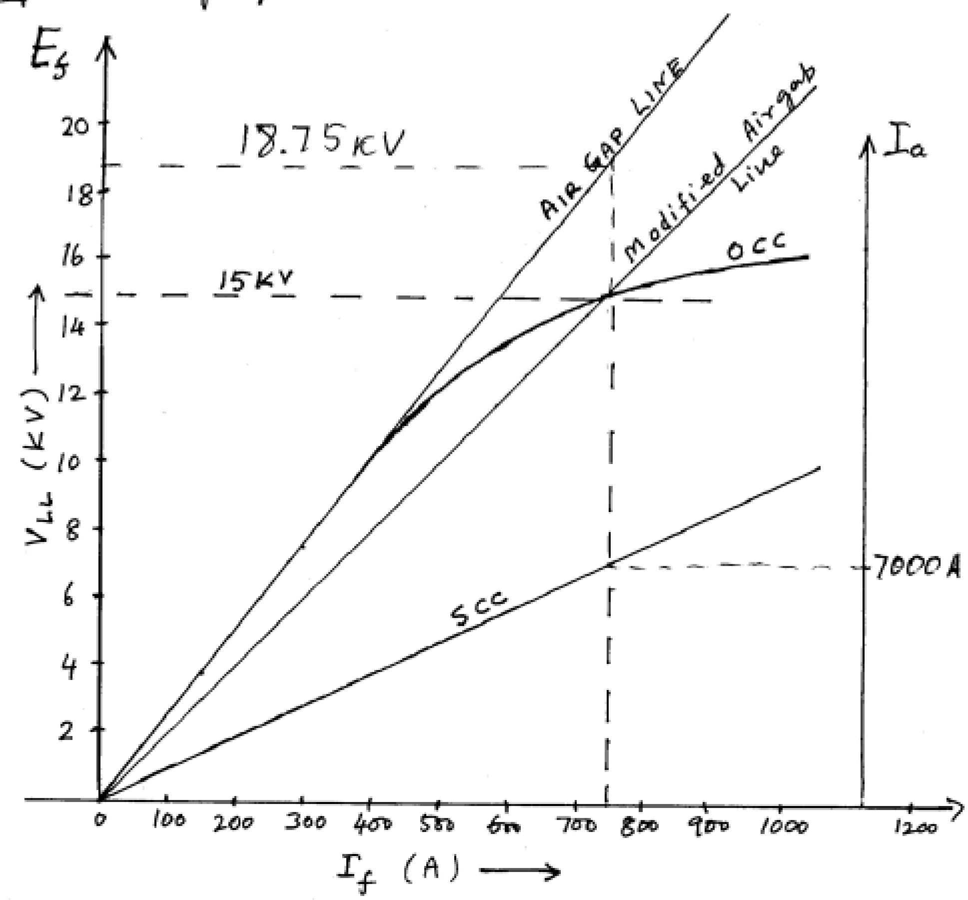
ELEC 342: Homework Assignment # 6, Synchronous Machines:

Textbook Chap. 6: Examples 6.2, 6.3, 6.5, and 6.7
Textbook Chap. 6: Problems: 6.3 only parts (a) and (b); 6.9; 6.12; 6.13; 6.30

$\boxed{6.3}$ (a) See graph



$\boxed{6.3}$ (b)

$$V_b = \frac{15\times10^3}{\sqrt{3}} = 8660.5\ V$$

$$I_b = \frac{195\times10^6}{\sqrt{3}\times15\times10^3} = 7505.8\ A$$

$$Z_b = \frac{8660.5}{7505.8} = 1.1538\ \Omega$$

$$X_s\big|_{unsat} = \frac{18.75\times10^3}{\sqrt{3}\times7000} = 1.5465\ \Omega$$

$$= \frac{1.5465}{1.1538} = 1.3404\ p.u.$$

$$X_s\big|_{sat} = \frac{15\times10^3}{\sqrt{3}\times700} = 1.2372\ \Omega \rightarrow 1.0723\ p.u$$

6.9 Consider the phasor diagram of Fig. 6.17a and equivalent circuit of Fig. 6.14e.

$$V_t = \frac{11000}{\sqrt{3}} = 6350.9\ \text{V}$$

$$I_a = \frac{25 \times 10^6}{\sqrt{3} \times 11 \times 10^3} = 1312.2\ \text{A}$$

$$\theta = \cos^{-1} 0.85 = 31.8°$$

$$I_a = 1312.2 \angle -31.8°\ \text{A}$$

The excitation voltage E_f is

$$E_f = 6350.9 \angle 0° + 1312.2 \angle -31.8° \,(0.45 + j4.5) = 11020.3 \angle 25.$$

6.12 $V_t = \frac{220}{\sqrt{3}} = 127\ \text{V}$

$I_a = \frac{10 \times 10^3}{\sqrt{3} \times 220} = 26.2\ \text{A}$

(a) $\theta = \cos^{-1} 0.8 = 36.9°$

$$I_a = 26.2 \angle -36.9°\ \text{A}$$

$$E_f = V_t \angle 0° + I_a \angle -\theta° \cdot (R_a + jX_s)$$

$$= 127 \angle 0° + 26.2 \angle 0° \,(0.25 + j5) = 233.8 \angle 25.6°\ \text{V}$$

(b) $E_f = V_t \angle 0° + I_a \angle 0° \cdot (0.25 + j5)$

$$= 127 \angle 0° + 26.2 \angle 0° \,(0.25 + j5) = 187.1 \angle 44.4°\ \text{V}$$

(c) $E_f = V_t \angle 0° + I_a \angle \theta° \cdot (0.25 + j5)$

$$= 127 \angle 0° + 26.2 \angle 36.9° \,(0.25 + j5) = 121.2 \angle 63.8°\ \text{V}$$

6.13 (a) $P_{out} = 10 \times 0.8 = 8\ \text{kW}$

Field current,

$$I_f = \frac{8}{187.1} \times 233.8 = 10\ \text{A}$$

Field loss,

$$P_f = 10^2 \times 5 = 500\ \text{W}$$

$P_{stator} = 3 \times 26.2^2 \times 0.25 = 514.8\ \text{W}$

$P_{core} = 250\ \text{W}$

$P_{rotation} = 200\ \text{W}$

$P_{loss} = 200 + 250 + 514.8 + 500 = 1464.8\ \text{W}$

$P_{in} = 8000 + 1464.8 = 9464.8\ \text{W}$

$\text{Eff} = \frac{8000}{9464.8} \times 100\% = 84.3\%$

(b) $P_{out} = 10 \times 1.0 = 10\ \text{kW}$

$I_f = 8\ \text{A}$

$P_f = 8^2 \times 5 = 320\ \text{W}$

$P_{loss} = 200 + 250 + 514.4 + 320 = 1284.8\ \text{W}$

$P_{in} = 10000 + 1284.8 = 11284.8\ \text{W}$

$\text{Eff} = \frac{10000}{11284.8} \times 100\% = 88.6\%$

(c) $P_{out} = 10 \times 0.8 = 8\ \text{kW}$

$I_f = \frac{8}{187.1} \times 121.2 = 5.18\ \text{A}$

$P_f = 5.18^2 \times 5 = 134.3\ \text{W}$

$P_{loss} = 200 + 250 + 514.4 + 134.3 = 1099.1\ \text{W}$

$P_{in} = 8000 + 1099.1 = 9099.1\ \text{W}$

$\text{Eff} = \frac{8000}{9099.1} \times 100\% = 87.9\%$

$\boxed{6.30}$ (a) $P = 1 = \frac{V_t E_f}{0.95}\sin 25° + \frac{V_t^2}{2}\left(\frac{1}{0.45} - \frac{1}{0.95}\right)\sin 50°$

$Q = 0 = \frac{V_t E_f}{0.95}\cos 25° - V_t^2\left(\frac{\sin^2 25°}{0.45} + \frac{\cos^2 25°}{0.95}\right)$

Solving for E_f & V_t

$V_t = 0.9823$ pu. $E_f = 1.299$ pu.

(Or From phasor diagram, $V_t \sin\delta = I_q X_q$ $V_t = \frac{0.9226 \times 0.45}{\sin 25°} = 0.9824$ P.U.

$E_f = V_t \cos\delta + I_d X_d = 0.9824\cos 25° + 0.4302 \times 0.95 = 1.299$ P.U.)

(b) $P = V_t I_a \cos\theta$

$1 = 0.9823 \times I_a \times 1.0$

$I_a = 1.018$ P.U

$I_d = 1.018 \sin 25° = 0.4302$ PU

$I_q = 1.018 \cos 25 = 0.9226$ pu.