ARID ZONE JOURNAL OF ENGINEERING, TECHNOLOGY & ENVIRONMENT
AZOJETE, June, 2019. Vol. 15(2):304-313
Published by the Faculty of Engineering, University of Maiduguri, Maiduguri, Nigeria.
Print ISSN: 1596-2490, Electronic ISSN: 2545-5818
www.azojete.com.ng

ORIGINAL RESEARCH ARTICLE

EFFECTS OF PID CONTROLLER ON PERFORMANCE OF DISH ANTENNA POSITION CONTROL FOR DISTRIBUTED MOBILE TELEMEDICINE NODES

A. T. Ajiboye*, A. R. Ajayi and S. L. Ayinla

(Department of Computer Engineering, University of Ilorin, Ilorin, Nigeria)
**Corresponding author's e-mail address: ajiboye.at@unilorin.edu.ng, atajiboye@yahoo.co.uk*

ARTICLE INFORMATION

Submitted 10 June, 2018
Revised 25 May, 2019
Accepted 10 June, 2019

Keywords:
Mobile telemedicine node
NigComSat-1R
PID controller
Time delay
Position control

ABSTRACT

Introduction of telemedicine into developing nation's healthcare delivery scheme could be a solution to a number of challenges facing the scheme including acute shortage of medical personnel. Because of distribution and mobility nature of the system combined with Nigeria's large land mass, the resulting propagation delay will be large which may lead to system poor quality of performance or instability if the system is not compensated. This study aimed at assessing the effects of introducing Proportional-Integral-Derivative (PID) controller into the control of the position of dish antenna mounted on distributed mobile telemedicine nodes within Nigeria when the link is via Nigcomsat-1R. The system closed loop composite transfer function was obtained and subjected to unit step forcing function which then yielded time domain parameters. There was reduction in the value of system time domain parameters obtained for PID controller compensated system compared to uncompensated system. Based on the value of the system time domain parameters obtained from the simulation, introduction of PID controller into this system has improved the system response significantly.

1.0 Introduction

Telemedicine is the provision of healthcare delivery and sharing of medical knowledge over a distance using Information and Communication Technology (ICT) (Kakkar et al., 2017; Saravanan and Sudhakar, 2017; Anyaegbunam, 2014). It is one of the pilot projects of NIGCOMSAT-1 to improve remote diagnosis and to deliver cost effective and qualitative healthcare in Nigeria (Anyaegbunam, 2014). The major objective of mobile telemedicine is to improve the quality and timeliness of healthcare delivery offered during the golden window of treatment opportunity immediately following injury, and to provide better information to health personnel just before physical presence of the patient at the health centre (Cullen et al., 1999). Integration of information and communication technology into healthcare delivery is making it more affordable and available even in rural areas without sacrificing the quality of delivery as obtainable in urban cities (Ibiyemi and Ajiboye, 2012a). Investing in the development of telemedicine technology if properly managed can serve as a way to alleviate the effects of acute shortage of medical personnel and low level of healthcare delivery in developing countries in general and Nigeria in particular. The medical information sent or received by the telemedicine nodes are usually through the dish antenna at the node. The quality of performance of any satellite tracking mobile dish antenna depends majorly on how effective the antenna position can be controlled. Many methods and approaches for dish antenna position control have been reported in the literature.

In (Waghmare et al., 2017; Maske et al., 2017; Chahar et al., 2016) satellite dish positioning system was designed to track geostationary satellite; the design was implemented using microcontroller. Although the system can be remotely controlled but there was limitation imposed by the distance the signal from the remote controller can cover as the transmission was by infrared signal. Many control system fundamentals like the plant model, controller algorithm were not considered because the control methodology employed was bang-bang control. Similar satellite dish position control system was designed by (Shubham et al., 2017), but in this case the reference position which has already been stored was sent remotely to the microcontroller via infrared signal. The interpretation of the sent position allows the system to locate the satellite of interest whose position has been sent. The system can only be used for a predetermined satellite and the distance covered by the remote control signal was limited as infrared signal was used. A microcontroller-based dish antenna positioning system was developed by (Rahane et al., 2018), in this system the reference input was dedicated to satellite identification. Since a given satellite which has been specified by its unique identity through the reference input was the target, any small out of sight from this satellite amount to an error which serve as input to the controller. The controller power the DC motor that rotate the satellite and the motor continue to rotate the dish until when the targeted satellite was tracked. This system operates on the strength of the radiated signal from the satellite not satellite position, therefore weather condition can have serious effects on the performance. A microcontroller-based dish antenna position control system was developed in (Amritha et al., 2017), the information about the satellite to be tracked was sent using an android phone, and then decoded by raspberry pi before being sent to the microcontroller as reference input. Based on this information the controller sends control signal to the servomotor to dictate the direction of rotation of the dish antenna and when the desired antenna position was reached the controller stops the motor and the dish tracks the satellite in question. It has enormous time delay which is capable of degrading the system quality of performance or even in the worst case scenario destabilises the system. Microcontroller-based automatic antenna position control system whose operation was solely dependent on the strength of the signal received `from the targeted satellite was developed by (Choudhary et al., 2014). When the signal from the targeted satellite was received by the antenna it passes through a monostable circuit and the output of the monostable gives a logic 1 if the signal was higher than a particular threshold and logic 0 if lower. The logic output serves as reference input to the microcontroller which initiates the rotation of the antenna by powering the driving motor when the logic was at level 1 and stop the rotation when the logic was at level 0. The angular position of the antenna with respect to a given reference was also sensed, processed by the microcontroller and displayed. The results from laboratory simulation using infrared signal shows that the system was feasible for real live implementation when the signal transmission distance was improved and the control can be carried out in two plane instead of the present one plane. Antenna azimuth angle control system using microcontroller-based rate corrected method was developed and implemented by (Mullaa and Vasambekarb, 2017). In this system, the speed of the antenna driven motor (stepper motor) was controlled by

Corresponding author's e-mail address: ajiboye.at@unilorin.edu.ng

the output of the microcontroller. Therefore, for fast positioning, high rotational speed and acceleration are required. The speed of the motor depends on the delay in the step sequence which was calculated using the speed rate corrected method. The results obtained from the laboratory tests shows improvement in the system response speed.

Aloo et al (2016) designed a hybrid of PID and LQR controller for DC servomotor-based antenna positioning system. The results of system performance evaluation carried out via simulation using MATLAB shows that the classical PID controller compensated system has lower rise time but higher overshoot and settling time compared with the hybrid PID-LQR controller compensated system. A PID controller designed using Ziegler-Nichols method and a separate controller designed using Quadratic Optimal Regulator (QOR) approach by (Ahmad et al., 2011) were tested via simulation on a modelled servomotor actuated parabolic dish antenna to control the antenna position. The system closed loop step response without controller; with the PID controller and with QOR controller was simulated respectively using MATLAB 7.1. The results show improvement in system performance when controller was incorporated with QOR controller compensated system having the best response. Ahmed et al., (2014) designed a Quadratic Optima Regulator (QOR) and incorporated it into the position control system of parabolic antenna dish, the response of the system with and without controller to unit step input were simulated using MATLAB, the value of the system time domain performance parameters obtained reveal that the response of the compensated system was superior to that of uncompensated system. A proportional-integral position controller for a parabolic satellite antenna used in tracking the precise location of a moving ship was designed by (Kim et al.,2013); the controller was designed for both the antenna azimuth and elevation. As the ship Pitch, Roll and Yaw varies, Gyro Sensor was incorporated to monitor these variables and the controller sees the Gyro sensor output as disturbances and handled as such. The reference input was the predetermined signal strength from the satellite that links the antenna to the ship position monitoring room. The time domain performance parameters obtained from the system step response indicate the effectiveness of the system. Classical and discrete PID controller was designed by (Yadav and Sharma, 2016) for controlling of elevation position of a giant meter wave radio telescope. The performance of this designed controller was evaluated from system step response; the result shows that the discrete PID controller has superior performance.

In this study, the link between the base station which is the system controller and the distributed mobile node of dish antenna which is the plant is via Nigerian's communication satellite (Nigcomsat-1R) which is located in ITU region1 at 42.5° East, therefore the transmitted signal will encounter propagation delay which is a function of the distance between the base station and the distributed nodes. Considering the Nigeria's large land mass of about 923,677 sq km and mobility nature of the distributed nodes, the propagation delay will be large and variable which led to system poor quality of performance or instability in the worst case if no controller is introduced (Ajiboye, 2012, Ibiyemi and Ajiboye, 2012a). The aim of this study is to assess the effects of introducing PID controller into the control of the position of satellite dish mounted on distributed mobile telemedicine nodes within Nigeria when the link is via Nigcomsat-1R. PID controller algorithm was proposed for the control and command in this study because of its structural simplicity, easy to tune and industrial popularity (Farhan, 2013; Farhan et al., 2017). More than 90% of all control loops are PID, therefore, PID is the first solution that should be

Corresponding author's e-mail address: ajiboye.at@unilorin.edu.ng

tried when feedback is to be used (Åström and Hägglund, 2001). In other to achieve the aim of this study, the delay was modelled and simulated to get the propagation delay transfer function. The closed loop composite transfer function was determined from the controller, delay and plant transfer functions. The system closed loop transfer function was subjected to unity step forcing function to obtain the system time-domain performance parameters.

2.0 Determination of Time Delay Range

The geographical coordinates of Nigeria are between longitude 2°43.207'E and 14°54.685'E and latitude 4°17.825'N and 13°52.837'N. The Base station is at University of Ilorin which is located at 4°40.500'E, 8°29.100'N and the dish mounted telemedicine nodes are distributed all over Nigeria as shown in Figure 1. The location and geographical coordinates of points A, B, C and D presented in Figure 1 are as follows: point A is located at Niger Republic and its coordinate is 2°43.207'E, 13°52.837'N; point B is located at Lake Chad and its coordinate is 14°54.685'E, 13°52.837'N; point C is located at Gulf of Guinea and its coordinate is 2°43.207'E, 4°17.825'N and finally point D is located at Cameroon and its coordinate is 14°54.685'E, 4°17.825'N. The subsatellite point for NigComSat-1R satellite is at 42.5°E, 0°.

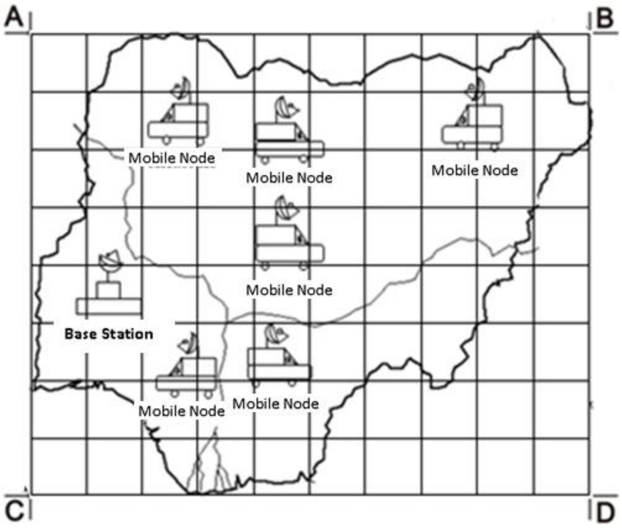

Figure 1: Nigeria Geographical Map showing distribution of Telemedicine Nodes (Ibiyemi and Ajiboye, 2012a)

The parameters needed for the determination of time delay are the distance between the base station and mobile telemedicine nodes and the signal speed. The equation for the determination of the distance between any two points on the earth surface via any geostationary satellite is as given in Equation (1) (Ibiyemi and Ajiboye, 2012a; Ibiyemi and Ajiboye, 2012b; Ibiyemi and Ajiboye, 2012c).

$$d_{sr} = \sqrt{D^2 + R^2 - 2DR\cos(\alpha_{sn})\cos(\Delta_{sn} - \Delta_s)} + \sqrt{D^2 + R^2 - 2DR\cos(\alpha_{rn})\cos(\Delta_{rn} - \Delta_S)} \quad (1)$$

where:

d_{sr}= distance between the source and the receiving node,

R = radius of the earth in km,

D = sum of the radius of the earth and satellite altitude in km,

Corresponding author's e-mail address: ajiboye.at@unilorin.edu.ng

Δ_S = angle of longitude of the subsatellite point in degrees,

α_{sn} = latitude of the sending node location on the earth surface in degrees,

α_{rn} = latitude of the receiving node location on the earth surface in degrees,

Δ_{sn} = angle of longitude of the sending node location on the earth surface in degrees and

Δ_{rn} = angle of longitude of the receiving node location on the earth surface in degrees.

Therefore, the model equation for the time delay encountered in sending signal between these two points was obtained by dividing the distance by the signal speed and is as shown in Equation (2).

$$T = \frac{d_{sr}}{v} \quad (2)$$

where:

T = Time delay in seconds and

v = signal speed in m/s

3.0 Determination of System Transfer Function

The plant transfer function was determined from the dish structure and jack actuator dynamics model. The determination of the dish dynamics was based on the moment of inertia of the dish structure (satellite dish and BUC/LNB), spring constant, and damping coefficient. These parameters were determined by experiment because their value cannot be read off the plant at the node (Ibiyemi and Ajiboye, 2012b). Due to the same reason the actuator jack dynamics was also empirically determined. The system can be represented by the block diagram of Figure 2.

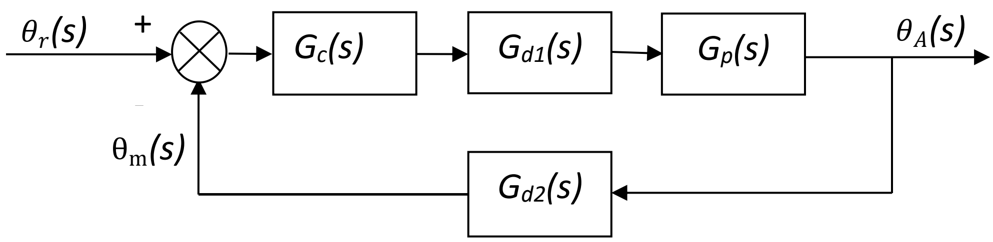

Figure 2: Block diagram of the Composite System

From Figure 2, the transfer functions for the uncompensated and compensated systems are as shown in Equations (3) and (4) respectively.

$$\frac{\theta_A(s)}{\theta_r(s)} = \frac{G_p(s)G_{d1}(s)}{1+G_p(s)G_{d1}(s)G_{d2}(s)} \quad (3)$$

where:

$\theta_A(s)$ = Dish actual position in degree,

$\theta_r(s)$ = Dish reference position in degree,

$G_{d1}(s)$ = Forward path time-delay transfer function,

$G_p(s)$ = Plant transfer function and

$G_{d2}(s)$ = Feedback time delay transfer function.

$$\frac{\theta_A(s)}{\theta_r(s)} = \frac{G_c(s)G_p(s)G_{d1}(s)}{1+G_c(s)G_p(s)G_{d1}(s)G_{d2}(s)} \quad (4)$$

where:

$G_c(s)$ = PID controller transfer function.

The plant transfer function is made up of the transfer function of the dish structure, and actuator jack and is as expressed in Equation (5):

$$G_p(s) = \frac{3.76}{s^4+67.56s^3+62.36s^2+150.52s} \quad (5)$$

The transfer function for the Forward and Feedback path time delay is as expressed in Equation (6).

$$\left.\begin{aligned} G_{d1}(s) &= e^{-T_1 s} \\ G_{d2}(s) &= e^{-T_2 s} \end{aligned}\right\} \quad (6)$$

where:

T_1 = Feed forward delay from base station to the node in seconds and

T_2 = Feedback delay from the node to base station in seconds.

Assuming that $T_1 = T_2 = T$,

Then from Equation (6)

$G_{d1}(s) = G_{d2}(s) = G_d(s) = e^{-Ts}$

Or

$$G_d(s) = e^{-Ts} \quad (7)$$

Transfer function for PID controller is as expressed in Equation (8)

$$G_c(s) = \frac{K_d s^2+K_p s+K_i}{s} \quad (8)$$

where:

K_p = Proportional gain,

K_i = Integral gain and

K_d = Derivative gain.

Substituting Equations (5) and (7) in Equation (3) gives the uncompensated system closed loop transfer function of Equation (9).

$$\frac{\theta_A(s)}{\theta_r(s)} = \frac{3.76e^{-Ts}}{s^5+67.56s^4+62.36s^3+150.52s^2+3.76e^{-2Ts}} \quad (9)$$

Substituting Equations (5), (7) and (8) in Equation (4) result to the PID compensated system closed loop transfer function of Equation (10).

$$\frac{\theta_A(s)}{\theta_r(s)} = \frac{3.76(K_d s^2+K_p s+K_i)e^{-T_1 s}}{s^5+67.56s^4+62.36s^3+150.52s^2+3.76(K_d s^2+K_p s+K_i)e^{-(T_1+T_2)s}} \quad (10)$$

The effects of PID controller on the system was evaluated by comparing the time domain performance parameters that is the rise time, time to peak overshoot, percentage overshoot, settling time and steady state error for the uncompensated system with that of PID controller

Corresponding author's e-mail address: ajiboye.at@unilorin.edu.ng

compensated system when the system is subjected to a unit step function. The performance parameters for the uncompensated system form the basis for the determination of the effects of the PID controller on the system.

4.0 Simulation and Analysis

Using Equation (2) and assuming the signal speed to be the speed of light (30×109 m/s.), the simulation of the time delay was carried out in MATLAB R2015a environment and the system time delay simulation graph is as shown in Figure 3. The maximum and minimum time delay was determined to be 0.2502 second and 0.2469 second respectively and these occurred at point A and point D as shown on the graph of Figure 3. Points A and D are in Niger Republic (2°43.207'E, 13°52.837'N) and Cameroon (14°54.685'E, 4°17.825'N) respectively.

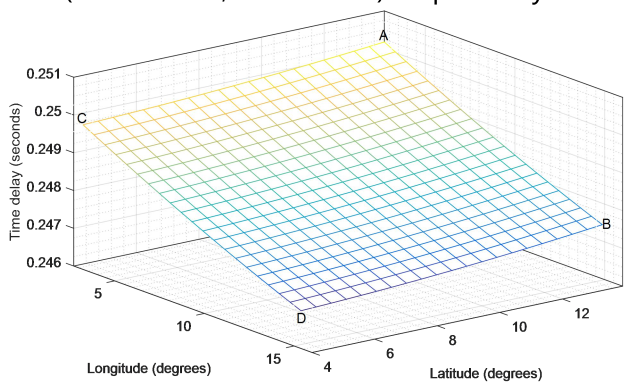

Figure 3: System time delay simulation graph

Also using Equations (9) and (10), simulation experiment was carried out in MATLAB R2015a environment to assess the effects of incorporating PID controller into the system. The PID controller parameter values obtained by (Ajiboye et al., 2013) for optimisation of system settling time for mobile satellite dish position control within Nigeria (K_p =20, K_i =4 and K_d =0) was adopted for the simulation because these controller gain values were determined for similar system with the same dynamics and architecture within Nigeria terrain. Also the maximum obtainable time delay (0.2502 second) being the worst case was used for the simulation.

For easy of comparison, the closed loop step responses for the uncompensated and PID controller compensated systems were presented on the same axis as shown in Figure 4.

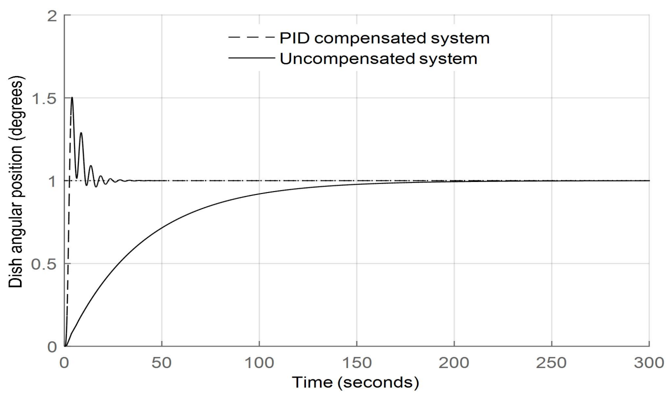

Figure 4: Step Response for Uncompensated and PID Compensated Systems

Corresponding author's e-mail address: ajiboye.at@unilorin.edu.ng

The time domain performance parameters obtained from the system step response of Figure 4 are as presented in Table 1.

Table 1: System time domain performance parameters

System condition	Rise time (seconds)	Time to peak overshoot (seconds)	Percentage overshoot (%)	Settling time (seconds)	Steady state error
System without PID controller	86.5	300	0	155	0 at 300 seconds
System with PID controller	1.34	3.94	50.5	21.3	0 at 30 seconds

As can be seen in Table 1, the system rise time was 86.5 seconds before the introduction of PID controller into the system but changed to 1.34 seconds when PID controller was introduced. This shows an improvement on system rise time as a result of incorporating PID controller into the system. The time to peak overshoot was 300 seconds when the system was without PID controller and reduced to 3.94 seconds when PID controller was introduced which is also an improvement as far as time to peak overshoot is concerned. The percentage overshoot was 0% when the system was without PID controller but it changed to 50.5 as a result of PID controller introduction into the system, this shows that the performance of compensated system has degraded compared with that of the uncompensated system that has overshoot of 0%. The settling time for the uncompensated system was 155 seconds as against the 21.3 seconds for PID compensated system which is an indication of improvement in compensated system performance with respect to settling time. The steady state error for system without PID controller and system with PID controller was 0 at 300 seconds and 0 at 30 seconds respectively which shows an improvement in the performance of the system with PID controller from steady state error point of view.

It can also be deduced from the simulation results of Table 1 that system with PID controller has both better transient and steady states response because of the lower value of system time domain parameters. The only time domain parameter that look abnormal for system with PID controller is the percentage overshoot which is 50% against the 0% for the uncompensated system. This will have no negative effect on the overall performance of the PID controller compensated system since this system would have settled down before the uncompensated system even rise as can be seen from the system step response of Figure 4 and the values of system rise and settling time in Table 1.

5.0 Conclusion

The propagation time delay between any sending and receiving nodes via any geostationary satellite was modeled. Using this model the minimum and maximum time delay incurred in sending data between University of Ilorin and any location within Nigeria via Nigcosat-1R was determined. The effects of introducing PID controller into the system were assessed based on time domain performance parameters using Matlab as simulation tool. The obtained results from the system step response simulation experiments shows remarkable improvement in the

Corresponding author's e-mail address: ajiboye.at@unilorin.edu.ng

performance of the PID compensated system over the uncompensated system in the area of rise time, time to peak overshoot and settling time.

References

Ahmad, M., Jiya, JD., Anene, EC. and Haruna, YS. 2011. Position Control of Parabolic Dish Antenna using Feedback, Zeigler-Nichols and Quadratic Optimal Regulator Methods. Continental J. Engineering Sciences, 6: 7-13.

Ahmed, M., Mamman, HB., Anene, EC. and Balami, IT. 2014. Parabolic Antenna Control. International Journal of Engineering Research & Technology (IJERT), 3: 759-761.

Ajiboye, AT. 2012. Development of Automatic Position Controller for Mobile Satellite Dish Network within Nigeria. PhD Thesis, University of Ilorin, Ilorin, Nigeria.

Ajiboye, AT., Ibiyemi, TS. and Falade, JA. 2013. Optimisation of Settling Time for PID Position Control in Mobile Satellite Dish Network within Nigeria. Journal of Telecommunications, 20 (5): 22-26.

Aloo, LA., Kihato, PK. and Kamau, SI. 2016. DC servomotor-based antenna positioning control system design using hybrid PID-LQR controller. European International Journal of Science and Technology, 5: 17-31.

Amritha, MAS., Divyasree, MV., Jesna, P., Kavyasree, SM. and Keerthana, V. 2017. Microcontroller Based Wireless 3D Position Control for Antenna. International Journal of Science and Research (IJSR), 6: 924-927.

Anyaegbunam, FNC. 2014. On National e-Healthcare Delivery Through Nigcomsat-1. International Journal of Engineering Research & Technology, 3: 2270-2276.

Åström, KJ. and Hägglund, T. 2001. The future of PID control. Control Engineering Practice, 9: 1163-1175.

Chahar, M., Chandak, M., Malav, M., Sardiwal, M. and Imran, M. 2016. Satellite Dish Positioning Control by DC Motor using IR Remote Control. International Journal of Electrical Engineering and Technology (IJEET), 7: 9-18.

Choudhary, SD., Rai, P., Kumar, A. and Alam, I. 2014. Microcontroller Based Wireless Automatic Antenna Positioning System. International Journal of Electronics, Electrical and Computational System, 3: 12-26.

Cullen, JS., Gagliano, DM., Gaasch, WR., Gunawardane, RDP., Hu, PF., Lamonte, MP., Mackenzie, CF. and Xiao, Y. 1999. Mobile Telemedicine Testbed. Systems and Information Technology Review Journal, Spring/Summer, 1-16.

Farhan, AS. 2013. New efficient model-based PID design method. European Scientific Journal, ESJ, 9: 181-199.

Farhan, AS., Mohamed, MK. and Usama, HI. 2017. Proposed Simple and Efficient Control Algorithm Design Approach. International Journal of Applied Engineering Research, 12: 2044-2053.

Ibiyemi, TS. and Ajiboye, AT. 2012a. Automatic Tracking of NigComSat-1R Satellite by Dish Network Mounted on Mobile Tele-Medicine Vehicles. International Journal of Engineering Research and Technology, 1(4): 1-4.

Ibiyemi, TS. and Ajiboye, AT. 2012b. On PID Controller Design for Mobile Node Network with Variable Delays. International Journal of Science and Advanced Technology, 2: 176-180.

Ibiyemi, TS. and Ajiboye, AT. 2012c. Robust PID Control of Mobile Satellite Dish Network within Nigeria. International Journal of Computer Applications, 41(21): 32-36.

Kakkar, A., Naushad, S. and Khatri, SK. 2017. Telemedicine and EHR Integrated Approach for An Effective E-Governance Healthcare Framework. International Journal of Medical Research and Health Sciences, 6: 108-114.

Kim, M., Kim, J. and Yang, O. 2013. Precise attitude control system design for the tracking of parabolic satellite antenna. International Journal of Smart Home, 7: 275-290.

Maske, SA., Vishwasrao, SA., Sanjay, SA. and Krushnat, MN. 2017. Dish Positioning By Using IR Remote. International Research Journal of Engineering and Technology (IRJET), 4: 266-269.

Mullaa, AA. and Vasambekarb, PN. 2017. Speed Rate Corrected Antenna Azimuth Axis Positioning System. International Journal of Electronics Engineering Research, 9: 151-158.

Rahane, SD., Mhaske, SA. and Shingate, SR. 2018. Design of Advanced Antenna Positioning System. International Journal of Research in Advent Technology, 6: 251-253.

Saravanan, S. and Sudhakar, P. 2017. Telemedicine Technology using Internet Communication. International Journal of Pure and Applied Mathematics, 115(6): 147-156 115, 147-156.

Shubham, P., Sankalp, PT., Tanmay, W. and Nandanwar, VS. 2017. Satellite Dish Positioning Control by Geared Motor Using RF Module. International Journal of Advanced Research in Science, Engineering and Technology, 4: 3388-3393.

Waghmare, S., Pathak, P., Meshram, P., Pawar, V. 2017. Satellite Dish Positioning System. International Journal for Innovative Research in Science and Technology (IJIRST), 4: 50-54.

Yadav, S. and Sharma, V. 2016. Modelling and Simulation of Elevation Position Control of a Giant Meter wave Radio Telescope (GMRT) in MATLAB using PID and Discrete PID Controllers. International Journal of Innovative Research In Electrical, Electronics, Instrumentation and Control Engineering, 7: 165-168.

Corresponding author's e-mail address: ajiboye.at@unilorin.edu.ng