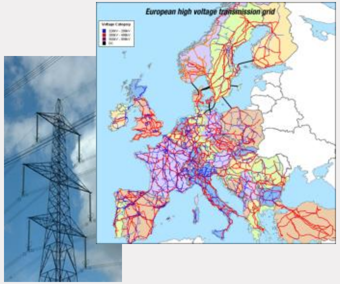
- What is control?
- Why do we need control?
- How does control essentially work?
- How are control systems implemented?
- Control Objectives

What is Control?



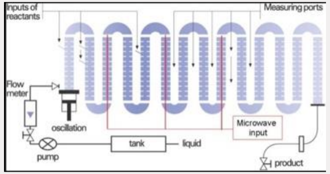






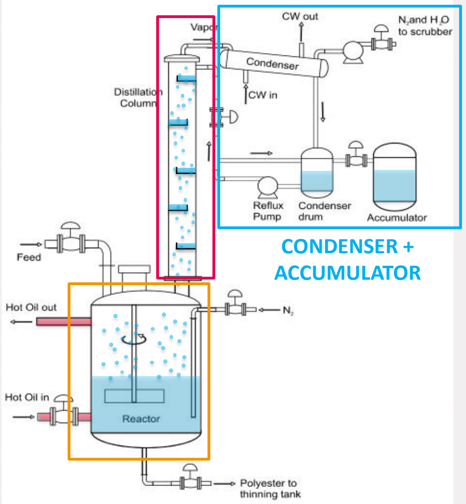
Control is Everywhere

Intelligent Decision Making



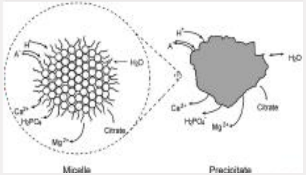
What is Control?

Specialty chemicals

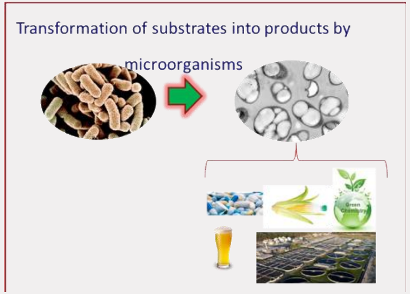


Reactive Distilllation Column
Quality Control

Milk acidification



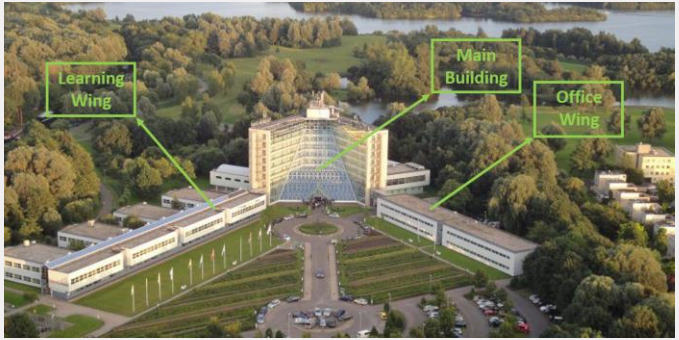
pH control



Optimal productivity

Fermentation Process

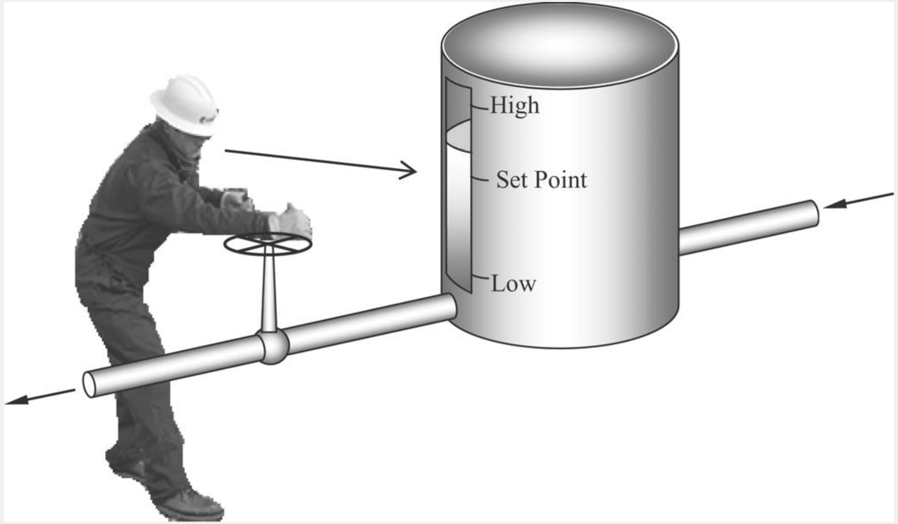
Hotel Groningen



Energy reduction in buildings

What is control?

Example 1: A primitive 'level control' system [1]



Control objective :
Keep the level at the desired level

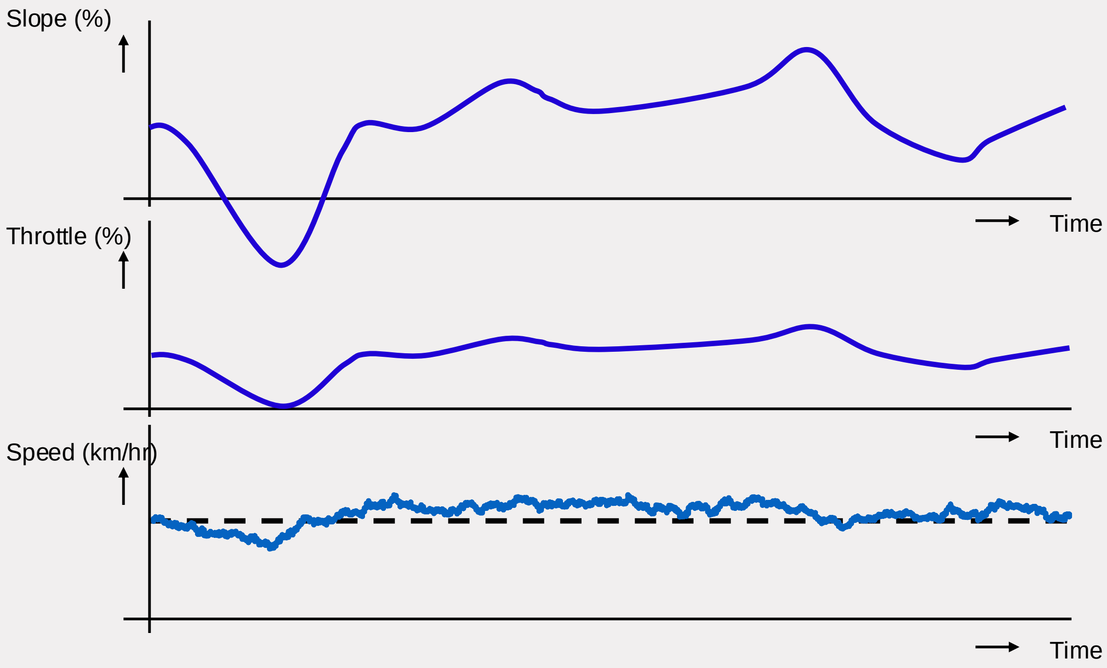
(1) Kravaris & Kookos

What is control?

Example 2: Cruise control system in a car (Volvo's Adaptive Cruise Control)

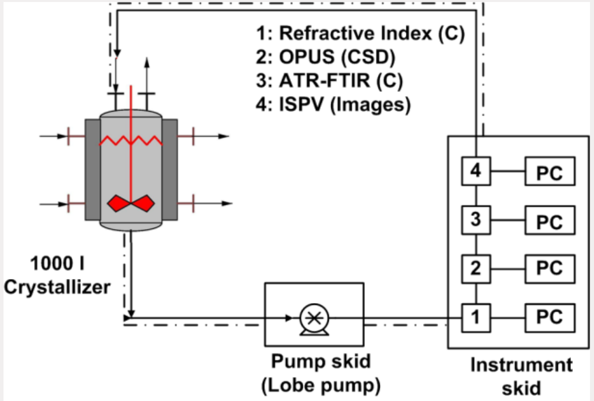
What is control?

<u>Example 2</u>: Cruise control system in a car



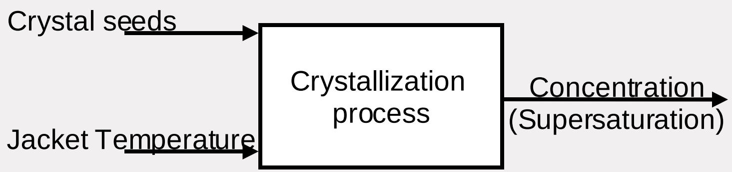
What is control?

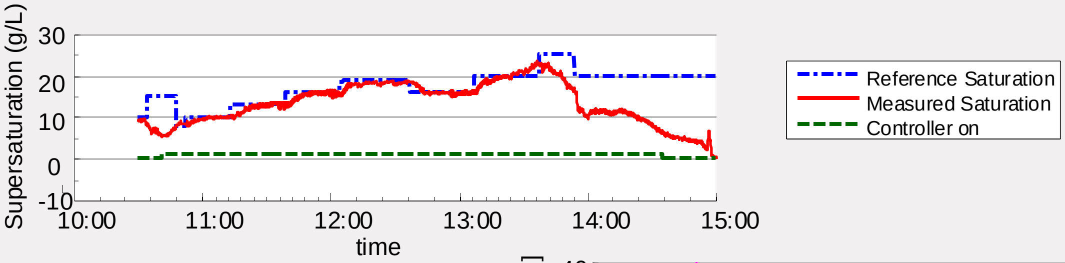
Control of an industrial scale batch crystallization process *)

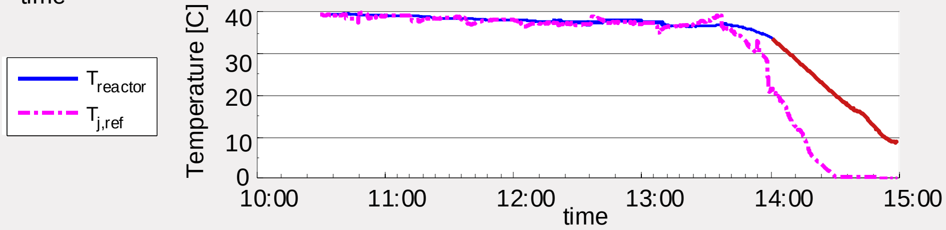


*) Courtesy of former MSD Apeldoorn

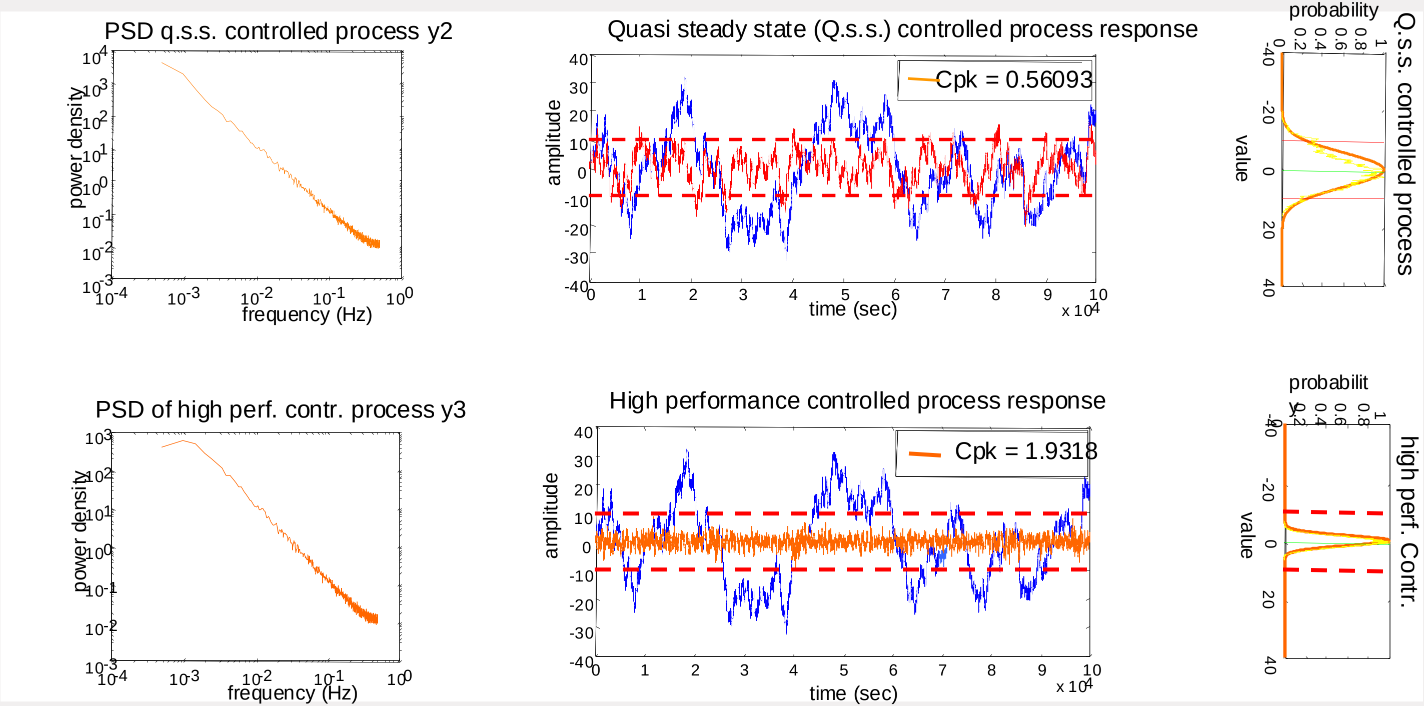
What is control?







What is control?



Why do we need control?

By nature every process, also any chemical process is dynamic, i.e. ever changing operating conditions:

- Composition of processed materials
- Temperature
- Pressure
- residence time

Why do we need control?

Control systems enable us to keep critical process variables within permitted operating conditions

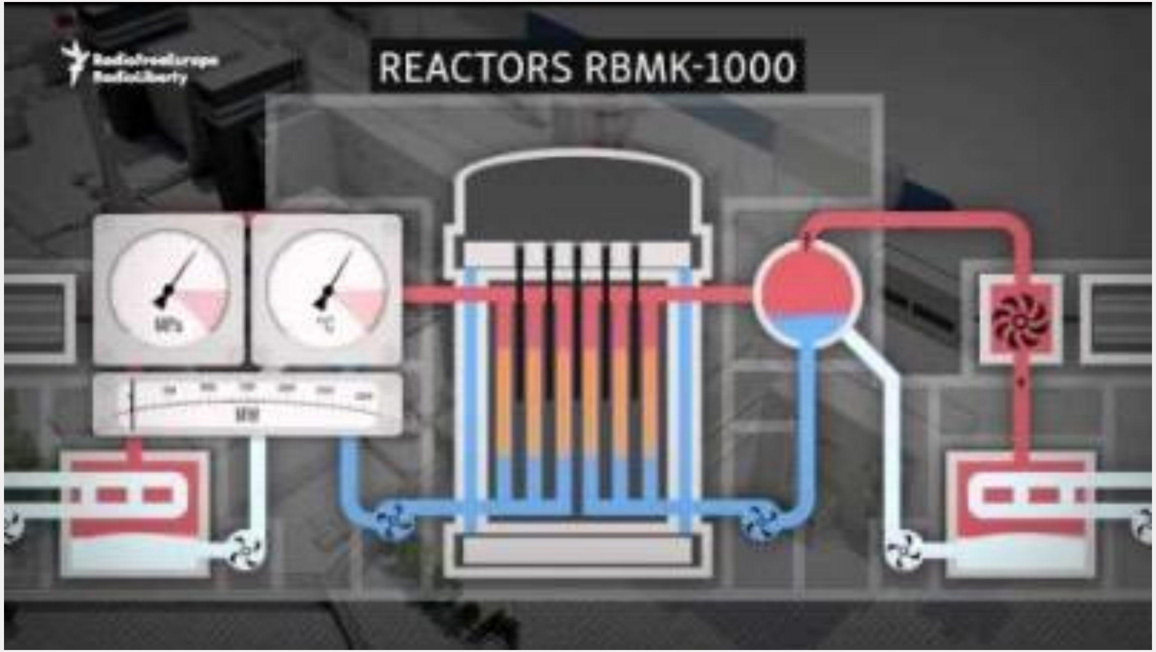
Example 1: Polymer reactor

- Reaction initiation requires heat
- Once initiated the reaction starts producing sufficient heat to initiate new reactions → runaway, unless the system is properly cooled
- Polymer properties are strongly influenced by time-temperature history of the polymer particles

Example 2: Cracker

- Cracking conversion and selectivity are strongly temperature dependent
- Large energy demand to perform cracking of heavy components

Why do we need control?



Why do we need control?

Ideal process operation involves making the process insensitive for disturbances by compensation. It requires tight control of applied operating conditions.

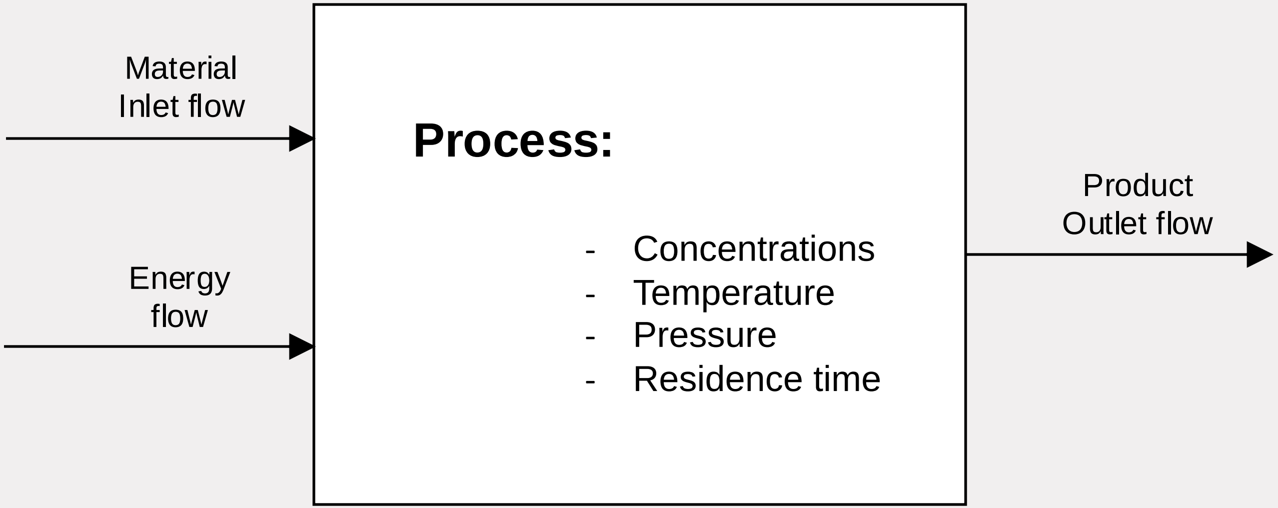
Compensation of disturbances (e.g. chemical reaction)

- Feed compositions
- Pressure
- Temperature
- Residence time

Drive the process to desired conditions

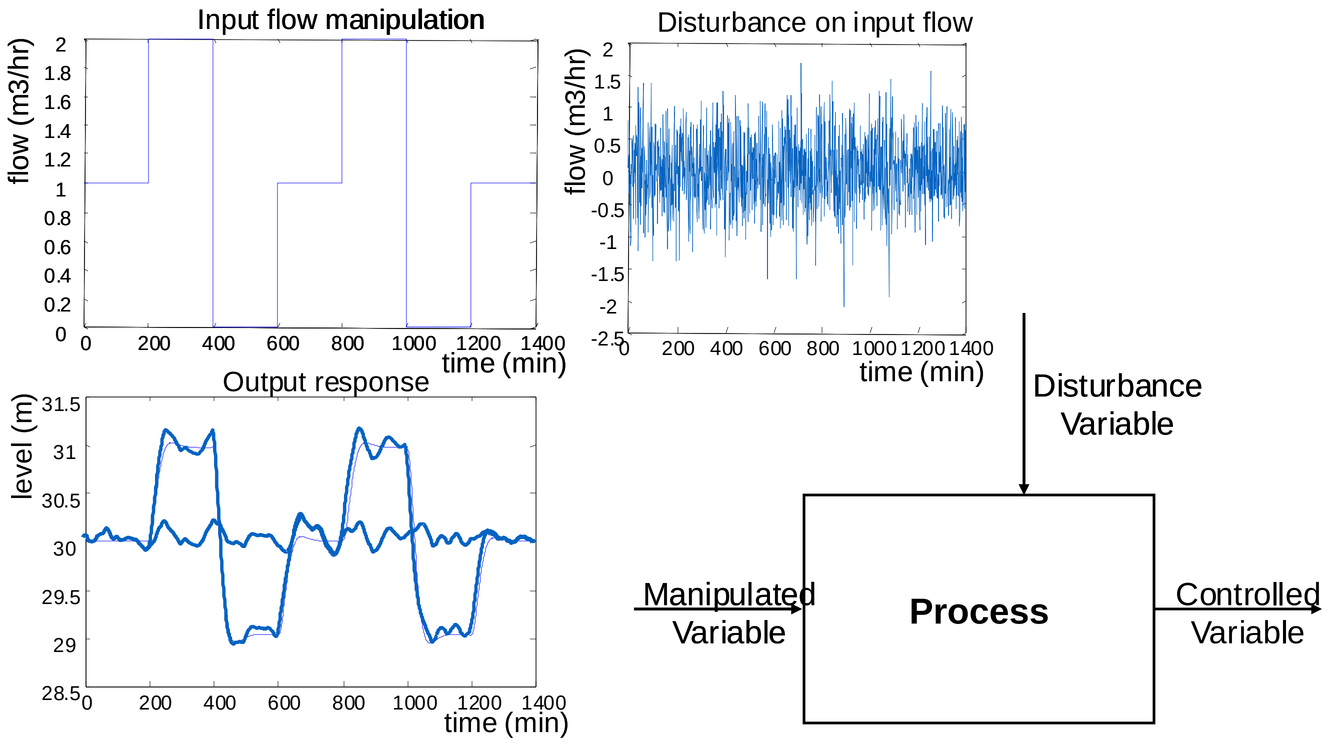
- Avoid dangerous operating conditions
- Follow preferred path for optimum production

How does control essentially work?



How does control essentially work?

The key element in a control system is the process



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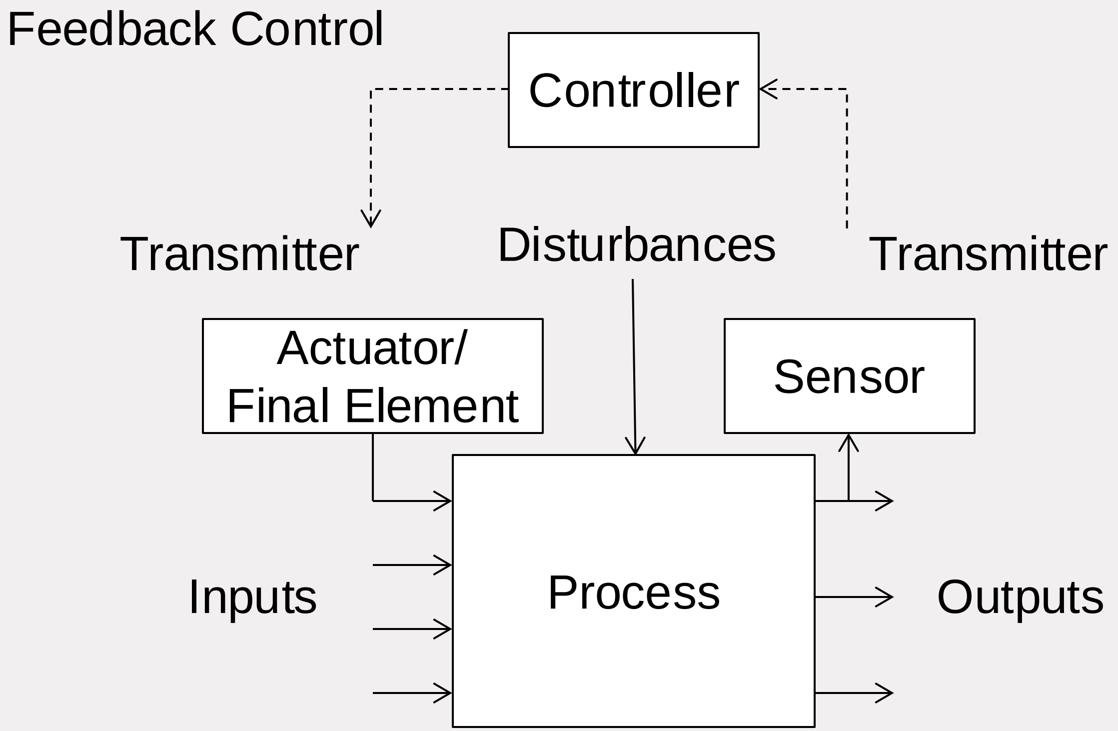
How does control essentially work?



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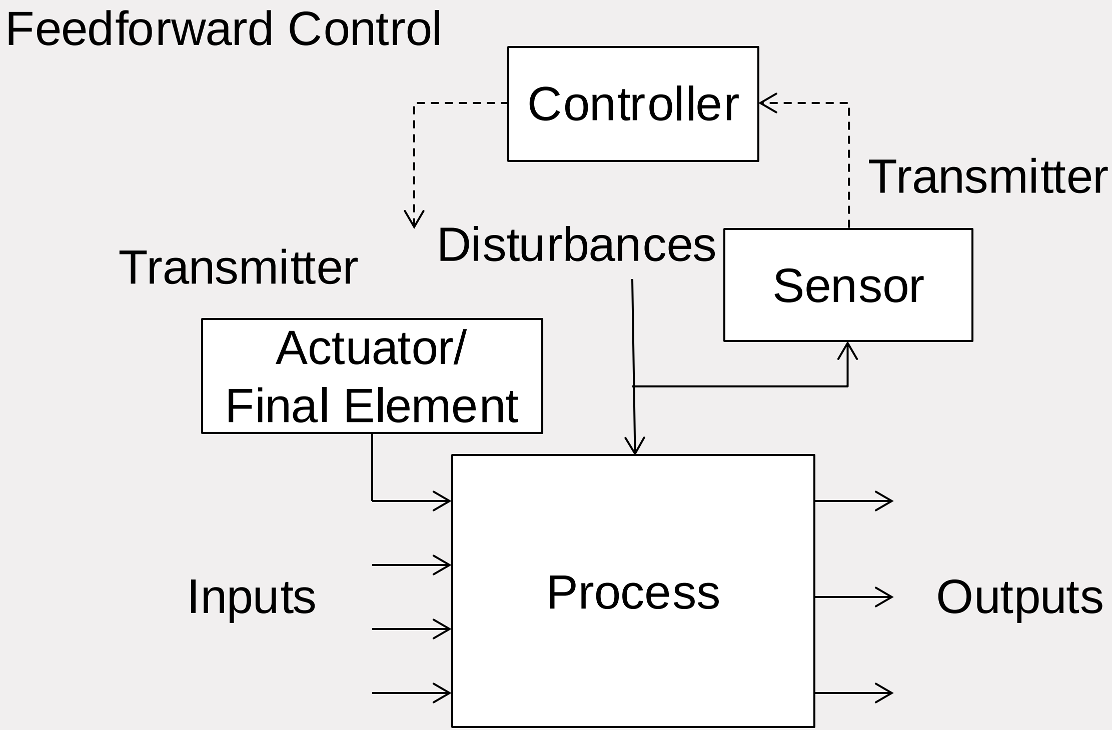
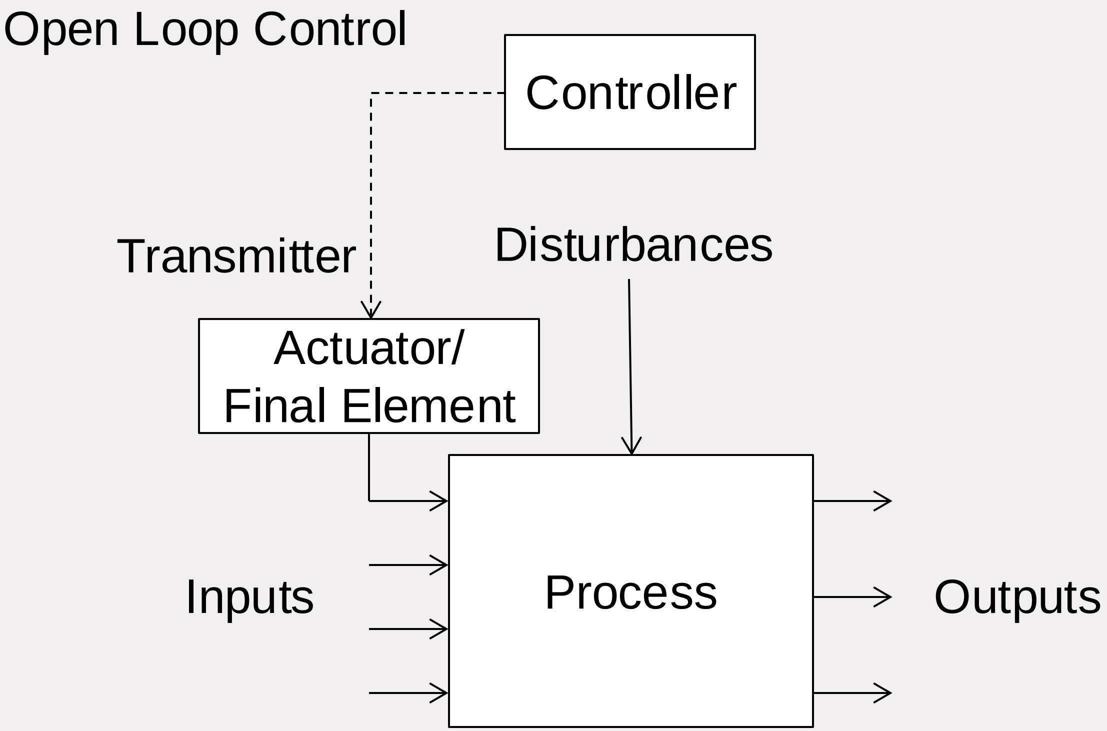


How does control essentially work?



How does control essentially work?

Process Variables:

INPUTS:

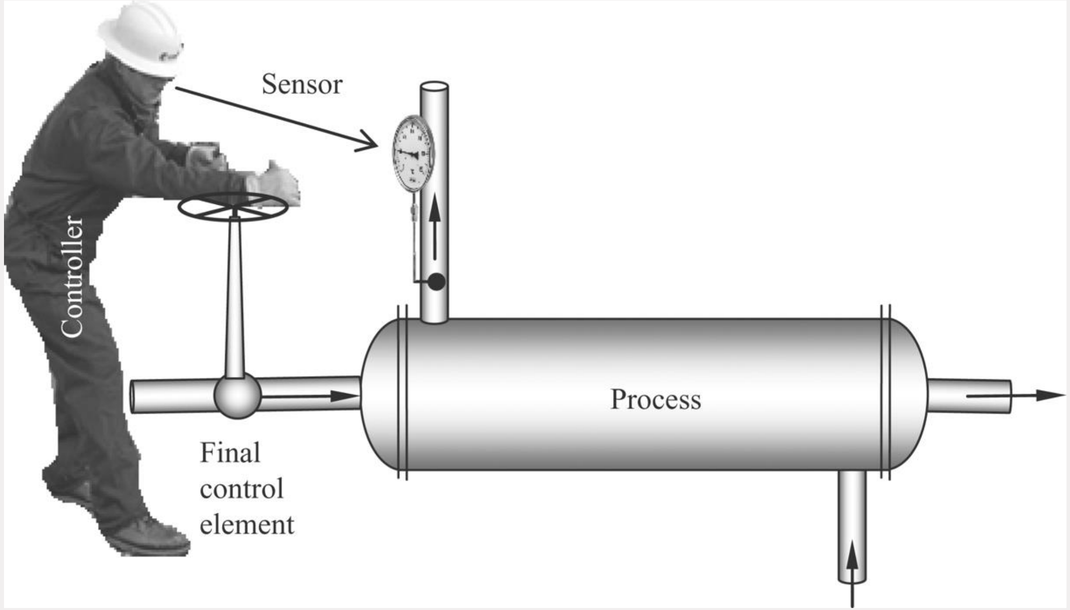
- Variables, which independently stimulate the system and can induce change in the internal conditions of the process
- Manipulated Variables
- Disturbances

OUTPUTS (MEASURED VARIABLES):

- Variables from which we can obtain information about the internal state of the process. The variables selected as output variables in general are directly relevant for process operation or are (related to) critical properties of products or intermediates

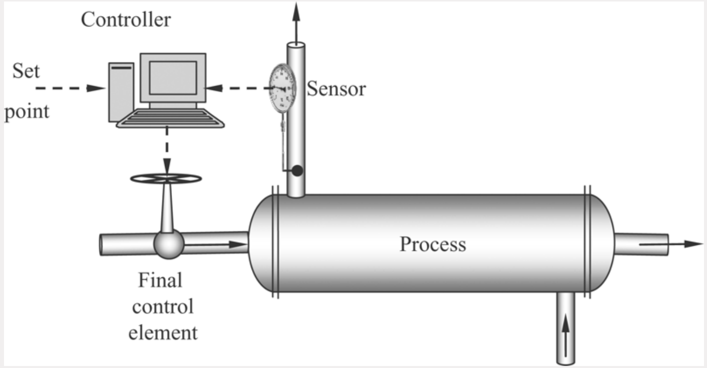
How does control essentially work?

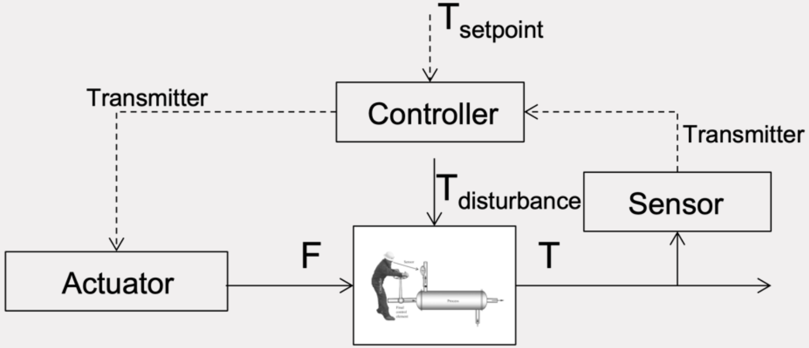
Process variables of a cooling system in a heat exchanger.



Input Variables: $F_{seawater}$
Output Variable: T_{out}
Disturbance Variable: ?

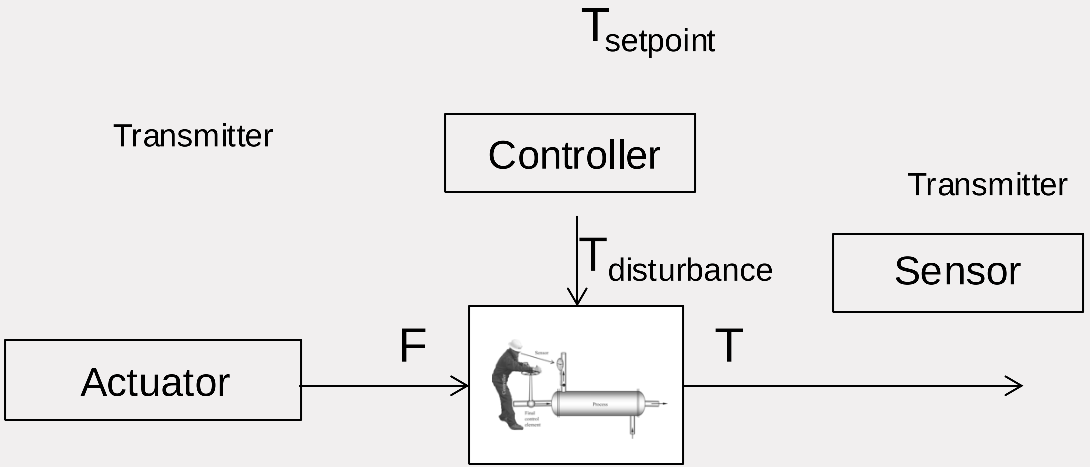
How does control essentially work?





How does control essentially work?

Feedforward Control of a Cooling system of a Heat Exchanger ?

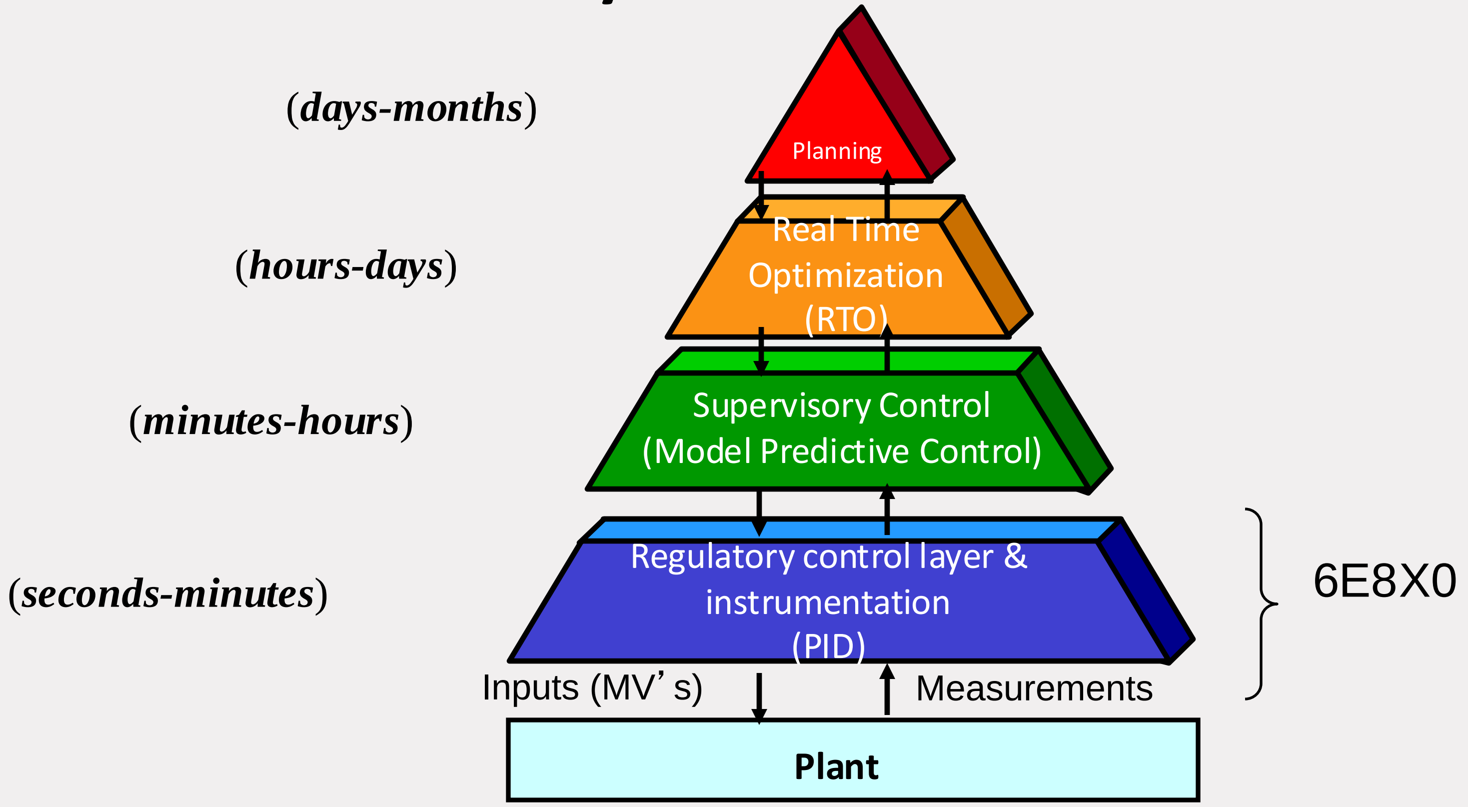


How are control systems implemented?

Control system evolution

- <1945 Only manual operator control
- 1945 – 1960 Pneumatic analog PID control
- 1960 – 1970 Analog electronic PID control systems
- 1970 – 1980 Digital PID control systems
- 1980 – today Distributed digital control systems
- 1985 – today Supervisory multivariable optimizing control (Model Predictive Control)
- 1990 – today Steady state model based plant wide optimization
- Future Dynamic/flexible model based plant wide optimization

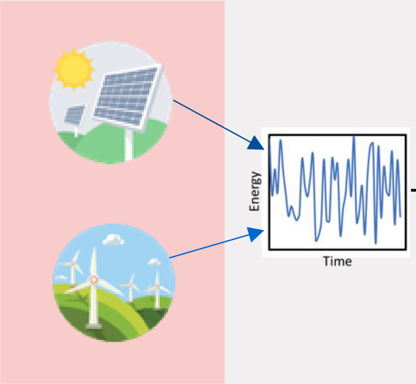
Process Control Hierarchy



Future is Promising

Electrification of the Process Industry

Smart Grid



Renewable energy

Production +Utilities

Transient Plant Operation

Coming lectures

- Topic 2: Introduction to frequency domain and Laplace transformation
- Topic 3: Dynamic Behavior of Linear Systems
- Topic 4: Frequency Response Analysis and Bode plots
- Topic 5: Mathematical Description of Chemical Systems
- Topic 6: Nonlinear ODE’s, Linearity, Linearization Feedback, Stability, Root Locus
- Topic 7: Feedback Controller Design and Bode stability
- Topic 8: Advanced (Enhanced)Process Control