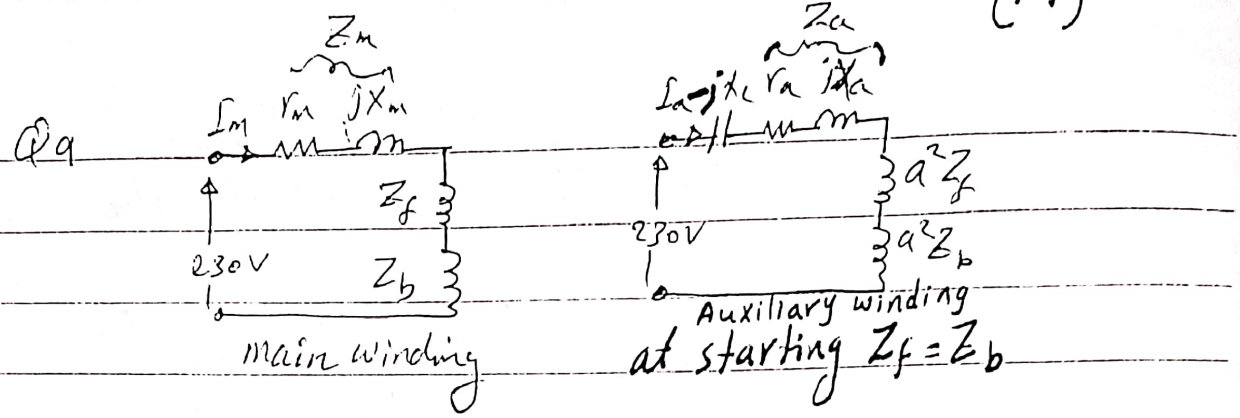
(14)



$r_m + jX_m = Z_m = 2 + j5$, $Z_f + Z_b = 5 + j4$

$a^2(Z_f + Z_b) = 1.2^2(5 + j4) = 7.2 + j5.76$

$Z_a = r_a + jX_a = 7 + j5$

$Z_M = Z_m + Z_f + Z_b = 2 + j5 + 5 + j4 = 7 + j9$

$Z_A = Z_a + Z_c + a^2(Z_f + Z_b) = 7 + j5 - \frac{j}{2\pi \times 50 \times 200 \times 10^{-6}} + 7.2 + j5.76$

$Z_A = 7 + j5 - j15.91 + 7.2 + j5.76 = 14.2 - j5.15$

$I_m = \frac{V_m}{Z_M} = \frac{V}{Z_M} = \frac{230\angle 0^\circ}{7 + j9} = 20.17\angle -52.12^\circ \ A$

$I_m = (12.38 - j15.92)\ A$

$I_a = \frac{V_a}{Z_A} = \frac{V}{Z_A} = \frac{230\angle 0^\circ}{14.2 - j5.15} = 15.22\angle 19.93^\circ \ A$

$I_a = (14.3 + j5.18)\ A$

$I_{in} = I_m + I_a = (12.38 - j15.92) + (14.3 + j5.18)$

$= 26.68 - j10.74 = 28.76\angle -21.92^\circ \ A$

$P_f = \cos(-21.92^\circ) = 0.927$ (lagging).

$|V_c| = |I_a||X_c| = 15.22 \times 15.91 = 242.15\ V$

$T_s = 4a|Ia||Im|\sin\alpha R_f$ in Synchronous Watt

$\alpha = 52.12 + 19.93 = 72.05°$

$T_s = 4 \times 1.2 \times 15.22 \times 20.17 \sin(72.05) \times \frac{5}{2}$

$T_s = 3504.54$ Synchronous Watt

$T_s = \frac{3504.54}{2\pi \times \frac{120 \times 50}{60 \times 4}} = 22.31$ Nm

(Q10)

$$n_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 \text{ rpm}$$

$$S = \frac{n_s - n_r}{n_s} = \frac{1500 - 1410}{1500} = 0.06$$

$$Z_f = R_f + jX_f = (jX_M/2) \,//\, (R_2/2S + jX_2/2) = \frac{(R_2/2S + jX_2/2) \times (jX_M/2)}{R_2/2S + jX_2/2 + jX_M/2}$$

$$Z_f = \frac{(30 + j1.25) \times j30}{30 + j1.25 + j30} = \frac{30.02 \angle 2.38^\circ \times 30 \angle 90^\circ}{43.31 \angle 46.16^\circ} = 20.79 \angle 46.22^\circ$$

$$Z_f = (14.38 + j15.01)\ \Omega$$

$$Z_b = R_b + jX_b = (jX_M/2) \,//\, (R_2/2(2-S) + jX_2/2)$$

$$Z_b = \frac{(R_2/2(2-S) + jX_2/2) \times (jX_M/2)}{R_2/2(2-S) + jX_2/2 + jX_M/2} = \frac{(0.92 + j1.25) \times j30}{0.92 + j1.25 + j30}$$

$$Z_b = \frac{1.55 \angle 53.64^\circ \times 30 \angle 90^\circ}{31.26 \angle 88.31^\circ} = 1.48 \angle 55.33^\circ = (0.84 + j1.21)\ \Omega$$

$$I_1 = \frac{V}{R_1 + jX_1 + Z_f + Z_b} = \frac{220 \angle 0}{2.3 + j2.5 + 14.38 + j15.01 + 0.84 + j1.21} =$$

$$I = 8.58 \angle -46.89^\circ \text{ A}$$

$$P_m = (1-S) P_g = (1-S) I_1^2 (R_f - R_b) = (1-0.06)\, 8.58^2\, (14.38 - 0.84)$$

$$P_m = 936.96 \text{ W}$$

$$T_L = T - T_{rot}, \text{ but } T_{rot} = 0, \text{ then}$$

$$T_L = T = \frac{P_m}{\omega_r} = \frac{936.96}{2\pi \times \frac{1410}{60}} = 6.34 \text{ N.m}$$

$T_L \propto n^2$, then $T_L = K n^2$

$$K = \frac{T_L}{n^2} = \frac{6.34}{(1410)^2} = 3.1889 \times 10^{-6} \ N.m/(rpm)^2$$

for $n = 1190$ rpm, $s = \frac{n_s - n_r}{n_s} = \frac{1500 - 1190}{1500} = 0.2$

$$Z_f = \frac{\left(\frac{3.6}{2\times 0.2} + j1.25\right) \times j30}{\frac{3.6}{2\times 0.2} + j1.25 + j30} = \frac{(9 + j1.25) \times j30}{9 + j1.25 + j30} = \frac{9\angle 7.9^\circ \times 30\angle 90^\circ}{32.5\angle 73.9^\circ}$$

$$Z_f = 8.3\angle 24^\circ = (7.58 + j3.37)\ \Omega$$

$$Z_b = \frac{\left(\frac{3.6}{2(2-0.2)} + j1.25\right) \times j30}{\frac{3.6}{2(2-0.2)} + j1.25 + j30} = \frac{1.6\angle 51.3^\circ \times 30\angle 90^\circ}{31.26\angle 88.1^\circ}$$

$$Z_b = 1.53\angle 53.2^\circ = (0.91 + j1.22)\ \Omega$$

$$Z_{total} = r_1 + jx_1 + Z_f + Z_b = 2.3 + j2.5 + 7.58 + j3.37 + 0.91 + j1.22 =$$

$$Z_{total} = 10.78 + j7.09 = 12.9\angle 33.3^\circ$$

$$T_L = Kn^2 = 3.1889 \times 10^{-6} \times (1190)^2 = 4.51 \ N.m$$

for $P_{rot} = 0$ $\quad P_{out} = P_m = T_L \omega_r$

$$\therefore P_m = 4.51 \times \left(\frac{2\pi \times 1190}{60}\right) = 562.0 \ W.$$

$$P_g = \frac{P_m}{1-s} = \frac{562}{1-0.2} = 702 \ W.$$

$$P_g = I_1^2 (R_f - R_b) \Rightarrow I_1 = \sqrt{\frac{P_g}{R_f - R_b}}$$

$$I_1 = \sqrt{\frac{702}{7.58 - 0.91}} = 10.25 \ A.$$

$$|Z| = \frac{|V|}{|I|} = \frac{220}{10.25} = 21.46\ \Omega$$

The resistance should be connected in series with the winding of the motor to reduce its speed to 1190 rpm is :

$$R = \sqrt{Z^2 - X^2} = 10.78 = \sqrt{(21.46)^2 - (7.09)^2} = 10.7$$

$$R = 9.47\ \Omega$$

$\Longrightarrow$