

Return by April 17, 2019

“Control System Design for Antenna Angular Position Control”

The angular position of an antenna is controlled by an armature controlled DC motor. A control system layout is presented in Fig. 1 and a block-diagram of an armature controlled DC motor is presented in Fig. 2.

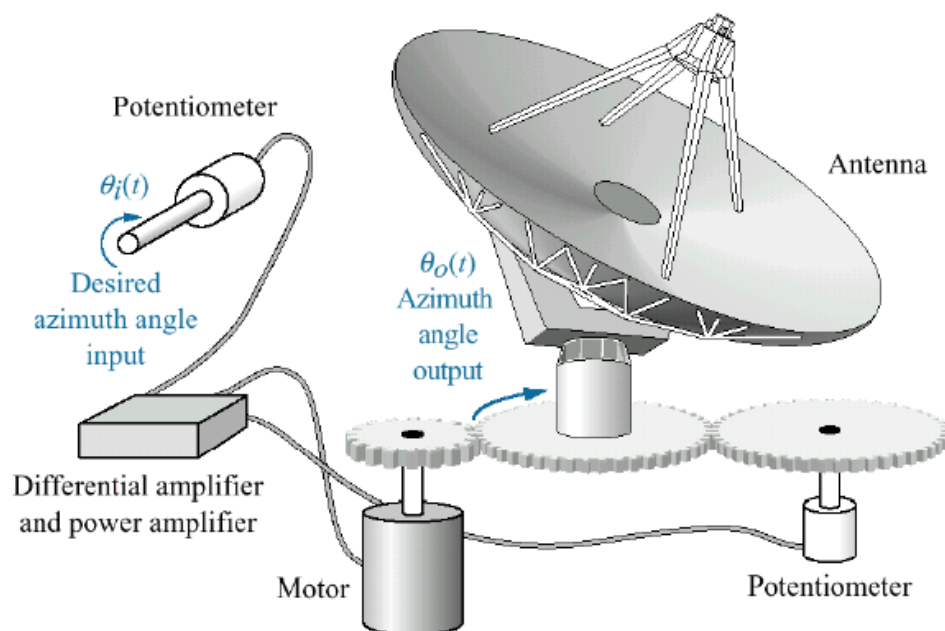


Fig. 1 Layout of antenna position control system

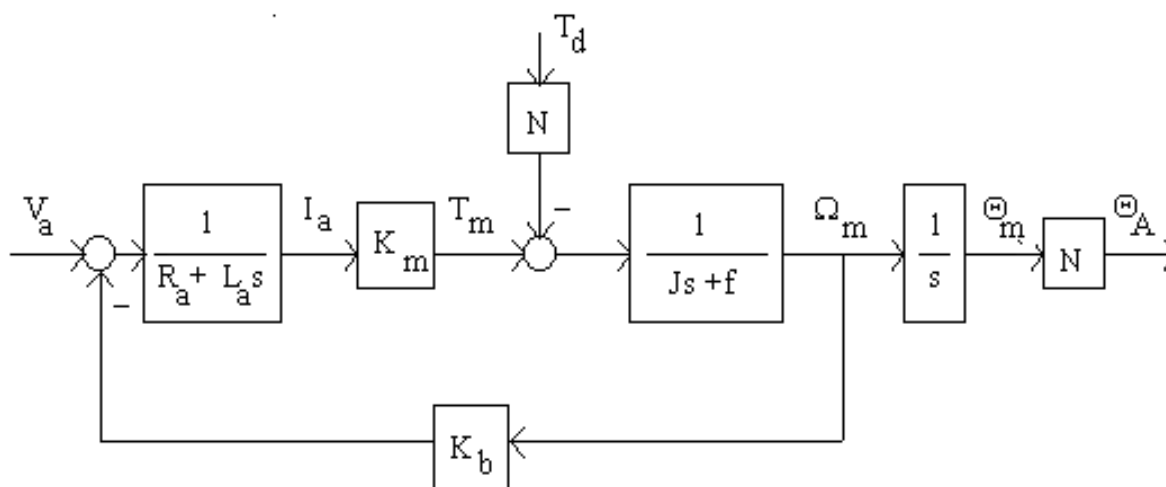


Fig. 2 Block-diagram of an armature controlled DC motor

Nomenclature:

Ω_m, Θ_m -	rotational speed (rad/s) and position (rad) of a motor
Θ_A	antenna position (rad)
$ V_a \leq 125 \text{ Volts}$	armature voltage (V), a control function
I_a	armature current (A),
T_m	torque of a motor (N-m)
$T_d(t) = 180 \cdot 1(t - 3.0) \text{ N-m}$	Wind (disturbance) torque (N-m)

The following system parameters are given (in SI units):

The sensor gain	$K_{\Theta \text{sen}} = 1.0 \text{ V/rad}$
The armature resistance	$R_a = 1.0 \ \Omega$
The torque constant	$K_m = 0.6 \text{ N} \cdot \text{m/A}$
The back-emf constant	$K_b = 0.6 \text{ V s/(rad)}$
The inertia of the motor's rotor with a load	$J = 0.05 \text{ N} \cdot \text{m} \cdot \text{s}^2/\text{rad}$
The viscous-friction coefficient of the motor with the load	$f = 0.1 \text{ N} \cdot \text{m}/(\text{rad/s})$
The antenna commanded position (set point)	$\Theta_A^* = 1(t) \text{ rad}$
The antenna initial position	$\Theta_A(0) = 0.0 \text{ rad}$
The gear-train ratio	$N = 0.1$

Neglect dynamics of the armature winding assuming $L_a = 0$ at the block-diagram of the armature controlled DC motor (Fig. 2).

1. Design the PD controller and a prefilter (fig. 3), (20 pts)

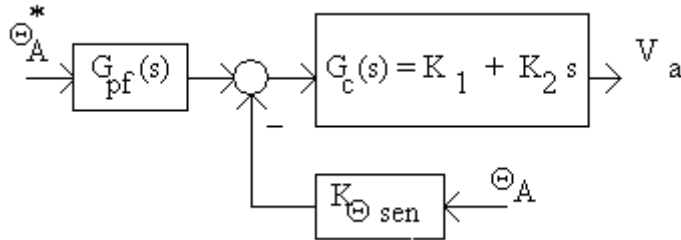


Fig. 3 PD compensator and a prefilter for the antenna position control system

based on the “prototype second order” system concept, i.e. identify the values of the parameters $K_1, K_2 > 0$ and the transfer function $G_{pf}(s)$ of the prefilter to achieve the following performance specifications of the closed loop antenna position control system:
the percent overshoot $\text{P.O.} \leq 10\%$, settling time $T_s \leq 1.2 \text{ sec}$ and the steady state error $e_{ss_\Theta} = 0$ (assuming the wind torque/disturbance $T_d(s)$ is equal to zero). Compute the steady state error e_{ss_T} caused by the disturbance T_d

Hint. $E_A(s) = \Theta_A^*(s) - \Theta_A(s)$

2. Present the simulation diagram and simulate the compensated closed loop antenna position control system (Fig. 2 and 3) with and without the prefilter and zero initial conditions. Apply the disturbance $T_d(t)$ in 3 seconds after $\Theta_A^*(s)$. Plot Θ_A^* vs t , Θ_A vs t , V_a vs t , e_A vs t and T_d vs t . **Type in your name** on all plots. The legends and the variable units must be included in the plots. (20 pts)
3. Given a settling time $T_s \leq 1.2\text{sec}$ design the PID controller and the prefilter (fig. 4), using the ITAE criterion, (20 pts)

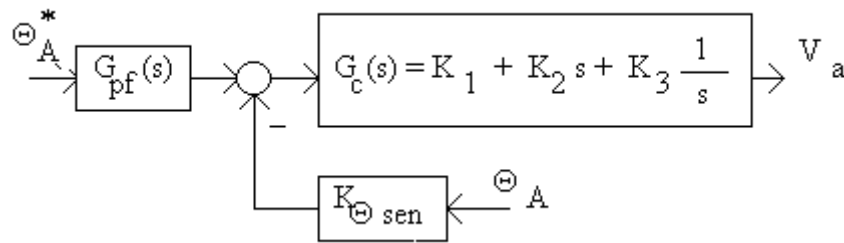


Fig. 4 PID compensator and a prefilter for the antenna position control system

- identify the values of parameters $K_1, K_2, K_3 > 0$ and the transfer function $G_{pf}(s)$ of the prefilter to meet the ITAE criterion completely for the closed loop control system. Compute the steady state error $e_{ss\theta}$ while the disturbance $T_d = 0$ and the steady state error e_{ssr} caused by the disturbance T_d .
4. Present the simulation diagram and simulate the compensated closed loop antenna position control system (Fig. 2 and 4) with and without the prefilter and zero initial conditions. Apply $T_d(t)$ in 3 seconds after applying $\Theta_A^*(t)$. Plot Θ_A^* vs t , Θ_A vs t , V_a vs t , and $T_d(t)$ vs t . **Type in your name** on all plots. The legends and the variable units must be included in the plots. (20 pts)
 5. Verify stability of the designed closed loop DC-motor antenna position control systems using
 - a) Routh-Hurwitz criterion of stability,
 - b) Nyquist criterion of stability (using Matlab),
 - c) Bode plot technique (using Matlab).**Type in your name** on all plots. The legends must be included in the plots. (10 pts)
 6. Present your conclusions on the PD and PID controller performances by comparing the simulation plots of the closed loop antenna position control systems with the PD and the PID controllers. (10 pts)

The report should consist of not more than 20 pages, including

1. Cover Sheet
2. Problem formulation (**attach the assignment sheets!**)
3. Introduction (why the problem that you are going to address in the project is important, a review of the control methods to be used).
4. Problem solution (each task should be covered in a separate subsection, simulations are to be attached)
5. Conclusions (task 6)
6. List of references