Dr. Eyad Abu AL-Feilat.

Tutorial (1) Solutions.

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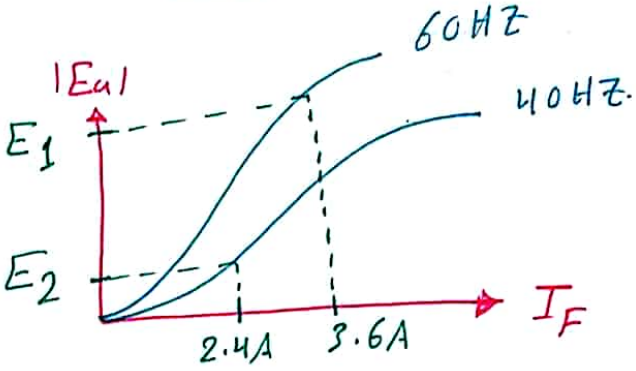
Summer Semester 2017

Q1 a) $|Ea| \propto f . I_F$

$$\frac{Ea_1}{Ea_2} = \frac{f_1 \; I_{F1}}{f_2 \; I_{F2}}$$

$$\Rightarrow Ea_2 = \frac{I_{F2} \; f_2 \; Ea_1}{f_1 \; I_{F1}}$$

$$= \frac{(40)\,(2.4)\,(360)}{(60)\,(3.6)} \Rightarrow \boxed{|Ea_2| = 160 \text{ volt.}}$$



b) $|V_t|_{NL} = |Ea| = 620$ volt.

$f = 60$ HZ.

if $\phi_2 = 0.85\,\phi_1$ & $n_2 = 1.1\,n_1$

$\Rightarrow I_{F2} = 0.85\, I_{F1}$ & $f_2 = 1.1\, f_1$

$\Rightarrow f_2 = 1.1\,(60) = 66$ HZ.

$$|E_2| = \frac{f_2 \; I_{F2} \; E_1}{f_1 \; I_{F1}}$$

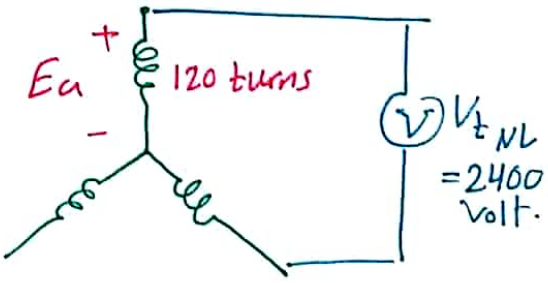
$$= (1.1)\,(0.85)\,(620)$$

$$\Rightarrow \boxed{|E_2| = 580 \text{ volt.}}$$

Q2

$$\Rightarrow n_s = \frac{120}{P} f = \frac{120}{8}(f) = 900$$

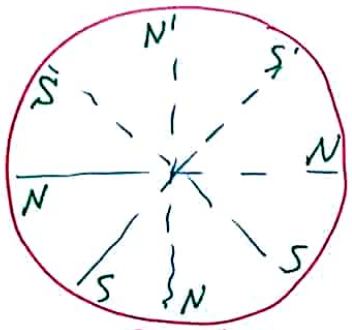
$\Rightarrow \boxed{n_s = 900 \text{ rpm}}$; so $\boxed{f = 60 \text{ Hz.}}$



$$E = 4.44 \, K_w \, f \, N_{ph} \, \phi$$

$$\phi = \frac{2400/\sqrt{3}}{4.44(0.9)(120)(60)}$$

$$\Rightarrow \boxed{\phi = 48.2 \text{ m Wb.}}$$



8-poles.

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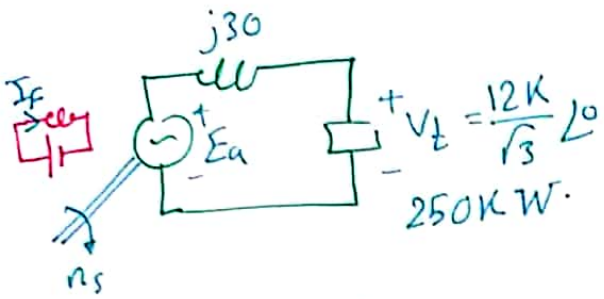
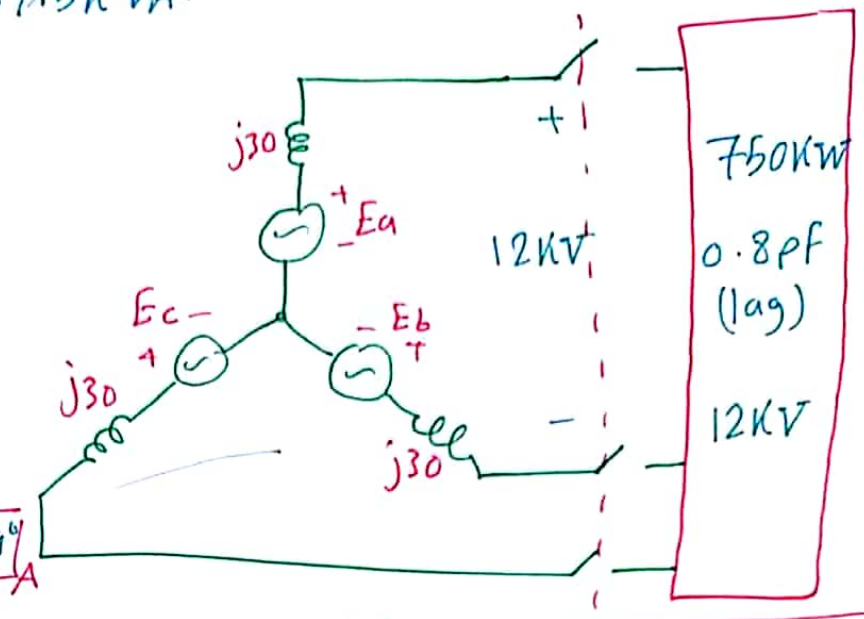
Q3 $|S| = \frac{P}{pf} = \frac{750K}{0.8} = 937.5K\,VA$.

per-phase cct:





$I_a = \frac{937.5K}{\sqrt{3} * 12K} = \boxed{45.1\angle -36.9^\circ}$

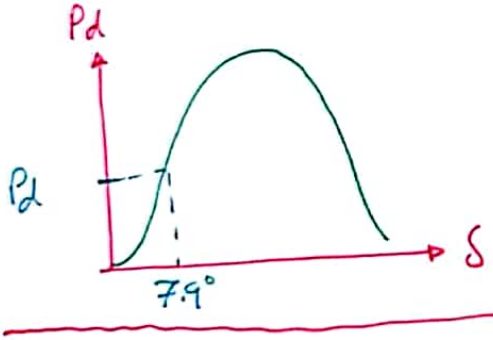
$E_A = V_t + jI_aX_s = \frac{12K}{\sqrt{3}}\angle 0 + j30(45.1\angle -36.9) \Rightarrow$ $\boxed{E_a = 7816\angle 7.9^\circ \text{ volt}.}$

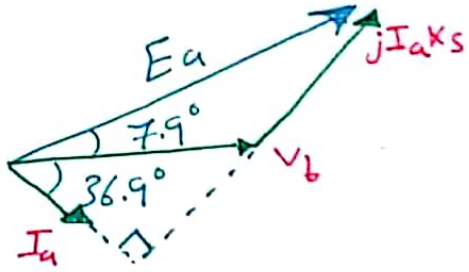
$\boxed{|E_a|_{LL} = 13.5K \text{ volt}.}$

$VR = \frac{V_{nL} - V_{fL}}{V_{fL}} * 100\% = \frac{13.5 - 12}{12} * 100\%$

$\Rightarrow$ $\boxed{VR = 12.5\%}$

* phasor diagram:





Q4

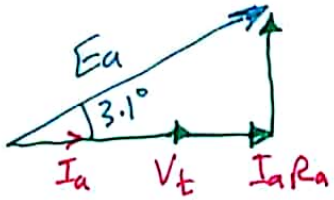
@ pf = 1 :

$I_a = 524.9\angle 0^\circ$ A

$E_a = 6412.7\angle 3.1^\circ$ volt.

$|E_a|_{LL} = 11.1K$ volt.

$\boxed{VR\% = 0.9\%}$



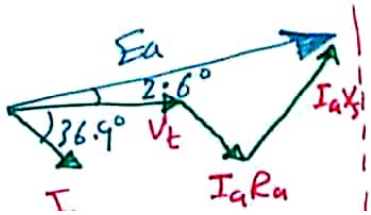
@ 0.8pf lag:

$I_a = 656.1\angle -36.9^\circ$

$E_a = 6670.4\angle 2.6^\circ$ volt.

$|E_a|_{LL} = 11.5K$ volt.

$\boxed{VR\% = 4.55\%}$



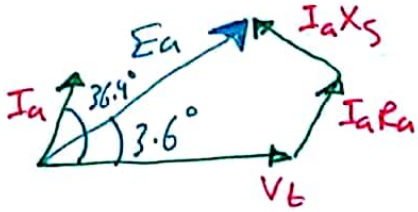
@ 0.8 pf lead:

$I_a = 656.1\angle +36.9^\circ$

$E_a = 6155.4\angle 3.6^\circ$ volt.

$|E_a|_{LL} = 10.7K$ volt.

$\boxed{VR\% = -2.73\%}$



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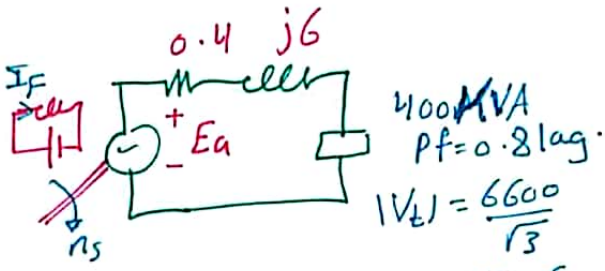
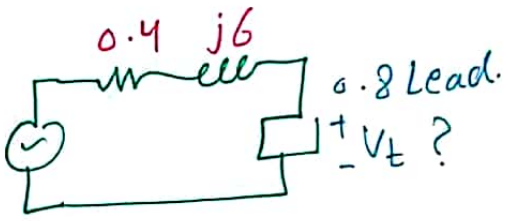
Q5



$$|I_a| = |I_L| = \frac{S_{3\phi}}{\sqrt{3}V_L} = \frac{1200 * 10^3}{\sqrt{3}\ 6600} = 105A.$$

$$E_a = V_t + I_a (R_a + jX_s) = 3810.5\angle 0 + 105\angle -36.9^\circ (0.4 + j6)$$

$$\Rightarrow \boxed{E_a = 4249.4\angle 66^\circ \text{ volt.}} \quad \boxed{|E_a|_{LL} = 7360 \text{ volt.}}$$



$$V_t = E_a\angle\delta - I_a (R_a + jX_s)$$

Two unKnowns.

4249.4 ∠δ°

so use:

$$|E_a|^2 = (V_t\cos\theta + I_a R_a)^2 + (V_t\sin\theta - I_a X_s)^2$$

$$(4249.4)^2 = (0.8V_t + 105 * 0.4)^2 + (V_t * 0.6 - 105 * 6)^2$$

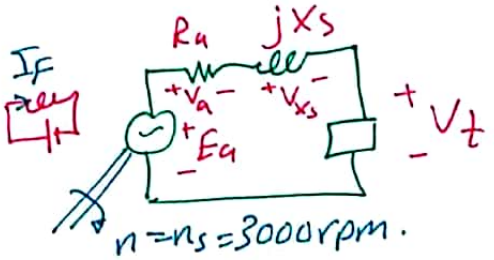
solve: $\Rightarrow$ $\boxed{|V_t| = 4831.2 \text{ volt.}}$ $\boxed{|V_t|_{LL} = 8367.9 \text{ volt.}}$

Q6

o/c Test: $I_F = 125A$, $V_{toc} = 8000V$, $n = n_s$

s/c Test: $I_F = 125A$, $I_{sc} = 800A$, $n = n_s$

@ rated Full-load $\Rightarrow V_{drop} = V_{Ra} = 3\%$ of the rated phase voltage.

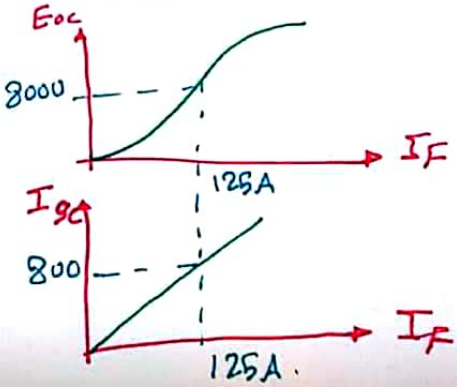


$$|Z_s| = \frac{|E_{oc}|_{ph}}{I_{sc}} = \frac{8000/\sqrt{3}}{800} = 5.7\Omega = \sqrt{R_a^2 + X_s^2}$$

$$I_{a_{FL}} = \frac{6000 * 10^3}{\sqrt{3}(6.6) * 10^3} = 524.8A.$$

$$|V_{Ra}| = R_a I_{a_{FL}} = \frac{3}{100} * \frac{6600}{\sqrt{3}} = 114.3 \text{ volt.}$$

$$R_a = \frac{114.3}{524.8} \Rightarrow \boxed{R_a = 0.22\Omega} \Rightarrow \boxed{X_s = 5.69\Omega}$$



$$E_a = V_t + I_a Z_s = \frac{6600}{\sqrt{3}} + 524.8\angle -36.9 (0.22 + j5.69)$$

$$\boxed{E_a = 6148\angle 22.1^\circ \text{ volt.}} \quad \boxed{|E_a|_{LL} = 10650 \text{ volt.}}$$

$$VR = \frac{10650 - 6600}{6600} * 100\%$$

$$\boxed{VR\% = 61\%}$$

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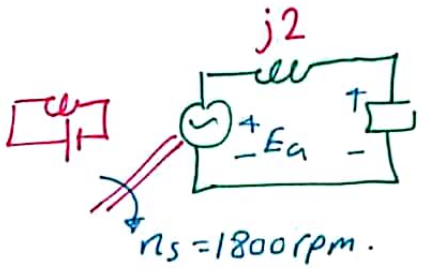
Q7

$E_a = V_t + j I_a X_s$

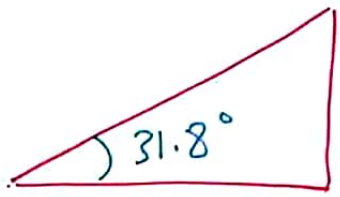
$\Rightarrow I_a = \frac{6000}{\sqrt{3}(208)*0.85} = 19.6\,A.$



$E_a = 120 + 19.6\angle -31.8^\circ\,(2\angle 90)$

$E_a = 144.6\angle 13.3^\circ$ volt.

$|E_a|_{LL} = 250.5$ volt.



$Q = P\tan\theta = 3.7\,KVAR.$

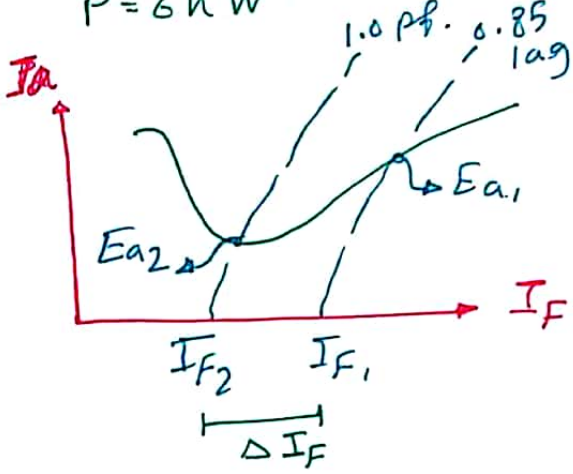
$P = 6\,KW.$

@ n=constant. $E_a \propto I_F$

$E_{a_2}\big|_{1.0pf} = 120\angle 0 + 16.7\,(2\angle 90)$

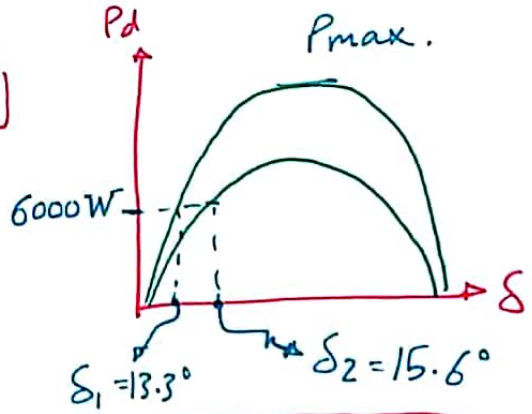
$\Rightarrow E_{a_2} = 124.6\angle 15.6^\circ$

$I_a\big|_{1.0pf} = \frac{6000}{\sqrt{3}(208)(1)} = 16.7\,A.$



$\frac{\Delta I_F}{I_{F_1}} = \frac{I_{F_2} - I_{F_1}}{I_{F_1}} = \frac{E_{a_2} - E_{a_1}}{E_{a_1}}$

$= \frac{124.6 - 144.6}{144.6} * 100\% = -13.8\%$



Q8

find:

a) E_a at rated conditions, pf = 0.8 lag. ?

b) $I_{F_2} = 1.2\,I_{F_1} \Rightarrow |E_{a_2}| = 1.2\,|E_{a_1}|$, find I_{a_2}, pf_2, Q_2 ?

c) $I_{F_3} = I_{F_1}$, find $P_{max} = 3\frac{V_t E_a}{X_s}$, pf_3, I_{a_3}, Q_3 ?

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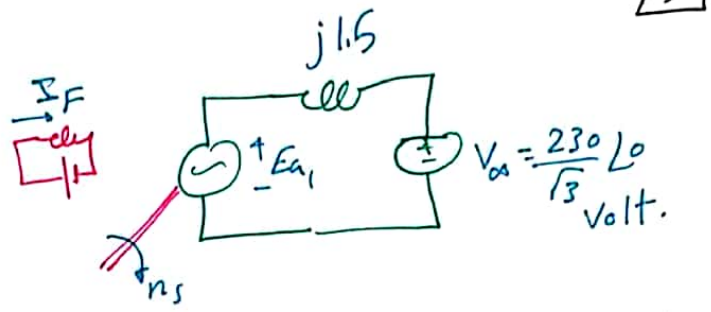
1)

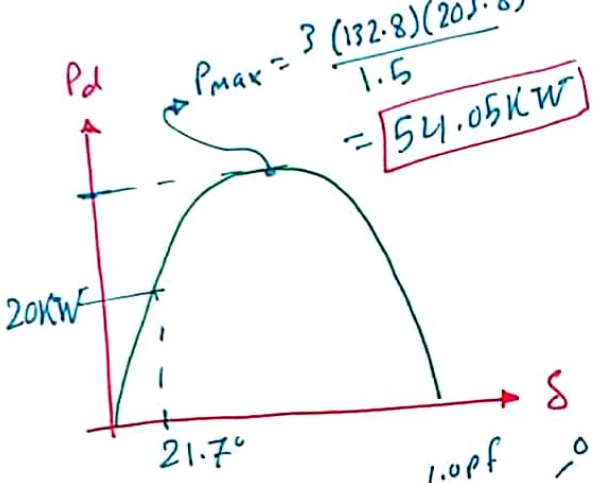
a) $E_a = V_t + jI_{a_1}X_s$

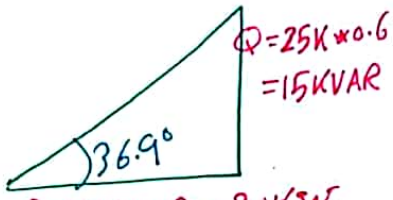


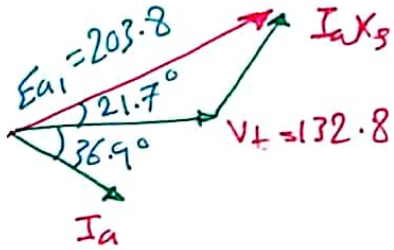
$|I_{a_1}|_{FL} = \frac{S_{3\phi}}{\sqrt{3}V_L} = 62.8A.$

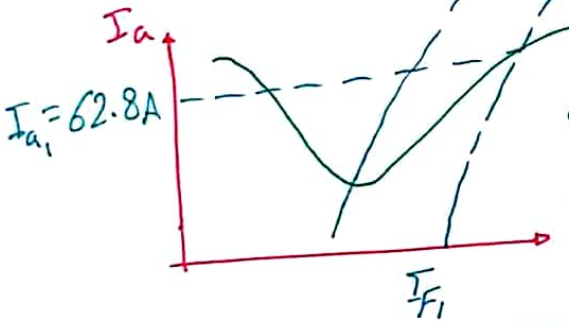
$\Rightarrow$ **$I_{a_1} = 62.8 \angle -36.9^\circ$**

$\Rightarrow E_{a_1} = 132.8 \angle 0^\circ + 62.8 \angle -36.9^\circ * (1.5 \angle 90) \Rightarrow$ **$E_{a_1} = 203.8 \angle 21.7^\circ$**, **$|E_{a_1}|_{LL} = 353$ volt.**









$P_d = \frac{3V_t E_a \sin\delta}{X_s}$

$P_d = P_{out} = 3V_t I_a \cos\theta$

b) $E_{a_2} = 1.2E_{a_1} \Rightarrow$ **$E_{a_2} = 244.6$ volt.**

$P_{d_1} = P_{d_2} = 20KW = \frac{3(132.8)(244.6)}{1.5}\sin\delta_2$

$\Rightarrow$ **$\delta_2 = 17.9^\circ$**

$\Rightarrow E_a = 244.6 \angle 17.9^\circ$

for I_{a_2}:

$I_{a_2} = \frac{E_{a_2} - V_t}{jX_s} \Rightarrow$ **$I_{a_2} = 83.4 \angle -53.1^\circ$ A.**

for Q:

method(1):

$Q_2 = 3V_t I_{a_2} \sin\theta = P_2 \tan\theta_2$

$=$ **26.5K VAR.**

method(2):

$Q_2 = \frac{3V_t}{X_s}[E_a \cos\delta - V_t]$

$=$ **26.5K VAR.**

$pf = \cos(53.1^\circ) = 0.6$ lagging.

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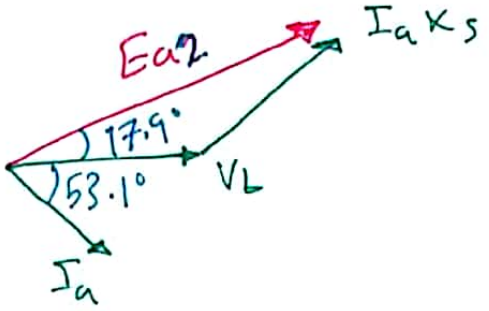
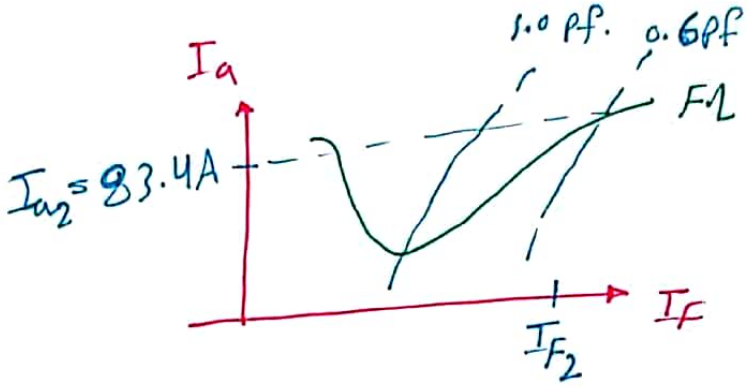
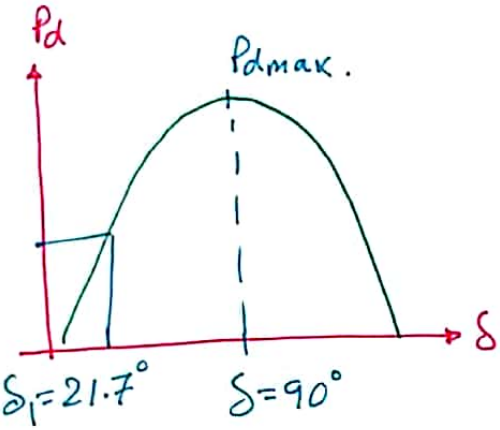




c)



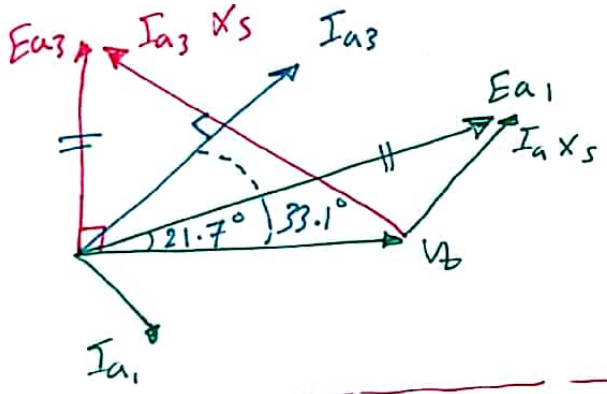
$|E_{a3}| = |E_{a1}| = 203.8$ volt.

$\Rightarrow \boxed{E_{a3} = 203.8 \angle 90^\circ}$

$I_{a3} = \dfrac{E_{a3} - V_t}{jX_s} = \dfrac{203.8\angle 90 - 132.8\angle 0}{1.5\angle 90}$

$\Rightarrow \boxed{I_{a3} = 162.2 \angle 33.1^\circ A}$

$pf_3 = \cos 33.1 = 0.838$ leading.



$Q_3 = 3 V_t E_{a3} \sin\theta$

$\boxed{Q_3 = -44.3 \text{ KVAR}}$

-35.27 KVAR

under excited
absorbing Q.

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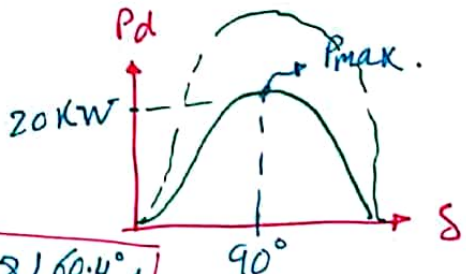
* additional: if I_f is reduced without using steady state stability Limit $\Rightarrow$ Find I_{a4}, pf_4, Q_4 ?



$P_{max} = 20KW = \dfrac{3(132.8)E_{a4}}{1.5} \Rightarrow \boxed{E_{a4} = 75.3\angle 90^\circ \text{ volt.}}$

$I_{a4} = \dfrac{E_{a4} - V_t}{jX_s} = \dfrac{(75.3\angle 90) - (132.8\angle 0)}{j1.5} \Rightarrow \boxed{I_{a4} = 101.8\angle 60.4^\circ A}$

$pf_4 = \cos(60.4) \Rightarrow \boxed{pf = 0.494}$ leading.

· for Q_4:

$Q_4 = 3 V_t E_{a4} \sin\theta = 3(132.8)(101.8)\sin(-60.4)$

$\Rightarrow \boxed{Q_4 = -35.3K \text{ VAR}.}$

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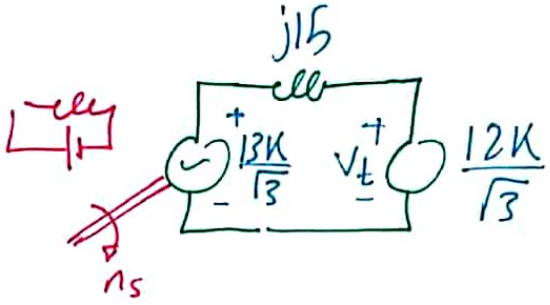
Question (9):

a) $P_{max}\Big|_{\delta=90^\circ} = \frac{3V_t E_a}{X_s} = \frac{V_{LL} E_{LL}}{X_s}$



$\Rightarrow P_{max} = \frac{12 \times 13 \times 10^6}{15} = \boxed{10.4\,MW}$

$\tau_{dmax} = \frac{P_{max}}{\omega_s} = \frac{60}{2\pi} \frac{P_{max}}{n_s} \Rightarrow \boxed{\tau_{dmax} = 55.1\,KN.m}$.

1800 rpm.

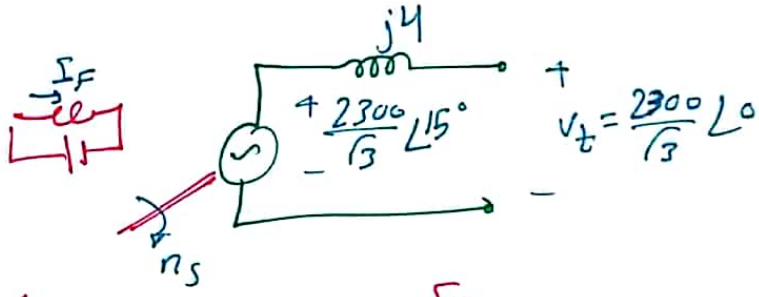
b) $I_a = \frac{E_a - V_t}{jX_s} = \frac{\frac{13K}{\sqrt3}\angle 90^\circ - \frac{12K}{\sqrt3}\angle 0^\circ}{15\angle 90} \Rightarrow \boxed{I_a = 680.9\angle 42.7^\circ A.}$

$pf = \cos(42.7) = 0.7349$ Leading.

Q10

$I_a = \frac{\frac{2300}{\sqrt3}\angle 15 - \frac{2300}{\sqrt3}\angle 0}{4\angle 90}$

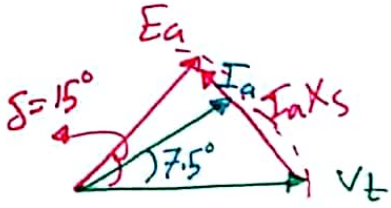
$\Rightarrow \boxed{I_a = 86.6\angle 7.5^\circ A.}$



pf: $pf = \cos(7.5) = \boxed{0.991}$ Leading.

$P_{out} = \frac{3V_t E_a}{X_s}\sin\delta = 3V_t I_a \cos\theta$

$Q_{out} = \frac{3V_t}{X_s}[E_a\cos\delta - V_t] = 3V_t I_a \sin\theta$



solving $\Rightarrow$ $\boxed{P_{out} = 1.323\,MW.}$ $\boxed{Q_{out} = -45.03\,KVAR.}$

$\Rightarrow I_a\Big|_{\delta=90^\circ} = \frac{\frac{2300}{\sqrt3}\angle 90^\circ - \frac{2300}{\sqrt3}\angle 0^\circ}{4\angle 90}$

$\boxed{I_a = 469.5\angle 45^\circ A.}$

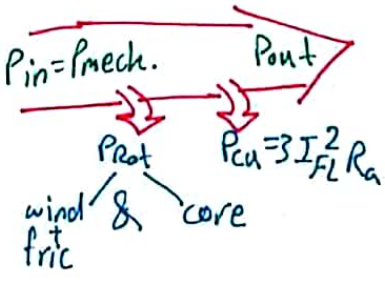
Q11

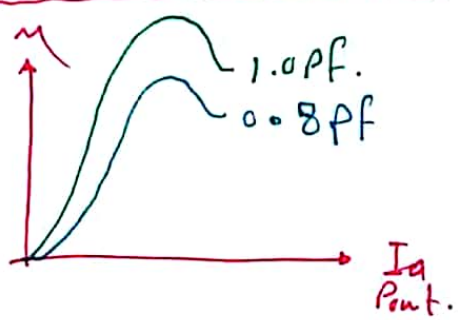
$I_{aFL} = \frac{10 \times 10^6}{\sqrt3 \times 12 \times 10^3} = 481.1\,A.$

$P_{out} = S_{rated} \times pf = \boxed{8\,MW}$

$P_{in} = P_{out} + \sum P_{losses} = P_{out} + P_{cu} + P_{rot}$

$\eta = \frac{P_{out}}{P_{in}} \times 100\% \Rightarrow \boxed{\eta = 97.6\%}$





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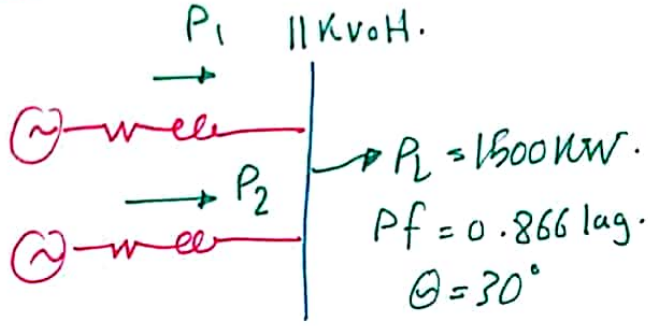
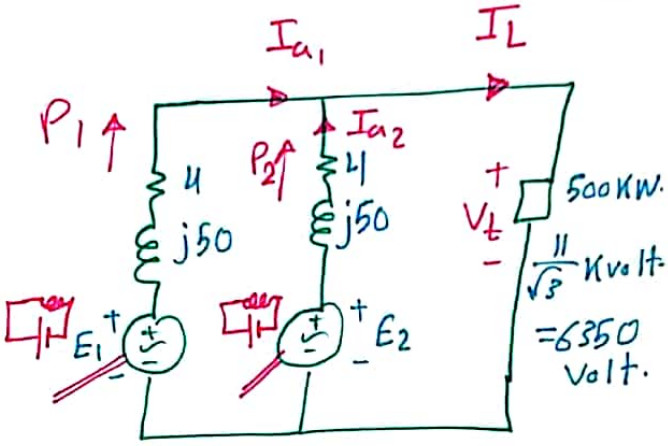
Question (12):





* since the share the load equally:

$$P_1 = P_2 = \frac{P_L}{2}$$

$$|I_L| = \frac{S_L}{\sqrt{3}V_{LL}} = \frac{P_L/Pf}{\sqrt{3}V_{LL}} = \frac{1500K/0.866}{\sqrt{3}*11K} \Rightarrow |I_L| = 90.9A.$$

$$\Rightarrow \boxed{I_L = 90.9\angle -30^\circ} A.$$

$$I_L = I_1 + I_2$$

$$P_1 = 3V_t I_1 \cos\theta_1 = \sqrt{3}V_L I_1 \cos\theta_1 = 750KW$$

$$\Rightarrow \boxed{\cos\theta_1 = Pf_1 = 0.7873} \text{ Lagging.} \Rightarrow \theta_1 = 38.1^\circ$$

$$I_2 = 90.9\angle -30^\circ - 50\angle -38.1^\circ \Rightarrow \boxed{I_2 = 42\angle -20.3^\circ A.}$$

$$Pf_2 = \cos(20.3) = \boxed{0.937} \text{ Lagging.}$$

* we can check the answer:

$$I_1\cos\theta_1 \stackrel{?}{=} I_2\cos\theta_2$$

$$50 * 0.787 \stackrel{?}{=} 42 * 0.937 \quad \text{(yes, equal each other).}$$

Now for VR:

$$E_{a1} = V_t + I_{a1}(R_a + jX_s) = 6350\angle 0 + 50\angle -38.1^\circ(4+j50)$$

$$\Rightarrow \boxed{E_{a1} = 8258.5\angle 12.9^\circ \text{ volt.}}$$

$$VR = \frac{8258.5 - 6350}{6350} * 100\% \Rightarrow \boxed{VR\% = 30.1\%}$$

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