

Modelling and Simulation of Elevation Position Control of a Giant Meter wave Radio Telescope (GMRT) in MATLAB using PID and Discrete PID Controllers

Sagar Yadav¹, Mrs. Vinni Sharma²

M.Tech. Scholar (I&CE), Department of Electronics and Telecommunication Engineering,

Bhilai Institute of Technology, Durg, India¹

Assistant Professor, Department of Electronics and Telecommunication Engineering,

Bhilai Institute of Technology, Durg, India²

Abstract: The proposed work focuses on simulating a control system for elevation 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-Integral-Derivative (PID) and Discrete Proportional-Integral-Derivative (DPID) controllers.

Keywords: GMRT; Elevation; PID control; DPID control.

I. INTRODUCTION

In astronomical research for capturing extraterrestrial information paraboloid 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. Here the main focus is on easily steering ability of a GMRT (a paraboloidal antenna) system so as to achieve appropriate look angles. A typical GMRT system [1] has been shown in fig.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 [2].

Elevation Angle: The elevation angle is defined as the angle by which the antenna bore sight should be rotated in the vertical plane that contains the direction of signal of interest from the horizontal.

Elevation angle ranges between 0° and 90°.

Elevation Angle is calculated as:

$$E = \arctan \left[\frac{\cos(G) \cos(L) - 1512}{\sqrt{1 - \cos^2(G) \cos^2(L)}} \right] \quad (1)$$

Where, E = Elevation of Antenna in Degrees, S = Source of Signal of Interest in Space, Longitude in Degrees, N = Earth Station Longitude in Degrees, L = Earth Station Latitude in Degrees and G = S-N.

Modelling and simulation of the GMRT system have been carried out in this study for elevation position control.

The nomenclature of this 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.

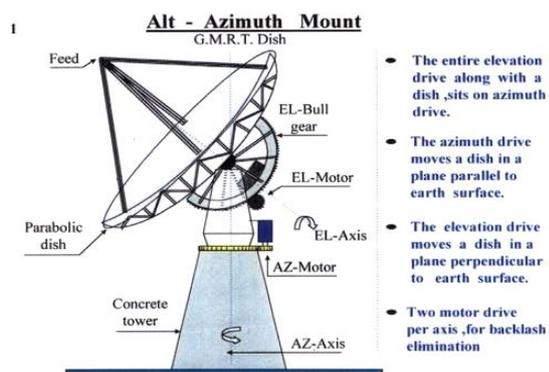


Fig. 1: A Typical GMRT System

II. 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 and the values of the schematic parameters have been taken from Table I.

The schematic representation of the GMRT elevation position control system is shown in fig.2. [5].

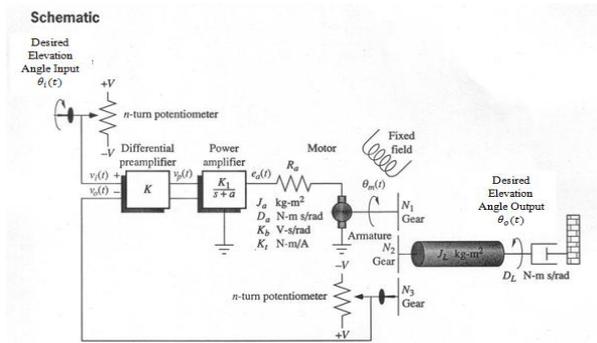


Fig. 2: Schematic Block Diagram Representation

TABLE I 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	500
N3	500
JL	1
DL	1

The corresponding block diagram of the system has also been obtained in fig.3.

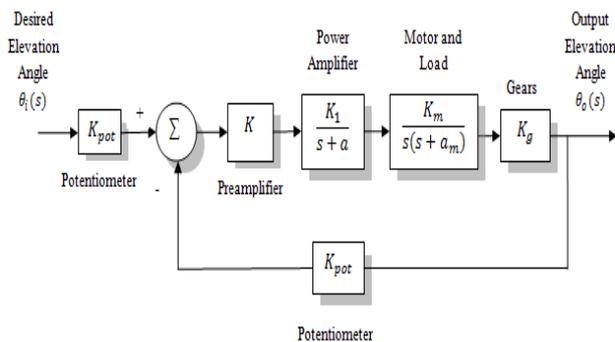


Fig. 3: Obtained System Block Diagram

When block diagram parameters, as given in Table II are replaced in Fig.3, the open loop and closed loop transfer functions of the system are obtained as given in equation (2) and (3) respectively.

TABLE II BLOCK DIAGRAM PARAMETERS

Parameter	Configuration Value
Kpot	0.138
K	-----
K1	100
a	100

Km	2.778
am	1.944
Kg	0.05

$$G(s) = \frac{4.42K}{s(s+100)(s+1.944)} \quad (2)$$

$$\frac{\theta_o(s)}{\theta_i(s)} = \frac{4.42K}{s^3 + 101.944s^2 + 194.4s + 4.42K} \quad (3)$$

III. PROPOSED SYSTEM RESPONSE

A. 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 (2), yields the response shown in fig.4.

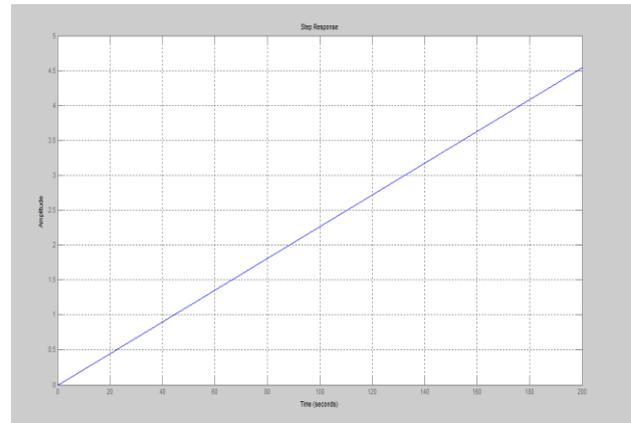


Fig. 4: Open Loop System Response

One can see 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.

B. Closed Loop System Response

Closed loop step response of the system without a controller is obtained in fig.5.

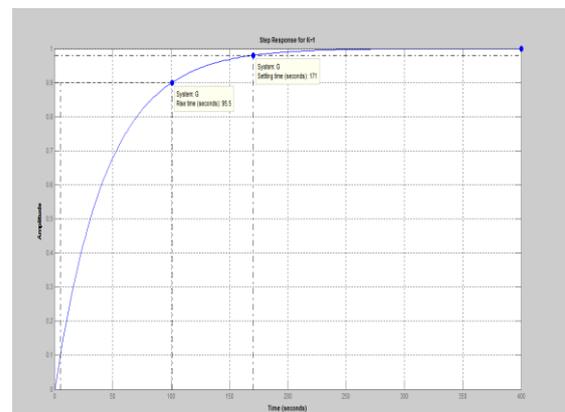


Fig. 5: Step response without a Controller

B.1 PID Controller:

The Proportional-Integral-Derivative (PID) controllers have been in regular use for the last 60 years in the process industry in spite of remarkable growth in advanced control systems. Almost 90 % of the control loops in industries are

PID based systems. Basic structure of a PID controller has been shown in the following fig 6.

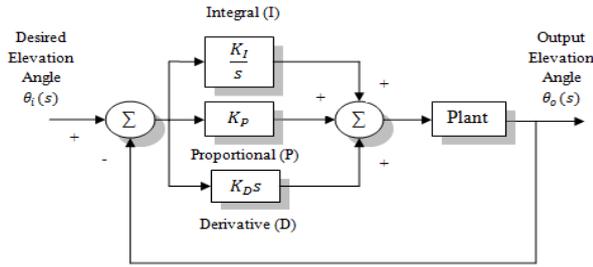


Fig. 6: Block Diagram of a PID Controller

Where K_P , K_I and K_D are proportional, integral and derivative gains and the plant is the system under consideration.

PID is an effective control system for continuous processes that performs two control tasks. Firstly, PID control keeps the output at a set level even though varying process parameters may tend to cause the output to vary from the desired set point. Second, PID promptly and accurately changes the process level from one set point level to another set point level [7].

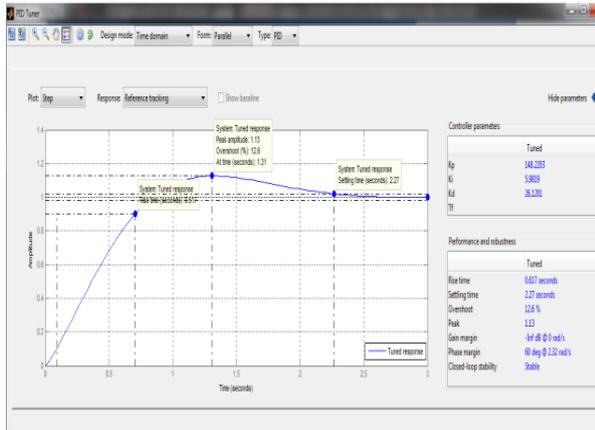


Fig. 7: Step Response after PID Control

When a PID controller is implemented into the system by using a pidtool command in MATLAB, a response is obtained as shown in fig. 7. Gains (K_P , K_I and K_D) are determined as:

$$K_P = 148.22, K_I = 5.98, K_D = 26.12$$

B.2 Discrete PID (DPID) Controller Design

Before applying a discrete PID, continuous system block diagram is required to be converted into discrete system block diagram as shown below in fig (8).

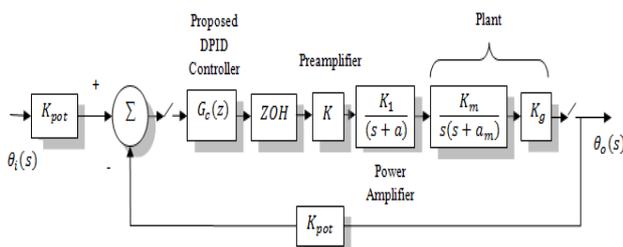


Fig. 8: Discrete System Block Diagram

Here $G_c(z)$ is the controller transfer function in z-domain and ZOH is the zero order hold. $G_c(z)$ is the proposed transfer function for the discrete PID (DPID) control. DPID is the subject of designing and plant's continuous transfer function is required to be converted into z-domain before applying into the above block diagram. Following assumptions are to be made for achieving this [5]:

- (i) Power amplifier's pole is assumed to be far enough away from the motor's pole hence power amplifier dc gain can be represented as unity.
- (ii) Pre-amplifier and potentiometer gains are considered as unity.

So the adjusted transfer function of the plant is given in equation (4).

$$G_p(s) = \frac{0.139}{s(s+1.944)} \quad (4)$$

Designing, a controller zero to cancel the plant pole on the s-plane at -1.944 yields a controller pole at -4. Hence the controller is given by equation (5).

$$G_c(s) = \frac{s+1.944}{s+4} \quad (5)$$

Using root locus to evaluate the gain, K , at the designing point yields $0.139K = 16$ or $K = 115$. So the controller is represented by equation (6).

$$KG_c(s) = 115 \frac{(s+1.944)}{(s+4)} \quad (6)$$

Hence the equivalent forward path Transfer function in s-plane, is given by equation (7).

$$G_{equi}(s) = KG_c(s)G_p(s) = \frac{15.98}{s(s+4)} \quad (7)$$

B.2.1 Selection of the Sampling Interval (T):

Astrom and Wittenmark (1984) have developed a guideline for selecting the sampling interval, T [5]. Their conclusion is that the value of T in seconds should be in the range $0.15/\omega_{\phi_M}$ to $0.5/\omega_{\phi_M}$, where ω_{ϕ_M} is the zero dB frequency (rad/sec) of the magnitude frequency response curve for the cascaded analog controller and plant.

From fig.9 the magnitude frequency response of eq. (7) is 0 dB at 3.2 rad/s. Thus the value of the sampling interval, T , should be in the range $0.15/\omega_{\phi_M} = 0.15/3.2 = 0.0468$ to $0.5/\omega_{\phi_M} = 0.5/3.2 = 0.156$ second.

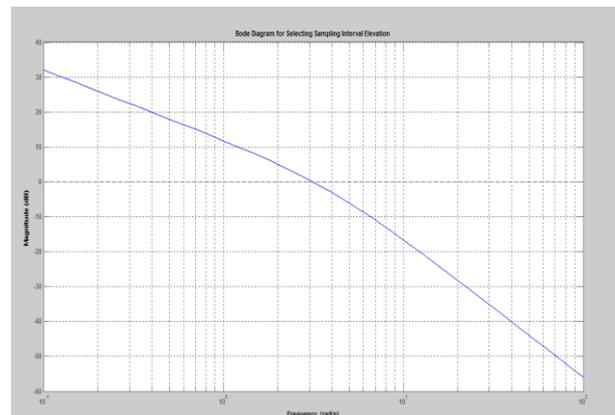


Fig. 9: Bode Diagram for Sampling Interval Selection

So choosing a smaller value in this range, say $T = 0.02$ second. The z-transform of the sampled plant ($T = 0.02$) is evaluated as shown in equation (8).

$$G_p(z) = \frac{2.744 \times 10^{-5}(z+0.9871)}{(z-1)(z-0.9619)} \quad (8)$$

The z-transform of the Controller is thus given as equation (9).

$$G_c(z) = \frac{112.73(z-0.9619)}{(z-0.9231)} \quad (9)$$

The above transfer function in z-domain is the proposed Discrete PID (DPID) controller. The system's response after having implemented the Discrete PID has been obtained as shown in fig.10.

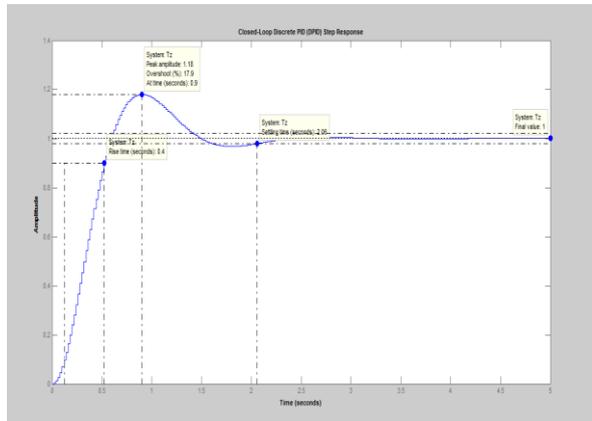


Fig. 10: Step Response of the System after DPID

IV. RESULTS

The following Table III gives us the comparative transient analysis for the system under consideration.

The Table III shows that the Discrete PID (DPID) exhibits:

- The utmost performance.
- Though the % overshoot is little higher as compared to a classical PID, yet well under the safe operating limit.
- Enhances system's closed loop stability.

TABLE III TRANSIENT RESPONSE OF THE PROPOSED SYSTEM

S. No.	Transient Parameters	PID Control	DPID Control
01	Rise Time (t_r)	0.617sec	0.40sec
02	Peak Time (t_p)	1.31sec	0.9sec
03	Overshoot (%)	12.6	17.9
04	Settling Time (t_s)	2.27sec	2.06sec
05	Closed Loop Stability	Stable	Stable

Hence if the system under consideration is linear and not affected by any disturbance or noise, DPID is suggested to be used as a controller for performing the control action.

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BIOGRAPHY



Sagar Yadav received his B.E. in Electronics and Telecommunication Engineering from Pt, Ravishankar Shukla University Raipur, India in 2005. He has 6 years of teaching experience at National Institute of Technology Raipur, India. Currently he is pursuing his M. Tech. in Instrumentation and Control

Engineering from Chhattisgarh Swami Vivekanand Technical University Bhilai, India. His areas of interest are robotics, neuro-fuzzy and modern control systems design for space vehicles.