1/ (a) $\bar{S}_1 = 10 \times (0.8 + j0.6)$ kVA $= 8 + j6$ kVA 2

$\bar{S}_2 = P_2 + jQ_2$ where $P_2 = 10$ kW

and $S_2 = \dfrac{P_2}{pf_2} = \dfrac{10}{0.8} = 12.5$ kVA

$\Rightarrow Q_2 = 12.5 \sin\phi = 12.5 \times 0.6 = 7.5$ kvar 3

$\therefore \bar{S}_f = P_1 + P_2 + j(Q_1 + Q_2)$ 5

$= \underline{\underline{18 + j13.5 \text{ kVA}}} = \underline{\underline{22.5 \angle 36.9^\circ \text{ kVA}}}$

(b) $\bar{I}_f = \left(\dfrac{\bar{S}_f}{\bar{V}_f}\right)^* = \dfrac{(18 - j13.5) \times 10^3}{477} = \underline{\underline{37.7 - j28.3 \text{ A}}}$

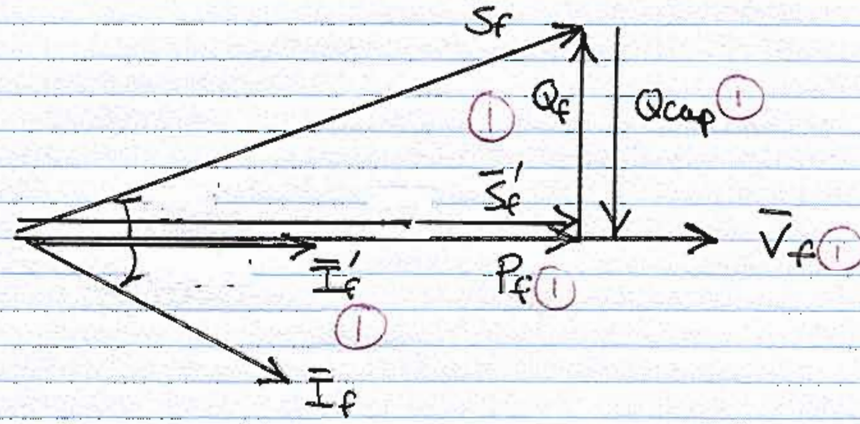
3 $= \underline{\underline{47.2 \angle -36.9^\circ \text{ A}}}$

(c) By inspection, we need $\underline{\underline{Q_{cap} = -13.5 \text{ kvar}}}$ to make $\bar{S}_f' = 18 + j0$ kVA (i.e. pf = 1). 4

(d) $\bar{I}_f' = \left(\dfrac{\bar{S}_f'}{\bar{V}_f}\right)^* = \dfrac{18 \times 10^3}{477} = \underline{\underline{37.7 + j0 \text{ A}}}$ 3

$= \underline{\underline{37.7 \angle 0^\circ \text{ A}}}$

(e)



1 For currents

1 For S's

1 For Q's

2/ (a) $\bar{S}_{load} = 3\, \bar{V}_{phase} \cdot \bar{I}^*_{phase}$ using rated load info:

$$60\times10^3\,(0.9 + j0.44) = 3 \cdot 600 \cdot \left(\frac{\bar{V}_{phase}}{\bar{Z}}\right)^* \quad 5$$

$$\Rightarrow \bar{Z} = \frac{3 \cdot 600 \cdot 600}{60\times10^3\,(0.9 - j0.44)} = \underline{\underline{16.1 + j\,7.9\ \Omega}} \quad 7$$

$$= \underline{\underline{18.0 \angle 26.1^\circ\ \Omega}}$$

(b) In a delta-connected load: $V_{line}^{load} = V_{phase}^{load}$.

Also, the voltage given for the sources is a phase voltage

$$V_{line}^{load} = V_{line}^{source} = \sqrt{3} \cdot V_{phase}^{source}$$

$$= \sqrt{3} \cdot 312 = \underline{\underline{540\ V}} \quad 2$$

$$\therefore V_{phase}^{load} = \underline{\underline{540\ V}} \text{ too} \quad 1$$

(c) The phase current in one of the branches of the load is:

$$\bar{I}_{phase}^{load} = \frac{\bar{V}_{phase}^{load}}{\bar{Z}} = \frac{540 \angle 0^\circ}{18 \angle 26.1^\circ} = 30.0 \angle -26.1^\circ \quad 3$$

$$\therefore I_{line}^{source} = \sqrt{3}\, I_{phase}^{load} \text{ for a } \Delta\text{-load.}$$

$$= \underline{\underline{52.0\ A}} \quad 2$$

(d) Three phase complex power:

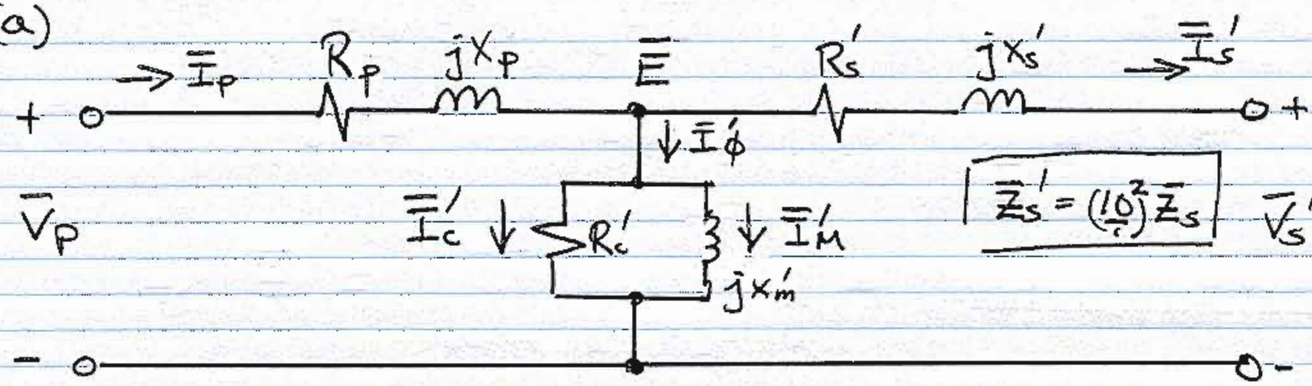
$$\bar{S}_{load} = 3 \cdot \bar{V}_{phase}^{load} \left(\bar{I}_{phase}^{load}\right)^* \quad 2$$

$$= 3 \cdot 540 \angle 0^\circ \cdot 30.0 \angle +26.1^\circ = 48.6 \angle 26.1^\circ$$

$$= \underline{\underline{43.7 + j\,21.2\ \text{kVA}}} \quad 3$$

2/

3/ (a)



Where: $R_c' = 46\ k\Omega$ $\quad X_m' = 23 k\Omega$

$R_s' = 5.8\ \Omega$ $\quad X_s' = 29\Omega.$

① For each

① For proper diagram.

(b) $\bar{I}_s' = \left(\dfrac{\bar{S}_\ell}{\bar{V}_s'}\right)^* = \dfrac{10\times10^3(0.8-j0.6)}{10\times(240)}$

referring to primary

rated secondary voltage

$= 3.3 - j2.5 \quad A = 4.14\angle{-37.1^\circ}\ A$ ②

i. Now to find the primary voltage & current, we may approach the analysis in two ways:

① Easy way: Move the magnetizing branch to the left of the primary impedance to form a cantilever circuit equivalent. Here this is reasonable as $|(R_p + R_s') + j(X_p + X_s')| << |R_c' + jX_m'|$.

↳ Needed if used.

② Harder way: Leave the magnetizing branch as is.

Both methods are acceptable. However, the use of the cantilever equivalent must be explicitly justified.

$$\text{①}\quad \bar{V}_p = \bar{V}_s' + \left[(R_s' + R_p) + j(X_s' + X_p)\right]\bar{I}_s' \qquad \text{③}$$

$$= 2400 + \left[11.6 + j58\right]\left[3.3 - j2.5\right]$$

$$= \underline{2583.3 + j162.4} \ \text{V}$$

$$\text{②}$$

$$= \underline{\underline{2588 \angle 3.6^\circ \ \text{V}}}$$

$$\bar{I}_p = \bar{I}_s' + \frac{\bar{V}_p}{R_c' + jX_m'} \qquad \text{③}$$

$$= 3.3 - j2.5 + \frac{2583.3 + j162.4}{(46 + j23)\times 10^3}$$

$$= 3.3 - j2.5 + \underbrace{0.0463 - j0.0196}_{\bar{I}_\phi'}$$

$$= 3.35 - j2.52 \ \text{A}$$

$$\text{②}$$

$$= \underline{\underline{4.19 \angle -37.0^\circ \ \text{A}}}$$

$$\text{②}\quad \bar{E} = \bar{V}_s' + (R_s' + jX_s')\bar{I}_s'$$

$$= 2400 + (5.8 + j29)(3.3 - j2.5) \qquad \text{②}$$

$$= 2492 + j81.2 \ \text{V} = 2493 \angle 1.9^\circ$$

$$\Rightarrow \bar{I}_c' = \frac{\bar{E}}{R_c'} = \frac{2493\angle 1.9^\circ}{46\times 10^3} = 0.054 \angle 1.9^\circ \ \text{A.}$$

$$\text{②}$$

$$\bar{I}_m' = \frac{\bar{E}}{jX_m'} = \frac{2493\angle 1.9^\circ}{23\times 10^3 \angle 90^\circ} = 0.108 \angle -88.1^\circ \ \text{A}$$

$$\Rightarrow P_{loss,core} = R_c' |\bar{I}_c'|^2 = 46\times 10^3 \times 0.054^2 = 134 \ \text{W}$$

$$\bar{V}_p = \bar{E} + (R_p + jX_p)(\bar{I}_s' + \bar{I}_c' + \bar{I}_m') = \bar{E} + (R_p + jX_p)\bar{I}_p \qquad 1$$

$$= 2492 + j81.2 + (5.8 + j29)(3.3 - j2.5 + 0.054 + j0.002 + 0.004 - j0.108)$$

4

$\Rightarrow \bar{I}_p = \underline{\underline{3.36 - j2.61}}$ A $= \underline{\underline{4.25 \angle -37.8^\circ}}$ A (2)

$\bar{V}_p = \underline{\underline{2587 + j164}}$ V $= \underline{\underline{2592 \angle 3.6^\circ}}$ V (2)

ii. From method (1)

$P_{loss, core} = \dfrac{|\bar{V}_p|^2}{R_c'} = \underline{\underline{146 \text{ W}}}$ (2)

From (exact) method (2)

$P_{loss, core} = \underline{\underline{134 \text{W}}}.$ (2)

iii. From method (1)

$P_{loss, copper} = |\bar{I}_s'|^2 (R_s' + R_p) = \underline{\underline{199 \text{W}}}$ (3)

From (exact) method (2)

$$P_{loss, copper} = |\bar{I}_p|^2 R_p + |\bar{I}_s'|^2 R_s'$$
$$= 105 + 99. = \underline{\underline{204 \text{ W}}}$$ (3)

(c) From method (1)

- $\bar{V}_p$ with or without the mag. branch is the same. $\Rightarrow$ No error. (2)
- $\bar{I}_p$: error $= \left(1 - \dfrac{\bar{I}_{p\,w/o}}{\bar{I}_{p\,with}}\right) \times 100\% = \left(1 - \dfrac{\bar{I}_s'}{\bar{I}_p}\right) \times 100\%$

$$= \left(1 - \frac{4.14}{4.19}\right) \times 100\% = 1.2\%$$ (3)

From method (2)

- $\bar{V}_p$: error $= \left(1 - \dfrac{\bar{V}_{p\,w/o}}{\bar{V}_{p\,with}}\right) \times 100\%$

$$= \left(1 - \frac{\bar{V}_p^{\,\text{method ①}}}{\bar{V}_p^{\,\text{method ②}}}\right) \times 100\%$$

$$= \left(1 - \frac{2588}{2592}\right) \times 100\% = \underline{\underline{0.15\ \%}}$$ ②

• $\bar{I}_p$: error $= \left(1 - \frac{\bar{I}_{p\,w/o}}{\bar{I}_{p\,with}}\right) \times 100\%$

$$= \left(1 - \frac{\bar{I}_s'}{\bar{I}_{p\,with}}\right) \times 100\%$$ ③

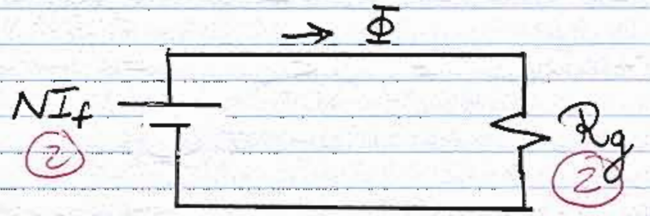
$$= \left(1 - \frac{4.14}{4.25}\right) \times 100\% = \underline{\underline{2.6\ \%}}.$$

//

4/ (a) As $\mu \to \infty$ for the core, its reluctance is negligible. Moreover, the mmf contributed by the air gap winding does not affect the net core flux (because of its orientation).

So,

① Sketch + flux direction



where $NI_f = 1000 I_f$; $R_g = \frac{l_g}{\mu_0 A}$

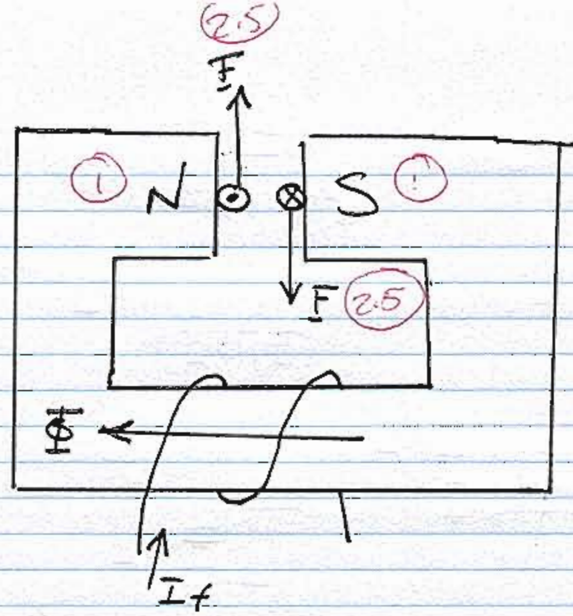
(b) $\boxed{NI_f = R_g \Phi} = R_g \boxed{BA}$ ② ⑤

$$\therefore I_f = \frac{R_g A}{N} B$$

$$= \frac{l_g A}{N \mu_0 A} B$$

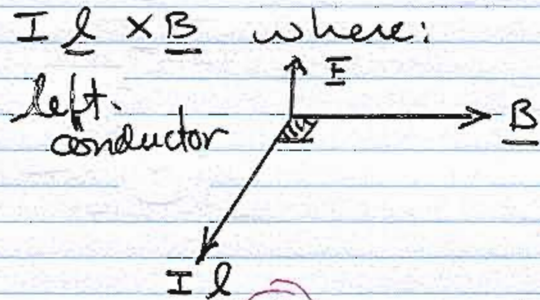
$$= \frac{0.1}{1000 \times 4\pi \times 10^{-7}} \cdot 0.5 = \underline{39.8\ A}$$ ③

(c)



(d) For each conductor:

$\underline{F} = I\underline{\ell} \times \underline{B}$ where:



$\therefore \quad |\underline{F}| = I\ell B = 100 \times 0.1 \times 0.5 = \underline{\underline{5\ N}}$ 2 1

The force is identical in magnitude on each conductor.

(e) See (c).