(1) 17/ENG06/037 MECHANICAL ENG 300LVL

415V, 3-phase, 4-wire, 50Hz

$P_{mech} = 74.6\,kW$

Power factor = 0.7 lagging

Efficiency = 85%

$\therefore$ Since efficiency = 85% $\therefore$ $85 = \frac{74.6}{x} \times 100$

$\therefore 85 = \frac{7460}{x}$

$x = 87.76\,kW$

$\therefore$ Power Input = 87.76 kW

~~$\therefore V_{phase} = \frac{V_{line}}{\sqrt{3}}$ $\therefore V_{phase} = \frac{415}{\sqrt{3}} = 239.6V$~~

$\therefore P.F = \frac{\text{Real Power}}{\text{Apparent Power}}$ $\therefore 0.7 = \frac{87.76 \times 10^3}{S}$

$\therefore S = 125371.43\,VA = 125.371\,kVA$

It is a Synchronous Motor

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∴ Recall Apparent Power $= \sqrt{(\text{Real Power})^2 + (\text{Reactive Power})^2}$

∴

Reactive Power (Q) $= \sqrt{(\text{Apparent Power})^2 - (\text{Real Power})^2}$

∴ Reactive Power (Q) $= \sqrt{(125.371 \times 10^3)^2 - (87.76 \times 10^3)^2}$

Reactive Power (Q) = 89532.5 VAR = 89.533 kVAR

(a) When power factor = 1

$\therefore 1 = \frac{\text{Real Power}}{125.371 \times 10^3}$

∴ Real Power = 125.371×10^3 KVA

∴ Reactive Power (Q) $= \sqrt{(125.371 \times 10^3)^2 - (125.371 \times 10^3)^2}$

$1 = \frac{87.76 \times 10^3}{S}$ ∴ $S = 87.76 \times 10^3$ VA

∴ Reactive Power (Q) $= \sqrt{(87.76 \times 10^3)^2 - (87.76 \times 10^3)^2}$

Reactive Power $Q_{new} = 0$ kVAR

∴ $Q_{cap} = 0 - (89.533 \times 10^3) = -89.533$ kVAR

∴ Recall $X_c = \frac{V^2}{Q}$ ∴ $X = \frac{(415.4)^2}{(-89.533 \times 10^3)}$

$X_c = 1.924\,\Omega$

∴ Recall $X_c = \frac{1}{2\pi F C}$ ∴ $C = \frac{1}{2\pi f X_c}$

$\therefore C = \frac{1}{2 \times \pi \times 50 \times 1.924}$

$C = 1.65 \times 10^{-3}$ F.

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(1)

(b) When power factor = 0.9.

$\therefore 0.9 = \frac{87.76 \times 10^3}{S}$

$\therefore S = 97511.11 \, kVA$

$\therefore$ Reactive Power (Q) = $\sqrt{(97.511 \times 10^3)^2 - (87.76 \times 10^3)^2}$

$= 42503.85 \, kVAR$

$\therefore Q_{capacitor} = 42503.85 - 89532.5 = -47028.65 \, VAR$

$\therefore X = \frac{V^2}{Q} \quad \therefore X = \frac{(415)^2}{(47028.65)}$

$X_c = 3.66 \, \Omega$

$\therefore C = \frac{1}{2\pi f X_c}$

$\therefore C = \frac{1}{2 \times \pi \times 50 \times 3.66}$

$C = 8.7 \times 10^{-4} \, F$

17/ENG06/037 MECHANICAL ENG 300LVL

(2) Power = 25hP   No of poles = 6 pole

Voltage ⇒ V_{Line} = 415V   f = 50Hz

Star connected: $V_{Line} = \sqrt{3} \cdot V_{phase}$

Stator / Rotor phase voltage: 6/5

$Z_1 \rightarrow (0.25 + j0.75)$

$Z_2 \rightarrow (1.173 + j0.52)$

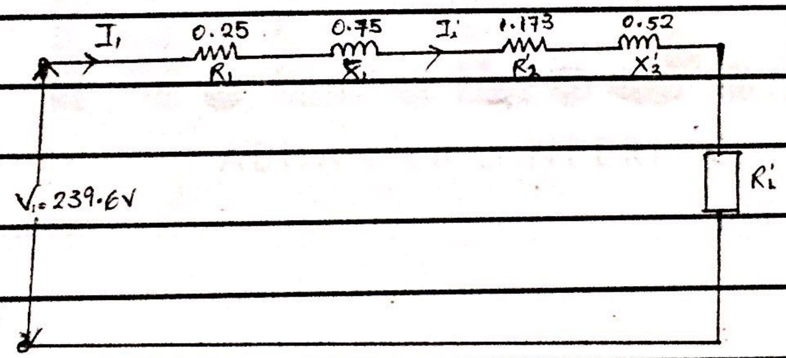
$S = 1$.

$\therefore V_{phase} = \frac{V_{Line}}{\sqrt{3}} = \frac{415}{\sqrt{3}} = 239.6V$

$\therefore \frac{E_1}{E_2} = \frac{6}{5}$ $\therefore \frac{239.6V}{E_2} = \frac{6}{5}$

$E_2 = 199.67V$ $\therefore k = 6/5 = 1.2$

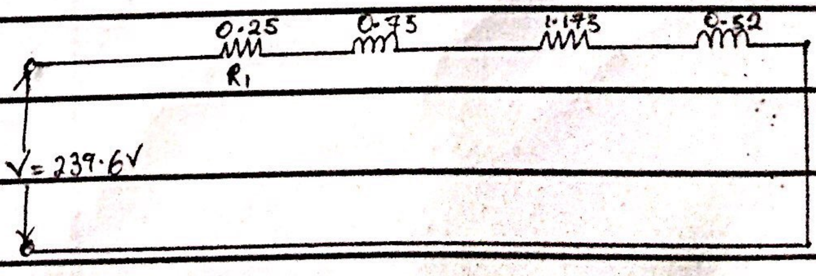
(a) Approximate Circuit Version 2 Diagram referred to the rotor side.



$I_1 = I_2'$ $R_L' = \frac{R_2'}{k^2}\left[\frac{1-s}{s}\right]$

$\therefore R_L' = \frac{1.173}{(1.2)^2}\left[\frac{1-1}{1}\right]$ $\therefore R_L' = 0\Omega$

∴ Resulting Diagram:



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(b) ∴ $Z_{total} = Z_1 + Z_2'$

$= (0.25 + j0.75) + (1.173 + j0.52)$

$= 1.423 + j1.27$

$\therefore I_1 = \frac{E_1}{Z_{total}}$

$I_1 = \frac{239.6}{(1.423 + j1.27)}$

$I_1 = 93.724 - j83.65 \rightarrow 125.62A \angle -41.75^\circ$

∴ Since it is the approximate version II

$I_1 = I_2'$

$\therefore I_2' = 125.62A \angle -41.75^\circ$

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(3)

When connected to DC : $f = 50Hz$, Power = 0.25Hp, $N_r = 2000rpm$

$i = 0.7A$, $V = 220V$, $R = 15\Omega$, $L = 0.25H$

When connected to AC : $V = 220V$, $f = 50Hz$, $i = 0.7A$

∴ On DC : $E_b = V - IR$

∴ $X_L = 2\pi fL$

$X_L = 2\pi \times 50 \times 0.25 = 78.54\Omega$

∴ $E_b = V - IR$

$E_b = 220 - (0.7)(15)$

$E_b = 209.5V$

(i) On AC : $E_b = \sqrt{V^2 - [IX_L]^2} - IR$ Also $\frac{E_{bac}}{E_{bdc}} = \frac{N_{ac}}{N_{dc}}$

$E_{bac} = \sqrt{(220)^2 - [0.7 \times 78.54]^2} - (0.7 \times 15)$

$E_{bac} = 202.52V$

∴ $\frac{202.52}{209.5} = \frac{N_{ac}}{2000}$

∴ $N_{ac} = 1933.37rpm$.

(ii) Power Factor ⇒ $\frac{IR + E_b}{V} = \frac{(0.7)(15) + 202.52}{220} = 0.97$

(iii) Power = $T\omega$ where T = torque, ω = Angular speed.

$\therefore$ Torque = $\frac{Power}{\omega}$

$\therefore \omega = \frac{2\pi N}{60} = \frac{2 \times \pi \times 1933.37}{60} = 202.46$ rads/s

$\therefore$ Power = $V_{Line} \cdot I_{Line} \cdot \cos\theta$

$\therefore$ Power = $220 \times 0.7 \times 0.97$

Power = 149.38 watts.

$\therefore$ Torque = $\frac{149.38}{202.46} = 0.74$ Nm.

(iv) A Universal Motor is to be used for this application.