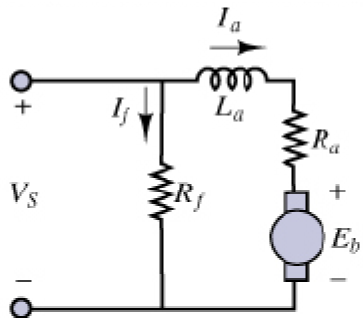
ELG2336: Tutorial on Electric Machines

Problem 1

A 200 V DC shunt **motor** with an armature resistance is 0.1 Ω and series field resistance of 100 Ω. The speed is 1100 rpm at an input current of 4 A (no load). Find the induced voltage E_b and the output power at 1100 rpm.

Solution:



Solution:

$$i_S = 4\,A \quad i_f = \frac{200}{100} = 2\,A \quad i_a = i_S - i_f = 2\,A$$

Also, $$E_b = 200 - 2 \times 0.1 = 199.8V$$

$$P = P_{in} - P_{copper\_loss} \quad = 200 \times 4 - (2^2 \times 100 + 2^2 \times 0.1) \quad = 399.6W$$

Problem 2 (The Alternator or Synchronous Generator): This is similar to the machine used for diesel generator in the case study.

Consider a 500 VA, 20 V diesel synchronous **generator**. At rated condition, the power factor is 0.85. The resistance per phase is 0.05 Ω. The field takes 2 A at 12 V. The friction and windage loss is 25 W while the core loss is 30 W. Find the efficiency of the generator under rated conditions.

Solution:

$$I_a = \frac{500}{20} = 25\,A \quad P_a = I_a^2 R_a = 31.25W$$

$$P_{out} = 500(0.85) = 425W \quad P_f = 2(12) = 24W$$

$$P_{in} = P_{out} + P_a + 25 + 30 + 24 = 535.25W$$

$$\% = \frac{425}{535.25} \times 100 = 79.4\%$$

Problem 3

Consider a 230 V, 10 hp, 60 Hz, Y-connected 3-phase synchronous motor that delivers a full load at a power factor of 0.8 leading. The synchronous reactance is 6 ohm. The rotational mechanical losses are 230 W and the field losses are 50 W. Find the armature current, the motor efficiency, and the power angle.

Solution:

$$P_{out} = 10\,hp = 7460\,W$$

$$P_{in} = P_{out} + P_r + P_{copper} = 7740$$

$$V_S = \frac{230}{\sqrt{3}} = 132.8\,V$$

$$\therefore I_S = \frac{2580}{132.8 \times 0.8} = 24.3\,A$$

$$V_S = 132.8\angle 0^\circ\,V,\ I_S = 24.3\angle 36.87^\circ\,A$$

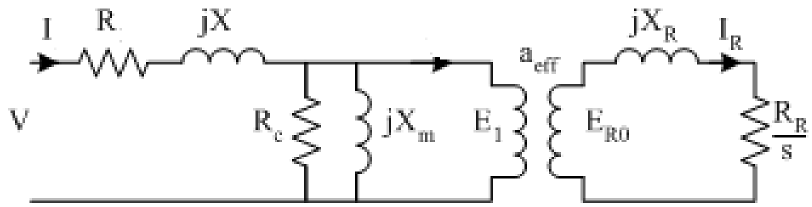
$$E_b = V_S - I_S(6\angle 90^\circ) = 249.2\angle -27.9^\circ\,V$$

$$efficiency = \frac{7460}{7740} = 0.964 = 96.4\%$$

$$power\ angle = -27.9^\circ$$

Problem 4 (The Induction Machine): This is similar to the machine used for the wind turbine in the case study.

Consider a 74.6 kW, 440 V (this voltage is always line-to-line) Y-connected three phase, four pole, 60 Hz induction motor. The equivalent circuit parameters are: $R_S = 0.06\ \Omega$, $R_R = 0.08\ \Omega$, $X_S = 0.3\ \Omega$, $X_R = 0.3\ \Omega$, $X_m = 5\ \Omega$. The no-load power input is 3240 W. Find the line current, the input power, and the developed torque at slip $s = 0.02$.



Solution:

$$V_S = \frac{400}{\sqrt{3}} = 254\angle 0^\circ\ V$$

$$Z_{in} = 0.06 + j0.3 + \frac{j5(4 + j0.3)}{4 + j5.3} = 2.328 + j2.294 = 3.268\angle 44.59^\circ\ \Omega$$

$$I_S = 77.7\angle -44.59\ A$$

$$P_{in} = 3 \times 254 \times 77.7 \cos(-44.59^\circ) = 42.16\,kW$$

$$I_2 = \frac{j5}{4 + j5.3} I_S = 58.51\angle -7.55^\circ\ A$$

The total power transferred to the rotor is:

$$P_T = 3\frac{R_S}{S}\left|I_2\right|^2 = 41.1\,kW$$

$$P_m = P_T - P_{copper\_loss\_in\_rotor} \quad = 41.1 \times 10^3 (1 - s) = 40.25\,kW$$

$$\omega_m = (1 - s)\omega_S = 0.98 \times 188.5 = 184.7\,rad/\sec$$

$$T_{dev} = \frac{P_m}{184.7} = 218\,N \cdot m \quad = 1880.3\angle -42.51^\circ\ V$$

Problem 5

Consider a 440 V, Y-connected three phase, 6 poles, 60 Hz induction motor. The equivalent circuit parameters are: Rs = 0.8 Ω, R_R = 0.3 Ω, Xs = 0.7 Ω, X_R = 0.7 Ω, Xm = 35 Ω. Find the input current and power factor of the motor for a speed of 1200 rpm.

Solution:

$$V_S = \frac{440}{\sqrt{3}} = 254\angle 0^\circ\ V$$

For $n_m = n_S = 1200\,rev/\min$, $s = 0\,(no\,load)$.

$$Z_{in} = R_S + j(X_S + X_m) = 0.8 + j35.7 = 35.71\angle 88.7^\circ\ \Omega$$

$$I_S = 7.11\angle -88.7^\circ\ A$$

$$P_{in} = 3\left|I_S\right|\left|V_S\right|\cos\theta = 121.4\,W$$