Question 1. 2.5 kW, 380 V, three-phase, 50 Hz, 2p=4, cos =0.8, Isn=5 A squirrel cage induction motor with star connected stator with 1460 rpm label value draws 40% of the nominal (full load current) in the supply when it is operated at no-load. Since $\cos\phi_{s0} = 0.087$ and Ps,v=0.05 Pf;

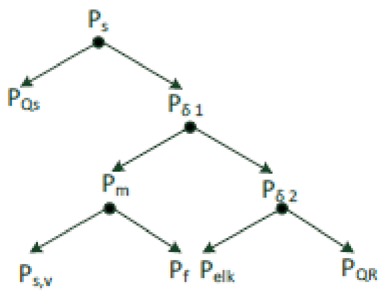
a) Slip at full load

b) Rotor currents frequency and speed

c) Mechanical power

d) the power transferred from the stator to the rotor

e) Find the active and reactive powers at no-load operation



a) $s = \frac{n_s - n}{n_s} = \frac{1500-1460}{1500} = \%2.66$

b) $f_R = s.f_s = 0.0266 . 50 = 133\ Hz$

$$n_2 = s . n_s = 40\ rpm$$

c) $P_m = P_f + P_{s,v} = (1+0.05)P_f = 1.05\ 2500 = 2625\ W$

d) $P_{\delta 1} = \frac{P_m}{1-s} = \frac{2625}{1-0.0266} = 2696.7\ W$

e) $\mathrm{P}_{s0} = \sqrt{3} . \mathrm{U} . \mathrm{I} . \cos\phi_{s0} = \sqrt{3}\ x\ 380\ x\ 5\ x\ 0.4\ x\ 0.087 = 114.5\ W$

$\mathrm{Q}_{s0} = \sqrt{3} . \mathrm{U} . \mathrm{I} . \sin\phi_{s0} = \sqrt{3}\ x\ 380\ x\ 5\ x\ 0.4\ x\ 0.996 = 1311\ VAr$

Question 2. 20 kW, 380 V, 50 Hz, cos = 0.8 I=44 A, 950 rpm, Delta connected values are available on the plate of the asynchronous motor. Since the no-load current is 40% of the full-load current and the no-load power factor is 0.05;

Find the active and reactive powers drawn by the motor from supply in no-load operation.

$$\mathrm{P}_s = 3 . \mathrm{U} . \mathrm{I} . \cos\phi$$

$$\mathrm{Q}_s = 3 . \mathrm{U} . \mathrm{I} . \sin\phi$$

$$\cos\phi = 0.05$$

$$\phi = 87.13$$

$$\sin\phi = 0.998$$

$$\mathrm{P_{s0}} = 3\,.\,380\,.\frac{44}{\sqrt{3}}\,.\frac{40}{100}\,.\,0.05 = 579.19\ \mathrm{W}$$

$$\mathrm{Q_{s0}} = 3\,.\,380\,.\frac{44}{\sqrt{3}}\,.\frac{40}{100}\,.\,0.998 = 11468.11\ \mathrm{Var}$$

Question 3. The power drawn from the supply by a three-phase, 50 Hz frequency asynchronous motor with 6 poles, is 3 kW and its speed is 925 rpm. In this case, stator copper and iron losses are 300W, friction and ventilation losses are 1.5% of the power transmitted to the rotor. According to this;

a) Find the efficiency of the motor at full load.

b) Find the stator and rotor current frequencies.

$$\mathrm{n_s} = \frac{60.f}{p} = \frac{60.50}{3} = 1000\ rpm$$

a) $\eta = \frac{P_f}{P_s}$

$$s = \frac{n_s - n}{n_s} = \frac{1000 - 925}{1000} = 0.075$$

$$P_{\delta 1} = P_s - P_{Qs} = 3000 - 300 = 2700\ W$$

$$P_{s,v} = \frac{1.5}{100}\,.\,P_{\delta 1} = \frac{1.5}{100}\,.\,2700 = 40.5\ W$$

$$P_{\delta 1} = P_m + P_{\delta 2} = P_m + s.P_{\delta 1}$$

$$P_m = P_{\delta 1} - s.P_{\delta 1}$$

$$P_m = 2700 - 0.075\,.\,2700 = 2497.5\ W$$

$$P_m = P_f + P_{s,v} \quad \rightarrow \quad P_f = 2497.5 - 40.5 = 2457\ W$$

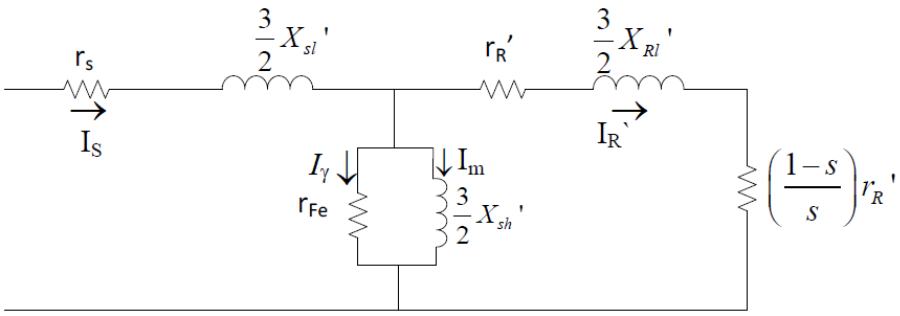
$$\eta = \frac{P_f}{P_s} = \frac{2457}{3000} = 0.81$$

b) $s.n_s = n_2 \quad \rightarrow \quad n_2 = 0.075\,.\,1000 = 75\ rpm$

$$f_r = \frac{p\,.\,n_2}{60} = \frac{3.75}{60} = 3.75\ Hz$$

$$f_s = 50\ Hz$$

Question 4. The nominal shaft power of a three-phase, rotor-wound, 2p=4 pole, star-connected stator asynchronous motor is 7.5 HP, the phase-to-phase voltage is 380 V, and the stator current is 15.9 A. The motor is connected to a 50 Hz supply and its rated speed is 1450 rpm. The stator winding resistance is 0.36 Ω/phase. In no-load operation, when Vs=380 V and f=50Hz, it draws 7.5A currentI_{s0} (=7.5 A) and 870 W power (P_{s0}=870 W) from the supply. In addition, when the stator applies 74 V between phases when the motor is stopped, the motor current is measured as 10.4 A and its power as 276 W. Find the parameters in the equivalent circuit of the motor



$$P_{s0} = 3\ x\ r_s\ x\ I_{s0}^2 + 3\ x\ \left(\frac{E_s^2}{r_{fe}}\right)^2$$

$$assume\ that\ V_s = E_s$$

$$870 = 3\ x\ 0.36\ (7.5)^2 + 3\left(\frac{\left(\frac{380}{\sqrt{3}}\right)^2}{r_{Fe}}\right)$$

$$r_{Fe} = 180\ \Omega$$

$$I_\gamma = \frac{220}{180} = 1.22\ A$$

$$3.\frac{V_{Fe}^2}{r_{Fe}} = 3\ x\ r_{Fe}\ x\ I_\gamma^2 = 810\ W$$

$$I_{s0} = \sqrt{I_m^2 + I_\gamma^2}$$

$$I_m = 7.4\ A$$

$$\frac{3}{2}\ X_{sh} = \frac{E_s}{I_m} = \frac{220}{7.4} = 29.6\ \Omega$$

When short circuit experimented is done, negleticng magnetization current

$$P_k = 3\,x\,[(r_s + r_R')\,x\,I_{kd}^2]$$

$$276 = 3x\,[(0.36 + r_R').10.4^2]$$

$$r_R' = 0.49\,\Omega$$

$$V_{sk} = z_k\,I_{kd} = \sqrt{(r_s + r_R')^2 + \left(\frac{3}{2}X_{sl} + \frac{3}{2}\,X_{rl}'\right)^2}$$

$$\frac{3}{2}X_{sl} + \frac{3}{2}\,X_{rl}' = 4\,\Omega$$

$$\frac{3}{2}X_{sl} = \frac{3}{2}\,X_{rl}' = 2\,\Omega$$

Question 5. 10 kW, 220/380, 50 Hz, 940 rpm, cos =0.8 End, $\eta = 0.86$. The stator of the asynchronous motor at full load is connected in delta.

a) Find the line and phase currents of the motor at full load.

b) Find the active and reactive powers that the motor will draw from the supply during no-load operation.

a)

$$I_{s0} = \%40\,I_{sn}\ \cos\phi\ = 0.087$$

$$P_s = \frac{P_f}{\eta} = \frac{10000}{0.86} = 11628\,W$$

$$I_s = \frac{11628}{\sqrt{3}\,220\,0.8} = 38.14\,A = I_{ph}$$

$$I_{s0} = 38.14\,x\,0.4 = 15.256\,A$$

$$I_{coil} = \frac{I_{ph}}{\sqrt{3}} = 22\,A$$

b)

$$\mathrm{P}_{s0} = \sqrt{3}\,.\,\mathrm{U}.\mathrm{I}\,.\cos\phi_{s0} = \sqrt{3}\,x\,220\,x\ \ 15.256\,x\,0.087 = 506\,W$$

$$\mathrm{Q}_{s0} = \sqrt{3}\,.\,\mathrm{U}.\mathrm{I}\,.\sin\phi_{s0} = \sqrt{3}\,x\,220x\ \ 15.256\,x\,0.996 = 5790\,VAr$$

Question 6. a) 3-phase, 10-pole synchronous generator, the stator inner diameter is D= 570mm and the stator length is l=350mm. When the air gap resultant flux density peak value is 0.55 Wb/m, how many V is induced in one conductor of the inductor at a frequency of 50 Hz.

b) The coil pitch in the stator winding of this generator is how many volts e.m.k. in one winding. is obtained?

a) $e_{imax} = B_{fmax}\, l\, v$

$$v = \frac{D}{2}\, w_r = \frac{\pi\, f\, D}{p} = \frac{\pi\ x\ 50\ x\ 0.57}{5} = 17.9\frac{m}{s}$$

$$e_{imax} = 0.55\ x\ 0.35\ x\ 17.9 = 3.44\ V/iletken$$

$$E_{ieff} = \frac{e_{imax}}{\sqrt{2}} = 2.43\ V/iletken$$

b) $Y_x = 150°e$

$$\beta = 180 - 150 = 30\ °e$$

$$k_a = \cos 15°e$$

$$E_s = 2\ E_i\ k_a = 4.69\frac{V}{sarım}$$

Question 7. A synchronous generator with 200 kVA power, 600V, 2p=4 poles, f= 50Hz, 3-phase, round poles is connected as star. The stator per phase resistance is Rs= 0.1Ω and its synchronous reactance is Xs= 0.7Ω.

a) Find synchronous speed.

b) Find the stator copper losses at the rated load current.

$$n_s = \frac{50x60}{2} = 1500\ rpm$$

$$I_s = \frac{200x100^3}{\sqrt{3}\ x\ 600} = 192.5\ A$$

$$P_{cu} = R_s\, (I_s)^2 = 0.1\, (192.5)^2 = 3705.6\ W$$

Question 8. A synchronous motor with 50 kVA, interphase voltage of 380 V, 2p=6, f=50 Hz, star connected synchronous reactance per phase is 0.8 Ω/phase, resistance per phase is Rs ≈ 0. (No copper losses) The friction loss of the motor is Ps = 3 kVA. (in case of cos = 1)

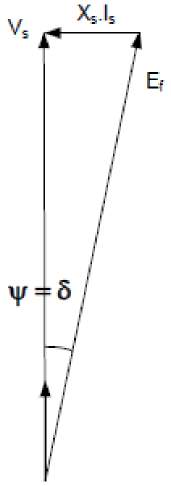
a) The current drawn by the motor from supply at no-load,

b) the phasor diagram for cos = 1,

c) Find the induced voltage at cos = 1.

$$I_{s0} = \frac{3x10^3}{\sqrt{3}\,380} = 4.5\;A$$

$$\cos\phi = 1 \qquad R_s = 0$$



$$E_f = \sqrt{V_s^2 + (X_s\,I_s)^2} = \sqrt{220^2 + (0.8x\;75)^2} = 228\;V$$

Question 9. A 460-V, 50-kW, 60-Hz, three-phase synchronous motor has a synchronous reactance of Xs=4.15 Ω and an armature-to-field mutual inductance, L_{af} = 83 mH. The motor is operating at rated terminal voltage and an input power of 40 kW. Calculate the magnitude and phase angle of the line-toneutral generated voltage E_{af} and the field current I_f if the motor is operating at (a) 0.85 power factor lagging, (b) unity power factor, and (c) 0.85 power factor leading.

part (a): The magnitude of the phase current is equal to

$$I_a = \frac{40 \times 10^3}{0.85 \times \sqrt{3}\,460} = 59.1\ \text{A}$$

and its phase angle is $-\cos^{-1} 0.85 = -31.8°$. Thus

$$\hat{I}_a = 59.1e^{-j31.8^\circ}$$

Then

$$\hat{E}_{af} = V_a - jX_s\hat{I}_a = \frac{460}{\sqrt{3}} - j4.15 \times 59.1e^{-j31.8^\circ} = 136 \angle -56.8^\circ \text{ V}$$

The field current can be calculated from the magnitude of the generator voltage

$$I_f = \frac{\sqrt{2}E_{af}}{\omega L_{af}} = 11.3 \text{ A}$$

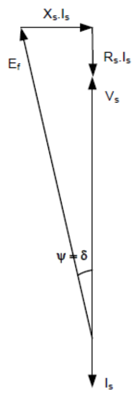
part (b):

$$\hat{E}_{af} = 266 \angle -38.1^\circ \text{ V}; \quad I_f = 15.3 \text{ A}$$

part (c):

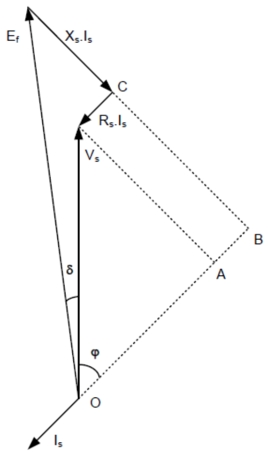
$$\hat{E}_{af} = 395 \angle -27.8^\circ \text{ V}; \quad I_f = 20.2 \text{ A}$$

The resistance per phase of a star-connected, three-phase cylindrical rotor synchronous generator with a power of 1000 kVA and a voltage between phases of 4600 V is Rs = 2 Ω/phase, synchronous reactance per phase is Xs = 20 Ω/phase. At rated load current;
a) Ohmic,
b) Cos = 0.75 inductive,
find the values of the voltages



$$I_s = \frac{1000x10^3}{\sqrt{3}x4600} = 125\ A$$

$$E_f = \sqrt{(V_s + R_s\, I_s)^2 + (X_s\, I_s)^2} = \sqrt{(2656 + 2x125)^2 + (20x125)^2} = 3833\ V$$



$$E_f = \sqrt{(V_s \cos\phi + R_s\, I_s)^2 + (V_s \sin\phi + X_s\, I_s)^2}$$

$$= \sqrt{(2656x0.75 + 2x125)^2 + (2656x0.66 + 2x125)^2} = 4808\ V$$