Problem 1 (25%)

(1) Please draw the reference frame axes for abc reference frame, dq rotating reference frame, and afa-bet stationary reference frame.

(2) Suppose now you have a set of 3-phase signals as:

$$v_a = V_{pk}\cos(\omega_e t),\quad v_b = V_{pk}\cos\left(\omega_e t - \frac{2\pi}{3}\right),\quad v_c = V_{pk}\cos\left(\omega_e t + \frac{2\pi}{3}\right)$$

where $\omega_e = 2\pi \cdot 50$ and $V_{pk} = 1$

Please draw the signal waveforms viewed in dq-frame for

- when the dq-frame is rotating at 50 Hz (in the anti-clockwise direction which is the positive rotational direction)
- when the dq-frame is rotating at –50Hz (which means it rotates in the negative (clockwise) direction).

(3) Transform the v_a, v_b, v_c signals in (2) to afa-bet reference frame.

(4) For the following 3-phase signals

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

Please draw its space vector at time $t = \frac{1}{50}$ (assuming $\omega_e = 2\pi \cdot 50$). Assuming $V_{pk} = 1$, what is the amplitude of this space vector?

(5) Transform the following power equation represented in afa-bet frame to dq-frame.

$$P = \overline{V}_{\alpha\beta} \cdot \left(\overline{I}_{\alpha\beta}\right)^*,$$

where $\left(\overline{I}_{\alpha\beta}\right)^* = (I_\alpha + jI_\beta)^* = I_\alpha - jI_\beta$, (complex conjugate operation)

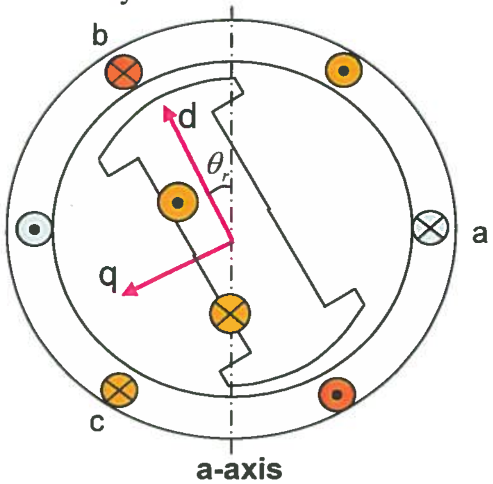
The relationship between the afa-bet frame and the dq-frame may be expressed as:

$$\bar{f}_{\alpha\beta} = \bar{f}_{dq} e^{j\theta}$$

where f stands for an arbitrary signal and θ is the angle between the d-axis and the afa-axis.

Problem 2 **(25%)**

A sketch of a synchronous machine is shown below.

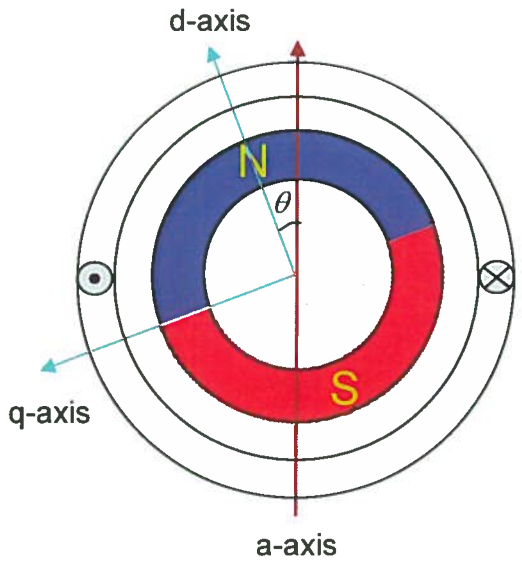


(1) Please describe how the mutual inductance between phase-a and phase-b is obtained?

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

(3) Please explain from the physical point of view, for such a machine, why the equivalent d, q-axes inductances will be position independent?

A simple single-phase PM machine is shown below.



(4) Please show its instantaneous torque waveform when the machine delivers maximum torque for a given sinusoidal armature current. Please also show the current waveform in relation to the rotor position. Please give your arguments.

(5) Does the inductance value have any influence on the output torque? Please explain.

(6) If the armature current contains a 3rd harmonic. Will this 3rd harmonic current component produce any torque? What is the instantaneous and average torque corresponding to this harmonic current?

4

$t=0$

SOLUCION EXAMEN

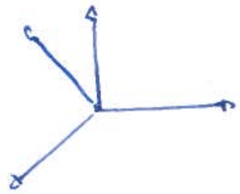
positivo

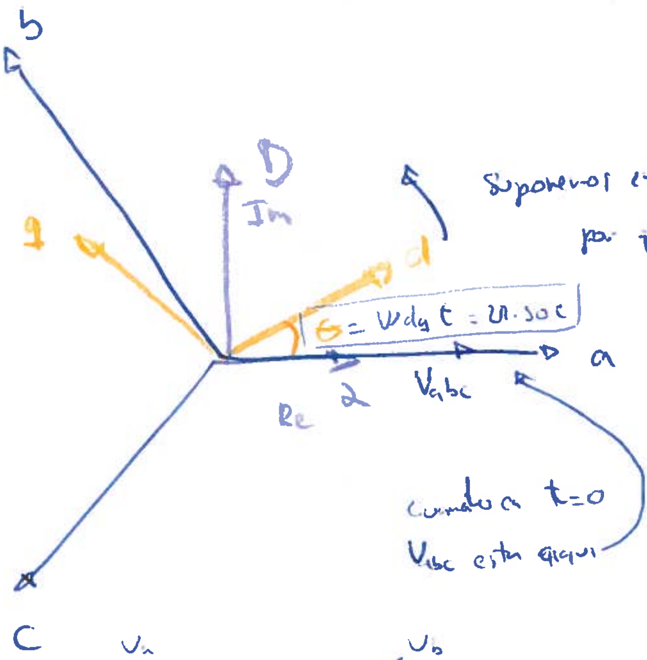
2) $w_e = 2\pi \cdot 50 = rad/s$

frecuency

Vdq como de rapido va el rotor, que velocidad angular tiene.

1)





Suponemos entonces que dq es el rotor por que se esta moviendo y la velocidad sera w_{dq} que en el ej 2 es $w_{dq} = 2\pi \cdot 50$

$$\bar{V}_{abc} = \frac{2}{3}\left(\overset{V_a}{\cos w_e t} + e^{j120^\circ} \overset{V_b}{\cos\left(w_e t - \frac{2\pi}{3}\right)} + e^{-j120^\circ} \overset{V_c}{\cos\left(w_e t + \frac{2\pi}{3}\right)}\right)$$

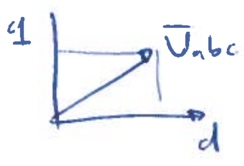
cuando $t=0$

$$V_{abc} = \frac{2}{3}\left[1 + e^{j120^\circ} \cdot \cos\frac{2\pi}{3} + e^{-j120} \cos\frac{2\pi}{3}\right]$$

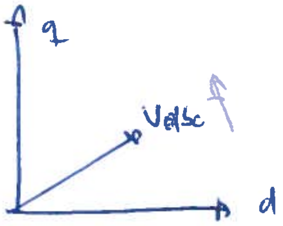
=

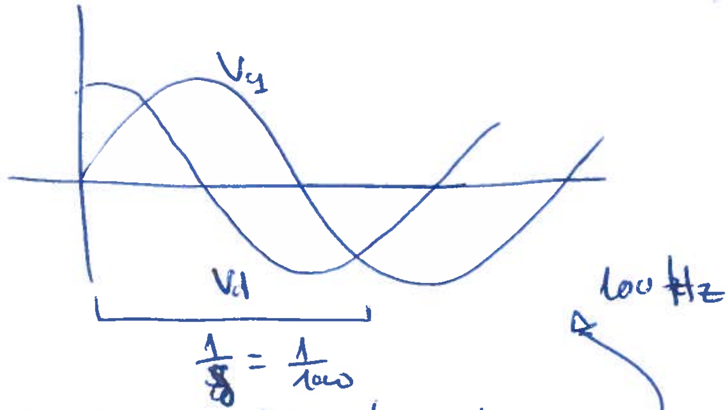
f sustituyendo en el tiempo en diferentes tiempos podemos allar la posicion de Vabc porque va ir rotando

Si el vector es 1



siempre sera 1 $\sqrt{q^2+d^2} = \bar{V}_{abc}$





Cuando estar rotando el vector V a 50 Hz y el eje dq a 50Hz ~~eje~~ en la otra dirección la velocidad entre ambos es de 100 Hz así que

c) $V_{ati} = 2\pi \cdot f = 2\pi \cdot 50 \cdot \frac{1}{50} = \boxed{2\pi = \theta}$

queremos saber la posicion de V_{abc} para $t = \frac{1}{50}$

$V_a = \cos\left(2\pi + \frac{\pi}{6}\right) = \cos \pi/6$

$V_b = \cos\left(\frac{\pi}{6} - \frac{2\pi}{3}\right)$

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

ángulo general de donde hemos partido 2π

tenemos los valores de V_a, V_b y V_c

por lo que tenemos $\underline{V_{abc}}$. $\rightarrow \bar{V}_{ab} = \frac{2}{3}\left(V_a + V_b e^{j120} + V_c e^{-j120}\right)$

2) —

del entehierro siempre es constante, siempre es el mismo para cada
así que la inductancia siempre es la misma.

$\boxed{\text{paginas 3 a 5}}$

4)

la inductancia release ganden store energy pero no influyen

la maxima torque cuando $\Theta = 0$

5)

6)

paginas

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

$\lambda_{mpm} \cos\theta$

$$\tau_{average} = \frac{1}{2\pi} \int_0^{2\pi} \tau \, d\theta$$

$$\frac{d}{dt} (\lambda_{mpm} \cancel{\cos\theta})$$

si derivar

viene de

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

$$= p \lambda_{mpm} I_m [\underbrace{\sin(\theta + \theta_t)\sin\theta)}_{1} - \underbrace{\sin\theta \sin 3\theta}_{\cancel{0}}]$$

viene de

the armonic contribut to de ~~armo~~ torque. sino esto deberia ser cero.

viene de ~~eq~~

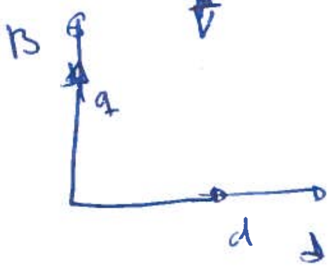
$$-\sin\theta - \operatorname{sen} 3\theta = \frac{\cos 4\theta - \cos 2\theta}{2}$$

the average torque es ~~0~~ total los armonicos no influyen en los torque average.

5)

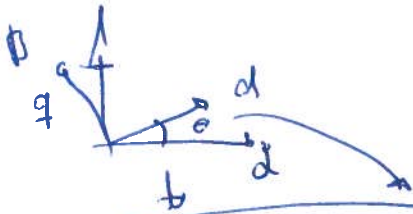
$$P = \bar{V}_{\alpha\beta} \left(\bar{I}_{\alpha\beta} \right)^{*}$$

$\Downarrow$



$$\boxed{\bar{S}_{\alpha\beta} = \bar{S}_{dq}}$$

pero si dq rota



$$\boxed{S_{\alpha\beta} = S_{dq}\, e^{+j\theta}}$$

$\Downarrow$

$$P = \bar{V}_{\alpha\beta} \left(\bar{I}_{\alpha\beta} \right)^{*}$$

$$= \left(V_{dq}\, e^{j\theta} \right) \left(\bar{I}_{dq}\, e^{j\theta} \right)^{*}$$

$\boxed{\text{sustituir}}$

a sabiendo el angulo que difiere podemos con S_{dq} sustituir cualquier valor y solucionarlo

sus

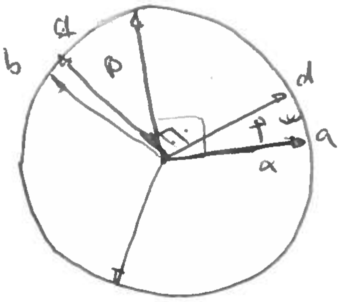
q al final quedaria como $\boxed{\bar{V}_{dq}\, I_{dq}^{*}\, e^{2j\theta}}$ pero la potencia no depende de la posicion, es siempre la misma asi que quitamos $\cancel{e^{2j\theta}}$ y dejamos $\boxed{\bar{V}_{dq} \cdot \bar{I}_{dq}^{*} = P}$

Problem 1

$i(\theta) = \cancel{L_1 + L_2 \cos}(2\theta)$

~~$\theta_r = 0$~~

1)



$V_a = V_{pk} \cdot \cos(\omega_e t)$

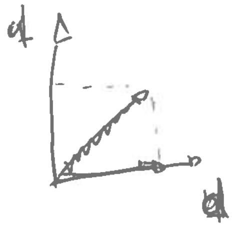
$V_b = V_{pk} \cdot \cos\left(\omega_e t - \frac{2\pi}{3}\right)$

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

$\omega_e = 2\pi 50$

$V_{pk} = 1$

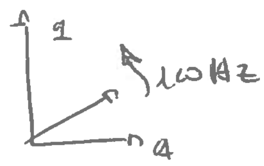
2)



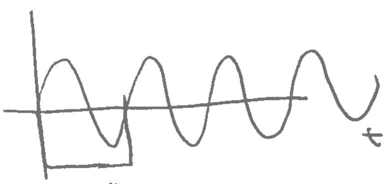
when there have any angle of

$d = 1$

$q = 0$



in the time



$f = 100\ Hz$

in d

3) V_a, V_b, V_c be Zero.

thus the velocity must

$$\begin{bmatrix} f_q \\ f_d \\ f_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos\theta & \cos(\theta - 120) & \cos(\theta + 120) \\ \text{sen}(\theta) & \sin(\theta - 120) & \sin(\theta - 120) \\ 1/2 & 1/2 & 1/2 \end{bmatrix} \begin{bmatrix} f_a \\ f_b \\ f_c \end{bmatrix}$$

~~Baaaaa~~

Cuando es la velocidad es cero

$$S_\alpha = S_d = \frac{2}{3} S_a \cos\theta + \frac{2}{3} S_b \cos(\theta - 120) + \frac{2}{3} S_c \cdot \cos(\theta + 120)$$

Cuando la velocidad es cero

$$S_\beta = S_q = \frac{2}{3} S_a \cdot \sin \operatorname{sen}\theta + \frac{2}{3} S_b(\operatorname{sen}(\theta - 120) + \frac{2}{3} S_c \cdot \operatorname{sen}(\theta + 120)$$

$$S_0 = 0$$

$$S_\alpha = \frac{2}{3} S_a \cos\theta + \frac{2}{3} S_b \cos(\theta - 120) + \frac{2}{3} S_c \cos(\theta + 120)$$

$$S_\beta = \frac{2}{3} S_a \cdot \operatorname{sen}\theta + \frac{2}{3} S_b \operatorname{sen}(\theta - 120) + \frac{2}{3} S_c \sin(\theta + 120)$$

$$S_0 = 0$$

$$V_a = V_{pk} \cdot \cos \omega t \quad = V_{pK}$$

$$V_b = V_{pK} \cdot \cos(-120)$$

$$V_c = V_{pK} \cdot \cos(120)$$

$$S_\alpha = \frac{2}{3} V_{pK} + \frac{2}{3} (V_{pK} \cdot \cos(-120) \cdot \cos(-120) + \frac{2}{3} V_{pK} \cdot \cos(-120) \cdot \cos(-120) =$$

$$S_\alpha = \frac{2}{3} \left(V_{pK} + V_{pK} (\cos - 120)^2 + V_{pK} \cdot (\cos 120)^2 \right) = \boxed{\frac{2}{3} V_{pK} \left(1 + (\cos -120)^2 + (\cos 120)^2 \right.}$$

$$S_\beta = \frac{2}{3} \cancel{V_{pk} \operatorname{sen} 0}^{\,0} + \frac{2}{3} V_{pk} (\cos + 120) \cdot (\operatorname{sen}(\theta 120)) + \frac{2}{3} V_{pk} \cdot \cos + 120 \cdot \operatorname{sen} 120$$

$$\boxed{S_\beta = \frac{2}{3} V_{pK} \left(\cos(120) \cdot \operatorname{sen}(120) + \cos(120) \cdot \operatorname{sen}(120) \right)}$$

(4) please draw its space vector at time $t = \frac{1}{50}$

$w_e = 2\pi \cdot 50$

$V_{pk} = 1$ the ampli

- the amplitude will be allways 1. $\boxed{V_{pk} = 1}$

-

$$V_a = V_{pk} \cdot \cos\left(2\pi \cdot \cancel{\frac{50}{50}} + \frac{\pi}{6}\right)$$

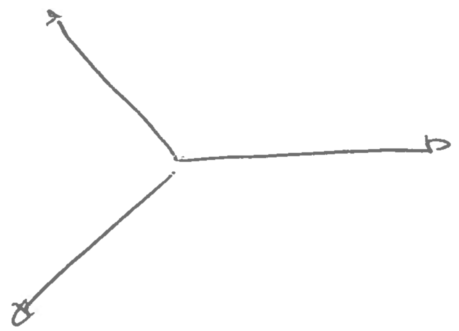
$$V_b = V_{pk} \cdot \cos\left(2\pi \cancel{\frac{50}{50}} + \frac{2\pi}{3} + \frac{\pi}{6}\right)$$

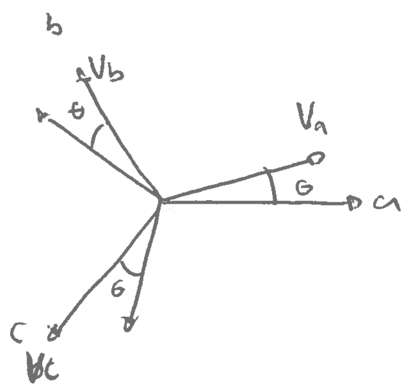
$$V_c = V_{pk} \cdot \cos\left(2\pi \cancel{\frac{50}{50}} + \frac{2\pi}{3} + \frac{\pi}{6}\right)$$

$\cancel{V_a = \frac{\pi}{6}} \rightarrow \boxed{V_a = V_{pk} \cdot \cos \frac{\pi}{6}}$

$\cancel{V_b = \frac{8\pi}{6} \quad \frac{4\pi}{6} - \frac{1}{6}} = -\frac{3\pi}{6} \quad \# \boxed{V_{pk} \cos\left(-\frac{\pi \cdot 3}{6}\right) = V_b}$

$\boxed{V_c = V_{pk} \cdot \cos \frac{5\pi}{6}}$





$\theta = \frac{\pi}{6}$

(5) transform the following power equation represented in α-β frame to d-q frame.

$$P = \bar{V}_{\alpha\beta} \cdot (\bar{I}_{\alpha\beta})^*$$

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

the relationship betwen the ~~α~~-β frame dq frame may be expressed as

$$\bar{f}_{\alpha\beta} = \bar{f}_{dq}\, e^{j\theta}$$

$$P = \bar{V}_{\alpha\beta} \cdot (I_{\alpha\beta})^*$$

$$\begin{cases} V_{\alpha\beta} = V_{dq}\, e^{j\theta} \\ I_{\alpha\beta} = I_{dq}\, e^{j\theta} \end{cases}$$

$$\boxed{P = \bar{V}_{dq}\, e^{j\theta} \cdot (\bar{I}_{dq}\, e^{j\theta})^*}$$

the power dont depend of the position so is allways the same.

$$\boxed{P = V_{dq} \cdot (I_{dq})^*}$$