Tutorial Sheet 6

The phase voltage applied to the machine is $\frac{415}{\sqrt{3}} = 240\ V$

2-pole, 50Hz machine has a synchronous speed of 3000rpm

With a slip of 5%, the rotor speed is 2850rpm = 298.5 rad/s

a) On no-load, motor input current is in magnetising branch only, i.e.

$$I_m = \frac{240}{50\angle 90^o} = 4.8\angle -90^0 \text{ Arms}$$

b)

i) Output mechanical power = Tω = 100×298.5 = 29.84kW = 9.95kW per phase

$$P_{em} = 3\ \left|I_1\right|^2 \frac{(1-s)R_2^{'}}{s}$$

Hence,

$$R_2' = \frac{sP_{em}}{3(1-s)|I_1|^2} = \frac{0.05 \times 9950}{3(1-0.05) \times 45^2} = 0.86\Omega$$

ii) There is no mention of iron loss in the question (as might be included with an additional resistor in parallel with the magnetizing reactance).

The only losses are therefore copper losses. The total copper loss for all 3 phases are given by:

$$P_{cu} = 3\left|I_1\right|^2 (R_1 + R_2^{'}) = 6196\text{W}$$

Hence,

$$Efficiency = \frac{P_{em}}{P_{em} + P_{cu}} = \frac{29840}{29840 + 6196} \times 100\% = 82.8\%$$

c) With the reduced load the slip is 0.027

i) The impedance of the main branch of the circuit is given by:

$$Z_e = \left(0.16 + 0.86/0.027\right) + j0.5 \ = 32.0\angle 0.9^o\,\Omega$$

$$I_1 = \frac{240}{32.0\angle 0.9^o} = 7.49\angle -0.9^o\ A \text{ rms}$$

The current in the magnetising branch is given by:

$I_m = \frac{240}{50\angle 90^o} = 4.8\angle -90^0$ Arms (as before)

The net input current is hence given by:

$I_{ip} = I_1 + I_m = (7.49 - j0.11) - j4.8 = 7.49 - j4.91 = 8.96\angle -33.2^o A$ rms

ii) Power factor = cos (-33.2^o) = 0.836 lagging

iii) Electromagnetic power is given by:

$$P_{em} = 3\ |I_1|^2\ \frac{(1-s)R_2^{'}}{s}$$

= 7.46kW

(i.e. much reduced compared to earlier load point)

$$T = \frac{P_{em}}{\omega_r} = \frac{7460}{2920 \times \frac{2\pi}{60}} = 24.4Nm$$

iv) Again, there is no iron loss specified.

$P_{cu} = 3|I_1|^2 (R_1 + R_2^{'}) =$ 246W

$$Efficiency = \frac{P_{em}}{P_{em} + P_{cu}} = \frac{7460}{7460 + 246} \times 100\% = 96.8\%$$