Advanced Process Control

CBEg 6142

School of Chemical and Bio-Engineering
Addis Ababa Institute of Technology
Addis Ababa University

Chapter 3

Feedforward Control

Feedforward Control: Introduction

- Feedforward controllers (FFC) are applied to processes that are significantly affected by disturbances that are measurable (or can be estimated) on-line.

- The basic concept of FFC is to measure large and frequent disturbances and take corrective action before they upset the process.

- Therefore feedforward control requires that the disturbances must be measured (or estimated) on-line.

- FFC is used when large and frequent disturbances affect the controlled variable, especially in a slow process.

Feedforward Control: Introduction

- Since only the measured disturbances are addressed by FFC unmeasured disturbance may still have significant impact on overall control performance.
- FFC is never used alone. It is used to together with feedback control.
- A feedforward controller requires process transfe functions (G_p) and load transfer functions (G_d), and its performance very much depends on the accuracy of the models.

Feedforward Control: Introduction

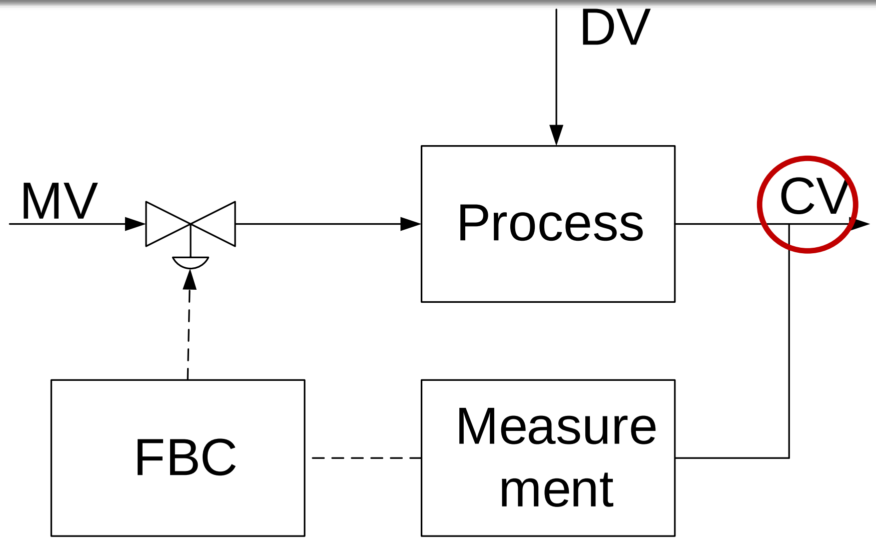


Figure 3.1 Feedback control system

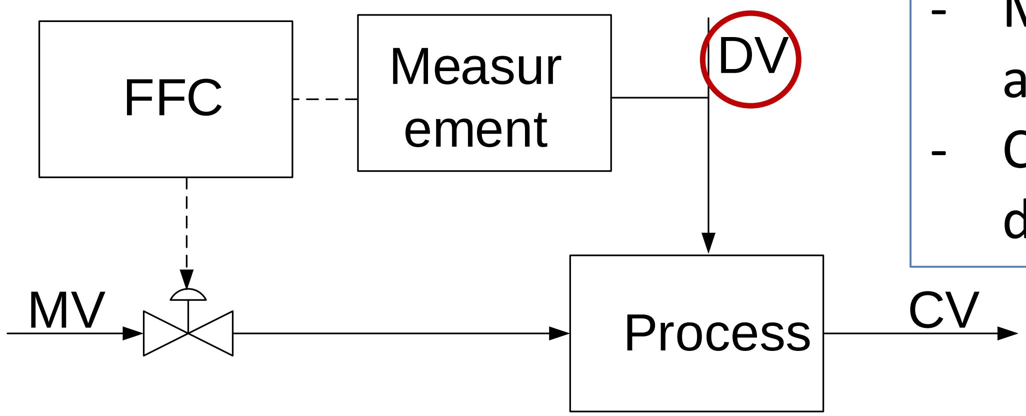


Figure 3.2 Feedforward control system

<u>FBC</u>

- Measure CV and take corrective action
- Corrective action is taken after disturbance causes a measureable change in CV

<u>FFC</u>

- Measure DV and take corrective action
- Corrective action is taken before disturbance affects CV

Example 1: Boiler Drum Level Control

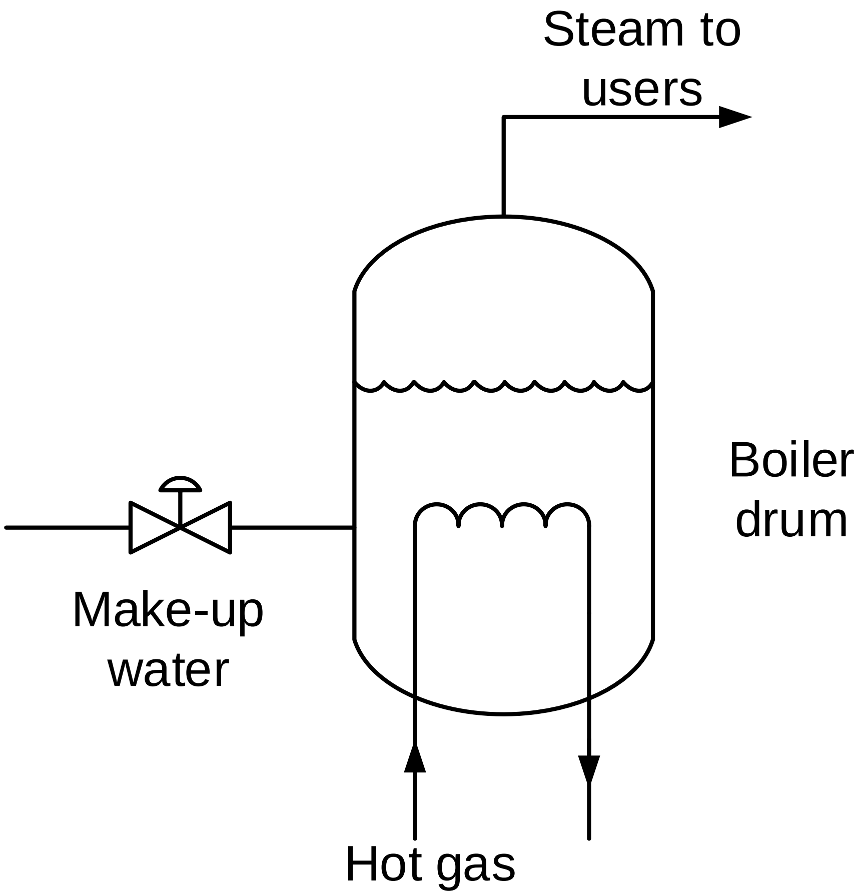


Figure 3.3 Boiler with variable steam use

<u>Control Objective</u>: To maintain the water level in the boiler drum at a desired level.

<u>Disturbance</u>: Changes in steam demand. It causes changes in drum water level.

Example 1: Boiler Drum Level Control

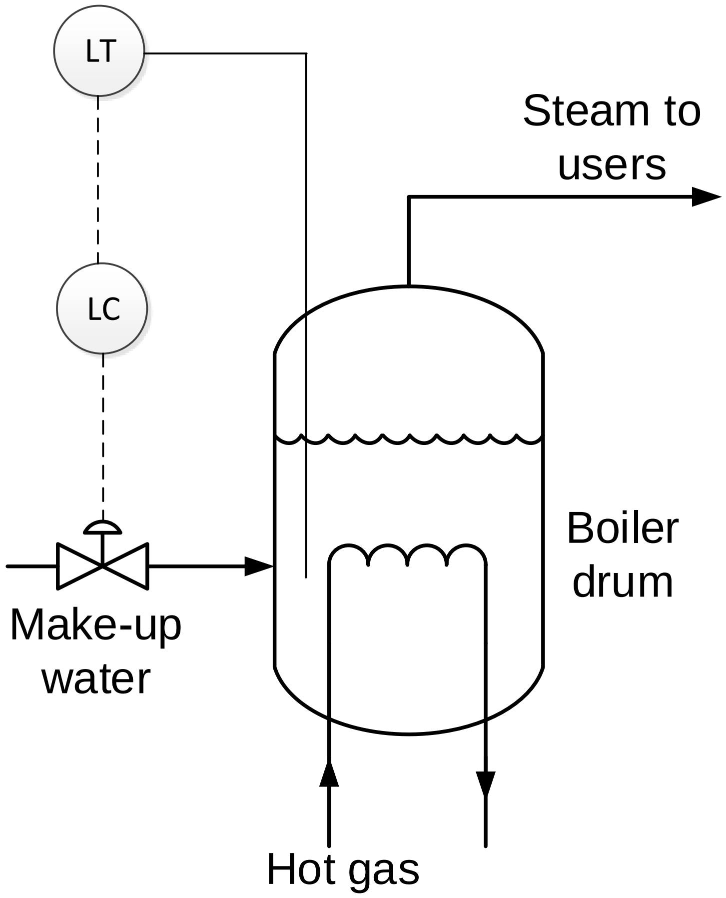


Figure 3.4 (a) Feedback control system

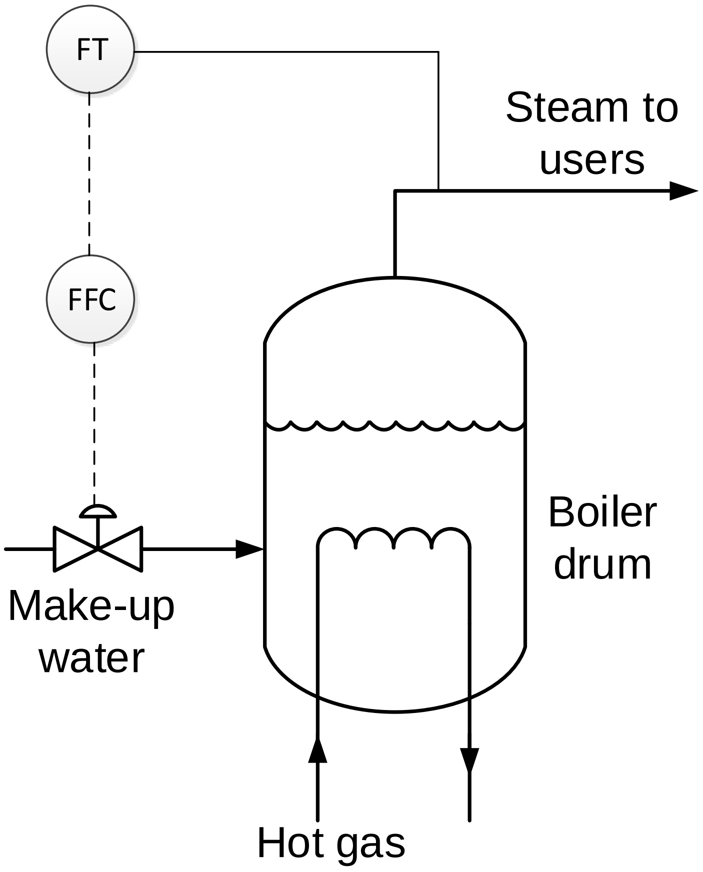


Figure 3.4 (b) Feedforward control system

Example 1: Boiler Drum Level Control

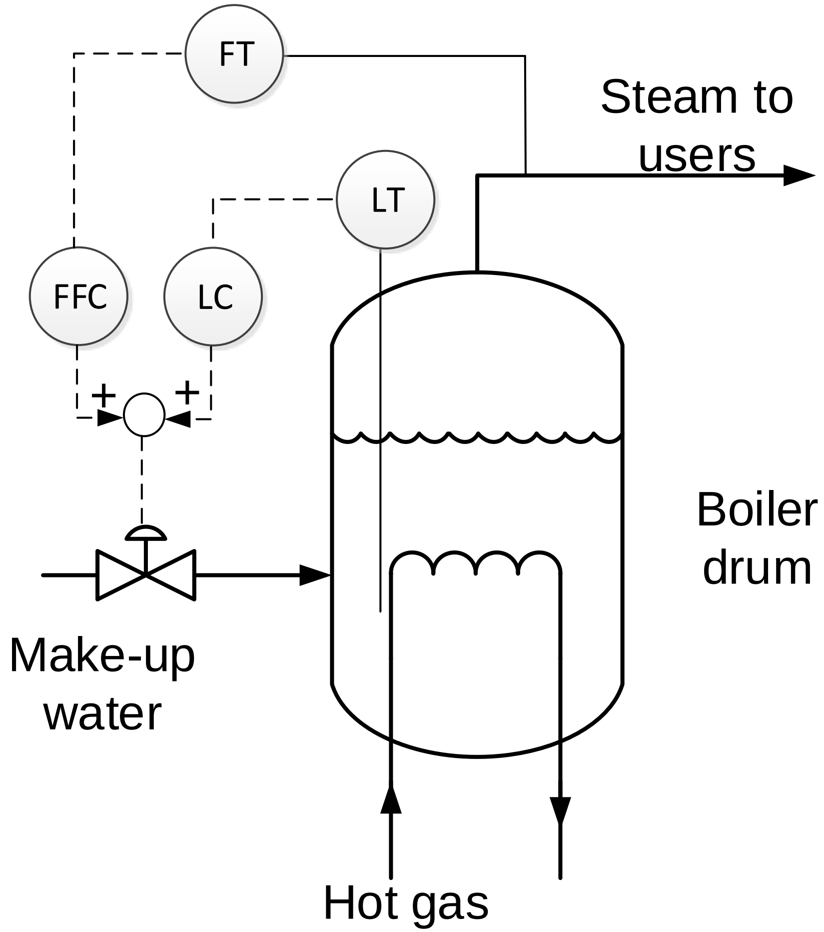
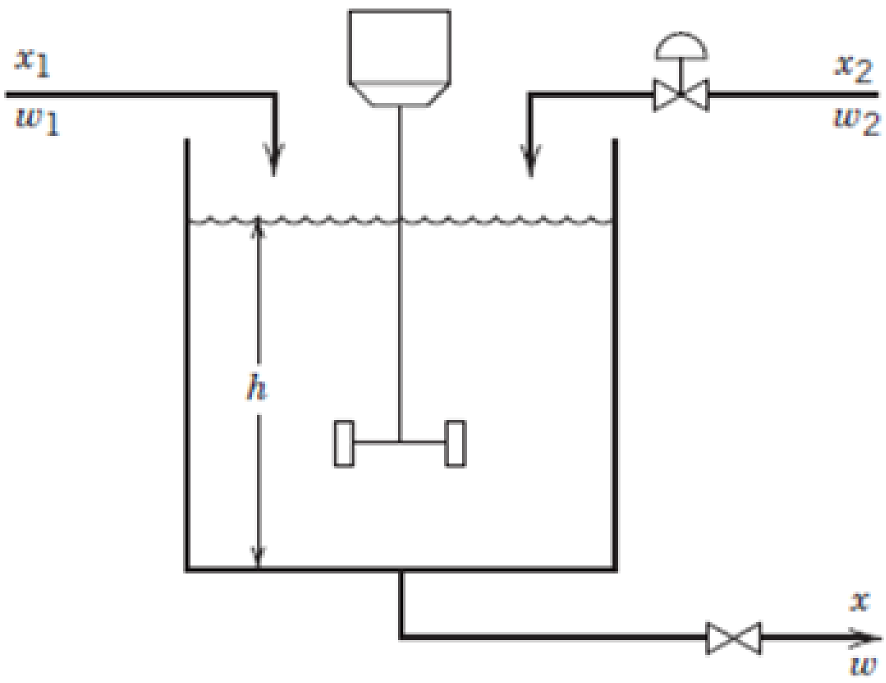


Figure 3.5 Boiler drum level control with Feedback and Feedforward together

Example 2: Blending Tank Composition Control



Control objective: To maintain the mass fraction at the outlet at a desired level.

Major Disturbance: The flow rate of stream 1. It varies frequently and significantly.

Figure 3.6 Boiler drum level control with Feedback and Feedforward control

Example 2: Blending Tank Composition Control

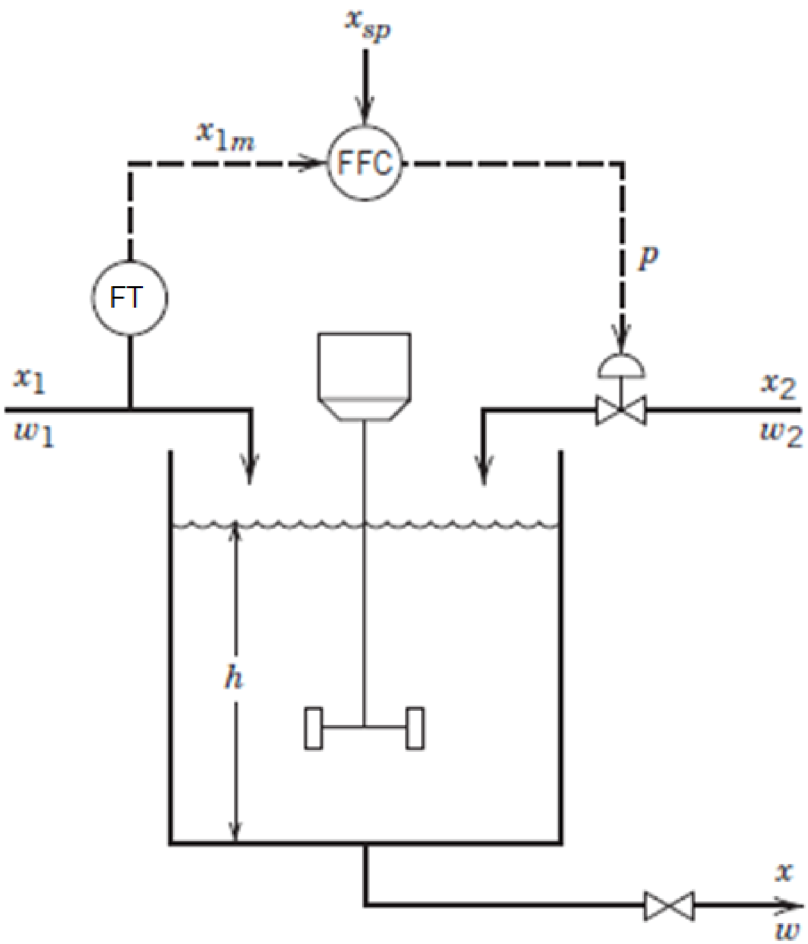


Figure 3.7 Boiler drum level feedforward control

Example 2: Blending Tank Composition Control

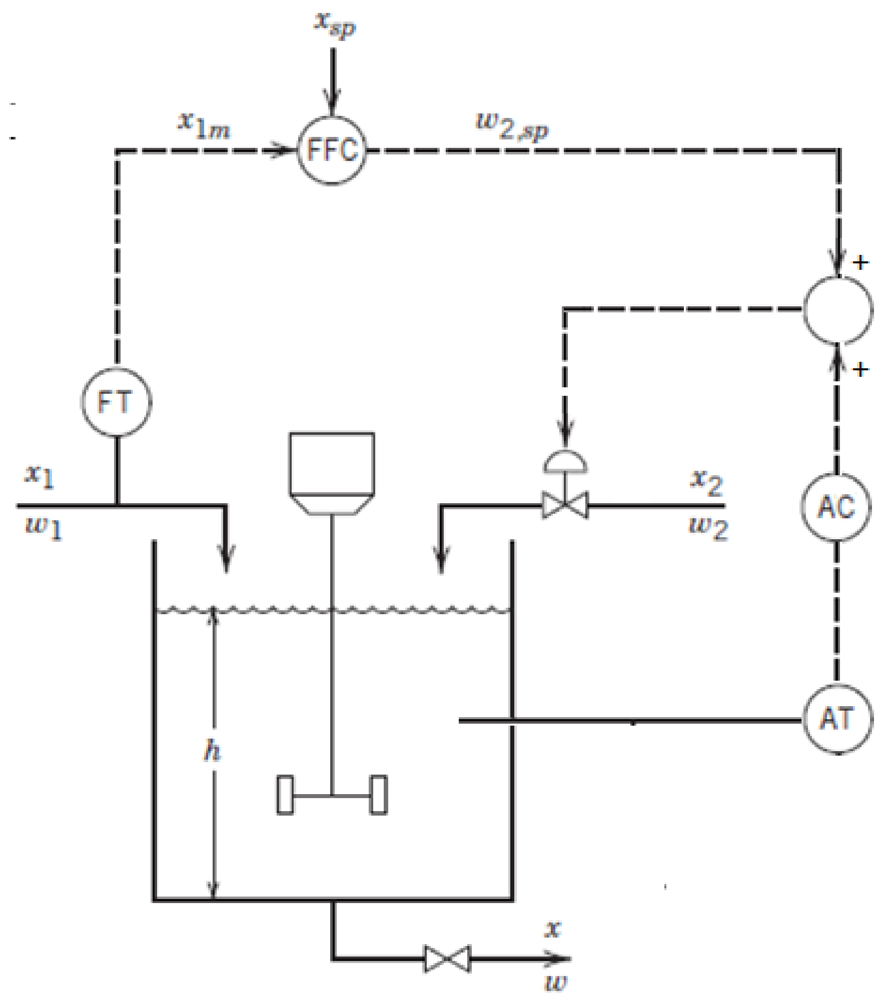


Figure 3.8 Boiler drum level Feedback - Feedforward control

Example 2: Design of Feedforward Controller

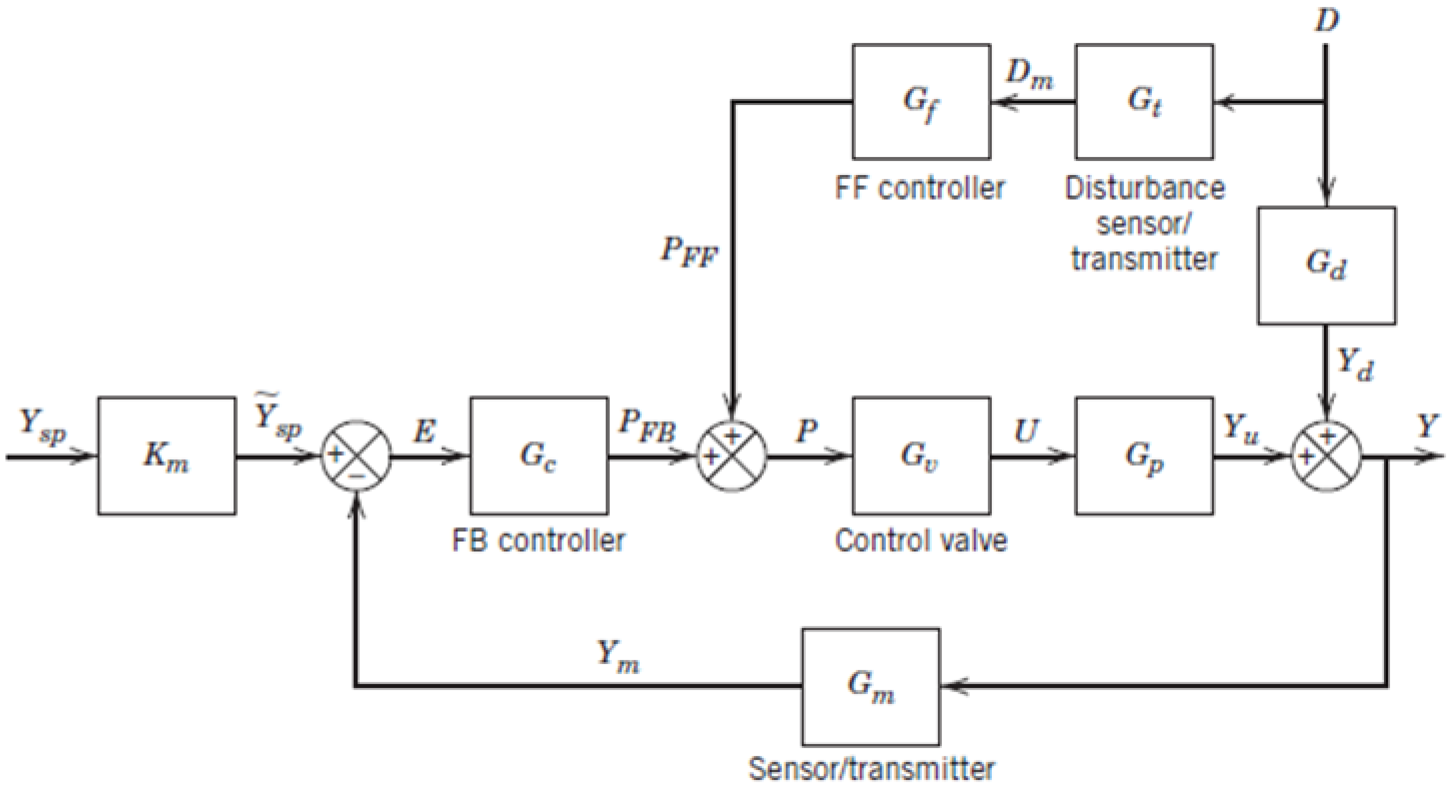


Figure 3.9 Block diagram of feedback-feedforward control system

Design of Feedforward Controller

To eliminate the effect of disturbance

$$DG_tG_fG_vG_p + DG_d = 0$$

Rearranging and solving for G_f

$$G_f = -\frac{G_d}{G_tG_vG_p}$$

Example 3.1

The transfer functions of a process and relevant instruments are given below design a feedforward controller.

$$G_v = K_v \quad G_t = K_t \quad G_d = \frac{K_d}{\tau_d s+1} \quad G_p = \frac{K_p}{\tau_p s+1}$$

Solution

$$G_f = -\left(\frac{K_d}{K_t K_v K_p}\right)\left(\frac{\tau_p s + 1}{\tau_d s + 1}\right)$$

Design of Feedforward Controller

Example 2 (Physically Unrealizable Controllers)

Design feedforward controller with the transfer functions given below.

$$G_v = 0.2 \qquad G_t = 1 \;\; G_d = \frac{2}{5s+1} \quad G_p = \frac{4}{(2s+1)(s+1)}$$

$$G_f = -\left(\frac{2}{0.2 \times 4}\right)\frac{(2s+1)(s+1)}{(3s+1)}$$

$$G_f =- -2.5\,\frac{(2s+1)(s+1)}{(5s+1)}$$

Is this controller physically realizable?

Design of Feedforward Controller

<u>Example 3</u> (Physically Unrealizable Controllers)

Design feedforward controller with the transfer functions given below.

<u>Solution</u>

$$G_v = 0.2 \qquad G_t = 1 \quad G_d = \frac{2e^{-1.2s}}{5s+1} \qquad G_p = \frac{4e^{-2.5s}}{(3s+1)}$$

$$G_f = -\left(\frac{2}{0.2 \times 4}\right)\frac{(3s+1)e^{1.3s}}{(5s+1)}$$

$$\boxed{G_f = -2.5\frac{(3s+1)e^{1.3s}}{(5s+1)}}$$

Is this controller physically realizable?

Lead –Lag Controller

- When the designed FFC is physically unrealizable we can use the following rule to get approximate lead-lag FFC.

  – Add time constants and negative time delays to the lead time.

- Applying the above rule Example 2 and 3 are solved in the next page.

Lead-lag controller

Example 4

Redo example 2 and 3 to get approximate lead-lag FFC.

(2) $$G_f = -2.5\frac{(2s+1)(s+1)}{(5s+1)} = -2.5\frac{3s+1}{5s+1}$$

(3) $$G_f = -2.5\frac{(3s+1)e^{1.3s}}{(5s+1)} = -2.5\frac{4.3s+1}{5s+1}$$

Exercises

Exercise 1

The transfer functions of a process and relevant instruments are given below. Design a feedorward controller and compare the performance of a FB-FFC with a simple FBC for regulator problem.

$$G_v = 0.1 \quad G_t = 1 \quad G_d = \frac{2e^{-1.5s}}{5s+1} \quad G_p = \frac{4e^{-0.2s}}{2s+1}$$

Exercise 2

Compare the performance of a simple FBC with FB-FFC Example 2 and 3 controller using MATLAB simulation.