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

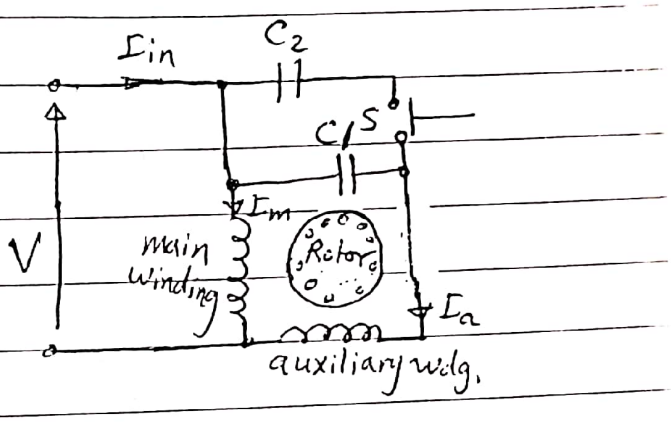
The resistance should be connected in series with the winding of the motor to reduce its speed to 1140 rpm is :

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

$$R = 9.47\ \Omega$$

$\Longrightarrow$

(P11).



At standstill $S = 1 \Rightarrow Z_f = Z_b$

$$Z_f = \left(j\frac{X_M}{2}\right) // \left(\frac{r_2}{2s} + j\frac{X_2}{2}\right) = Z_b$$

$$Z_f = \frac{\left(\frac{4.12}{2\times1} + j\frac{2.12}{2}\right) \times j\frac{66.8}{2}}{\frac{4.12}{2} + j\frac{2.12}{2} + j\frac{66.8}{2}} = \frac{(2.06 + j1.06) \times j33.4}{2.06 + j1.06 + j33.4} =$$

$$Z_f = Z_b = \frac{2.31\angle 27.2^\circ \times 33.4\angle 90^\circ}{34.52\angle 86.57^\circ} = 2.23\angle 30.63^\circ$$

$$Z_f = (1.91 + j1.13)\ \Omega = Z_b$$

$$Z_M = Z_m + Z_f + Z_b = 2.02 + j2.79 + 2\times(1.91 + j1.13)$$

$$Z_M = (5.84 + j5.05)\ \Omega = 7.72\angle 40.85^\circ\ \Omega$$

$I_m = \frac{V_m}{Z_M}$, but $V_m = V_a = V$, then

$I_m = \frac{110\angle 0^\circ}{7.72\angle 40.85^\circ} = 14.24\angle -40.85^\circ\ A =$

$I_m = (10.77 - j\,9.31)\ A$.

At starting, the starting and running capacitors are connected in parallel.

$Z_c = (3 - j14.5) /\!/ (9 - j172)$

$Z_c = \frac{(3 - j14.5)(9 - j172)}{3 - j14.5 + 9 - j172} = \frac{14.8\angle -78.31^\circ \times 172.23\angle -87^\circ}{186.88\angle -86.31^\circ}$

$Z_c = 13.63\angle -79^\circ\ \Omega = (2.6 - j13.37)\ \Omega$.

$I_a = \frac{V}{Z_a + Z_c + a^2(Z_f + Z_b)}$

$I_a = \frac{110\angle 0^\circ}{7.4 + j3.22 + 2.6 - j13.37 + (1.18)^2(2 \times 1.91 + 2 \times j1.13)}$

$I_a = \frac{110\angle 0}{15.31 - j7} = 6.53\angle 24.5^\circ\ A$

$I_a = (5.94 + j2.7)\ A$.

$I_{in} = I_a + I_m = 5.94 + j2.7 + 10.77 - j9.31 =$

$I_{in} = (16.71 - j6.6)\ A = 17.96\angle -21.5^\circ\ A$

$P_f = \cos(-21.5^\circ) = 0.93$ (tagging).

$V_c = I_a Z_c = 6.53\angle 24.5^\circ \times 13.63\angle -79^\circ =$

$V_c = 89\angle -54.5^\circ\ V = (51.68 - j\,72.45)\ V$

The starting torque in N.m is

$$T_s = \frac{4\alpha |I_a||I_m| \sin\alpha R_f}{\omega_s}$$

$$\alpha = 24.5 + 40.85 = 65.35^\circ$$

$$\omega_s = \frac{2\pi n_s}{60} = \frac{120 \times f}{p \times 60} \cdot 2\pi = \frac{2\pi \times 120 \times 50}{4 \times 60} =$$

$$\omega_s = 157.07 \text{ rad/sec}.$$

$$T_s = \frac{4 \times 1.18 \times 6.53 \times 14.24 \sin(65.35) \times 1.91}{157.07} =$$

$$T_s = 4.85 \text{ N.m}.$$