EE595S
Homework 4, Problem 4

Parameters

$v_{batt} := 200$ $\quad L_q := 11.4\cdot 10^{-3}$ $\quad J := 0.005$

$r_{batt} := 2$ $\quad L_d := L_q$ $\quad r_s := 2.98$

$C_{dc} := 1000\cdot 10^{-6}$ $\quad \lambda_m := 0.156$ $\quad P := 4$

Steady-State Operating Point

$T_L := 1 \qquad \omega_{rm} := 200$

$$\omega_{r0} := \frac{P}{2}\cdot\omega_{rm}$$

$$\phi_{v0} := 0$$

$$v_{ds0} := 0$$

$$i_{qs0} := \frac{T_L}{\frac{3}{2}\cdot\frac{P}{2}\cdot\lambda_m}$$

$$i_{ds0} := \frac{\omega_{r0}\cdot L_q\cdot i_{qs0}}{r_s}$$ Since d-axis voltage is zero - because of phase shift

$$v_{qs0} := r_s\cdot i_{qs0} + \omega_{r0}\cdot\lambda_m + L_d\cdot\omega_{r0}\cdot i_{ds0}$$

$$v_{qs0} = 83.677$$

$$m_0 := \frac{v_{batt}\cdot\cos(\phi_{v0}) - \sqrt{v_{batt}^{2}\cdot\cos(\phi_{v0})^2 - 6\cdot\cos(\phi_{v0})\cdot v_{qs0}\cdot\left(i_{qs0}\cdot\cos(\phi_{v0}) - i_{ds0}\cdot\sin(\phi_{v0})\right)}}{3\cdot\cos(\phi_{v0})\cdot\left(i_{qs0}\cdot\cos(\phi_{v0}) - i_{ds0}\cdot\sin(\phi_{v0})\right)}$$

$$m_0 = 0.421$$

$$v_{dc0} := v_{batt} - \frac{3}{2}\cdot m_0\cdot\left(i_{qs0}\cdot\cos(\phi_{v0}) - i_{ds0}\cdot\sin(\phi_{v0})\right)$$

$$v_{dc0} = 198.65$$

Problem 5

$$A := \begin{bmatrix} \frac{-1}{C_{dc} \cdot r_{batt}} & -\frac{3 \cdot m_0}{2 \cdot C_{dc}} \cdot \cos(\phi_{v0}) & \frac{3 \cdot m_0}{2 \cdot C_{dc}} \cdot \sin(\phi_{v0}) & 0 \\ \frac{m_0 \cdot \cos(\phi_{v0})}{L_q} & \frac{-r_s}{L_q} & \frac{-L_d}{L_q} \cdot \omega_{r0} & \frac{-\lambda_m}{L_q} - \frac{L_d}{L_q} \cdot i \\ \frac{-1}{L_q} \cdot m_0 \cdot \sin(\phi_{v0}) & \frac{L_q}{L_d} \cdot \omega_{r0} & \frac{-r_s}{L_d} & \frac{L_q}{L_d} \cdot i_{qs0} \\ 0 & \frac{1}{J} \cdot \frac{3}{2} \cdot \left(\frac{P}{2}\right)^2 \cdot \left[(L_d - L_q) \cdot i_{ds0} + \lambda_m\right] & \frac{1}{J} \cdot \frac{3}{2} \cdot \left(\frac{P}{2}\right)^2 \cdot (L_d - L_q) \cdot i_{qs0} & 0 \end{bmatrix}$$

$$B := \begin{bmatrix} \frac{-3}{2C_{dc}} \cdot \left(i_{qs0} \cdot \cos(\phi_{v0}) - i_{ds0} \cdot \sin(\phi_{v0})\right) \\ \frac{1}{L_q} \cdot v_{dc0} \cdot \cos(\phi_{v0}) \\ \frac{-1}{L_d} \cdot v_{dc0} \cdot \sin(\phi_{v0}) \\ 0 \end{bmatrix} \cdot \frac{1}{2}$$

The 1/2 is because m=d/2 for sine triangle modulaton

$$C := \begin{pmatrix} 0 & 0 & 0 & \frac{2}{P} \end{pmatrix}$$

The output is mechanical rotor speed

$$N := 100$$

$$i := 0 .. N - 1$$

$$logf_i := -3 + \frac{i}{N - 1} \cdot 6$$

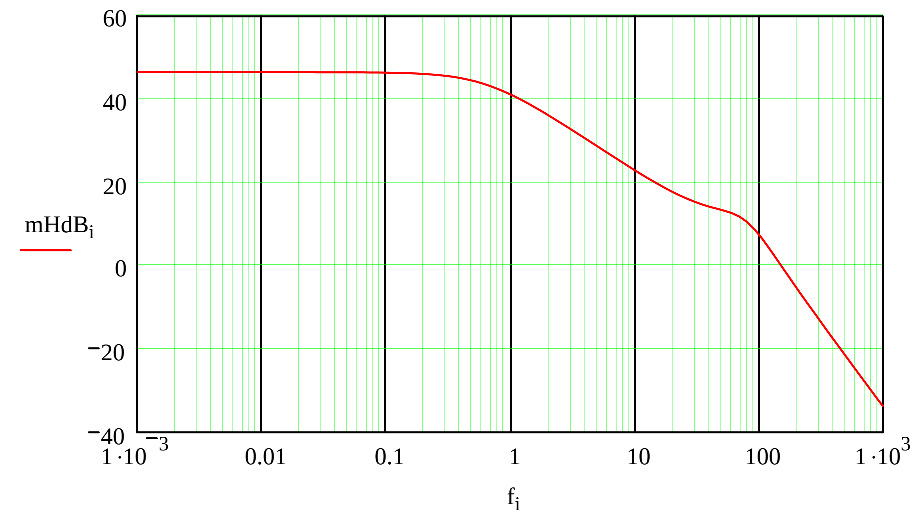
$$f_i := 10^{logf_i}$$

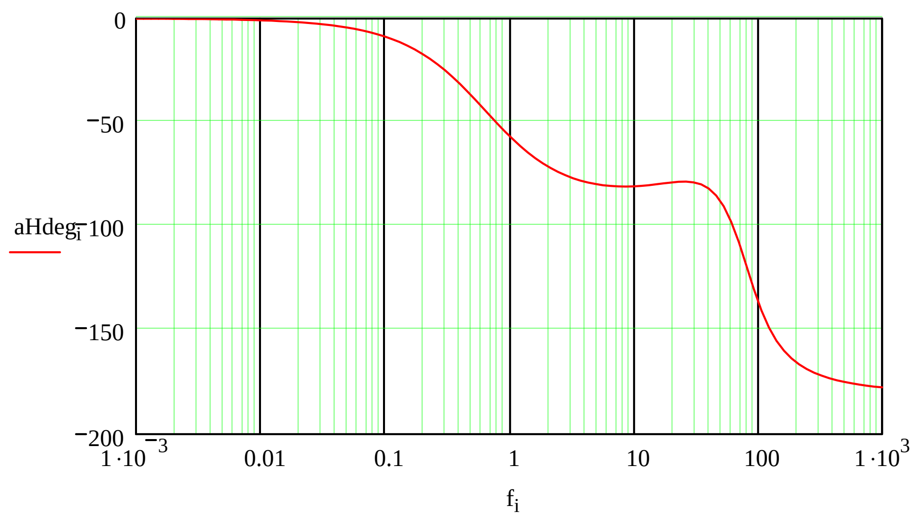
$$s := j \cdot 2 \cdot \pi \cdot f$$

$$H_i := C\cdot\left[s_i\cdot\begin{pmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{pmatrix} - A\right]^{-1}\cdot B$$

$$mHdB_i := 20.0\cdot\log\left(\left|H_i\right|\right)$$

$$aHdeg_i := \arg\left(H_i\right)\cdot\frac{180}{\pi}$$





By inspection, the gain margin is infinite, the phase margin is roughly 20 degrees ds0