Real-time Implementation of PID control algorithm using Power Pmac Controller for Antenna Position Control system.

Nupoor Patil
IMTPL,Group Intelmac,
Ambegaon,Pune
nupoor@intelmotion.com

Durgesh Behere
IMTPL,Group Intelmac,
Ambegaon,Pune
durgesh@intelmotion.com

***Abstract*—Ground station antennas find their application in communication with satellites. An antenna communicates with the spacecraft by sending command signals and receiving the data from the spacecraft. Antenna dish rotates with respect to elevation axis and whole antenna structure rotates on circular track which is an azimuth axis [1]. System identification is an important task of modelling of a process. A model merely represents the actual process in much simpler format. Modelling is required to design and simulate new control technique before real time application .This paper discusses modeling of antenna control systems and implementation of PID algorithm into power Pmac controller. Simulation results have been evaluated for open loop as well as closed loop system. Controller has been applied to real-time antenna system and hardware results for step and ramp signals for azimuth position have been evaluated. Paper concludes with inferences drawn from the designed control algorithm.**

Keywords—System Identification, Step test, Ramp test,Antenna Control systems,Power Pmac,Matlab,Simulink.

I. INTRODUCTION

Under ISTRAC's (ISRO) Network stations new 11m-antenna second terminal has been installed in ground station at Bhopal, Madhya Pradesh . This is a co-located antenna along with antenna ground station at Port-Blaire(Andaman) ; with the first terminal as a full backup terminal for supporting ISRO's upcoming launch and satellite programs. A position control system basically consists of position sensing module and error correction module. The aim to; set the actual value from the position encoder (22 bit) to match with desired position value, thus reducing the error. For positioning control standard servo PID algorithm in Power Pmac controller has been used .Antenna servo control system with monopulse tracking has been described briefly in section II. Section III explains System identification technique .Section IV simulation of PID algorithm on antenna position control system. Section V is about introduction to power Pmac controller. .Section VI describes real- time results of developed PID algorithm. Section VII concludes the paper. References and ackowledgements are provided in Section VIII and IX respectively.

II. ANTENNA CONTROL SYSTEM

For assurance of continuous tracking during earth's rotation antenna dish rotates with respect to two control axis. Figure (1) displays antenna system without controller. The input and feedback potentiometer each have an associated transfer function, in the form of a gain. The potentiometer changes the input angle, θ(s) to a voltage, Vi(s).

The purpose of the preamplifier is to take the input signal voltage and output a voltage that the power amplifier can use. The Preamplifier is also modeled by a gain that can be specified by the design engineer to achieve a desired output[2]. The Preamplifier is a system in which the input voltage is amplified by some gain K and output as a voltage. takes the output voltage from the Preamplifier and converts it to a Voltage that is useable by the motor. This requires the Power Amplifier to output a significant amount of power, something that the Preamplifier is not capable of.

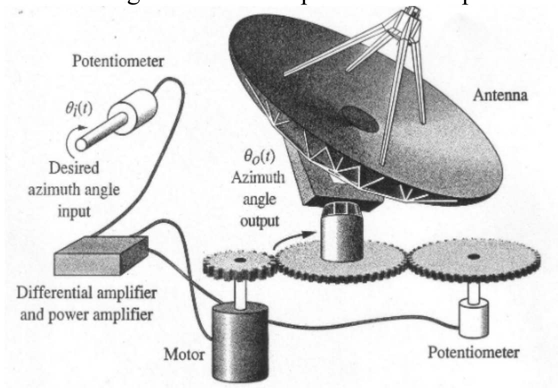

Figure 1: Antenna System without controller

The horizontal control axis is called elevation and vertical axis is azimuth. Antenna servo control systems (ACSS)consists of two parts are is situated in pedestal room. The antenna control unit (ACU)is a part of ACSS which consists of controller responsible for position control .Antenna drive unit (ADU) is a part of ACSS which consists of electrical driving components like drives ,motors, gears etc.[3]

Figure (2) shows antenna control systems. The primary operator interface for the Antenna control servo system is the Remote Antenna Console (RAC) located in the TTC Control Room at a distance from the Antenna Control Unit (ACU) which provides remote control of ACU. The Remote Antenna Console (RAC) communicates with the Antenna Control Unit (ACU) over

OFC (Optical Fiber Cable) Interface for 100 to 300 m distance.

ACU is responsible for closing the position loop, reading the position sensors and commanding the Antenna Azimuth/Elevation Drives (ADU). In order to remove the effect of backlash in gears ADU has been provided with counter torque arrangement. The position loop is built with appropriate inner loops (rate loop and current loops) such that the equal-and-opposite counter-torque-bias is added appropriately at the rate loop input and both motors feedback taken in the loops. ACU provides antenna control functions for remote operations from motion and control system through RAC.

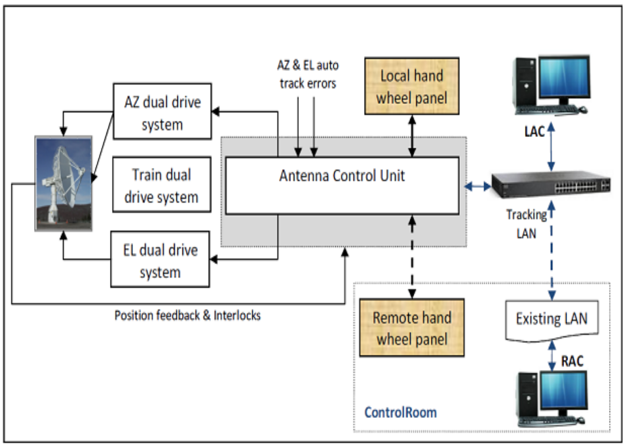

Figure 2: Antenna Control systems

An integral or external color display allows the operator to continuously and simultaneously view all information of interest in clear alphanumeric font. The Major subsystems like RAC, ACU or Servo-Controller, Servo Motors and the associated Drive Amplifiers etc. have after sales service support for a minimum period of 10 years.

III. SYSTEM MODELS FROM IDENTIFICATION

Obtaining a model of plant is a tedious task for control theory applications. Models can be obtained by two ways either through rigorous calculations or through recording data. Models obtained by calculations provide good insight of the plant .However it requires an expertise to get an accurate model .Another method of obtaining a model is through empirical system identification or data based system identification . It is the most accurate and fastest method because the models are obtained by real time plant data that inherently includes all the measured and unmeasured parameters that directly or indirectly affect the system. However, the technique does not give actual insight of the system under operation. The system identification toolbox of Matlab being the most powerful tool is used for identifying the plant model[4].

State space schematic of antenna positioning system is shown in figure (3).

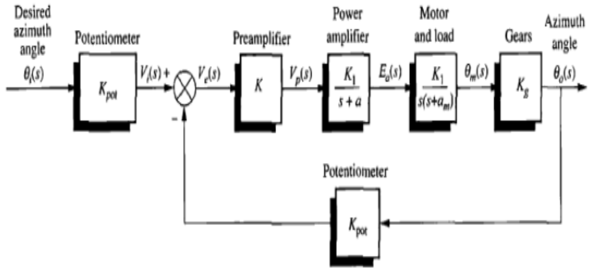

Figure 3:State space schematic of antenna positioning system

Controller takes two inputs; firstly the input which is reference value and secondly a value from the feedback. Input of the process is the reference position value. Actual position is measured using encoder .The controller tries to minimize the error between actual and reference value so that the target is achieved. Empirical or data-based System identification is a task of determining the relationship between the input and output data based upon the collected and observed data. It builds a mathematical map between the applied value and the measured value. All the blocks that include electrical drives , electrical motor ,antenna load and gear box are considered as a single transfer function model with applied input as target torque (applied at drive) and actual position as output (recorded at the encoder). Figure(4) exemplify the data of measured input and output value used for system identification. System identification toolbox is used for obtaining the process model as well as the transfer function model of the system.

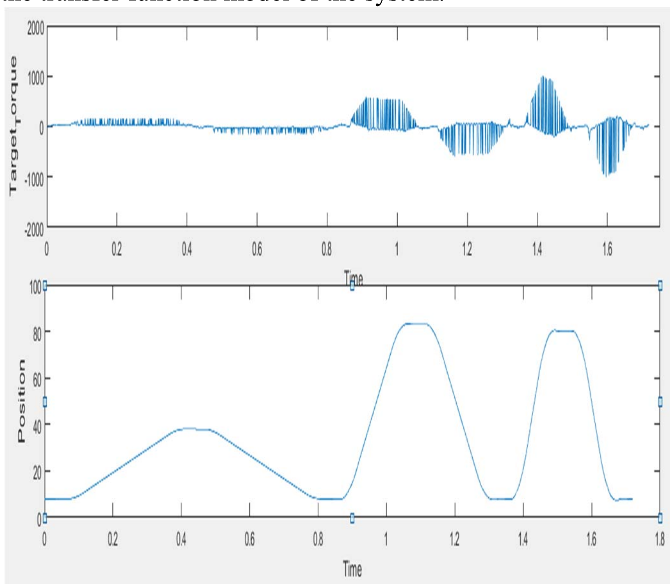

Figure 4:Data set for system identification

Figure (5) point up the percentage fit for obtained models with respect to validation data. For identification and validation two different data sets taken from same plant have been used. The transfer function obtained is

$$G(s) = \frac{272.9}{(s*s) + 76.75s + 5.531} \dots\dots\dots (1)$$

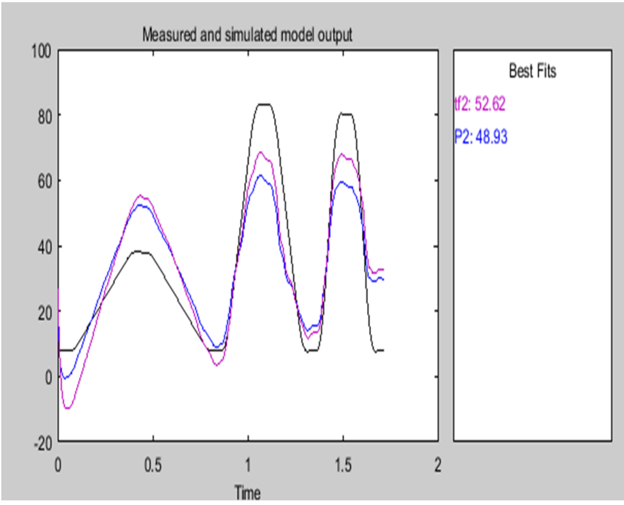

Figure 5:Percentage fit for antenna models

The obtained transfer function model was validated using cross correlation for noise spectrum analysis. It can be seen from figure (6) that data stays within confidence level proving that there is no cross correlation between output and input value. So the model obtained is a noble model.

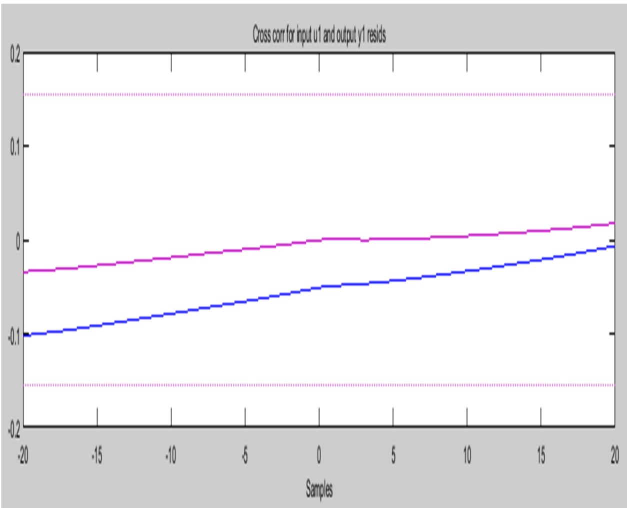

Figure 6:Cross-corelation of data set

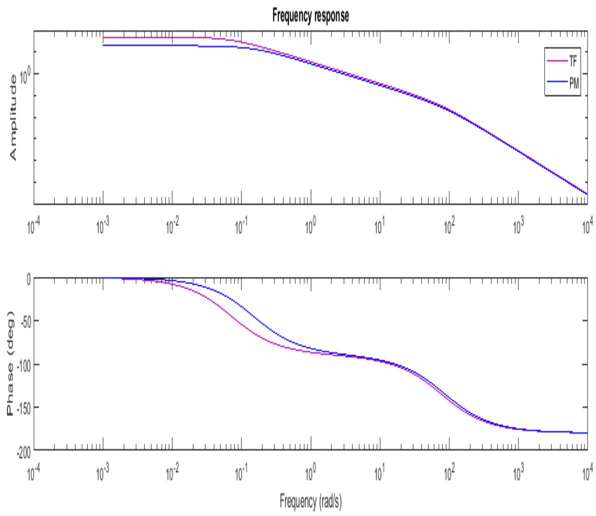

Figure 7:Bode plot of system model

Figure (7) depicts the bode analysis of the model. It can be said that model replicates the graph that of a low pass filter having good gain at lower frequencies and disturbing gain at higher frequencies. Thus model attenuates any gain changes at higher frequencies and amplifies any minute changes at lower frequencies[5].

IV. SIMULATION OF PID ALGORITHM ON ANTENNA POSITION CONTROL SYSTEM

PID controller is the most basic form of controller for any application. It has three parameters that can be tuned to obtain a desired response. The proportional constant is responsible for system gain but creates an steady state offset. The integral constant nullifies the steady state offset created due to proportional action but makes the system response sluggish. The derivative constant is used for anticipatory action improving transient as well as steady state response. Figure (8) shows the PID simulation for the obtained transfer function. A continuous PID block is applied to continuous transfer function that represents the load system (drive, motor, antenna and gearbox).Simulation results have been obtained for step input and ramp input .

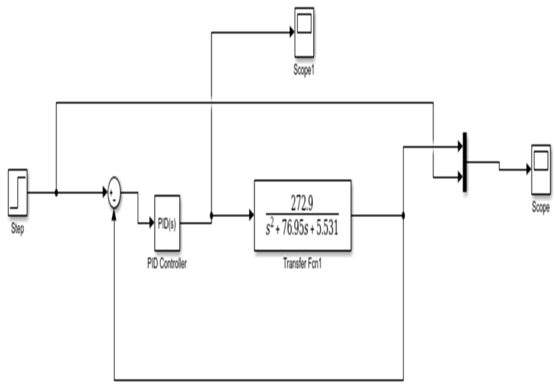

Figure 8:Simulation of PID control algorithm

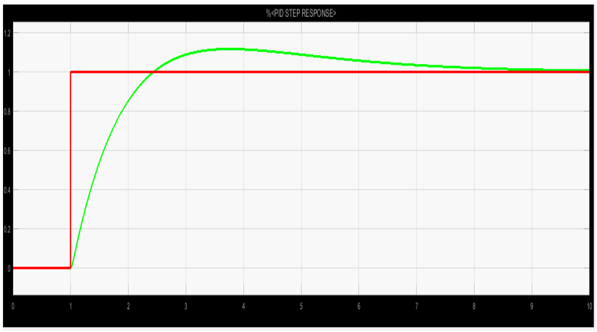
Figure 9:Step Response of PID signal

Figure (9) displays the simulation results for step response of system Various step data information like rise time. settling time for open loop as well as closed loop system with controller have been obtained for understanding the improvement in performance Tuning values taken are Kp=0.1; Ki=0.001 and Kd=8. Table(1) displays the performance criteria for designed PID data.

Table 1:Step response of open loop and closed loop system

Parameters	Open loop response	PID performance evaluation
Rise Time	30.53 secs	1.03secs
Settling Time	54.38 secs	6.88secs
Overshoot	0%	11.5
Gain Margin	Inf	44.7
Phase Margin	88.5	75.9

The open loop performance depicts the rise time as 30 secs and settling time as 54 secs .However inclusion of PID controller has brought the rise time to 1 secs and settling time to 6 secs. The system response with controller displays an overshoot of 11% with gain margin of 44.7 and phase margin of 75.9.Since values of both gain margin and phase margin are positive even after implication of controller the closed loop system is BIBO stable.

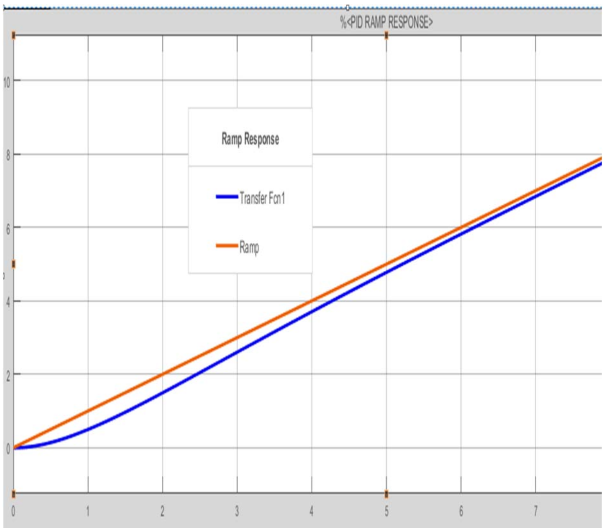

Figure 10:Ramp response of the system simulation

Figure (10) illustrates ramp response of the system. It can be evidenced that ramp of slope 1 has been applied as input and system tracks the ramp signal with minimum error. Therefore, for simulation purpose two types of input signals namely step and ramp have been used for analyzing the performance of designed controller.[6]

V. POWER PMAC CONTROLLER

Power Pmac is a motion controller and computer rolled up in one. The Power PMAC family of controllers is the latest generation of motion and machine controllers from Delta Tau Data Systems, Inc. It is available in a large and increasing number of configurations, permitting the user to configure controller hardware and software to particular application needs. Power PMAC is a general-purpose embedded computer with a built-in motion and machine-control application. It also provides a wide variety of hardware machine interface circuitry that permits connection to common servo and stepper drives, feedback sensors, and analog and digital I/O points[7]. Power Pmac is compatible with Matlab-Simulink facilitating user program ccode generation. The objective is to fully automate code generation for Power PMAC's servo loop closure routines (tasks) utilizing Simulink control blocks. Figure (11) shows the Power Pmac simulation diagram for PID algorithm.

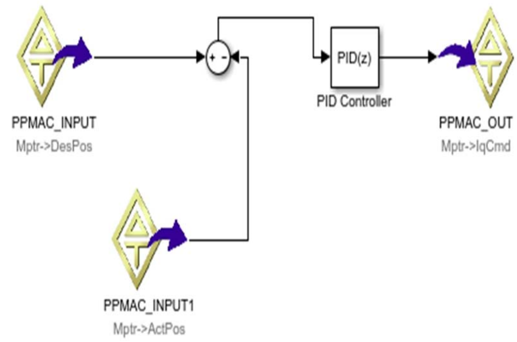

Figure 11:Power Pmac simulation for PID algorithm

The plant transfer function blocks have been replaced with power Pmac components so as to separate the controller from the plant. The ccode for the controller can then be generated using Mathworks' Embedded code generation .The generated code needs to deployed and then compiled in user code generation setup of power Pmac IDE software .Once the ccode gets downloaded successfully the PPmac controller now works on user generated PID algorithm.[8]

VI. REAL- TIME RESULTS OF DEVELOPED PID ALGORITHM

PID algorithm which was generated has been deployed in power Pmac .The controller was then checked for step response and ramp response. Figure(12) exhibits the step response of the system. For step response, a positive step was first applied to the system followed by a negative step. It was observed that system responds for target step value with a maximum following error of 694 counts for 22 bit encoder in essence 0.05 deg.[9]

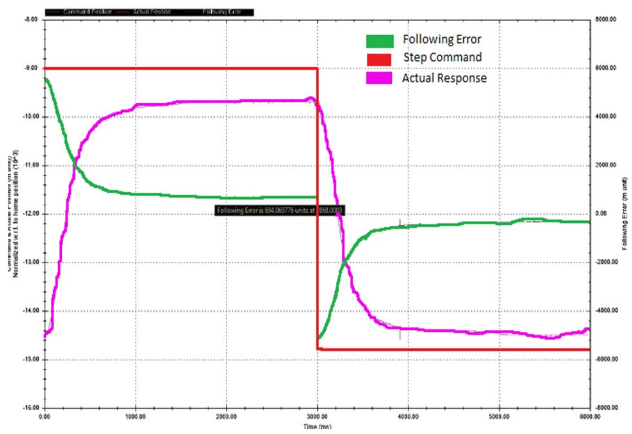

Figure 12:Step response of real time antenna control system

Figure (13) reveals ramp response of the system for the implemented controller .A ramp of positive slope was applied initially followed by a ramp of negative slope ,It can be observed that system tracking is achieved for applied ramp signal with maximum following error of +/- 27 counts in essence 0.002 deg (+ for positive ramp test and – negative ramp test) . The actual position maps the desired position which concludes that controller designed is a noble controller[10].

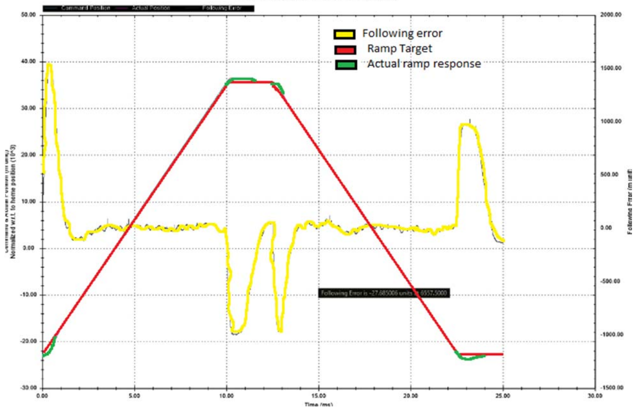

Figure 13:Ramp response of real time antenna control system

VII. CONCLUSION

Paper is about antenna position control systems used for both azimuth and elevation positioning control. First the antenna hardware has been explained in the system. Modeling is done using black box technique of system identification which takes input as target torque and output as actual position of antenna. Simulation of obtained transfer function model for PID controller has been done. Step and ramp responses for simulation have been implemented for open loop and closed loop system. PID algorithm was implemented in power Pmac controller

The real time step response and ramp response have been evaluated in the hardware. It can thus been concluded that designed PID algorithm shows appropriate response for the system with minimum following error. Thus, power Pmac controller is suitable for antenna position control systems application as it also provides facilities for customizable code generation using Matlab

VIII. REFERENCES

[1] W. Gawronski, Dynamics and Control of Strictures: A Modern Approach, New York, Springcr-Verlag, 1998.
[2] Okumus H.I., Sahin E., Akyazi O., Antenna Azimuth Position Control with Classical PID and Fuzzy Logic Controllers. IEEE Transaction on Education, 2012.
[3] Xuan L., Estrada J., Digiacomandrea J., Antenna Azimuth Position Control System Analysis and Controller Implementation. Term Project, 2009
[4] Lennart Ljung, “System Identification: Theory for the User”, P T R Prentice Hall, Englewood Cliffs, New Jersey 0763
[5] A. K. Tangirala, “Principles of system identification: theory and practice,” 2014.
[6] W. Gawronski, “Modelling and Control of Antennas and Telescopes”,Springer.
[7] Power Pmac controller manual available at http://www.deltatau.com/manuals/
[8] Evans W.R., Graphical Analysis of Control Systems. Transactions of the AIEE, 67, 547– 551, 1948.
[9] Kalman R.E., On the General Theory of Control Systems. IRE Transactions on Automatic Control, 4, 3, 110, 1959. Abstract. Full Paper Published in Proceedings of the 1st IFAC Congress, Moscow, 1960.
[10] Grimholt, C. and Skogestad, S. (2013). Optimal PID control on first order plus time delay systems & verification of the Sims rules. In 10th IFAC International Symposium on Dynamics and Control of Process Systems.

IX. ACKNOWLEDGEMENT

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X . AUTHORS’ BIOGRAPHIES

Miss. Nupoor Patil.

Qualification: MTech (Electrical Control Systems) ,BE,Diploma(Electrical)
Work : Application Engineer at Intelligent Motion Technology,(P)Limited,Pune.
Area of Research: Control Systems, System Identification and Control Theory Applications.

Mr.Durgesh Behere

Qualification: BE (Electrical)
Work: Application Engineer at Intelligent Motion Technology,(P)Limited,Pune.
Area of Research: Motion Controller,