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System Control for Seagoing Vessel's Antenna by a Pole Placement Technique

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ABSTRACT

A position control system is imperative in broadcasting, communication, and military operations. The wider area coverage capability of the satellite TV broadcasting system provides the sailor with the opportunity to listen to news and entertainment. However, due to the satellite TV receiver's dish antenna alignment condition with the transmitting satellite in space, the Sheep constant change of position, it is extremely difficult to watch satellite television onboard vessels. This paper presents how a control system can be used onboard a seagoing vessel to automatically positions its satellite television signal receiver antenna using pole placement by state feedback technique simulated in Matlab (Simulink) software. The proportional controller was first developed followed by the proportional-integral controller, then the proportional-integral derivatives, and finally the close loop Pole placement by state feedback approach was implemented. The response of each controller was analyzed and the performance was noted in terms of the pre-determined design criteria. This ensures that seagoing vessels receive seamless satellite television signals at sea with minimized antenna positioning errors and improvedcontroller performance. The system design was evaluated by comparing the response with the Proportional integral derivative (PID). The results show that the overall performance of the position control system with pole-placement by state feedback technique is much better than that of the PID controllers in terms of reduced percentage overshoot, rise time, and settling time response of the system.

Key words: Alignment, antenna, Control, Performance, Positioning

1. INTRODUCTION

As a satellite TV broadcasting system involves the transmission of the signal from a ground TV station to an orbiting satellite, the signal is received, amplified, and retransmitted by the satellite back to the subscribers on earth, thus covering wider and remote areas including open sea [1]. The basic set-up of the TV system requires that the subscriber receiver dish on the earth surface should be lock-on to the transmitting satellite in space at all times for quality signal reception. It is quite unfortunate that this could not be achieved by the receiver dish onboard a seagoing vessel at all times because of its maneuverability and heading. In other words, due to constant changing of directions during ships' maneuvers and the effects of ship's degree of freedom at sea, signal reception dish antennae often misalign with the service provider's transmitting satellite and this leads to a poor or complete loss of signal onboard the vessels.

The receiver antenna position control system based on the principle of antenna look angle estimation in conjunction with a closed-loop pole placement by state feedback technique has been employed to achieve desired results. The system stability and other control performance indicators of a closed-loop linear time-invariant system largely depend on the pole locations. Therefore, the pole-placement method is used to place the poles of the closed-loop system in the desired positions by state feedback or output feedback as the system performance is closely related to the pole positions. The pole placement in system design is very important and there are two main steps to carry out. The first step is the placement or assignment of poles and the second step is the identification of the feedback gain matrix. The sufficient and necessary condition of arbitrary closed-loop pole placement by state feedback is that the system must be controllable [2]. The closed-loop pole placement by state feedback method employed is basically to improve the performance of the system. Thus, by chosen an appropriate gain matrix for state feedback, it is possible to force the designed system to have closed-loop poles at desired locations. This position control system is very essential in any sphere of life ranging from Broadcasting, Communication to Military operations. The automatic positioning of the receiver's dish antenna is controlled by placing the using a state feedback control system. State feedback will improve the position control of the Vessel's receiver antenna so that constant alignment with the transmitting satellite is maintained as required. MATLAB's graphic user interface has been designed and responses at various pole positions simulated.

2. RELATED WORKS

The Linear control system makes use of the linear control theorems and approaches for control system analysis and design [3][4][1][5][6][7][8] for the positioning/tracking control of the parabolic dish antenna system to improve the precision and system response to both internal and external disturbances.
Solatani et al [5] considered the case of overseas satellite telecommunication where the control system directs onboard motorized antenna towards a selected satellite in the presence of disturbances from the high sea waves. Fault-Tolerant Control (FTC) system was designed to maintain the tracking functionality.
The effectiveness of this method was tested using ship simulator facility. However, fault estimation has proved to be an extremely challenging task. Consequently, the team proposed the use of fault estimation in an adaptive reconfiguration system as future research. An overview of different antenna pointingmechanisms modeled and implemented for varied space applications was provided.[9] traditionally, servo systems with DC motors or hydraulic actuators are used for antenna driving and different control algorithms: PI, PID or Linear Quadratic Gaussian (LQG) was used to improve performance of the pointing systems. PI controllers are easy to implement but take much time to reach set point and have degraded performance under system nonlinearities. LQG controllers are not only optimal but also have the ability to estimate non-measurable states by using observers to reconstruct them and provide better performance in case of wind gusts noise. As future work, they proposed the use of stepper motors which provide good torque, to replace DC motor and servos which adds backlash as well as friction. The problem presentedwas to analyze and implement a controller on an off the shelf antenna azimuth position control system. They analyzed the open loop and closed loop characteristics of the system and determined the most stable and implementable controller. The suggested solution was to implement a PID controller between the power amplifier and the preamplifier as shown in Figure 1.1. This allowed for better stability and response times as was observed from the MATLAB simulations.

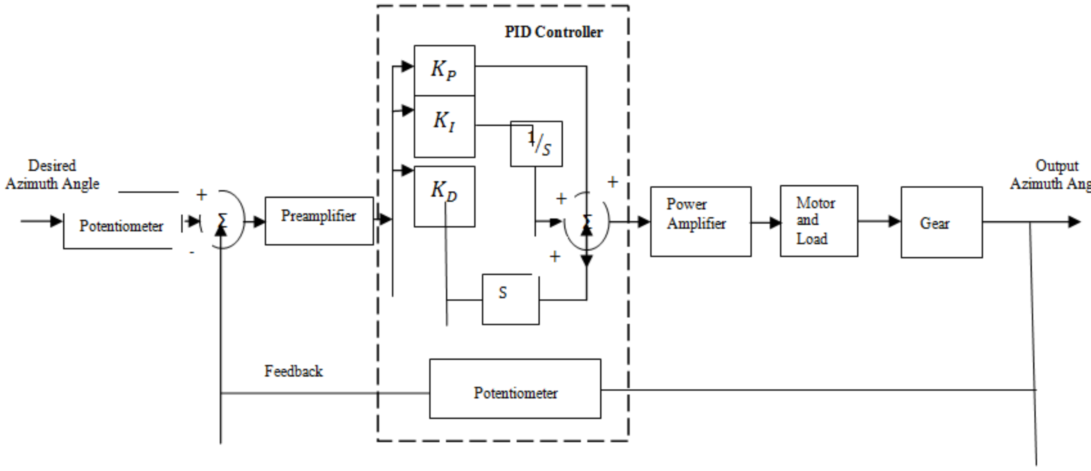

Fig. 1.1 Antenna Azimuth Position Control System Block Diagram

The discrete-time controller for tracking of a target communication satellite using the sampled-data H-infinity (H_∞) control theory along with the reference signal generated by an improved conventional step tracking algorithm was [7] designed. This controller demonstrated superior robustness for the longer sampling period when compared with a simple PID controller. However, the performance of the antenna tracking system largely depends on step sizes, with smaller step sizes creating a computational delay. Further work was needed to design attitude correction systems so that surface vehicles such as ships may receive satisfactory satellite broadcasts. An H-infinity controller was proposed [4] for tracking operation of the Digital Satellite Service (DSS-13) antenna to reduce disturbances due to wind. The H-infinity controller shows superior performance in terms of wind disturbance rejection and stability, followed by the linear-quadratic-Gaussian (LQG) controller and then the proportional-integral (PI) controller. [8] developed satellite antenna position controller using an adaptive variable structure to get of the problem of model uncertainties which was achieved using the feed-forward compensation technique. Tests were conducted using the satellite antenna pointing compound full-physical simulation system and results showed that the controller had improved the pointing accuracy of the system.

3. METHODOLOGY

The design methodology of the position control system involves four units, namely: The Sensorunit, Control unit, Motor driver unit, and Display unit as shown in figure 3.1.

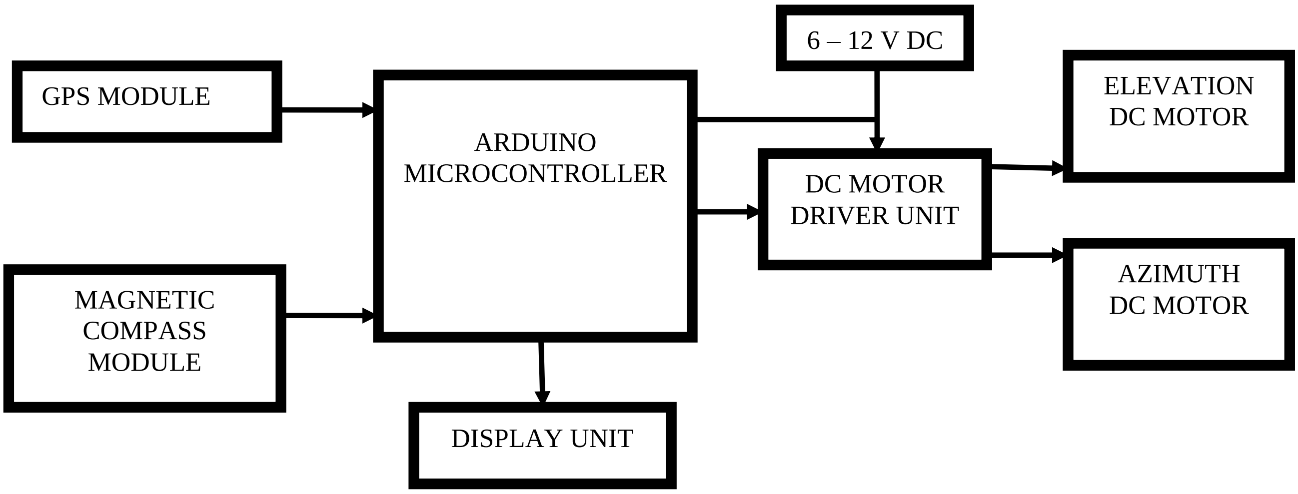

Fig. 3.1 Block Diagram of Basic Set-up of the Satellite TV Tracking System

The concept adopted for the design of this research work is based on the principle of look angle determination with the aid of a GPS sensor and subsequent rotation of the DC motors bythe driver unit to achieve desired results. The Sensor unit is made of two basic sensors, namely: the GPS receiver and the Magnetic Compass modules. The GPS receiver modulein the set-up senses the position of the ship at all-time giving information about thelatitude and longitude of the ship's coordinate. The ship's current position translates to the Earth station coordinates. The transmitting satellite in space is in a geostationary orbit, thus it appears to be static in its position on the equator (i.e O^0 latitude) andunique Longitudinal coordinate (i.e. 36.0 Degree East for DSTV and 3 Degree West for STV). The coordinate information of the Earth station and thesatellite is constantly fed into the microcontroller for further processing. On the otherhand, the Magnetic compass module senses the ship's heading about the truenorth of the earth's magnetic field. This is essentially useful for the accurate estimation ofthe Azimuth component of the Look angle for the Satellite dish receiver. The control unitis made up of the programmable Arduino microcontroller board. This unit forms the heartof the tracking system. It is programmed to read input data obtain from the GPSreceiver and the Magnetic compass modules for onward processing and subsequently turnit to output (Look Angle) to activate the DC motor driver unit. The microcontroller is responsible for the constant computation of the satellite dish's look angle at differentship's positions. The DC motor driver unit is compactable with the microcontroller unitand reads the output of the microcontroller to drive the DC motors in either clockwise oranticlockwise directions for the rotation of the dish in search of a signal. The L293 and L293D ICs are quadruple high current half-Hdrivers. It is designed to provide bidirectional drive currents of up to 1A at voltages from 4.5V to 36V. It is also designed to provide bidirectional drive currents of up to 600mA atthe same voltage. They are used to drive inductive loads such as Relays, Solenoids, DC, and Bipolar Stepping Motors, as well as other high-current/high-voltage loads in positivesupply applications. The display unit is made up of the Liquid Crystal Display (LCD). The LCD is used to display the status of the tracker stating when the signal is available and whentracking in progress. The employment of the closed-loop pole placement technique is basically to improve theperformance of the system. Thus, by choosing an appropriate gain matrix for state feedback, it was possible to force the designed system to have closed-loop poles at desired locations for efficient antenna tuning operations in terms of rising time, settling time, percentage overshoot, etc.

Table -3.1 Calculated Satellite TV Dish Elevation and Azimuth Angles at various positions at sea during the voyage from Calabar to Lagos.

S/No	Dish Position	Latitude/Longitude	Elevation	Azimuth
1.	Calabar	4.5ºN/8.3ºE	57.99º	98.05º
2.	Bonny	4.3ºN/7.2ºE	56.86º	97.74º
3.	Lagos	6.3ºN/3.5ºE	52.68º	99.78º
4.	Brass	4.2ºN/6.2ºE	55.82º	97.71º
5.	PH	4.8ºN/7.0ºE	56.57º	98.58º
6.	Warri	5.4ºN/5.0ºE	54.38º	98.89º
7.	Okitipupa	6.2ºN/4.3ºE	53.52º	98.05º
8.	Sapele	5.6ºN/4.9ºE	54.37º	98.11º

4. RESULTS AND DISCUSSION

The designed pole placement by state feedback Control system has been addressed by simulation. Furthermore, its response has been comparedwith the P, PI, and PID controllers to evaluate its performance. Response of closed-loop antenna positioncontrol system with unity gain Proportional (P) controller is shown in figure 4.1, from which it was noticed thatthe system response was accompanied by an unacceptable overshoot. Also, figure 4.2 is the step response of a Proportional Integral (PI), with a deficiency of an underdamped step response. Meanwhile, in figure 4.3, the step response of the system showed improvement with the introduction of the PID controller which significantly reduces the value of steady-state error, the rise time, and the settling time. However, the response was not satisfactory on account of the high overshoot.

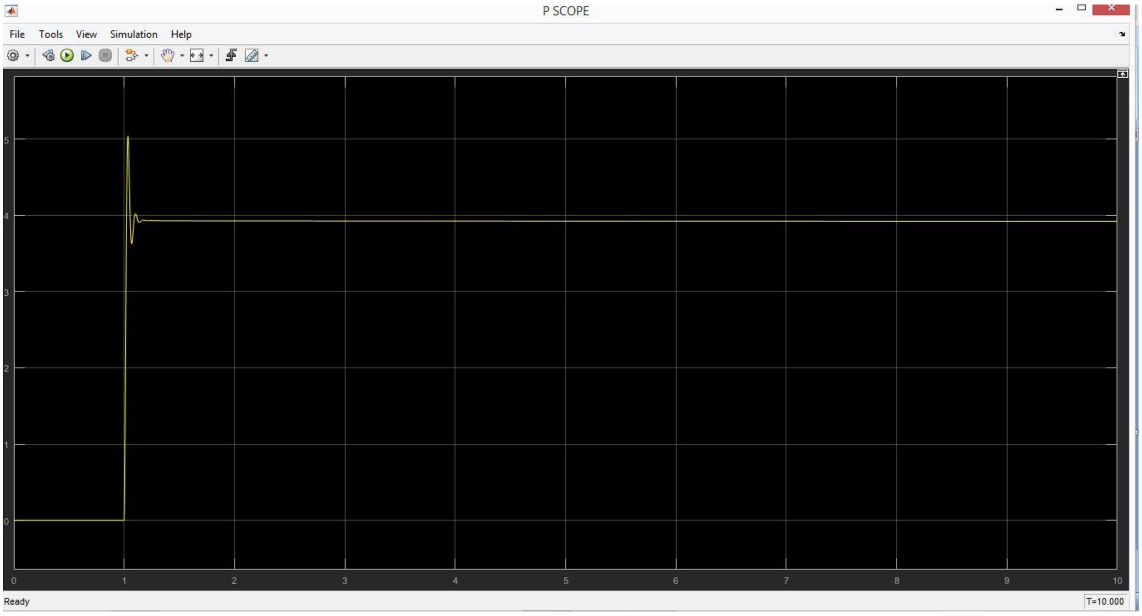

Fig 4.1 Proportional (P) controller Step response

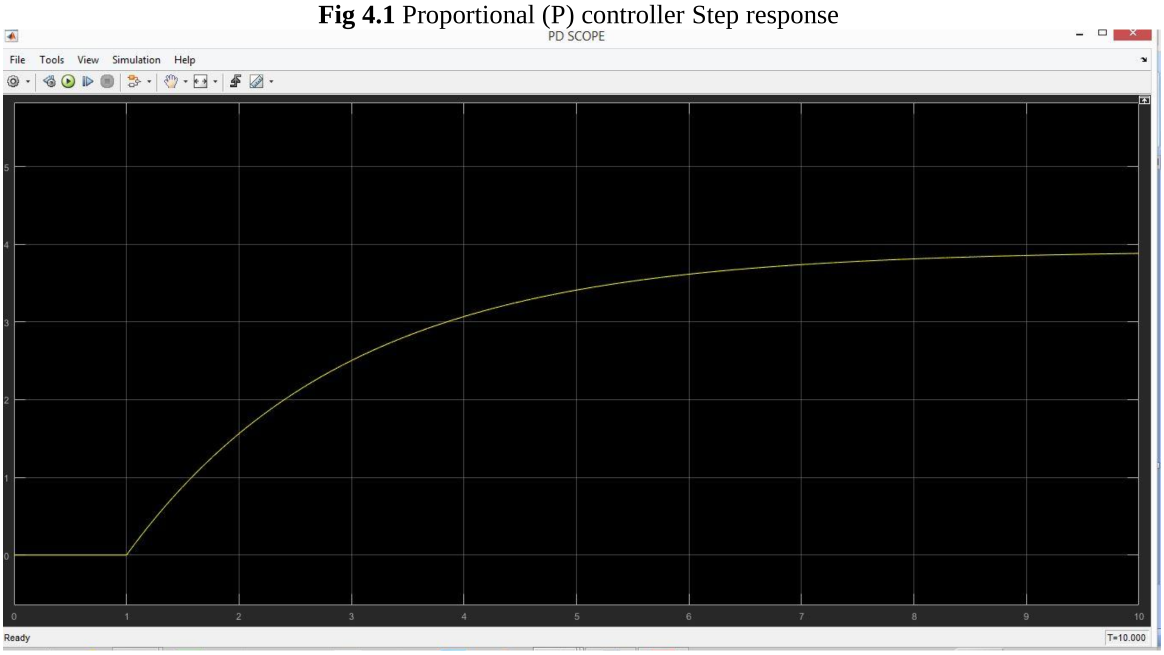

Fig. 4.2 Proportional Integral (PI) controller Step response

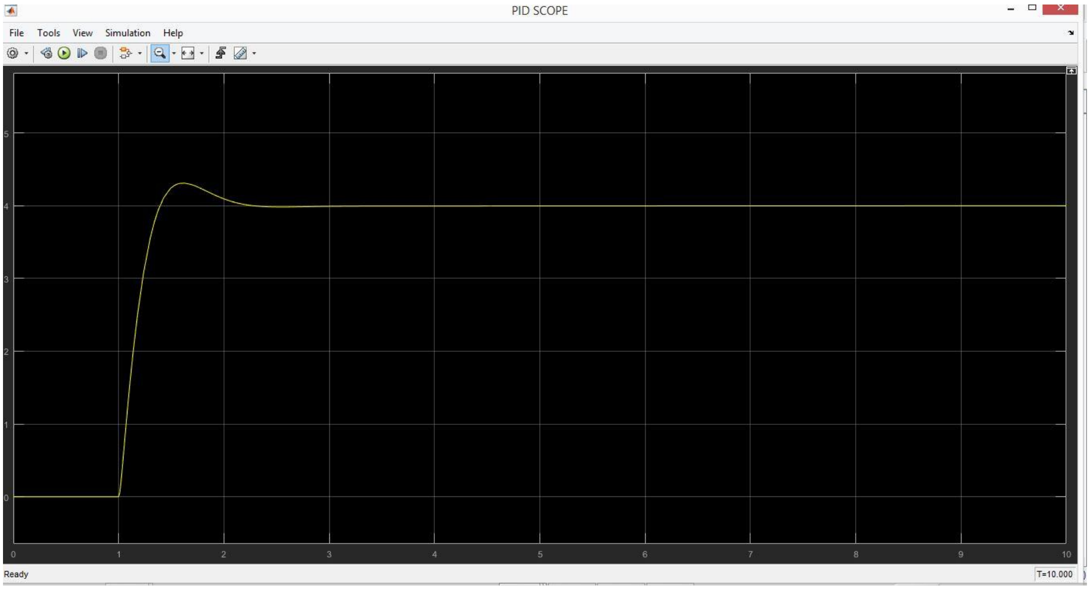

Fig 4.3 Proportional Integral Derivative (PID) controller Step response

Figure 4 shows the system response by applying Tuned PID Controller with the gain parameters set at (P = 1.617, I = 7.698 and D = 0.00605). It was observed that the tuned system response conformed to the system performance requirements.

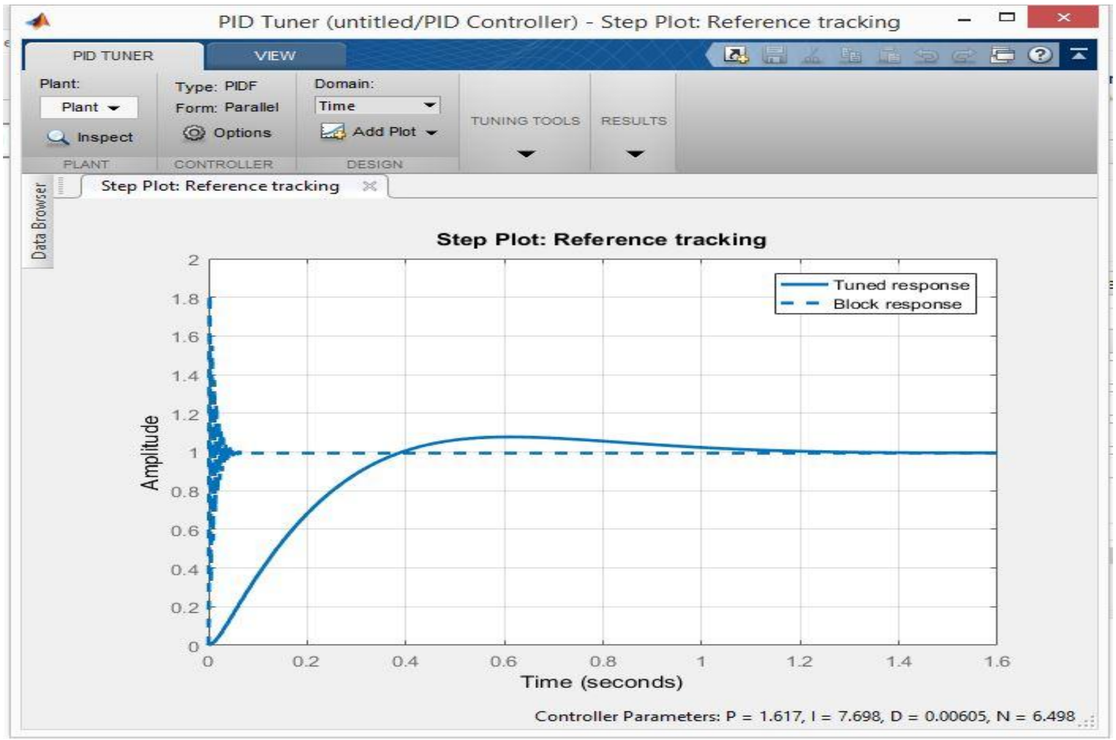

Fig. 4.4 Tuned Proportional Integral Derivative (PID) controller Step response

A single MATLAB m-file was also developed to simulate the performance of the closed-loop pole placement controltechnique for tracking setpoint commands and reducing the sensitivity of *ref* ω to load disturbances. A feed-forward control design was also included.

The torque *T* models load disturbances (changes in the torque opposed by the motor load). The controllermust minimize the position/speed variations induced by such disturbances. Figure 3 shows the response toa step command =1 *ref* ω with a disturbance *T Nm d* = −0.15 between *t* = 4sec and*t* = 6sec. Once again, thanks to its additional degrees of freedom, the Pole placement compensator performs best at rejecting loaddisturbances compared to the PID controller. Feed forward control handles load disturbances poorly. From the simulation results, it was seen that the PPTcontroller response with faster settling times and reducedovershoots when compared to the PID controller. The maximum overshoot with PPT is minimized to less than 4.0% while it was 23.5% with PID alone. The rise time is 0.2 seconds with the PID controller and 0.9 seconds with the PPT for response to transit from 10% to 90% of the steady-state value. Moreover, in addition to thestrengths of PPT over PID, the PPT registered the best overall performance of 0.2secondsrise time, 5.0 % overshoot, and 1 second settling time.

CONCLUSION

The Satellite TV parabolic dish antenna's position control systemusing pole placement by state feedback method has been designed, studied and theperformance was evaluated by simulation. The pole placement technique satisfied all the design requirements and resultsindicated a significant improvement from the classical controllers (PD and PID) in maintainingthe performance of approximate zero overshoot and minimum stabilizing time as compared to the classical PIDcontroller which despite having lower rise time, suffered a lot in terms of registering higher overshoots andsettling times. The objectives were met in both the design approach and software simulations. Future work is touse incorporate artificial intelligence-based techniques to solve the same problem and investigatewhether better results could be achieved.

REFERENCES

[1]. G. Maral, M. Bousquet, and Sun Z. "Satellite Communication Techniques and Technology.," *John Wiley and Sons, New York, NY, USA 5th edition, 2009*. .

[2]. K. Ogata, "Modern Control Engineering Fifth Edition," 2010.

[3]. C. H. Cho, S. H. Lee, T. Y. Kwon, and C. Lee, "Antenna control system using step tracking algorithm with H ∞ controller," *Int. J. Control. Autom. Syst.*, vol. 1, no. 1, pp. 83–92, 2003.

[4]. W. Gawronski, "An H ∞ Controller With Wind Disturbance Rejection Properties for the DSS-13 Antenna," 1996.

[5]. M. N. Soltani, R. Izadi-Zamanabadi, and R. Wisniewski, "Reliable control of ship-mounted satellite tracking antenna," *IEEE Trans. Control Syst. Technol.*, vol. 19, no. 1, pp. 221–228, 2011, doi: 10.1109/TCST.2010.2040281.

[6]. A. Uthman and S. Sudin, "Antenna azimuth position control system using PID controller & state-feedback controller approach," *Int. J. Electr. Comput. Eng.*, vol. 8, no. 3, pp. 1539–1550, 2018, doi: 10.11591/ijece.v8i3.pp1539-1550.

[7]. M. Ahmad, J. D. Jiya, E. C. Anene, and Y. S. Haruna, "in Nigeria POSITION CONTROL OF PARABOLIC DISH ANTENNA USING FEEDBACK, ZEIGLER-NICHOLS AND QUADRATIC OPTIMAL REGULATOR METHODS," 2011.

[8]. J. Jie, X. Luo, and Q. Yongyuan, "Study of adaptive variable structure attitude control and its full physical simulation of multi-body satellite antenna drive control," *2009 WRI World Congr. Comput. Sci. Inf. Eng. CSIE 2009*, vol. 2, pp. 546–549, 2009, doi: 10.1109/CSIE.2009.81.

[9]. S. S. and K. G. S. Sheth, "Antenna position control systems, review and new perception," *J. Inf. Knowl. Res. Electron. Commun. Eng, 2013.* .