REPORT ON REGELTECHNIEK WPO SESSION

Date
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THIRD SESSION - EXERCISES

1. Consider the following control setup

```
clear all;
close all;

%% a.1 simulation parameters
fs=100; % sampling frequency
t_max=100; %max time
t=(0:1/fs:t_max)'; % time scale
r=20*ones(size(t)); %reference signal - set point SP

s=tf('s');
G_controller=1;
G_system=10/(1+5*s)*exp(-8*s); %tf([10],[5 1],'InputDelay',8)
G_sensor=0.5/(1+s);

%open loop gain
G_0=G_controller*G_system*G_sensor; % G_0=*G_system*G_sensor;
% closed loop system
G_closed=feedback(G_controller*G_system,G_sensor); %G_system/(1+system*G_sensor)


%% a.1 calculating the responses

% system output -process variable PV
y=lsim(G_closed,r,t); % y=20*step(G_closed,t)
% measured output - measured process variable MPV
y_m=lsim(G_closed*G_sensor,r,t); %y_my=20*step(G_closed*G_sensor,t)
% error signal
e=r-y_m;
figure; hold on;
plot(t,r);
plot(t,y);
plot(t,y_m);
plot(t,e);
xlabel('time [sec]'); ylabel('amplitude')
legend({'reference (SP)','output (PV)','measured output (MPV)','error'})

%% a.2
figure; bode(G_0); grid on
figure; margin(G_0); % according to this the system is stable ;)


%% b.1.

w=10e-3:10e-4:1;
figure; bode(G_0,w); grid on
% phase 120 degree is at 0.158 rad/sec, the magnitude there is 11.8 dB
gain=1/10^(11.8/20); %-11.8 dB

G_controller=gain;
G_0=G_controller*G_system*G_sensor;
G_closed=feedback(G_controller*G_system,G_sensor);

figure; margin(G_0); grid on

%% b.2.

y_P=lsim(G_closed,r,t);
y_m_P=lsim(G_closed*G_sensor,r,t);
e_P=r-y_m_P;
figure; hold on; plot(t,r); plot(t,y_P); plot(t,y_m_P); plot(t,e_P);
```

```
xlabel('time [sec]'); ylabel('amplitude')
legend({'reference (SP)','output (PV)','measured output (MPV)','error'})
% WARNING: simulation time is insufficient!!!

t_max=500; t=(0:1/fs:t_max)'; r=20*ones(size(t));
y_P=lsim(G_closed,r,t);
y_m_P=lsim(G_closed*G_sensor,r,t);
e_P=r-y_m_P;
figure; hold on; plot(t,r); plot(t,y_P); plot(t,y_m_P); plot(t,e_P);
xlabel('time [sec]'); ylabel('amplitude')
legend({'reference (SP)','output (PV)','measured output (MPV)','error'});

%% b.3.

E_P_therory=20*(1/(1+dcgain(G_0))) % steady state error, theoretical
E_P_simulated=e_P(end) % steady state error, simulated

%% c.1
Ti=max(-(1/real(roots(G_0.Denominator{:})))); % you can read it from Bode,step response as well
G_controller=gain*(1+1/(s*Ti));
G_0=G_controller*G_system*G_sensor;
G_closed=feedback(G_controller*G_system,G_sensor);

y_m=lsim(G_closed*G_sensor,r,t);
figure; plot(t,y_m); legend({'measured output (MPV)'}); xlabel('time [sec]'); ylabel('amplitude')

figure; bode(G_0,w); grid on % phase 120 degree is at 0.041 rad/sec, the magnitude there is 29.7 dB

%% c.2
gain_pi=1/10^(29.7/20); %-29.7 dB
G_controller=gain*gain_pi*(1+1/(s*Ti));
G_0=G_controller*G_system*G_sensor;
G_closed=feedback(G_controller*G_system,G_sensor);


y_PI=lsim(G_closed,r,t);
y_m_PI=lsim(G_closed*G_sensor,r,t);
e_PI=r-y_m_PI;
figure; hold on; plot(t,r); plot(t,y_PI); plot(t,y_m_PI); plot(t,e_PI);
xlabel('time [sec]'); ylabel('amplitude')
legend({'reference (SP)','output (PV)','measured output (MPV)','error'})

E_PI_therory=20*(1/(1+dcgain(G_0))) % steady state error, theoretical
E_PI_simulated=e_PI(end) % steady state error, simulated


%% c.3

figure; hold on; plot(t,r); plot(t,y_m_P); plot(t,y_m_PI); plot(t,e_P,'--'); plot(t,e_PI,'--');
xlabel('time [sec]'); ylabel('amplitude')
legend({'reference (SP)','P','PI','e_P','e_{PI}'})
```

2. Consider the following control setup using *Simulink*

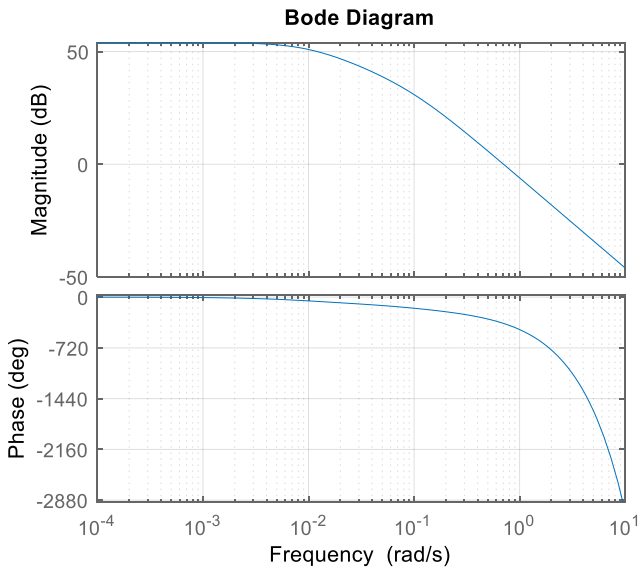
a) Realize the systems with the following parameters $G_{controller}(s) = 1, G_{system}(s) = \frac{0.5}{s^2+0.11s+0.001}, G_{sensor}(s) = 1$

b) Design a P controller that have 45 degrees of phase margin. Apply 20 (Celsius) as step reference signal

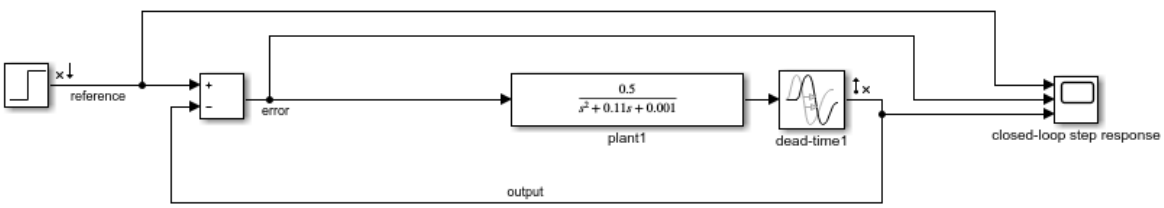
c) Consider exercise b) but with a PI controller

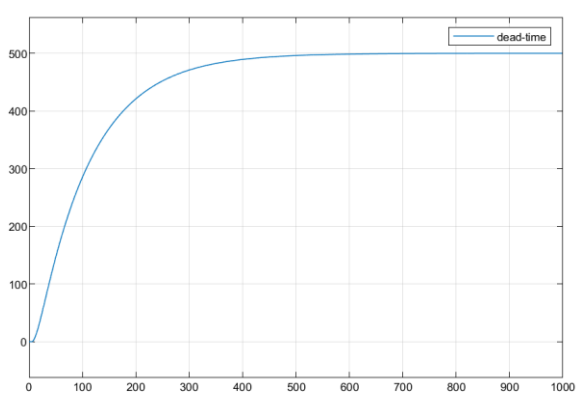
d) Consider exercise c) but with a PID controller

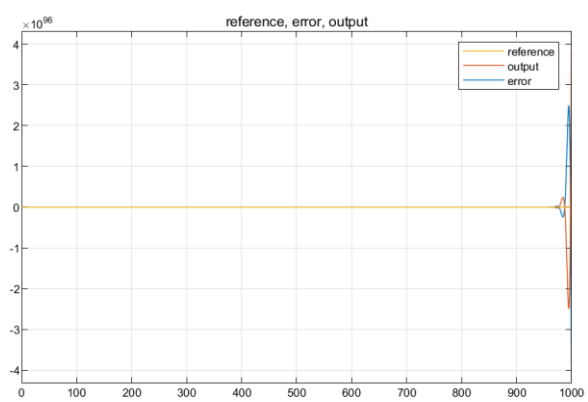
e) Compare the step responses from b)-d) with the reference signal and analyze the results. What conclusions can you draw?

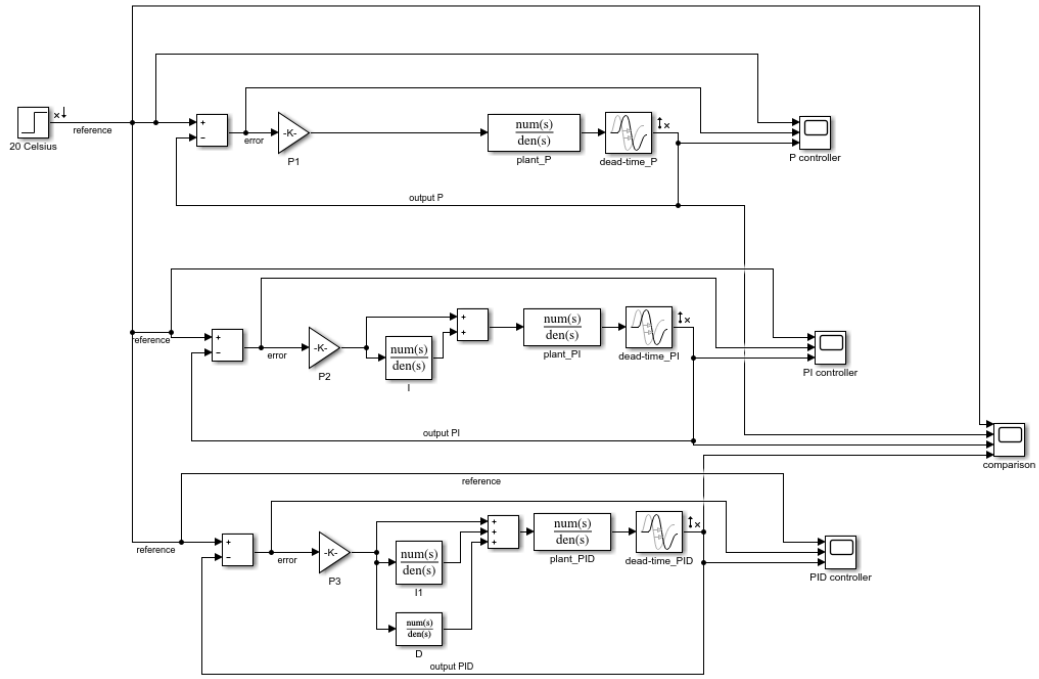

Bode Diagram
Magnitude (dB)
50
0
-50
Phase (deg)
0
-720
-1440
-2160
-2880
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
Frequency (rad/s)

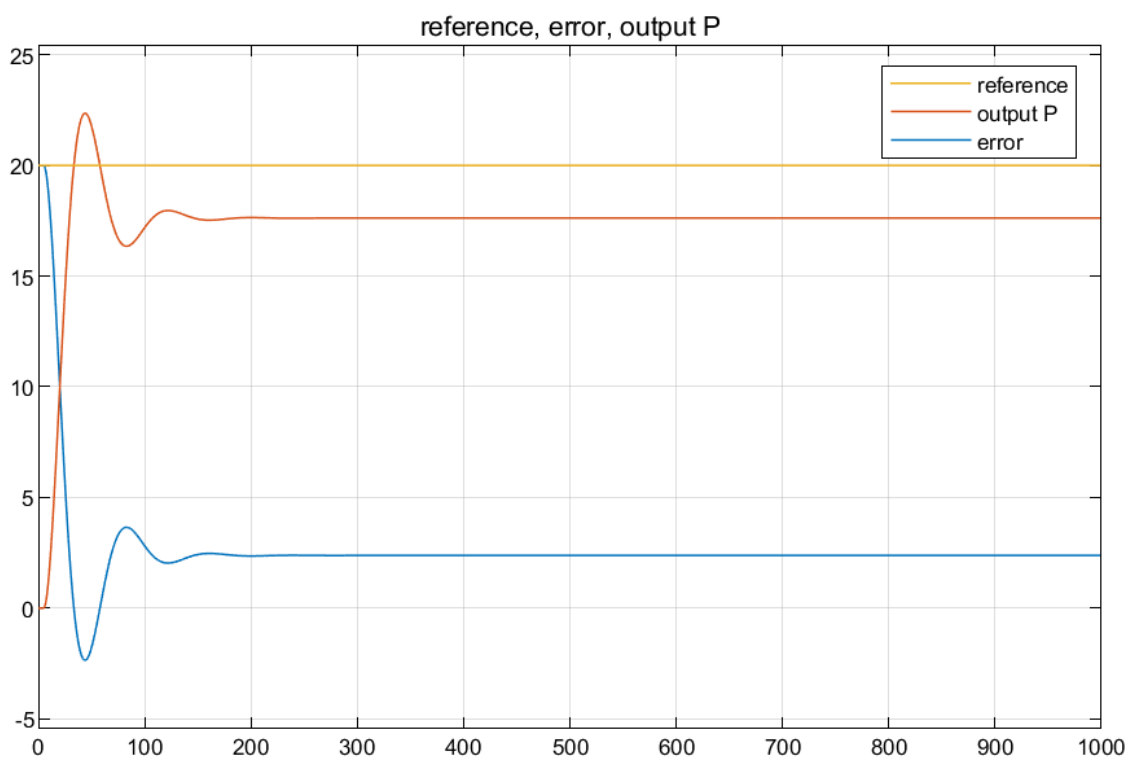

$\frac{0.5}{s^2+0.11s+0.001}$
plant
dead-time
open-loop step response

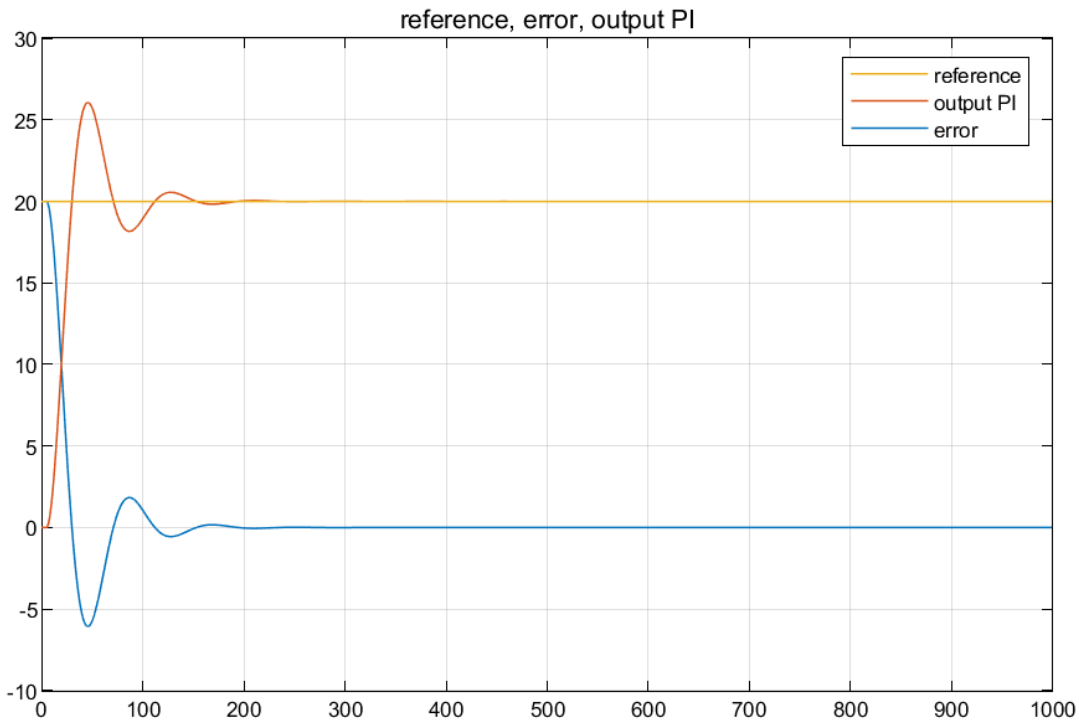

reference
error
$\frac{0.5}{s^2+0.11s+0.001}$
plant1
dead-time1
closed-loop step response
output

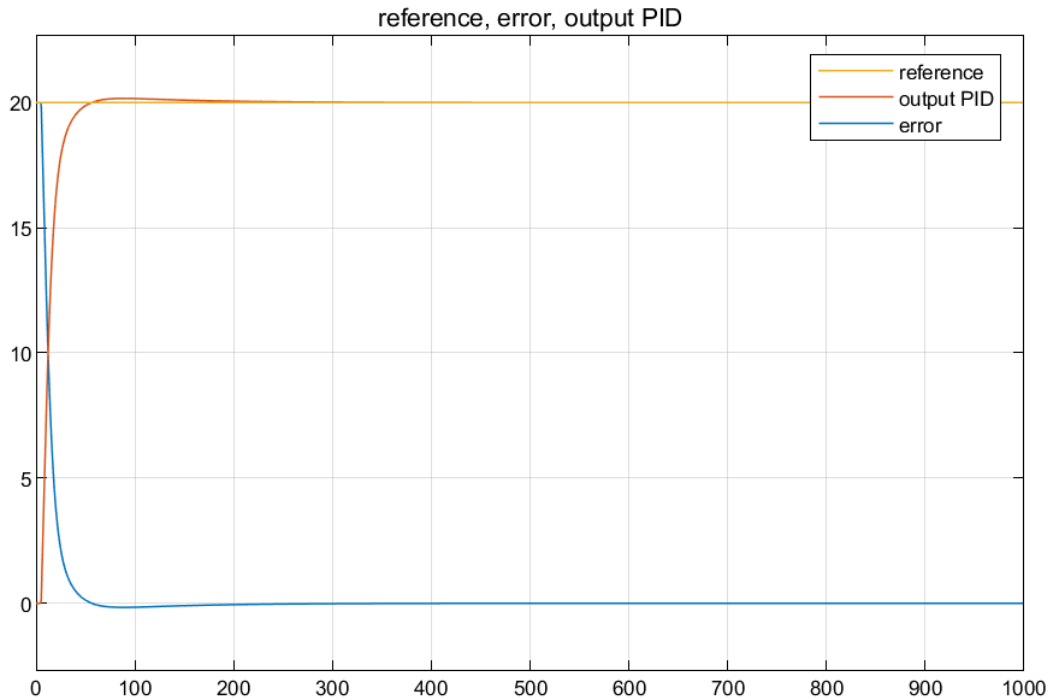

dead-time
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
1000


reference, error, output
$\times 10^{96}$
reference
output
error
4
3
2
1
0
-1
-2
-3
-4
0
100
200
300
400
500
600
700
800
900
1000


20 Celsius
reference
error
-K-
P1
num(s)
den(s)
plant_P
dead-time_P
P controller
output P
reference
error
-K-
P2
I
plant_PI
dead-time_PI
PI controller
output PI
comparison
reference
reference
error
-K-
P3
I1
D
plant_PID
dead-time_PID
PID controller
output PID


reference, error, output P
reference
output P
error
25
20
15
10
5
0
-5
0
100
200
300
400
500
600
700
800
900
1000


reference, error, output PI
reference
output PI
error
30
25
20
15
10
5
0
-5
-10
0
100
200
300
400
500
600
700
800
900
1000


reference, error, output PID
reference
output PID
error
20
15
10
5
0
0
100
200
300
400
500
600
700
800
900
1000


reference, output P, output PI, output PID
reference
output PID
output PI
output P
25
20
15
10
5
0
0
20
40
60
80
100
120
140
160
180
200