Homework #4, Problem #1

Monday, October 11, 2021 10:13 AM

4.1 Using the steady-state exciter model of (4.20) and (4.22) with $K_E = 1.0$, $V_{R\max} = 8.0$, $S_{E\max} = 0.9$, $S_E 0.75\max = 0.5$ (all pu), find $E_{fd\max}$, A_x, and B_x.

(4.20) $0 = -(K_E + S_E(E_{fd}))E_{fd} + V_R.$

(4.22) $S_E(E_{fd}) = A_x e^{B_x E_{fd}}.$

Using (4.20) to solve for $E_{fd,max}$:

$$0 = -(1 + 0.9)E_{fd} + 8 \qquad \boxed{E_{fd,max} = 4.211 \text{ pu}}$$

Using (4.22) to solve for A_x, B_x

$$\Rightarrow \quad 0.9 = A_x e^{B_x E_{fd,max}}$$

$$0.5 = A_x e^{0.75 B_x E_{fd,max}}$$

Solving this system of equations $\Rightarrow$ $\boxed{\begin{array}{l} A_x = 0.0857 \\ B_x = 0.5584 \end{array}}$

Homework #4, Problem #2

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4.3 Using the exciter model of (4.18) and (4.22) with $V_R = V_{res} = 0.05$, find $K_{E_{self}}$ so that $E_{fd} = 1.0$ when $A_x = 0.1$ and $B_x = 0.6$ (all pu).

(4.18) $$T_E \frac{dE_{fd}}{dt} = -\left(K_{E_{self}} + S_E(E_{fd})\right) E_{fd} + V_R.$$

(4.22) $$S_E(E_{fd}) = A_x e^{B_x E_{fd}}.$$

$$\Rightarrow T_E \frac{dE_{fd}}{dt} = -\left(K_{E_{self}} + A_x e^{B_x E_{fd}}\right) E_{fd} + V_R$$

At Steady State we get:

$$\Rightarrow 0 = -\left(K_{E_{self}} + A_x e^{B_x E_{fd}}\right) E_{fd} + V_R$$

$$\Rightarrow \boxed{K_{E_{self}} = -0.132}$$

Homework #4, Problem #3

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4.7 Starting with the dynamic model of (4.46)–(4.49), derive the following dynamic model (a fast static exciter/regulator):

$$T\frac{dE_{fd}}{dt} = -E_{fd} + K(V_{\text{ref}} - V_t).$$

$$T_E\frac{dE_{fd}}{dt} = -(K_E + S_E(E_{fd}))E_{fd} + V_R \tag{4.46}$$

$$T_F\frac{dR_f}{dt} = -R_f + \frac{K_F}{T_F}E_{fd} \tag{4.47}$$

$$T_A\frac{dV_R}{dt} = -V_R + K_A R_f - \frac{K_A K_F}{T_F}E_{fd} + K_A(V_{\text{ref}} - V_t) \tag{4.48}$$

$$V_R^{\min} \leq V_R \leq V_R^{\max} \tag{4.49}$$

Assuming (4.47) is at steady state $\Rightarrow R_f = \frac{K_F}{T_F}E_{fd}$

$\Rightarrow$ (4.48) at steady state:

$$0 = -V_R + K_A R_f - \frac{K_A K_F}{T_F}E_{fd} + K_A(V_{ref} - V_t)$$

$$0 = -V_R + \cancel{K_A\left(\frac{K_F}{T_F}E_{fd}\right)} - \cancel{\frac{K_A K_F}{T_F}E_{fd}} + K_A(V_{ref} - V_t)$$

$$0 = -V_R + K_A(V_{ref} - V_t)$$

$$\Rightarrow V_R = K_A(V_{ref} - V_t)$$

$\Rightarrow$ Plugging these into (4.46), while ignoring saturation $\left(S_E(E_{fd}) = 0\right)$

$$\Rightarrow T_E\frac{dE_{fd}}{dt} = -K_E E_{fd} + V_R$$

$$\Rightarrow T_E\frac{dE_{fd}}{dt} = -E_{fd} + K_A(V_{ref} - V_t)$$ • Assume $K_E = 1$

Homework #4, Problem #4

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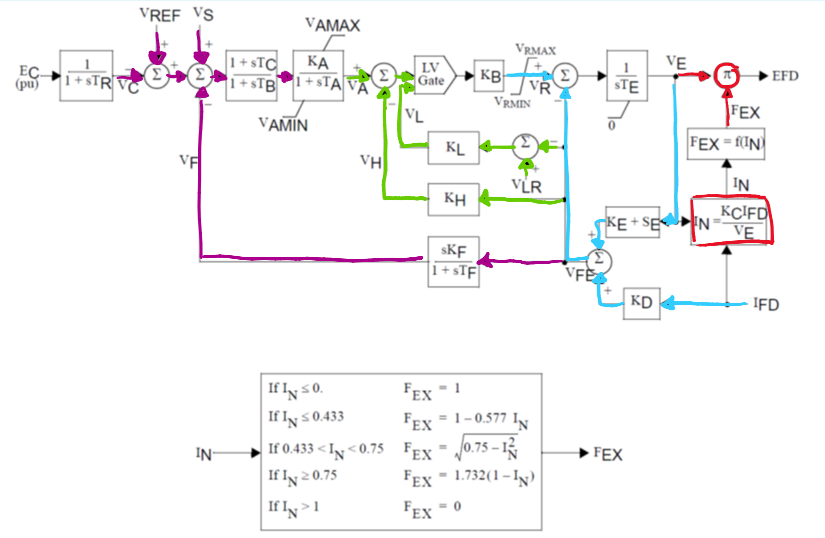

$V_S = V_{OTHSG} + V_{UEL} + V_{OEL}$

$T_r = 0.05$	$K_a = 300$	$K_f = 0.0$	$V_{a,min} = -8$
$T_a = 0.02$	$K_b = 20$	$K_h = 0$	$V_{a,max} = 8$
$T_b = T_c = 1$	$K_c = 0.3$	$K_l = 10$	$V_{r,min} = -10$
$T_e = 0.8$	$K_d = 0$		$V_{r,max} = 10$
$T_f = 1$	$K_e = 1$		

$V_{LR} = 4.4$ $E_1 = 3.3$ $E_2 = 4.4$

$SE_1 = 0.03$ $SE_2 = 0.08$

$E_{fd} = I_{fd} = 3.1866$ pu $E_c = 1.0446$

I) Calculate what I_N value to use.

Red area implies: $V_E \times F_{EX} = E_{FD}$

- If $I_N \le 0$, $F_{EX} = 1$, where $I_N = \dfrac{K_c I_{FD}}{V_E}$

$\Rightarrow V_E = E_{FD} \Rightarrow I_N = K_c \Rightarrow I_N = 0.3 \not\le 0$

So condition 1 does not hold.

- If $I_N \le 0.433$, $F_{EX} = 1 - 0.577 I_N$ ×

$$\Rightarrow V_E = \frac{E_{FD}}{F_{EX}} = \frac{E_{FD}}{1 - 0.577 I_N}$$

$$\Rightarrow I_N = K_c I_{FD} \times \frac{(1 - 0.577 I_N)}{E_{FD}}$$ From the block diagram

$$I_N = K_c - 0.577 K_c I_N$$

$\Rightarrow I_N = 0.256 \leq 0.433$ ✓

$\Rightarrow I_N = 0.256\ ,\ F_{EX} = 0.852$

II) Use saturation to solve for A, B

$S_e = B(E - A)^2$

$\Rightarrow 0.03 = B(3.3 - A)^2 \Rightarrow A = 1.562$

$0.08 = B(4.4 - A)^2 \qquad B = 0.0099$

III) Calculate V_R

Following the path in blue, we get:

$V_{FE} = V_R = K_E V_E + V_E \times S_e(V_E) + \cancel{K_D I_{fd}} \rightarrow 0$

$$\Rightarrow V_R = 1\left(\frac{E_{fd}}{F_{EX}}\right) + B\left(\frac{E_{fd}}{F_{EX}} - A\right)^2\left(\frac{E_{fd}}{F_{EX}}\right)$$

$\Rightarrow \boxed{V_R = 3.914\ pu}$

IV) Calculate V_A

Following the path in green, we get:

$V_R = K_B \min(V_L, V_A - \cancel{K_H V_{FE}}) \rightarrow 0$

where: $V_L = K_L(VLR - V_{FE})$

$$\Rightarrow \frac{V_R}{K_B} = \min(10(4.4 - 3.914), V_A)$$

$\Rightarrow 0.196 = \min(4.859, V_A) \Rightarrow \boxed{V_A = 0.196\ pu}$

V) Calculate V_{ref}

Assume $V_s = 0$, following the purple path

$$\Rightarrow V_{ref} - E_c = \frac{V_A}{K_A} - V_f\ ,\ \text{where } V_f = 0$$

$$\Rightarrow V_{ref} = \frac{V_A}{K_A} + E_c \Rightarrow \boxed{V_{ref} = 1.0953pu}$$

Homework #4, Problem #5

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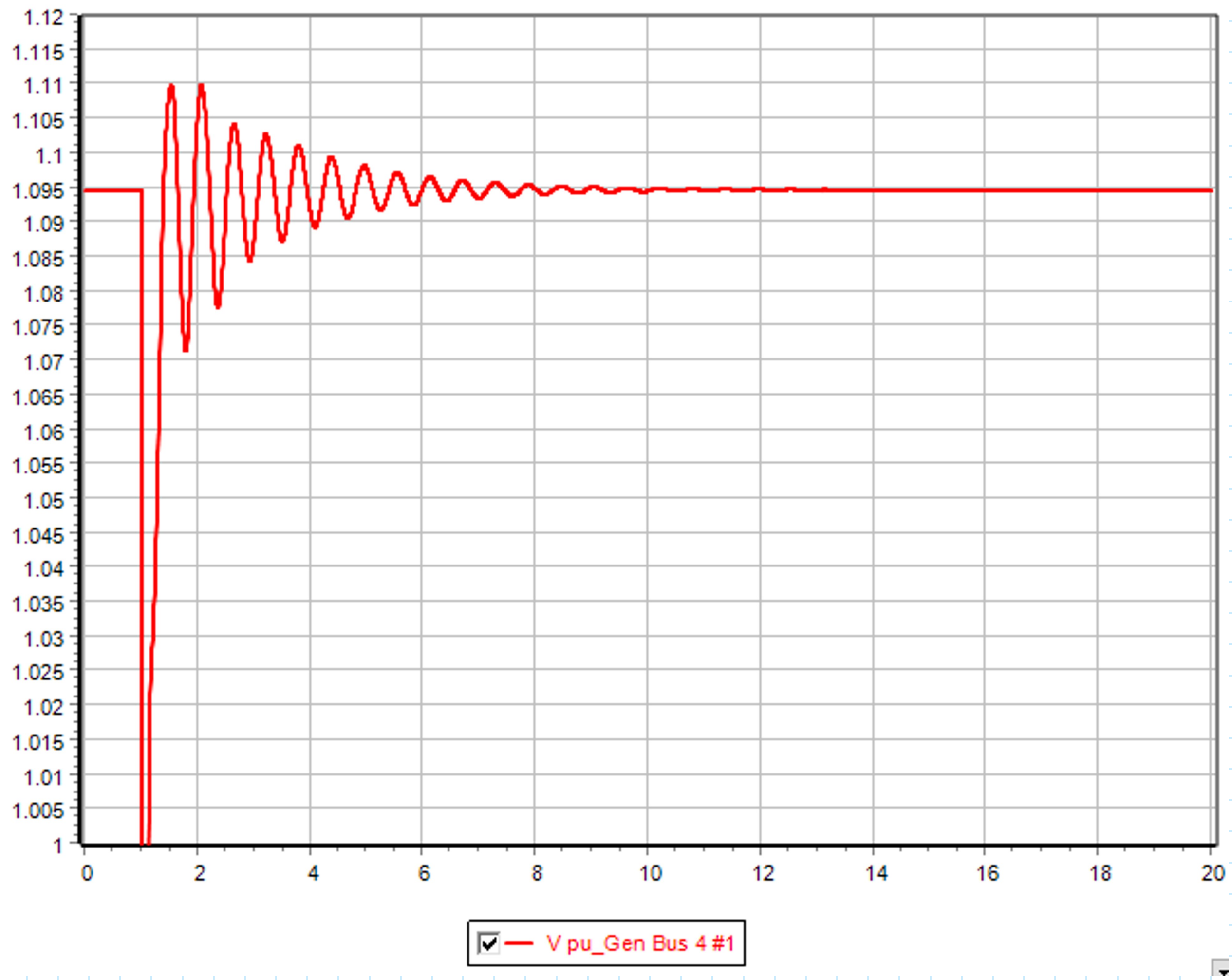
The minimum K_F is roughly 0.007 pu to minimize the oscillations.



However, there exists a rough range of K_f values that will reduce the oscillations around 0.007 pu.