**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.

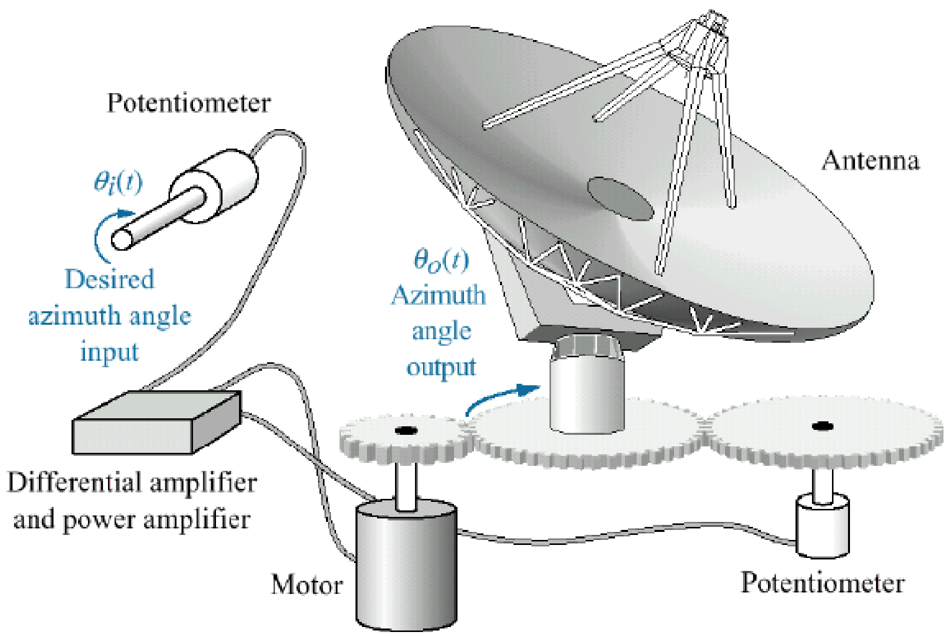


Fig. 1 Layout of antenna position control system

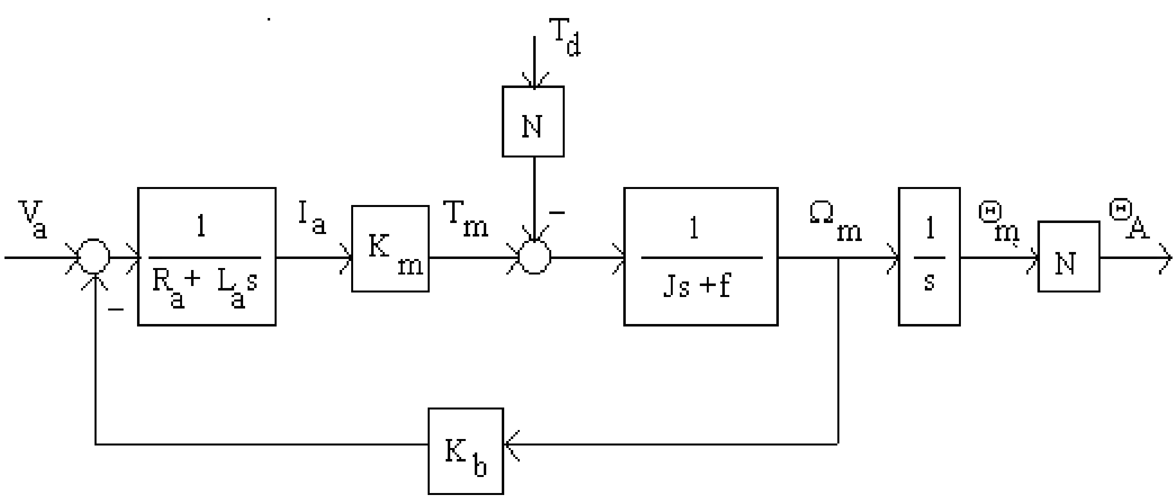


Fig. 2 Block-diagram of an armature controlled DC motor

Nomenclature:

| | |
|---|---|
| $\Omega_m, \Theta_m$ - | rotational speed (rad/s) and position (rad) of a motor |
| $\Theta_A$ | antenna position (rad) |
| $\lvert V_a \rvert \le 125\,Volts$ | armature voltage (V), a control function |
| $I_a$ | armature current (A), |
| $T_m$ | torque of a motor (N-m) |
| $T_d(t) = 180 \cdot 1(t-3.0)$ N-m | Wind (disturbance) torque (N-m) |

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

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

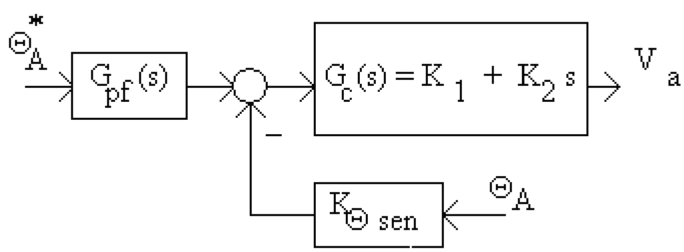


Fig. 3 PD compensator and a prefilter for the antenna position control system

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 P.O. $\le 10\%$, settling time $T_s \le 1.2$ 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 $\Theta^*_A$ vs $t$, $\Theta_A$ 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 $\mathrm{T_s} \leq 1.2\,\mathrm{sec}$ design the PID controller and the prefilter (fig. 4), using the ITAE criterion, ***(20 pts)***

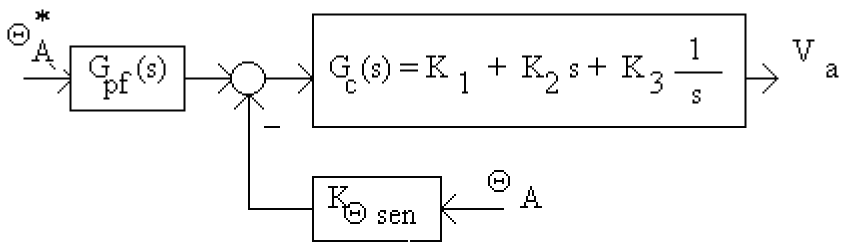


Fig. 4 PID compensator and a prefilter for the antenna position control system

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 $\mathrm{e}_{ss_T}$ 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 $\Theta^*_A$ vs $t$, $\Theta_A$ 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