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To: Samuel PD Anantadjaya <ethan.eryn@gmail.com>

Analysis of a Satellite Antenna Azimuth Angle Positioning Control System Using P, PI, and PID Controllers

Manuscript Number: HELIYON-D-24-00878

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Abstract:

This study aims to select a suitable control system from P, PI, and PID controllers for controlling the azimuthal angle of a satellite antenna. The objective is to accomplish accurate, stable, and fast control of the position of the antenna. At first, the transfer function of the control system representing the relationship between the input signal and the output position is derived. The stability and performance of the system are initially analyzed without including any controller. After adding one of the proposed controllers, the Ziegler-Nichols method obtains the initial controller parameters. The parameters are further tuned by MATLAB simulation to provide the best performance. System response plots are presented to demonstrate the effectiveness of each controller for different controller parameters. The PID controller with a proportional controller gain of 200, integral controller gain of 100, and derivative controller gain of 150 is the best option for this system since it offers a quick and stable response without any apparent jerking or overshooting.

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1 message

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Manuscript Number: HELIYON-D-24-00878

Title: Analysis of a Satellite Antenna Azimuth Angle Positioning Control System Using P, PI, and PID Controllers

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Reviewer Recommendation and Comments for Manuscript Number HELIYON-D-24-00878

Analysis of a Satellite Antenna Azimuth Angle Positioning Control System Using P, PI, and PID Controllers

Original Submission
Samuel PD Anantadjaya

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The antenna often received the blind-spotting phenomena, this is never address

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It is important since the lower gain response curve needs the necessary adjustments to satisfy the precision and timing criteria of a practical positioning control system. The amplifier extracts the sensor & reduces noise, then how come it becomes the proposed solutions?

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Analysis of a Satellite Antenna Azimuth Angle Positioning Control System Using P, PI, and PID Controllers

--Manuscript Draft--

Manuscript Number:	HELIYON-D-24-00878
Article Type:	Original Research Article
Section/Category:	Physical and Applied Sciences
Keywords:	Antenna; Controller; Steady-state analysis; Error analysis; Settling time.
Abstract:	This study aims to select a suitable control system from P, PI, and PID controllers for controlling the azimuthal angle of a satellite antenna. The objective is to accomplish accurate, stable, and fast control of the position of the antenna. At first, the transfer function of the control system representing the relationship between the input signal and the output position is derived. The stability and performance of the system are initially analyzed without including any controller. After adding one of the proposed controllers, the Ziegler-Nichols method obtains the initial controller parameters. The parameters are further tuned by MATLAB simulation to provide the best performance. System response plots are presented to demonstrate the effectiveness of each controller for different controller parameters. The PID controller with a proportional controller gain of 200, integral controller gain of 100, and derivative controller gain of 150 is the best option for this system since it offers a quick and stable response without any apparent jerking or overshooting.

Highlights

- A satellite antenna azimuth angle positioning control system is numerically analyzed
- Impact of P, PI, and PID controllers with different controller gains is investigated
- Initial controller gains are obtained using the Ziegler-Nichols tuning method
- A PID controller with $K_p = 200$, $K_i = 100$, and $K_D = 150$ is found to be the best selection
- Optimum gains result the desired response with no overshoot and least settling time

Analysis of a Satellite Antenna Azimuth Angle Positioning Control System Using P, PI, and PID Controllers

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Abstract

This study aims to select a suitable control system from P, PI, and PID controllers for controlling the azimuthal angle of a satellite antenna. The objective is to accomplish accurate, stable, and fast control of the position of the antenna. At first, the transfer function of the control system representing the relationship between the input signal and the output position is derived. The stability and performance of the system are initially analyzed without including any controller. After adding one of the proposed controllers, the Ziegler-Nichols method obtains the initial controller parameters. The parameters are further tuned by MATLAB simulation to provide the best performance. System response plots are presented to demonstrate the effectiveness of each controller for different controller parameters. The PID controller with a proportional controller gain of 200, integral controller gain of 100, and derivative controller gain of 150 is the best option for this system since it offers a quick and stable response without any apparent jerking or overshooting.

Keywords: Antenna; Controller; Steady-state analysis; Error analysis; Settling time.

1. Introduction

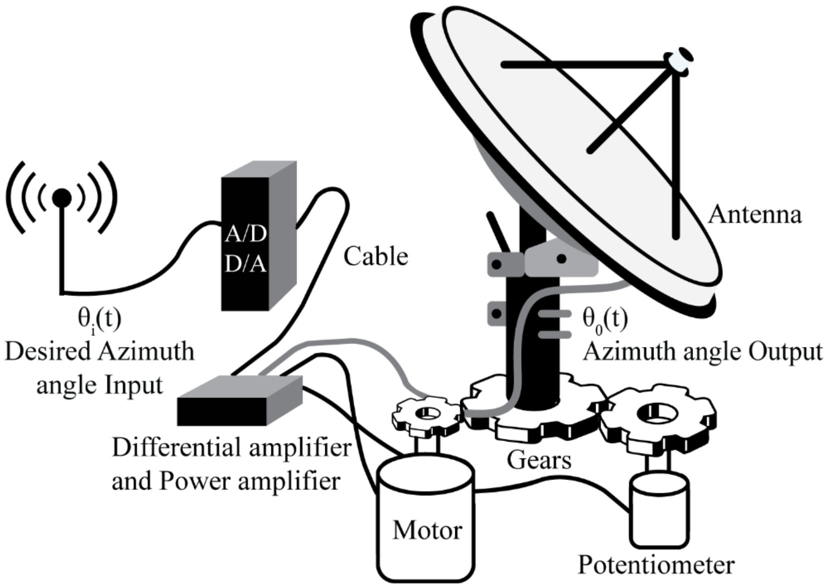
Satellite antennas have widespread applications in modern communications and networking systems, from deep space exploration to telecommunications data traffic control [1- 4]. Satellite technologies have come to fill a niche in communication technology, allowing for both data capture and transfer, irrespective of time and location [5]. The adept application of satellite antennas in deep space and lower orbit data transfer depends on the antenna's positioning [6, 7]. Nowadays, miniaturized satellites are being used to implement small-range signal communication for applications of the Internet of Things (IoT) in residential and commercial settings [8]. Thus, the usage of such technologies is ingrained in all aspects of modern life.

Satellite antennas can typically rotate with respect to a coordinate system in two axis directions: the azimuth axis and the elevation axis [9]. Of these, the azimuth axis position is the key parameter for proper signal communication of satellite antennas since the pointing accuracy of a satellite antenna is heavily dependent on the accuracy of the azimuth angle. The pointing action of an antenna initially occurs via a phenomenon named blind-pointing, where the positions of the antenna with respect to the anticipated position of the signal are captured. Once the blind-pointing occurs, the antenna receives a 'correcting signal' from the transmission source, which is then processed to reveal the actual position of the incoming signal and finally used to rectify the antenna position [1, 10]. Therefore, the initial positioning of the antenna with respect to a pre-determined data input is crucial in the operation of the signal capture process.

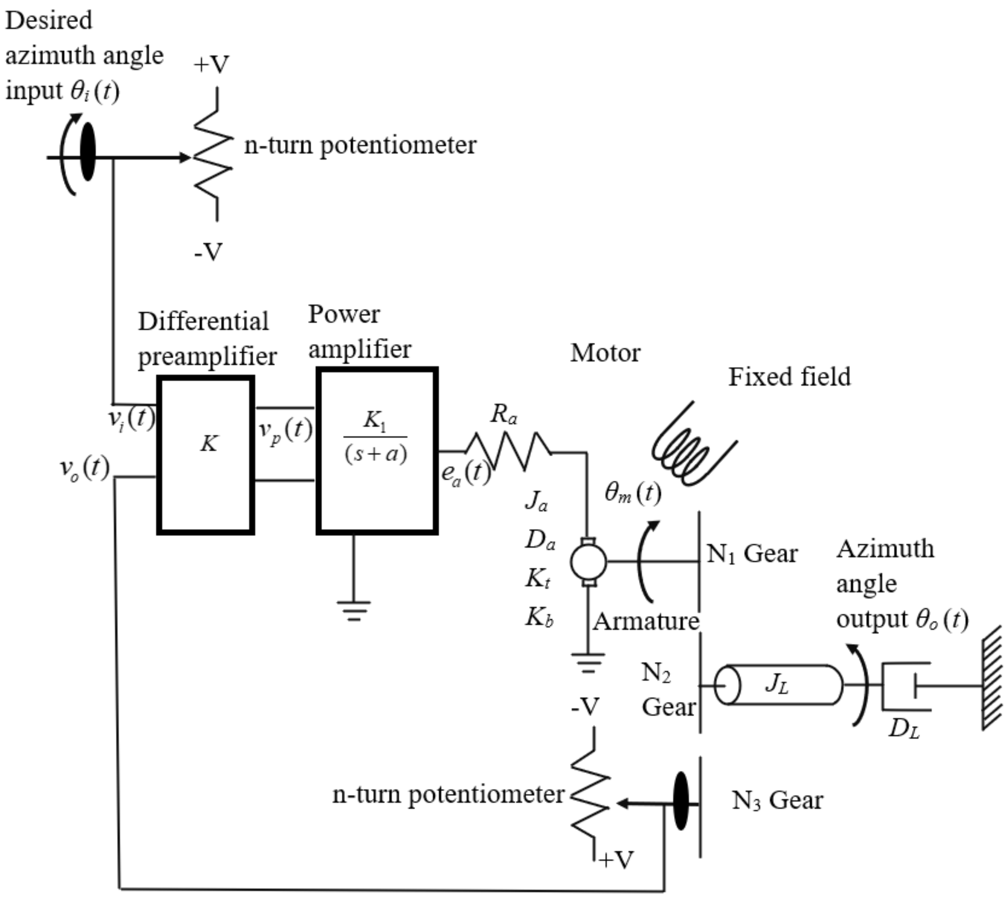
Since the conception of antennas in 1888 by Heinrich Hertz [11, 12], the challenges in their usage remain in the initial blind-positioning. The accuracy of the initial position of the antenna determines whether the desired information/signal is captured well by the antenna. In a world where information is generated on the scale of zettabytes per year, even missed data points from a small-time increment could result in the loss of invaluable information, which in the context of radio wave propagation may become lost forever [13]. Thus, contemporary researchers in recent years have turned their attention toward the accurate and timely initial positioning of the antennas to minimize the bottlenecking of incoming signal capture and improve the performance of the underlying data capture system. For cellular networks and low-orbit satellite tracking, the positioning of antennas can be predicted through the studies of population density in a locality and the movement pattern of satellites over a period of time [7, 10]. However, when considering antennas mounted on vessels with variable geographic positions and movement patterns, i.e., marine vessels, aerial vehicles, or automobiles, only survey data will not be enough to ensure the proper initial positioning of the antenna. Thus, systems with continuous correction mechanisms of the antenna position must be placed to ensure appropriate communication. Soltani et al. [14] derived a dynamical model of nonlinear characteristics to control satellite antennas for tracking telecommunication signals. Kelechi et al. [15] suggested using multiple input, multiple output technology to operate uncrewed aerial vehicles when they operated out of sight. Thus, the control systems became invaluable to satellite technology to facilitate antenna positioning. Both Asiegbu et al. [16] and Temelkovski and Achkoski [17] inferred the modeling of a control system where the controlling variable was the azimuth angle of the satellite antenna. Similarly, Sidek et al. [18] designed a solar tracking system that used a PID controller to facilitate the control of elevation and azimuth angle.

Various controllers are currently available, namely fuzzy logic controllers, sliding mode controllers, and continuous controllers based on proportional (P), integral (I), and derivative (D) control actions. Chishti et al. [3] compared classical PID controllers and linear quadratic regulators in controlling antenna positioning in the context of radio telescopes. Fandaklı et al. [5] experimentally demonstrated antenna position control using controllers such as – PID, Fuzzy logic, and sliding mode. Rao [19] studied and compared various continuous controllers and their relative merits and demerits in the DC motor speed control context. Using such controllers to increase the pointing accuracy of antennas was implemented in recent years [20, 21]. Okumus et al. [21] compared fuzzy logic controllers with PID controllers and found that fuzzy logic controllers could provide better responses. Building on that, they further analyzed an antenna azimuth control system using PI, fuzzy logic, and a self-tuning fuzzy logic controller [22]. They found that a self-tuning fuzzy logic controller confirmed the best results. Hoi et al. [23] designed a fuzzy PID controller and analyzed its performance against traditional PID controllers. Romsai et al. [24] proposed the design of a PID controller in the context of azimuth position control using the Lévy-flight intensified current search algorithm. They compared their design with the result of the Ziegler-Nichols tuning method [25] and determined that LFICuS could provide satisfactory results.

From the discussion above, it is evident that the traditional continuous controllers are the basic stepping-stone to analyzing and correcting antenna positioning and providing system accuracy regarding antenna pointing. It requires the control of system characteristics such as settling time, percent overshoot, and rise time to find and retain an optimum system performance. Due to the increasing importance of antenna technology in modern life, the effort behind improving the technology is rightfully a topic of interest among contemporary researchers. As such, this paper, following the ongoing effort to design an efficient and highly functioning antenna-pointing control system, proposes a comparative study between various traditional continuous controllers- P, PI, and PID to determine the key metrics of an efficient and highly functioning antenna azimuth angle control system, with the focus being not only the accuracy but also the response time of the system. Thus, the current study aims to derive the optimum scheme for controlling the blind positioning of an antenna azimuth angle using P, PI, and PID controllers.



(a)



(b)

Figure 1: (a) Physical layout and (b) schematic block diagram of an antenna azimuth angle positioning control system.

2. Derivation of system block diagrams without controller

The antenna azimuth angle control system depicted in Fig. 1(a) is a position control system that controls a positioning parameter, i.e., the antenna azimuth angle. The schematic block diagram of the antenna azimuth control system shown in Fig. 1(b) can be presented with respect to the components' functions. This feedback system is such that it operates without a controller.

The transfer functions of the individual components are determined to model the system mathematically. The input potentiometer receives angular displacement (θ_i) as input from the user and sends an output voltage (v_i), which rotates the antenna to its desired position. The output potentiometer in the feedback loop receives the angular displacement of the antenna (θ_o) as the input and sends a correction voltage (v_o) in the feedforward signal. As the forms of input and output signals are the same for both potentiometers, they are configured in the same manner. The transfer function for both potentiometers is the ratio of the output voltage to the angular displacement. The center position of the potentiometer signifies zero output voltage. As the knob is turned five times, it induces a voltage of 10 V in the circuit. Thus, the transfer function of the potentiometer can be expressed as,

$$\frac{V_i(s)}{\Theta_i(s)} = \frac{V_o(s)}{\Theta_0(s)} = \frac{10}{10\pi} = \frac{1}{\pi} = K_{pot}. \tag{1}$$

For the amplifiers, the transfer function is the ratio of the output voltage (v_p) divided by the input voltage. In this problem, the gain of the preamplifier (K) is varied to optimize the performance of the system. The next component, the power amplifier, receives this voltage (v_p) and transfers the voltage (e_a) required for the motor. Assuming the system never reaches a saturation point and neglecting the dynamics of the preamplifier, the transfer function of the power amplifier is considered to be as follows:

$$\frac{E_a(s)}{V_p(s)} = \frac{K_1}{s+a}. \tag{2}$$

For this problem, both K_1 and a are 100. The system's remaining components are the motor, gear arrangement, and load. The equivalent inertia (J_m) is expressed as,

$$J_m = J_a + J_L\left(\frac{N_1}{N_2}\right)^2, \tag{3}$$

where J_a and J_L are the moments of inertia of the armature and the load, respectively, N_1 and N_2 denote the numbers of teeth in the gears. The resultant viscous damping (D_m) in the system can be modeled as,

$$D_m = D_a + D_L\left(\frac{N_1}{N_2}\right)^2, \qquad (4)$$

where D_a and D_L are the damping of the armature and the load, respectively. To express the transfer function of the motor, assuming there are no outside disturbances, the relation between motor displacement (θ_m) and input voltage (e_a) can be expressed from [26] as,

$$\frac{\theta_m(s)}{E_a(s)} = \frac{K_t/(R_a J_m)}{s\left(s + \frac{1}{J_m}\left(D_m + \frac{K_t K_b}{R_a}\right)\right)}. \qquad (5)$$

Here, K_t is the motor torque constant, R_a is the electric resistance of the armature circuit and K_b is the back emf constant. For ease of mathematical expression, two new variables are considered and expressed as such,

$$K_m = \frac{K_t}{R_a J_m}, \qquad (6)$$

$$a_m = \frac{1}{J_m}\left(D_m + \frac{K_t K_b}{R_a}\right). \qquad (7)$$

Using (6) and (7), equation (5) can be simplified as,

$$\frac{\theta_m(s)}{E_a(s)} = \frac{K_m}{s(s + a_m)}. \qquad (8)$$

The transfer function of the gears, K_g is simply the gear ratio of the motor to the load, which is expressed as,

$$K_g = \frac{N_1}{N_2}. \qquad (9)$$

The schematic block diagram shown in Fig. 1(b) can be mathematically illustrated in Fig. 2 using the individual transfer function of each component used in the antenna azimuth angle positioning control system. The control system depicted in Fig. 2 can be described by the following transfer function,

$$G(s) = \frac{\Theta_o(s)}{\Theta_i(s)} = \frac{KK_g K_1 K_m K_{pot}}{KK_g K_1 K_m K_{pot} + s(s+a)(s+a_m)}. \qquad (10)$$

The values of different parameters used in the above transfer function of the system are listed in Table 1.

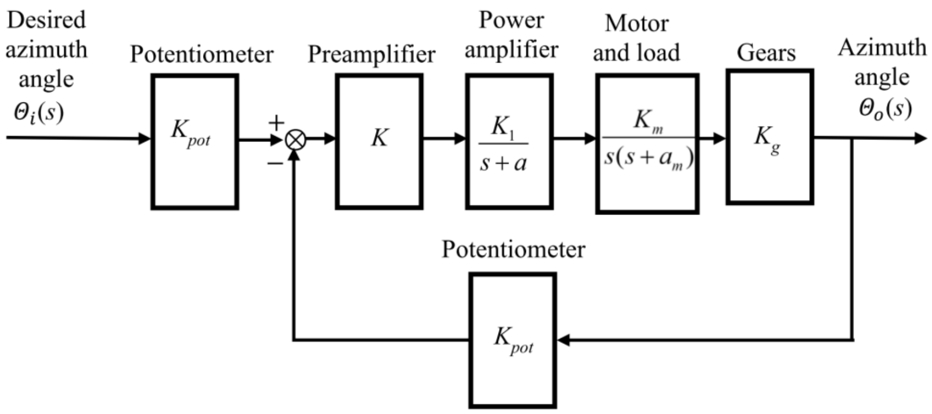


Figure 2: Mathematical block diagram (without controller) of the current antenna azimuth angle positioning system.

Table 1: Parameters used for the amplifiers, motor, load, and gear systems [26].

Parameter name	**Symbol [Unit]**	**Value**
Power amplifier	a	100
	K_1	100
Motor parameters	K_t [N.m/A]	0.5
	K_b [V.s/rad]	0.5
	R_a [Ω]	8
	K_m [1/V.s^2]	2.083
	a_m [1/s.rad]	1.71
Load parameters	J_L [kg.m^2]	1
	D_L [N.m.s/rad]	1
Armature parameters	J_a [kg.m^2]	0.02
	D_a [N.m.s/rad]	0.01
Potentiometer	K_{pot} [V/rad]	0.318
Preamplifier	K	-
Gears	K_g	0.1
	N_1	25
	N_2	250

After using these values in (10), the system transfer function can be simplified as follows:

$$G(s) = \frac{6.63K}{s^3 + 101.71s^2 + 171s + 6.63K}. \tag{11}$$

3. Derivation of system transfer function with controller(s)

The system performance can be improved by various continuous controllers that can be used to infer the best system layout for proper positioning. The proposed system uses a negative unity feedback loop and a closed-loop control system. The system characteristics change based on the angle input and the controller used. The controller will continue to send a signal to the input transducer until the appropriate azimuth angle is found as its input. Moreover, the transfer function will change depending on the selected controller after introducing a controller in the system. The new mathematical block diagram is presented in Fig. 3, and the modified transfer functions caused by the P, PI, and PID controllers are shown in Table 2, where K_p, K_i, and K_D are the proportional, integral, and derivative controller gains, respectively.

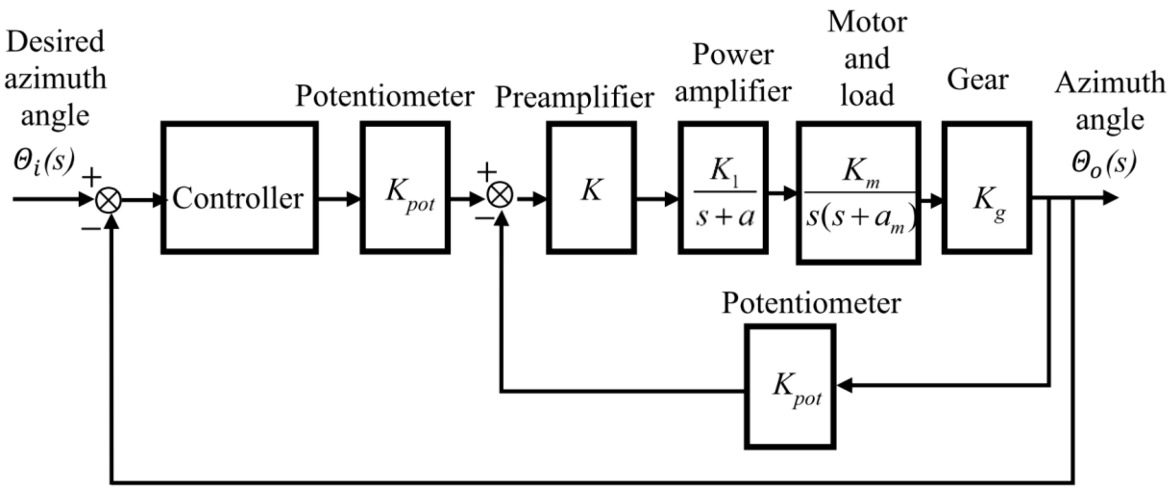


Figure 3: Mathematical block diagram (with controller) of the current antenna azimuth angle positioning system.

Table 2: Transfer function of the system after inserting the controller.

Type of Controller	Transfer Function, G(s)
P	$\frac{6.63KK_p}{s^3+101.71s^2+171s+6.63K(1+K_p)}$
PI	$\frac{6.63K(K_ps+K_i)}{s^4+101.71s^3+171s^2+6.63K(1+K_p)s+6.63KK_i}$
PID	$\frac{6.63K(K_Ds^2+K_ps+K_i)}{s^4+101.71s^3+(171+6.63KK_D)s^2+6.63K(1+K_p)s+6.63KK_i}$

4. Results and discussion

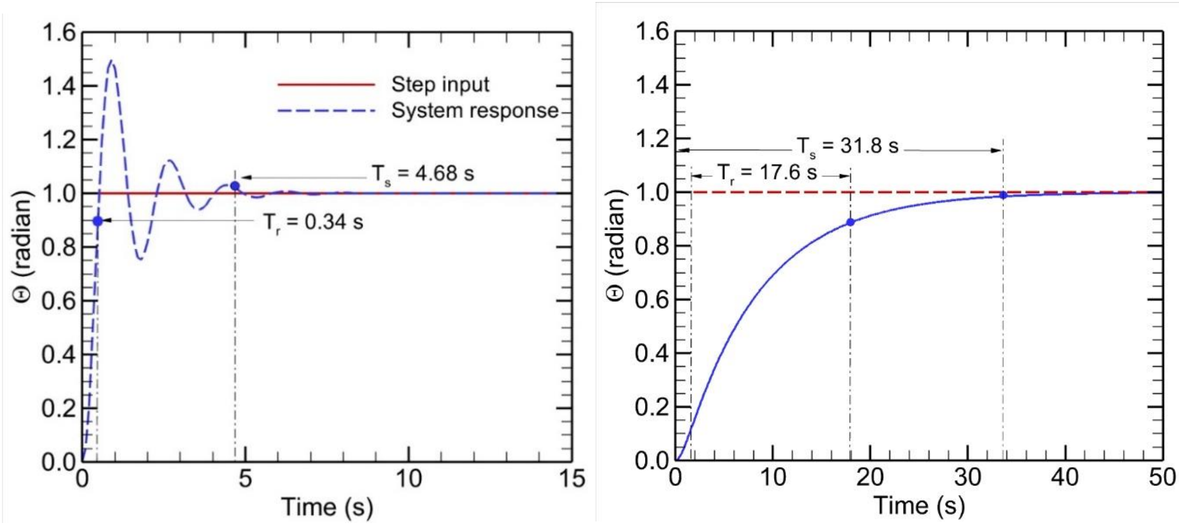
For precise blind-pointing of a radio antenna, the positioning control system of the antenna azimuth angle has been analyzed in this study. Initially, the system response has been observed with regard to the preamplifier gain. After that, the analysis has been continued employing Ziegler-Nichols tuning [25] parameters to the system. These initial values are then used as a stepping-stone for further trial and error evaluations to capture the proposed system's most suitable combination of controller gain values. This evaluation compares rise time, settling time, and percentage overshoot criteria. This analysis defines rise time (T_r) as the time required for the response to rise from 10% to 90%. Besides, settling time (T_s) denotes the time required for the amplitude of the oscillating transient response to decay 2% of the steady-state value. Finally, percentage overshoot (%OS) measures the percentage change of amplitude when the waveform at the peak overshoots the steady-state value. The relevant results are obtained by solving transfer functions listed in Table 2 using MATLAB software.

4.1. System response without controller

The transfer function derived in (11) is a closed loop and a type-0 transfer function. The step response of this system varies with respect to the preamplifier gain, as displayed in Fig. 4. The system is examined using a unit step input. The response curve using a high value of K (= 200) shows the underdamped characteristics. Fig. 4(a) shows that the response curve overshoots and has damped oscillations. The rise time of the response is 0.34 s, and the settling time is 4.68 s. On the other hand, a lower value of K (= 3) shows characteristics of the overdamped response, as shown in Fig. 4(b), where T_r = 17.6 s and T_s = 31.8 s. The underdamped system would not be feasible since the pointing control system needs precise and faster blind-pointing positioning to function correctly. Even though it has a shorter settling time, the oscillations will wear out the mechanical mountings of the antenna. Thus, a lower preamplifier gain value of K = 3 should be chosen, and the corresponding transfer function becomes,

$$G(s) = \frac{19.89}{s^3 + 101.71s^2 + 171s + 19.89}. \quad (12)$$

It is important to note that the lower gain response curve requires adjustments to meet the precision and timing criteria of a practical positioning control system. As the preamplifier typically extracts the signal from a sensor and reduces noise, changing its gain would never practically solve this problem [27]. Thus, it is imperative to use a controller to control the positioning accuracy.



(a) (b)

Figure 4: System step response characteristics without using controller when (a) K = 200, and (b) K = 3 (color online).

4.2. Ziegler-Nichols tuning criterion

The values of the controller gains are identified using the Ziegler-Nichols tuning criterion [25] as the initiation point. The proportional controller gain for marginal system stability is 875.92, and the frequency of sustained oscillation is 13.12 rad/s. Thus, the values for the controller gains obtained using the Ziegler-Nichols tuning criterion [25] to derive initial system responses are tabulated in Table 3.

Table 3: Ziegler-Nichols tuning values of P, PI, and PID controller for the azimuth angle positioning system.

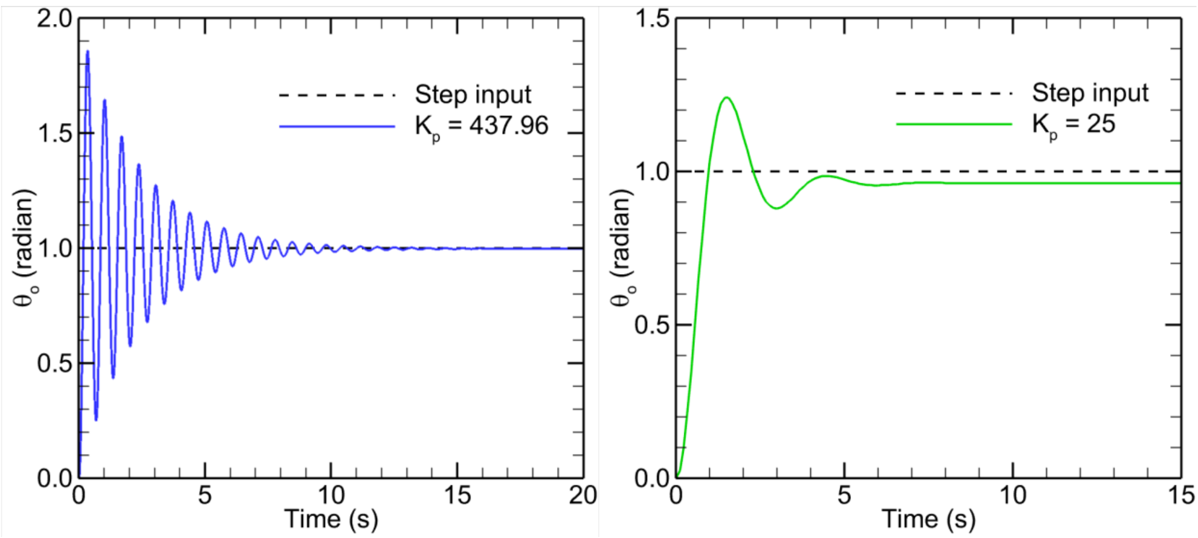
Type of Controller	K_p	K_i	K_D
P	437.96	-	-
PI	394.17	985.41	-
PID	525.55	2194.36	31.46

4.3. System response using controllers

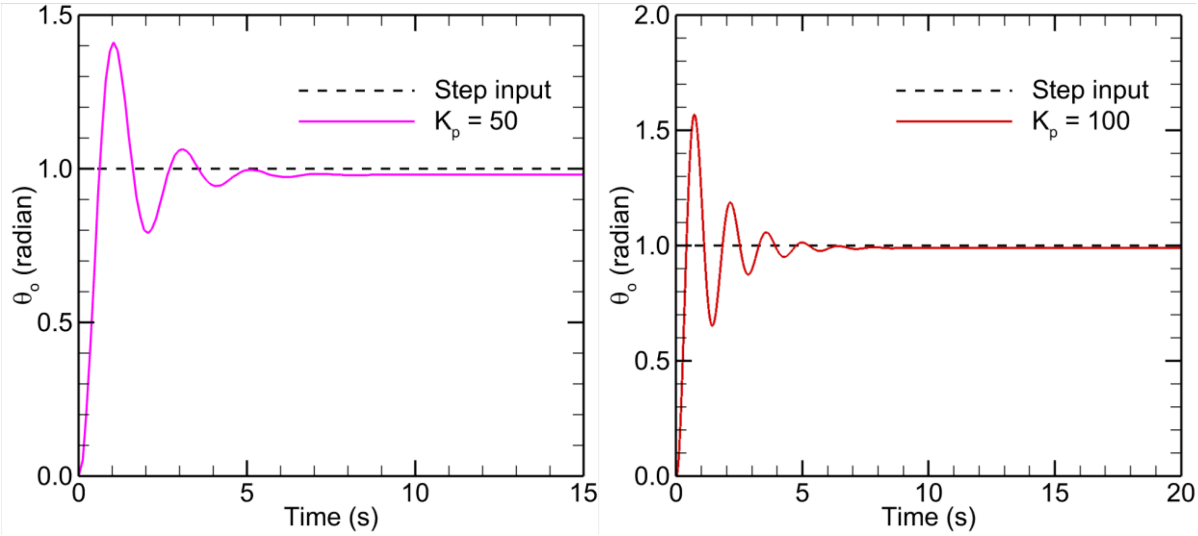
Three separate continuous (P, PI, and PID) controllers are employed to analyze the system response. Following the initial values (see Table 3), other values for the controller gain are assumed, and the change in the system response is observed. This iterative process examines the performance of such controllers in the antenna positioning control system.

4.3.1. P controller

Figure 5 demonstrates the change in system response with the proportional gain. First, the response attained from using the initial gain of the Ziegler-Nichols tuning method is observed. From Fig. 5(a), it is seen that the response exhibits the properties of a damped oscillation. It has a rise time of 0.12 s and a settling time of 9.18 s. Furthermore, a percentage overshoot of 86.04 is present. A trial proportional gain of 25 is considered for further analysis, as shown in Fig. 5(b), to reduce the oscillations and improve the system's stability before the output settles down. It is noticeable that this response is more stable compared to the previous one. However, a steady-state error is present, which is not ideal. This response has a rise time of 0.62 s and a settling time of 4.77 s. More importantly, the percentage of overshoot has decreased to 29.22. The value of K_p = 50 is employed in the next iteration to minimize the steady-state error, and the corresponding response is presented in Fig. 5(c). The steady-state error has undoubtedly decreased, yet the response oscillates more before becoming steady. This response has a rise time of 0.4 s, a settling time of 4.44 s, and an overshoot of 44.04%. In the final iteration, a higher value, K_p = 100, is selected, and the respective response curve is illustrated in Fig. 5(d). The number of oscillations increases before it settles down compared to the cases of K_p < 100 and eventually decreases the steady-state error. Therefore, it can be summarized that the settling time and stability are adversely affected when K_p increases. However, reducing the value of K_p leads to higher steady-state error. Since none of the K_p values yields an appropriate response, a P controller alone cannot provide a suitable system response.



(a) (b)



(c) (d)

Figure 5: System responses using P controller when (a) K_p = 437.96, (b) K_p = 25, (c) K_p = 50, and (d) K_p = 100 (color online).

4.3.2. PI controller

When the P controller could not provide a suitable response, the integral controller is added to the proportional controller for further improvement, as shown in Fig. 6. For the PI controller, the Ziegler-Nichols tuning value provides disastrous results concerning the system stability (not included here). In this case, the oscillating amplitude increases rapidly once the oscillation is initiated, and the system is ascribed as unstable. Therefore, tinkering with proportional gain (K_p) and integral controller gain (K_i) is necessary. First, K_p of 350 and K_i of 100 are selected, and the corresponding response has the characteristics of the damped oscillation, as shown in Fig. 6(a). The system is stable, with a settling time of 10.65 s. Besides, it has a speedy rise time of 0.13 s and exhibits a %*OS* of 87.09. Now, further improvement can be achieved by considering different values of these parameters, such as K_p = 300 and K_i = 10. The response in Fig. 6(b) oscillates and decays to a steady-state value. The system has a rise time of 0.14 s and a settling time of 7.4 s. However, the overshoot is still present, reaching a value of 79.34%. Since these characteristics are undesirable for the antenna's control, further tuning of the system parameters is required. From Figs. 6(a) and (b), it is observed that a reduction of the values of K_p and K_i makes the system more stable. Hence, the next iteration is carried out, selecting lower values of the controller gains, as shown in Figs. 6(c) and (d). In Fig. 6(c), the response has a relatively lower overshoot and very few oscillations before it attains a steady-state value when K_p = 30.15 and K_i = 1.16. If K_p and K_i are further reduced to 1.26 and 0.35, respectively, a lower %*OS* of 12.26 is yielded. However, the rise time (T_r = 6.17

s) and the settling time (T_s = 24 s) become more prolonged. It demonstrates that the PI controller is unsuitable for the required controlling system without attaining proper tuning.

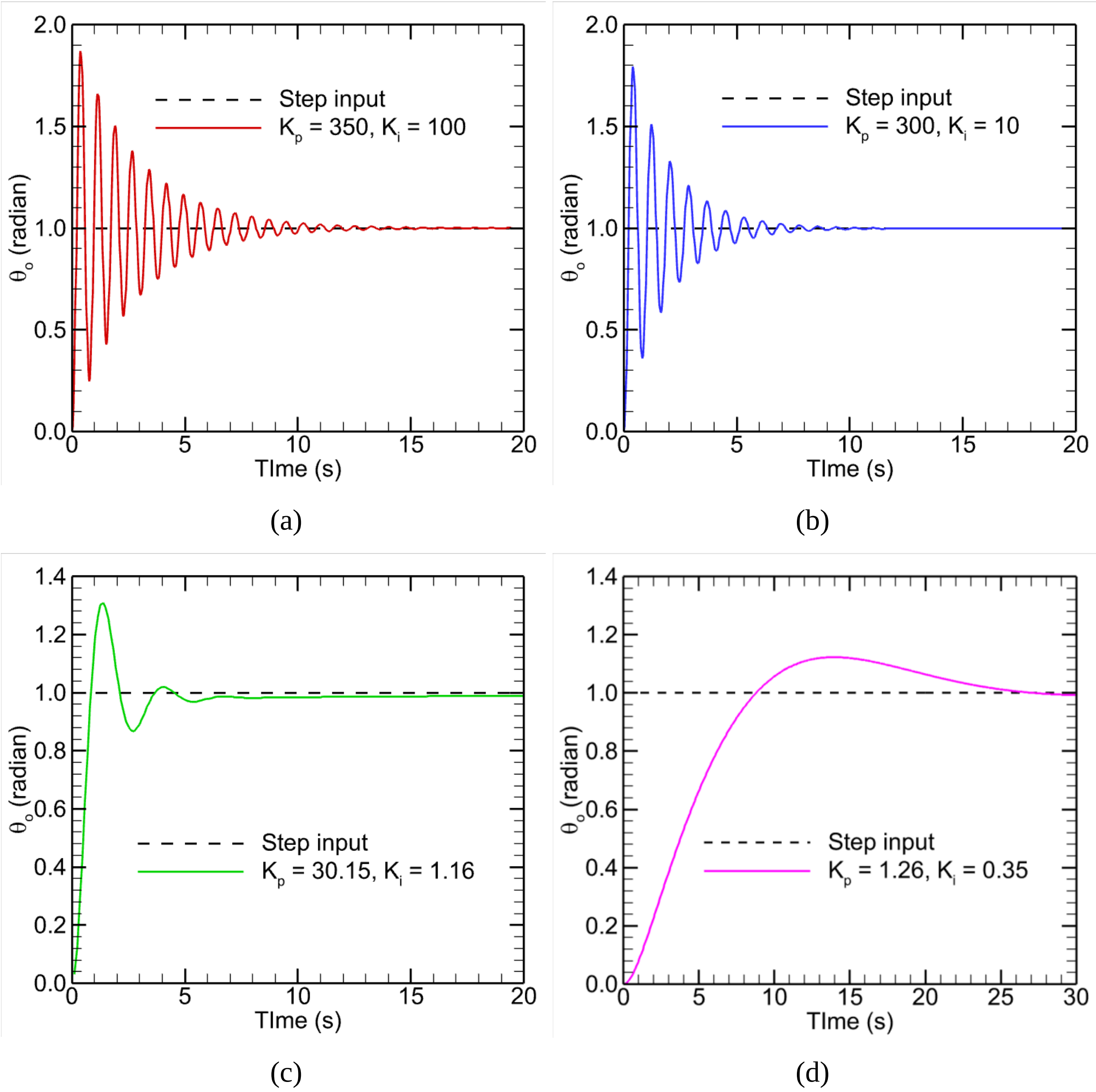
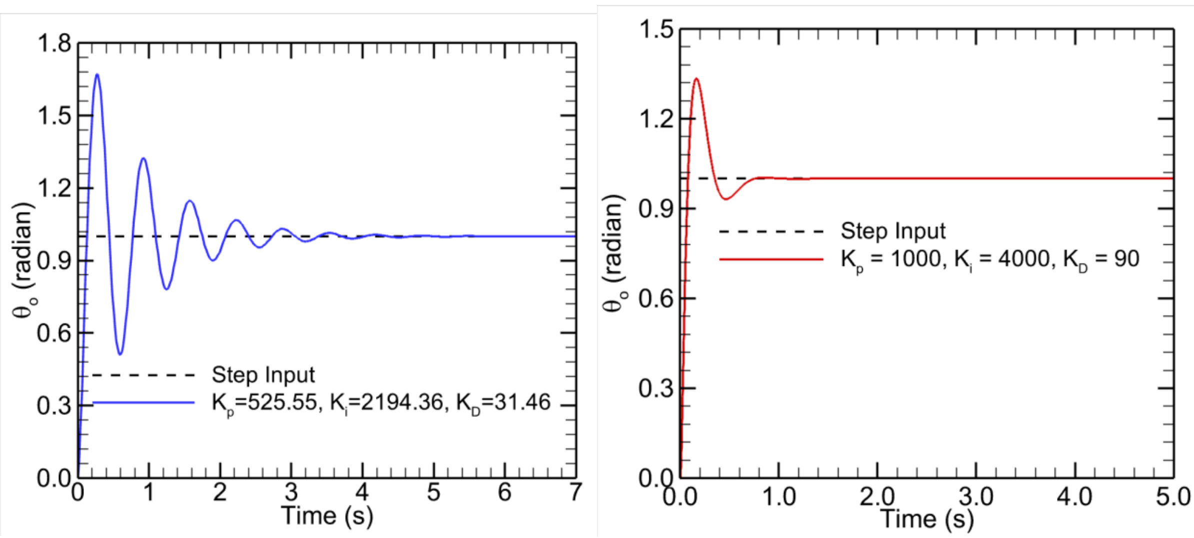


Figure 6: System responses using PI controllers when (a) K_p = 350 and K_i = 100, (b) K_p = 300 and K_i = 10, (c) K_p = 30.15 and K_i = 1.16, and (d) K_p = 1.26 and K_i = 0.35 (color online).

4.3.3. PID Controller

The influence of the PID controller on the azimuth angle positioning control system is presented in Fig. 7. Initially, the values of the governing parameters such as K_p, K_i, and K_D are determined using the Ziegler-Nichols tuning method as listed in Table 3. The corresponding response is shown in Fig. 7(a). The plot shows the response to be a damped oscillation with T_r = 0.09 s, T_s = 3.23 s, and a %*OS* of 67.07. These initial outcomes confirm that further tuning is required for the PID controller since the response exhibits an undesirable oscillation. Therefore, an iterative process of selecting the best possible values of K_p, K_i, and K_D is continued to identify the desired response. First, the gains are increased from their initial values obtained from the Ziegler-Nichols tuning method, such as K_p = 1000, K_i = 4000, and K_D = 90. The corresponding response is plotted in Fig. 7(b), which shows that the oscillatory behavior decays with a single overshoot of 33.5%. Besides, the rise time becomes 0.06 s, and the settling time is 0.64 s. These performance indicators are better than the responses obtained for all previous cases. However, the initial overshoot must be removed from the transient response to make the perfect overall system response. Hence, another case of K_p, K_i, and K_D selection is made where the gains are quite lower than the initial Ziegler-Nichols tuning values except K_D. Here, K_p = 250, K_i = 120, and K_D = 180 are considered, and the corresponding response curve is plotted in Fig. 7(c). Compared to all previous response curves (see Figs. 5 and 6), this outcome shows quite an improvement. There is almost no oscillation, and the rise and the settling times become 0.04 and 0.07 s, respectively. However, a tiny overshoot is present, which can be eliminated by further fine-tuning. A final selection of K_p = 200, K_i = 100, and K_D = 150 tends to make the response more stable, faster, and accurate. The new response curve validated this claim is displayed in Fig. 7(d). The response has no oscillation and a rise time of 0.06 s with a settling time of 0.1 s. This final tuning provides quite good performance for the azimuth control of the satellite antenna. Hence, for the controller's design, K_p = 200, K_i = 100, and K_D = 150 are reasonable choices. A comparative table (see Table 4) summarizes the findings obtained from the above study.



(a) (b)

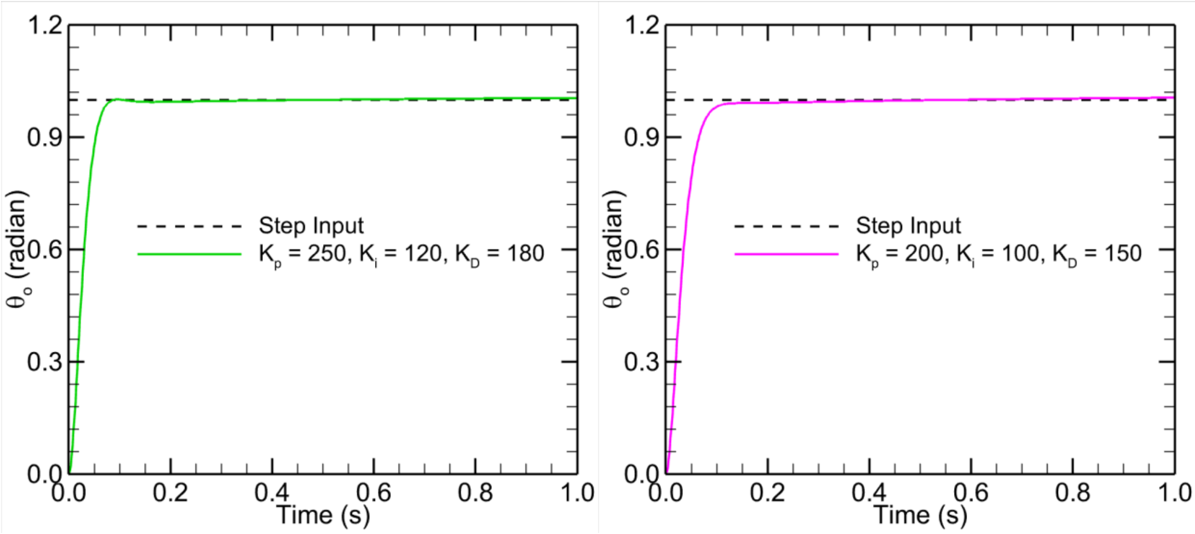


Figure 7: System responses using PID controller when (a) $K_p = 525.55$, $K_i = 2194.36$, and $K_D = 31.46$, (b) $K_p = 1000$, $K_i = 4000$, and $K_D = 90$, (c) $K_p = 250$, $K_i = 120$, and $K_D = 180$, and (d) $K_p = 200$, $K_i = 100$, and $K_D = 150$ (color online).

Table 4: Comparison of the performances of P, PI, and PID controllers for the antenna azimuth angle positioning system.

Controller	K_p	K_i	K_D	T_r (s)	T_s (s)	%OS
P	25	-	-	0.62	4.77	29.22
	50	-	-	0.4	4.44	44.04
	100	-	-	0.26	5.12	58.36
	437.96	-	-	0.12	9.18	86.04
PI	350	100	-	0.13	10.65	87.09
	300	10	-	0.14	7.4	79.34
	30.15	1.16	-	0.56	6.07	31.02
	1.26	0.35	-	6.17	24.0	12.26
PID	525.55	2194.36	31.46	0.09	3.23	67.06
	1000	4000	90	0.06	0.64	33.5
	250	120	180	0.04	0.07	0.09
	200	100	150	0.06	0.1	0

5. Conclusion

Due to numerous applications in communications, data traffic control, and deep space missions, it is crucial to assess the control system for positioning a satellite antenna. Firstly, a functional model with multiple amplifiers, motors, and loads, from which the mathematical model has been derived for the satellite antenna positioning control system. Then, the preamplifier value is determined by selecting an overdamped system depending on the physical system's durability. The unmanned antenna azimuth control system has been analyzed using P, PI, and PID controllers. The Ziegler-Nichols tuning method is initially used to get the initial tuning values for subsequent iterations. This study highlights achieving optimum system accuracy, stability, and faster transient response by an iterative selection of different controllers' gains. Based on these findings, the following conclusions can be reached:

i. Considering system stability and steady-state error, the P controller alone is insufficient for this system.

ii. The PI controller also delivers undesirable results without being tuned appropriately. The integral action changes the results of this system so little because the system's natural response has properties similar to the function of the I controller.

iii. The PID controller yields impressive results that are suitable for the system. A system with zero overshoot and minimum rise and settling times can be achieved using $K_p = 200$, $K_i = 100$, and $K_D = 150$.

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