VASAVI COLLEGE OF ENGINEERING
(AUTONOMOUS)
(Affiliated to Osmania University)
Hyderabad - 500 031.
DEPARTMENT OF : ECE

NAME OF THE LABORATORY : control systems Engineering

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

Steady State Error Analysis

Aim:- To analyze the steady state error of different types of control systems.

Apparatus:- PC loaded with MATLAB

Theory:-

Steady state error analysis is crucial in control systems engineering because it helps engineers understand how well a control system performs under steady state conditions. By analyzing steady-state conditions, engineers can assess the system's ability to accurately track and maintain the desired output in response to various disturbances and reference inputs. This analysis is essential for designing and tuning control systems to meet performance specifications, ensuring stability, responsiveness, and accuracy in real world applications. Additionally, steady state error analysis provides insights into system behaviour and helps in optimizing control system performance for different operation conditions.

Type 0:-

$G(s) = \frac{10}{s+2}$ $H(s) = 1$

Unit step:

$e_{ss} = \frac{1}{1+K_p}$

$K_p = \lim_{s \to 0} G(s)$

$= 5$

$e_{ss} = 1/6$

Unit ramp:

$e_{ss} = \frac{1}{K_v}$

$K_v = \lim_{s \to 0} s \cdot G(s) H(s)$

$= \frac{10s}{s+2} \Big|_{s=0}$

$= 0$

$e_{ss} = \infty$

Parabola:

$e_{ss} = \frac{1}{K_a}$

$K_a = \lim_{s \to 0} s^2 \cdot G(s) H(s)$

$= \frac{10s^2}{s+2} \Big|_{s \to 0}$

$= \frac{10}{\frac{1}{s} + \frac{2}{s^2}} \Big|_{s=0}$

$= 0$

$e_{ss} = \infty$

Type 1:-

$G(s) = \frac{10}{s(s+2)}$ $H(s) = 1$

Unit step:

$e_{ss} = \frac{1}{1+K_p}$

$K_p = \lim_{s \to 0} G(s)$

$= \infty$

$e_{ss} = 0$

Unit ramp:

$e_{ss} = \frac{1}{K_v}$

$K_v = \lim_{s \to 0} s \cdot G(s) H(s)$

$= \frac{10s}{s(s+2)} \Big|_{s=0}$

$= 5$

$e_{ss} = 0.2$

Parabola:

$e_{ss} = \frac{1}{K_a}$

$K_a = \lim_{s \to 0} s^2 \cdot G(s) H(s)$

$= s^2 \frac{10}{s(s+2)}$

$= \frac{10s}{s+2} \Big|_{s=0}$

$= 0$

$e_{ss} = \infty$

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Code:-

```
%Program 1 - To analyse steady state errors of type 0,
              type 1, type 2 systems
clc;
close all;
clear;
t = -10:0.01:10;
x2 = (t.*(t>=0)) + (0.*(t<0));
x = (1.*(t>=0)) + (0.*(t<0));
x3 = t.^2/2;
%Type 0
s = tf('s');
n=[10]
d=[1 2]
g = tf(n,d)
kp=dcgain(g)
n1=conv(n,[1 0])
g1= tf(n1,d)
kv= dcgain(g1)
n2 = conv(n,[1 0 0])
g2 = tf(n2,d)
ka=dcgain(g2)
```

Type 2:

$G(s) = \frac{10(s+1)}{s^2(s+2)}$ $H(s)=1$

Unit step:

$e_{ss} = \frac{1}{1+k_p}$

$k_p = \lim_{s\to 0} G(s)$

$= \frac{10\left(\frac{1}{s}+\frac{1}{s^2}\right)}{(s+2)}\Bigg|_{s=0}$

$= \infty$

$e_{ss} = 0$

Ramp:

$e_{ss} = \frac{1}{k_v}$

$k_v = \lim_{s\to 0} s \cdot G(s) H(s)$

$= \frac{10(s+1)}{s(s+2)}\Bigg|_{s=0}$

$= \frac{10\left[1+\frac{1}{s}\right]}{(s+2)}\Bigg|_{s=0}$

$= \infty$

$e_{ss} = 0$

Parabolic:

$e_{ss} = \frac{1}{k_a}$

$k_a = \lim_{s\to 0} s^2 \cdot G(s)H(s)$

$= \lim_{s\to 0} \frac{10(s+1)}{(s+2)}$

$= \frac{10}{2} = 5$

$e_{ss} = \frac{1}{5}$

$= 0.2$

```
ess - step = 1/(1+kp)
ess - ramp = 1/kv
ess - parabola = 1/ka
tf1= feedback(g,1);
subplot(2,2,1)
impulse(tf1)
title('Impulse response- Type 0 --1602-21-735-117')
subplot(2,2,2)
lsim(tf1,'r',x,t)
title('step response-Type 0 --1602-21-735-117')
subplot(2,2,3)
lsim(tf1,'r',x2,t)
title('Ramp response- Type 0--1602-21-735-117')
subplot(2,2,4)
lsim(tf1,'r', x3,t)
title('Parabolic response - Type 0 --1602-21-735-117')

% Type1
n=[10]
d=[1 2 0]
g = tf(n,d)
kp =dcgain(g)
n1= conv(n,[1 0])
g1=tf(n1,d)
```

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```
kv=dcgain(g1)
n2=conv(n,[1 0 0])
g2=tf(n2,d)
ka=dcgain(g2)
ess_step= 1/(1+kp)
ess_ramp=1/kv
ess_parabola=1/ka
tf1=feedback(g,1);
figure(2)
subplot(2,2,1)
impulse(tf1)
title('Impulse response- Type 1 --1602-21-735-117')
subplot(2,2,2)
lsim(tf1,'r',x,t)
title('step response-Type1--1602-21-735-117')
subplot(2,2,3)
lsim(tf1,'r',x2,t)
title('Ramp response - Type 1 --1602-21-735-117')
subplot(2,2,4)
lsim(tf1,'r',x3,t)
title('Parabolic response- Type1 --1602-21-735-117')
```

```
%Type 2
n=[10 10]
d=[1 2 0 0]
g=tf(n,d)
kp=dcgain(g)
n1=conv(n,[1 0])
g1=tf(n1,d)
kv=dcgain(g1)
n2=conv(n,[1 0 0])
g2=tf(n2,d)
ka=dcgain(g2)
ess_step = 1/(1+kp)
ess_ramp =1/kv
ess_parabola =1/ka
figure(3)
tf1=feedback(g,1);
subplot(2,2,1)
impulse(tf1)
title('Impulse response - Type 2 - 1602-21-735-117')
subplot(2,2,2)
lsim(tf1, 'r', x, t)
title('step response - Type 2 - 1602-21-735-117')
subplot(2,2,3)
```

$$G_1 = \frac{k_1(2s+1)}{s(5s+1)(1+s)^2} \qquad \text{input} = (1+6t)$$

It is type 1 system

For type 1 system, ramp input is preferrable and also the steady state error due to constant function is zero in type 1 system. so, neglect 1 in (1+6t) input and consider only 6t

$$K_V = \lim_{s \to 0} s \cdot G(s)$$

$$= \left. \frac{s(2s+1)k_1}{s(5s+1)(1+s)^2} \right|_{s=0}$$

$$= k_1$$

$$K_V = k_1$$

$$e_{ss} = \cancel{6}\ 6 \times \frac{1}{K_V}$$

$$0.1 = \frac{6}{k_1}$$

$$k_1 = 60.$$

```
lsim(tf1, 'r', x2, t)
title ('Ramp response - Type 2 - -1602-21-735-117')
subplot(2,2,4)
lsim (tf1, 'r', x3, t)
title ('Parabolic response - Type 2 - -1602-21-735-117')

% Program 2 - sum.
% G1 = k1 (2s+1) / s(5s+1)(1+s)^2 ; input = (1+6t)
% Determine min. value of k1 so that steady state
  error is less than 0.1

clc;
close all;
clear;

% Type1
s = tf('s');
g = 60* (2* s+1) /(s* (5* s+1) *(1+s)^2)
kv = dcgain(g* s)
ess_ramp = 6/kv
```

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Observation:-

→ For type 0 systems,

ess_step = finite ⇒ Acceptable

$\left.\begin{array}{l}\text{ess\_ramp} = \infty \\ \text{ess\_parabola} = \infty\end{array}\right\}$ Not preferrable

→ For type 1 systems,

$\left.\begin{array}{l}\text{ess\_step} = 0 \\ \text{ess\_ramp} = \text{constant}\end{array}\right\}$ Acceptable

ess_parabola = ∞ ⇒ Not preferrable.

→ For type 2 systems,

$\left.\begin{array}{l}\text{ess\_step} = 0 \\ \text{ess\_ramp} = 0 \\ \text{ess\_parabola} = \text{constant}\end{array}\right\}$ Acceptable.

Result:- Analyzed the steady state errors of type 0, type 1 and type 2 systems.