Course:

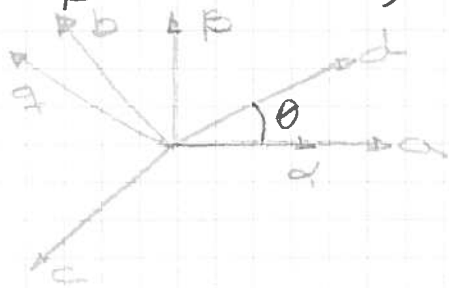
Date: Page: /

EXAM 2012

[2 problemas de Dynamical
1 de NOn control]

Problem 1

- Please draw the reference frame axes for abc reference frame, dq rotating reference frame and α-β stationary reference frame.



- Suppose now you have a set of 3-phase signals as

$$V_a = V_{pk} \cdot \cos(w_e t) \qquad w_e = 2\pi 50$$

$$V_b = V_{pk} \cdot \cos\left(w_e t - \frac{2\pi}{3}\right) \qquad V_{pk} = 1$$

$$V_c = V_{pk} \cdot \cos\left(w_e t + \frac{2\pi}{3}\right)$$

Please draw the signal waveforms viewed in dq reference frame for

a) dq reference frame is rotating at 50 Hz (↺)

$\boxed{abc2dq}$ $j = (f_d + j f_q) \cdot e^{j\theta}$

$\boxed{\begin{matrix} V_a = \\ V_b = \\ V_c = \end{matrix}}$ We define this

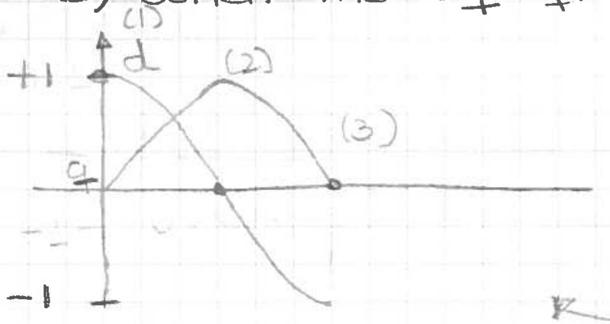
$$V_{dq} = abc2dq\,(f_a, f_b, f_c)$$

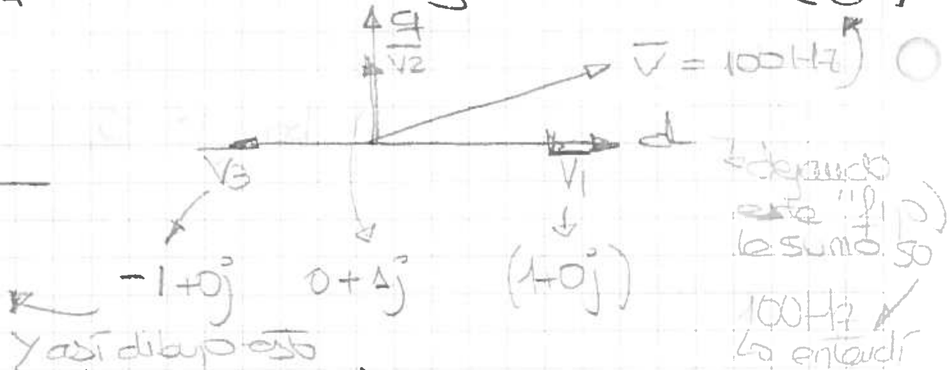
$$f_d = \frac{2}{3}\left(f_a \cos(\theta) + f_b \cdot \cos(\theta - 120) + f_c \cdot \cos(\theta + 120)\right)$$

$$f_q = \frac{2}{3}\left(-f_a \cdot \sin(\theta) - f_b \cdot \sin(\theta - 120) - f_c \cdot \sin(\theta + 120)\right)$$

$$V_{dq} = f_d + j f_q$$

b) When the dq-frame is rotating at −50Hz (↶)





∘ Transform the Va, Vb, Vc signals in 2 to alpha-β reference frame.

(Demostration) I'm not going to do it

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ 1/2 & 1/2 & 1/2 \end{bmatrix} \times \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$\boxed{V_\alpha} = V_a - \frac{V_b}{2} - \frac{V_c}{2} \quad ; \quad \boxed{V_\beta} = V_b \cdot \frac{\sqrt{3}}{2} - V_c \cdot \frac{\sqrt{3}}{2}$$

∘ For the following 3-phase signals

$$V_a = V_{pk} \cdot \cos\left(w_e t + \frac{\pi}{6}\right)$$
$$V_b = V_{pk} \cdot \cos\left(w_e t - \frac{2\pi}{3} + \frac{\pi}{6}\right) \qquad w_e = 2\pi 50$$
$$V_c = V_{pk} \cdot \cos\left(w_e t + \frac{2\pi}{3} + \frac{\pi}{6}\right) \qquad V_{pk} = 1$$

Please draw its space vector at time $t = \frac{1}{50}$; what is the amplitude of this space vector?

$$V_a = V_{pk} \cos\left(2\pi 50 \frac{1}{50} + \frac{\pi}{6}\right) = \sqrt{3}/2 \qquad \boxed{\text{RAD}}$$
$$V_b = V_{pk} \cos\left(2\pi - \frac{2\pi}{3} + \frac{\pi}{6}\right) = 0$$
$$V_c = V_{pk} \cos\left(2\pi + \frac{2\pi}{3} + \frac{\pi}{6}\right) = -\sqrt{3}/2 \qquad \boxed{\text{DEG}}$$

$$\vec{f}_{t=0} = \frac{2}{3}\left(\frac{\sqrt{3}}{2} \cdot e^{j0} - \frac{\sqrt{3}}{2} \cdot e^{-j120}\right) = \frac{2}{3}\left(\frac{\sqrt{3}}{2} - \frac{\sqrt{3}}{2}\left(\cos 120 - j\,\text{sen} 120\right)\right)$$

$$= \frac{2}{3}\left(\frac{\sqrt{3}}{2} - \frac{\sqrt{3}}{2}\cos 120 + \frac{\sqrt{3}}{2} \cdot \text{sen} 120\, \vec{j}\right) = 1 \angle 30^\circ \quad !!$$

es igual que
$\cos(-120) + j(\text{sen}-$

- Transform the following power eq. in $\boxed{\alpha-\beta}$ frame to $\boxed{dq}$ frame.

$$P = V_{\alpha\beta}\,(I_{\alpha\beta})^*$$

where $(I_{\alpha\beta})^* = (I_\alpha + j I_\beta)^* = I_\alpha - j I_\beta$

The relationship between the $\alpha-\beta$ frame and the dq frame is: $\boxed{f_{\alpha\beta} = f_{dq}\cdot e^{j\theta}}$

$\cos\theta - j\sin\theta$

$P = V_{\alpha\beta}(I_{\alpha\beta})^*$ $\qquad f_{\alpha\beta} = f_{dq}\cdot e^{j\theta}$

$P = (V_{dq}\cdot e^{j\theta})(I_{dq}\cdot e^{j\theta})^* = V_{dq}\cdot e^{j\theta}\cdot(I_{dq})^*(e^{j\theta})^* =$

$= V_{dq}\, I_{dq}^*$

↳ Think the power doesn't depend on position

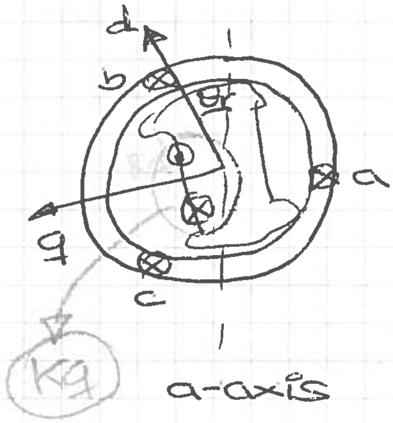
$f_\alpha + j f_\beta$

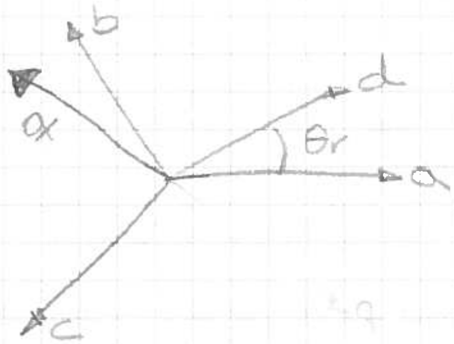
$(f_d + j f_q)\cdot e^{j\theta}$

$$\boxed{\begin{aligned} f_\alpha &= f_d \\ f_\beta &= f_q \end{aligned}}$$

Problem 2

A sketch of a synchronous machine is shown belowe





$(f_d + jf_q)\cdot e^{j\theta}$

- Please describe how the mutual inductance between phase a and phase b is obtained

$$M_{asbs} = L_{aad}\cdot Re\left(\frac{e^{j\theta}}{e^{j0}}\right)\left(\frac{e^{j\theta}}{e^{j120}}\right) + L_{aaq}\cdot Re\left(\frac{e^{j(\theta-90)}}{e^{j0}}\right)\left(\frac{e^{j(\theta-90)}}{e^{j120}}\right)$$

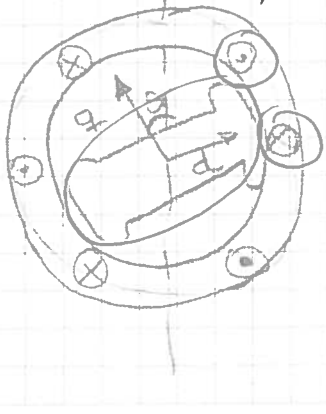
$$= L_{aad}\cdot\cos\theta\cdot\cos(\theta-120) + L_{aaq}\cdot\cos(\theta-90)\cdot\cos(\theta-90-120) =$$

$$= L_{aad}\cdot\cos\theta\cdot\cos(\theta-120) + L_{aaq}\cdot\sin\theta\cdot\sin(\theta-120)$$

- How the mutual inductance between the rotor winding and the stator phase-a winding is obtained?

$$M_{askq} = M_{skq}\cdot Re\left(\frac{e^{j(\theta r+90)}}{e^{j0}}\right) Re\left(\frac{e^{j(\theta r+90)}}{e^{j(\theta r+90)}}\right) = M_{sk}\cdot\cos(\theta r+9 \; = -M_{sk}\cdot\sin(\theta r$$

- Please explain from the physical point of view, for such a machine, why the eq. $\boxed{dq \text{ axis}}$ inductances will be position independent?



They rotate together, at the same speed, so airgap doesn't change and hence inductance doesn't change

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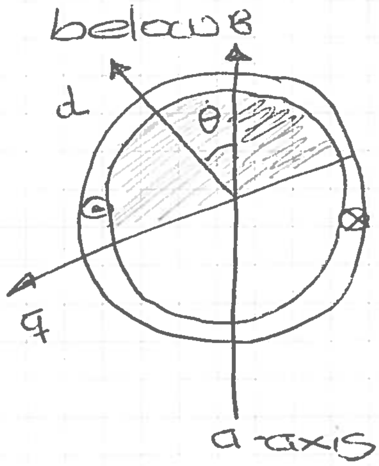
A simple single-phase PM machine is shown below



⊳ it is single phase, so 1 (⊗ ⊙)

- Please show its instantaneous torque waveform when the machine delivers max torque for a given sinusoidal armature current. Please also show the current wave form in relation of the rotor pos.

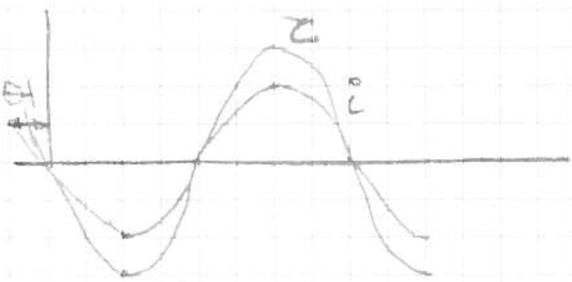
OK

$i = -I_m \cdot \sin(\theta + \theta t)$ → 270°

$\tau = p \cdot i \times \lambda_{mpm} (-\sin\theta) \Rightarrow$ max torque $\sin(270°) = -1$

$\theta = \omega t$; $270° = 3\pi/2$

$\boxed{\tau = i \, p \cdot \lambda_{mpm}}$ OK



- Does the inductance value have any influence on the output torque? Please explain

$\tau_{ave} = \frac{1}{2} p I_m \lambda_{mpm} \cos\theta t$

$\tau = p i \cdot \lambda_{mpm} (-\sin\theta)$

⊳ No influence

"The power is influence by inductance"

- If the armature current contains a 3th harmonic. Will this 3th harmonic current component produce any torque? What is the inst. and average torque corresponding to this harmonic current?

$\tau = p \cdot i \lambda_{pm} (-\sin\theta)$

i = has a 3th harmonic.

$\tau = p\lambda_{pm} \cdot I_m [-\sin(\theta + \theta t) + \sin 3\theta][-\sin\theta]$

$= p\lambda_{pm} I_m [\sin(\theta + \theta t) \cdot \sin\theta - \sin\theta \cdot \sin 3\theta]$

The 3th harmonic contributes

$-\sin\theta \cdot \sin 3\theta = \frac{\cos 4\theta - \cos 2\theta}{2}$ will interact with the rotor $\left(\frac{d}{dt}(\lambda_{pm} \cdot \cos\theta)\right)$ → 4th and 2th harmonic

$T_{ave} = \frac{1}{2\pi}\int_0^{2\pi} \tau \, d\theta = \frac{1}{2\pi}\int_0^{2\pi} \frac{\cos 4\theta - \cos 2\theta}{2} \, d\theta$

$= 0$

I have no average torque, it is a waste, we try to avoid this.

| Ripe and no gain |

oTvo examen

Question 1 (– Lecture 2)

- Please draw the reference frame axes for abc-referene frame, dq rotating reference frame, and afa-bet stationary reference frame.
- Suppose you have the following three phase voltages:

$$V_a = V_{pk}\cos\left(\omega_e t + \frac{\pi}{6}\right)$$

$$V_b = V_{pk}\cos\left(\omega_e t - \frac{2\pi}{3} + \frac{\pi}{6}\right)$$

$$V_c = V_{pk}\cos\left(\omega_e t + \frac{2\pi}{3} + \frac{\pi}{6}\right)$$

Where $\omega_e = 2\pi \cdot 50$

At time $t = 0$, please draw the space vector (also called the general vector) for the above abc-system. Please draw the space vector again at time $t = \frac{1}{300}$.

- Please roughly indicate what is the waveform in afa-bet reference frame and in a dq-reference frame that rotates at 50 (Hz).

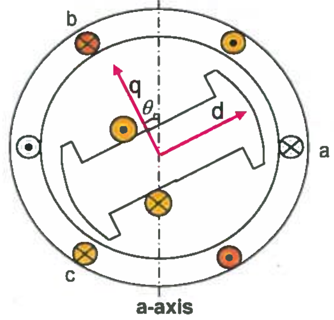
Question 2 (– Lecture 2)

Using the space vector (also called the general vector) method to describe how different reference frame transformation matrices are obtained

- Please write the expressions for the space vectors expressed in the abc-reference frame, and in a rotating dq reference frame.
- Please tell how these two vectors are related to each other.
- Please then indicate how the transformation matrices between abc-2-dq, and dq-2-abc may be obtained.
- When the space vector expressed in the abc-reference frame is known, how the instantaneous phase b variable may be obtained from the known space vector?
- If the dq-frame is a rotating reference frame and it rotates at a speed of $-2\pi * 10$ radian per second. For a balanced set of 3-phase voltages at a frequency of 50 Hz, what are the voltage waveforms in this rotating dq reference frame? Suppose at t=0, the voltage space vector is aligned with the phase-a axis, and the d-axis is also aligned with the phase-a axis.

Question 3 (– Lecture 3 & 4)

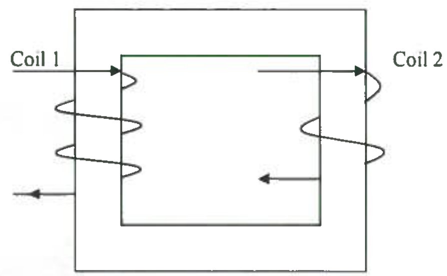
Given such a motor drawing as below



- Please describe how the mutual inductance between phase-b and phase-c is obtained.
- How the mutual inductance between the rotor winding and the stator phase-b is obtained
- Please explain from the physical point of view, for such a machine, why the equivalent d, q-axes inductances will be position independent?
-

Question 4 (– Lecture 1, 4 & 5)

There is a transformer with two coils sketched as below.



- Please express the flux linkage for coil 1 using the coils 1 self-inductance (L1) and coil 1 and coil 2 mutual inductance (M)
- Suppose coil 1 has N1 turns, and coil 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, which parameters and variables related to coil 2 are affected by the turns ratio transformation?

- Please give the voltage and flux linkage equations for coil No.2 after turns ratio transformation.

Question 5 (– Lecture 5)

Regarding the Simulink example model discussed in lecture 5 (P20-25).

- Please write down the voltage and flux linkage equations on the d-axis of this machine.
- Please explain how the equations could be modeled in Simulink.
- Please tell is there any initial conditions to be set in the Simulink model?
- Please tell what is the mechanical equation that should be used?
- Please give the machine equation in steady state.
- What is the rated voltage for the rotor field winding based on the data given on P20?

Question 6 (– Lecture 6)

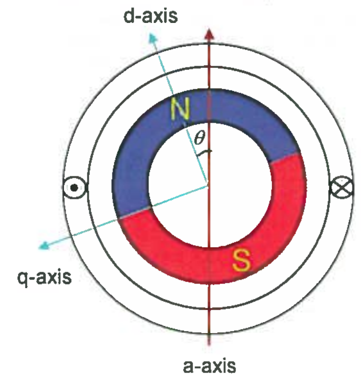
- For an induction machine, its stator self-inductance matrix is (slide P11)

$$\begin{bmatrix}\lambda_{as}\\ \lambda_{bs}\\ \lambda_{cs}\end{bmatrix} = \underline{L_s}\cdot\begin{bmatrix}i_{as}\\ i_{bs}\\ i_{cs}\end{bmatrix} = \begin{bmatrix} L_{ls}+L_{ms} & -\frac{L_{ms}}{2} & -\frac{L_{ms}}{2}\\ -\frac{L_{ms}}{2} & L_{ls}+L_{ms} & -\frac{L_{ms}}{2}\\ -\frac{L_{ms}}{2} & -\frac{L_{ms}}{2} & L_{ls}+L_{ms}\end{bmatrix}\cdot\begin{bmatrix}i_{as}\\ i_{bs}\\ i_{cs}\end{bmatrix}$$

  Please explain **<u>from the physical point of view</u>**, why there is a co-efficient -1/2 before the mutual inductance.
- Is the leakage inductance a constant? For the main inductance and the leakage inductance, which one is more important and is more predominant?
- Why the speed related coefficient in the rotor side voltage equation is onl $(\omega_b-\omega_r)$? (Slide P17)
- Please given the induction machine model in steady state and is represented in the afa-bet reference frame.

Question 7 (– Lecture 7)

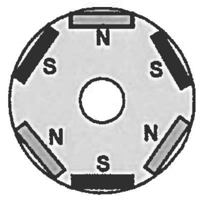
For a single-phase PM machine, as sketched below



- Please describe how its instantaneous torque equation is obtained.
- Does the inductance value have any influence on the output torque for this machine?
- Please sketch how its torque waveform looks like?
- Suppose you have a 3[rd] harmonic component in the winding current, please demonstrate its instantaneous torque waveform and give its average torque equation.
- Suppose you supply the machine with a trapezoidal current waveform instead of sinusoidal, what is the consequence in the output torque? Can you still be able to rotate the machine?

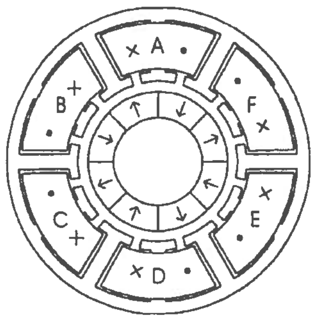
Question 8 (– Lecture 8)

- In the model of a synchronous PM machine, how the rotor PM flux linkage is used in the model? Is its RMS value or its peak value used? Please give explanations.
- Please use the voltage / flux linkage equations of the machine to drive the following: when the PM machine is driven by a DC motor, and is rotating at the rated speed with stator windings open-circuited, what will be the winding terminal voltages measured on the d,q –frame?
- For the following PM machine rotor, please indicate its flux lines and determine if Ld < Lq or Ld > Lq?



Question 9 (– Lecture 9)

Examine the following machine



- o How the rotor magnet flux will link the stator poles? Please draw a sketch.
- o How the flux produced by a stator winding will link its neighboring poles? (Remember that for examining the flux produced by stator winding current, the rotor magnets are replaced by air.)
- o What is the mutual inductance between different windings?
- o What will be the voltage equation for this machine?
- o What will be the torque equation for this machine?

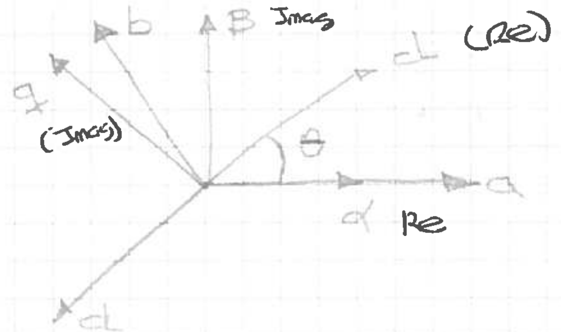
Course: ____________________

Date: ____________ Page: ____ / ____

Exam – All Questions

1

Please draw the reference frame axes for abc reference frame, dq rotating reference frame and α–β stationary reference frame.



Suppose you have the following 3-phase voltages:

$V_a = V_{peak}(\omega_e t + \frac{\pi}{6})$ $\omega_e = 2\pi 50$

$V_b = V_{pk}(\omega_e t - \frac{2\pi}{3} + \frac{\pi}{6})$

$V_c = V_{pk}(\omega_e t + \frac{2\pi}{3} + \pi/6)$

$\bar{f}$

At time $t=0$, please draw the space vector (also called the general vector) for the above abc system. Please draw the space vector again at time $t = 1/300$

$\bar{f} = \frac{2}{3}(f_a \cdot e^{j0} + f_b \cdot e^{j120} + f_c \cdot e^{-j120})$

$t=0$

$f_a = \cos(\omega t + \frac{\pi}{6}) \longrightarrow f_a = \sqrt{3}/2$

$f_b = \cos(\omega t - \frac{2\pi}{3} + \frac{\pi}{6}) \longrightarrow f_b = 0$

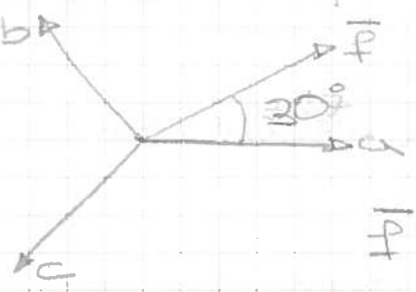
$f_c = \cos(\omega t + \frac{2\pi}{3} + \frac{\pi}{6}) \longrightarrow f_c = -\sqrt{3}/2$

$\bar{f}_{t=0} = \frac{2}{3}(\sqrt{3}/2 \cdot e^{j0} - \sqrt{3}/2 \cdot e^{-j120}) = \frac{2}{3}(\sqrt{3}/2 - \sqrt{3}/2 (\cos 120 -$

$\cos 120 - j\,sen 120$ $-j\,sen120)$ $\sqrt{3}/2$

$- j\,sen 120) = \frac{2}{3}(\frac{3\sqrt{3}}{4} + j\frac{3}{4}) = 1 \angle 30°$

The vector is rotated 30° with the phase-a-axis, which is the reference.



$\bar{f} = \frac{2}{3}\left(\frac{\sqrt{3}}{2}\cdot(\cos 120 + j\sin 120) - \frac{\sqrt{3}}{2}(\cos 120 - j\sin 120)\right)$

$\boxed{t = 1/300}$

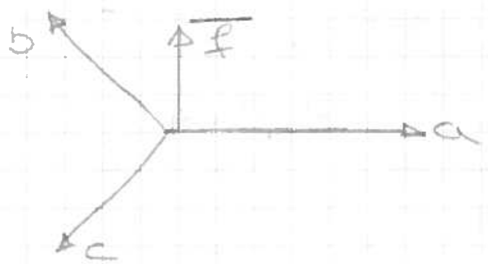
$f_a = 0$

$f_b = \frac{\sqrt{3}}{2}$

$f_c = -\sqrt{3}/2$

$\bar{f} = \frac{2}{3}\left(-\frac{\sqrt{3}}{4} + \frac{\sqrt{3}}{4} + j\left(\frac{\sqrt{3}}{2}\sin 120 + \frac{\sqrt{3}}{2}\sin 120\right)\right) =$

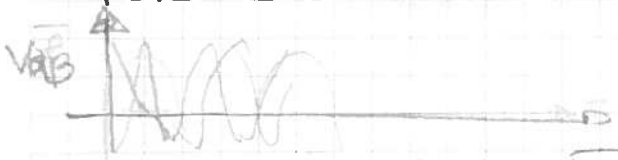
$= 1 \lfloor 90°$



Please roughly indicate what is the waveform in α-β reference frame and in d-q reference frame that rotates at 50 Hz.

$f = 50Hz$

$T = 1/50 = 0{,}02$



↳ mirar en $\boxed{IM}$

d-q

$\boxed{\text{Figura 8.11}}$ ó puedo ver

Course: ______________________________

Date: ______________ Page: _____ / _____

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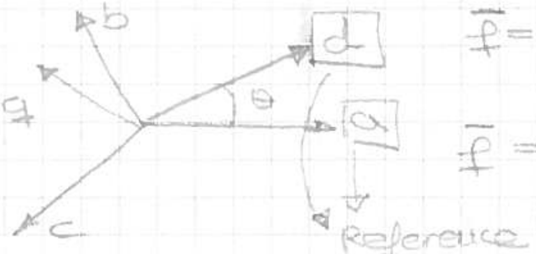
2 Question 2

Using the space vector (also called the general vector) method to describe how different reference frame transformation matrices are obtained.

- Please write the expressions for the space vector expressed in the abc-reference frame and in a rotating dq reference frame.



$$\bar{f} = \frac{2}{3}\left(f_a \cdot e^{j0} + f_b \cdot e^{j120} + f_c \cdot e^{-j120}\right)$$

$$\bar{f} = (f_d + j f_q) \cdot e^{j\theta}$$

- Please tell how these two vectors are related to each other.

θ is the angle rotated between the reference of both vectors.

- Please then indicate how the transformation matrices between abc2dq and dq2abc may be obtained.

Easy

- When the space vector expressed in the abc-reference frame is known, how the instantaneous phase b variable may be obtained from the known space vector?

$$\bar{f} = \frac{2}{3}\left(f_a \cdot e^{j0} + f_b \cdot e^{j120} + f_c \cdot e^{-j120}\right)$$

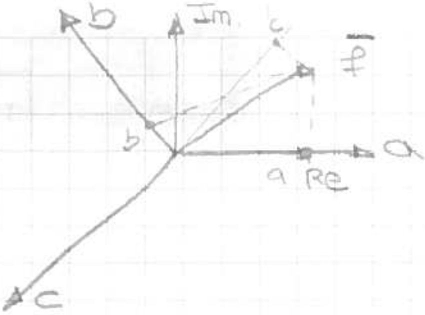
known

a + bi

r /α

The vector and phase a-axis is rotated α which is known.

Kike



$$\bar{f} = \frac{2}{3}\left(f_{a0} \cdot e^{j0} + f_{b0} e^{j120} + f_{c0} \cdot e^{-j240}\right)$$

$\downarrow$

$$\bar{f} + \bar{f}^{*} \cdot e^{j240} = 2 f_{b0} \cdot e^{j120}$$

$\Downarrow$

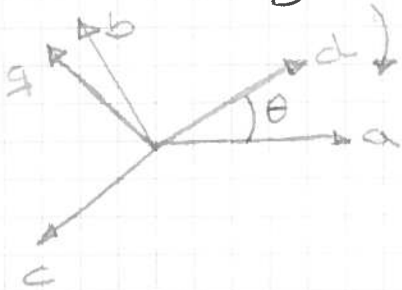
$$\bar{f} \cdot e^{-j120} + \bar{f}^{*} \cdot e^{j120} = 2 f_{b0} \rightarrow \text{we know } f^{*}$$

so we know f_{b0}

$$f_{b0} = f_b - f_0$$

$$f_0 = \frac{1}{3}\left(f_a + f_b + f_c\right) = 0 \quad \text{(in symmetrical systems)}$$

- If the dq frame is a rotating reference frame and it rotates at a speed of $-2\pi 10 \ \frac{rad}{s}$. For a balanced set of 3-phase voltages at a $f_s = 50$ Hz, what are the voltages wave forms in this dq reference frame? Suppose at $t=0$, the voltage space vector is aligned with the phase a-axis, and the d-axis is also aligned with the phase-a axis.



$\omega = -2\pi 10 = -20\pi$

$\rightarrow \omega = 2\pi 50 = 100\pi$

$\downarrow$

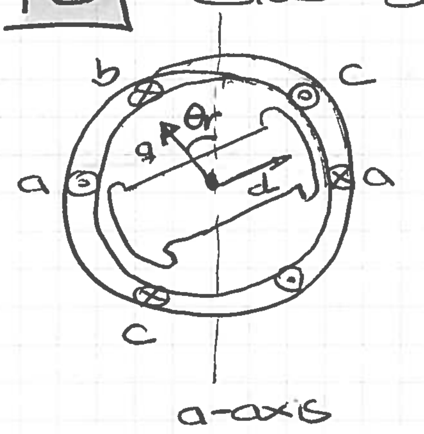
Reference frame, so I fix a $\rightarrow \omega = 0 \ \frac{rad}{s}$

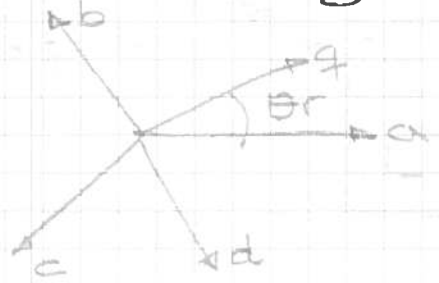
$-20\pi - 100\pi = -120\pi \ ; \ \omega = -120\pi$

$\parallel \theta t$

$$\bar{f} = (f_d + j f_q) \cdot e^{j\theta}$$

3 Given such a motor drawing as below





o Please describe how the mutual inductance between phase b and phase c is obtained.

$$M_{bscs} = L_{aaq} \cdot Re\left(\frac{e^{j\theta r}}{e^{j120}}\right) \cdot Re\left(\frac{e^{j\theta r}}{e^{-j120}}\right) + L_{aad} \cdot Re\left(\frac{e^{j(\theta r - 90)}}{e^{j120}}\right) \cdot Re\left(\frac{e^{j(\theta r-90)}}{e^{-j120}}\right) =$$

$$= L_{aaq} \cdot \cos(\theta r - 120) \cdot \cos(\theta r + 120) + L_{aad} \cdot (\cos\theta \cdot \cos 120 + \operatorname{sen} 90 \cdot \operatorname{sen} 120) \cdot (\cos\theta \cdot \cos 120 - \operatorname{sen} 90 \cdot \operatorname{sen} 120)$$

$$M_{bscsm} = -\frac{1}{2} L_A - L_2 \cdot \cos(2\theta r)$$

o How the mutual inductance between the rotor winding and the stator phase b is obtained

$$M_{bsfdm} = L_{sfd} \cdot Re\left(\frac{e^{j(\theta r - \pi/2)}}{e^{j120}}\right) =$$

$$= L_{sfd}\left(\cos(\theta r - 90) + j \operatorname{sen}(\theta r - 90)\right)\left(\cos 120 - j \operatorname{sen} 120\right) =$$

$$= L_{sfd} \cdot \left(\cos(\theta r - 90) \cdot \cos 120 + \operatorname{sen}(\theta r - 90) \cdot \operatorname{sen} 120\right) =$$

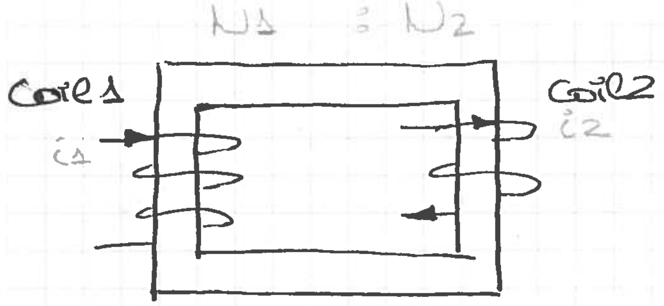
$$= L_{sfd} \cdot \sin(\theta r - 120) \qquad \cos(\theta r - 90 - 120) = \sin(\theta r - 120)$$

o Why the equivalent dq axes inductances are position independent?

$$\lambda = \lambda_l + \lambda_m = L_l \cdot i + L_m \cdot i = \left\{ \lambda_{qm} = L_{mq} \cdot i_q \rightarrow L_{mq} = \frac{3}{2} L_{aaq} \right.$$

position independent

4 There is a transformer with two coils sketched as bellow.



The current goes into the transformer the direction is OK, is positive

- Please express the flux linkage for coil 1 using the coils 1- self inductance (L1) and coil 1 and coil 2 mutual inductance

$\lambda_1 = L_{T1} \cdot i_1 + L_m \cdot i_1 \pm M i_2$

↳ depending of the direction

$\boxed{\lambda_1 = L_{11} \cdot i_1 + M \cdot i_2}$

$= L_{11} \cdot i_1 - M \cdot i_2$

- Suppose coil 1 has N1 turns and coil 2 N2 turns, if it is desired to perform turns of ratio transformation, to let coil 2 to have the same number of turns as coil 1, which parameters and variables related to coil 2 are affected by the turns ratio transformation?

$L_{11} = L_m + L_{1T}$; $L_{22} = \left(\frac{N_2}{N_1}\right)^2 L_m + L_{2T}$; $M = L_m \cdot \frac{N_2}{N_1}$

$\lambda_1 = L_{1T} \, i_1 + L_m \cdot i_1 - L_m \cdot i_2'$

$\lambda_2' = -L'_{2T} \cdot i_2' - L_m \, i_2' + L_m \cdot i_1$

Parameters affected: L_{2T}', R_2', i_2', v_2', λ_2'

↑ Te lo pone en las diapositivas

- Please give the voltage and flux linkage eq. for coil 2 after turns ratio transformation.

$$\lambda_2' = -L'_{2\sigma} \cdot i_2' - L_m \cdot i_2' + L_m \cdot i_1$$

$$v_2' = -R_2' i_2' + \frac{d\lambda_2'}{dt}$$

Check if the sign is ok.

5 Skip it, do it later (simulink model)

6 For an induction machine, its stator self-inductance matrix is:

$$\begin{bmatrix} \lambda_{as} \\ \lambda_{bs} \\ \lambda_{cs} \end{bmatrix} = L_s \times \begin{bmatrix} i_{as} \\ i_{bs} \\ i_{cs} \end{bmatrix} = \begin{bmatrix} L_{ls}+L_{ms} & -L_{ms}/2 & -L_{ms}/2 \\ -L_{ms}/2 & L_{ls}+L_{ms} & -L_{ms}/2 \\ -L_{ms}/2 & -L_{ms}/2 & L_{ls}+L_{ms} \end{bmatrix} \begin{bmatrix} i_{as} \\ i_{bs} \\ i_{cs} \end{bmatrix}$$

? what do U mean?

Please explain from the physical point of view, why there is a coefficient $-\frac{1}{2}$ before the mutual inductance.

$$M_{asbs} = L_{aag} \cdot Re\left(\frac{e^{j\theta}}{e^{j0}}\right) Re\left(\frac{e^{j\theta}}{e^{j120}}\right) + L_{aad} \cdot Re\left(\frac{e^{j(\theta-90)}}{e^{j0}}\right) Re\left(\frac{e^{j(\theta-90)}}{e^{j120}}\right)$$

$L_{aag} = L_{aad}$ (IM) because the airgap is constant so the inductance has the same value in every point = $= -L_{ms}/2$

- Is the leakage inductance a constant? For the main inductance and the leakage inductance which one is more important and is more predominant?

L_{ls} = is a constant

The most predominant L_{ms} (mutual inductance) more important I think is the same answer.

o Why the speed related coefficient in the rotor side voltage equation is $(\omega_e - \omega_r)$?

$\omega_B = \omega_e - \omega_r$ => It is explained.

o Please give the induction machine model in steady state and represented in the α-β reference frame.

Same question as in the exercises

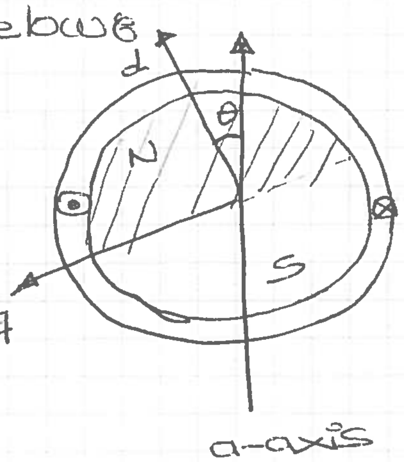
Course:

Date: Page: /

DSE DE STUDERENDES ERHVERVSKONTAKT

$\boxed{7}$

For a single-phase PM machine, as sketched below



∘ Please describe how its instantaneous torque eq. is obtained

$$\tau = \frac{1}{\sqrt{2}} P_{mec} = \frac{1}{\sqrt{2}} \cdot i \frac{d\lambda_{pm}}{dt} = p \cdot i \, \lambda_{mpm} \, (-\sin\theta)$$

$$\downarrow \; i = -I_m \cdot \sin(\theta + \theta t)$$

$$\tau = p I_m \lambda_{mpm} \cdot \sin\theta \cdot \sin(\theta + \theta t) = \frac{1}{2} p I_m \cdot \lambda_{mpm} \times$$

$$\times \left[\cos\theta t - \cos(2\theta + \theta t)\right]$$

∘ Does the inductance value have any influence on the output torque for this machine?

NO

∘ Please sketch how its torque waveform looks like.

→ Like the current

?

∘ Suppose you have a 3^{th} harmonic component in the winding current, please demostrate its instantaneous torque waveform and give its average torque eq.

$\omega = 2\pi f$ → fundamental

$3\omega = 3 \times 2\pi f$ ⇒ 3^{th} harmonic

Average torque = $\frac{1}{2} p I_m \lambda_{mpm} \cdot \cos 3\theta t$

↳ due to 3^{th} harmonic

Ya se ha hecho

∘ Suppose you supply the machine with a trapezoidal current waveform instead of sinusoidal, what is the consequence in the output torque? Can you still be able to rotate the machine? → I think so

?

onda senoidal con armónicos

Yes, but you have to control the seq. of the 3 phases. The torque will be vibrating. a trapez. signal contains a sinusoidal with harmonics.

Therefore the torque will not be cte. It will be vibrating.