DESIGN OF PID CONTROLLER USING REACTION CURVE METHOD

In this method, the variables being measured are those of a system that is already in place. A disturbance is introduced into the system and data can then be obtained from this curve.

1. First the system is allowed to reach steady state.
2. Then a disturbance, X_o, is introduced to it.
3. The percentage of disturbance to the system can be introduced by a change in either the set point or process variable.

For example, if there is a thermometer in which it can be only be turned up or down by 10 degrees, then raising the temperature by 1 degree would be a 10% disturbance to the system. These types of curves are obtained in open loop systems when there is no control of the system, allowing the disturbance to be recorded.

The process reaction curve method usually produces a response to a step function change for which several parameters may be measured which include: transportation lag or dead time, τ_{dead}, the time for the response to change, τ, and the ultimate value that the response reaches at steady-state, M_u.

τ_{dead} - transportation lag or dead time: the time taken from the moment the disturbance was introduced to the first sign of change in the output signal

τ - the time for the response to occur

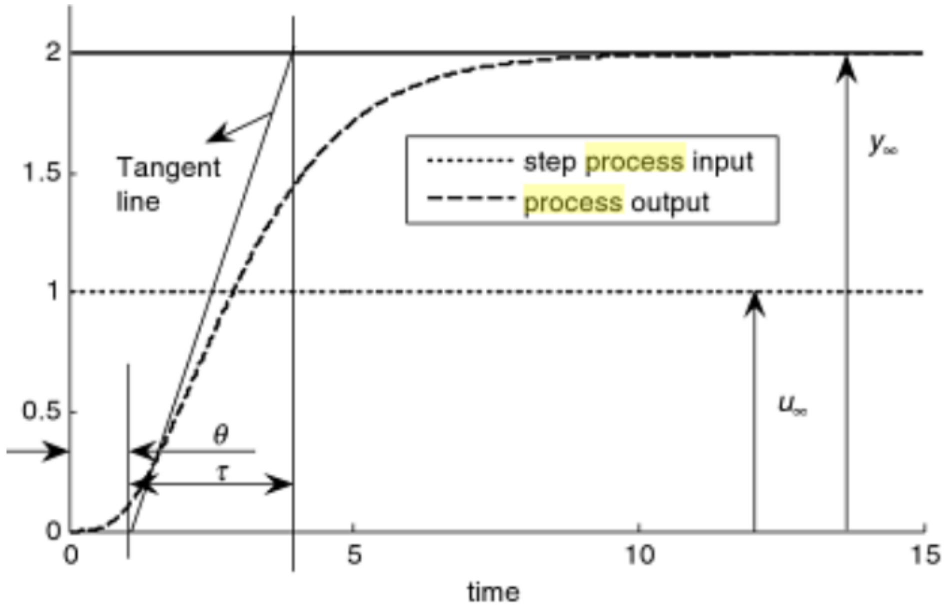
X_o - the size of the step change

M_u - the value that the response goes to as the system returns to steady-state

$$R = \frac{\tau_{\text{dead}}}{\tau}$$

$$K_o = \frac{X_o}{M_u}\frac{\tau}{\tau_{\text{dead}}}$$

An example for determining these parameters for a typical process response curve to a step change is shown below. In order to find the values for τ_{dead} and τ, a line is drawn at the point of inflection that is tangent to the response curve and then these values are found from the graph.



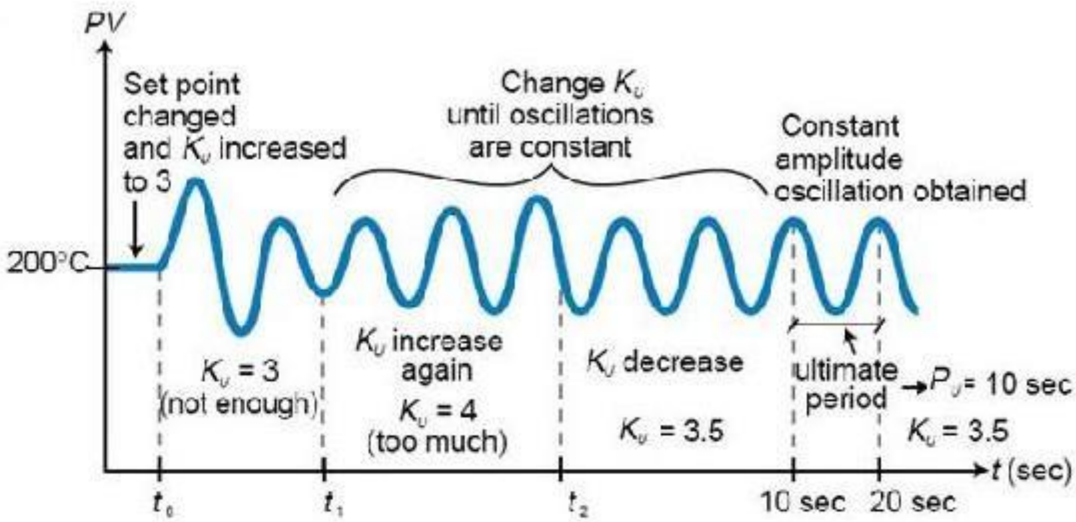
ZIEGLER-NICHOLS TUNING

a. Ziegler-Nichols closed-loop tuning method

The Ziegler-Nichols closed-loop tuning method allows you to use the ultimate gain value, Ku, and the ultimate period of oscillation, Pu, to calculate Kc. It is a simple method of tuning PID controllers and can be refined to give better approximations of the controller. You can obtain the controller constants Kc , Ti , and Td in a system with feedback. The Ziegler-Nichols closed-loop tuning method is limited to tuning processes that cannot run in an open-loop environment. Determining the ultimate gain value, Ku, is accomplished by finding the value of the proportional-only gain that causes the control loop to oscillate indefinitely at steady state. This means that the gains from the I and D controller are set to zero so that the influence of P can be determined. It tests the robustness of the Kc value so that it is optimized for the controller. Another important value associated with this proportional-only control tuning method is the ultimate period (Pu). The ultimate period is the time required to complete one full oscillation while the system is at steady state. These two parameters, Ku and Pu, are used to find the loop-tuning constants of the controller (P, PI, or PID). To find the values of these parameters, and to calculate the tuning constants, use the following procedure:

Closed Loop (Feedback Loop)

1. Remove integral and derivative action.
2. Set integral time (Ti) to 999 or its largest value.
3. Set the derivative controller (Td) to zero.
4. Create a small disturbance in the loop by changing the set point.
5. Adjust the proportional, increasing and/or decreasing, the gain until the oscillations have constant amplitude.
6. Record the gain value (Ku) and period of oscillation (Pu).
7. Plug these values into the Ziegler-Nichols closed loop equations.
8. Determine the necessary settings for the controller.



	K_c	T_I	T_D
P	$K_u/2$		
PI	$K_u/2.2$	$P_u/1.2$	
PID	$K_u/1.7$	$P_u/2$	$P_u/8$

Advantages

- Easy experiment; only need to change the P controller
- Includes dynamics of whole process, which gives a more accurate picture of how the system is behaving

Disadvantages

- Experiment can be time consuming
- Can venture into unstable regions while testing the P controller, which could cause the system to become out of control

b. Ziegler-Nichols Open-Loop Tuning Method or Process Reaction Method

This method remains a popular technique for tuning controllers that use proportional, integral, and derivative actions. The Ziegler-Nichols open-loop method is also referred to as a process reaction method, because it tests the open-loop reaction of the process to a change in the control variable output. This basic test requires that the response of the system be recorded, preferably by a plotter or computer. Once certain process response values are found, they can be plugged into the Ziegler-Nichols equation with specific multiplier constants for the gains of a controller with either P, PI, or PID actions.

Open Loop (Feed Forward Loop)

To use the Ziegler-Nichols open-loop tuning method, you must perform the following steps:

a. Make an open loop step test
b. From the process reaction curve determine the transportation lag or dead time, τ_{dead}, the time constant or time for the response to change, τ, and the ultimate value that the response reaches at steady-state, Mu, for a step change of Xo.

$$K_o = \frac{X_o}{M_u}\frac{\tau}{\tau_{dead}}$$

c. Determine the loop tuning constants. Plug in the reaction rate and lag time values to the Ziegler-Nichols open-loop tuning equations for the appropriate controller namely, P, PI, or PID to calculate the controller constants.

	K_c	T_i	T_d
P	K_0		
PI	$0.9K_0$	$3.3\tau_{dead}$	
PID	$1.2K_0$	$2\tau_{dead}$	$0.5\tau_{dead}$

Advantages

a. Quick and easier to use than other methods
b. It is a robust and popular method
c. Of these two techniques, the Process Reaction Method is the easiest and least disruptive to implement

Disadvantages

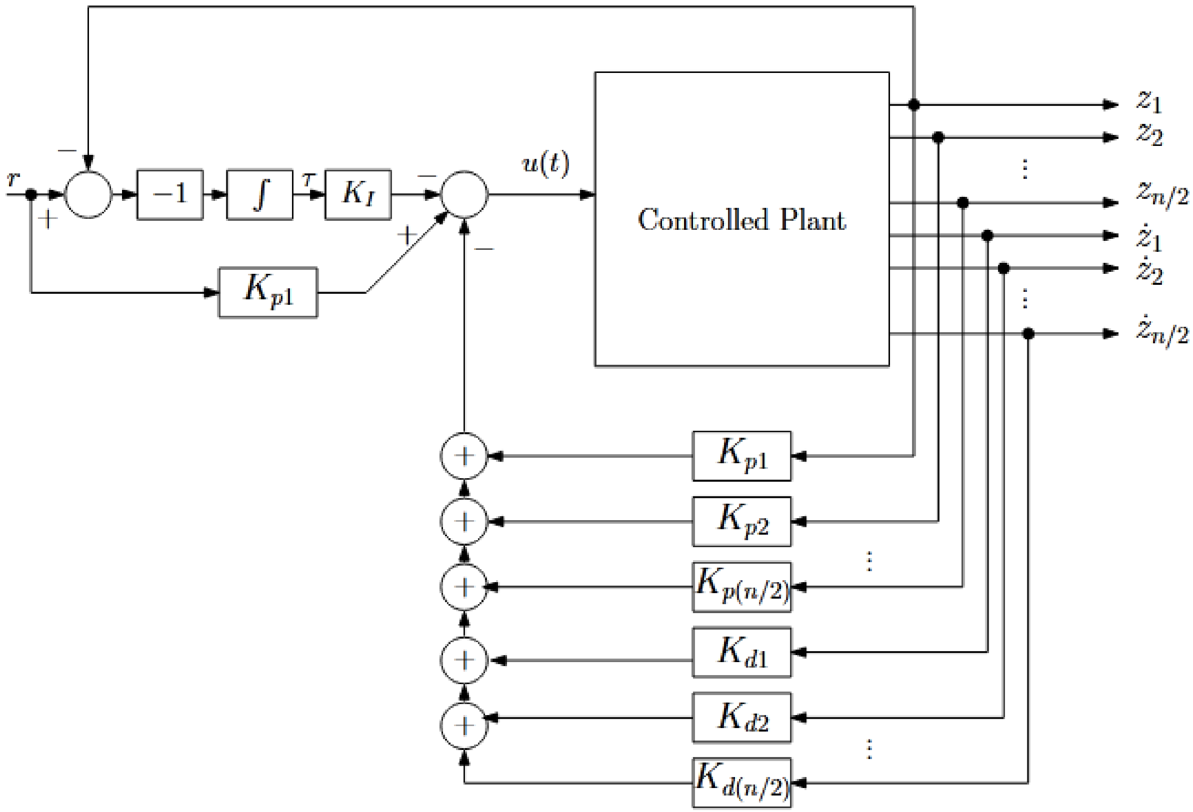
a. It depends upon purely proportional measurement to estimate I and D controllers.
b. Approximations for the Kc, Ti, and Td values might not be entirely accurate for different systems.
c. It does not hold for I, D and PD controllers

PID CONTROL IN STATE FEEDBACK FORM

State feedback (SF) controllers are based on a state space model of the plant, and operate by creating a control input to the plant formed from a linear combination of the plant states. The SF controller gains can be computed using a variety of techniques.

$$\begin{aligned} \dot{z} &= A(t)z + B(t)u \\ \dot{\tau} &= z_1 - r \\ y &= Cz \\ u &= \underbrace{[K_{p1}\ K_{p2} \cdots K_{p(n/2)}\ K_{d1}\ K_{d2} \cdots K_{d(n/2)} \mid K_I]}_{\tilde{K}} \underbrace{\left[\frac{z}{\tau}\right]}_{\tilde{z}} \end{aligned} \quad ($$

$$z = [z_1\ z_2\ z_3 \cdots z_{n/2}\ \dot{z}_1\ \dot{z}_2\ \dot{z}_{n/2}]^T$$



r
+
−
−1
∫
τ
K_I
−
+
−
K_{p1}
$u(t)$
Controlled Plant
z_1
z_2
$z_{n/2}$
$\dot{z}_1$
$\dot{z}_2$
$\dot{z}_{n/2}$
K_{p1}
K_{p2}
$K_{p(n/2)}$
K_{d1}
K_{d2}
$K_{d(n/2)}$