Problem 3 (10 %)

There is a transformer with two coils sketched as below.

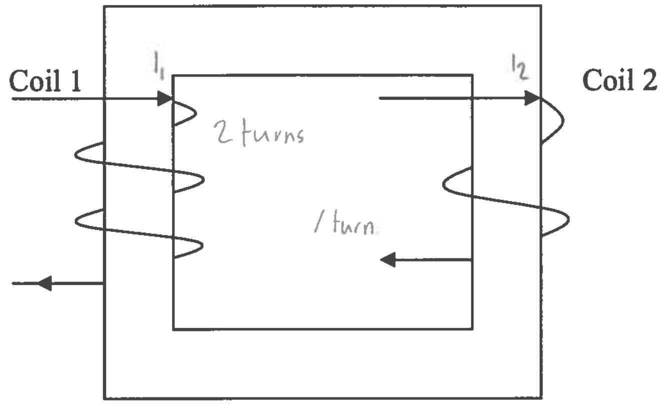


Fig. 3

(1) Please express the flux linkage for coil 1 using the coils 1 self-inductance (L1) and coil 1 and coil 2 mutual inductance (M). The positive current directions are already given in Fig. 3.

(2) Suppose coil 1 has N1 turns, and coils 2 has N2 turns. If it is desired to perform turns ratio transformation, to let coil 2 to have the same number of turns as coil 1. How the flux linkage equation derived before should be modified?

(3) Which parameters and variables related to coil 2 are affected by the turns ratio transformation?

$\lambda_1 = L_1 i_1 + M i_2$

DMoEM - Jan 14

Problem 3 - A transformer

1 - The flux linkage of coil 1.

$$\lambda_1 = \underbrace{L_1}_{\text{Coil 1 self-inductance}} i_1 + \underbrace{M}_{\text{Mutual inductance.}} i_2$$

2 - Turns ratio transformation:

- It is desired to lets coil 2 have the same # of turns as coil 1.
  - Flux linkage eq.:

$$\lambda_2 = L_2 i_2 + M i_1$$

$$M = \frac{N_1 \phi_2}{i_2}$$

If $N_1 = N_2$, then the # of winding for N_2 are doubled, then only half the line current are needed to produce the same flux.

$$M = \frac{N_1 \phi_2}{i_2/2} \Rightarrow 2\frac{N_1 \phi_2}{i_2} = 2M$$

Thus:

$$\lambda_1 = L_1 i_1 + 2M i_2$$

3 - Parameters/variables affected by the turn ratio transformation:

- If it is desired to produce the same flux

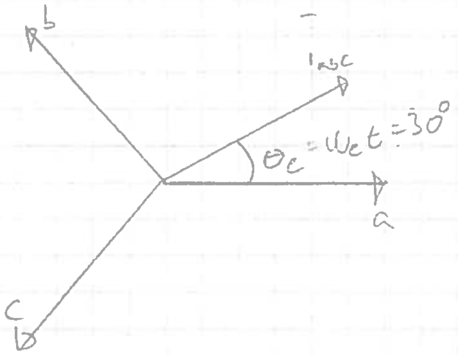
$$N_1 \propto \frac{1}{i_2}$$

Elektriske maskiner eksamen - Jan 2014

Problem 1

1) $\omega_e = 2\pi 50$ rad/s

$I = 10A \quad \angle 30^0$



$\bar{i}_{abc} = 10 \cdot e^{j30^0}$

$i_a = Re\left(\frac{10 e^{j30}}{e^{j0}}\right) = 10 \cos(30^0)$

$= 8{,}66$ A

$i_b = Re\left(\frac{10 \cdot e^{j30^0}}{e^{j120^0}}\right) = 10 \cdot \cos(30^0 - 120^0)$

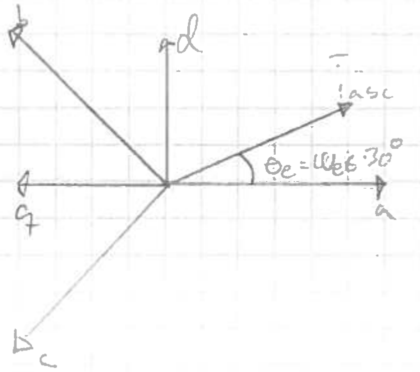
$= 10 \cdot \cos(-90^0) = 0$

$i_c = Re\left(\frac{10 e^{j30}}{e^{-j120^0}}\right) = 10 \cdot \cos(30^0 + 120^0)$

$= -8{,}66A$

2) Determine dq component values

$\theta = 90^0$



$i_d = Re\left(\frac{\bar{i}_{abc}}{e^{j\theta}}\right) = 10 \cdot \cos(30^0 - \theta)$

$= 5A$

$i_q = Re\left(\frac{\bar{i}_{abc}}{e^{j\theta + 90}}\right) = 10 \cdot \cos(30 - (\theta + 90))$

$= -8{,}66A$

$\bar{i}_{dq} = (5A - j\,8{,}66A)\, e^{j90^0}$

3) At $t = 0{,}05$ sek d-axis is leading the current vec by 90 deg, thus

$\bar{I} = 10 e^{j30^0} \cdot e^{j\theta_e}$

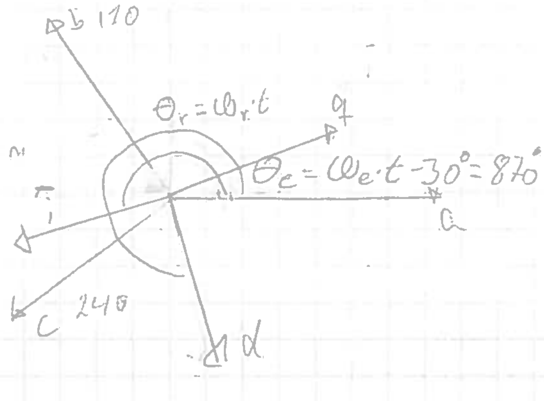
$= 10 \cdot \cos(30^0 - 150^0)$

$\theta_r = \omega_r \cdot t = \theta_e + 90^0 \ (t = 0{,}05)$

$\omega_r = \frac{(870 + 90)}{0{,}05\,\text{sek}} =$

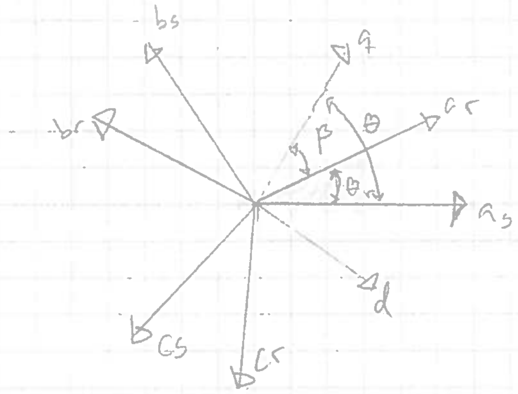
$= 356{,}03$ rad/s

$f_r = 56{,}67 Hz$



Problem 2

Induction machine   s stator   r rotor



1) What is the mutual inductans (stator phase b and c)

$$M_{sbscm} = L_{aaq} \cdot Re\left(\frac{e^{j\theta}}{e^{j\frac{2}{3}\pi}}\right) Re\left(\frac{e^{j\theta}}{e^{j-\frac{2}{3}\pi}}\right) +$$

$$L_{aad}\ Re\left(\frac{e^{j(\theta-\frac{\pi}{2})}}{e^{j\frac{2}{3}\pi}}\right) Re\left(\frac{e^{j(\theta-\frac{\pi}{2})}}{e^{j-\frac{2}{3}\pi}}\right)$$

2) Mutual inductans rotor phase c and stator phase b?

q pos   q pos

$$M_{rcsbm} = L_{aaq}\ Re\left(\frac{e^{j\theta}}{e^{j(-\frac{2}{3}\pi-\theta_r)}}\right) Re\left(\frac{e^{j\theta}}{e^{j(\frac{2}{3}\pi)}}\right) +$$

c_r pos b_s pos

d pos   d pos

$$L_{aad}\ Re\left(\frac{e^{j(\theta-\frac{\pi}{2})}}{e^{j(-\frac{2}{3}\pi-\theta_r)}}\right) Re\left(\frac{e^{j(\theta-\frac{\pi}{2})}}{e^{j(\frac{2}{3}\pi)}}\right)$$

c_r pos b_s pos

3) The rotor shaft speed is 120 RPM. Nr. pole pairs is 2. Please cal the rotor angular vel. ω_r, to be used in this machine model

$$\omega_m = 120\,\frac{2\pi}{60} = 4\pi \qquad \omega_r = 2\cdot 4\pi = 8\pi$$

③ Related variables affected?

the current in coil 2 is now expressed as $i_2' = i_2 \cdot \frac{N_2}{N_1}$

Problem 4

8 pole = 4 pole pairs induction motor

① Cal efficiency

$P = 400\,V_{RMS} \cdot \sqrt{2} \cdot 2,1\,A_{RMS}\,\sqrt{2}\;0,6 = 1,008\,kW$

$\eta = \frac{0,6\,kW}{1,008\,kW} = 0,59 \approx 60\%$

② V/f control

5