ECE 431. SP 2020 . HW5. Soln.

Problem 5.1.

a) $|\bar{E}_a| = \frac{\omega_e L_{af} I_f}{\sqrt{2}} \Rightarrow L_{af} = \frac{\sqrt{2}\, E_a}{2\pi f_e I_f} = \frac{\sqrt{2} \times 11.5k/\sqrt{3}}{2\pi 60 \times 750} = 0.0332\,H$

b) $|E_{a,op}| = \frac{\omega_{e,new} L_{af} I_{f,new}}{\sqrt{2}} = \frac{2\pi 50 \times 0.0332 \times 700}{\sqrt{2}} = 5.164\,kV.$

$V_{open\,ckt,\,ll,\,rms} = \sqrt{3}\,|E_{a,op}| = 8.944\,kV.$

c) $L = \frac{N^2}{R} \quad R = \frac{l}{\mu A} \quad L' = 1.5L \Rightarrow L' = \frac{L}{1.5} = 0.0221\,H$

$I_f' = \frac{\sqrt{2} E_a}{2\pi f_e L'} = \frac{\sqrt{2} \times 11.5k/\sqrt{3}}{2\pi 60 \times 0.0221} = 1125\,A.$

Problem 5.2.

a) $V_{base} = \frac{V_{ll}}{\sqrt{3}} = \frac{11.5k}{\sqrt{3}} = 6640\,V.$

$I_{base} = \frac{S_\phi}{V_{base}} = \frac{100MV3}{6640} = 5020\,A$

$Z_{base} = \frac{V_{base}}{I_{base}} = 1.323\,\Omega$

$X_S = Z_{base} \cdot \frac{AFSC}{AFNL} = 1.323 \frac{120}{170} = 0.934\,\Omega$

$\because PF = 1$ $\therefore V_a I_a$ in phase.

$\bar{E}_a = (jX_S)\bar{I}_a + \bar{V}_a = (j\,0.934)(5020\angle 0^\circ) + 6640\angle 0^\circ = 8129 \angle 35.2^\circ\,V.$

@ AFNL $E_{aoc} = \omega \cdot AFNL \cdot k \Rightarrow \frac{11.5k}{\sqrt{3}} = 2\pi 60 \cdot 170\,k \Rightarrow k = 0.104$

$|\bar{E}_a| = \omega I_f k \Rightarrow I_f = \frac{E_a|}{2\pi f_e k} = \frac{8129}{2\pi 60 \times 0.104} = 207.34\,A.$

b) @ AFNL $|\bar{E}_a| = \frac{V_{ll}}{\sqrt{3}} = 6640\,V.$

use terminal voltage as reference : $V_a = 6640\angle 0^\circ\,V.$

assume $\bar{E}_a = 6640\angle\delta\,V.$

$P = \frac{3|\bar{E}_a||\bar{V}_a|}{X_S}\sin(\delta) \Rightarrow \sin(\delta) = \frac{100M \times 0.934}{3 \times 6640 \times 6640} = 0.706 \Rightarrow \delta = 44.92^\circ$

$\bar{I}_a = \frac{\bar{E}_a - \bar{V}_a}{jX_S} = \frac{6640\angle 44.92^\circ - 6640\angle 0^\circ}{j\,0.934} = 5431.98 \angle 22.46^\circ\,A.$

$PF = \cos(22.46^\circ) = 0.924$ leading.

c) $PF = 0.85$ lagging. $\Rightarrow \theta = -31.8^\circ$ $\therefore \angle \bar{I}_a = -31.8^\circ$

$P = 3|\bar{I}_a||\bar{V}_a|\cos\theta \Rightarrow |\bar{I}_a| = \frac{100M}{3 \times 6640 \times 0.85} = 5905.98\ A$

$\bar{E}_a = \bar{V}_a + jX_s \bar{I}_a = 6640\angle 0^\circ + j0.934 \times 5905.98 \angle -31.8^\circ = 10636 \angle 26.15^\circ\ V.$

$I_f = \frac{E_{a1}}{\omega k} = \frac{10636}{2260 \times 1.104} = 271.28\ A$

Problem 玉 5.3.

a) taking terminal voltage as reference $V_a = \frac{208}{\sqrt{3}} = 120.1\angle 0^\circ\ V,$

$PF = 1 \Rightarrow \angle \bar{I}_a = 0^\circ$

$\bar{E}_a = \bar{V}_a - jX_s \cdot \bar{I}_a = 120\angle 0^\circ - j15.50\angle 0^\circ = 141.51 \angle -32^\circ\ V.$

$\delta = -32^\circ$

b) $P = 3|\bar{I}_a||\bar{V}_a|\,PF_{(a)} = 3 \times 120 \times 50 \times 1 = 18kW.$

$PF_{(b)} = 0.8$ leading $\Rightarrow \theta = 36.9^\circ$ $\therefore \angle \bar{I}_a' = 36.9^\circ$

$|\bar{I}_a'| = \frac{P}{3|\bar{V}_a|PF_{(b)}} = \frac{18k}{3 \times 120 \times 0.8} = 625\ A$

$\bar{E}_a = \bar{V}_a - jX_s \bar{I}_a' = 120\angle 0^\circ - j1.5 \times 625\angle 36.9^\circ = 191.6\angle -23.04^\circ\ V.$

$I_f = \frac{191.6}{141.51} \times 7 = 9.48\ A.$ (linear, OC).

c) from b) $\delta' = -23.04^\circ$