CH5120 ASSIGNMENT 11

Question-1

Model Equation:

**τ = 0.5**

%% Controller Parameters

ySP=1; % Setpoint

m=4; % Control horizon

p=10; % Prediction horizon

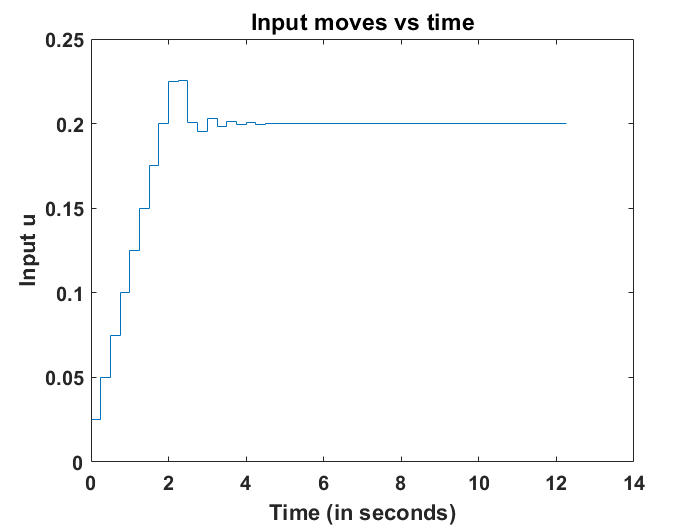
Q=1; % Output weight

R=0.1; % Input rate weight

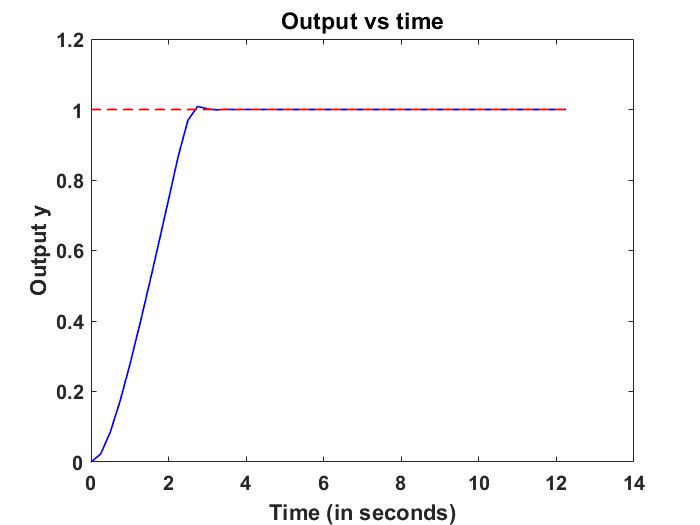
Constraints: and

Initial plant state is set to zero by default.

The measurement errors were set to zero using mpcsimopt. (Default is white noise, so we have to explicitly set it to zero)



We can visually see that the input moves satisfy the constraints: .



As expected the controller is able to smoothly increase the output the set-point.

|  |  |  |  |
| --- | --- | --- | --- |
| **Time (in s)** | **Input move** | **Time (in s)** | **Input move** |
| 0 | 0.0250 | 6.2500 | 0.2000 |
| 0.25 | 0.0500 | 6.5000 | 0.2000 |
| 0.50 | 0.0750 | 6.7500 | 0.2000 |
| 0.75 | 0.1000 | 7.0000 | 0.2000 |
| 1 | 0.1250 | 7.2500 | 0.2000 |
| 1.25 | 0.1500 | 7.5000 | 0.2000 |
| 1.50 | 0.1750 | 7.7500 | 0.2000 |
| 1.75 | 0.2000 | 8.0000 | 0.2000 |
| 2 | 0.2250 | 8.2500 | 0.2000 |
| 2.25 | 0.2255 | 8.5000 | 0.2000 |
| 2.50 | 0.2005 | 8.7500 | 0.2000 |
| 2.75 | 0.1955 | 9.0000 | 0.2000 |
| 3 | 0.2028 | 9.2500 | 0.2000 |
| 3.25 | 0.1983 | 9.5000 | 0.2000 |
| 3.50 | 0.2011 | 9.7500 | 0.2000 |
| 3.75 | 0.1993 | 10.0000 | 0.2000 |
| 4 | 0.2004 | 10.2500 | 0.2000 |
| 4.25 | 0.1997 | 10.5000 | 0.2000 |
| 4.50 | 0.2002 | 10.7500 | 0.2000 |
| 4.75 | 0.1999 | 11.0000 | 0.2000 |
| 5 | 0.2001 | 11.2500 | 0.2000 |
| 5.25 | 0.2000 | 11.5000 | 0.2000 |
| 5.50 | 0.2000 | 11.7500 | 0.2000 |
| 5.75 | 0.2000 | 12.0000 | 0.2000 |
| 6 | 0.2000 | 12.2500 | 0.2000 |

# Question-2

Model Equation:

%% Controller Parameters

ySP=1; % Setpoint

m=4; % Control horizon

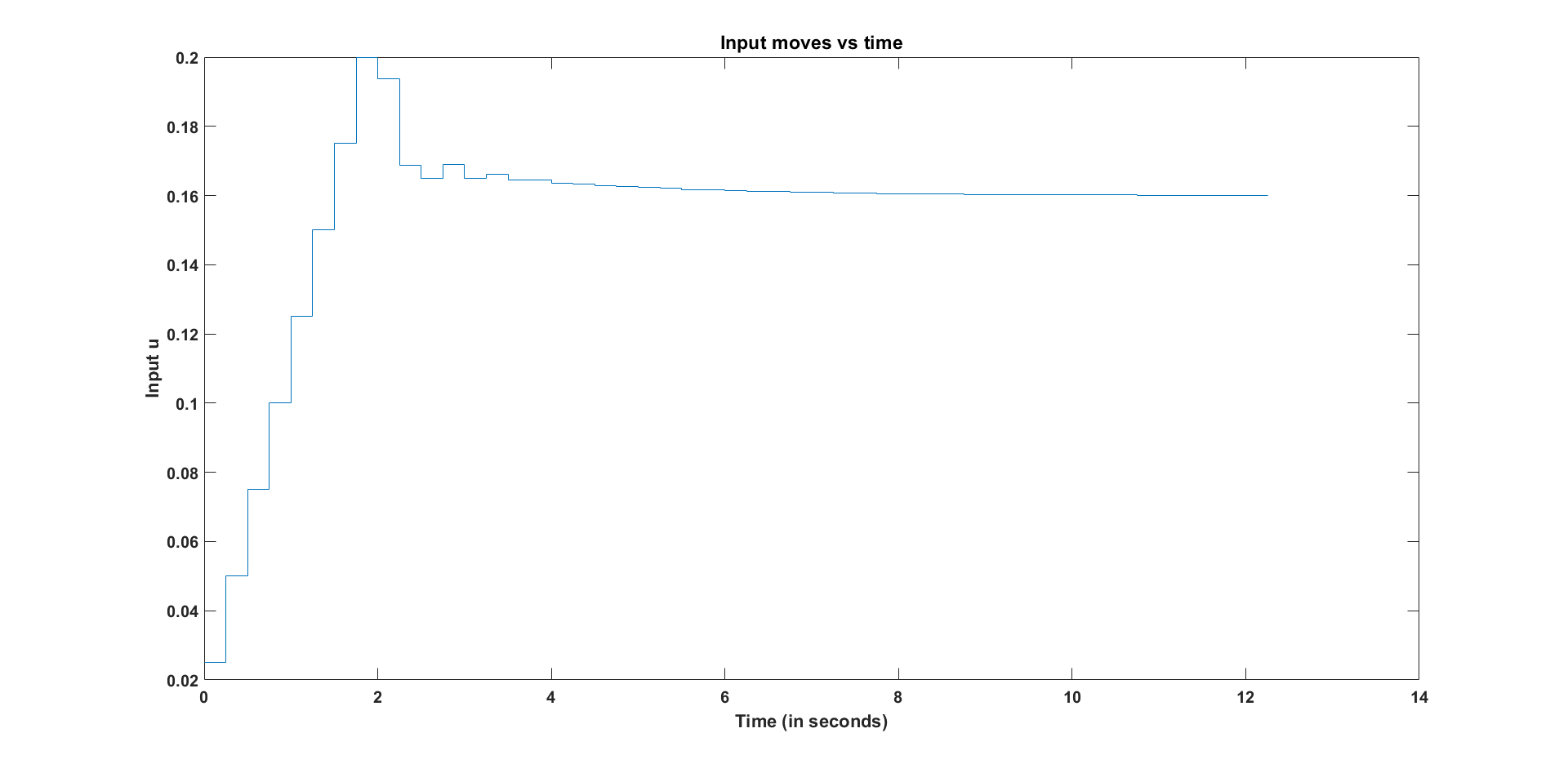
p=10; % Prediction horizon

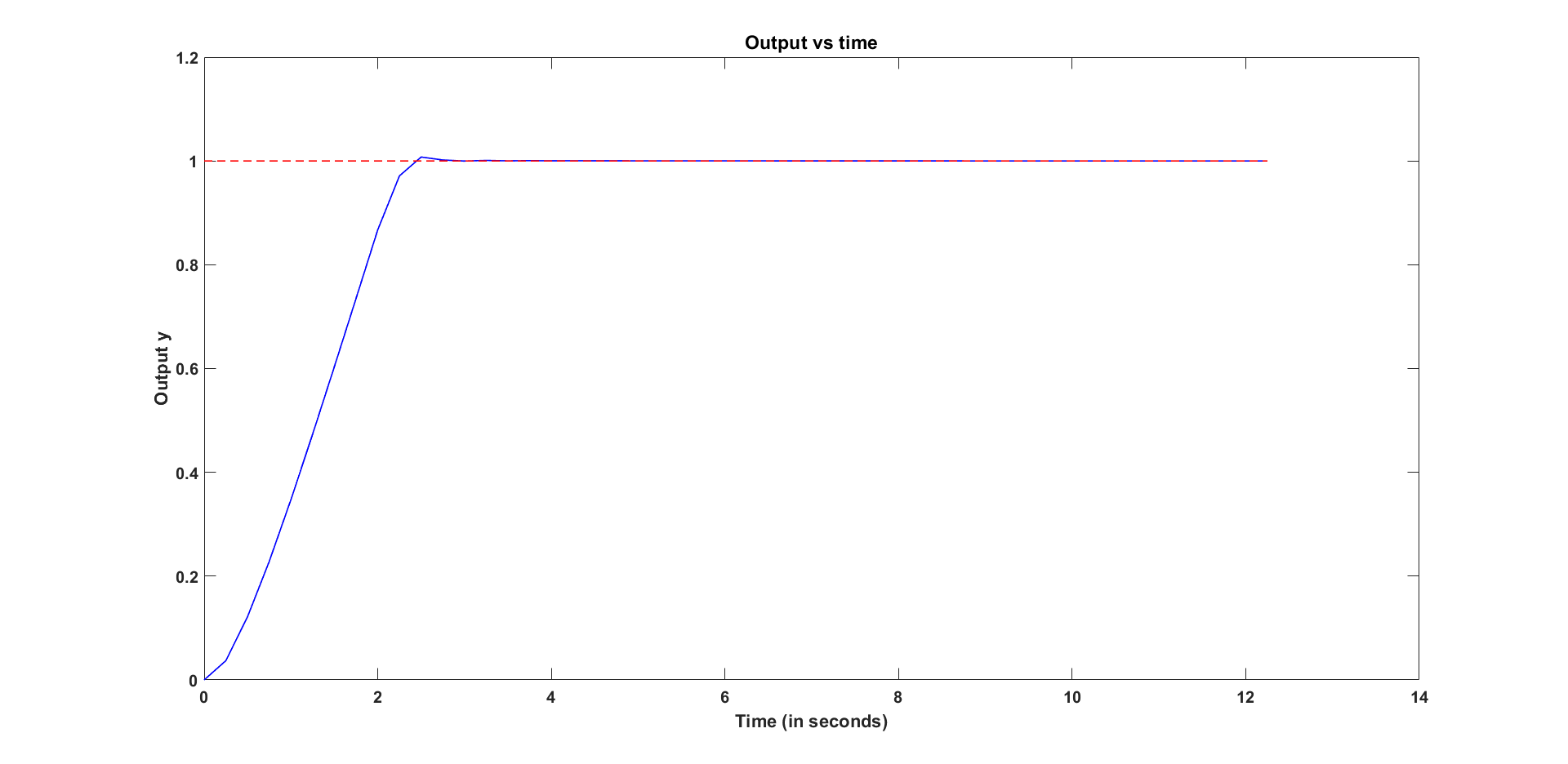
Q=1; % Output weight

R=0.04; % Input rate weight

Constraints: and

* Disturbance is simply a step change given at t=0. The value of the disturbance is given as a vector to the **sim** function. (d(k) = 0.5)
  + This is done in MATLAB by declaring the model incorporating the measured disturbance along with the manipulated input as a **2-input 1-output** model.
  + Then using **setmpcsignals**, the input corresponding to the transfer function of the disturbance model, is termed as the ‘Measured Disturbance’.
* Once again, the measurement errors are set to zero.





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| --- | --- | --- | --- |
| **Time (in s)** | **Input move** | **Time (in s)** | **Input move** |
| 0 | 0.0250 | 6.2500 | 0.1612 |
| 0.25 | 0.0500 | 6.5000 | 0.1611 |
| 0.50 | 0.0750 | 6.7500 | 0.1610 |
| 0.75 | 0.1000 | 7.0000 | 0.1608 |
| 1 | 0.1250 | 7.2500 | 0.1607 |
| 1.25 | 0.1500 | 7.5000 | 0.1607 |
| 1.50 | 0.1750 | 7.7500 | 0.1606 |
| 1.75 | 0.2000 | 8.0000 | 0.1605 |
| 2 | 0.1938 | 8.2500 | 0.1605 |
| 2.25 | 0.1688 | 8.5000 | 0.1604 |
| 2.50 | 0.1650 | 8.7500 | 0.1604 |
| 2.75 | 0.1689 | 9.0000 | 0.1603 |
| 3 | 0.1651 | 9.2500 | 0.1603 |
| 3.25 | 0.1662 | 9.5000 | 0.1602 |
| 3.50 | 0.1644 | 9.7500 | 0.1602 |
| 3.75 | 0.1645 | 10.0000 | 0.1602 |
| 4 | 0.1636 | 10.2500 | 0.1602 |
| 4.25 | 0.1634 | 10.5000 | 0.1601 |
| 4.50 | 0.1629 | 10.7500 | 0.1601 |
| 4.75 | 0.1626 | 11.0000 | 0.1601 |
| 5 | 0.1623 | 11.2500 | 0.1601 |
| 5.25 | 0.1620 | 11.5000 | 0.1601 |
| 5.50 | 0.1618 | 11.7500 | 0.1601 |
| 5.75 | 0.1616 | 12.0000 | 0.1601 |
| 6 | 0.1614 | 12.2500 | 0.1601 |

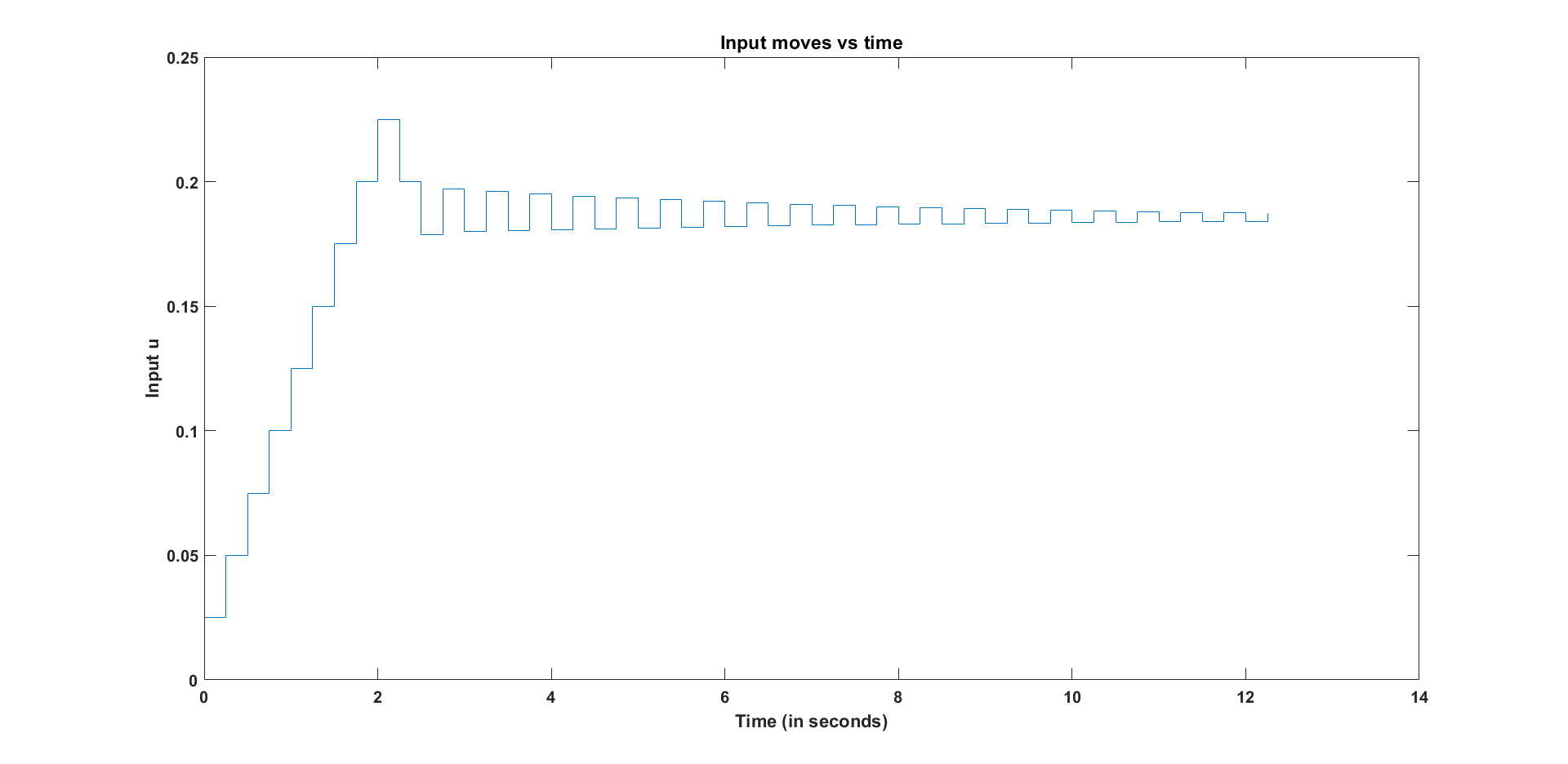
# Question-3

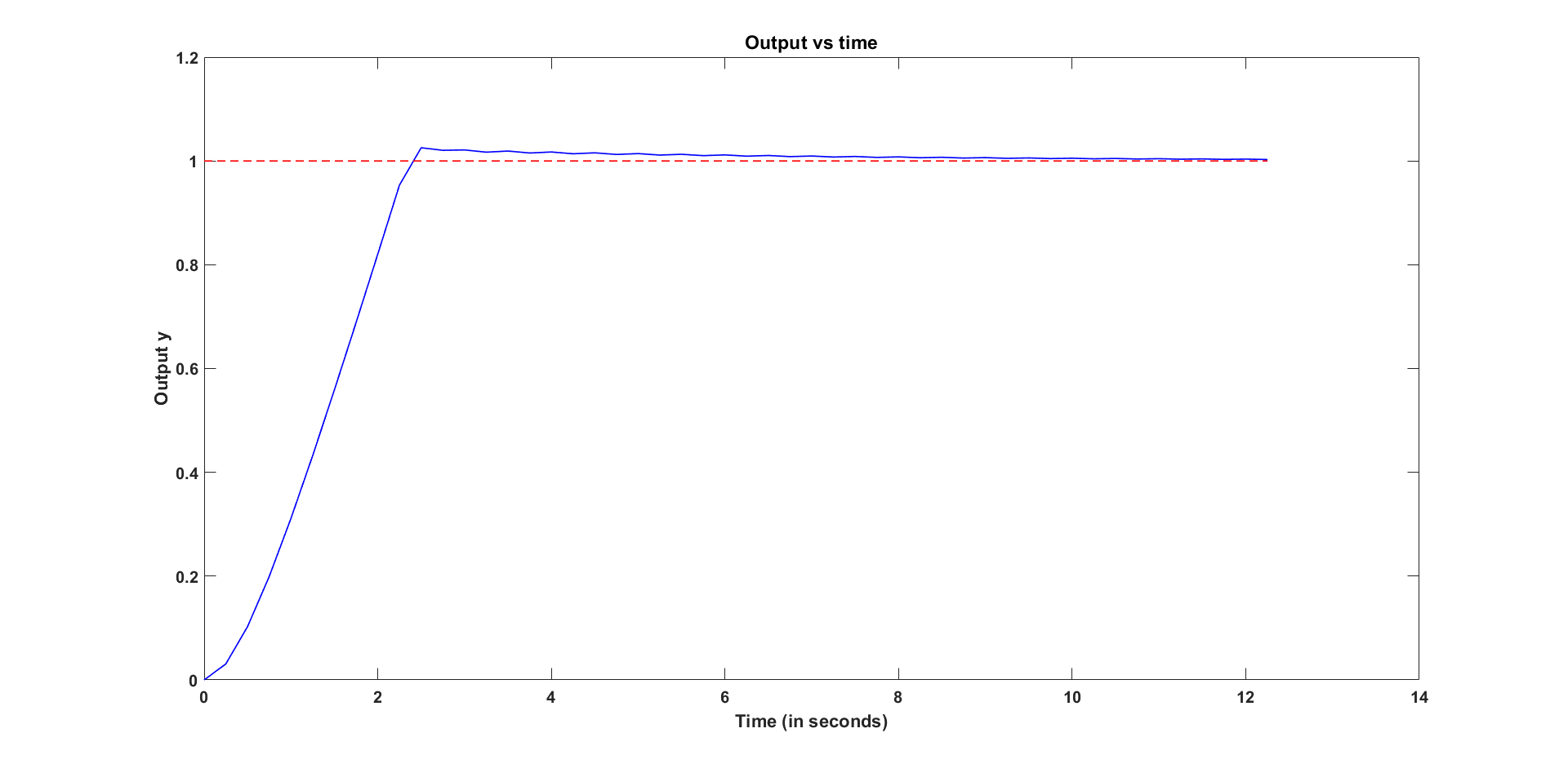
Here the tuning parameters remain the same and we remove the disturbance effects. Instead, this question deals with **model-plant mismatch**.

Model:

True Plant:

* The constraints and tuning parameters are same as in that of previous cases.
* The time taken to get reasonably close to the set-point value (~0 error) is more for the case with mismatch. This extra time is needed to incorporate the effects of the mismatch (bias in the model).
* The mismatch effect was implemented in MATLAB by updating the plant model in the options structure created using mpcsimopt().
* The measurement errors were set to zero.

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| --- | --- | --- | --- |
| **Time (in s)** | **Input move** | **Time (in s)** | **Input move** |
| 0 | 0.0250 | 6.2500 | 0.1914 |
| 0.25 | 0.0500 | 6.5000 | 0.1823 |
| 0.50 | 0.0750 | 6.7500 | 0.1909 |
| 0.75 | 0.1000 | 7.0000 | 0.1825 |
| 1 | 0.1250 | 7.2500 | 0.1904 |
| 1.25 | 0.1500 | 7.5000 | 0.1827 |
| 1.50 | 0.1750 | 7.7500 | 0.1899 |
| 1.75 | 0.2000 | 8.0000 | 0.1829 |
| 2 | 0.2250 | 8.2500 | 0.1895 |
| 2.25 | 0.2000 | 8.5000 | 0.1831 |
| 2.50 | 0.1786 | 8.7500 | 0.1891 |
| 2.75 | 0.1970 | 9.0000 | 0.1833 |
| 3 | 0.1800 | 9.2500 | 0.1888 |
| 3.25 | 0.1960 | 9.5000 | 0.1834 |
| 3.50 | 0.1804 | 9.7500 | 0.1885 |
| 3.75 | 0.1951 | 10.0000 | 0.1836 |
| 4 | 0.1808 | 10.2500 | 0.1882 |
| 4.25 | 0.1942 | 10.5000 | 0.1837 |
| 4.50 | 0.1811 | 10.7500 | 0.1879 |
| 4.75 | 0.1934 | 11.0000 | 0.1838 |
| 5 | 0.1815 | 11.2500 | 0.1877 |
| 5.25 | 0.1927 | 11.5000 | 0.1839 |
| 5.50 | 0.1818 | 11.7500 | 0.1875 |
| 5.75 | 0.1920 | 12.0000 | 0.1840 |
| 6 | 0.1820 | 12.2500 | 0.1873 |

# Codes

## Q1)

% DMC SISO with no disturbances and measurement errors

clear; close all;

%% Model

a = 0;

tau = (a+1)/2;

G = tf(5,[tau,1],'inputdelay',0.15);

sys = ss(G);

sampling\_time = 0.25;

model = c2d(sys,sampling\_time);

%% Setting up the Controller

p = 10; % Prediction horizon

m = 4; % Control Horizon

Q = 1; % Output weight

R = 0.1; % Input rate weight

Weights.ManipulatedVariablesRate = R;

Weights.OutputVariables = Q;

Weights.ManipulatedVariables = 0;

mp1 = mpc(model,sampling\_time,p,m,Weights);

mp1.ManipulatedVariables.Min = -0.4;mp1.ManipulatedVariables.Max = 0.4;

mp1.ManipulatedVariables.RateMin = -0.025; mp1.ManipulatedVariables.RateMax = 0.025;

%% Running the controller

ySP = 1; % Setpoint

T = 50; % Number of simulation steps

options = mpcsimopt();

options.InputNoise = 0;

options.OutputNoise = 0;

[y,t,u,xp,xmpc,SimOptions,status] = sim(mp1,T,ySP,options);

%% Plotting the results

plot(t,y,'-b',... % Plots the output

t,ones(size(t)),'--r','linewidth',1); % Plots set-point

set(gca,'fontsize',12,'fontweight','bold');

title('Output vs time','fontsize',14,'fontweight','bold');

xlabel('Time (in seconds)');ylabel('Output y');

figure();

stairs(t,u); % Plots the input

set(gca,'fontsize',12,'fontweight','bold');

title('Input moves vs time','fontsize',14,'fontweight','bold')

xlabel('Time (in seconds)');ylabel('Input u');

## Q2)

% DMC SISO with no disturbances and measurement errors

clear; close all;

%% Models

a = 0;

tau = (a+1)/2;

% Plant model

G = tf(5,[tau,1],'inputdelay',0.15);

sys = ss(G);

sampling\_time = 0.25;

plant\_model = c2d(sys,sampling\_time);

% Disturbance model

Gdist = tf(0.4,[2,1],'inputdelay',0.1);

dist = ss(Gdist);

dist\_model = c2d(dist,sampling\_time);

%Combined Model

tf\_model = [G Gdist];

ss\_model = ss(tf\_model);

model = c2d(ss\_model,sampling\_time);

%% Setting up the Controller

p = 10; % Prediction horizon

m = 4; % Control Horizon

Q = 1; % Output weight

R = 0.1; % Input rate weight

Weights.ManipulatedVariablesRate = R;

Weights.OutputVariables = Q;

Weights.ManipulatedVariables = 0;

model2 = setmpcsignals(model,'MD',2);

mp1 = mpc(model2,sampling\_time,p,m,Weights);

mp1.ManipulatedVariables.Min = -0.4;mp1.ManipulatedVariables.Max = 0.4;

mp1.ManipulatedVariables.RateMin = -0.025; mp1.ManipulatedVariables.RateMax = 0.025;

% Dist.Name = 'd';

% Dist.Units = 1;

% mp1.DisturbanceVariables = Dist;

% mp1.Disturbance = dist\_model;

%% Running the controller

ySP = 1; % Setpoint

T = 50; % Number of simulation steps

d = 0.5\*ones(T,1); % Measured Disturbance

options = mpcsimopt();

options.InputNoise = 0;

options.OutputNoise = 0;

[y,t,u,xp,xmpc,SimOptions,status] = sim(mp1,T,ySP,d,options);

%% Plotting the results

plot(t,y,'-b',... % Plots the output

t,ones(size(t)),'--r','linewidth',1); % Plots set-point

set(gca,'fontsize',12,'fontweight','bold');

title('Output vs time','fontsize',14,'fontweight','bold');

xlabel('Time (in seconds)');ylabel('Output y');

figure();

stairs(t,u); % Plots the input

set(gca,'fontsize',12,'fontweight','bold');

title('Input moves vs time','fontsize',14,'fontweight','bold')

xlabel('Time (in seconds)');ylabel('Input u');

## Q3)

% DMC SISO with no disturbances and measurement errors

clear; close all;

%% Model

a = 0;

tau = (a+1)/2;

% Plant Model

G = tf(5,[tau,1],'inputdelay',0.15);

sys = ss(G);

sampling\_time = 0.25;

model = c2d(sys,sampling\_time);

% Actual Plant

Gplant = tf(5.4,[tau 1],'inputdelay',0.12);

p = ss(Gplant);

plant = c2d(p,sampling\_time);

%% Setting up the Controller

p = 10; % Prediction horizon

m = 4; % Control Horizon

Q = 1; % Output weight

R = 0.1; % Input rate weight

Weights.ManipulatedVariablesRate = R;

Weights.OutputVariables = Q;

Weights.ManipulatedVariables = 0;

mp1 = mpc(model,sampling\_time,p,m,Weights);

mp1.ManipulatedVariables.Min = -0.4;mp1.ManipulatedVariables.Max = 0.4;

mp1.ManipulatedVariables.RateMin = -0.025; mp1.ManipulatedVariables.RateMax = 0.025;

%% Running the controller

ySP = 1; % Setpoint

T = 50; % Number of simulation steps

options = mpcsimopt();

options.Model = plant;

options.InputNoise = 0;

options.OutputNoise = 0;

[y,t,u,xp,xmpc,SimOptions,status] = sim(mp1,T,ySP,options);

%% Plotting the results

plot(t,y,'-b',... % Plots the output

t,ones(size(t)),'--r','linewidth',1); % Plots set-point

set(gca,'fontsize',12,'fontweight','bold');

title('Output vs time','fontsize',14,'fontweight','bold');

xlabel('Time (in seconds)');ylabel('Output y');

figure();

stairs(t,u); % Plots the input

set(gca,'fontsize',12,'fontweight','bold');

title('Input moves vs time','fontsize',14,'fontweight','bold')

xlabel('Time (in seconds)');ylabel('Input u');