Guidelines to develop a control scheme

DINAMICA E CONTROLLO DEI PROCESSI CHIMICI
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MolBNL MOLECULAR BIOLOGY AND NANOTECHNOLOGY LABORATORY
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THE PLANT TO BE CONTROLLED IS A DYNAMIC SYSTEM!

- A consideration of dynamics should be factored into the design of a plant at an easrly stage, *i.e.* as early as the conceptual design stage
  - It is much more convenient to design the plant to make it «easy» to control, than using a sophisticated control system afterwards to keep it under control.
- Objective of control system and how to design the process:
  - To provide effective damping of disturbance
    - ensure enough holdups (5-10 min) in surge tanks, reflux drums, column bases, …
  - To be able to handle dynamic changes and upsets during operation
    - provide sufficient excess of heat transfer area in reboilers, condensers, cooling jackets
  - To be able to modulate flows across an adequate range
    - select control valves of appropriate size

Adapted from Barolo M

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HOW TO SOLVE A CONTROL PROBLEM

1) Look at the problem and identify your objective, constraints, variables and disturbances
2) Draw a scheme of your system without any control element
3) Try to model your system using first principle approach at steady state
4) Evaluate how the dynamics of your system would evolve when a perturbation occurs
   - use the process scheme for qualitative evaluation or the derived equations in deviation variables for quantitative evaluation
5) Include the necessary control elements within your scheme in order to prevent deviations from steady state
6) Evaluate the transfer functions of your dynamic elements and create the flow diagram into Simulink
   - You may want to size your valves at this stage
7) Choose the actions of your controllers and calculate their transfer function
8) Tune your controllers using suitable techniques
9) Apply a series of different disturbances on your system and evaluate the robustness of your controllers design

Adapted from Barolo M

GENERAL GUIDELINES /cont'd

1) Keep the control system structure as simple as possible
   - Everyone involved in the process (from plant manager down to operators) should be able to understand how the control system works
     - At different level of details, obviously
   - Use as few pieces of control hardware as possible
     - Each element can fail or drift
     - However, use as much measurement instrumentation as possible
2) Use feedforward control to compensate for large, frequent and measurable disturbance
3) Use override control to operate the system close to its constraints without hitting them

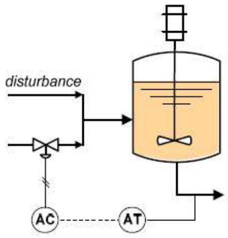
Adapted from Barolo M

GENERAL GUIDELINES /cont'd

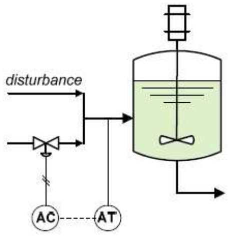
4) Avoid including large time lags and deadtimes (time delays) within feedback loops
   - Control is improved by keeping lags and deadtimes, which are inside the loop, as small as possible
   - The measurement sensor should be located close to where the MV enters the process

Example: Control of a blender

Scheme a)



Scheme b)



   - Scheme (a): the dynamic lag of the tank is included within the feedback loop
   - Scheme (b): by moving the sensor upstream the tank, the process lag is very small because the tank is outside the loop; additionally, the tank acts as a filter to average out any fluctuations in composition

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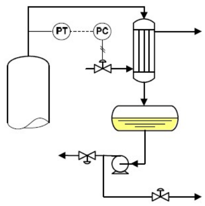
GENERAL GUIDELINES /cont'd

5) Use **proportional-only** controllers to control levels whose value is **not critical** (e.g., surge tanks, distillation columns)
6) Reject minor disturbances by using cascade control systems where possible
7) Avoid control loop interaction if possible
   - If not, make sure the controllers are tuned to make the **entire system** stable
   - A common way to avoid interaction is to tune one loop very tight and the other loop loose
     - The performance of the slow loop is thus sacrificed
8) Check the control system for potential dynamic problems under abnormal conditions or at operating conditions that are different from the designed ones (robustness)
   - E.g., operation at low throughput. At low throughput, process gains and time constants may change dramatically → controllers might need retuning
   - E.g.2, seasonal variations in cooling water temperature can cause rangeability problems in the control valve
     - In summer: T=30°C → large water flow needed → a «big» valve is required
     - In winter: T=10°C → small flow sufficient → the «big» valve remains almost fully closed → poor pressure control may result
     - It may be convenient to design a double-valve system (big valve+small valve)



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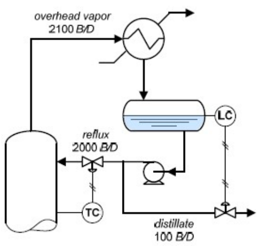
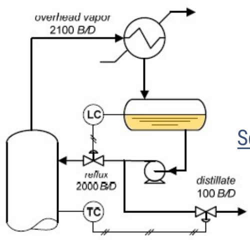
GENERAL GUIDELINES /cont'd

9) Avoid control configurations leading to saturation of a **manipulated variable**

- Example: control of distillation columns with high/low reflux ratio R (difficult/easy separation)

Scheme a)





Scheme b)

- If R=20 and the vapor boilup drops by only 5%, in Scheme a) the distillate flow would go to zero
- Any bigger drop in vapor boilup would cause the drum to run dry (unless a low-level override controller were used to pinch the reflux rate, thus loosing the control of composition)
- Scheme b) is more appropriate

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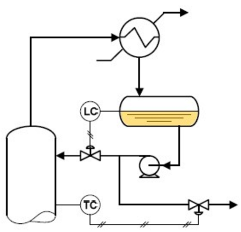
GENERAL GUIDELINES /cont'd

10) Avoid nested **control loops**

- Two control loops are nested if the operation of the external loop depends on the operation of the internal loop
- Example: control of top purity in a distillation column



- The distillate flow has **no direct effect** on the pilot tray temperature
- Only through the **reflux** flow can the pilot temperature change
- If the level controller is set to **manual**, the control temperature is lost

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