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SFERA-III 2nd Summer School
October, 5th- 6th, 2021
Almería (Spain)

Lecture:
Advanced control of solar process heat applications

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Content:

- Automatic control: a (very) brief introduction
- Control structures of continuous systems. SHIP and water desalination processes.

Automatic control. Introduction

- Device or process working by itself with little or no direct human control.
- To maintain the variables of a process within defined limits, with a desired behavior and minimizing the effect of external variables

Automatic control. Introduction

- Device or process working by itself with little or no direct human control.
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What do you do during the shower time?

1. Open the water tap
2. Touch the water with your hand
3. Manipulate the tap trying to reach the desired water temperature

Automatic control. Introduction

1. To observe the behavior of the real process
2. Compare the behavior with the desired one
3. Act over the process to reach the desired objective

Automatic control. Introduction

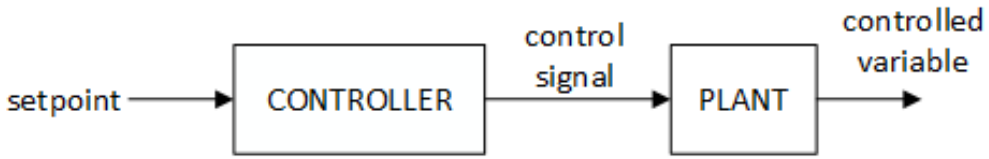
Control systems. Some definitions

- **Plant/Process**. The mechanism, device or process to be controlled.
- **Output** (controlled variable, process variable). Variable or property of the plant that must be controlled.
- **Input** (control variable). Variable or signal that, when adjusted, produces important changes in the plant output
- **Reference** (setpoint). Signal that represents the behavior that is desired at the plant output.
- **Error**. Difference between the setpoint and the controlled variable
- **Disturbance**. A signal that is external to the control system having deleterious effects on the performance of the closed-loop system.
- **Actuator**. A device that applies the input signal to the plant.
- **Constraints**. Limitations in the variables

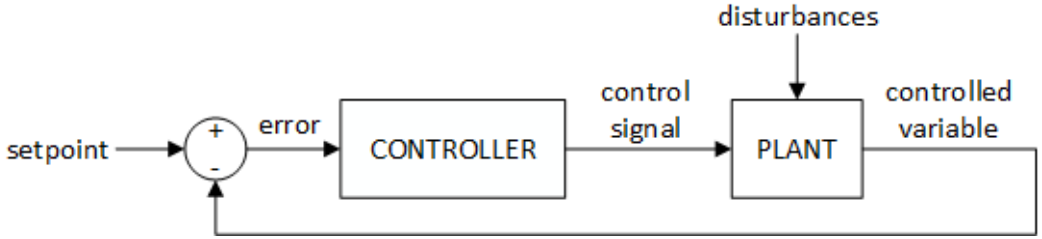
Automatic control. Introduction

Control systems. Some definitions

- **Open-loop control**. Information is not gained directly from the measurement of the controlled signal.



- **Closed-loop (feedback control).** The controlled signal is measured. The control error influences the input of the process



Control structures of continuous systems

Key concepts

Block diagram

SHIP & solar desalination application

Control structures of continuous systems

Category I: Basic control approaches

- PID
- Feedforward
- Cascade controller

Category II, III & IV: advanced control

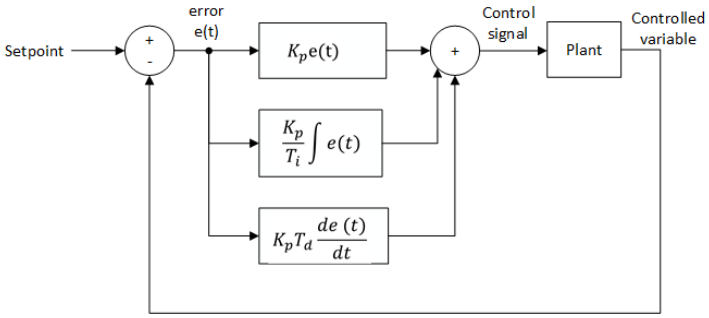
- Gain scheduling GS
- Time delay compensation TDC
- Decoupling control
- Model predictive control MPC
- Neural Network
- …

Seborg, D. E. (1999). A perspective on advanced strategies for process control (revisited). In Advances in Control (pp. 103-134). Springer, London.

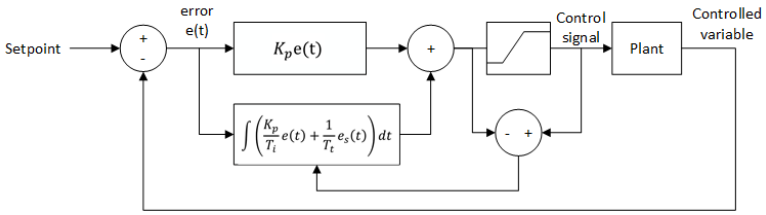
Control structures of continuous systems

The PID controller

- The most common algorithm
- It has the ability of eliminating steady state offsets
- It can anticipate the future



PID Non-interacting form

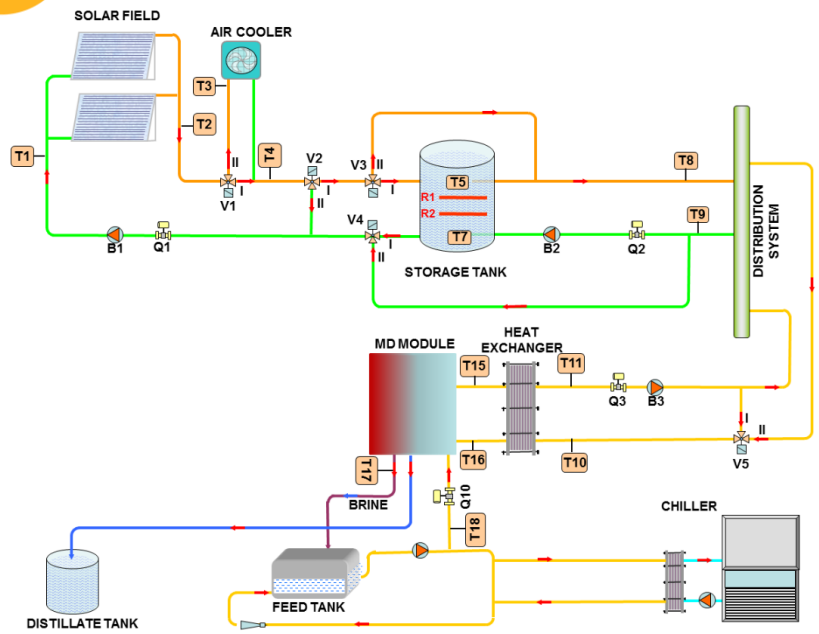


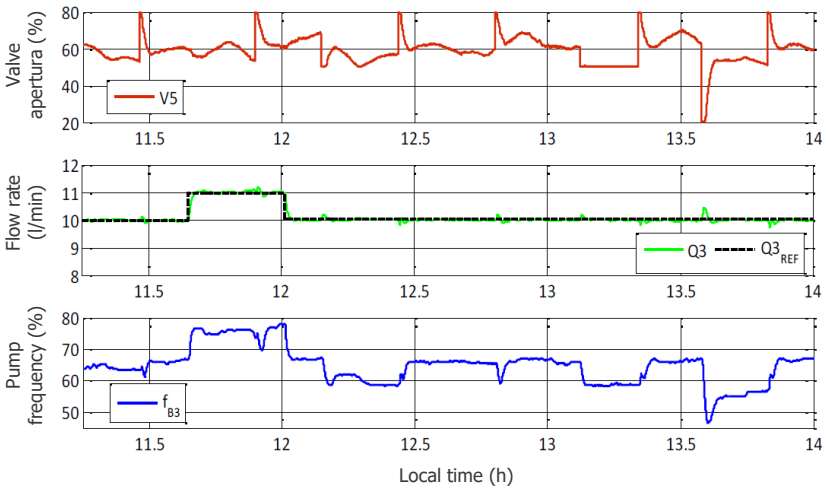
Anti-windup

Control structures of continuous systems

The PID controller

Water flow rate in solar membrane distillation system





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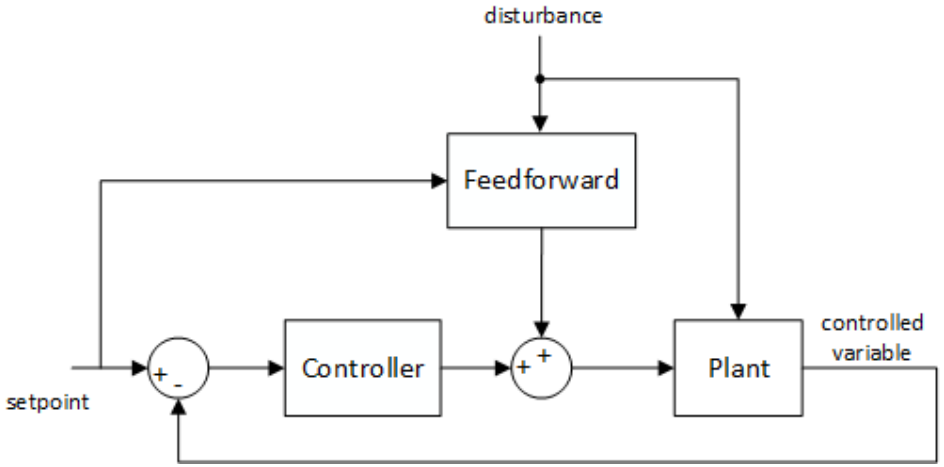
Control structures of continuous systems

The feedforward controller

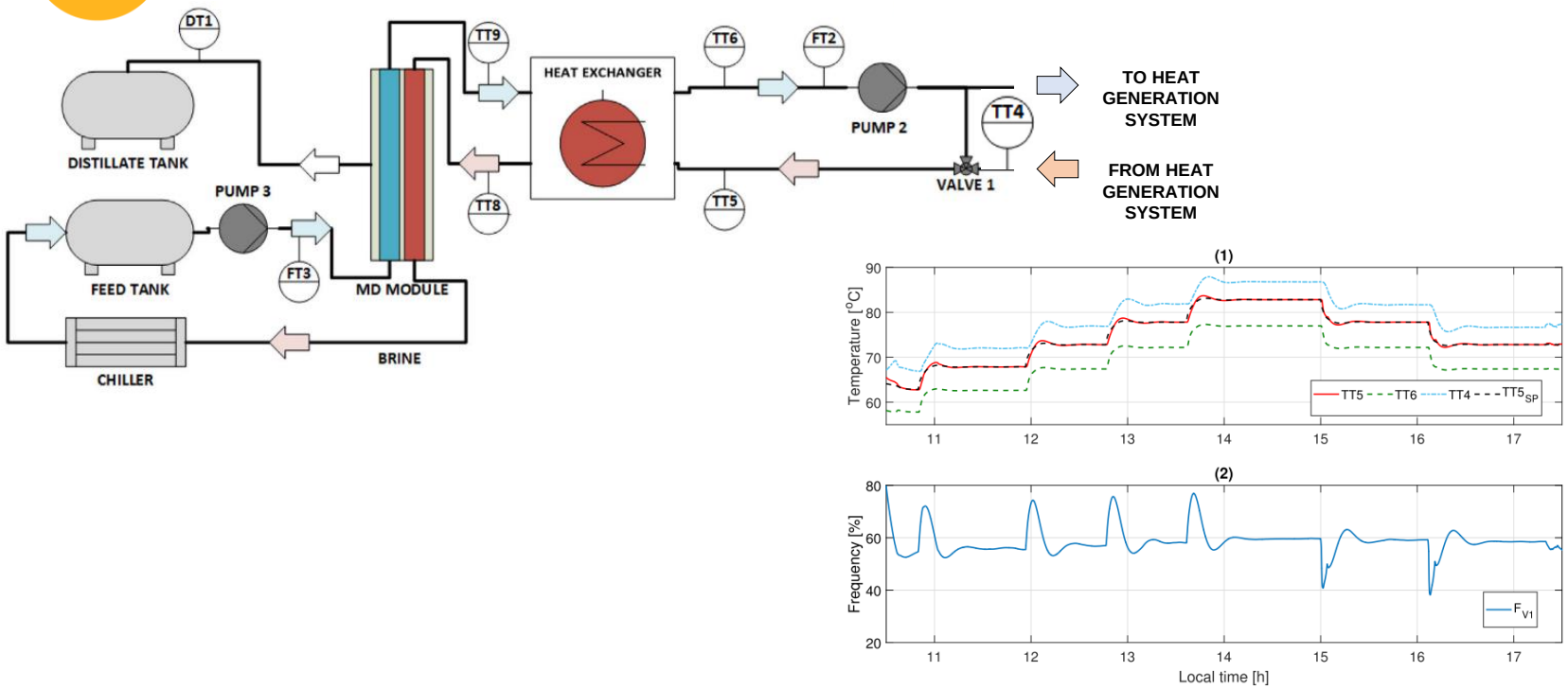
- It eliminates the effect of disturbances before they have created control errors.
- It requires process models
- It requires disturbance measurements
- It complements feedback control



Control structures of continuous systems

The feedforward controller

Three way valve in solar membrane distillation system



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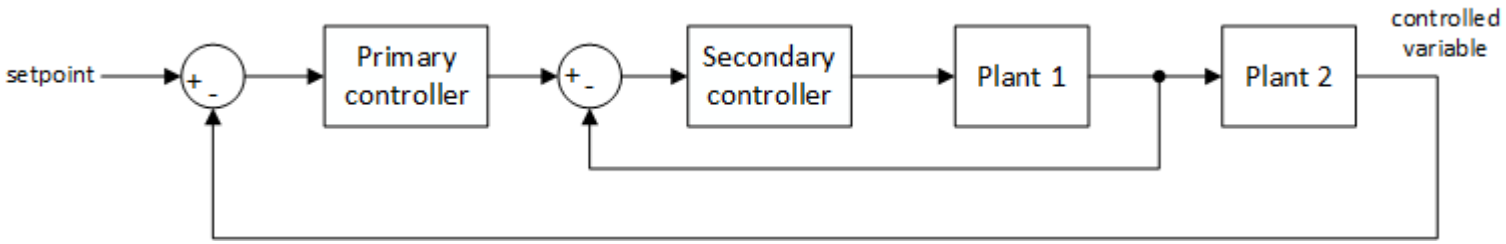
Control structures of continuous systems

Cascade controller

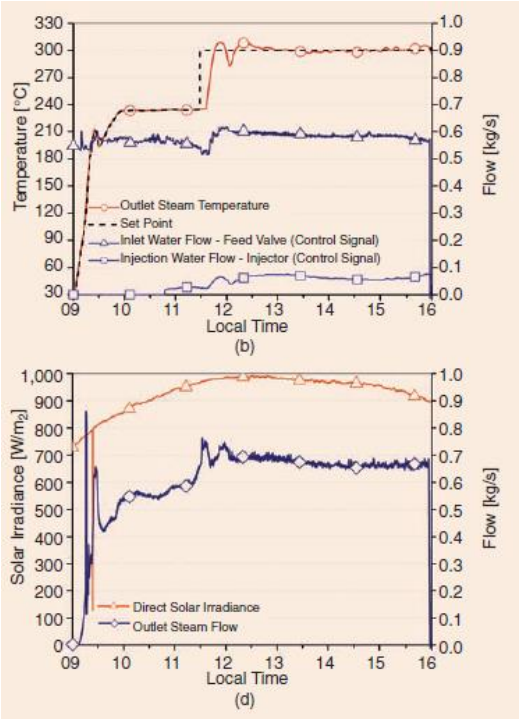
- It can be used when there are several measurement signals and one control variable.
- It splits the control problem in two time scales and two control loops: an inner control loop (slave) and the outer control loop (master).

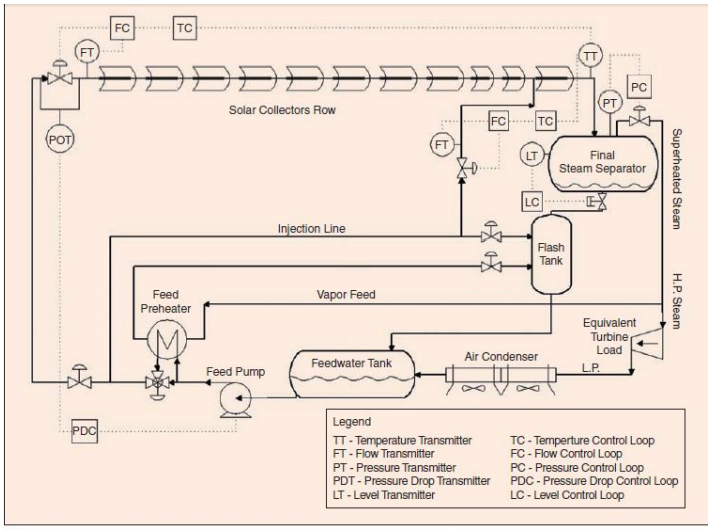


Control structures of continuous systems

Cascade controller

Outlet steam temperature





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Control structures of continuous systems

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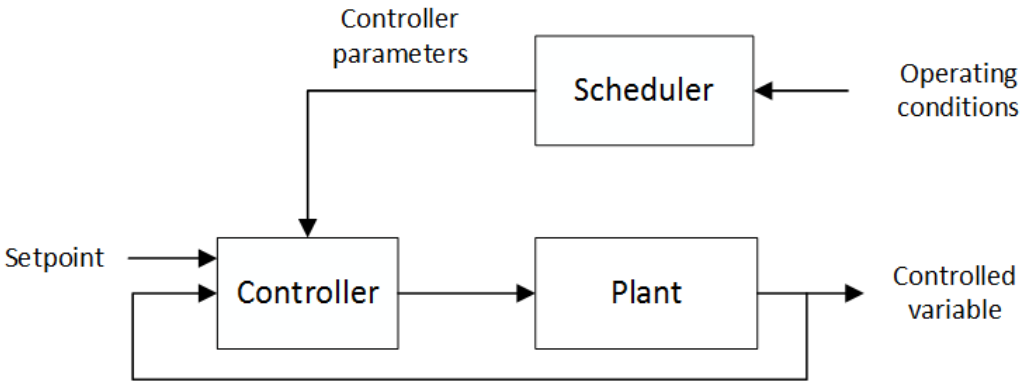
Control structures of continuous systems

Gain scheduling

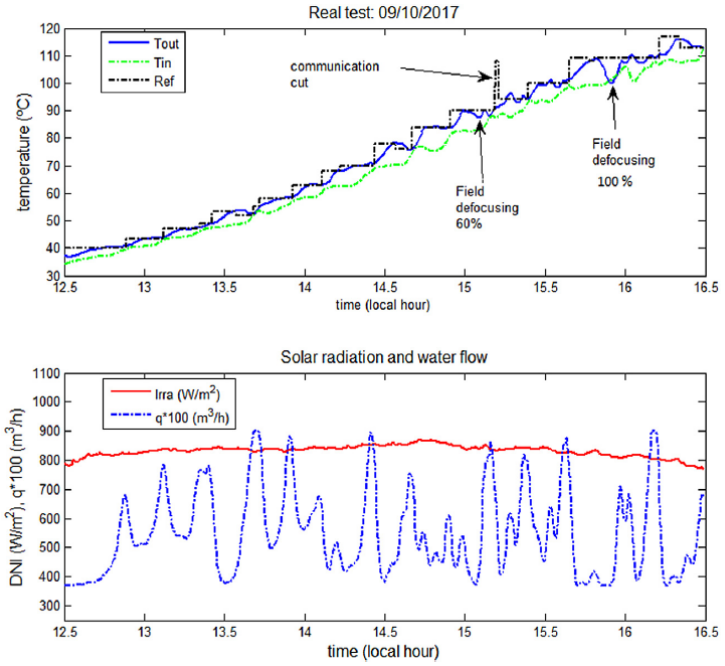
- Controllers that have the ability of adapting to changes in process dynamics
- Controller parameters can be computed from measurement variables related to the operating point or operating conditions

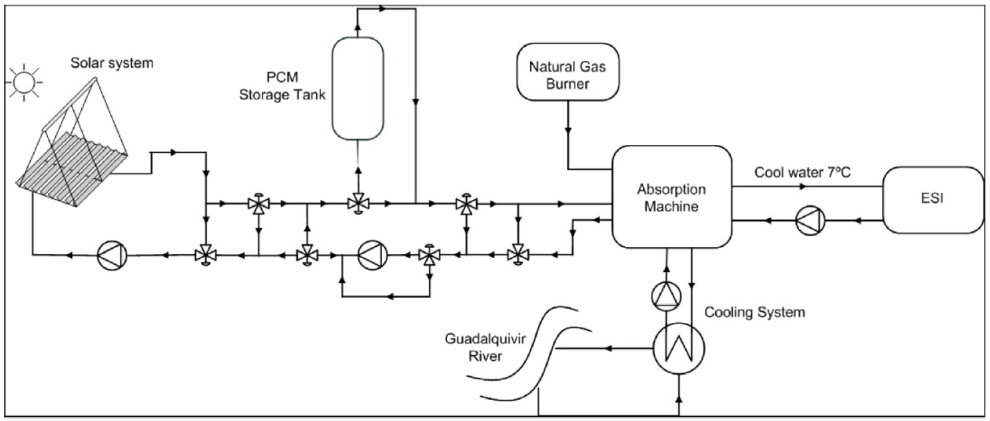


Control structures of continuous systems

Gain scheduling

Fresnel collector field





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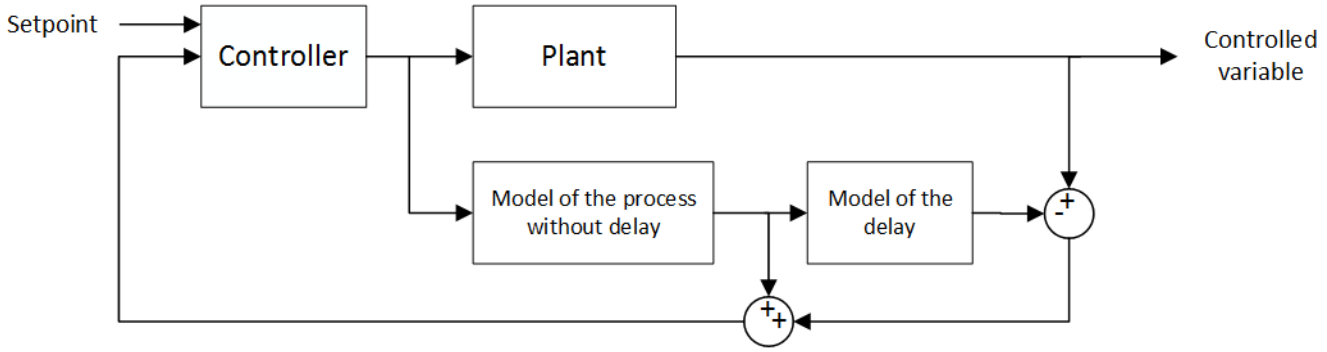
Control structures of continuous systems

Time delay compensation

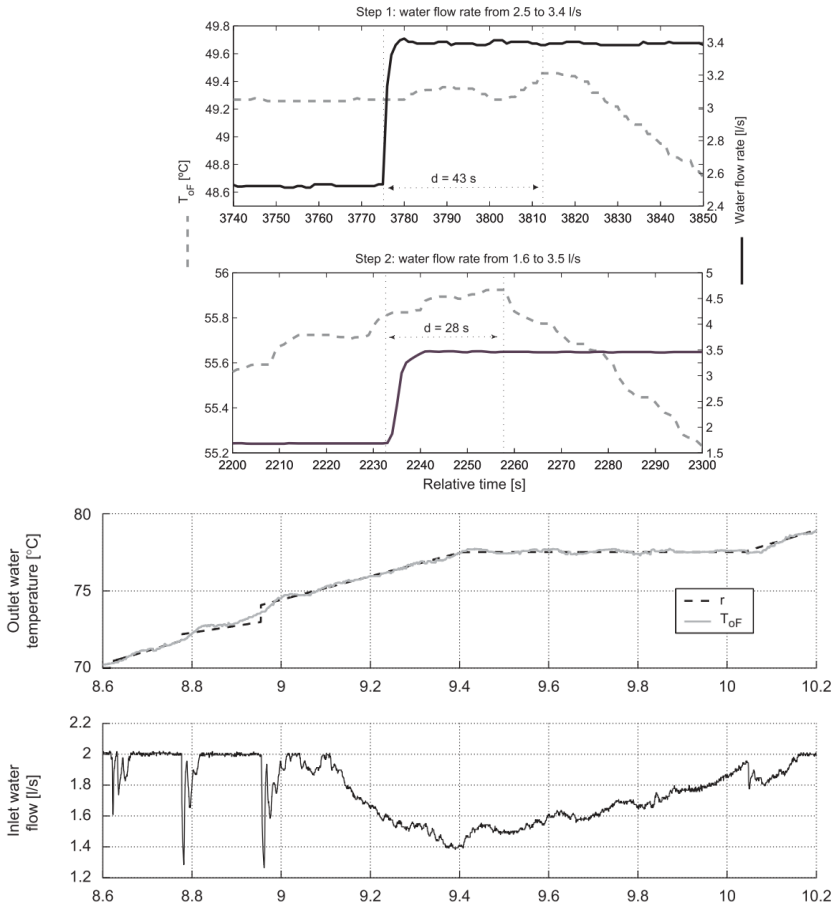
- Dead times appears in many solar processes, usually associated with mass transport or doe to the accumulation of several low-order systems.
- In TDC schemes, the controller is designed without considering the delay of the process



Control structures of continuous systems

Time delay compensator

- Compound parabolic concentrators



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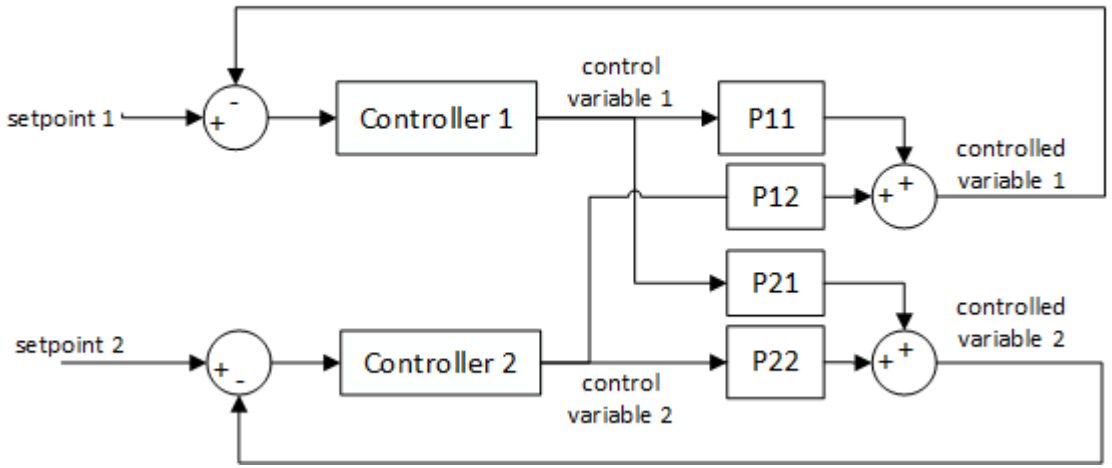
Control structures of continuous systems

Decoupling control

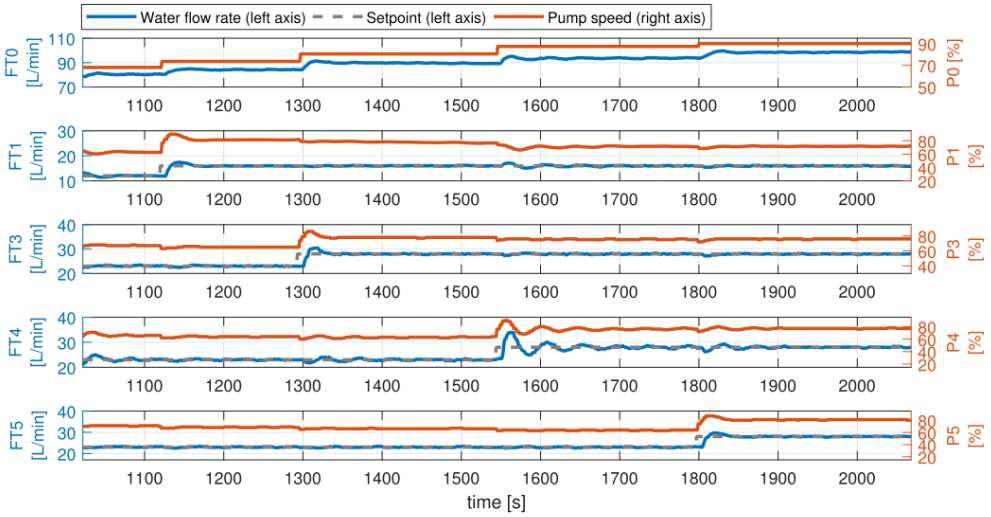
- In Multi-Input-Multi-Output (MIMO) systems we must control simultaneously M variables with N available control signals.
- One of the most important problems in MIMO systems control is the coupling problem
- We can use decouplers to compensate for undesirable process interactions

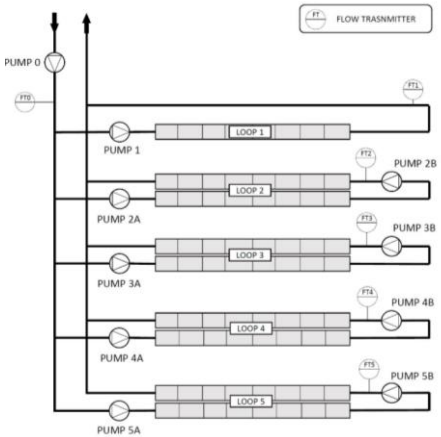


Control structures of continuous systems

Decoupling control

Flat plate collectors





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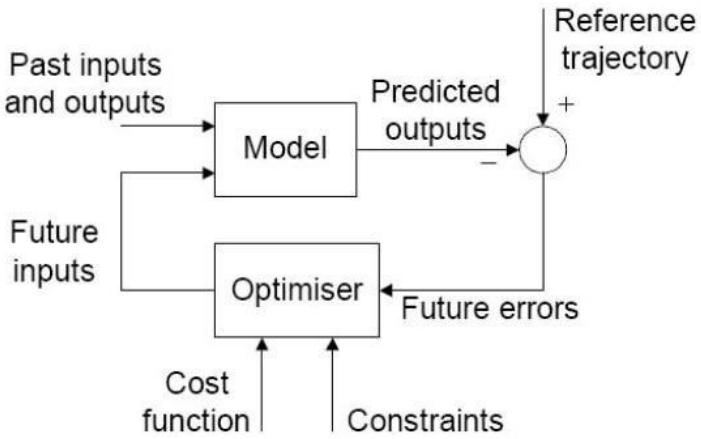
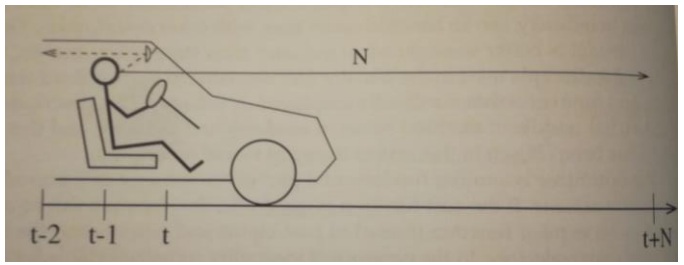
Control structures of continuous systems

Model predictive control

It does not designate a specific control strategy but an ample range of control methods. The ideas are:

- Explicit use of a model to predict the process output at future time (horizon)
- The control sequence is calculated by minimizing an objective function
- Receding strategy





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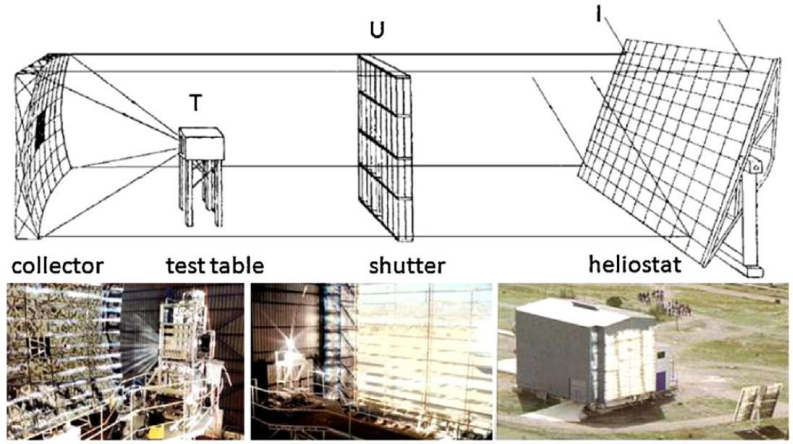
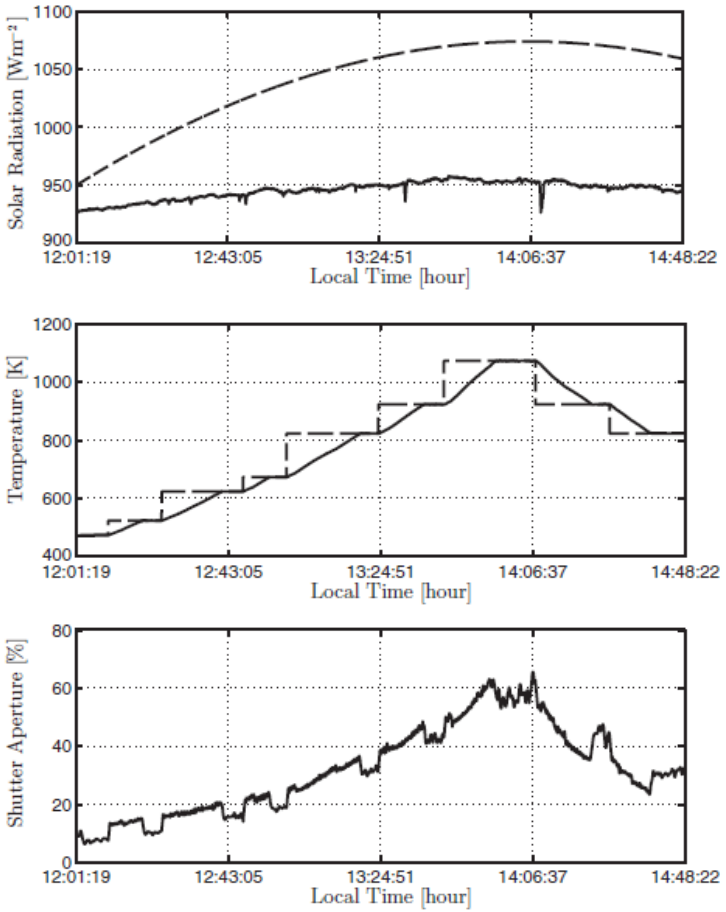
Control structures of continuous systems

Model predictive control

Solar furnace





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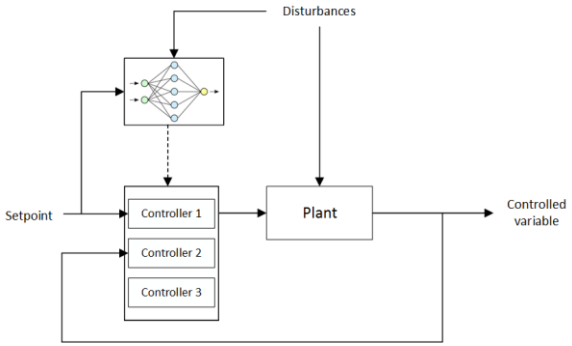
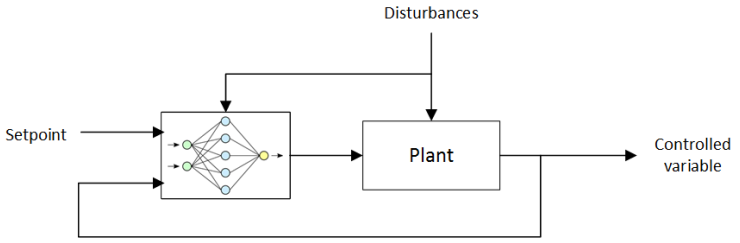
Control structures of continuous systems

Neural network control

- Artificial Neural Networks (ANN) are models designed to emulate the human brain
- They are good for tasks to complete information, they can learn from examples and are able to deal with non-linear problems.
- They can be used in diverse applications in control (to model the behavior of the plant or to calculate the control signal)

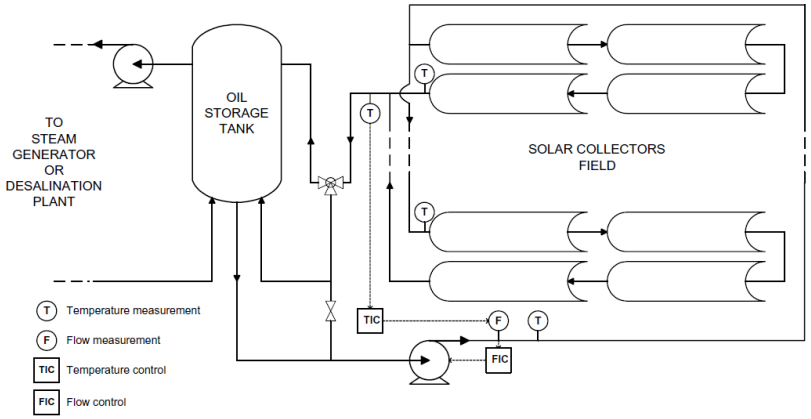




Control structures of continuous systems

Neural network control

Solar parabolic-through plant



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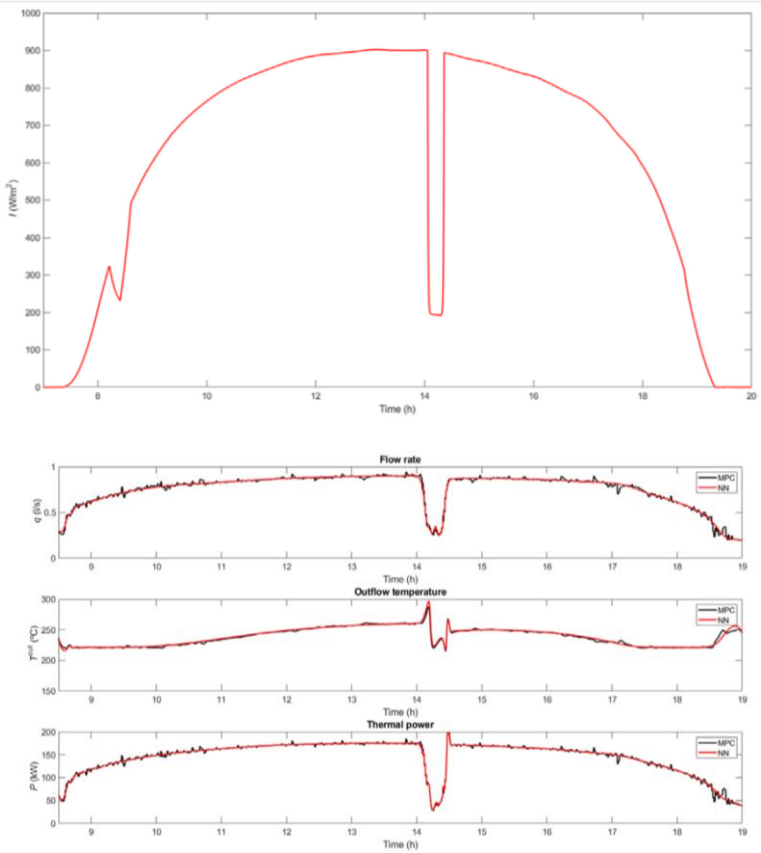

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End of Presentation

- Thank you for your attention
- Questions ?

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