Exam #1 SOLUTION SPRING 1990

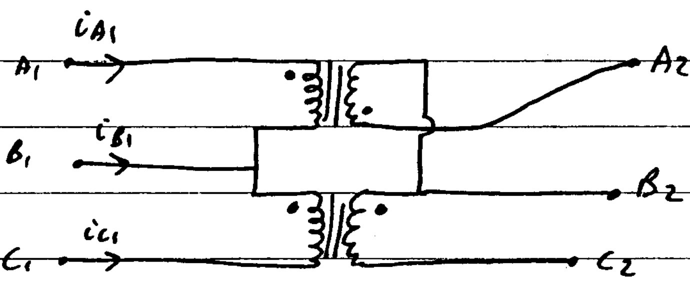
#1 $P_{wm} = |\bar{V}_{AB}||\bar{I}_c|\cos(\measuredangle\bar{V}_{AB} - \measuredangle\bar{I}_c)$ For ABC seq., if $\measuredangle\bar{V}_{AB} = 30°$, then $\measuredangle\bar{I}_c = 120° - \phi$ (ϕ = power factor angle)

Since $\bar{S}_{3\phi} = \sqrt{3}V_{\ell\ell}I_\ell\underline{|\phi} = 1500 + j1500$, $V_{\ell\ell}I_\ell = \frac{1}{\sqrt{3}}1500\sqrt{2}$ and $\phi = 45°$

$P_{wm} = V_{\ell\ell}I_\ell\cos(30° - (120° - \phi)) = \frac{1}{\sqrt{3}}1500\sqrt{2}\cos(30° - 75°) = \underline{866\ w}$

#2

(a)



For $v_{AB} = V\cos(\omega t + 30°)$
$v_{BC} = V\cos(\omega t - 90°)$
the two transformer exciting currents with saturation are:

(b) $\underline{i_{A_1} = I_1\cos(\omega t + \theta) + I_3\cos(3\omega t + \gamma)}$

$\underline{i_{C_1} = -I_1\cos(\omega t - 120° + \theta) - I_3\cos(3\omega t + 360° + \gamma)}$

and $i_{B_1} = -(i_{A_1} + i_{C_1}) = -(I_1\cos(\omega t + \theta) - I_1\cos(\omega t - 120 + \theta)) = \underline{\sqrt{3}I_1\cos(\omega t - 150° + \theta)}$

#3

$|\bar{S}_{IN_{3\phi}}| = \sqrt{3}\times 208\times 8 = 2880\,VA$

At no load, $|\bar{S}_{IN_{3\phi}}| \approx Q_{IN_{3\phi}}$ ($P \approx 0$ AT NO LOAD)

To reduce line current to essentially zero, the reactive power must be supplied by the capacitors. The reactive power of the capacitors is $Q_{3\phi} = 3\times 208^2/(1/377C)$

So: $C = \frac{2880}{208^2\times 3\times 377} = \underline{59\,\mu F}$

$\boxed{\#4}$ From the data, first assume that "full load" means,

$P_{\substack{TO\\shaft}} = (2\text{ h.p.})(746\text{ w/h.p.}) = 1492\text{ w.}$ From 60 Hz, 6 pole, $RPM_{sync} = 1200.$

The "full load" slip is $S = \frac{1200-1120}{1200} = 0.067$

From the equivalent circuit with $r_s, x_{ls}, x'_{lr}, g_{cos}, P_{wf}$ all zero,

$$1492 = P_{\substack{TO\\shaft}} = (1-s)P_{\substack{TO\\rotor}} = (1-.067)\,3\times|\bar{I}_r'|^2(R_r'/.067)\ ,\quad |\bar{I}_r'| = \frac{120}{R_r'/.067}$$

So: $1492 = .933\times3\times\frac{120^2}{R_r'}.067$, $\underline{R_r' = 1.81\,\Omega}$, $\underline{|\bar{I}_r'| = 4.44\,a}$ and

$$T_{\substack{TO\\shaft}} = \frac{1492}{\frac{2\pi}{60}1120} = \underline{12.7\text{ NM}}$$. For operation at 80% voltage

and 80% frequency, $|\bar{V}_{as}| = 0.8\times120 = 96\,v$, $RPM_{sync} = 0.8\times1200 = 960\text{ RPM}$

The term "full load" can be interpreted two ways, as follows:

a) Rated h.p., $P_{\substack{TO\\shaft}} = 1492 = (1-s)\times3\times\frac{96^2(s)}{1.81}$ or $s^2 - s + .0977 = 0$

$s = 0.5 \pm 0.39$, choose $s = .1097$, $RPM_{shaft} = (1-.1097)\,960 = \underline{855\text{ RPM}}$

This gives $\underline{|\bar{I}_r'| = 5.8\text{ amps}}$ and $\underline{T_{\substack{TO\\shaft}} = 16.7\text{ NM}}$

b) Rated rotor current, $\underline{|\bar{I}_r'| = 4.44} = 96\frac{s}{1.81}$ or $s = 0.0837$

$RPM_{shaft} = (1-.0837)\,960 = \underline{880\text{ RPM}}$

This gives $P_{\substack{TO\\shaft}} = (1-.0837)\times3\times4.44^2\frac{1.81}{.0837} = 1172\text{ w}$ (1.6 h.p.)

$T_{\substack{TO\\shaft}} = \frac{1172}{\frac{2\pi}{60}880} = \underline{\mathbf{12.7}\text{ nm}}$. This second interpretation is

also the same as assuming $T_{\substack{TO\\shaft\\full\ load}} = 12.7\text{ NM}$