```matlab
%HW 7. Aly Khater
clear; close all; clc;

%Discrete Equation to get is th(k+1)=0.7788th(k)+0.0442q(k)+0.2212th_a(k)
%Model is th_dot=kq/T+th_a/T-th/T
%th_dot = (-1)th+(0.2)q+(1)th_a
A = -1;
B = [0.2 1];
C = 1;
D = zeros(1,2);
%Continous time system
sys_c = ss(A,B,C,D)
```

```
sys_c =

  A =
       x1
   x1  -1

  B =
       u1    u2
   x1  0.2    1

  C =
       x1
   y1   1

  D =
       u1   u2
   y1   0    0

Continuous-time state-space model.
Model Properties
```

```matlab
% Discrete transform with sampling time
Ts = 0.25; %Sampling interval
T = 1; %Sampling period
sys_d = c2d(sys_c, Ts);
Bu = sys_d.B(:,1); % control input q
Bd = sys_d.B(:,2); % disturbance input theta_a
Du = sys_d.D(:,1);
Dd = sys_d.D(:,2);
```

```matlab
%Convert to MOD format
%pmod = ss2mod(sys_d.A, Bu, sys_d.C, Du, Bd, Dd, Ts);
B_full = [Bu Bd];    % Bu = control input, Bd = measured disturbance
D_full = [Du Dd];    % Du and Dd are scalars

% minfo
minfo = [Ts, 1, 1, 1, 0, 1, 0];   % [dt, n, nu, nd, nw, nym, nyu]

pmod = ss2mod(sys_d.A, B_full, sys_d.C, D_full, minfo);
```

```matlab
% MPC Params for smpcon
Hp = 10; % Prediction horizon
Hu = 3; % Control horizon
ywt = ones(Hp,1); % Output Weights
uwt = zeros(Hu,1); % Control weights
% smpcon to get K_s
%Output should be K_s=[22.604,-17.604,-22.604]
Ks = smpccon(pmod, ywt, uwt, Hu, Hp)
```

```
Ks = 1×4
   22.6041  -17.6041  -22.6041   -5.0000
```

```matlab
% Part c
th_a = 15;           % Constant theta_a
th_set = 20;         % setpoint  given
tend = 30;           % Number of sim steps
r = th_set * ones(tend,1);  % Setpoint

% All zero
ulim = [];
ylim_ = [];
Kest = [];
z = [];
v = th_a * ones(tend,1); %th_a = 15
w = [];
wu = [];

% plot SCMPC with setpoints
[y,u] = scmpc(pmod, pmod, ywt, uwt, Hu, Hp, tend, r, ulim, ylim_, Kest, z, v, w, wu);

figure;
plotall(y, u, T);  % T = 1 hour from earlier
subplot(2,1,1);
ylim([18 23]);;
yline(20,"r--","Setpoint");
title("T = 1 hour. With th_a = 15")
% plot the error
subplot(2,1,2);
error = y-th_set;
plot(error);
title("T = 1 hour. Error")
```

T = 1 hour. With th$_a$ = 15

Setpoint

Time

T = 1 hour. Error
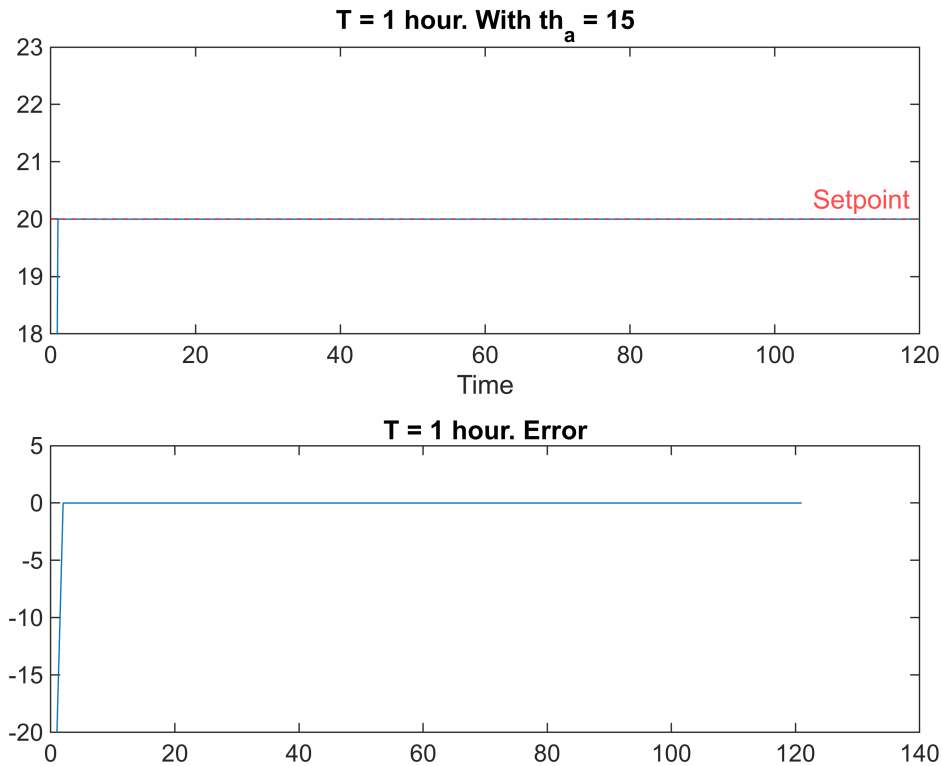
```
% Pool parameters changed: T = 1.25 hr, k = 0.3
T_c = 1.25;
k_c = 0.3;
A_c = -1 / T_c;
Bq_c = k_c / T_c;
Ba_c = 1 / T_c;

% Create continuous and discrete-time systems
sys_c_c = ss(A_c, [Bq_c Ba_c], C, D);
sys_d_c = c2d(sys_c_c, Ts);

% full B and D matrices
B_full_c = sys_d_c.B;    % [Bu Bd]
D_full_c = sys_d_c.D;    % [Du Dd]

%
minfo_c = [Ts, 1, 1, 1, 0, 1, 0];  % same structure as original

% Create MOD-format model with measured disturbance
pmod_c = ss2mod(sys_d_c.A, B_full_c, sys_d_c.C, D_full_c, minfo_c);


% plot SCMPC with setpoints
[y_c,u_c] = scmpc(pmod_c, pmod, ywt, uwt, Hu, Hp, tend, r, ulim, ylim_, Kest, z, v,
w, wu);
```
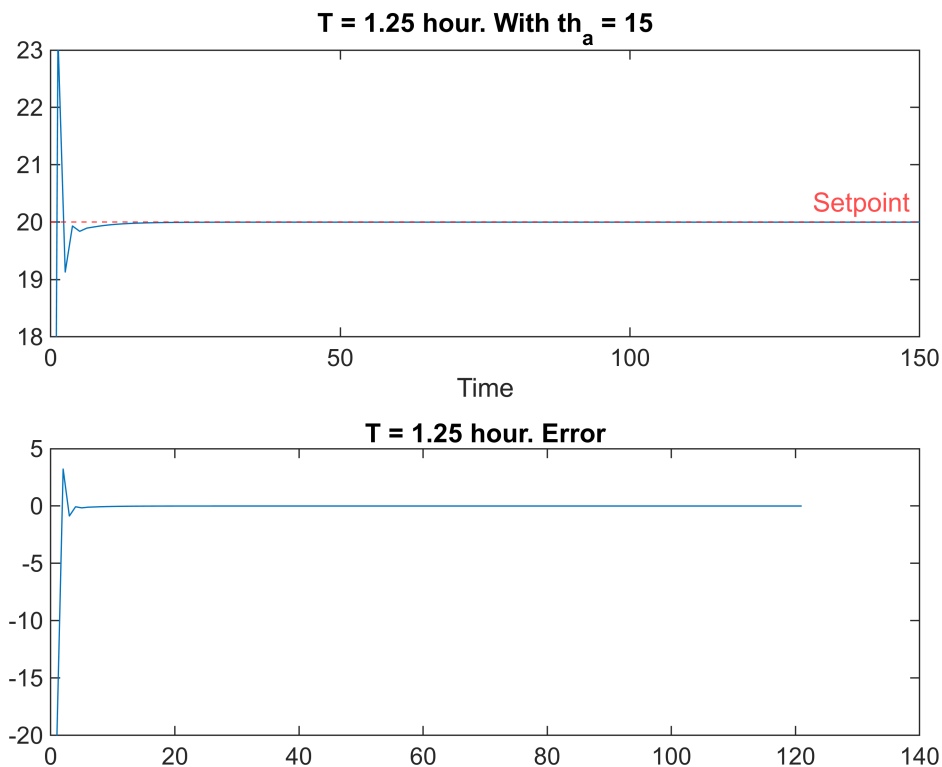
3

```matlab
figure;
plotall(y_c, u_c, T_c);   % T = 1.25 hour
subplot(2,1,1);
ylim([18 23]);
yline(20,"r--","Setpoint");
title("T = 1.25 hour. With th_a = 15")
% plot the error
subplot(2,1,2);
error = y_c-th_set;
plot(error);
title("T = 1.25 hour. Error")
```



```matlab
% They both sit at 20 for the setpoint
```

```matlab
% Part d, change th_a again. Has disturbance
% create a time vector according to sampling interval
tend = 96; %for 24 hours 96 x .25
t_v = (0:tend-1);
th_a_sin = 15+10*sin((2*pi/24)*t_v); %diurnal sinusoidal theta_a

v = th_a_sin'; % Measured disturbance

[y_sin,u_sin] = scmpc(pmod_c, pmod, ywt, uwt, Hu, Hp, tend, r, ulim, ylim_, Kest,
z, v, w, wu);
```
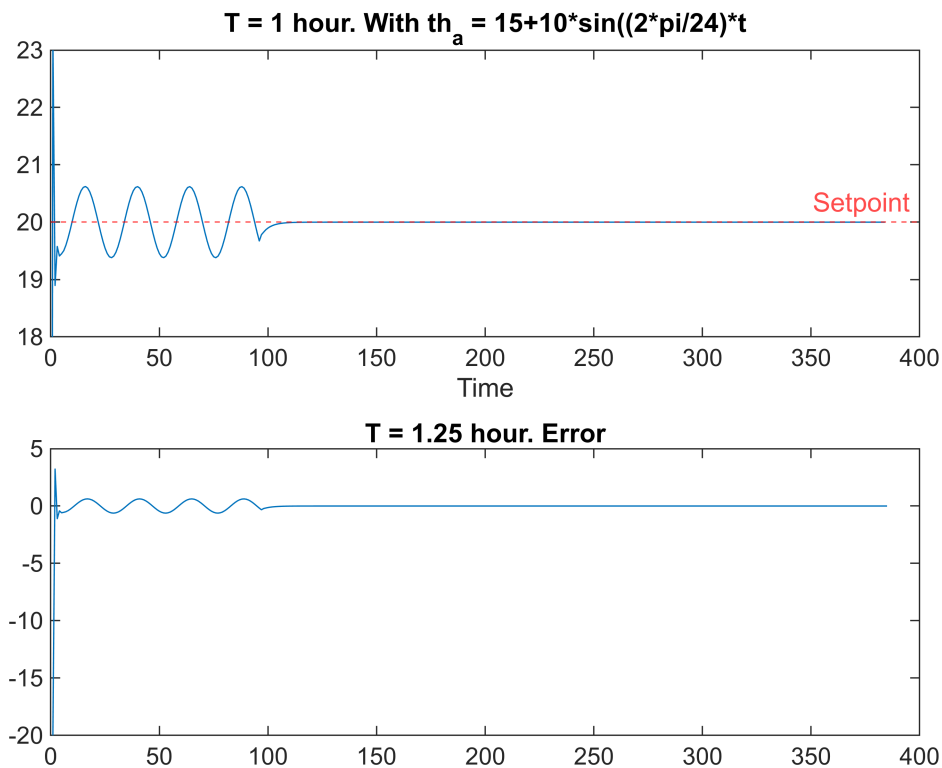
4

```
figure;
%ylim([0 25]);
plotall(y_sin, u_sin, T);  % T = 1 hour
subplot(2,1,1);
ylim([18 23]);
yline(20,"r--","Setpoint");
title("T = 1 hour. With th_a = 15+10*sin((2*pi/24)*t")
% plot the error
subplot(2,1,2);
error = y_sin-th_set;
plot(error);
title("T = 1.25 hour. Error")
```


T = 1 hour. With th$_a$ = 15+10*sin((2*pi/24)*t

T = 1.25 hour. Error

```
% Part e. Add contrained input 0<=q<=40kW
ulim = [0 40 Inf];
[y_con,u_con] = scmpc(pmod_c, pmod, ywt, uwt, Hu, Hp, tend, r, ulim, ylim_, Kest,
z, v, w, wu);
```

One or more constraints on delta_u were > 1e6 or < 1e-6.
Modified to prevent numerical problems in QP.

```
figure;
%ylim([0 25]);
plotall(y_con, u_con, T);  % T = 1 hour
```

```
subplot(2,1,1);
ylim([18 23]);
yline(20,"r--","Setpoint");
title("T = 1 hour. With th_a = 15+10*sin((2*pi/24)*t")
% plot the error
subplot(2,1,2);
error = y_con-th_set;
plot(error);
title("T = 1.25 hour. Error")
```