Analytical study and Designing of a I-PD controller (a practical Modified PID controller) for a third order system using MATLAB simulation

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Abstract— The paper discusses the most prominent advantage of an I-PD controller over the conventional PID controller, with the identical use of hardware circuits. Even the MATLAB based PID parameters optimization could easily be applied for an I-PD controller and making the controller 'simpler to design' and 'easier to implement' in practice. For unit step inputs the PID control action results into sudden overshoot of the output variable, because of the presence of the differentiating action in the forward path, whereas in the I-PD configuration no such steep rise of the output should take place. Hence I-PD controller will always safer than the PID, as the sharp rise in the output variable may in some cases cause breakdown of the system, if the ratings of various subsystems are not chosen properly.

Keywords— I-PD controller, Optimal PID tuning using MATLAB, I-PD advantage over PID controller, set-point kick-off , closed loop control , differentiator , as the set-point kick phenomenon.

Introduction

In this article, an I-PD controller is being studied to highlight the advantages of I-PD controller actions over conventional PID controllers. We know that with respect to usual step inputs, PID module which contains a differentiator block, gives rise to a sudden high magnitude peak of the system response. To eliminate such a disadvantage, the derivative action is introduced in the feedback path, and improving the response of the system. The system chosen for our analysis is a servo mechanism whose transfer function is
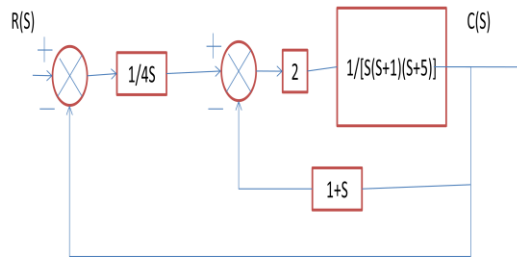
$$\frac{1}{s(s+1)(s+5)}$$

Analysis of the conventional PID response for a system:

The transfer function of the system chosen for our study is: $\frac{1}{s(s+1)(s+5)}$

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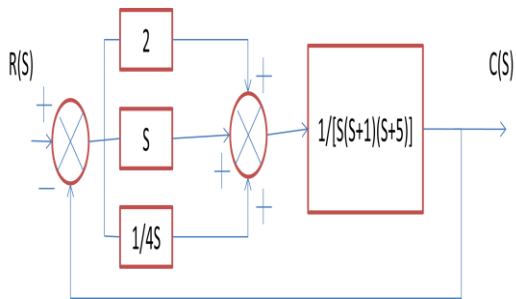
PID BLOCK DIAGRAM: **I-PD BLOCK DIAGRAM:**

MATLAB PROGRAM

Matlab program that finds the optimal values of PID parameters for a specified range of maximum peak overshoot for a unit step input given to a third order system:

```
t=0:0.01:15;

for K=20:-0.2:2; %starts the outer loop to vary the K values

for a=1.5:-0.2:0.5; %starts the inner loop the vary the 'a' values

num=[0 0 K 2*K*a K*a^2];

den=[1 6 5+K 2*K*a K*a^2];

y=step(num,den,t);

m=max(y);

if m<1.25 &m>1.05

break; %breaks the loop

end

end

plot(t,y)

grid

title('Unit step response')

xlabel('t sec')

ylabel('Output')

KK=num2str(K); %String-value of K to be printed on plot

aa=num2str(a); %String value of a to be printed on plot

text(4.25,0.54,'K= '),text(4.75,0.54,KK)

text(4.25,0.46,'a= '),text(4.75,0.46,aa)
```
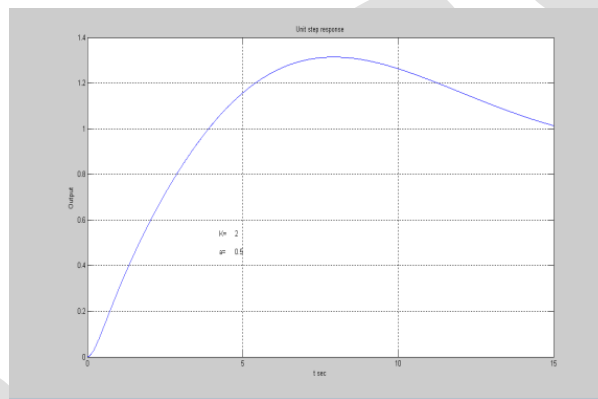
sol=[K;a;m]

end

sol =

   2.0000

   0.5000

   1.3139

The corresponding system response of the optimal PID controlled system is as shown below

MATLAB PROGRAM

Matlab program that finds the corresponding response of the said system for an I-PD control action with same values of Kp, Td and Ti for a unit step input given to the same third order system:

num=[0 0 0 0 0.5]

den=[1 6 7 2 0.5]

tf1=tf(num,den)

t=0:1:30

step(tf1,t)

num =

    0   0   0   0   0.5000

den =

  1.0000   6.0000   7.0000   2.0000   0.5000

Transfer function:

          0.5

----

s^4 + 6 s^3 + 7 s^2 + 2 s + 0.5

The corresponding system response with I-PD controller:
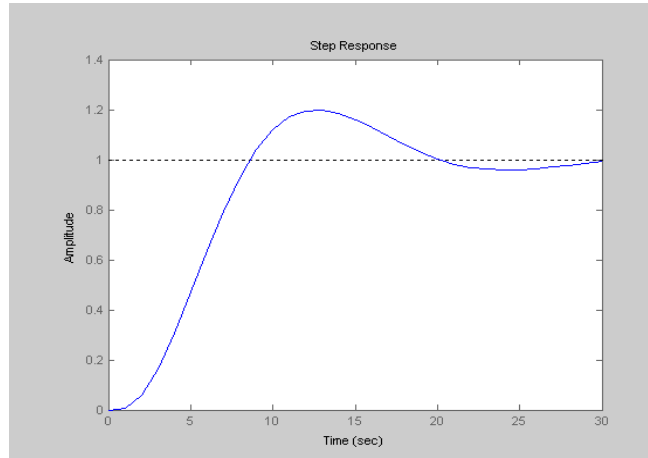
ANALYSIS OF THE MODIFIED PID CONTROLLER (NAMELY I-PD CONTROLLER) MODULE

It is observed that the maximum overshoot is reduced due to the application of I-PD configuration for the same third order system. But the system rise time is increased, making the system sluggish. In our opinion, avoidance set-point kick-off (generation of an impulse due to the introduction of differentiating device in the forward path in the case of conventional PID module) phenomenon is more important for any physical system that deals with a highly sensitive change in the output variable.

HARDWARE CIRCUITS NEEDED FOR THE PURPOSE

Op-amp based Amplifier, differentiator, and Integrator circuits are to be used for the hardware implementation of the I-PD controller

AREAS OF APPLICATIONS

The I-PD Control action can be used in any physical systems that uses closed loop control of output variable. It can therefore be applied for position, speed, temperature, level control systems etc.

CONCLUSIONS

So far as the results of the I-PD controllers are concerned, the system response is highly acceptable, *as the set-point kick phenomenon* i.e. the generation of an impulse due to the presence of differentiator in the forward path of a conventional PID controller is avoided.

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