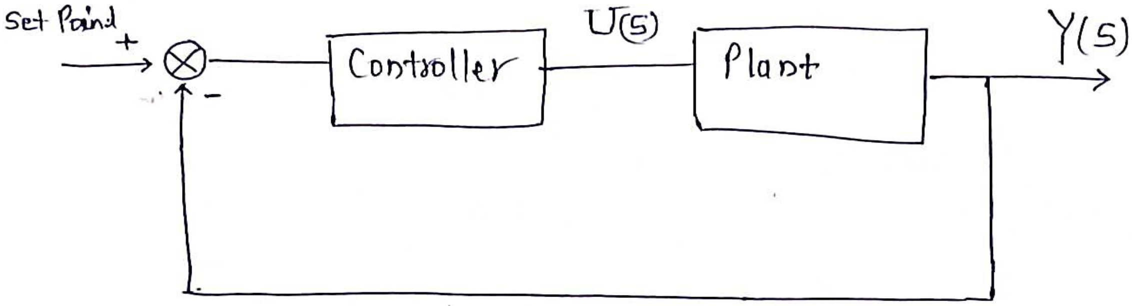
Chapter -4

MATLAB CODES



$$\frac{Y(S)}{U(S)} = \frac{e^{-0.2s}}{(s+1)^2}$$

$$Y(S)\,(s+1)^2 = e^{-0.2s} \quad U(S)$$

$$s^2 Y(S) + 2s\,Y(S) + Y(S) = e^{-0.2}\;U(s)$$

↓ Time domain

$$\frac{d^2y}{dt^2} + 2\frac{dy}{dt} + y(t) = u(t-0.2)$$

Let $\frac{dy}{dt} = x$ $\quad \therefore \frac{d^2y}{dt^2} = \frac{dx}{dt}$

$$\frac{dx}{dt} + 2x + y = u(t-0.2)$$

$$\frac{dx}{dt} = u(t-0.2) - y - 2x$$

$$\boxed{F\_xy = @(u, y, x) \quad u - y - 2*x}$$

(Way to write in Matlab)

Note :- $\frac{dy}{dt} = x$

$$\frac{y(i+1) - y(i)}{h} = x(i+1)$$

(h = step size)

$$\boxed{y(i+1) = y(i) + h * x(i+1)}$$

We have written the code for following process model.

- $G_p(s) = \dfrac{e^{-Ls}}{(1+s)^2}$, L=0.2 and 0.3;
- $G_p(s) = \dfrac{e^{-Ls}}{s(s+1)}$, L=0.2 and 0.3;

SN.	PROCESS MODEL	DELAY	ULTIMATE GAIN (calculated at first delay)	ULTIMATE PERIOD
1-	$G_p(s) = \dfrac{e^{-Ls}}{(1+s)^2}$	L=0.2 and 0.3	10.5	2.0333
2	$G_p(s) = \dfrac{e^{-Ls}}{s(s+1)}$	L=0.2 and 0.3	5.09	2.9

Matlab code for Ultimate gain and Ultimate time period calculation of the process model $G_p(s) = \dfrac{e^{-Ls}}{(1+s)^2}$

```
%%%% calculation of ultimate gain and time period
%%%%tf=exp(-0.2s)/(s2+2s+1)
```

```
clc;
clear all;

h=0.1;
t = 0:h:30;
y = zeros(1,length(t));
u = zeros(1,length(t));
e = zeros(1,length(t));
x = zeros(1,length(t));
i = zeros(1,length(t));
input = 1;
y(1) = 0;
x(1)=0 ;
e(1)=input - y(1);

kp=10.5;

u(1)=kp*e(1);

F_xy = @(x) -2*x;

for i = 1:2

%y and u taken as time input and x as output

k_1 = F_xy(x(i));
k_2 = F_xy(x(i)+0.5*h*k_1);
k_3 = F_xy((x(i)+0.5*h*k_2));
k_4 = F_xy((x(i)+k_3*h));


x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

y(i+1)=y(i)+h*x(i+1);

e(i+1)=1-y(i+1);

u(i+1)=kp*e(i+1);

end

F_xy = @(u,y,x) u-y-2*x;


for i = 3:length(t)

k_1 = F_xy(u(i-2),y(i),x(i));

k_2 = F_xy(u(i-2)+0.5*h,y(i)+0.5*h,x(i)+0.5*h*k_1);

k_3 = F_xy((u(i-2)+0.5*h),(y(i)+0.5*h),(x(i)+0.5*h*k_2));
```

```
k_4 = F_xy((u(i-2)+h ) ,(y(i)+h) ,(x(i)+k_3*h));


x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

y(i+1)=y(i)+h*x(i+1);

e(i+1)=1-y(i+1);

u(i+1)=kp*e(i+1);

end


z=y(1:301)
plot(t,z)
xlabel('value of time t')
ylabel('value of y')
title(' calculation of ultimate gain,k =10.5 ultimate period=2.033sec, second order system tf=exp(-0.2s)/(s2+2s+1)
')
grid on
```

Matlab code for CPID of TF1

```
clc;
 clear all;

h=0.1;
t = 0:h:16;

tf=16/h;
y = zeros(1,length(t));
u = zeros(1,length(t));
e = zeros(1,length(t));
x = zeros(1,length(t));
y(1) = 0;
x(1)=0 ;
r=1
e(1)=r - y(1);

ku=10.5;
tu=2.033;

kc=0.6*ku
ti=tu/2
td=tu/8

 u(1)=kc*(e(1) +(0.1/ti)*sum(e));
```

```
 F_xy = @(x) -2*x;

 for i = 1:2
          %y and u taken as time input and x as output
           k_1 = F_xy(x(i));
           k_2 = F_xy(x(i)+0.5*h*k_1);
           k_3 = F_xy((x(i)+0.5*h*k_2));
           k_4 = F_xy((x(i)+k_3*h));

           x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

           y(i+1)=y(i)+h*x(i+1);

           e(i+1)=r-y(i+1);

           er=sum(e);

           ed=e(i+1)-e(i);

           u(i+1)=kc*(e(i+1) +(0.1/ti)*sum(e)+(td/0.1)*ed);

end

F_xy = @(u,y,x) u-y-2*x;

for i = 3:(tf/2)
        k_1 = F_xy(u(i-2),y(i),x(i));

        k_2 = F_xy(u(i-2)+0.5*h,y(i)+0.5*h,x(i)+0.5*h*k_1);

        k_3 = F_xy((u(i-2)+0.5*h),(y(i)+0.5*h),(x(i)+0.5*h*k_2));

        k_4 = F_xy((u(i-2)+h ) ,(y(i)+h) ,(x(i)+k_3*h));

        x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

       y(i+1)=y(i)+h*x(i+1);
       e(i+1)=r-y(i+1);
       er=sum(e);
       ed=e(i+1)-e(i);

      u(i+1)=kc*(e(i+1) +(0.1/ti)*sum(e)+(td/0.1)*ed);

end

% effect of load on the process(25%)

u((tf/2)+1)=-14

F_xy = @(u,y,x) u-y-2*x;


for i = (tf/2)+1:length(t)

    k_1 = F_xy(u(i-2),y(i),x(i));

    k_2 = F_xy(u(i-2)+0.5*h,y(i)+0.5*h,x(i)+0.5*h*k_1);

    k_3 = F_xy((u(i-2)+0.5*h),(y(i)+0.5*h),(x(i)+0.5*h*k_2));
```

```
    k_4 = F_xy((u(i-2)+h ) ,(y(i)+h) ,(x(i)+k_3*h));
    x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

   y(i+1)=y(i)+h*x(i+1);
   e(i+1)=r-y(i+1);
   er=sum(e);
   ed=e(i+1)-e(i);
    u(i+1)=kc*(e(i+1) +(0.1/ti)*sum(e)+(td/0.1)*ed);
end

z=y(1:tf+1);
plot(t,z,'--')
xlabel('Time t ')
ylabel('Response y')
title(' CPID(- - -) Response of second order system TF=exp(-0.2s)/s2+2s+1)')
grid on
```

Matlab code for APID of TF1

```
%%%APID  adaptive PID CONTROLLER  Response of second order system TF=exp(-0.2s)/s2+2s+1

clc;
clear all;

h=0.1;
t = 0:h:16;
tf=16/h;

y = zeros(1,length(t));
u = zeros(1,length(t));
e = zeros(1,length(t));
x = zeros(1,length(t));

kpp = zeros(1,length(t));
kii = zeros(1,length(t));
kdd = zeros(1,length(t));

v = zeros(1,length(t));
x = zeros(1,length(t));

r= 1;

setpoint=r;
y(1) = 0;
x(1)=0 ;
e(1)=r - y(1);


ku=10.5;
tu=2.033;

kp=0.6*ku
ti=tu/2
td=tu/8

ki=kp*(0.1/ti)
kd=kp*(td/0.1)

k1=1
```

```
k2=1
k3=12

u(1)=kp*e(1)+ki*sum(e);

 kpp(1)=0;
 kii(1)=0;
 kdd(1)=0;
 v(1)=0;


F_xy = @(x) -2*x;

for i = 1:2


k_1 = F_xy(x(i));
k_2 = F_xy(x(i)+0.5*h*k_1);
k_3 = F_xy((x(i)+0.5*h*k_2));
k_4 = F_xy((x(i)+k_3*h));

x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

y(i+1)=y(i)+h*x(i+1);

e(i+1)=r-y(i+1);

er=sum(e);

ed=e(i+1)-e(i);

v(i+1)=(e(i+1)/r)*(ed/r);

kpp(i+1)=kp*(1+k1*abs(v(i+1)));
kii(i+1)=ki*(0.3+k2*v(i+1));
kdd(i+1)=kd*(1+k3*abs(v(i+1)));


u(i+1)=kpp(i+1)*e(i+1)+ kii(i+1)*sum(e)+ kdd(i+1)*ed;

end


F_xy = @(u,y,x) u-y-2*x;

for i = 3:(tf/2)
k_1 = F_xy(u(i-2),y(i),x(i));

k_2 = F_xy(u(i-2)+0.5*h,y(i)+0.5*h,x(i)+0.5*h*k_1);

k_3 = F_xy((u(i-2)+0.5*h),(y(i)+0.5*h),(x(i)+0.5*h*k_2));

k_4 = F_xy((u(i-2)+h ) ,(y(i)+h) ,(x(i)+k_3*h));

x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

y(i+1)=y(i)+h*x(i+1);

e(i+1)=r-y(i+1);
```

```
ed=e(i+1)-e(i);
er=sum(e);
v(i+1)=(e(i+1)/r)*(ed/r);
kpp(i+1)=kp*(1+k1*abs(v(i+1)));

kii(i+1)=ki*(0.3+k2*v(i+1));

kdd(i+1)=kd*(1+k3*abs(v(i+1)));


u(i+1)=kpp(i+1)*e(i+1)+ kii(i+1)*sum(e)+ kdd(i+1)*ed;

end


u((tf/2)+1)= -14;

F_xy = @(u,y,x) u-y-2*x;


for i = (tf/2)+1:length(t)
    k_1 = F_xy(u(i-2),y(i),x(i));

    k_2 = F_xy(u(i-2)+0.5*h,y(i)+0.5*h,x(i)+0.5*h*k_1);

    k_3 = F_xy((u(i-2)+0.5*h),(y(i)+0.5*h),(x(i)+0.5*h*k_2));

    k_4 = F_xy((u(i-2)+h ) ,(y(i)+h) ,(x(i)+k_3*h));

    x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

   y(i+1)=y(i)+h*x(i+1);

e(i+1)=r-y(i+1);
ed=e(i+1)-e(i);
er=sum(e);
v(i+1)=(e(i+1)/r)*(ed/r);
kpp(i+1)=kp*(1+k1*abs(v(i+1)));

kii(i+1)=ki*(0.3+k2*v(i+1));

kdd(i+1)=kd*(1+k3*abs(v(i+1)));


u(i+1)=kpp(i+1)*e(i+1)+ kii(i+1)*sum(e)+ kdd(i+1)*ed;

end


z=y(1:(tf+1));

plot(t,z)
hold on
xlabel('Time t ')
ylabel('Response y')
title('APID  Response of second order system TF=exp(-0.2s)/s2+2s+1) ')
grid on
```

Matlab code for genetic algorithm based PID controller , GA-CPID of TF1

```
%%%%%%%%%%%%%%%genetic algorithm based pid controller
%%%% exp(-0.2s) /(s+1)^2

%%%first we will clculate kp ki kd from zeigler nichols method.
%By varying plus minus 20% of all the tuned values(kp ki kd)
%We will calculate best tuned valuve of kp ki kd with the help of genetic algotithm

clc ;

clear;

popsize=10;

Nt=12;

no_of_variable=3;


pop=round(rand(popsize,Nt));


aa=pop(:,1:4);

bb=pop(:,5:8);

cc=pop(:,9:12);


d1=bi2de(aa,'left-msb');
d2=bi2de(bb,'left-msb');
d3=bi2de(cc,'left-msb');


%%%initialization %%%%%%%%%%%%


  ku=10.5;
  tu=2.0333;


 kp=0.6*ku;


 ti=tu/2;
 td=tu/8;

ki=kp*(0.1/ti);
kd=kp*(td/0.1);




xh1=kp+0.20*kp;
```

```
xl1=kp-0.20*kp;


xh2=ki+0.20*ki;
xl2=ki-0.20*ki;

xh3=kd+0.20*kd;
xl3=kd-0.20*kd;

w1=1;
w2=1;

nmut=2;


h=0.1;

t = 0:h:16;


tf=160

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

for i=1:10


x1(i,1)=xl1+((xh1-xl1)/(2^4-1))*d1(i);

x2(i,1)=xl2+((xh2-xl2)/(2^4-1))*d2(i);

x3(i,1)=xl3+((xh3-xl3)/(2^4-1))*d3(i);



end




d=[x1 x2 x3 ] ;





%%%%%objective function

for j=1:10


    kp=d(j,1);
    ki=d(j,2);
    kd=d(j,3);




% % %
% % % h=0.1;
```

```
% % %
% % % % step size
% % %
% % % t = 0:h:16;
% % % tf=160


y = zeros(1,length(t));
u = zeros(1,length(t));
e = zeros(1,length(t));
x = zeros(1,length(t));
input = 1;
y(1) = 0;
x(1)=0 ;
e(1)=input - y(1);

 u(1)=kp*e(1)+ki*sum(e);

F_xy = @(x) -2*x;

for i = 1:2
  %y and u taken as time input and x as output



   k_1 = F_xy(x(i));
   k_2 = F_xy(x(i)+0.5*h*k_1);
   k_3 = F_xy((x(i)+0.5*h*k_2));
   k_4 = F_xy((x(i)+k_3*h));




    x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

    y(i+1)=y(i)+h*x(i+1);

   e(i+1)=1-y(i+1);



   ed=e(i+1)-e(i);



   u(i+1)=kp*e(i+1)+ki*sum(e)+kd*ed;



end


F_xy = @(u,y,x) u-y-2*x;


for i = 3:80

    k_1 = F_xy(u(i-2),y(i),x(i));
```

```
    k_2 = F_xy(u(i-2)+0.5*h,y(i)+0.5*h,x(i)+0.5*h*k_1);

    k_3 = F_xy((u(i-2)+0.5*h),(y(i)+0.5*h),(x(i)+0.5*h*k_2));

    k_4 = F_xy((u(i-2)+h ) ,(y(i)+h) ,(x(i)+k_3*h));



    x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

   y(i+1)=y(i)+h*x(i+1);

   e(i+1)=1-y(i+1);

   ed=e(i+1)-e(i);

  u(i+1)=kp*e(i+1)+ki*sum(e)+kd*ed;

end

u(81)=-20;



F_xy = @(u,y,x) u-y-2*x;

for i = 81:length(t)

    k_1 = F_xy(u(i-2),y(i),x(i));

    k_2 = F_xy(u(i-2)+0.5*h,y(i)+0.5*h,x(i)+0.5*h*k_1);

    k_3 = F_xy((u(i-2)+0.5*h),(y(i)+0.5*h),(x(i)+0.5*h*k_2));

    k_4 = F_xy((u(i-2)+h ) ,(y(i)+h) ,(x(i)+k_3*h));



    x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

   y(i+1)=y(i)+h*x(i+1);

   e(i+1)=1-y(i+1);

   ed=e(i+1)-e(i);
```

```
   u(i+1)=kp*e(i+1)+ki*sum(e)+kd*ed;

end


z=y(1:161);

figure(j+1)

plot(t,z)

xlabel('Time t(s) ')

ylabel('Response y')

title(' exp(-0.2s) /(s+1)^2  ')

grid on


%%%%iaeitae

iaeiae(j,1)=0.1*sum(abs(e));

h=0.1;

for i= 1:length(t)

g(i)=0.01*i*e(i);

end

itaeitae(j,1)=sum(abs(g));


 end


iae=w1*iaeiae+w2*itaeitae;




[iae ind]=sort(iae);

pop=pop(ind,:);

d=d(ind,:);
```

```
iga=0;

 while iga<20



iga=iga+1;

%%%%%%%%%%%%%%%%selection of mimimum five iae%%%%%%%%%%%%%%%%%%%%%%%

  pop;

  p1=[pop(1,1:2) pop(2,3:4) pop(1,5:6) pop(2,7:8) pop(1,9:10) pop(2,11:12) ];

  p2=[pop(2,1:2) pop(1,3:4) pop(2,5:6) pop(1,7:8) pop(2,9:10) pop(1,11:12) ];

  p3=[pop(3,1:2) pop(4,3:4) pop(3,5:6) pop(4,7:8) pop(3,9:10) pop(4,11:12)  ];

  p4=[pop(4,1:2) pop(3,3:4) pop(4,5:6) pop(3,7:8) pop(4,9:10) pop(3,11:12)  ];

  p5=[pop(5,1:2) pop(1,3:4) pop(5,5:6) pop(1,7:8) pop(5,9:10) pop(1,11:12)  ];




  m =[p1;p2;p3;p4;p5];

  pop(6:10,:)=m ;






aa=pop(:,1:4);

bb=pop(:,5:8);

cc=pop(:,9:12);

d1=bi2de(aa,'left-msb');
d2=bi2de(bb,'left-msb');
d3=bi2de(cc,'left-msb');



for i=1:10


x1(i,1)=xl1+((xh1-xl1)/(2^4-1))*d1(i);
```

```
x2(i,1)=xl2+((xh2-xl2)/(2^4-1))*d2(i);

x3(i,1)=xl3+((xh3-xl3)/(2^4-1))*d3(i);




end

d=[x1 x2 x3 ] ;


 %%%%objective function


for j=1:10


    kp=d(j,1);
    ki=d(j,2);
    kd=d(j,3);



y = zeros(1,length(t));
u = zeros(1,length(t));
e = zeros(1,length(t));
x = zeros(1,length(t));
input = 1;
y(1) = 0;
x(1)=0 ;
e(1)=input - y(1);


 u(1)=kp*e(1)+ki*sum(e);

F_xy = @(x) -2*x;

for i = 1:2
  %y and u taken as time input and x as output

   k_1 = F_xy(x(i));
   k_2 = F_xy(x(i)+0.5*h*k_1);
   k_3 = F_xy((x(i)+0.5*h*k_2));
   k_4 = F_xy((x(i)+k_3*h));





    x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

    y(i+1)=y(i)+h*x(i+1);

   e(i+1)=1-y(i+1);

   ed=e(i+1)-e(i);


   u(i+1)=kp*e(i+1)+ki*sum(e)+kd*ed;
```

```
end

F_xy = @(u,y,x) u-y-2*x;

for i = 3:80
    k_1 = F_xy(u(i-2),y(i),x(i));
    k_2 = F_xy(u(i-2)+0.5*h,y(i)+0.5*h,x(i)+0.5*h*k_1);
    k_3 = F_xy((u(i-2)+0.5*h),(y(i)+0.5*h),(x(i)+0.5*h*k_2));
    k_4 = F_xy((u(i-2)+h ) ,(y(i)+h) ,(x(i)+k_3*h));
    x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;
   y(i+1)=y(i)+h*x(i+1);
   e(i+1)=1-y(i+1);

   ed=e(i+1)-e(i);
  u(i+1)=kp*e(i+1)+ki*sum(e)+kd*ed;

end

u(81)=-20


F_xy = @(u,y,x) u-y-2*x;

for i = 81:length(t)
    k_1 = F_xy(u(i-2),y(i),x(i));
    k_2 = F_xy(u(i-2)+0.5*h,y(i)+0.5*h,x(i)+0.5*h*k_1);
    k_3 = F_xy((u(i-2)+0.5*h),(y(i)+0.5*h),(x(i)+0.5*h*k_2));
    k_4 = F_xy((u(i-2)+h ) ,(y(i)+h) ,(x(i)+k_3*h));
    x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;
   y(i+1)=y(i)+h*x(i+1);
   e(i+1)=1-y(i+1);

   ed=e(i+1)-e(i);
```

```
   u(i+1)=kp*e(i+1)+ki*sum(e)+kd*ed;

end



z=y(1:161);

figure(j+1)
plot(t,z)


xlabel('Time t(s) ')

ylabel('Response y')

title(' exp(-0.2s) /(s+1)^2  ')

grid on



%%%%iaeitae

iaeiae(j,1)=0.1*sum(abs(e))


h=0.1;

for i= 1:length(t)

g(i)=0.01*i*e(i);

end

itaeitae(j,1)=sum(abs(g));



 end



iae=w1*iaeiae+w2*itaeitae

[iae ind]=sort(iae);

pop=pop(ind,:);

d=d(ind,:)
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%mutation%%%%%%%%%%%%%%


pop ;


mrow=ceil(rand(1,nmut)*(popsize-1))+1 ;

mcol=ceil(rand(1,nmut)*Nt) ;


for ii=1:nmut

pop(mrow(ii),mcol(ii))=abs(pop(mrow(ii),mcol(ii))-1);

end




pop ;

aa=pop(:,1:4);

bb=pop(:,5:8);

cc=pop(:,9:12);

d1=bi2de(aa,'left-msb');
d2=bi2de(bb,'left-msb');
d3=bi2de(cc,'left-msb');



for i=1:10


x1(i,1)=xl1+((xh1-xl1)/(2^4-1))*d1(i);

x2(i,1)=xl2+((xh2-xl2)/(2^4-1))*d2(i);

x3(i,1)=xl3+((xh3-xl3)/(2^4-1))*d3(i);




end




d=[x1 x2 x3 ] ;
```

```
for j=1:10


    kp=d(j,1);
    ki=d(j,2);
    kd=d(j,3);





h=0.1;

% step size

t = 0:h:16;
tf=160


y = zeros(1,length(t));
u = zeros(1,length(t));
e = zeros(1,length(t));
x = zeros(1,length(t));
input = 1;
y(1) = 0;
x(1)=0 ;
e(1)=input - y(1);


 u(1)=kp*e(1)+ki*sum(e);


F_xy = @(x) -2*x;

for i = 1:2
  %y and u taken as time input and x as output




   k_1 = F_xy(x(i));
   k_2 = F_xy(x(i)+0.5*h*k_1);
   k_3 = F_xy((x(i)+0.5*h*k_2));
   k_4 = F_xy((x(i)+k_3*h));






    x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

    y(i+1)=y(i)+h*x(i+1);

   e(i+1)=1-y(i+1);




   ed=e(i+1)-e(i);
```

```
    u(i+1)=kp*e(i+1)+ki*sum(e)+kd*ed;


end

F_xy = @(u,y,x) u-y-2*x;

for i = 3:80
     k_1 = F_xy(u(i-2),y(i),x(i));
     k_2 = F_xy(u(i-2)+0.5*h,y(i)+0.5*h,x(i)+0.5*h*k_1);
     k_3 = F_xy((u(i-2)+0.5*h),(y(i)+0.5*h),(x(i)+0.5*h*k_2));
     k_4 = F_xy((u(i-2)+h ) ,(y(i)+h) ,(x(i)+k_3*h));


     x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;
    y(i+1)=y(i)+h*x(i+1);
    e(i+1)=1-y(i+1);

    ed=e(i+1)-e(i);
   u(i+1)=kp*e(i+1)+ki*sum(e)+kd*ed;

end

u(81)=-20


F_xy = @(u,y,x) u-y-2*x;

for i = 81:length(t)
     k_1 = F_xy(u(i-2),y(i),x(i));
     k_2 = F_xy(u(i-2)+0.5*h,y(i)+0.5*h,x(i)+0.5*h*k_1);
     k_3 = F_xy((u(i-2)+0.5*h),(y(i)+0.5*h),(x(i)+0.5*h*k_2));
     k_4 = F_xy((u(i-2)+h ) ,(y(i)+h) ,(x(i)+k_3*h));
```

```
    x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

   y(i+1)=y(i)+h*x(i+1);

   e(i+1)=1-y(i+1);


   ed=e(i+1)-e(i);



   u(i+1)=kp*e(i+1)+ki*sum(e)+kd*ed;

end



z=y(1:161);

figure(j+1)
plot(t,z)


xlabel('Time t(s) ')

ylabel('Response y')

title(' exp(-0.2s) /(s+1)^2  ')

grid on



%%%%iaeitae

iaeiae(j,1)=0.1*sum(abs(e))


h=0.1;

for i= 1:length(t)

g(i)=0.01*i*e(i);

end

itaeitae(j,1)=sum(abs(g));



 end



iae=w1*iaeiae+w2*itaeitae
```

```
[iae ind]=sort(iae);

pop=pop(ind,:);

d=d(ind,:)


end


ind;

iga

d;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

 for j=1
     kp=d(j,1);
    ki=d(j,2);
    kd=d(j,3);



% % %
% % %
% % % h=0.1;
% % %
% % % % step size
% % %
% % % t = 0:h:16;




y = zeros(1,length(t));
u = zeros(1,length(t));
e = zeros(1,length(t));
x = zeros(1,length(t));
input = 1;
y(1) = 0;
x(1)=0 ;
e(1)=input - y(1);


 u(1)=kp*e(1)+ki*sum(e);

F_xy = @(x) -2*x;

for i = 1:2
  %y and u taken as time input and x as output




   k_1 = F_xy(x(i));
   k_2 = F_xy(x(i)+0.5*h*k_1);
   k_3 = F_xy((x(i)+0.5*h*k_2));
   k_4 = F_xy((x(i)+k_3*h));
```

```
    x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

    y(i+1)=y(i)+h*x(i+1);

   e(i+1)=1-y(i+1);


   ed=e(i+1)-e(i);


   u(i+1)=kp*e(i+1)+ki*sum(e)+kd*ed;


end

F_xy = @(u,y,x) u-y-2*x;

for i = 3:80

    k_1 = F_xy(u(i-2),y(i),x(i));

    k_2 = F_xy(u(i-2)+0.5*h,y(i)+0.5*h,x(i)+0.5*h*k_1);

    k_3 = F_xy((u(i-2)+0.5*h),(y(i)+0.5*h),(x(i)+0.5*h*k_2));

    k_4 = F_xy((u(i-2)+h ) ,(y(i)+h) ,(x(i)+k_3*h));

    x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

   y(i+1)=y(i)+h*x(i+1);

   e(i+1)=1-y(i+1);

   ed=e(i+1)-e(i);

  u(i+1)=kp*e(i+1)+ki*sum(e)+kd*ed;

end

u(81)=-20;


F_xy = @(u,y,x) u-y-2*x;

for i = 81:length(t)
```

```
    k_1 = F_xy(u(i-2),y(i),x(i));

    k_2 = F_xy(u(i-2)+0.5*h,y(i)+0.5*h,x(i)+0.5*h*k_1);

    k_3 = F_xy((u(i-2)+0.5*h),(y(i)+0.5*h),(x(i)+0.5*h*k_2));

    k_4 = F_xy((u(i-2)+h ) ,(y(i)+h) ,(x(i)+k_3*h));

    x(i+1) = x(i) + (1/6)*(k_1+2*k_2+2*k_3+k_4)*h;

   y(i+1)=y(i)+h*x(i+1);

   e(i+1)=1-y(i+1);


   ed=e(i+1)-e(i);


   u(i+1)=kp*e(i+1)+ki*sum(e)+kd*ed;

end

z=y(1:161);

figure(1)

plot(t,z)

xlabel('Time t(s) ')

ylabel('Response y')

title(' exp(-0.2s) /(s+1)^2  ')

grid on

 end



%%%%% time domain specification -over shoot,risetime ,settling time
%%%%% ,iae,itae


y;

yy = y(1:(tf/2));

[yymax tp]=max(yy);

peak_time=(tp-1)*0.1;


overshoot=(yymax-1)*100


rr=1;
```

```
while y(rr)<1.0001


    rr=rr+1;

end

rise_time=(rr-1)*0.1

s=(tf/2);

while y(s)>0.98 & y(s)<1.02;
    s=s-1;
end


settling_time=(s-1)*0.1

iae=0.1*sum(abs(e))


h=0.1;

for i= 1:length(t)

g(i)=0.01*i*e(i);

end

itae=sum(abs(g));

itae
```