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Process Control in Water Industry

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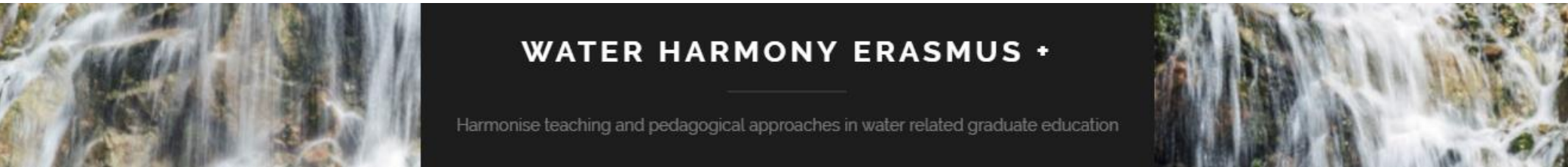

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Process Control

- Activities involved in ensuring the process are predictable, stable, and consistently operating at the target level of performance within only normal variation
- It is a deliberate influence on the process to achieve a desired performance of the given object
- In practice Process Control is carried out by Process Control Systems (PCS)

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Different Control Technologies

	UNIT	PROCESS	ENTERPRISE
Optimization Control	Local Optimisation	Multi-Unit Optimisation	Non-linear Optimization
Model Based Control	Smith Predictors etc.	Multivariable Predictive Control	
Advanced Process Control	Feedforward Control	Dynamic Decoupling Control	Constrained Control
Regulatory Control	Single PI/PID Regulator	Cascade	

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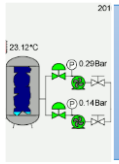
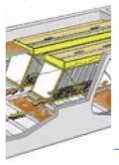
ERP/MRP

- Coordination of operations of separated workshops or plants
- Economy tasks planning
- Insuring effective control of the plant in general



SCADA

- Search of optimal modes of interconnected devices
- Distribution of load between separate units or machines working in parallel
- Data collection from meters e.g. flow- and mass-meters in the process
- Process control based on collected data in order to insure maximum efficiency in process safety



LCS

- Stabilizing of preset technological parameters of the process
- Alarming
- Blocking of equipment in case of emergency

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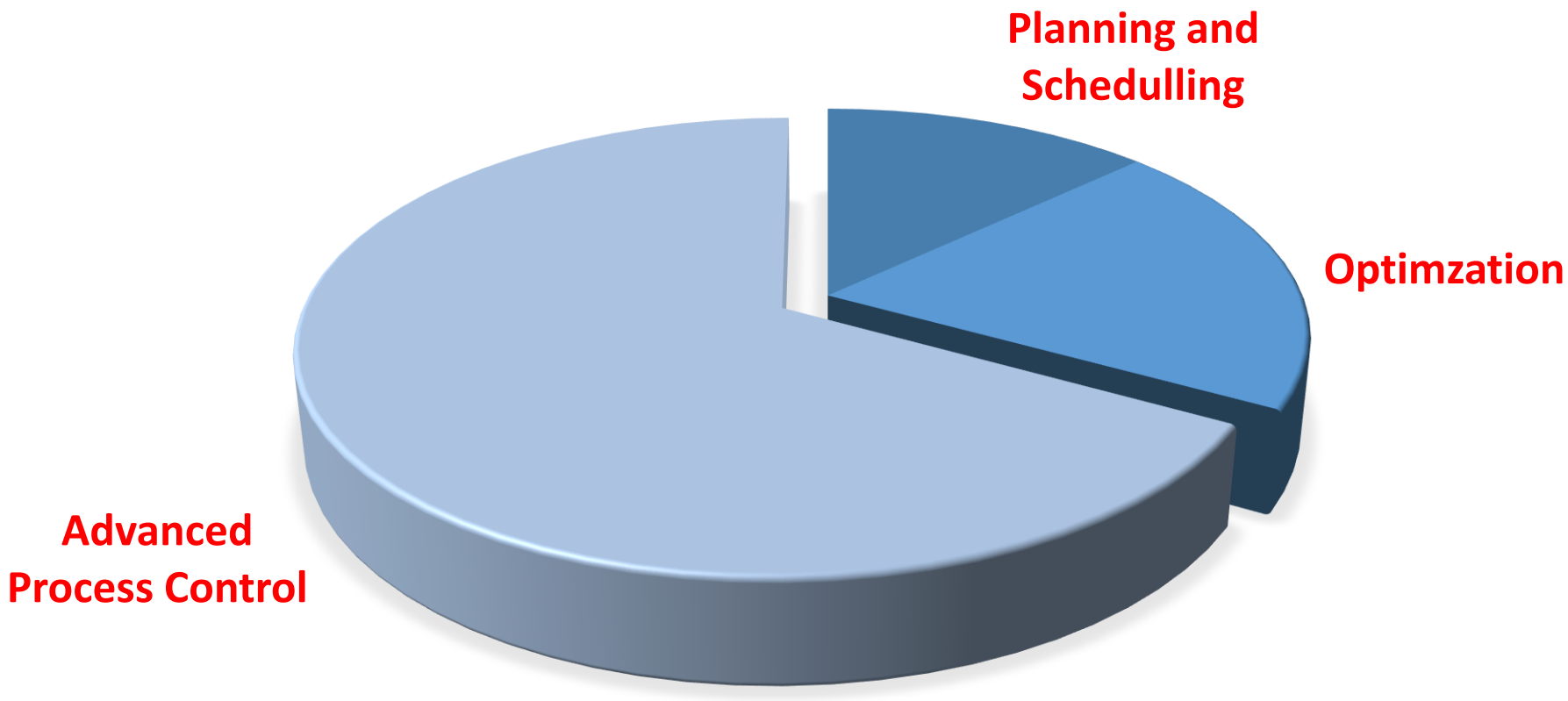
Available Economic Benefits



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Control Strategies in WWT

- Treatment efficiency
  - turbidity, SS, pH etc.
- Chemicals economy
  - minimization of reagent consumption (coagulant, alkaline agent, flocculants) without reducing the treatment quality
- Minimum maintenance effort
  - due to communication with all kinds of equipment, checking the state of mechanical equipment such as pumps, mixers, valves etc.
  - PCS helps plant owners/consumers to control advanced processes with less operating personnel

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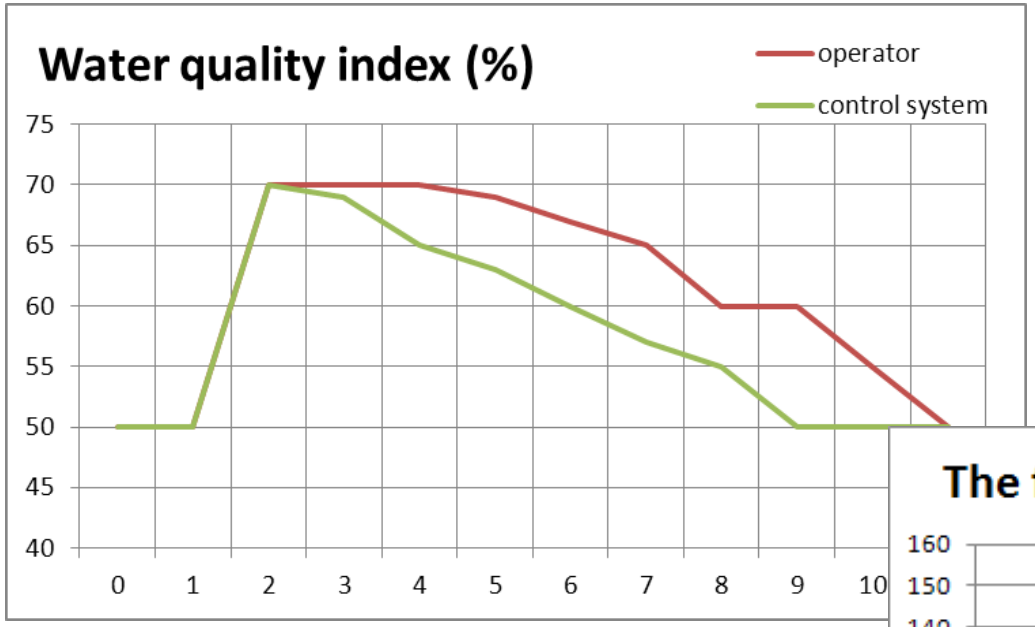
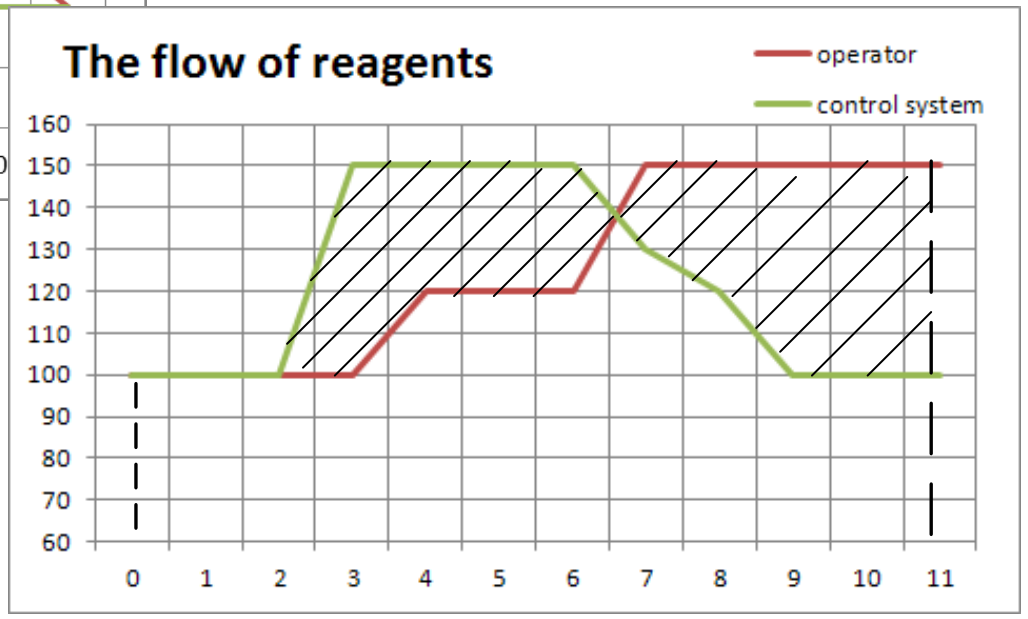
Manual vs Automatic Control





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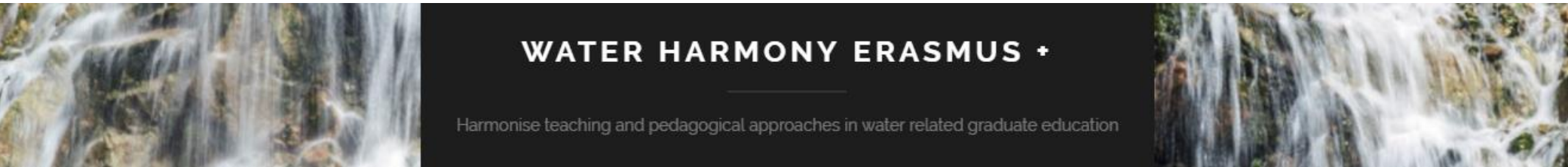
How and when to influence the process?



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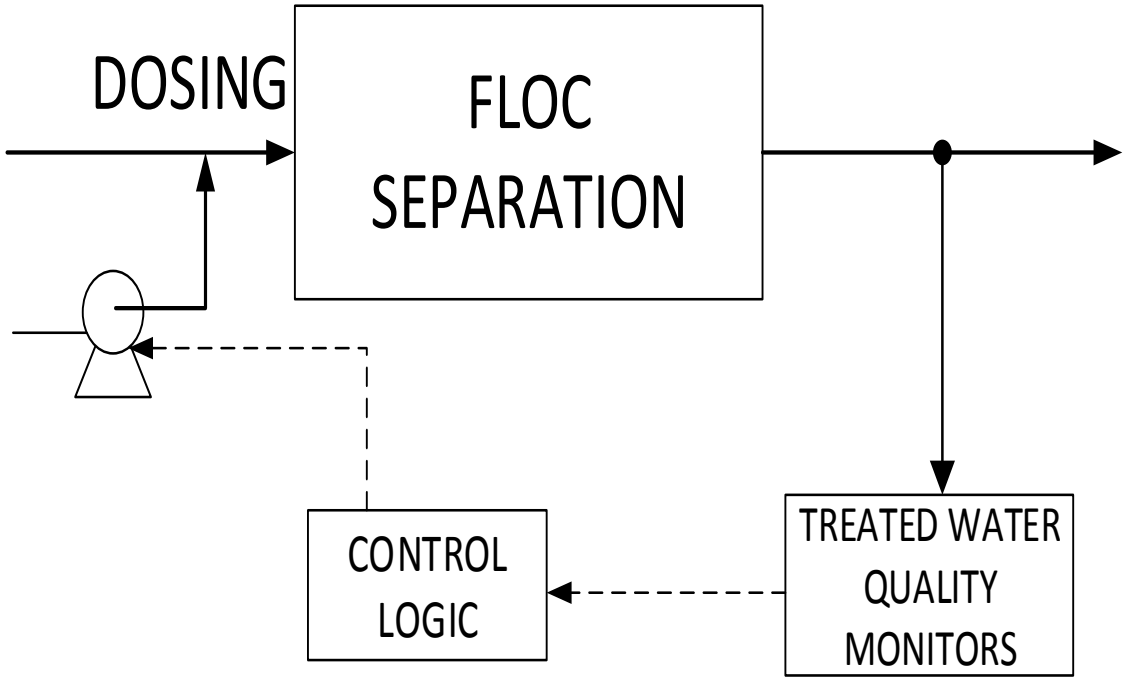
Feed-back Control

- The most useful control technique
- Disadvantage
  - influence the process after deviation detected



Feed-back Control Scheme
based on treated water quality

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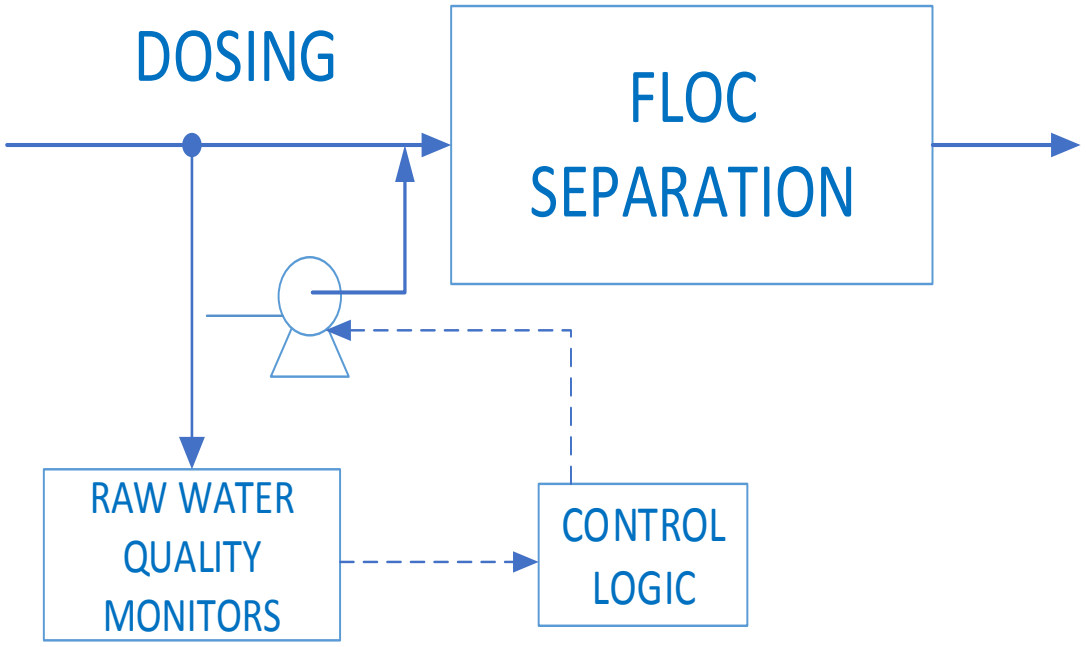
Feed-forward Control

- Advantage
  - influence the process before deviations occurre
- Disadvantage
  - Can't receive output response



Feed-forward Control Scheme based on raw water quality

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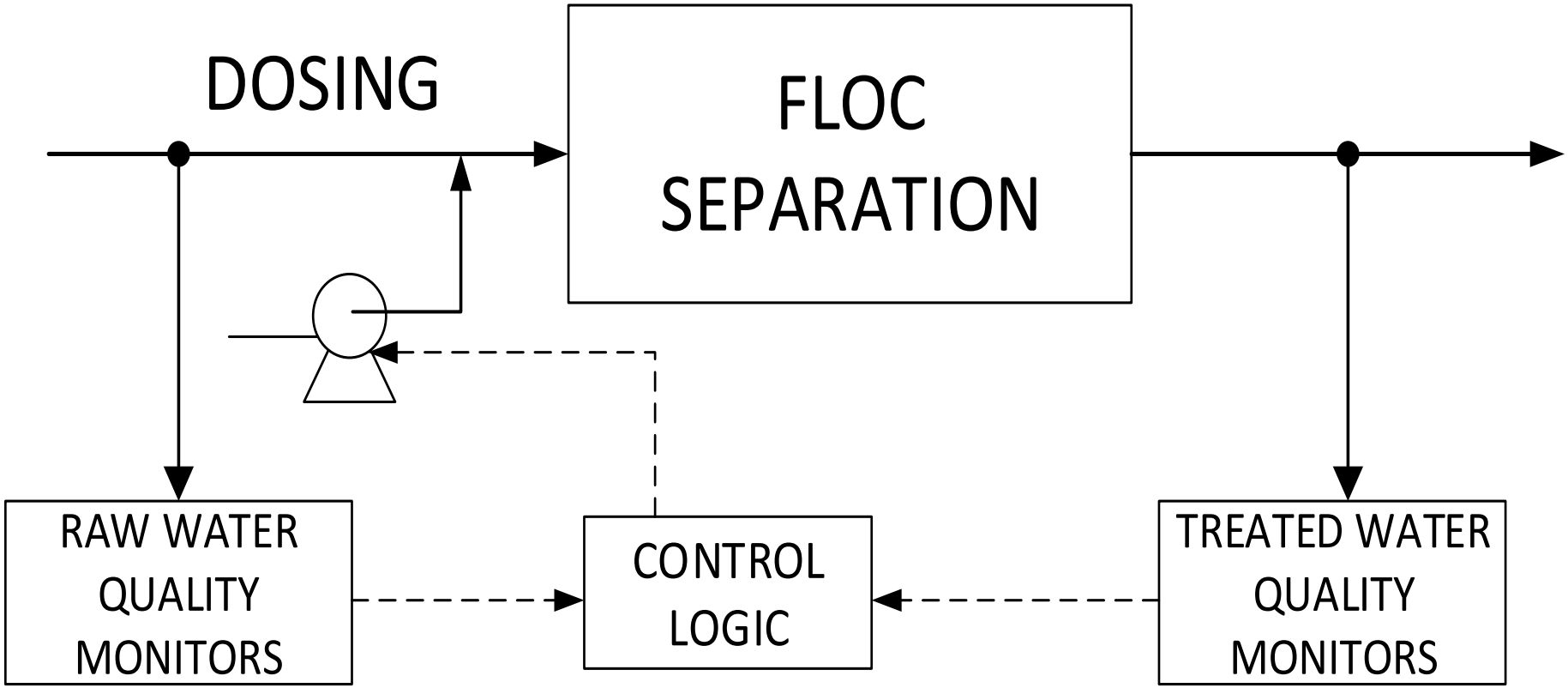
Combined Control



Combined Control Scheme based on raw and finished water quality

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Typical Project Phases

- Understanding the process
- Functional design and benefit analysis

Object

- Identifying key parameters
- Model calibration and validation

Model

- Calculating optimal modes
- Controller design and tuning

Controller

- Full-scale Experiment

Experiment

- Full-scale Implementation

Implementation

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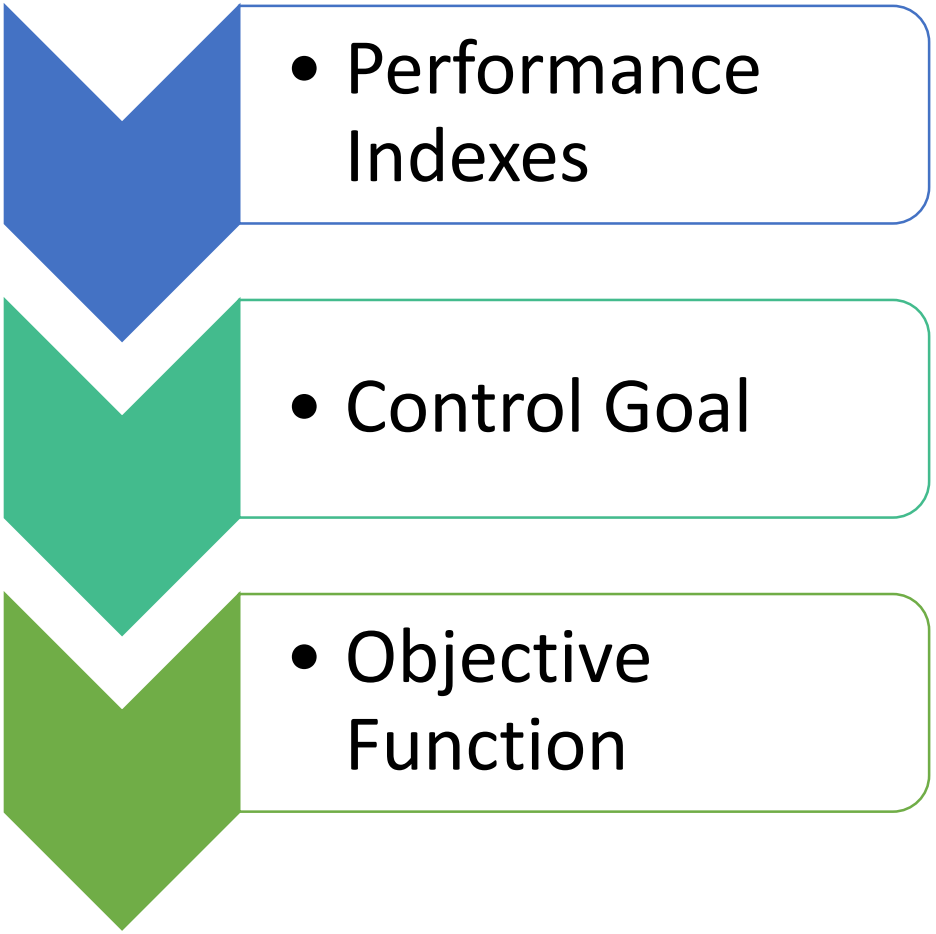
Functional Design

- Define Process Control Goals
  - Economy
  - Operation
  - Instruments
- Specify
  - Manipulated Variables
  - Disturbance Variables
  - Controlled Variables



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Identifying Key Parameters

- The current mode of the object (mode parameters)
- What values influence the process?
- When the object changes its given mode and which of its states is the given one?

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Process Instruments

- Sensors should function correctly
  - minimum noise
  - responsive
    - minimum deadtime
    - quick
  - representative
- Valves in working order
  - minimum hysteresis
  - free moving
- Where possible, fix problems

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Instruments

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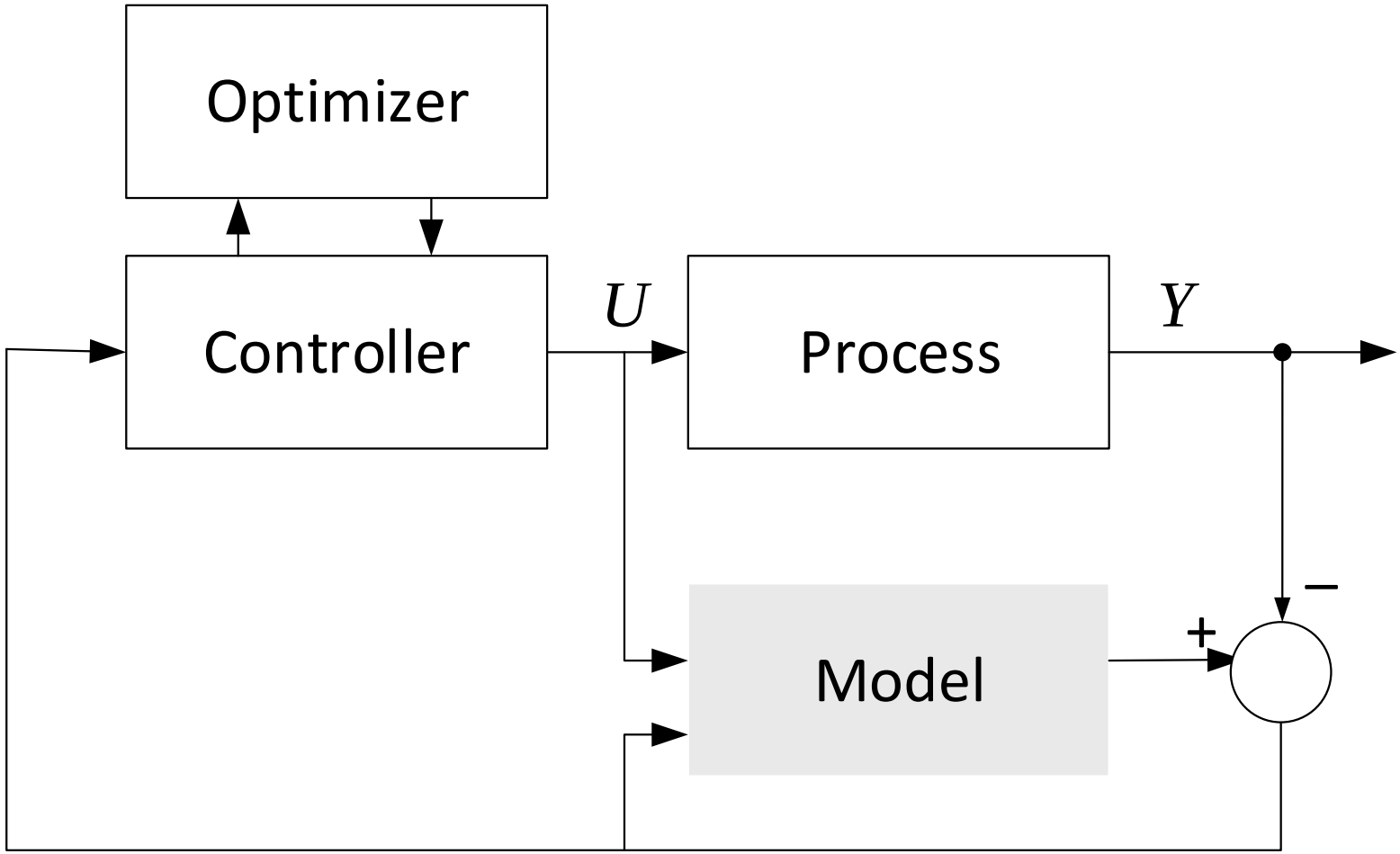
Model Considerations



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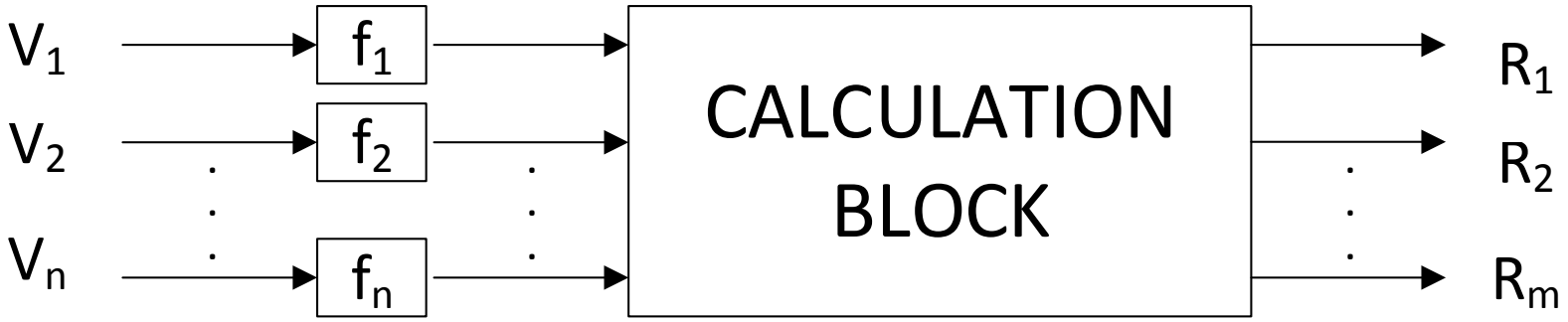
Building a house on good foundation

- Develop / understand the models for calculations and the assumptions behind them
  - WEAP®, STOAT®, MatLab, …
- Most models are steady state models
- Consider lab / analyser update scheme in the model
- Consider filtering of raw data (inputs)



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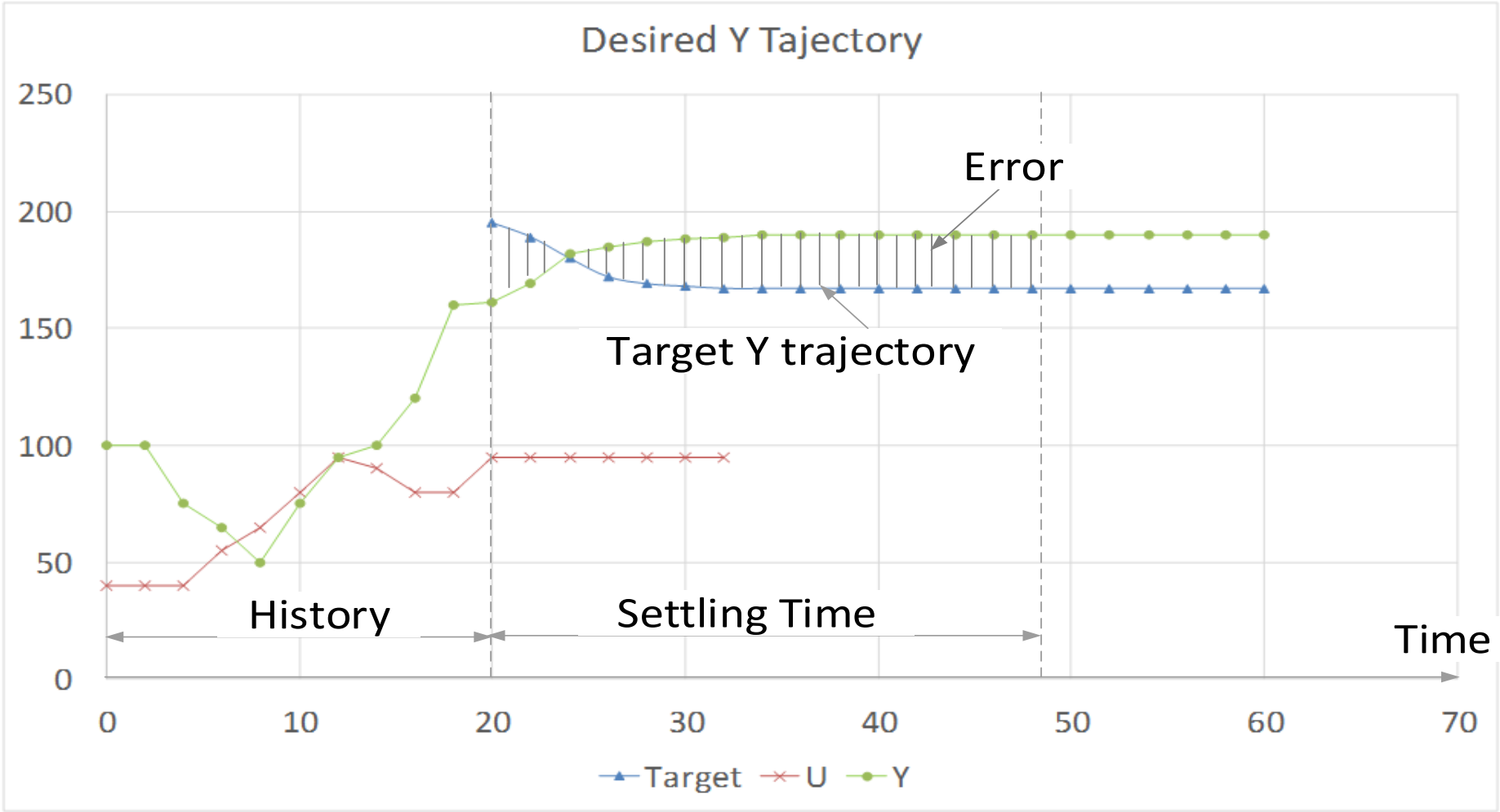
Simulation



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Model Testing

- Model testing requires significant effort

- Minimum time for pre-step testing t_{pst} is given by

$$t_{pst} = 4 \cdot (n_U + n_Z) \cdot t_{ss},$$

where

- n_U - number of U
- n_Z - number of Z
- t_{ss} - time for steady-state

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Choosing Objective Function

- Product Value Optimization

$$I = \begin{bmatrix} Product\ Flows \times Product\ Values - \\ -Feed\ Flows \times Feed\ Costs - \\ -Energy/UtilityFlows \times Energy/UtilityCosts \end{bmatrix} \rightarrow \min$$

- Limitations (examples)
  - Overloading
  - Flooding
  - Lack of overhead cooling

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Choosing Objective Function

- Linear Program Optimization

- $I = \sum_i \$_i^{cost} \times y_i + \sum_j \$_j^{cost} \times u_j$ (1)
- $I = \sum_j \$_j^{cost} \times u_j$ (2)

- Use to minimise utilities or other operating variables
- Use to maximise product value

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Choosing Objective Function

- Quadratic Program (QP) Optimization
- $I = \sum_i \$_i^{cost} \times (y_i - y_i^{ss})^2 + \sum_j \$_j^{cost} \times \left(u_j - u_j^{ss}\right)^2$ (1)
- $I = \sum_j \$_j^{cost} \times \left(u_j - u_j^{ss}\right)^2$ (2)

where y_i^{ss} , u_j^{ss} – “ideal operating point”

- Need to pre-calculate “ideal” U/Y values
- Difficult to specify QP U/Y costs

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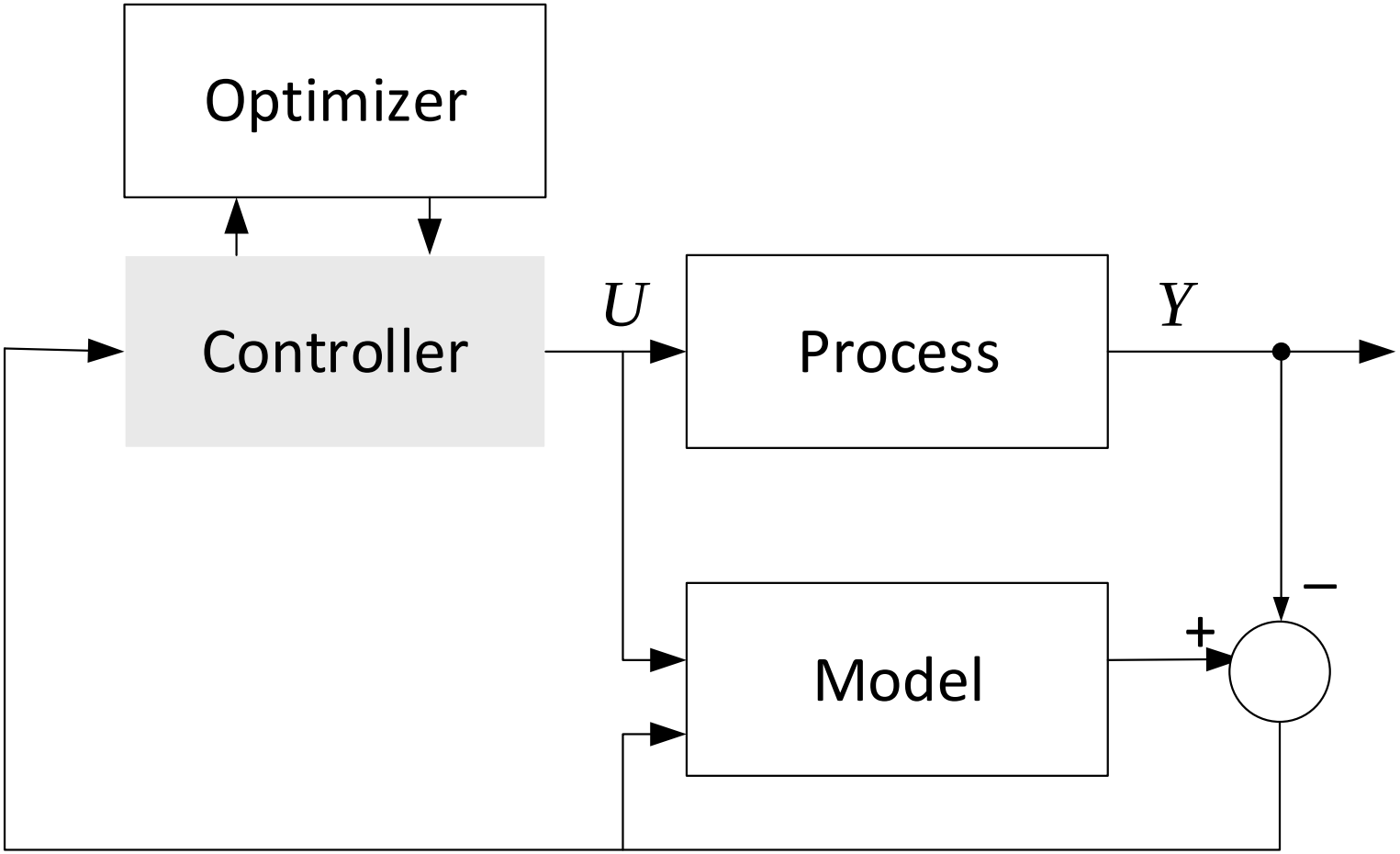
Controller Design and Tuning



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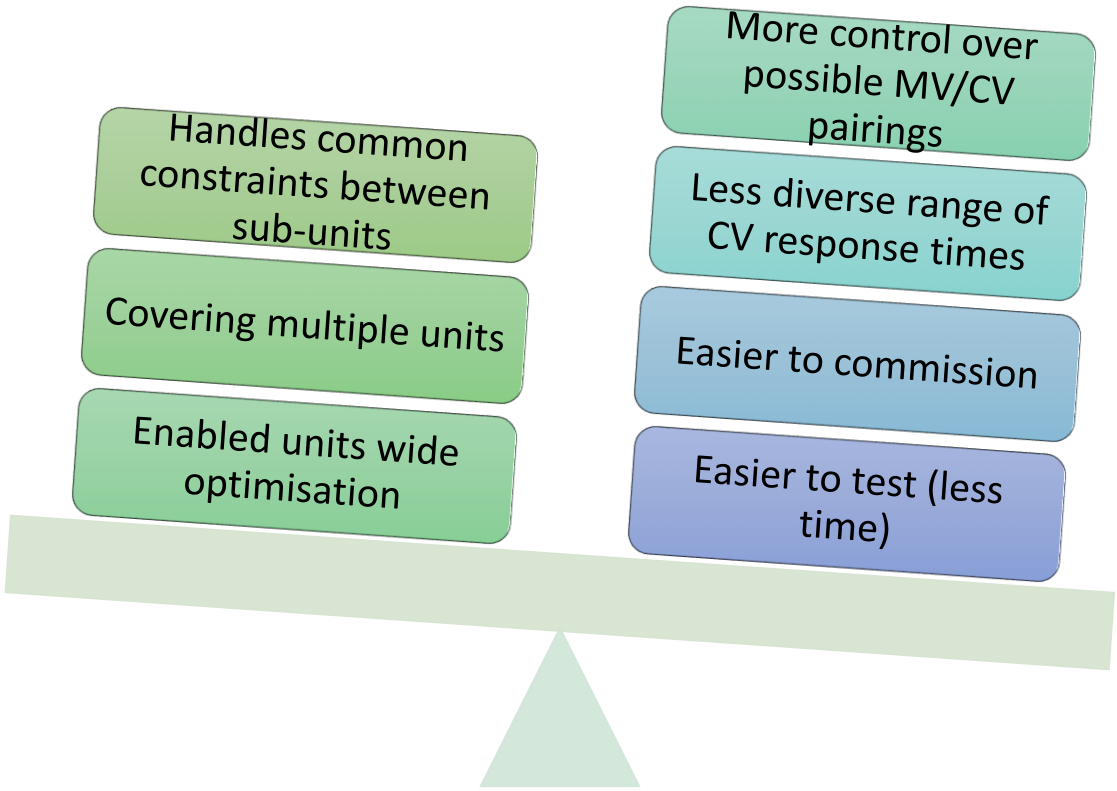
Poor controller design leads to poor performance

One big controller

Separate controllers



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Review of Process Control Systems

- PCS is the heart of the plant. Should it fail, the manager has to significantly increase staff number to run the plant in manual mode

- PCS collects data from meters e.g. flow- and mass-meters in the process. PCS also checks the state of mechanical equipment such as pumps, mixers, valves etc.
- PCS uses the collected process data to adjust parameters such as pump speed to ensure stable flow or chemicals right dosage

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Review of Process Control Systems

- For an operator the interface of the Process Control System is the computer-based SCADA-system. SCADA stands for *Supervisory Control and Data Acquisition*
- PCS has a “communication module” that helps communicate with all kinds of equipment through the following standards: 4-20 mA, Ethernet (TCP/IP) or different types of industry protocols (Profibus, Modbus)
- The actions to be done are determined by the PLC (Programmable Logic Controller), based on the program made by the automation engineer

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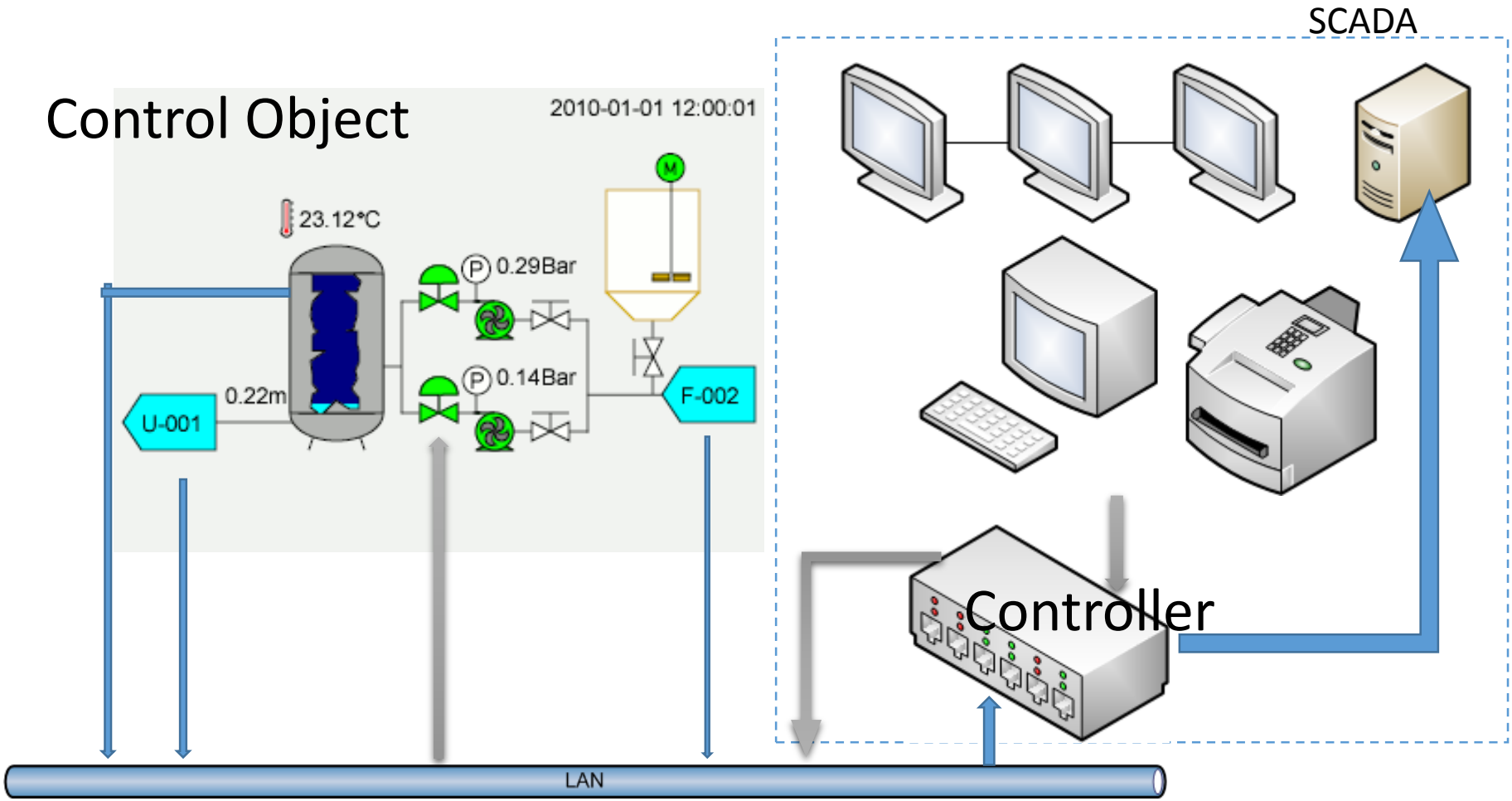
How it works?



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