**Lecture#10 Type of controllers**

**\*** a number of different controllers are used in industry like pharmaceuial and chemical industry and in other field. In quit general these controller can be divided into two groups:

1) conventional controllers 2) unconventional controllers

\*في النوع الأول يجب ان يكون النموذج الرياضي لprocess او plant لغرض تصمبم ال controller

\*في النوع الثاني يسنخدم طرق التصميم ال controllerبحيث ان النموذج الرياضي لprocess او plant يكون غيرمطلوب

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**\* Classifications of Industrial Controllers:** Industrial controllers may be classified according to their control actions as:

**1.** Two-position or on-off controllers

**2.** Proportional controllers (P-controller)

**3.** Integral controllers (I-controller)

4. Proportional-plus-integral controllers (PI-controller)

**5.** Proportional-plus-derivative controllers (PD-controller)

***6.*** Proportional-plus-integral-plus-derivative controllers (PID-controller)

\*in general any controller system must meet some time response specification like:

1-steady state error. 2-damping factor and MP  3-settling time

\*if any controller meet these specifications a controller can be used.

\* u(s) is called (controller output or control action or control signal or actuator signal)

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**1) Two-Position or On-Off Control Action.** In a two-position control system, the actuating element has only two fixed positions, which are, in many cases, simply(on and off).Two-position or on-off control is relatively simple and inexpensive and, for this reason, is very widely used in both industrial and domestic control systems. Let the output signal from the controller be ***u*(*t*)**and the actuating error signal be ***e*(*t*)*.***

In two-position control, the signal ***u(t)*** remains at either a maximum or minimum value, depending on whether the actuating error signal is positive or negative, so that

***u(t)*** =  *Kl* for ***e(t)*** > *0*

*K2*  for ***e(t*)**< *0*

where *K1* and *K2* are constants. *K1*  is maximum gain and *K2* is theminimum gain, the minimum value *K2* is usually either zero or *–Kl.*



**2)Proportional Controller(P-controller).** For a controller with proportional control action, the relationship between the output of the controller ***u(s)*** and the actuating error signal *E(s)*



in time domain, 

us.s is the control signal at the steady state.

\* A proportional controller reduces error but does not eliminate it (unless the process has naturally integrating properties), i.e. an offset between the actual and desired value will normally exist.

**\*** many industrial controllers have defined a proportional band(PB) instead of gain PB=100/KP .

**3) Integral Controller (I-controller):** In a controller with integral control action, the value of the controller output *u(s)* is 

in time domain, )

\* where Ki is integral gain, Ki= KP/Ti , where Ti is integral time or reset time.

\* this controller will effect on steady state response.

\*The integral mode (often referred to as reset) corrects for any offset (error) that may occur between the desired value (input) and the process (or plant) output automatically over time.

**4) proportional-Integral Controller (PI-controller):** In a controller with PI control action, the value of the controller output *u(s)* is 

in time domain, )

**5) proportional-derivative (PD-controller):** In a controller with derivative control action, the value of the controller output *u(s)* is 

in time domain, )

\* Derivative action (also called rate or pre-act) will effect on system transient response.

\* Kd=Kp\*Td , where Td is the ‘rate time’ or derivative time constant.

\* the derivative action improve dynamic response by remove or reduce the oscillation.

\* the problem of noisy signals makes the use of derivative action undesirable (differentiating noisy signals can translate into excessive u movement).

\* Derivative action depends on the slope of the error, unlike P and I. If the error e(t) is constant derivative action has no effect.

**6) proportional-Integral- derivative Controller (PID-controller):** In a controller with PID control action, the value of the controller output *u(s)* is 



in time domain, 

\* this controller will effect on transient and steady state response.

\* ان زيادة الgain مثل KP يودي الى زيادة الoscillation

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\* فائدة هذا المسيطر هو تقليل الdelay الموجود ب الresponse , وذلك بتقليل ts وبتقليل او الغاء oscillation بالإضافة الى جعل es.s=0

Ex1: for system shown below, applay PD controller with KP and Kd

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Ex2: for Ex1 show that the derivative action D in PD controller has no effect on es.s(use 1-R(s) is unit step, 2- R(s) is unit ramp).

Ex3:check the effect of f/b derivative controller on es.s for the system shown below.

Ex4: for the same system in Ex1 apply PI-controller with KP=1 and Ki=2.

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H.W: apply PID controller to Ex1 with KP=1, Ki=1, Kd=2, cheek es.s( if the i/p is 1-unit step, 2-unit ramp).

Note: Effects of each controller P, I, and D on a closed-loop system are summarized in the Table

(\*)



**Controller tuning**

Controller tuning involves the selection of the best values of KP, Ki, and Kd(or KP, Ti, Td). A number of methods have been proposed like:

1- Ziegler Nichols open loop method(first method).

2-Ziegler Nichols closed loop method(second method).

3-RobustPID controller.

4-Cohen – Coon tuning method.

5-poles-zeros cancelation.

6-direct synthesis tuning method.

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**1- Ziegler Nichols open loop method(first method):** In the first method, we obtain experimentally the response of the plant to a unit-step input, as shown in Figure 10-2. If the plant involves neither integrator(s) or dominant complex-conjugate poles, then such a unit-step response curve may look S-shaped, as shown in Figure 10-3. This method applies if the response to a step

input exhibits an S-shaped curve. Such step-response curves may be generated experimentally or from a dynamic simulation of the plant.

The S-shaped curve may be characterized by two constants, delay time L and time constant *T.* The delay time and time constant are determined by drawing a tangent line at the inflection point of the S-shaped curve and determining the intersections of the tangent line with the time axis and line *c(t)* = K, as shown in Figure 10-3. The transfer function C(s)/U(s) may then be approximated by a first-order system with a transport lag as follows:









**2-Ziegler Nichols closed loop method(second method):** In the second method, using the proportional control action only (see Figure 10-4), increase *K*Pfrom 0 to a critical value Kcr at which the output first exhibits sustained oscillations. (If the output does not exhibit sustained oscillations for whatever value *K*Pmay take, then this method does not apply.) Thus, the critical gain Kcr and the corresponding period Pcrare experimentally.



Fig.(10.4):closed loop system.



\*Note that if the system has a known mathematical model (such as the transfer function), then we can use the root-locus method to find the critical gain Kcrand the frequency of the sustained oscillations wcr where( Pcr=).These values can be found from the crossing points of the root-locus branches with the *jw* axis.

Ex5: Consider the control system shown in Figure 10-6 in which a PID controller is used to control the system. The PID controller has the transfer function: 



Fig.(10.6):closed loop controlled system.







**3) *Cohen - Coon***

This method depends upon the identification of a suitable process model. Practical use of the technique If the process delay is small (in the limit as it approaches zero) increasingly large controller gains will be predicted. The method is therefore not suitable for systems where there is zero or virtually no time delay.



**4) poles-zeros cancelation**