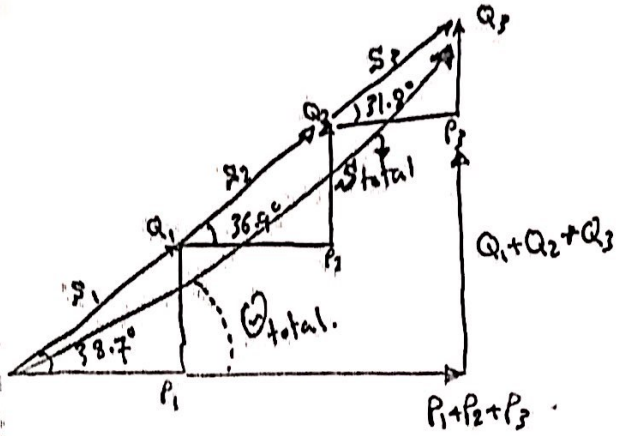



$$S_{tot.} = S_1 + S_2 + S_3$$

$$= (P_1 + jQ_1) + (P_2 + jQ_2) + (P_3 + jQ_3)$$

$$\boxed{S_{tot.} = (P_1 + P_2 + P_3) + j(Q_1 + Q_2 + Q_3)}$$

$$pf_{total} = \cos\tan^{-1}\frac{Q_{tot}}{P_{tot.}}$$

$Q_1 = 80.2$ KVAR.
$Q_2 = 150$ KVAR
$Q_3 = 93$ KVAR.

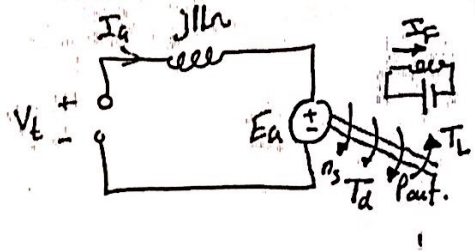
$\Rightarrow$ $P_{tot} = 450$ KW
$Q_{tot} = 323.2$ KVAR.

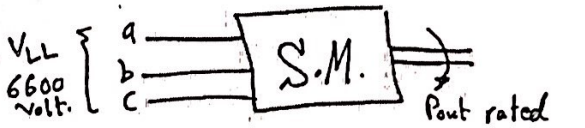
※ Tutorial (2) Solutions:

$\boxed{1\ hp = 746\ W.}$

**Q1**

Equivalent cct:




$$S_{3\phi} = \frac{P_{3\phi in}}{pf}$$

$$\Rightarrow P_{3\phi in} = \frac{Pout_{FL}}{\eta} = \frac{3000 * 746}{0.746}$$

$\boxed{P_{3\phi in} = 3\ MW.}$

$$\Rightarrow S_{3\phi} = \frac{0.3M}{0.8} \Rightarrow \boxed{S_{3\phi} = 3.75\ MVA.}$$

kVA

$S_{3\phi} = 3V_\phi I_\phi = \sqrt{3} V_L I_L$

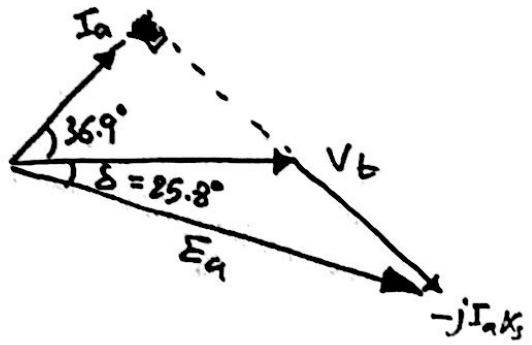
$S_\phi = V_{ph} \cdot I_{ph} = 1.25\ MVA$ kVA

in Y-con. $|I_L| = |I_{ph}|$.

$$|I_L| = \frac{S_{3\phi}}{\sqrt{3} V_L} = \frac{3.75M}{\sqrt{3} * 6600} = |I_{ph}| = 328$$

So $\boxed{I_a = 328\ \angle -36.87°\ A}$ $\Rightarrow$

⇒ *phasor diagram:




$E_a = \frac{6600}{\sqrt{3}} \angle 0 - 328 \angle 36.9° \times 11 \angle 90°$

$E_{aph.} = 6636.8 \angle -25.8°$ volt.

$|E_a|_{LL} = 11493.7$ volt.

$E_{aph} = 4037.3 \angle -4.1°$

$|E_{a_{LL}}| = 6992$ V over excited supply

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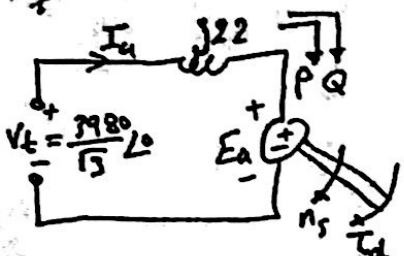
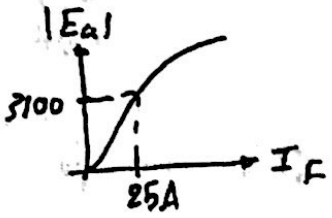
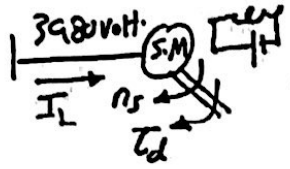
**Q2** P=4, f=60Hz, Y-conn, $|V_t|_{LL} = 3980$ volt.

Equ. cct:




$n_s = 1800$ rpm.




$E_{a_{LL}} = 3100$ volt.

$I_F = 25$ A.

a) $I_{ph} = I_L = \frac{V_t - E_a}{jX_s} = \frac{\frac{3980}{\sqrt{3}} \angle 0 - \frac{3100}{\sqrt{3}} \angle -30°}{22 \angle 90°}$

⇒ $\boxed{I_L = 53 \angle -40° \text{ A}}$.

b) $pf = \cos(40°) \Rightarrow \boxed{pf = 0.766}$ lagging.

c) $\omega_s = \frac{2\pi n_s}{60} = 188.5$ rad/sec.

$P_d = P_{in} = \sqrt{3} I_L V_L \cos\theta = \frac{3 E_a V_t}{X_s} \sin\delta$

$R_a = 0$ $\quad P_d = 280.4$ KW.

$\tau_d = \frac{P_d}{\omega_s} = \frac{280.4 \times 10^3}{188.5} \Rightarrow \boxed{\tau_d = 1487 \text{ N.m.}}$

*phasor diagram: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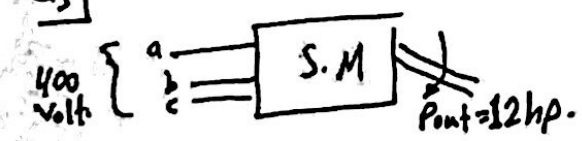
**Q3**



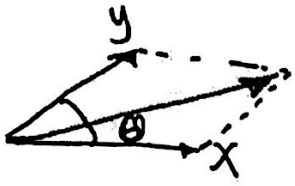

$\sum P_{loss} = 1200$ W.

$P_{in} = P_{out} + \sum \text{losses} = 12 \times 746 + 1200$

$= 10152$ W.

$\eta = \frac{P_{out}}{P_{in}} = \frac{12 \times 467}{10162} \Rightarrow \boxed{\eta = 88\%}$

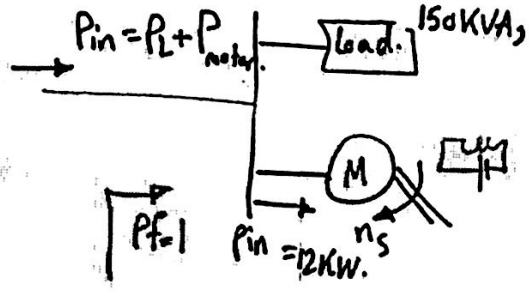
*Remember the following relation:



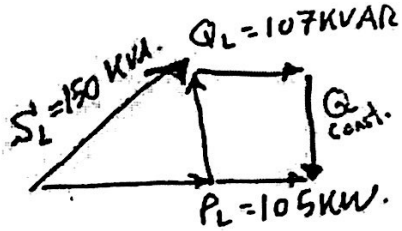

$$|x+y| = \sqrt{x^2+y^2+2xy\cos\theta}$$

* * *

**Q4**




over excited:
⇒ Leading Pf.
& $|E_a| > V_t$.




$Q_m = Q_L = 107\,KVAR.$

$|S_m| = \sqrt{P_m^2 + Q_m^2} = \sqrt{12^2+107^2} \Rightarrow \underline{|S_m| = 107.6\,KVA}.$

$pf_m = \cos\left[\tan^{-1}\frac{Q_m}{P_m}\right] = \cos\left[\tan^{-1}\frac{107}{12}\right] \Rightarrow \boxed{Pf = 0.111}$ leading.

$P_{in_m} = \frac{100 \times 746}{0.9} = \underline{82.9\,KW}.$

$S_m = \sqrt{(82.9)^2+(107)^2} = \underline{135.4\,KVA}.$

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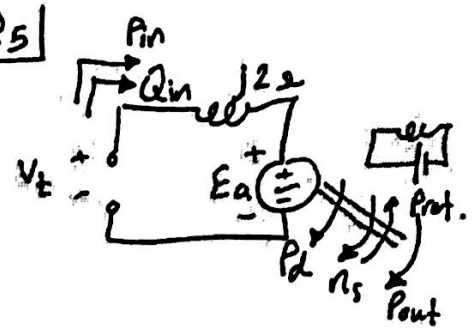
**Q5**




I. a) $P_{in} = \sqrt{3}\,V_t I_L \cos\theta$

$\Rightarrow 400K = \sqrt{3} \times 6.6K \times I_L \times 0.8$

$\Rightarrow |I_L| = |I_a| = 43.7A$

so $\boxed{I_a = 43.7\angle -36.9^\circ\,A}$.

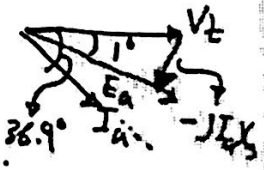
b) $E_a = V_t - j I_a X_s$

$= \frac{6600}{\sqrt{3}}\angle 0 - 43.7\angle -36.9^\circ \times 2\angle 90^\circ$

$\Rightarrow \boxed{E_a = 3758.6\angle -1^\circ \text{ volt.}}$

$\boxed{|E_a|_{LL} = 6510 \text{ volt.}}$

c) $T_{max} = \frac{P_{dmax}}{\omega_s}$




$P_{dmax} = \frac{3V_t E_a}{X_s} = \underline{21.4\,MW}.$

$T_{dmax} = \frac{9.55\,P_{dmax}}{n_s} = \frac{9.55 \times 21.4 \times 10^6}{1000}$

$\boxed{T_{dmax} = 205.2\,KN.m.}$ ⇒

II. $I_{f_2} = 1.25\, I_{f_1} \Rightarrow E_{a_2} = 1.25\, E_{a_1} = 1.25 * 3758.6$

$$\boxed{E_{a_2} = 4698.25 \text{ volt}}$$

a) $P_{d_1} = P_{d_2}$

$$\frac{3V_t E_{a1}}{X_s} \sin\delta_1 = \frac{3V_t E_{a2}}{X_s} \sin\delta_2 \Rightarrow E_{a_1} \sin\delta_1 = 1.25 E_{a_1} \sin\delta_2$$

$$\sin\delta_2 = \frac{\sin\delta_1}{1.25} = \frac{\sin(1)}{1.25} \Rightarrow \boxed{\delta_2 = 0.8^\circ}$$

b) $$I_{a_2} = \frac{V_t - E_{a_2}}{jX_s} = \frac{3810.5\angle 0 - 4698.25\angle -0.8}{2\angle 90^\circ} \Rightarrow \boxed{I_{a_2} = 445\angle +85.8^\circ \text{ A}}$$

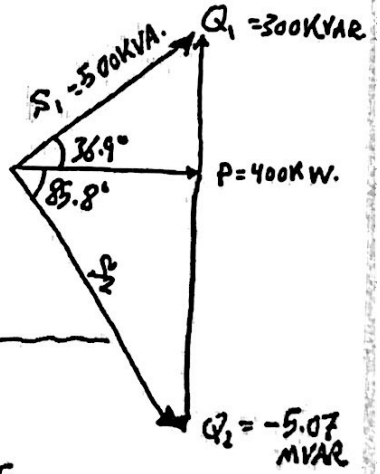
c) $Pf = \cos\theta_2 = \cos(85.8) \Rightarrow \boxed{Pf = 0.073}$ leading.

d) $P_{max_2} = 1.25\, P_{max_1} = 1.25 \times 21.4M \Rightarrow \boxed{P_{max_2} = 26.7MW.}$

$P_1 = 400KW.$

$$Q_1 = \frac{P}{Pf} \sin\theta = \frac{400K}{0.8} \times 0.6 = 300KVAR.$$

$$Q_2 = \sqrt{3}\, I_L V_L \sin\theta_2 = \sqrt{3}\,(6600)\,(445)\sin(-85.8)$$
$$= -5.07MVAR.$$

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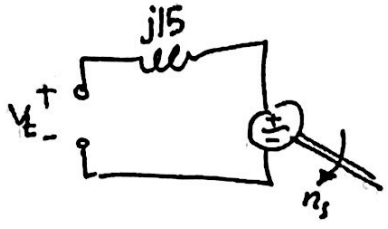
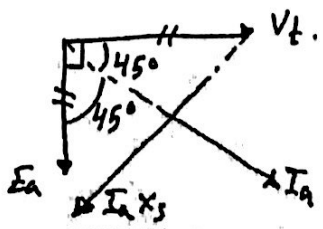
Q6| 3.3KV, 50HZ, P=2, Y-con., $X_s = 15\Omega$

$|E_a| = |V_t| = 3.3K$ volt.

a) $$P_{max}\Big|_{\delta=90^\circ} = \frac{3.3K * 3.3K}{15} = \underline{726KW.}$$

$$\tau_{max} = \frac{P_{max}}{\omega_s} = \frac{726K}{314} = \underline{2310.9 \text{ N.m.}}$$



b) $I_a = \frac{V_t - E_a}{jX_s} = \frac{\frac{3300}{\sqrt{3}}\angle 0 - \frac{3300}{\sqrt{3}}\angle -90^\circ}{15\angle 90^\circ} \Rightarrow \boxed{I_a = 179.6\angle -45^\circ\ A.}$

$Pf = \cos\theta \Rightarrow Pf = \cos 46 \Rightarrow \boxed{Pf = 0.707}$ lagging.

$Q = \sqrt{3} V_L I_L \sin\theta$ (absorbed). $= \sqrt{3} * 3.3K * 179.6 * 0.707$

$\Rightarrow \boxed{Q = 726\ KVAR.}$

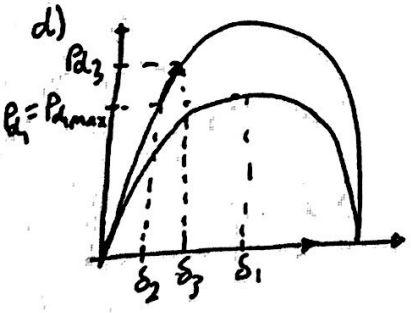
c) $E_{a_2} = 1.2\, E_{a_1} = 1.2 * \frac{3300}{\sqrt{3}} \Rightarrow E_{a_2} = 2286$ volt.

$\delta_2 = \sin^{-1}\left(\frac{\sin\delta_1}{1.2}\right) = \sin^{-1}\left(\frac{\sin 90}{1.2}\right) \Rightarrow \boxed{\delta_2 = 56.4^\circ}$

$I_{a_2} = \frac{\frac{3300}{\sqrt{3}}\angle 0 - 2286\angle -56.4}{15\angle 90^\circ} \Rightarrow \boxed{I_a = 134\angle -18.6^\circ\ A.}$ $\boxed{Pf = 0.948}$ lagging

$Q_2 = \sqrt{3} * 3300 * 134 \sin(18.6) \Rightarrow \boxed{Q_2 = 244.3\ KVAR.}$

d)




$P_{d_3} = 1.1\, P_{d_{1\,max}} = 1.1 * 726K = \boxed{798.6KW.}$

$P_{d_3} = 3\frac{V_t E_{a_3}}{X_s}\sin\delta_3$

$798.6 * 10^3 = 3 * \frac{\frac{3300}{\sqrt{3}} * 2286}{15}\sin\delta_3$

$\Rightarrow \boxed{\delta_3 = 66.5^\circ}$

$\boxed{I_a = 154.7\angle -25.4^\circ A}$, $\boxed{Pf = 0.903}$ lagging., $\boxed{Q_3 = 379.3\ KVAR.}$

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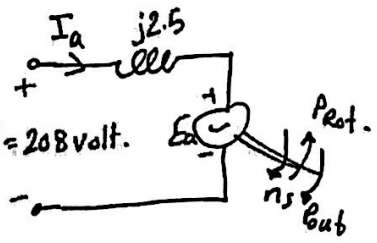
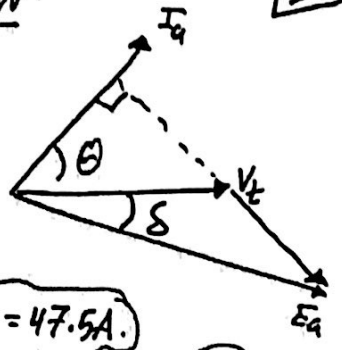
**Q7** $V_t = 208$ volt, 45KVA.
0.8 pf lead.
Δ-connected.
$f = 60$ HZ & $X_s = 2.5\Omega$
$P_{F\&W} = 1.5KW$, $P_{core} = 1$ KW.
$P_{out} = 15$ hp.



$\Rightarrow P_{in} = P_d = P_{Rot} + P_{out} = (1.5+1+11.2)K = 13.7KW.$

$P_{out} = 746 * 15$




$|I_d| = \frac{P_{in}}{3 V_{ph} \cos\theta} = \frac{13.7*10^3}{3*208*0.8} = 27.4A.$

$\Rightarrow \boxed{I_a = 27.4 \angle 36.9^\circ A} \Rightarrow |I_L| = \sqrt{3}|I_{ph}| \Rightarrow \boxed{|I_L| = 47.5A.}$

$P_{in_2} = P_{out_2} + P_{Rot} = 22.4 + 2.5 = 24.9 KW.$

$\boxed{E_a = 255 \angle -12.4^\circ \text{ volt.}}$

$P_{in_2} = \frac{3 V_t E_{a_2}}{X_s} \sin\delta_2 \Rightarrow I_{a_2} = \frac{V_t - E_a \angle -\delta^\circ}{jX_s}$

$\Rightarrow \boxed{\delta_2 = 23^\circ}$

$\Rightarrow \boxed{I_{a_2} = 41.3 \angle 15^\circ A}$, $\boxed{|I_L| = 71.5A}$

$\boxed{pf = 0.966 \text{ leading.}}$

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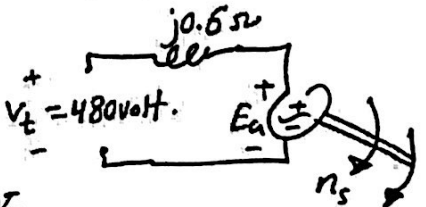
**Q8**




a) $n_s = \frac{120}{p} * f = \frac{120}{8} * 60 \Rightarrow \boxed{n_s = 900 rpm.}$

b) $P_{in} - P_{out} = 400 * 746 \Rightarrow \underline{P_{in} = 298.4KW.}$

$P_{in} = 3 V_t I_a pf \Rightarrow I_a = \frac{298.4K}{3*480*0.8} \Rightarrow \boxed{I_a = 259 \angle -36.9^\circ} A.$

$E_a = V_t - I_a (jX_s) = 480\angle 0^\circ - (259\angle -36.9^\circ) * 0.6j \Rightarrow \boxed{E_a = 406.2 \angle -17.8^\circ \text{ volt.}}$

c) $\boxed{\delta = 17.8^\circ}$ $\tau = \frac{P_{in}}{\omega_s} = \frac{298.4K}{2\pi * \frac{900}{60}} \Rightarrow \boxed{\tau \simeq 3166 N.m}$

$P_{in_{max}} = \frac{3 V_t E_a}{X_s} = \frac{3*480*406.2}{0.6} = 974.88 KW.$

$\tau_{max} = \frac{P_{max}}{\omega_s} \Rightarrow \boxed{\tau_{max} \simeq 10344 N.m.}$ $\tau$ is $\underline{30.6\%}$ of $\tau_{max}$.

d) $E_{a_2} = 1.3 E_{a_1} \Rightarrow \boxed{|E_{a_2}| = 528 \text{ volt.}}$

$\sin\delta_2 = \frac{\sin\delta_1}{1.3} = \frac{\sin 17.8}{1.3} \Rightarrow \boxed{\delta_2 = 13.6^\circ}$

$I_a = \frac{V_t - E_a \angle -\delta}{jX_s} \Rightarrow \boxed{I_a = 214.2 \angle 15^\circ A.}$ $\boxed{pf = 0.966 \text{ leading}}$

$\Rightarrow$

* * *