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:

\[ i_S = 4 \, A \quad \frac{I_f}{100} = 2 \, A \quad i_a = i_S - i_f = 2 \, A \]

Also,

\[ E_b = 200 - 2 \times 0.1 = 199.8 \, V \]

\[ P = P_{in} - P_{copper\_loss} = 200 \times 4 - \left(2^2 \times 100 + 2^2 \times 0.1\right) = 399.6 \, W \]

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:

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

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

\[ P_{in} = P_{out} + P_a + 25 + 30 + 24 = 535.25 \, W \]

\[ \% = \frac{425}{535.25} \times 100 = 79.4\% \]
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:

\[ P_{\text{out}} = 10 \text{ hp} = 7460 \text{W} \]
\[ P_{\text{in}} = P_{\text{out}} + P_r + P_{\text{copper}} = 7740 \]
\[ V_S = \frac{230}{\sqrt{3}} = 132.8 \text{V} \]
\[ \therefore I_S = \frac{2580}{132.8 \times 0.8} = 24.3 \text{A} \]

\[ V_S = 132.8 \angle 0^\circ \text{V}, \quad I_S = 24.3 \angle 36.87^\circ \text{A} \]
\[ E_b = V_S - I_S(6 \angle 90^\circ) = 249.2 \angle -27.9^\circ \text{V} \]

\[ \text{efficiency} = \frac{7460}{7740} = 0.964 = 96.4\% \]

\[ \text{power angle} = -27.9^\circ \]

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:
\[ V_S = \frac{440}{\sqrt{3}} = 254 \angle 0^\circ \text{ V} \]

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

\[ I_S = 77.7 \angle -44.59 \text{ A} \]

\[ P_{in} = 3 \times 254 \times 77.7 \cos(-44.59^\circ) = 42.16 \text{ kW} \]

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

The total power transferred to the rotor is:

\[ P_T = 3 \frac{R_S}{S} |I_2|^2 = 41.1 \text{ kW} \]

\[ P_m = P_T - P_{copper\_loss\_in\_rotor} = 41.1 \times 10^3 (1 - s) = 40.25 \text{ kW} \]

\[ \omega_m = (1 - s) \omega_S = 0.98 \times 188.5 = 184.7 \text{ rad/sec} \]

\[ T_{dev} = \frac{P_m}{184.7} = 218 N \cdot m = 1880.3 \angle -42.51^\circ \text{ V} \]

**Problem 5**

Consider a 440 V, Y-connected three phase, 6 poles, 60 Hz induction motor. The equivalent circuit parameters are: \( R_s = 0.8 \Omega \), \( R_R = 0.3 \Omega \), \( X_s = 0.7 \Omega \), \( X_R = 0.7 \Omega \), \( X_m = 35 \Omega \). Find the input current and power factor of the motor for a speed of 1200 rpm.

**Solution:**

\[ V_S = \frac{440}{\sqrt{3}} = 254 \angle 0^\circ \text{ V} \]

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

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

\[ I_S = 7.11 \angle -88.7^\circ \text{ A} \]

\[ P_{in} = 3 |I_S| |V_S| \cos \theta = 121.4 \text{ W} \]