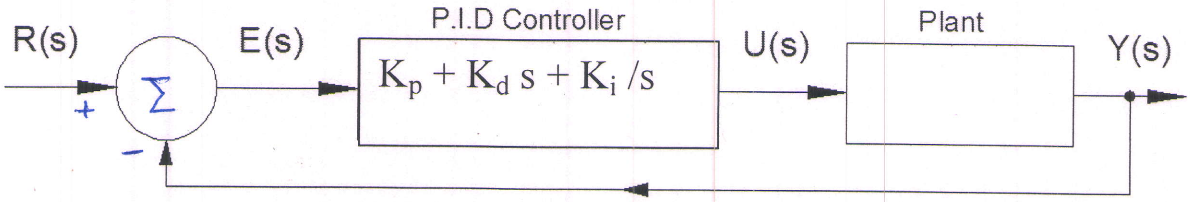
PID Controller

A controller or compensator popular in control systems and particularly in process industries is a PID controller.

PID controller is a combination of Proportional (P), Integral and Derivative (D) elements. Typical control system with PID elements is as shown below.



The input to the controller is the error signal $e(t) = (r(t) - y(t)$, and the output of the controller which is the input to the plant u(t) is given by

$$u(t) = Kp\ e(t) \ + Ki \int e(t)\ dt \ + Kd\ (de(t)/dt)$$

or in Laplace form

$$U(s) = (Kp \ + Ki\ /s + Kd\ s\ )\ E(s)$$

Where, Kp is the simple gain or amplification without any dynamics, Ki is the coefficient of the integral term and Kd the coefficient of the derivative term.

Each of the terms affects the performance in certain way. A combination of terms with appropriate coefficients is used, depending on the process requirements and stability.

<u>Proportional term</u>: Effect of Kd is to speed up the response, but steady state error is not corrected.

<u>Integral term</u>: Ki being the coefficient of the integral action term, makes steady state error zero, but has a tendency to take long to settle.

<u>Derivative term</u>: Effect of Kd is a quick response but decaying fast even though there is a finite error.

Typical step responses for P, I and D terms as well as the effect of the combination terms are shown in the Figure.

Effect of individual elements (See Fig. a, b, c)

a. Pure P action improves the speed of response (rise time) but error steady state error persists.
b. Pure I action increases the rise time, but steady state error becomes zero.
c. Pure Derivative action drastically increase the response but may make the system unstable as the error may go on increasing with time.

Effect of Combination Terms (see Figure d,e,f)

a. P+I - Improves rise time and makes steady stste error zero.
b. P+D – Response is faster than P+I but Steady state error persists
c. P+I+D – Low rise time, zero error in steady state and settles faster than P+I or P+D controller.

It may be noted that

(i) PID controllers can be used when the mathematical model of the plant or system to be compensated is not known.
(ii) Coefficients of P.I and D elements are usually tuned by trial and error methods to obtain optimal response as required for the particular control system, with known or unknown plant model.

(See the typical Responses shown on next page)

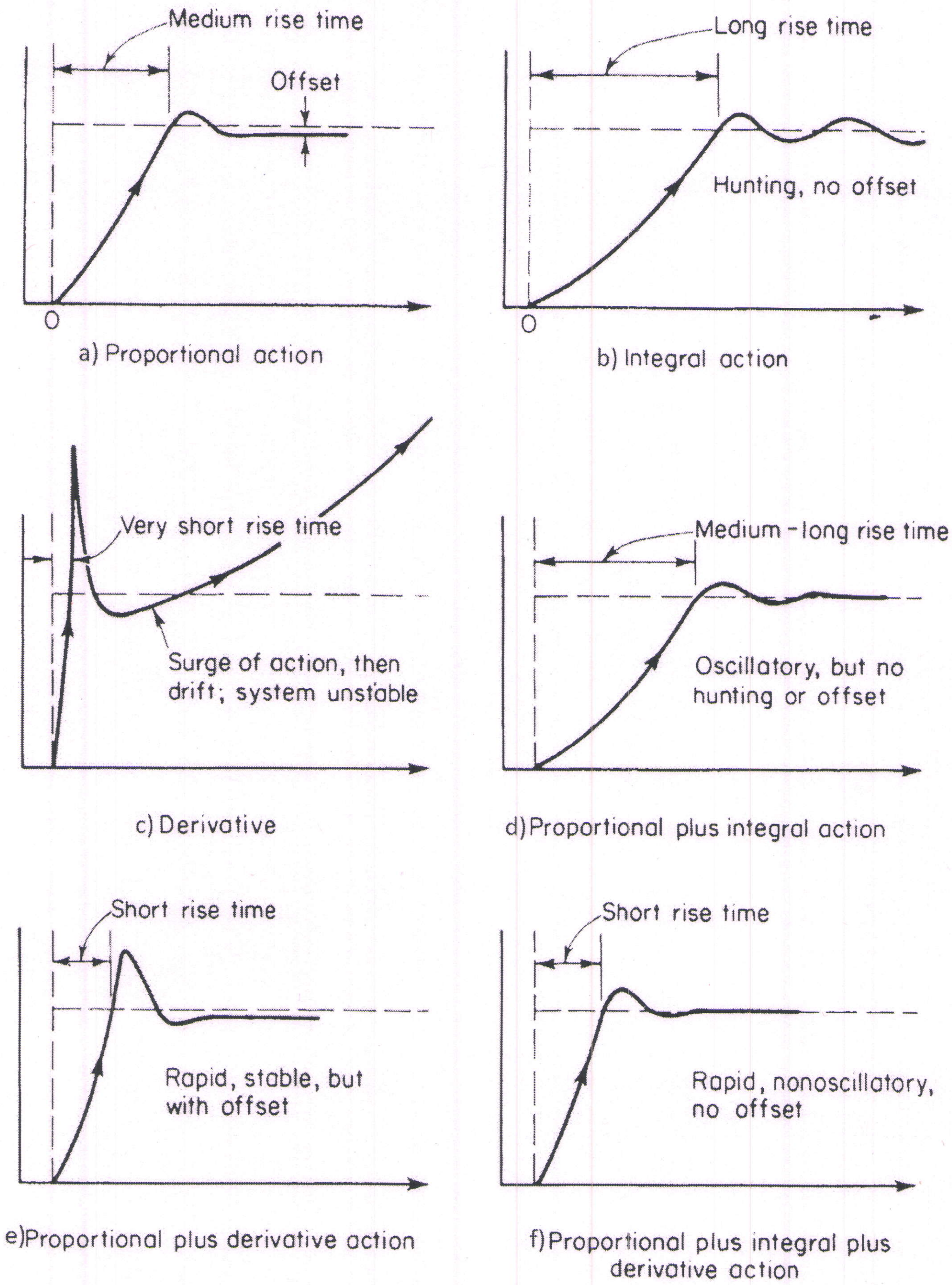


Fig. Response to step input of a typical system for various controller actions

(From: *Engineering Systems and Automatic Control - Peter Dransfield*)