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Performance Evaluation of Azimuth Position Control of a Giant Metre wave Radio Telescope in Matlab/Simulink using P and PD Controllers

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Abstract

The proposed work focuses on modelling and simulating a control system for azimuth position control of a Giant Metre wave Radio Telescope (GMRT) for turning the input commands into corresponding output positions. GMRTs are large parabolic dish antennas established by National Centre for Radio Astrophysics (Tata Institute of Fundamental Research) in India. The GMRT system has initially been modelled and evaluation of the system performance (using a reference step signal) has been done by using Proportional (P) and Proportional-Derivative (PD) controllers.

Keywords: Azimuth P. Control, GMRT, Look Angle and PD control.

Introduction

In astronomical research for capturing extraterrestrial information parabolic antennas with a focal feed point are used as earth stations.

Earth stations characteristics are mainly governed by its antenna characteristics and should meet three requirements e.g. high directive gain, low noise temperature and easily steerable[1].

Here the main focus is on easily steering ability of a GMRT (a parabolic antenna) system so as to achieve appropriate look angles. A typical GMRT system has been shown in Figure-1. Antenna look angles are the azimuth (A) and elevation angles (E). These are calculated on the basis of knowledge of latitude and relative longitude both in degrees of the earth station.

Azimuth angle: Azimuth angle is defined as the angle by which the antenna, pointing at the horizon must be rotated clockwise around its vertical axis from the geographical north to bring the antenna bore sight into the vertical plane containing the direction of a signal of interest. Value of the azimuth angle is between 0° and 360°.

For an earth station in northern hemisphere,
Azimuth Angle (A) = 180° - A'; Earth station west of direction of signal of interest in space. (1)

A = 180° + A'; Earth station east of direction of signal of interest in space. (2)

For an earth station in southern hemisphere,
A = A'; Earth station west of direction of signal of interest in space. (3)

A = 360° - A'; Earth station east of direction of signal of interest in space. (4)

and $A' = \tan^{-1}\{\frac{\tan(\theta_S-\theta_L)}{\sin\theta_l}\}$ (5)

Where: θ_S = longitude of direction of signal of interest in space, θ_L= earth station longitude and θ_l = earth station latitude[1].

Modeling and simulation of the GMRT system have been carried out for the azimuth position control in this study. The approach of the proposed work is as follows: section II represents the proposed system modelling, section III represents the proposed system response and section IV has the result of the proposed work.

Proposed System Modelling

The position command of the antenna is entered manually with the help of a potentiometer to adjust the angle of it. A second potentiometer is used to get feedback knowledge of the system. Orientation of the antenna to the desired angle, an armature controlled dc servo motor has been used.

Motor is connected to the antenna with the help of a gear system[2].

Physical layout of the GMRT azimuth position control and schematic representation of the system are shown in Figure-2 and Figure-3 respectively[3].

The corresponding block diagram of the system has also been shown in Figure-4.

The values of the schematic parameters and block diagram parameters have been taken from Table-1 and Table-2[3].

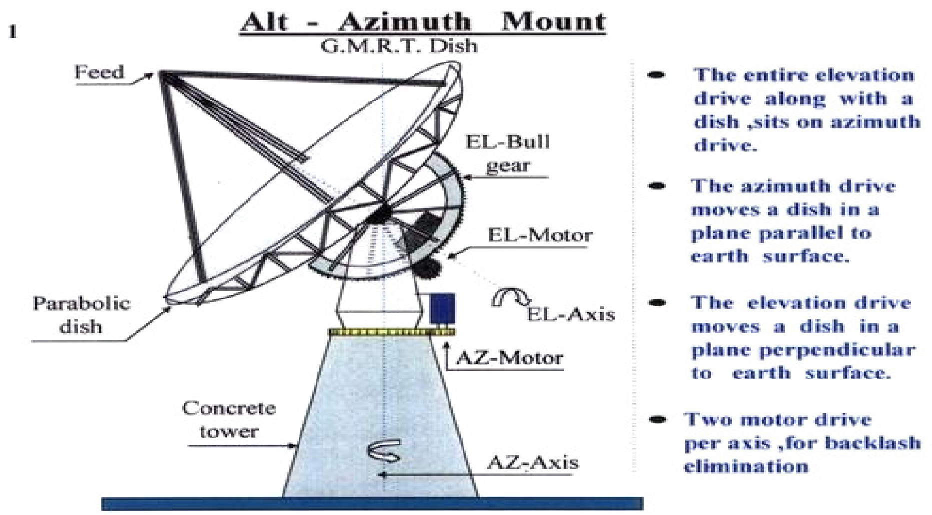

Figure-1
A Typical GMRT System

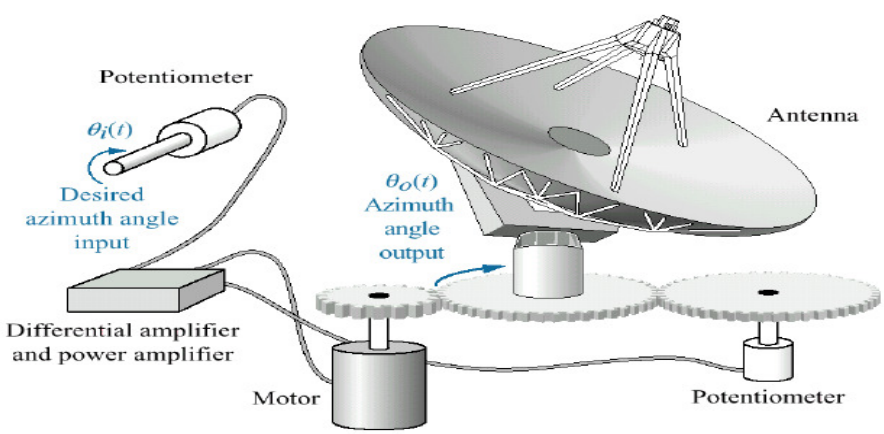

Figure-2
Physical Layout of the Antenna Azimuth Position Control

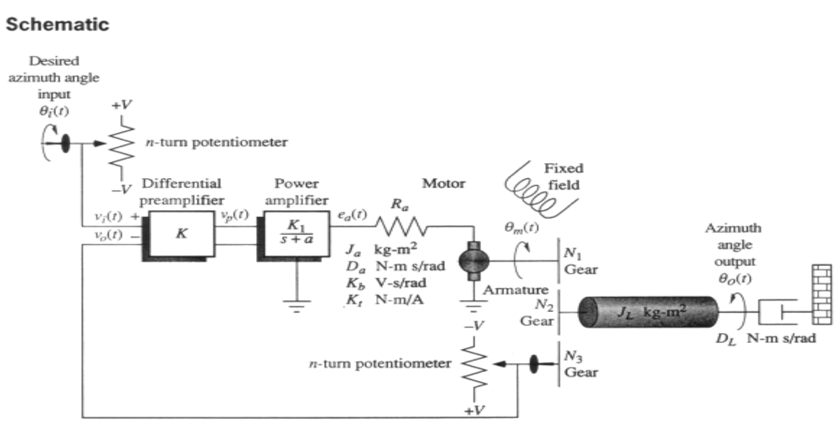

Figure-3
Schematic Representation of the System

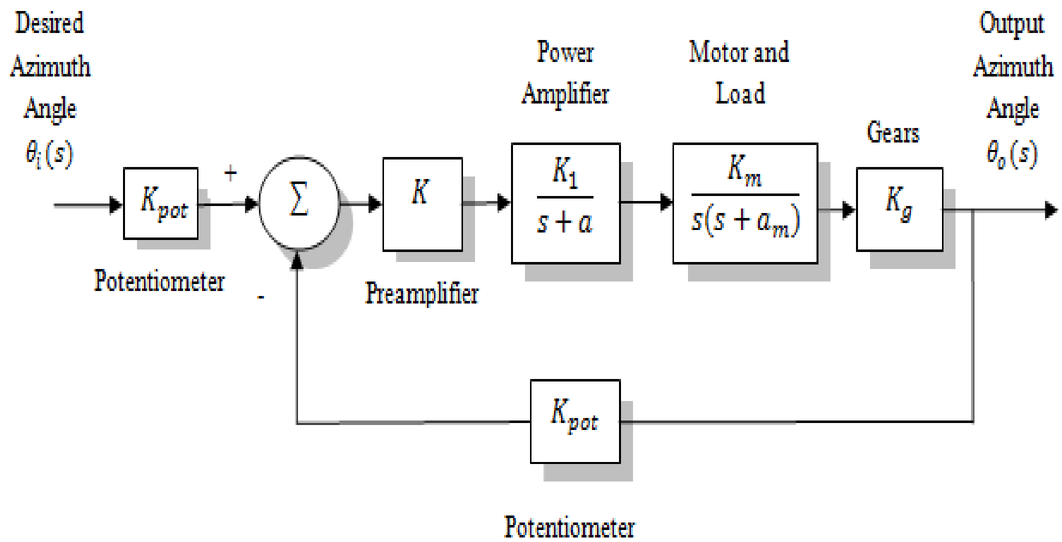

Figure-4
Proposed System Block Diagram

Table-1
Schematic Parameters

Parameter	Configuration Value
V	10
n	10
K	---
K1	100
a	100
Ra	8
Ja	0.02
Da	0.01
Kb	0.5
Kt	0.5
N1	25
N2	250
N3	250
JL	1
DL	1

When block diagram parameters, as given in Table-2 are replaced in Figure 4, the open loop and closed loop transfer functions of the system are obtained as given in equation (6) and (7) respectively.

Table-2
Block Diagram Parameters

Parameter	Configuration Value
Kpot	0.138
K	------
K1	100
a	100
Km	2.083
am	1.71
Kg	0.1

$$G(s) = \frac{6.63K}{s(s+1.71)(s+100)} \quad (6)$$

$$\frac{\theta_o(s)}{\theta_i(s)} = \frac{6.63K}{s^3+101.71s^2+171s+6.63K} \quad (7)$$

Proposed System Response

Open Loop System Response: Application of a step signal (a preferred test signal usually employed as a reference command signal) to the open loop transfer function equation 6, yields the response shown in Figure-5.

Figure-5 shows that the step response of the open loop system is unstable and results in a ramp output that will quickly saturate the components of the system. This response shows that the damping ratio is 1 and the natural frequency is 0[4].

Closed Loop System Response: Closed loop system response has been carried out initially without a controller and then subsequently applying different controllers viz. a P control and PD control.

B.1 System Response without a Controller: Keeping the value of preamplifier gain K as unity and checking the system response, following Figure-6 is obtained.

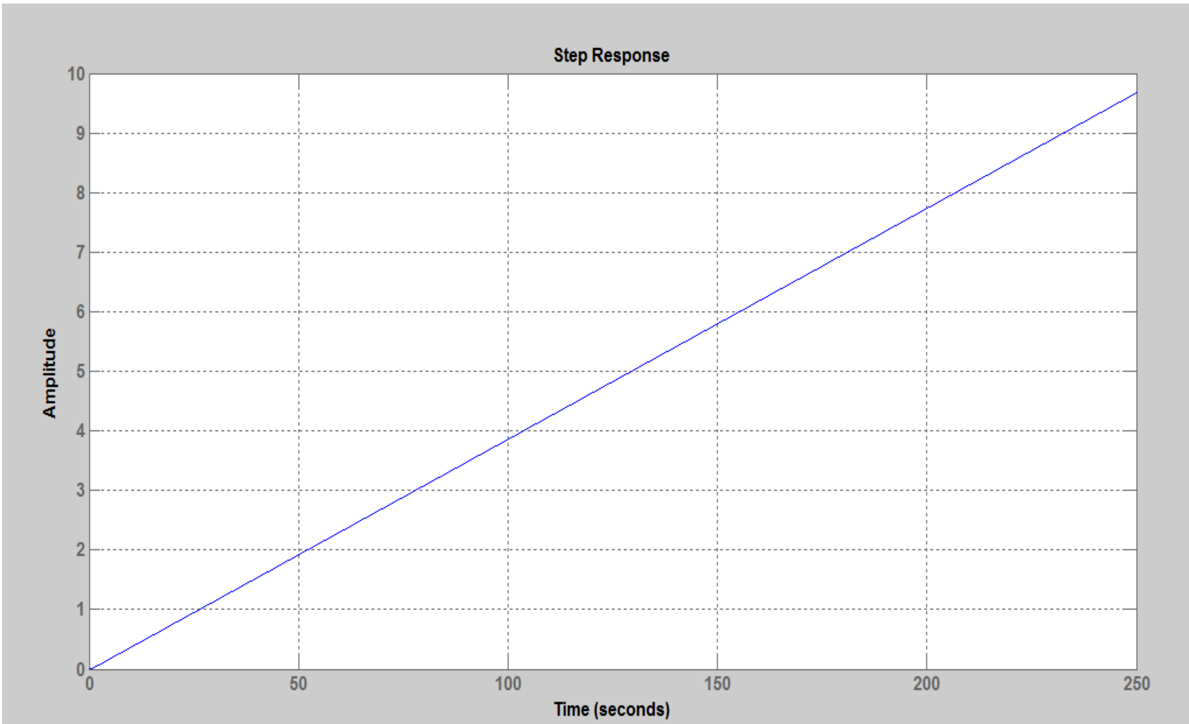

Figure-5
Open Loop System Response

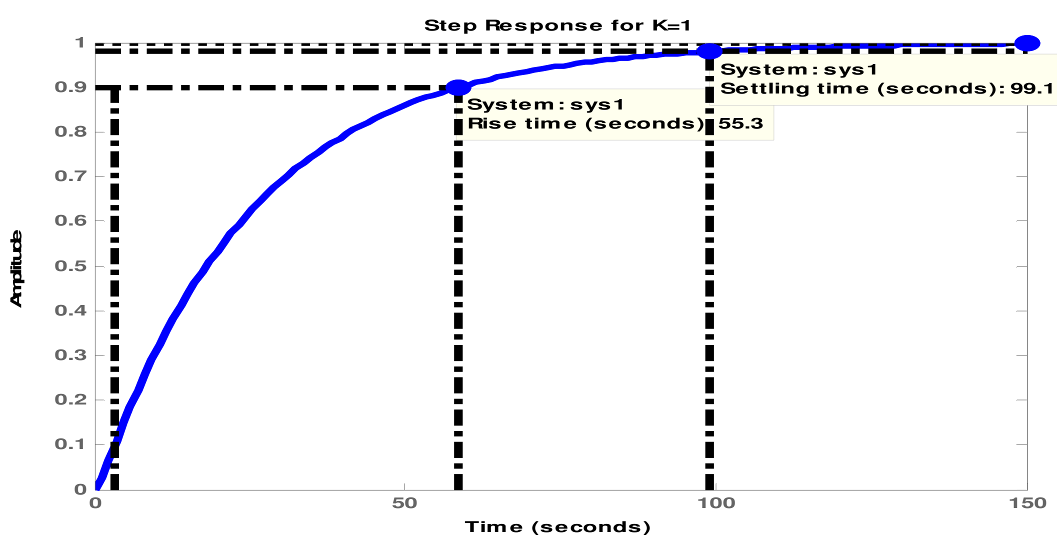

Figure-6
Closed Loop System Response without a Controller

Above response shows that the system is stable but sluggish in nature if not controlled by any controller. System response is required to be improved. This has been accomplished by implementing P and PD controllers.

B.2 System Response with Proportional (P) Control**:** In proportional control the actuating signal (output of the preamplifier) for the control action is proportional to the error signal. The error signal is the difference between the reference input signal and the feedback signal obtained from the output.

Closed loop transfer function equation 7 is a third order system, its characteristic equation is given by

$$s^3 + 101.71s^2 + 171s + 6.63K = 0 \qquad (8)$$

Application of Routh-Hurwitz criterion into the above equation gives the following range of preamplifier gain K for the system to be stable.

$$0 < K < 2623 \qquad (9)$$

Hence selection of different values of K within this range and implementing them into the system is the Proportional Control. The values of K have been chosen purely on trial and hit basis.

It is clear from the responses (Figure-7, 8) that the sluggish response obtained without using a controller (Figure-6) can be made faster by increasing preamplifier gain K of the system. The increase in gain K reduces the steady state error but at the cost of increasing the number of oscillations and increase in maximum overshoot. A large overshoot may damage the subsystems of a control system under consideration. For satisfactory performance of the system a convenient adjustment has to be made between the maximum overshoot and steady state error[5].

Proportional-Derivative (PD) Control: Without sacrificing the steady state accuracy, the maximum overshoot can be reduced to some extent by modifying the actuating signal. This modification is achieved by a PD control. In Proportional-Derivative control the actuating signal consists of proportional error signal added with derivative of the error signal[5]. A typical block diagram of a PD controller has been shown in the following Figure-9.

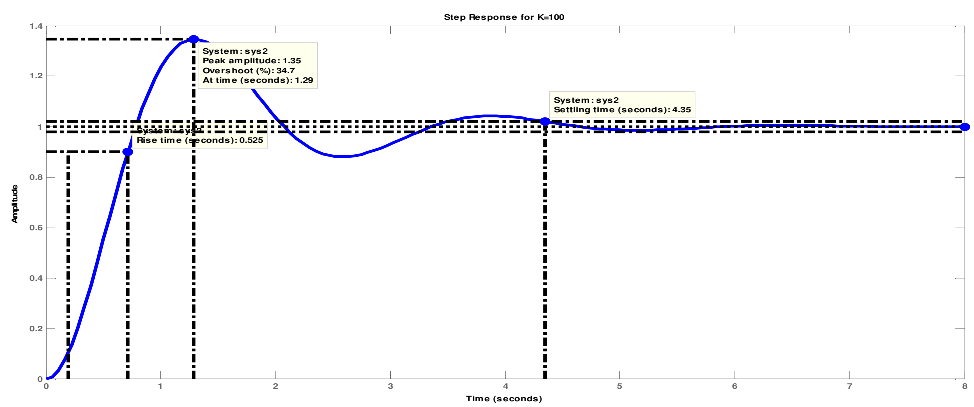

Figure-7
Closed Loop System Response with K=100

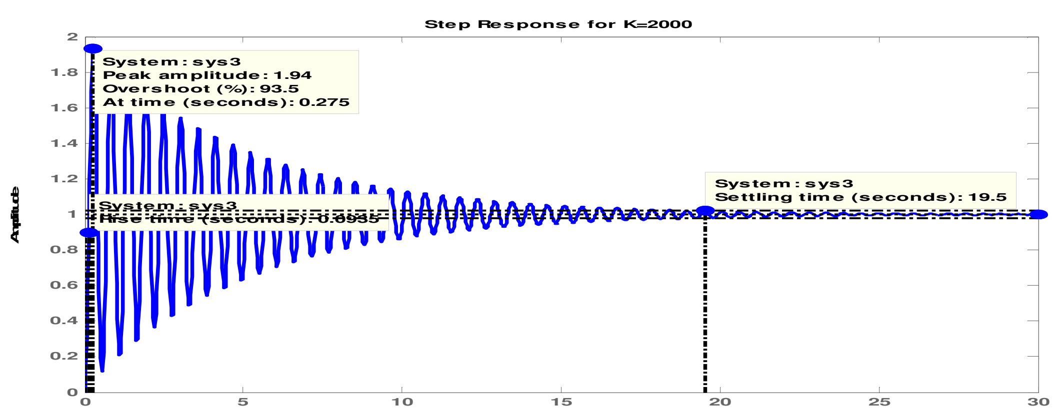

Figure-8
Closed Loop System Response with K=2000

Where, K_P and K_D are proportional and derivative gains and the Plant is the system under consideration.

PD controller introduces an extra zero to the system thereby changes the overall transfer function of the system. MATLAB sisotool is used to design a PD controller which requires some steps to be followed[3].

Figure-10, 11 depict the root locus editor and compensator editor respectively which are obtained in the PD design process using MATLAB sisotool.

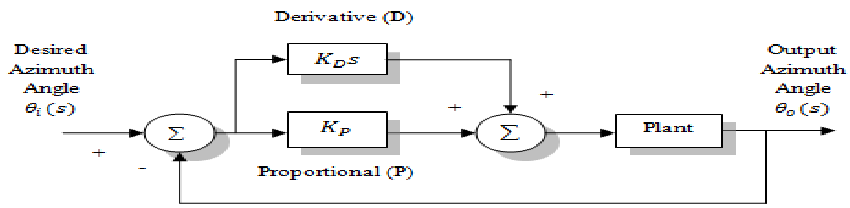

Figure-9
PD Control Block Diagram

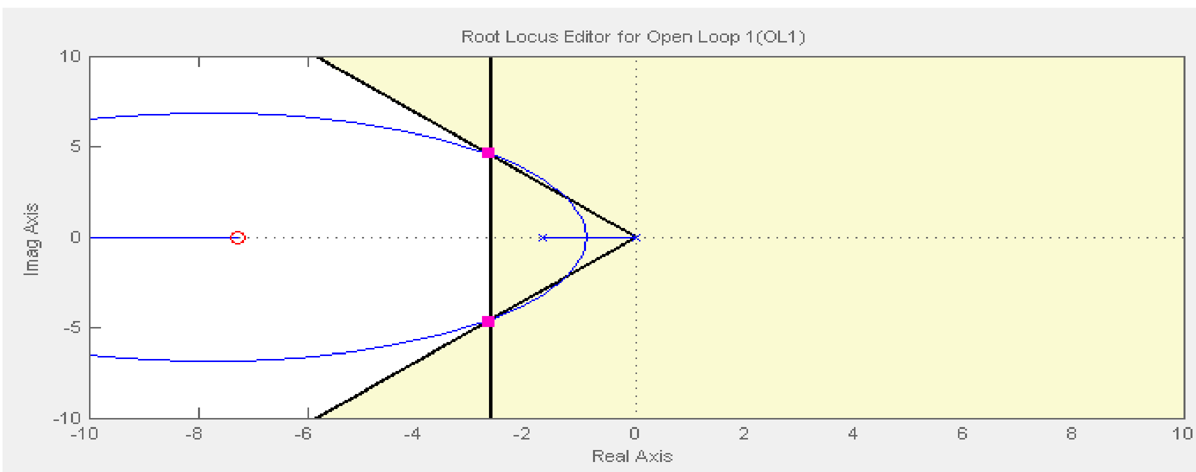

Figure-10
Root Locus Editor

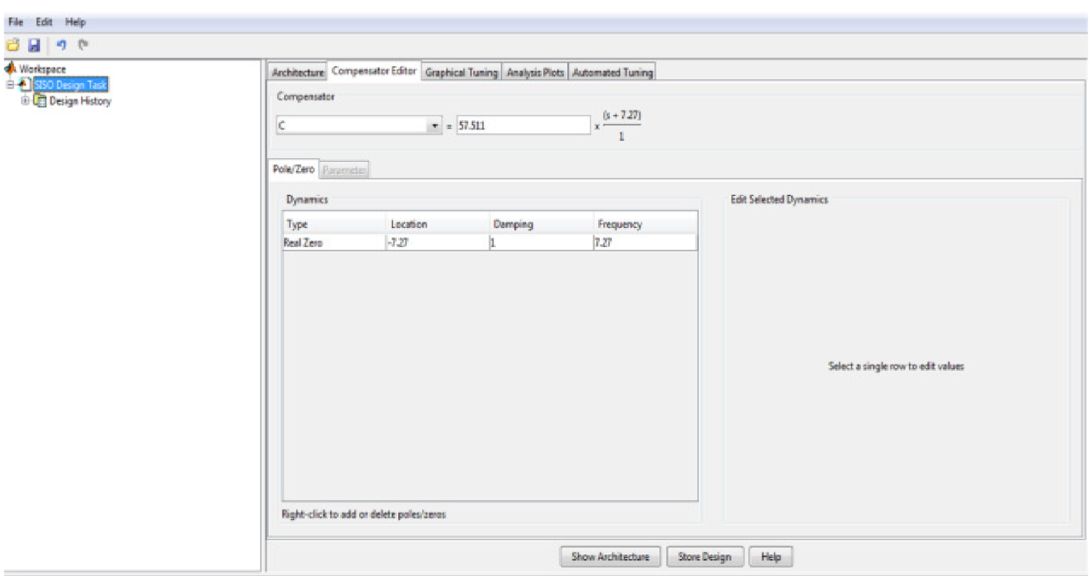

Figure-11
Compensator Editor

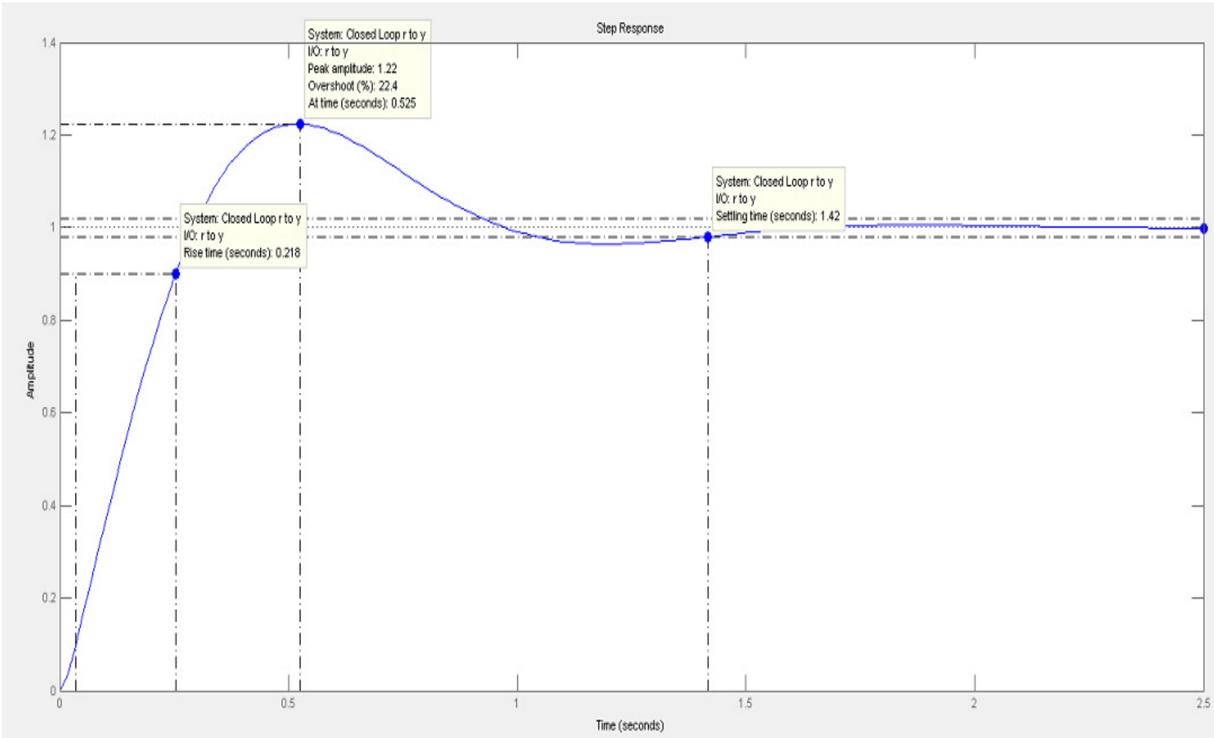

Figure-12
System Response with PD Control

This gives the controller of the following form given in equation (10).

$$G_{PD}(s) = \frac{57.511(s+7.27)}{1} \quad (10)$$

Implementation of the designed PD controller into the proposed system gives the response as shown in Figure-12.

Results and Discussion

Following results are obtained after evaluating the P and PD controllers as given in Table-3.

Table-3
Transient Analysis of the Proposed System

S. No.	Transient Parameters	P Control (K=100)	PD Control
01	Rise Time (tr)	0.52sec	0.218sec
02	Peak Time (tp)	1.29sec	0.525sec
03	Overshoot (%)	34.7	22.4
04	Settling Time (ts)	4.35sec	1.42sec
05	Closed Loop Stability	Stable	Stable

In order to obtain the improved proposed system response, various transient parameters viz. Rise Time, Peak Time, Peak Overshoot and Settling Time have been examined. To see the performances of the controllers, they have been compared with each other. As a result, it is observed that the PD Controller gives the better result than a P controller. However a PD controller has two drawbacks[3]: i. It requires an active circuit to perform the differentiation. ii. The differentiation is a noisy process. The level of the noise is low, but the frequency of the noise is high compared to the signal. Differentiation of high frequencies can lead to large unwanted signals or saturation of amplifiers and other components.

Conclusion

Future work is required to overcome the drawbacks encountered while using a PD controller. A compensator that uses a passive network is suggested, to overcome the disadvantages of a PD controller and still retains the ability to improve the transient response.

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