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Q3. The input current to the motor at rated conditions

$$= \frac{10 \times 10^3}{0.87} = 11.494 \times 10^3 \text{ W}$$

The supply current to the motor is

$$= \frac{11.494 \times 10^3}{240} \text{ A} = 47.89 \text{ A}$$

Neglecting the field copper loss the armature current

$$= 47.89 \text{ A}$$

The back EMF at the rated conditions is

$$= 240 - 47.89 \times 0.4 = 220.843 \text{ V}$$

(a) At $\alpha = 0$, the converter voltage is

$$V_a = \frac{2V_m}{\pi}\cos\alpha = \frac{2 \times \sqrt{2} \times 250}{\pi} \times \cos 0^\circ$$

$$= 225 \text{ V.}$$

As the load torque is constant the armature current is same. Therefore the back EMF is

$$= 225 - 47.89 \times 0.4 = 205.844 \text{ V}$$

We know that $E_b = k\omega$.

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$$\omega = \frac{1000 \times 2\pi}{60} = 104.719 \text{ rad/s}$$

$$\therefore k = \frac{E_b}{\omega} = \frac{220.844}{104.719} = 2.11 \text{ V.s/rad.}$$

At $\alpha = 0^\circ$

$$\text{Speed} = \frac{E_b}{k} = \frac{205.844}{2.108} = \cancel{95.235}\ 97.649 \text{ rad/sec}$$

$$N = \frac{\cancel{95.235}\ 97.649 \times 60}{2\pi} = \cancel{909.443}\ 932.479 \text{ RPM}$$

$$\text{Displacement Factor} = DF = \cos\phi = \cos 0^\circ = 1$$

$$\text{Power factor} = PF = \frac{2\sqrt{2}}{\pi}\cos\alpha = \frac{2\sqrt{2}}{\pi}\cos 0 = 0.9$$

$$\text{Input} = 225 \times 47.89 = 10775.25 \text{ W}$$

Output varies linearly with speed

$$\therefore \text{output at } \cancel{909.443}\ 932.479 \text{ RPM} = 10 \text{ kW (rated)} \times \frac{\cancel{909.4}\ 932.479}{1000}$$

$$= \cancel{9.094}\ 9.32479 \text{ kW}$$

$$\therefore \eta = \frac{O/P}{I/P} = \frac{\cancel{9.094}\ 9.32479}{10.77525} = \cancel{84.4\%}\ 86.538\%$$

(b) At $\alpha = 60^\circ$, the converter voltage is.

$$V_{\alpha} = \frac{2V_m}{\pi}\cos\alpha = \frac{2\sqrt{2} \times 250}{\pi} \times \cos 60^\circ = 112.5 \text{ V}$$

As the load torque is constant, the armature current is same. Therefore the back EMF is.

$$= \cancel{225}\ 112.5 - 47.89 \times 0.4 = 93.344 \text{ V}$$

We know that

$E_b = k\omega$

$\omega = \frac{1000 \times 2\pi}{60} = 104.719$ rad/s.

$\therefore k = \frac{E_b}{\omega} = \frac{\cancel{220}\ \cancel{104}\ \cancel{93.344}\ 220.844}{104.719} = \cancel{0.891}\ 2.108$ ~~rad/s~~ V.s/rad.

At $\alpha = 60°$.

Speed $= \frac{E_b}{k} = \frac{93.344}{\cancel{0.891}\ 2.108} = 44.28$ rad/s.

$N = \frac{44.28 \times 60}{2\pi} = 422.8$ RPM

Displacement factor $= DF = \cos\phi = \cos 60 = 0.5$.

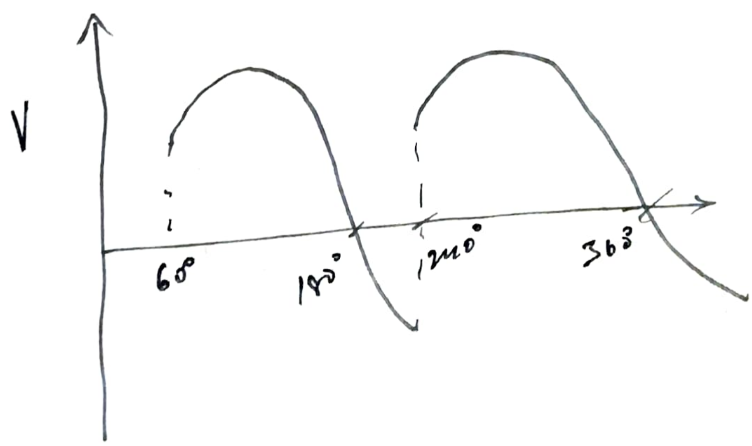
Power factor $= \frac{2\sqrt{2}}{\pi}\cos\alpha = \frac{2\sqrt{2}}{\pi} \times \frac{1}{2} = 0.45$

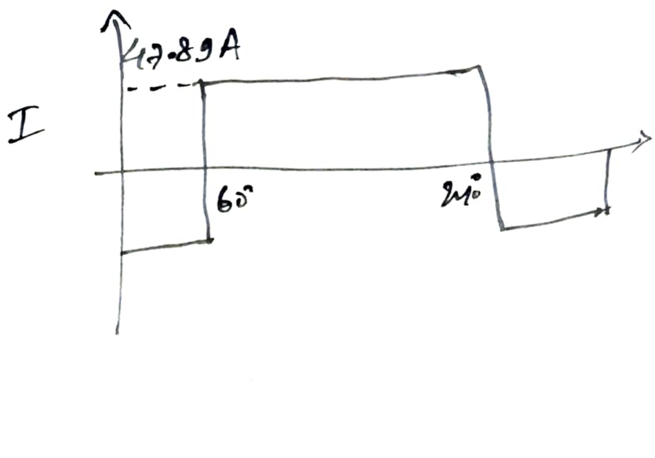
Input $= 112.5 \times 47.89 = 5.387$ kW

Output at ~~909.4~~ 422.8 rpm $= 10\ \text{kW}_{(rated)} \times \frac{422.8}{1000}$

$= 4.2227$ kW

$\therefore \eta = \frac{O/P}{I/P} = \frac{4.2227}{5.387} = \cancel{78.96\%}$ 78.3386%





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Q6. At rated operation, (980 RPM),

$$E_1 = 210 - 0.04 \times 100\ V = 206\ V$$

At 1000 rpm,

$$E_2 = \frac{1000}{980} \times 206\ V = 210.204\ V$$

(a) For plugging operation,

$$R_B + R_A = \frac{E+V}{I_a} = \frac{210.204+210}{2 \times 100} = 2.10102\ \Omega$$

$$\Rightarrow R_B = (2.10102 - 0.004)\ \Omega = 2.06\ \Omega$$

(b) ~~When~~ the braking torque ~~at~~ ~~has fallen to~~ at 1000 RPM,

In steady state, $P_m = P_e$

$$T = \frac{E_2 \times I_a}{\omega_m} = \frac{210.204 \times 200}{1000 \times 2\pi/60} = 401.46\ N\text{-}m$$

At zero speed, $E=0$

$$I_a' = \frac{V}{R_B + R_A} = \frac{210}{2.10102}\ A = 99.95\ A$$

As $T \propto I_a$

$$T' = 401.46 \times \frac{99.95}{200} = 200.629\ N\text{-}m.$$

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Q2.

We know, $T = \frac{J d\omega}{dt}$

$$J\frac{d\omega}{dt} = 7-4 = (T_m - T_L)$$

$$\frac{J d\omega}{dt} = 3 \text{ Nm}$$

$$J d\omega = 3 dt$$

$$J \int_0^{\frac{2\pi}{60}\times 1570} d\omega = \int_0^{150} 3\, dt$$

$$\Rightarrow J \times \frac{2\pi}{60} \times 1570 = 2 \times 150$$

$$\Rightarrow J = \frac{2\times 150}{1570 \times \frac{2\pi}{60}} = 1.8247$$

In second case,

$$T = \frac{J d\omega}{dt} = T_m - T_L = 3(0.6\omega + 15) - (5 + 0.7\omega)$$

$$= 10 - 0.1\omega$$

At steady state,

$T = 0 \Rightarrow \omega = 100$ rad/s.

$$T = \frac{J d\omega}{dt} = 10 - 0.1\omega$$

$$10 - 0.1\omega = J \cdot \frac{d\omega}{dt}$$

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95% of ω = 95 rad/s.

$$\frac{1}{J}\int_0^t dt = \int_0^{95} \frac{d\omega}{10-0.1\omega}$$

$$\Rightarrow t = \frac{J}{-0.1} \log(10-0.1\omega)\Big|_0^{95}$$

$$\Rightarrow t = -10 \times 1.8247 \times \log\frac{0.5}{10}\ s$$

$$= 23.739\ s \simeq 23.74\ s.$$

Q10

$$\omega = \omega_{mo} - \frac{R_a}{k_b^2} T_m$$

$$\frac{3}{100} = \frac{\frac{R_a}{k_b^2} \times T_m \times \frac{1}{2}}{\omega_{mo}}$$

$$\omega_m = \frac{V_a}{k_b}$$

$$0.03 = \frac{R_a \times I_a \times 0.5}{V_a}$$

$$0.03 = \frac{I_a R_a}{210} \times 0.5$$

$$I_a R_a = 12.6\ V$$

$$I_a(\text{starting}) = \frac{V_a(\text{starting})}{R_a}$$

$$42 \times R_a = 12.6$$

$$\boxed{R_a = \frac{12.6}{42}\ \Omega = 0.3\ \Omega}$$

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(a) $I_a(\text{starting}) = \frac{210}{0.3} A = 700\ A$

(b). $T \propto I'$

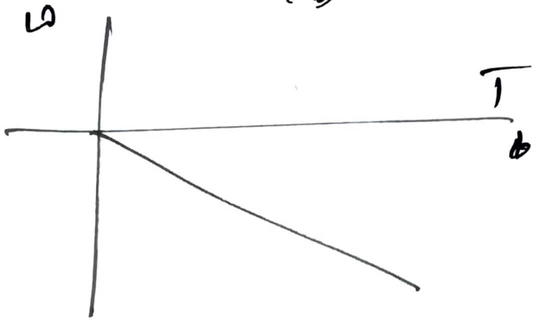
$I' = 2 \times \cancel{700}\ 42\ A = 84\ A$

$V_a(\text{starting}) = I_a R_a = 84 \times 0.3\ V$

$= \boxed{25.2\ V}$

(c) $V_a = 0$

$\omega = \frac{-T_m \times R_a}{(k_\phi)^2}$



when $V_a = 0$.

(d) $\omega = \frac{90 \times 2\pi}{60} = 3\pi$

$3\pi = \frac{-T_m \times R_a}{k_\phi^2}$

$T_m = \frac{-3\pi \times (k_\phi)^2}{R_a}$

$T_m\ \text{rated} = k_\phi \times I_a$

$\omega = \frac{210}{k_\phi} - \frac{I_a R_a}{k_\phi}$ $\Rightarrow \omega = \frac{1500 \times 2\pi}{60}$

$= 50\pi$

$\omega \times k_\phi = (210 - 12.6)\ V$

$k_b = 1.2566$

$$\frac{T_m}{T_{(rated)}} = \frac{3\pi \times k_b}{I_a R_a}$$

$$= \frac{3 \times \pi \times 1.2566}{12.6}$$

$$= 0.9399 \simeq \cancel{94}\ 93.99\%$$