Control System Design of Precision Antenna Positioner

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***Abstract - Antenna positioners usually used for dynamic tracking and telemetry data purpose, such as data from missiles or aircraft. Hence control system design using DC servomotor a PID controller and a gear box for loop stabilization for both azimuth and elevation has been carried out. And their respective frequency response and time response will be used for the design purpose. Certain non-linearity such as wind load is superimposed in the model to verify the design and evaluate the performance using MATLAB software*.**

Keywords - Antenna positioner, DC servomotor, PID controller.

1. INTRODUCTION

Antennas are designed to transmit and receive radio waves. There are many types of antennas, but here we are considering the parabolic antenna –the advantage of parabolic antenna is that it has high directivity and functions similar to a search light or flash light, parabolic antenna's large use is for radar in which there is a need to transmit a narrow beam of radio waves to track static and dynamic systems like ships, airplanes and guided missiles.

Antenna positioning is the interface that positions or steers the antenna in azimuth and elevation planes of operation, in order to provide high reliability while withstanding severe environmental conditions. Positioning systems have been traditionally implemented using DC motors due to the relative ease in controlling them. However, there are still disadvantages in using such motors for positioning systems i.e in particular, for high speed repetitive motion, the brushes are subject to excessive mechanical wear and consequently lead to a decrease in performance. Positioning systems were then implemented using stepper motors but as the rotor follows the command position, if pulse frequency higher than natural frequency of the motor then the rotor will lose synchronization, and the user has no way to be sure that the motor has actually reached the desired position. For the reasons just enumerated positioning systems are now being implemented using servo motors, the main reason to use servo systems is to improve transient response times, steady state errors, to meet the torque and speed requirements and are suitable to run in any environment.

PID controller is unquestionably the most commonly used control algorithm. The main reason is its relatively simple structure, which can be easily understood and implemented in practice. As the antennas are placed in the open area there will be disturbances occurred such as wind load effect.

Further we are going to see the proposed system i.e DC servomotor model in section 2, experimental details in section 3. Section 4 contains the conduction procedure that is the current, velocity and position loop models and the model with disturbance are included, section 5 contains the simulation results obtained for the three loops and the disturbances using software tool called MATLAB. Section 6 contains the conclusion and finally the references.

2. SYSTEM MODEL

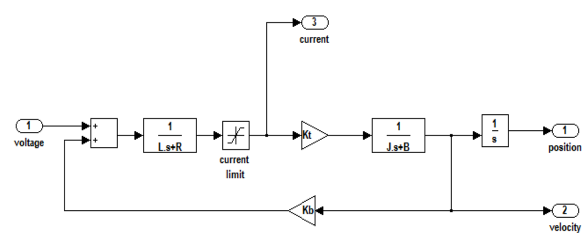


Fig.1 Simulink model of DC servomotor

The motor equation for the motor are given as

$$V = L\frac{di}{dt} + RI + k_b\dot{\theta}$$

$$J\ddot{\theta} = k_t I - B\dot{\theta}$$

Motion control vary widely in industry today depending on the application, motion control can refer to simple on–off control or a sequencing of events, controlling the speed of a motor, moving objects from one point to another, or precisely constraining the speed, acceleration, and position of a system throughout a move. Servo control in general can be broken into 2 fundamental classes of problems the first class deals with command tracking and second class deals with disturbance rejection characteristics of the system.

In the existing motion control systems, usually three control loops are connected: position, velocity, and torque loops. In general, the position and velocity loops are the major focus of the motion control design, while the torque control loop is completed through electrical current loop. It is due to the fact that the current control loop has much higher bandwidth than that of the position and velocity control loops. Since the position and velocity control loops directly deal with the system load, they would definitely be limited by the physical ability of motor drives and the effective load. Therefore, the overall performance of the motion control systems is usually restricted by the bandwidth of the position and velocity control loops.

3. EXPERIMENTAL DETAILS

The base line requirements of the control system are

Frequency domain parameters:

- closed loop bandwidth
- gain and phase margin
- line of sight jitter isolation characteristics

Time domain parameters:

- rise time
- overshoot

Mechanical parameter estimation:

Table1: mechanical parameters

parameters	Azimuth	elevation
Inertia torque	1.82Nm	1.65Nm
Friction torque	3.0Nm	3.0Nm
Wind torque	30.93Nm	16.71Nm
Holding torque	-	55.13
Safety factor	1.2	1.2

Considering the above mentioned requirements the suitable motors are selected i.e for Azimuth 28LT12 portescap motor is selected and for Elevation RE35 maxon motor is selected.

Motor details:

ELEVATION:

Table 2: servomotor details for elevation

Supply voltage(V)	24V
Inductance (L)	0.191mH
Resistance (R)	0.583Ω
Torque constant (Kt)	29.2mNm/A
Motor inertia (Jm)	79.2kgm^2
Load inertia(Jl)	3.1kgm^2
Back EMF constant (Kb)	29.12mV/rad/sec
Current (I)	3.62A
Gear ratio	21*50

AZIMUTH:

Table 3: servomotor details for azimuth

Supply voltage(V)	18V
Inductance (L)	0.5mH
Resistance (R)	6.2Ω
Torque constant (Kt)	21.4mNm/A
Motor inertia (Jm)	10.7kgm^2
Load inertia(Jl)	3.35kgm^2
Back EMF constant (Kb)	21.4mV/rad/sec
Current (I)	3A
Gear ratio	24*50

4. CONDUCTION PROCEDURE

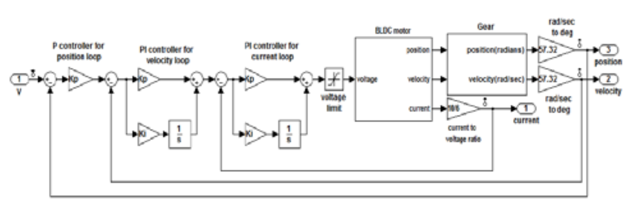
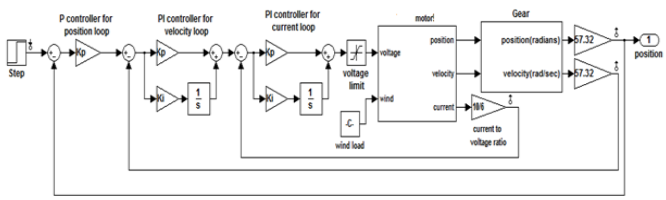


Fig4.1. Current, velocity and position loop controller model

The design of current, velocity and position loop controller is as shown in fig 2. Where the targeted bandwidth for current loop is 1KHz, for velocity loop 35Hz and for position loop 7Hz, the gain at that particular frequencies are observed. The observed gain is then augmented with the unity feedback gain to achieve the adequate current, velocity and position loop bandwidth and their respective frequency responses are plotted (bode plot) . Time responses are plotted (step response) for a step input of 1^{o}/sec and their respective rise time, overshoot and max. speed are noted.



Similarly now adding the disturbance, the wind load effect and their respective time responses are plotted for a step input of 1^{o}/sec.

5. SIMULATION RESULTS

The computer simulation have been done using MATLAB/Simulink which is a software tool developed by Math works.

AZIMUTH: frequency response

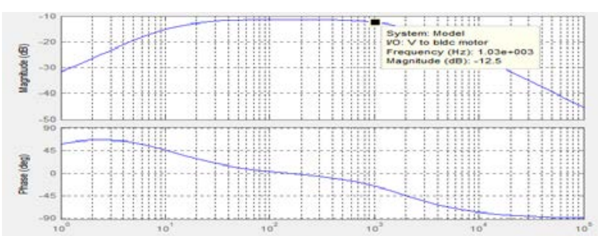


Fig5.1 current loop (open)

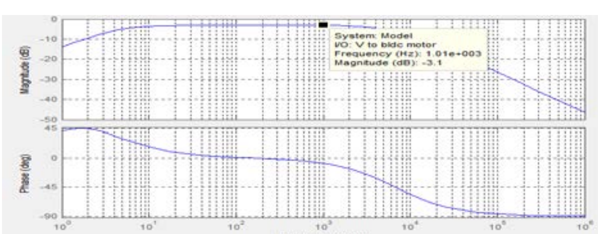


Fig5.2 current loop (closed)

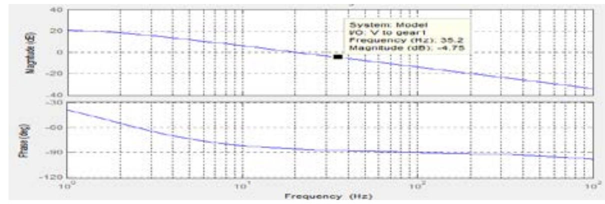


Fig5.3 velocity loop (open)

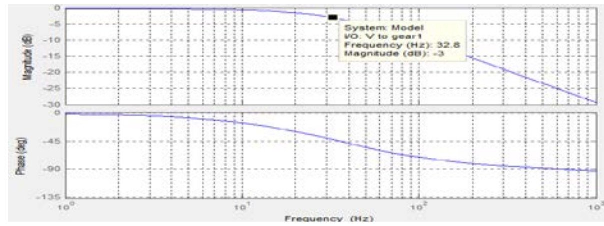


Fig5.4 velocity loop (closed)

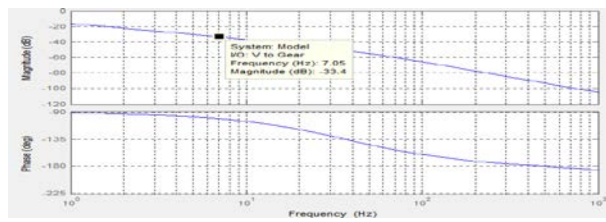


Fig5.5 position loop (open)

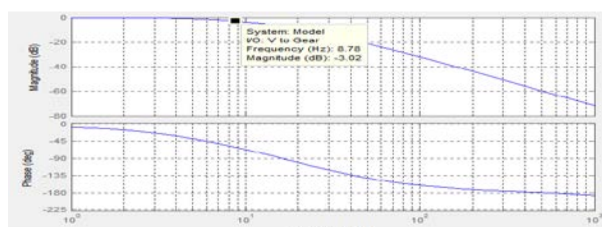


Fig5.6 position loop (closed)

Control loop	Open loop B.W	Closed loop B.W at 3db
Current(1KHz)	-12.5db; K=4.21	1KHz
Velocity(35Hz)	-4.75db; K=1.72	32.8Hz
Position(7Hz)	-33.4db; K=47	8.76Hz

Time response without disturbance:

Rise time: 47.7ms

Overshoot: 3.4660%

Max Speed: 0.39r/s

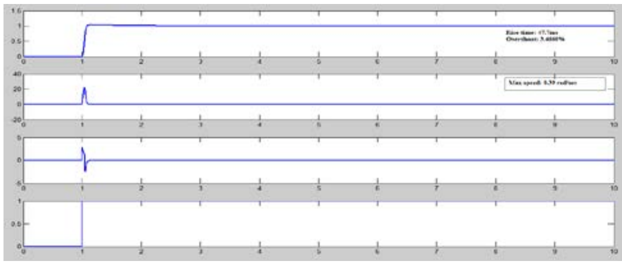


Fig5.7 time response without disturbance

Time response with disturbance:

Rise time: 82.8ms

Overshoot: 9.0992%

Max Speed: 0.1956r/s

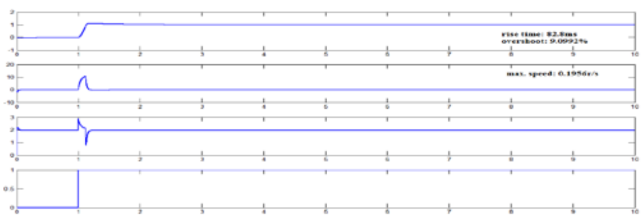


Fig5.8 time response with disturbance

ELEVATION:

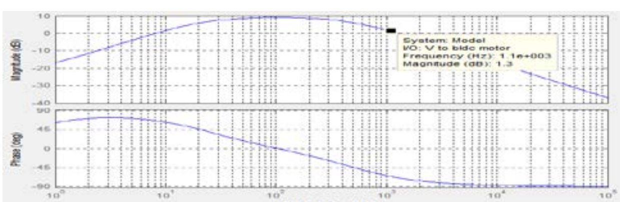


Fig5.9 current loop (open)

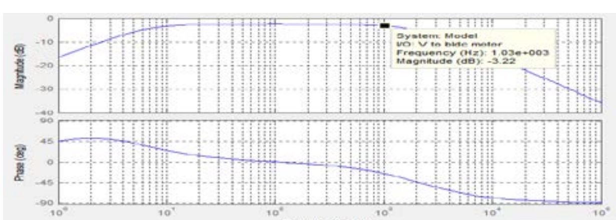


Fig5.10 current loop (closed)

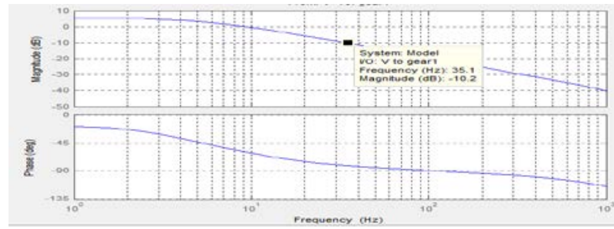


Fig5.11 velocity loop (open)

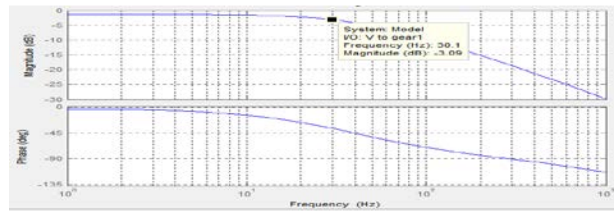


Fig5.12 velocity loop (closed)

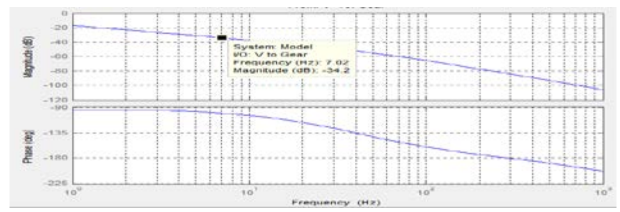


Fig5.13 position loop (open)

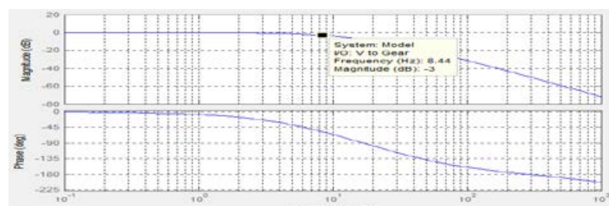


Fig5.14 position loop (closed)

Control loop	Open loop B.W	Closed loop B.Wat 3db
Current(1KHz)	1.3db; K=1.16	1KHz
Velocity(35Hz)	-10.2db; K=3.2	30.1Hz
Position(7Hz)	-34.2db; K=51.28	8.44Hz

Time response without disturbance:

Rise time: 47ms

Overshoot: 4.4857%

Max Speed: 0.396r/s

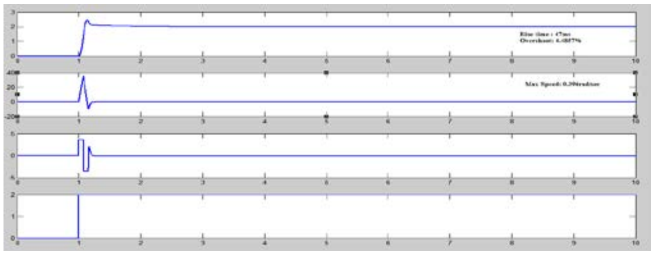


Fig5.15 time response without disturbance

Time response with disturbance:

Rise time: 53ms

Overshoot: 5.4305%

Max Speed: 0.3630r/s

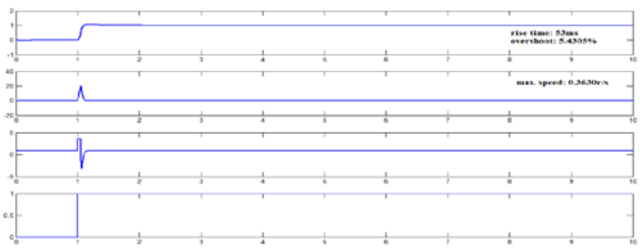


Fig5.16 time response with disturbance

6. CONCLUSION

Advancements in modern computing technologies have shifted the control of RF measurement positioners into the digital domain with increased system flexibility. These advancements provide the opportunity to improve measurement capabilities and accuracies through the use of advanced secondary feedback devices with true error compensation control loops.

The control system design of antenna positioners for loop stabilization and jitter isolation requirement for both azimuth and elevation channels has been carried out using two DC motors and PI controller along with a planetary gear to meet the torque requirements. The frequency response for the three control loops and the time response are plotted as per the required specifications and the jitter isolation characteristics, considering a position disturbance injected in the velocity loop for different frequencies has been done and their respective position outputs have been monitored. All the results presented above, using mathematical equations and simulation in MATLAB.

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AUTHOR'S PROFILE

Sharon Shobitha O has received her Bachelor of Engineering degree in Electrical & Electronics Engineering from New Horizon College of Engineering College, Bangalore in the year 2013. At present she is pursuing M.Tech, with the specialization of computer applications in industrial drives in Sri Siddhartha Institute Of Technology. Her area of interest Control system, Renewable energy sources and logic design.

K.L.Ratnakar had the privilege to get both B.Tech, and M.Tech, degrees from Jawaharlal Nehru Technological University, College of Engineering, Kakinada and stood first in M.Tech, with 85.25%. He has vast teaching experience of 30 years at undergraduate and postgraduate levels. He has presented around 20 technical papers in the national and International conferences, including one at Brisbane, Australia. He has authored a text book on “Electrical Power Transmission and Distribution” for Engineering students. His main area of interest is Power Systems and High Voltage Engineering. He has a life membership of Indian Society for Technical Education (ISTE) and The Institution of Engineers (India). Presently he is working in Sri Siddhartha Institute of Technology from December 1985.