Control system with multiple loops

MODULE 4

Multiple loops

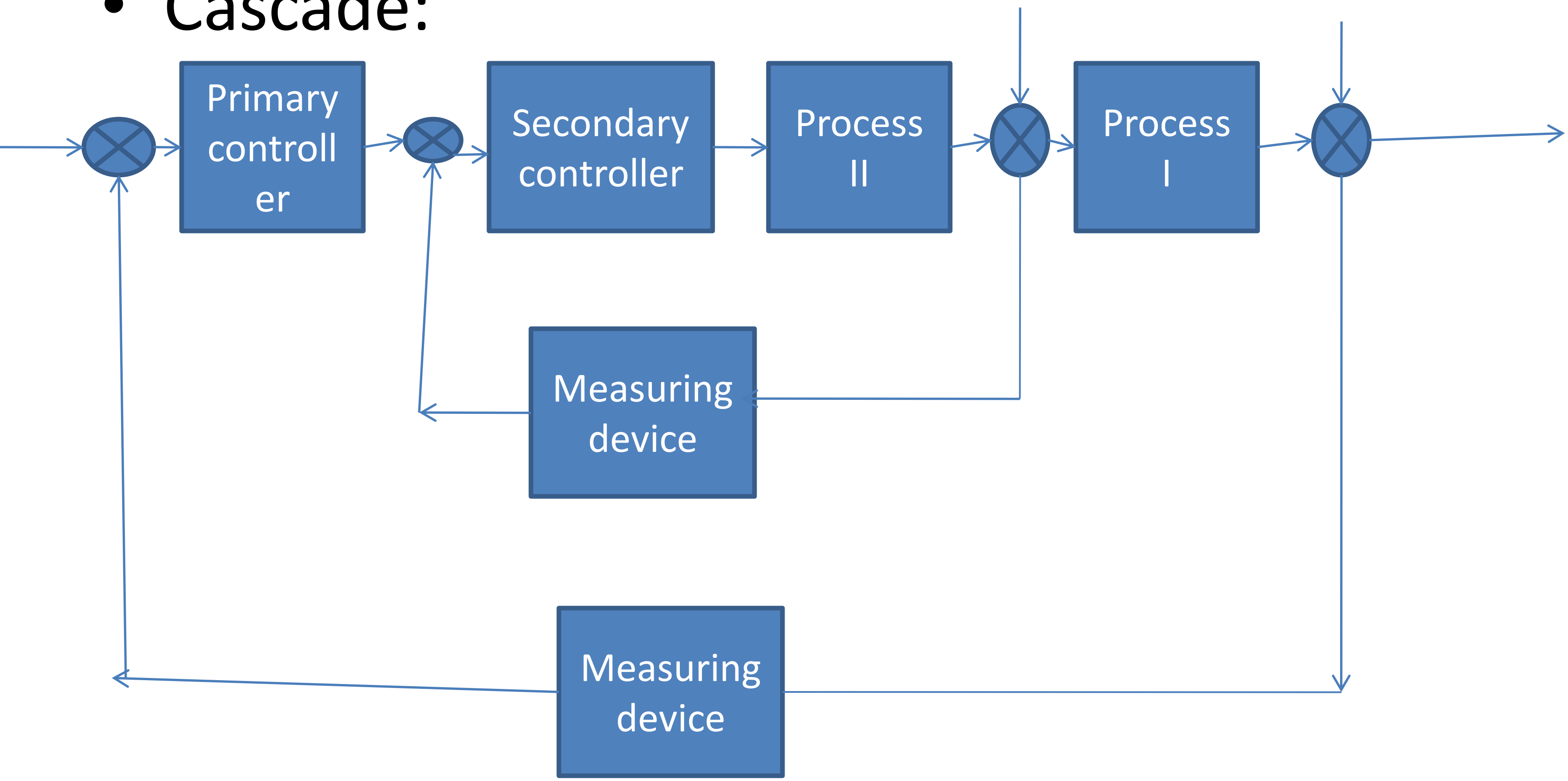
- Multiple loops are needed to control a system by taking more than one measurement and one manipulation OR one measurement and more than one manipulated variable. Such as

1. Cascade control
2. Selective control
3. Split range control

Cascade control

- Example 1: exothermic reaction in a CSTR
- Objective: to keep the temperature of the reacting mixture, T, constant at a desired value.
- Disturbance: temperature of feed & coolant
- Manipulated variable: flow rate of coolant
- Simple feedback: measure reacting mixture temp (T) and manipulate flow rate of coolant
- Cascade: measure reacting mixture temp (T) and manipulate flow rate and temperature of coolant

- Cascade:



Primary controll er
Secondary controller
Process II
Process I
Measuring device
Measuring device

- Example 2: heat exchanger
- Objective: to keep the outlet temperature constant at desired value
- Measure outlet temp. and manipulate temp and flow rate of heating/cooling fluid
- Example 3 : distillation column
- Objective: to keep the temperature & concentration at bottom & top of the column
- Manipulate the flow rate to meet the objective.
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Dynamics of cascade control

- Overall transfer function for secondary loop

$$openloop : G_{\sec indary} = G_{cII}.G_{PII}$$

$$closeloop : 1 + G_{\sec indary} = 1 + G_{cII}.G_{PII} = 0$$

- Overall transfer function for primary loop

$$openloop : G_{primary} = \frac{G_{cII}.G_{PII}}{1 + G_{cII}.G_{PII}}.G_{cI}.G_{PI}$$

$$closeloop : 1 + G_{primary} = \frac{G_{cII}.G_{PII}}{1 + G_{cII}.G_{PII}}.G_{cI}.G_{PI} = 0$$

Remarks

- Generally, a P-controller is used for secondary loop, although a PI controller although PI controller with small integral action is not unusual.
- Any offset caused by P control in the secondary loop is not important since we are not interested to control the output of the secondary process.
- i)The dynamics of the secondary loop is much faster than that of the primary loop. Consequently, the phase lag of the closed secondary loop will be less than that of the primary loop.
- ii)"The crossover frequency for the secondary loop is higher than that for the primary loop.

Tuning of cascade controller

- First, determine the settings for the secondary controller using one of the methods Cohen and Coon or Ziegler-Nichols or others using time-integral criteria or phase and gain margin considerations;
- Second, from the Bode plots of the overall system determine the crossover frequency using the settings for the secondary loop we found above. Then, using the frequency response techniques choose the settings for the primary controller

SELECTIVE CONTROL SYSTEMS

- These are control systems which involve one manipulated variable and several controlled outputs.
- Different types of selective control system : Override control for the protection of process equipment and Auctioneering control.

Override control

- During the normal operation of a plant or during its start-up or shut-down it is possible that dangerous situations may arise, which may lead to destruction of equipment and operating personnel.
- In such cases it is necessary to change from the normal control action and attempt to prevent a process variable from exceeding an allowable upper or lower limit. This can be achieved through the use of special types of switches such as high selector switch (HSS) and low selector switch (LSS).

Examples:1

- Protection of a boiler system: Usually, the steam pressure in a boiler is controlled through the use of a pressure control loop on the discharge line. At the same time the water level in the boiler should not fall below a lower limit which is necessary to keep the heating coil immersed in water and thus prevent its burning out.
- the override control system using a low switch selector (LSS). According to this system, whenever the liquid level falls below the allowable limit, the LSS switches control action from pressure control to level control and closes the valve on the discharge line.

Examples:2

- Protection of a compressor system: To prevent the discharge pressure from exceeding an upper limit, an override control with a high switch selector (HSS) is introduced. It transfers control action from the flow control to the pressure control loop whenever the discharge pressure exceeds the upper limit

Auctioneering Control Systems

- Catalytic tubular reactors with highly exothermic reactions: the hydrocarbon oxidation reactions like the oxidation of o-xylene or naphthalene to produce phthalic anhydride. The highest temperature in temperature profile along the length of the tubular is called hot spot. The location of the hot spot moves along the length of the reactor depending on the feed conditions (temperature, concentration, flow rate) and the catalyst activity.
- The primary control objective is to keep the hot spot temperature below an upper limit. Therefore, we need a control system that can identify the location of the hot spot and provide the proper control action. This can be achieved through; -

1. - the placement of several thermocouples along the length of the reactor and
2. - the use of an auctioneering system to select the highest temperature, which will be used to control the flow rate of the coolant

SPLIT-RANGE CONTROL

- the split range control configuration has one measurement only (controlled output) and more than one manipulated variables.
- A Single process output by coordinating the actions of several manipulated variables, all of which have the same effect on the controlled output.

example

- The control objective is to maintain constant pressure in the steam header when the steam demand at the various processing units changes. There are several manipulated variables (steam flow from every boiler) which can be used simultaneously.
- It should be noted that instead of controlling the steam flow from each boiler, we could control the firing rate and thus the steam production rate at each boiler.