Module G1

Solution to problem 1

(a)

$$V_t = \frac{30kV}{\sqrt{3}} = 17.32kV$$

$$P = 50MW$$

$$pf = 0.8 = \cos\theta$$

$$\Rightarrow \theta = 36.87°$$

$$P = 3|V_t||I_a|\cos\theta \Rightarrow \frac{P}{3\cdot|V_t|\cos\theta} = \frac{50\times10^6}{3(17.32\times10^3)\cdot(0.8)} = |I_a| = 1202.8A$$

$$\Rightarrow I_a = 1202.8\angle-36.87°A$$

$$E_f = V_t + I_a(jX_s) = 17.32\times10^3\angle0° + (1202.8\angle-36.87°)\cdot(j0.9)$$

$$= 17970.0 + j866V$$

$$= 17991\angle2.759°V$$

$$Q_{out} = \frac{3|V_t|\cdot|E_f|}{X_s}\cos\delta - \frac{3|V_t|^2}{X_s} = 37.5MVar$$

(b)

$$P_{out} = 25MW$$

$$\Rightarrow P_{out} = 25M = \frac{3(17.32\times10^3)(17990)}{0.9}\sin\delta$$

$$\Rightarrow \delta = \sin^{-1}(0.0241) = 1.38°$$

$$Q_{out} = \frac{3(17.32\times10^3)(17.99\times10^3)}{0.9}\cos(1.38°) - \frac{3(17.32\times10^3)^2}{0.9} = 38.38MVar$$

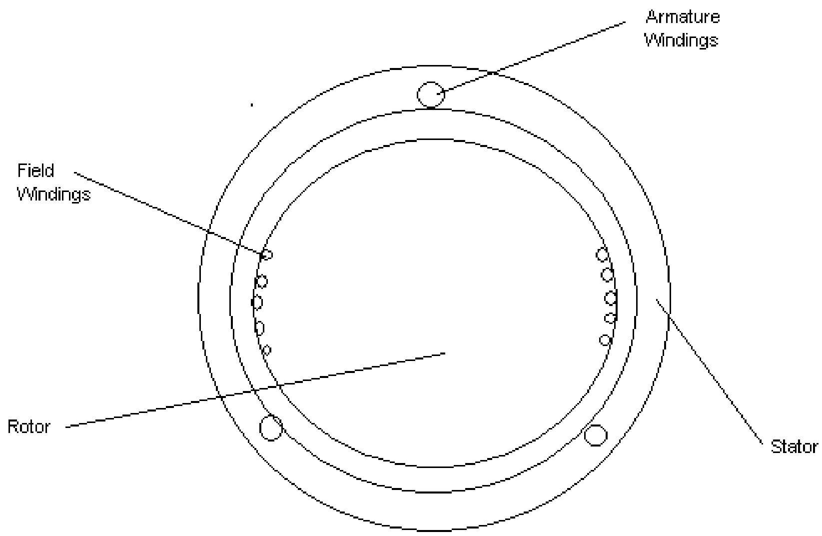
(c)

With $|E_f|$=14,248.8volts, we need to find new angle

$$P = \frac{3|V_t||E_f|}{X_s}\sin\delta \Rightarrow \frac{(50\times10^6)\cdot0.9}{3(17.32\times10^3)(14248)} = 0.060 \Rightarrow \delta = 3.48°$$

$$Q_{out} = \frac{3\cdot(17.32\times10^3)\cdot(14,248)}{0.9}\cos(3.48) - \frac{3(17.32\times10^3)^2}{0.9} = -178.867MVar$$

Solution to problem 4



Solution to problem 8

a)

$$P = \frac{3 \cdot |V_t| \cdot |E_f|}{2} \cdot \sin(\delta) = \frac{3 \cdot |127.02| \cdot |132.98|}{2} \cdot \sin(10.23°) = 4499.8$$

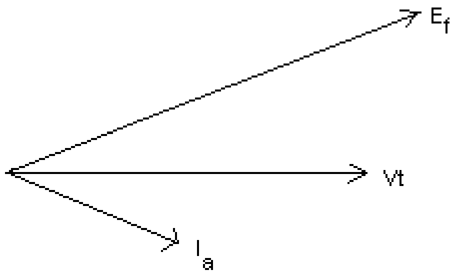
b)

$$Q = \frac{3 \cdot |V_t| \cdot |E_f|}{2} \cdot \cos(\delta) - \frac{3 \cdot |V_t|^2}{2} = \frac{3 \cdot |127.02| \cdot |132.98|}{2} \cdot \cos(10.23°) - \frac{3 \cdot |127.02|^2}{0.95} = 732.8\,\text{var}$$

c)

$$I_a = \frac{E_f - V_t}{jX_s} = \frac{(132.98\angle 10.23°) - (127.02\angle 0°)}{2\angle 90°} = 11.96\angle -9.25°$$

d)



e) lagging

f)

$$Q = \frac{3\cdot|V_t|\cdot|E_f|}{2}\cdot\cos(\delta) - \frac{3\cdot|V_t|^2}{2} = \frac{3\cdot|127.02|\cdot|132.98|}{2}\cdot\cos(\delta) - \frac{3\cdot|127.02|^2}{0.95} = 0$$

$$(25336.7)\cos(\delta) - (24201.1) = 0$$

$$\delta = 17.22^\circ$$

Solution to problem 9

a)

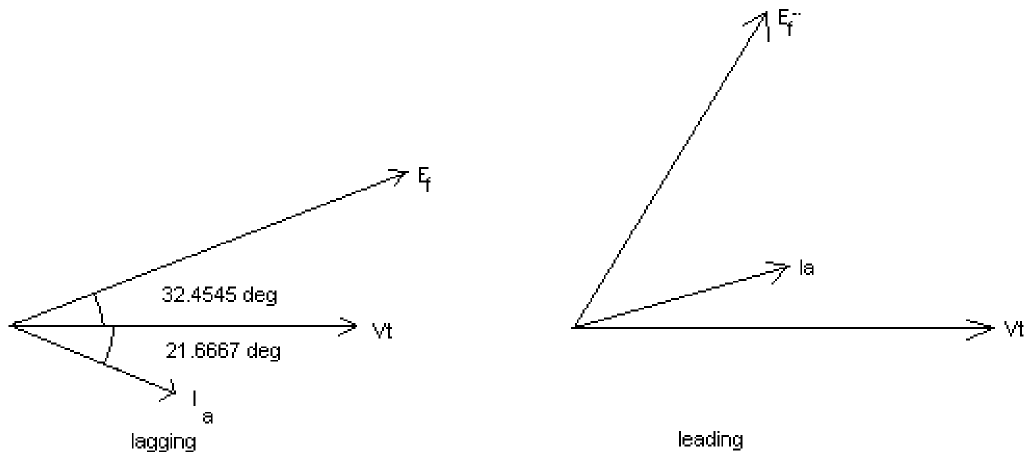
$$Q = 3\left(\frac{E_f V_t}{X_s}\cos\delta - \frac{|V_t|^2}{X_s}\right) = 3\left(\frac{132.98\times\frac{220}{\sqrt{3}}}{2}\cos(10.23) - \frac{\left(\frac{220}{\sqrt{3}}\right)^2}{2}\right) = 733.319 Var$$

b) $$I_p^* = \frac{1000 + j200}{\frac{220}{\sqrt{3}}\angle 0^\circ} = 7.873 + j1.575 = 8.0289\angle 11.31^\circ$$

$$E_f = \frac{220}{\sqrt{3}}\angle 0^\circ + I_p\cdot j2 = \frac{220}{\sqrt{3}}\angle 0^\circ + (7.873 - j1.575)\cdot j2 = 130.166 + j15.75$$
$$= 131.115\angle 6.897^\circ V$$

Solution to problem 10

a)



b) To get the below answers in MW and MVAR, multiply by the 3-phase power base, which is specified in the problem to be 100 MVA.

$$P = \frac{|V_1||E_g|}{X_g}\sin(\delta) = \frac{|1.0||1.5136|}{0.95}\sin(30.4545) = 0.8076$$

$$Q = \frac{|V_1||E_g|}{X_g}\cos(\delta) - \frac{|V_1|^2}{X_g} = \frac{|1.0||1.5136|}{0.95}\cos(30.4545) - \frac{|1.0|^2}{0.95} = 0.3208$$

c)

$$S_{3,2} = VI^* = (0.9713\angle -4.7692)(0.8689\angle -21.6667) = 0.8075 + j0.2453$$

d) P is the same because the transformer has no ‘R’ to cause real power loss. Q is not the same due to the losses in X_x.

Solution to problem 11

(a)

$$V_t = \frac{13.8kV}{\sqrt{3}} = 7967.4Volts$$

$$E_f = V_t + j \cdot X_s \cdot I_a = 7967.4V + (j \cdot 3)\cdot(400\angle -30°) = 7967.4V + 1200\angle 60°$$

$$E_f = 8630.2\angle 6.92°$$

(b) At Q = 0,

$$|E_f| \cdot \cos\delta = V_t \Rightarrow |E_f| = \frac{|V_t|}{\cos\delta} = \frac{7967.4V}{\cos 6.92°} = 8025.9Volts$$