Kuliah ke-12

Pada kuliah ini, kita telah membicarakan stabilitas sistem kendali dengan menggunakan Metode *Root Locus* atau Metode tempat kedudukan akar-akar dengan analisis dan metode grafis untuk kestabilan sistem.

Pada kuliah ke-12 ini kita akan membicarakan metode *Kriteria Rowth.*

"*Kriteria Rowth* menggunakan suatu kestabilan mutlak. *Kriteria Rowth* dapat menggunakan persamaan karakteristik sistem kendali"

Kriteria Rowth

1. Analisisnya menggunakan determinan
2. Suatu sistem kendali stabil apabila ada perubahan tanda pada kolom pertama setelah diadakan analisis maka sistem stabil
3. Suatu sistem tidak stabil apabila ada perubahan tanda pada kolom pertama determinan setelah analisis
4. Suatu sistem kendali dimana pada persamaan karakteristik gain (K) maka pada analisisnya ditentukan batas-batas nilai (K) sistem stabil atau tidak.

Untuk memudahkan analisis sistem kendali kita gunakan persamaan sistem kontrol yang dimodelkan dengan persamaan polynomial derajat tiga saja, seperti berikut:

	$as^3 + bs^2 + cs + d = 0$	
s^3	a	c
s^2	b	d
s^1	b_1	
s^0	b_2	

Menentukan nilai b_1 dan b_2 digunakan determinan

$$\frac{1}{b}\begin{vmatrix} a & c \\ b & d \end{vmatrix} = b_1$$

$$b_1 = \frac{bc - ad}{b}$$

Menentukan nilai b_2 adalah

$$\frac{1}{b_1}\begin{vmatrix} a & c \\ b_1 & 0 \end{vmatrix} = b_2$$

Contoh 1.

Suatu sistem kendali yang dimodelkan dengan persamaan polynomial sebagai berikut:

	$s^3 + 3s^2 + 2s + 5 = 0$	
s^3	1	2
s^2	3	5
s^1	b_1	
s^0	b_2	

Penyelesaian:

$$b_1 = \frac{1}{3}\begin{vmatrix} 1 & 2 \\ 3 & 5 \end{vmatrix} = \frac{6-5}{3}$$

$$b_1 = \frac{1}{3}$$

$$b_2 = \frac{1}{b_1}\begin{vmatrix} 3 & 5 \\ 1/3 & 0 \end{vmatrix} = 3\begin{vmatrix} 3 & 5 \\ 1/3 & 0 \end{vmatrix}$$

$$b_2 = 5$$

Menurut syarat (1) maka sistem stabil karena tidak ada perubahan tanda pada kolom pertama tetap positif.

Contoh 2.

Suatu sistem kendali disimulasikan sebuah persamaan polynomial sebagai berikut tentukan apakah sistem stabil atau tidak.

$2s^3 + 6s^2 + 3s - 2 = 0$

	$2s^3 + 6s^2 + 3s - 2 = 0$	
s^3	2	3
s^2	6	-2
s^1	$3\,{}^2/_3$	0
s^0	-2	

Pada ketentuan syarat stabil apabila tidak ada perubahan sistem tanda pada kolom pertama dari positif (+) ke negatif (-) maka pada sistem adalah stabil. Karena ada perubahan tanda pada kolom pertama pada determinan.

Contoh 3.

$s^3 + 4s^2 + 5s + 6 = 0$

	$s^3 + 4s^2 + 5s + 6 = 0$	
s^3	1	5
s^2	4	6
s^1	$3\,{}^1\!/_3$	
s^0	6	

Berdasarkan hasil analisis dari determinan diatas pada kolom pertama tidak ada perubahan tanda maka sistem stabil.

Contoh 4.

Suatu sistem kendali dengan fungsi alih daur terbuka adalah

$$GH(s) = \frac{K}{s(0.2s + 1)(0.5s + 2)}$$

Tentukan persamaan karakteristiknya.

Setelah kita menyelesaikan karakteristik

$$GH(s) + 1 = 0$$

Diperoleh persamaan karakteristiknya adalah:

$$0.1s^3 + 0.4s^2 + 2s + K = 0$$

Menentukan nilai K apakah sistem stabil kita selesaikan dengan *Kriteria Rowth* sebagai berikut:

	$0.1s^3 + 0.4s^2 + 2s + K$	
s^3	0.1	2
s^2	0.4	K
s^1	b_1	
s^0	b_2	

$$b_1 = \frac{1}{0.4}\begin{vmatrix} 0.1 & 2 \\ 0.4 & K \end{vmatrix} = \frac{0.8 - 0.1K}{0.4}$$

$$b_2 = \frac{1}{b_1}\begin{vmatrix} 0.4 & K \\ b_1 & 0 \end{vmatrix} = K$$

$$b_2 = \frac{1}{b_1}\begin{vmatrix} 0.4 & K \\ b_1 & 0 \end{vmatrix} = K$$

Menentukan nilai K

(1) $\frac{0.8-0.1K}{0.4} = 0$ maka $K = 8$

(2) Untuk $K = 0$

Jadi batas nilai K adalah $0 \leq K \leq 8$ sistem stabil.

KULIAH SELANJUTNYA ADALAH APLIKASI ROOT LOCUS & KRITERIA ROWTH DENGAN MENGGUNAKAN MATLAB KULIAH 13

KULIAH 13

APLIKASI METODE ROOT LOCUS &ROWTH PADA SISTEM TENAGA LISTRIK

SOALNYA DIAMBIL DARI BUKU POWER SYSTEN ANALYSIS CHAPTER 12 HADI SAADAT DAN PENYESAIAN SOAL DIGUNAKAN BUKU MODERN CONTROL ENGINEERING KATSUHIKO OGATA DENGAN METODE MATLAB

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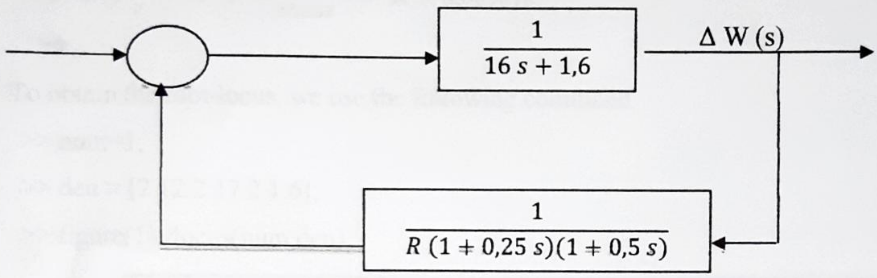
DEPARTEMEN TEKNIK ELEKTRO

MAKASSAR 2021

1,. Diketahui : - Turbine time constant TT = 0,5 s

- Governer time constant TG = 0,25 s
- Generator inertice constant H = 8 s
- Governor speed regulation = R per unit
- Load varies 1,6 % for 1 %
- D = 1,6



$$KG(s)H(s) = \frac{K}{(16s + 1.6)(1 + 0.25s)(1 + 0.5s)}$$

$$= \frac{K}{2s^3 + 12.2s^2 + 17.2s + 1.6}$$

Where $k = \frac{1}{R}$

A. The characteristic equation is given by

$$1 + KG(s)H(s) = 1 + \frac{K}{2s^3 + 12.2s^2 + 17.2s + 1.6} = 0$$

Which results in the characteristic polynomial equation

➔ $2s^3 + 12.2s^2 + 17.2s + 1.6 + K$

The Routh-Hurwitz array for this polynomial is :

S3	2	17,2
S2	12,2	1,6 + k
S1	$\frac{206,64 - 2k}{12.2}$	0
S0	1,6 + k	0

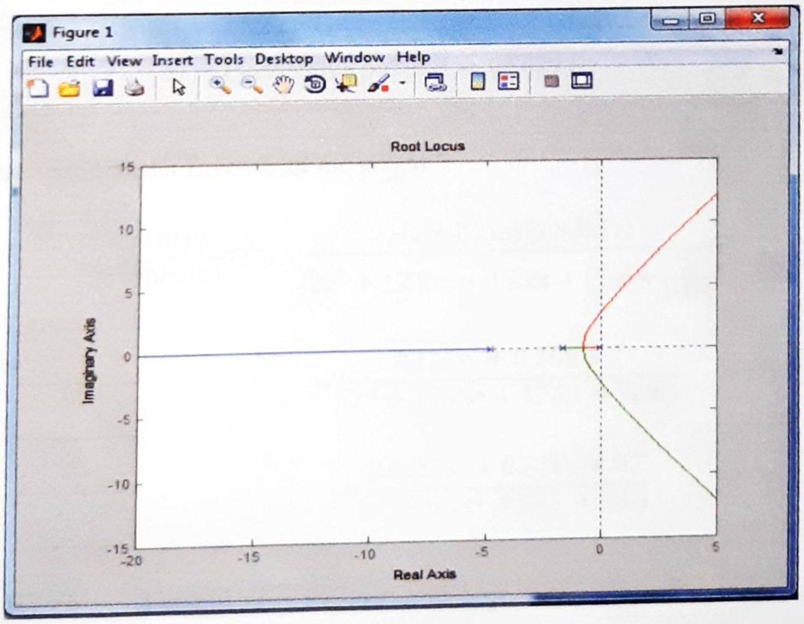
➔ K< 103,32

➔ $R = \frac{1}{K}$ ➔ $R = \frac{1}{103.32}$ ➔ **R > 0,009678**

➔

B. To obtain the root-locus, we use the following command.

```
>> num=1;
>> den = [2 12.2 17.2 1.6];
>> figure(1),rlocus(num,den)
```



2. Diketahui : - R : 0,04 per unit

- Output turbine 200 Mw

- Sudden Load change : 50 Mw

- $\Delta PL = 0\boldsymbol{\Omega s}$ **/unit**

A. The steady-state frequency deviation due to a step input is

$$\Delta w_{ss} = \lim_{s \to 0} s\Delta\Omega(s) = (-\Delta PL(s))\frac{1}{D+\frac{1}{R}} = (-0.25)\left(\frac{1}{1{,}6+\frac{1}{0.04}}\right)$$

$$= (-0.25)\left(\frac{1}{26.6}\right)$$

$$= -0.009398\, pu$$

The steady-state frequency deviation in hertz due to de sudden application of a 50 MW load is

$$\Delta f = (-0.009398\, pu)(60) = 0.5639\ Hz$$

B. The close-loop transfer function of the system :

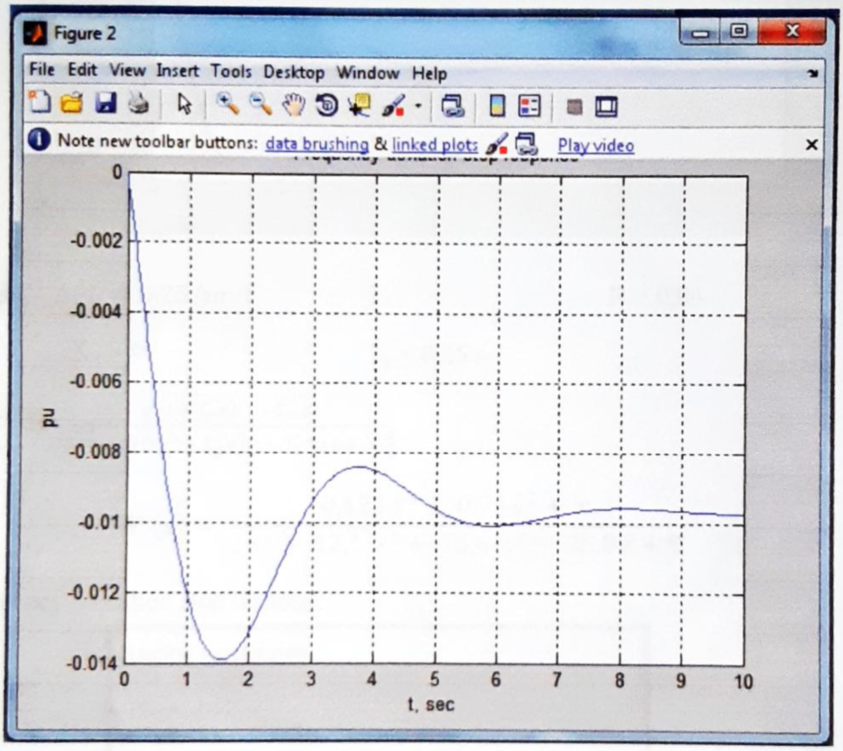
$$\frac{\Delta\Omega(s)}{-\Delta PL(s)} T(s) = \frac{(1+0.25s)(1+0.5s)}{2s^3 + 12.2s^2 + 17.2s + (1.6 + \frac{1}{0.04})}$$

$$= \frac{0.125s^2 + 0.75s + 1}{2s^3 + 12.2s^2 + 17.2s + 26.6)}$$

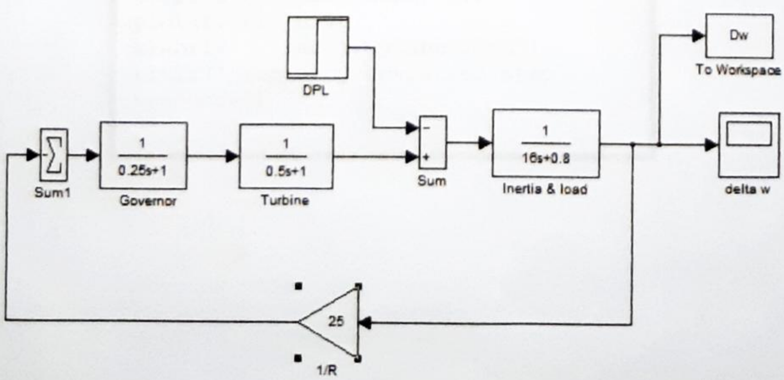
$$= \frac{0.0625s^2 + 0.375s + 0.5}{s^3 + 6.1s^2 + 8.6s + 13.3}$$

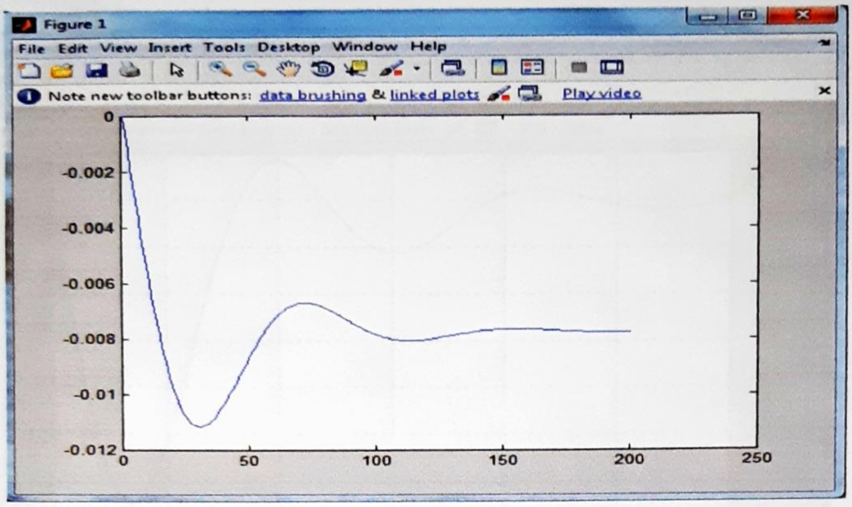
To obtain the step response, we use the following commands

```
>> PL = 0.25; numc = [0.0625 0.375 0.5];

>> denc = [1 6.1 8.6 13.3];

>> t = 0: 0.02 :10; c=-PL*step(numc,denc,t);

>> figure(2),plot(t,c),xlabel('t, sec'),ylabel('pu')

>> title('Frequency deviation step response'),grid timespec(num,den)
```



C. the SIMULINK block diagram and obtain the frequency deviation response is :





3. Diketahui: - $\Delta PL = 0{,}25/unit$ T_T = R = 0,04

- K_I = 9 T_g = 0,25 s

A. $\frac{\Delta\Omega\,(s)}{\Delta PL\,(s)} = \frac{s\,(1+T_g\,s)(1+T_T\,s)}{S\,(2H\,s+D)(1+T_g\,s)(1+T_T\,s)+K_I+\frac{S}{R}}$

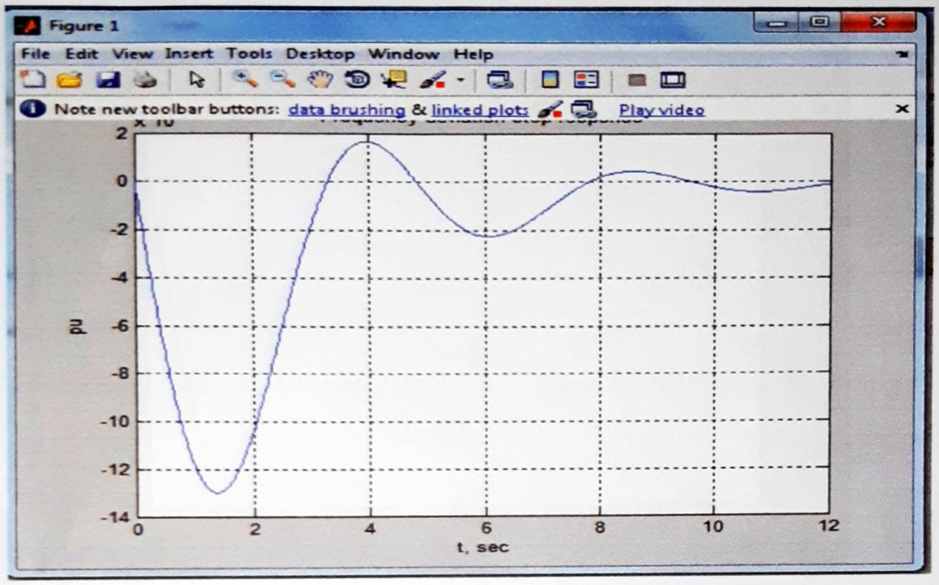
$$T\,(s) = \frac{0{,}125\,s^3 + 0{,}75\,s^2 + s}{2\,s^4 + 12{,}1\,s^3 + 16{,}6\,s^2 + 25{,}8\,s + 9}$$

- frequency deviation step response

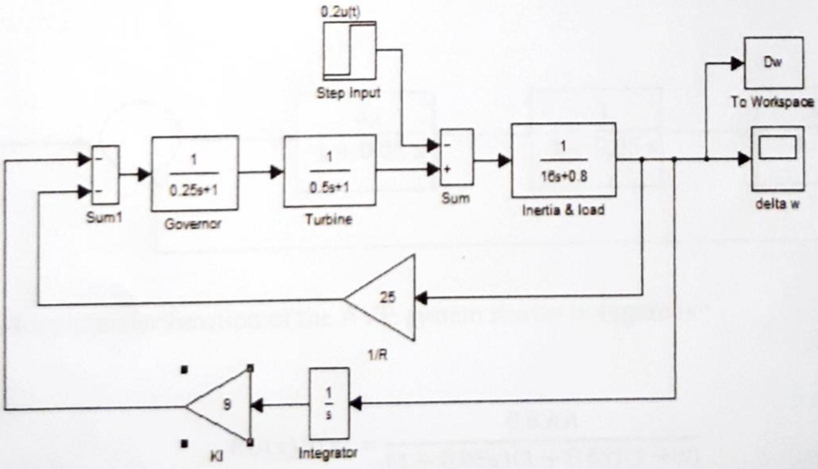
-

Listing matlabnya

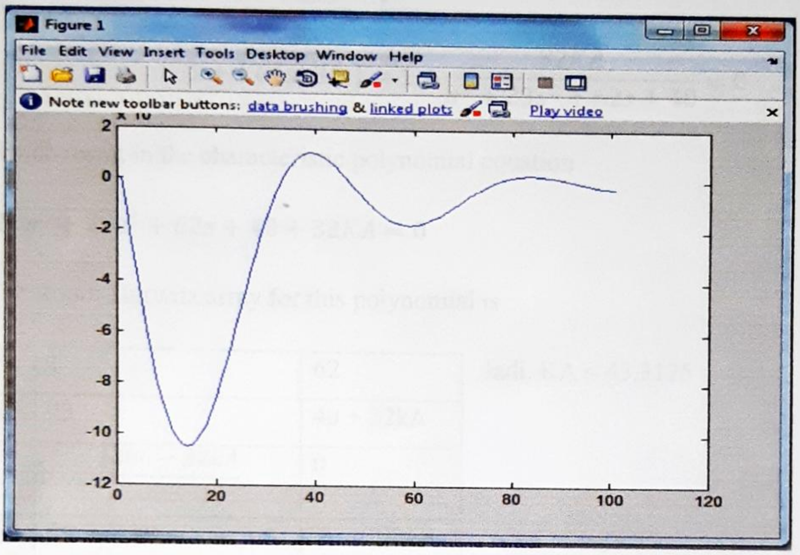
```
PL = 0.25;
KI = 9;
numc = [0.125  0.75  1 0];
denc = [2   13   16.6   25.8 KI];
t = 0:.02:12;
c=-PL*step(numc, denc, t);
plot(t, c), grid
xlabel('t, sec'), ylabel('pu')
title('Frequency deviation step
response')
```



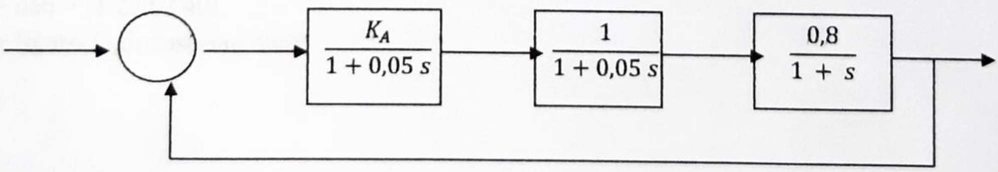
B. SIMULINK block diagram and frequency deviation response



Simulation diagram for Example 12.3



4 Diketahui :



The open-loop transfer function of the AVR system shown in Figure is :

$$KG(s)H(s) = \frac{0.8\,KA}{(1+0.05s)(1+0.5s)(1+s)}$$

$$= \frac{0.8KA}{0.025s^3 + 0.575s^2 + 1.55s + 1}$$

$$= \frac{32KA}{s^3 + 23s^2 + 62s + 40}$$

A. The characteristic equation is given by

$$1 + KG(s)H(s) = 1 + \frac{32KA}{s^3 + 23s^2 + 62s + 40} = 0$$

Which result in the characteristic polynomial equation

➔ $s^3 + 23s^2 + 62s + 40 + 32KA = 0$

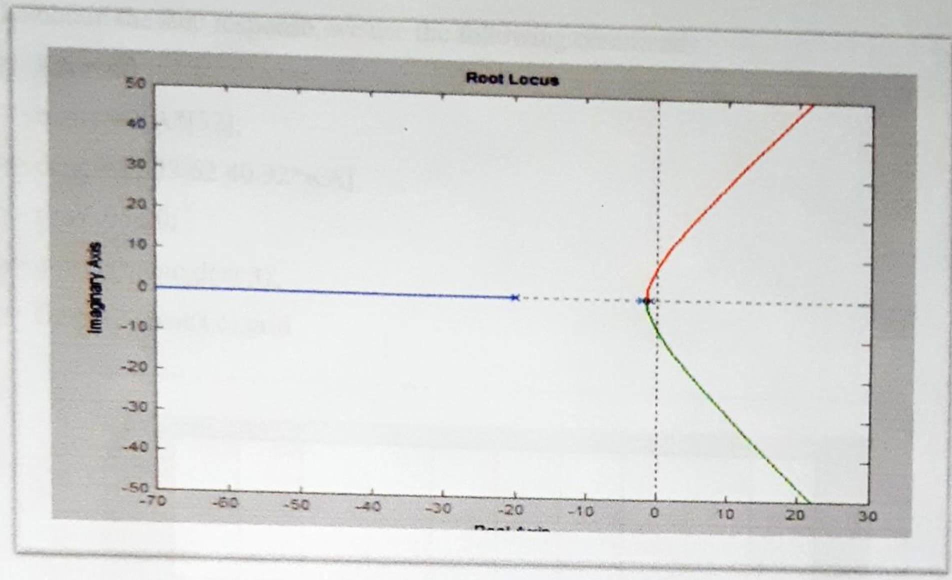
The Routh-Hurwitz array for this polynomial is :

S^3	1	62
S^2	23	40 + 32kA
S^1	$\frac{1386 - 32kA}{23}$	0
S^0	40 + 32kA	0

Jadi, KA < 43,3125

B. To obtain the root-locus plot for the range of K from 0 to 43,3125, we use the following commands.

```
>> num = 32;
>> den = [1 23 62 40];
>> figure(1),rlocus(num,den);
```



C. $K_A = 40$

The closed-loop transfer function of the system is :

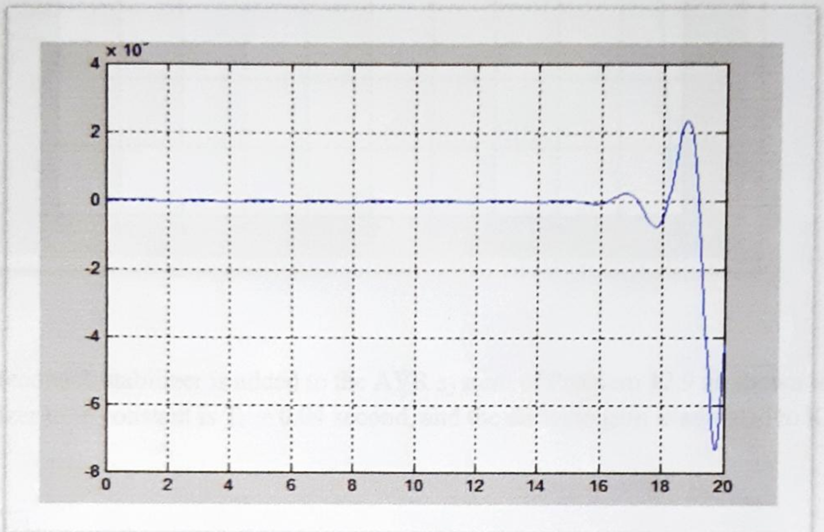
$$\frac{Vt(s)}{Vref(s)} = \frac{32KA}{s^3 + 23s^2 + 62s + 40 + 32KA}$$

$$\frac{Vt(s)}{Vref(s)} = \frac{32(40)}{s^3 + 23s^2 + 62s + 40 + 32(40)}$$

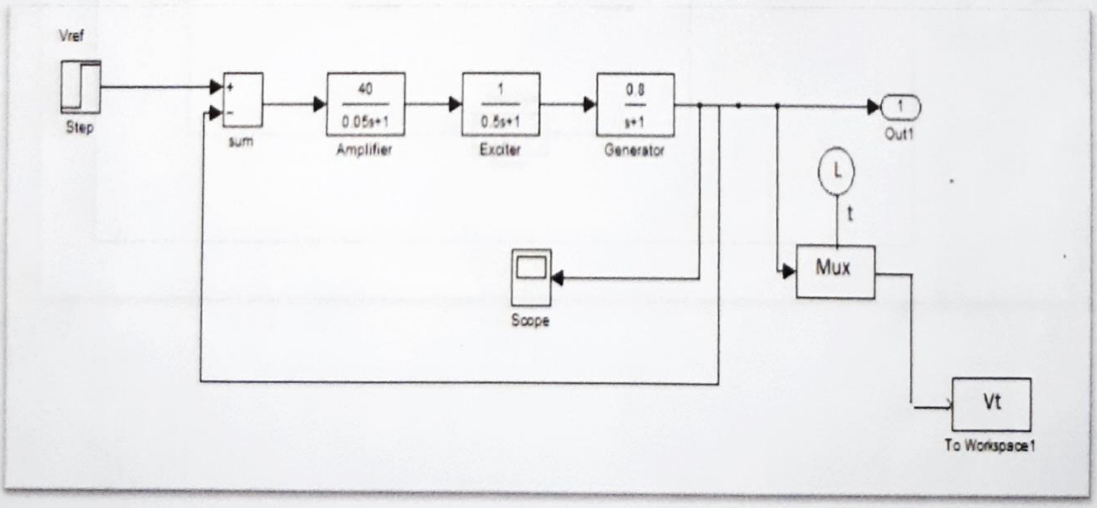
$$\frac{Vt(s)}{Vref(s)} = \frac{1280}{s^3 + 23s^2 + 62s + 40 + 1320}$$

To obtain the step response, we use the following commands :

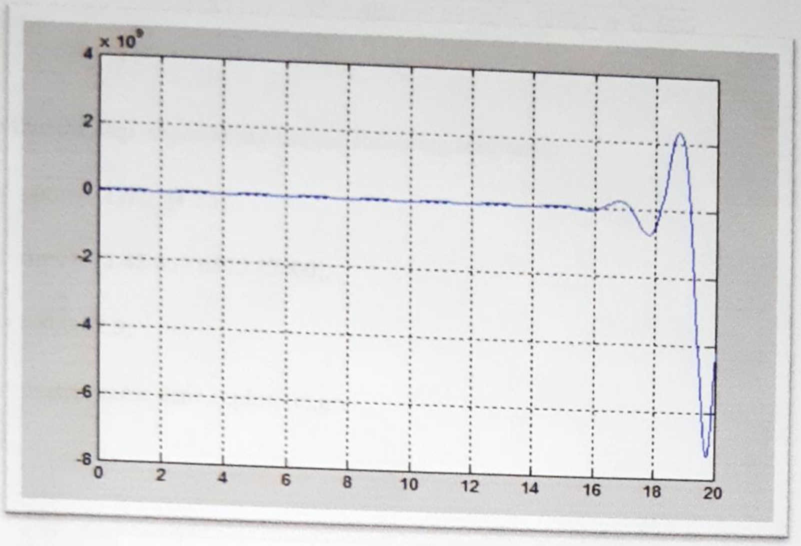
```
>> KA = 40;
>> numc = KA*[32];
>> denc = [1 23 62 40 32*KA];
>> t=0:0.05:20;
>> c=step(numc,denc,t);
>> figure(2),plot(t,c),grid
```



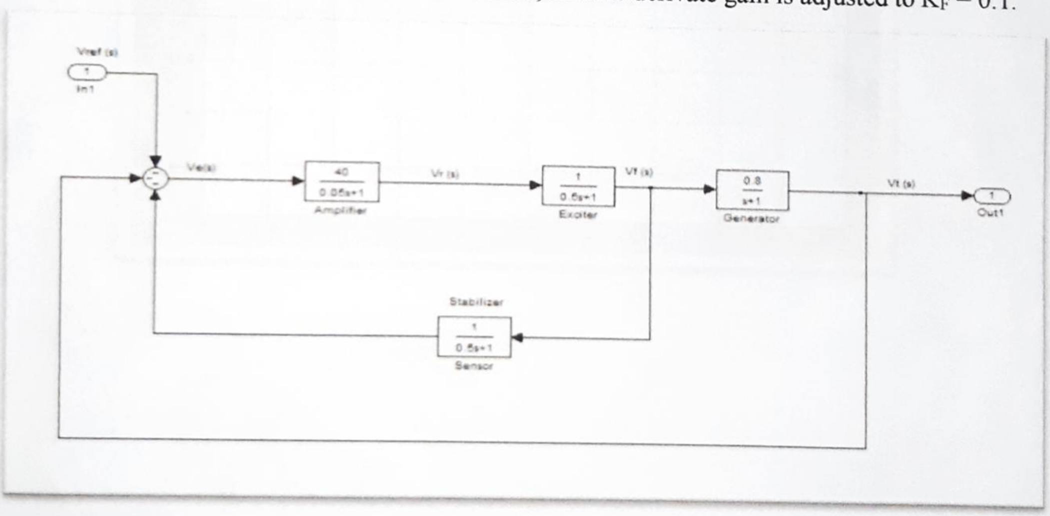
D. Construct the SIMULINK block diagram and obtain the step response.



Hasil simulasi



5 . A rate feedback stabilizer is added to the AVR system of Problem 12.9 as shown in figure. The stabilizer time constant is $T_F = 0.04$ second, and the derivate gain is adjusted to $K_F = 0.1$.

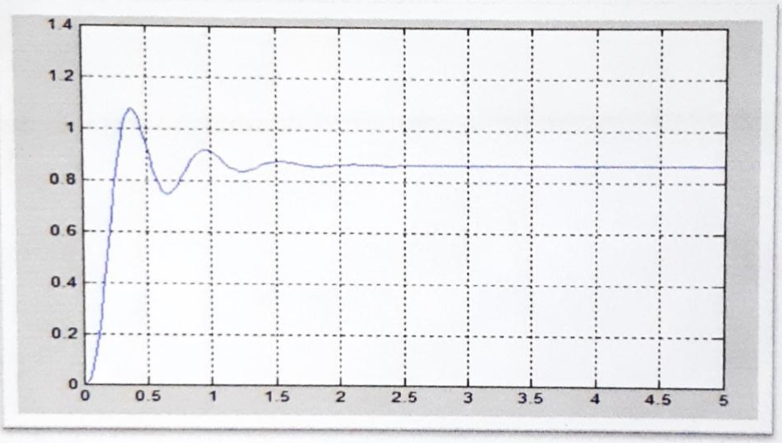


A. The closed-loop transfer function of the system is :

$$\frac{Vt(s)}{Vref(s)} = \frac{1280(s+25)}{s^4 + 48s^3 + 637s^2 + 6870s + 37000}$$

To find the step response, we use the following commands :

```
>> numc = 1280*[1 25];

>> denc = [1 48 637 6870 37000];

>> t=0:0.02:5;

>> c=step(numc,denc,t);plot(t,c),gri
```



B. Construct the SIMULINK model, and obtain the step response :