VASAVI COLLEGE OF ENGINEERING

(AUTONOMOUS)
(Affiliated to Osmania University)
Hyderabad - 500 031

DEPARTMENT OF : ICE

NAME OF THE LABORATORY : CSE

Name G.Sri Ganga Pranav Roll No. 1602-21-735-117 Page No.

Effect of controllers on 2nd order systems

Aim:- To analyse the effect of PI, PD, PID controllers on second order systems.

tools Required:- A PC loaded with MATLAB

Theory:-

Controllers are particularly significant in second-order systems within control systems engineering due to their ability ~~of~~ to regulate system response characteristics, such as damping, settling time, and overshoot. In second order systems, which are common in engineering applications, controllers can adjust parameters like gain and phase to stabilize the system, impove its performance, and ensure its responds appropriately to disturbances. By tuning the controller, engineers can fine-tune the system's response to meet specific requirements, such as minimizing overshoot or reducing settling time, thus optimizing the overall system performance

Program:-

```
% PID controller
clc;
clear;
close all;

s = tf('s');
t = -3:0.01:3;
x = t;
```

a) Design a PID controller for a system with OLTF $G(s) = \frac{100}{(s+1)(s+5)(s+20)}$ to meet the following specifications:-

(i) Closed loop dominant pole at $s = -4 \pm j$

(ii) Steady state error for unit ramp input less than 0.05

PID controller :-

$$G_c(s) = K_p + K_d s + \frac{K_I}{s}$$

$$G(s) = \frac{100}{(s+1)(s+5)(s+20)}$$

$s_d = -4 + j$ $\quad e_{ss} = 0.05$ for ramp i/p

$$K_V = \frac{1}{e_{ss}} = 20$$

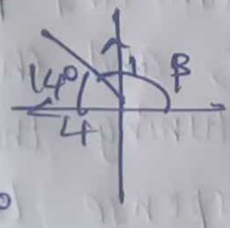
$$\cancel{K_V = \lim_{s \to 0} s\,G(s) = \lim\ 100}$$

OLTF after introducing PID controller

$$G_c(s)\,G(s) = \left[\frac{100}{(s+1)(s+5)(s+20)}\right]\left[K_p + K_d s + \frac{K_I}{s}\right]$$

$$K_V = \lim_{s \to 0} s\,G(s) = \lim_{s \to 0} \frac{100\,(sK_p + s^2 K_d + K_I)}{(s+1)(s+5)(s+20)}$$

$$= \frac{100\,K_I}{5 \times 20} = 20$$



$$K_I = 20$$

$$\beta = 180^\circ - \tan^{-1}\left(\frac{1}{4}\right)$$

$$= 180^\circ - 14^\circ = 166^\circ$$

$$G(s_d) = \frac{100}{(-4+j+1)(-4+j+5)(-4+j+20)}$$

$$|G(s = s_d)| = \frac{100}{\sqrt{10}\,\sqrt{2}\,\sqrt{257}} = 1.39$$

$$\phi = \angle G(s_d) = -\tan^{-1}\left(\frac{1}{-3}\right) - \tan^{-1}\left(\frac{1}{1}\right) - \tan^{-1}\left(\frac{1}{16}\right) = -30.1^\circ$$

$$K_p = \frac{-\sin(\phi + \beta)}{|G(s_d)|\,\sin\beta} - \frac{2 K_I \cos\beta}{|s_d|} = 7.35$$

$$K_d = \frac{\sin(180^\circ - \phi)}{|G(s_d)|\,|s_d|\,\sin\beta} + \frac{K_I}{|s_d|^2} = 0.816$$

```
gs = 100/((s+1)*(s+5)*(s+20));
gpid = ((7.36*s)+20+(0.816*s*s))/s;
g = series(gs,gpid);
cltf = feedback(g,1);
lsim(cltf,x,t)
figure
pzmap(cltf)
```

```
% PD controller
clc;
clear;
close all;
s = tf('s');
```

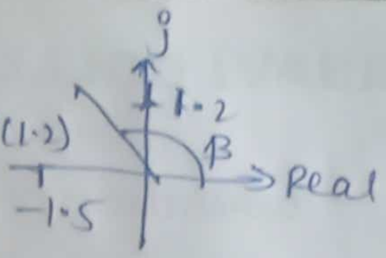
Q) Design a PD controller for a system with OLTF $G(s) = \frac{10}{s(s+1)(s+5)}$ to get closed loop dominant poles at $s = -1.5 \pm j(1.2)$

```
gs = 10*(1+1+0.76*s)/(s*(s+5)*(s+1));
cltf = feedback(gs,1);
pzmap(cltf)
~~figure~~
% PI controller
```

Q) Design a PI controller for a system with OLTF $G(s) = \frac{10}{(s+2)(s+5)}$ to get closed loop transfer function at $s = -2 \pm j(1.2)$

PD controller:-

Consider $S_d = -1.5 + j(1.2)$



$G_c(s) = K_p + K_d s$

$\beta = 180^\circ - \tan^{-1}\left(\frac{1.2}{1.5}\right)$

$= 180^\circ - \tan^{-1}\left(\frac{4}{5}\right) = 141.3^\circ$

For PD controller, $K_I = 0$

$G(S_d) = \frac{10}{(-1.5+1.2j)(-1.5+1.2j+1)(-1.5+1.2j+5)}$

$|G(S_d)| = \frac{10}{\sqrt{1.5^2+1.2^2}\sqrt{0.5^2+1.2^2}\sqrt{3.5^2+1.2^2}}$

$= \frac{10}{1.92 \times 1.3 \times 3.7} = 1.08$

$\phi = \angle G(S_d) = -\tan^{-1}\left(\frac{1.2}{-1.5}\right) - \tan^{-1}\left(\frac{1.2}{-0.5}\right) - \tan^{-1}\left(\frac{1.2}{3.5}\right)$

$= 87.115^\circ$

$K_p = \frac{-\sin(\phi+\beta)}{|G(S_d)|\sin\beta} = 1.1$

$K_d = \frac{\sin(180^\circ - \phi)}{|S_d|\,|G(S_d)|\sin\beta}$

$= 0.76$

OLTF after cascading controller $= G(s) \cdot G_c(s)$

$= \frac{10}{s(s+1)(s+5)}(1.1 + 0.76 s)$

$CLTF = \frac{OLTF}{1+OLTF}$

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DEPARTMENT OF : ECE

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Name: G-Sri Ranga Pranav Roll No. 1602-21-735-117 Page No. ______

```
clc;
clear;
close all;
s = tf('s');
gs = 10*(0.74 + 1.63/s) / ((s+5)*(s+2));
cltf = feedback(gs, 1);
pzmap(cltf)
```

~~figure~~

Result: Designed PID, PI and PD controllers for the given specifications.

~~$G_c(s) = K_p$~~

PI controller:-

$G_c(s) = K_p + \frac{K_I}{s}$

consider $-2 + j(1.2) = s_d$

$$\beta = 180^\circ - \tan^{-1}\left(\frac{1.2}{2}\right)$$

$$= 149.03^\circ$$

$$G(s_d) = \frac{10}{(-2+2+1.2j)(-2+1.2j+5)}$$

$$= \frac{10}{1.2j\,(3+1.2j)}$$

$$|G(s_d)| = \frac{10}{1.2 \times \sqrt{3^2+1.2^2}} = 2.57$$

$$\phi = \angle G(s_d)$$

$$= -\tan^{-1}\left(\frac{1.2}{0}\right) - \tan^{-1}\left(\frac{1.2}{3}\right)$$

$$= -90^\circ - 21.8^\circ = -111.8^\circ$$

For PI controller $K_d = 0$

$$K_d = \frac{\sin(180^\circ - \phi)}{|s_d|\,|G(s_d)|\sin\beta} + \frac{K_I}{|s_d|^2}$$

$$0 = \frac{-7.02}{2.33} + \frac{K_I}{5.44} \Rightarrow K_I = 1.63$$

$$K_p = \frac{-\sin(\phi+\beta)}{|G(s_d)|\sin\beta} - \frac{2K_I\cos\beta}{|s_d|} \Rightarrow K_p = 0.74$$

OLTF after adding PI controller $= G(s)\,G_c(s) = \frac{10}{(s+2)(s+5)}\left(0.74 + \frac{1.63}{s}\right)$

$$CLTF = \frac{OLTF}{1+OLTF}$$