ELEC ENG 4CL4:

Control System Design

Notes for Lecture #33

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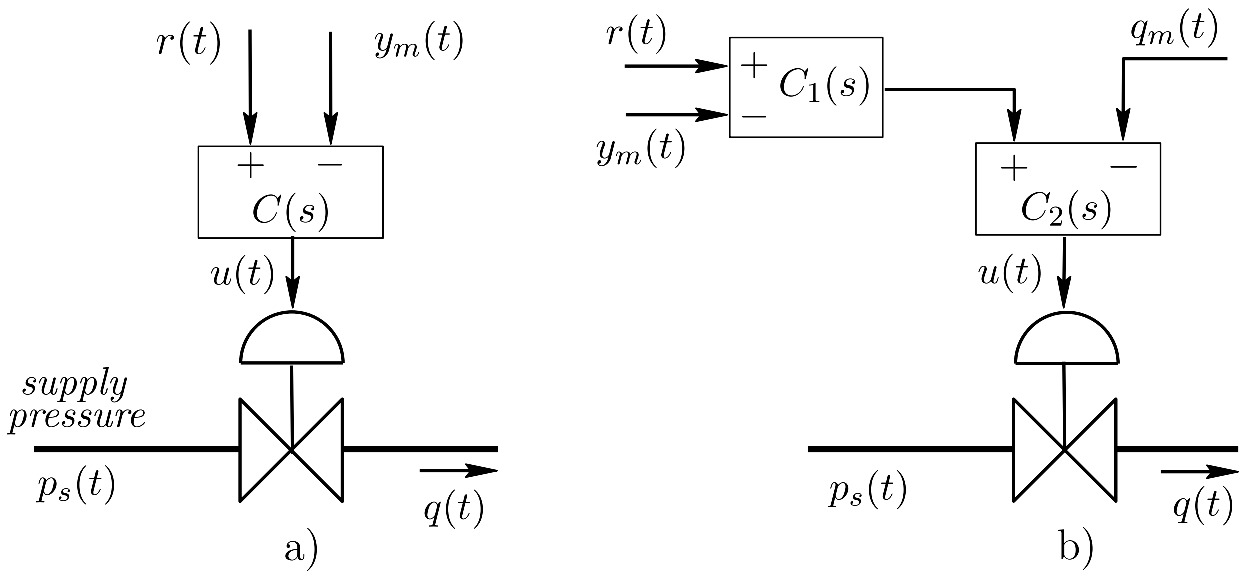
3. Cascade Control

Next we turn to an alternative architecture for dealing with disturbances. The core idea is to feedback intermediate variables that lie between the disturbance injection point and the output. This gives rise to so called, *cascade control*.

Cascade control is very commonly used in practice. For example, if one has a valve in a control loop, then it is usually a good idea to place a cascade controller around the valve. This requires measurements to be made of the flow out of the valve (*see next slide*) but can significantly improve the overall performance due to the linearizing effect that local feedback around the valve has.

Figure 10.7: *Example of application of cascade control*

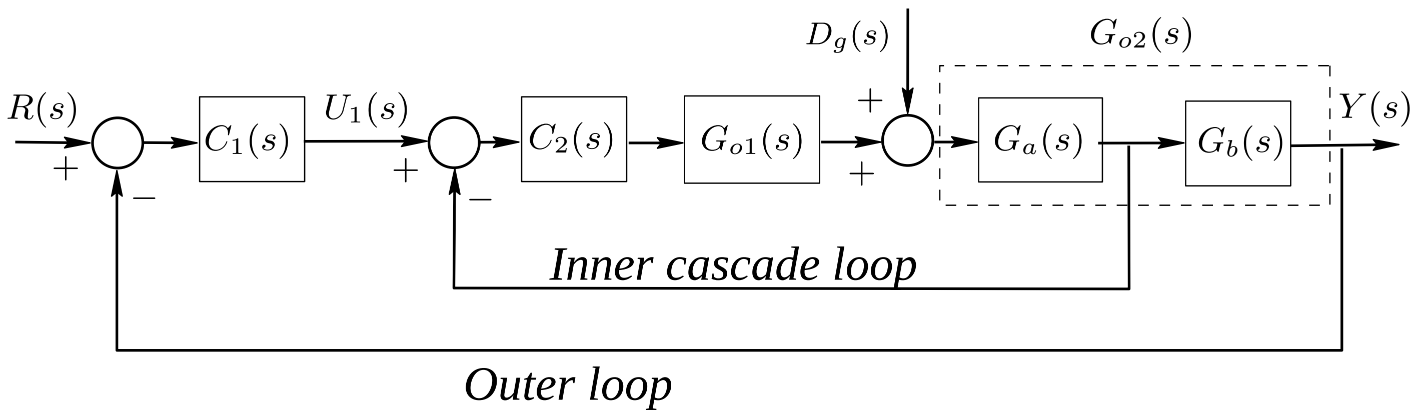


Non-cascade Valve Controller

Cascade Valve Controller

Figure 10.8: *Cascade control structure*

The generalization of this idea has the structure as shown below:



Referring to Figure 10.8 (*previous slide*), the main benefits of cascade control are obtained

(i) when $G_a(s)$ contains significant nonlinearities that limit the loop performance;

or

(ii) when $G_b(s)$ limits the bandwidth in a basic control architecture.

Example of Cadcade Control

Consider a plant having the same nominal model as in the previous example on disturbance feedforward. Assume that the measurement for the secondary loop is the input to $G_{02}(s)$,

$$G_{o1}(s) = \frac{1}{s+1}; \qquad G_{o2}(s) = \frac{e^{-s}}{2s+1}; \qquad G_a(s) = 1; \qquad G_b(s) = G_{o2}(s) = \frac{e^{-s}}{2s+1}$$

We first choose the secondary controller to be a PI controller where

$$C_2(s) = \frac{8(s+1)}{s}$$

This leads to an inner loop having effective closed loop transfer function of

$$T_{o2}(s) = \frac{8}{s+8}$$

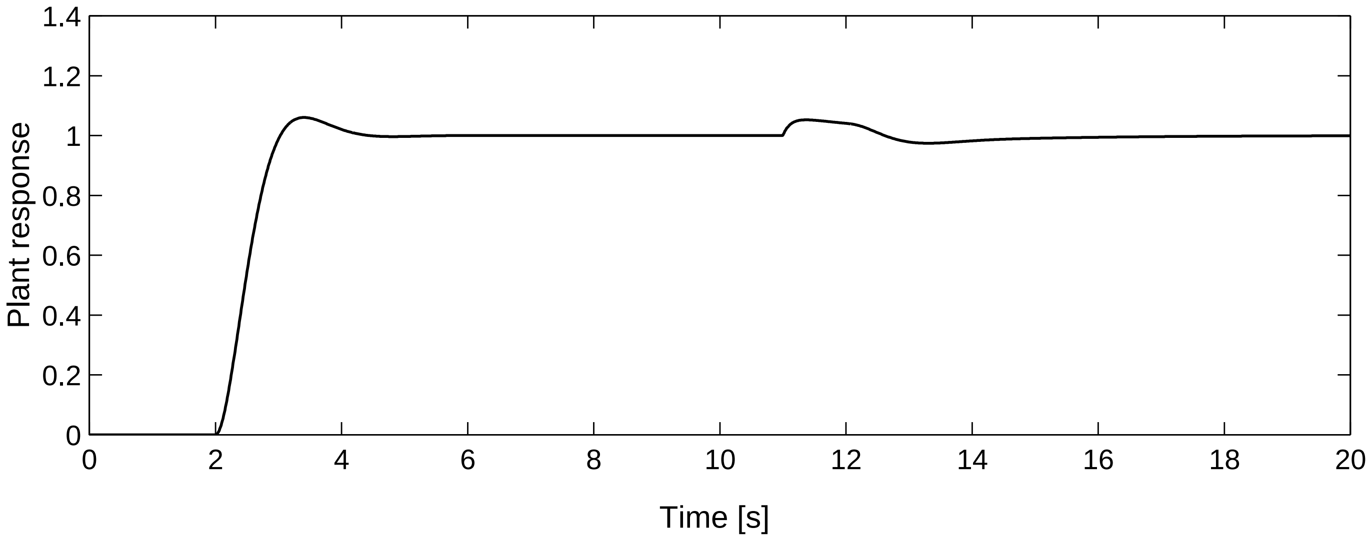
Hence the primary (or outer loop) controller sees an equivalent plant with transfer function

$$G_{oeq}(s) = \frac{8e^{-s}}{2s^2 + 17s + 8}$$

The outter controller is then designed using a Smith Predictor (*see Chapter 7*).

The results for the same disturbance as in the earlier example on disturbance feedforward are shown in the next slide. [A unit step reference is applied at $t = 1$ followed by a unit step disturbance at $t = 5$].

Figure 10.9: *Disturbance rejection with a cascade control loop*



Comparing Figure 10.9 with Figure 10.3 we see that cascade control has achieved similar disturbance rejection (*for this example*) as was achieved earlier using disturbance feedforward.

The main features of cascade control are

(i) Cascade control is a feedback strategy.

(ii) A second measurement of a process variable is required. However, the disturbance itself does not need to be measured. Indeed, the secondary loop can be interpreted as having an observer to estimate the disturbance.

(iii) Measurement noise in the secondary loop must be considered in the design, since it may limit the achievable bandwidth in this loop.

(iv) Although cascade control (in common with feedforward) requires inversion, it can be made less sensitive to modeling errors by using the advantages of feedback.