Exercise: Speed variation and vector control

I- Preliminary Issues

1) Make a constitution schematic of an AC speed variator.

2) Explain the principle of scalar control of induction machine.

II- Scientific document analysis

Let's consider the following document excerpt ("extrait de") from the article: **"Vector Control of Permanent Magnet Synchronous Motor Based On Sinusoidal Pulse Width Modulated Inverter with Proportional Integral Controller",** Kaushik Jash, Pradip Kumar Saha, Goutam Kumar Panda, *Int. Journal of Engineering Research and Applications* www.ijera.com *ISSN : 2248-9622, Vol. 3, Issue 5, Sep-Oct 2013, pp.913-917*

1) Synthesize the principle of machines vector control

2) Which mathematic transformations are necessary for machines vector control?

3) List the advantages and disadvantages of machines vector control

4) Knowing that for a PMSM the torque equation becomes:
   $\boldsymbol{T_e = \left(\frac{3}{2}\right) p \, \emptyset \, i_q}$ with $\boldsymbol{p}$ number of pole pairs, $\emptyset$ flux linkage and $\boldsymbol{i_q}$ Torque-producing component of stator current,

   What is the condition to make vector control possible?

VECTOR CONTROL

Vector control is also known as decoupling or field orientated control. Vector control decouples three phase stator current into two phase d-q axis current, one producing flux and other producing torque. This allows direct control of flux and torque. So by using vector control, the PMSM is equivalent into a separately excited dc machine. The model of PMSM is nonlinear. So by using vector control, the model of PMSM is linear.

The scheme of vector control is based on coordinate transformation and motor torque equation by means of controlling stator current to improve the performances of motor, and is widely used in the field of PMSM servo system. In the control of a three-phase PMSM system, modulated current is supplied to the A-B-C stator windings to build rotated magnetic field and drive the rotator. The vector control strategy is formulated in the synchronously rotating reference frame. By Clarke–Park transformations and inverse transformations the equivalent relations of currents are built among a.b,c stator coordinates, stationary α, β axis coordinates and rotating d, q axis coordinates.

Fig.2. shows a vector diagram of the PMSM. Phase a is assumed to be the reference. The instantaneous position of the rotor (and hence rotor flux) is at θr from phase a. The application of vector control, so as to make it similar to a DC machine, demands that the quadrature axis current i_q be in quadrature to the rotor flux. Consequently i_d has to be along the rotor flux since in the reference used i_d lags i_q by 90°.

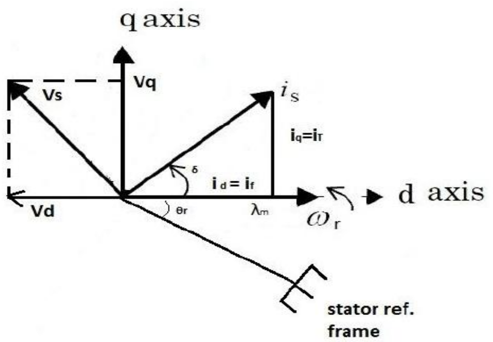


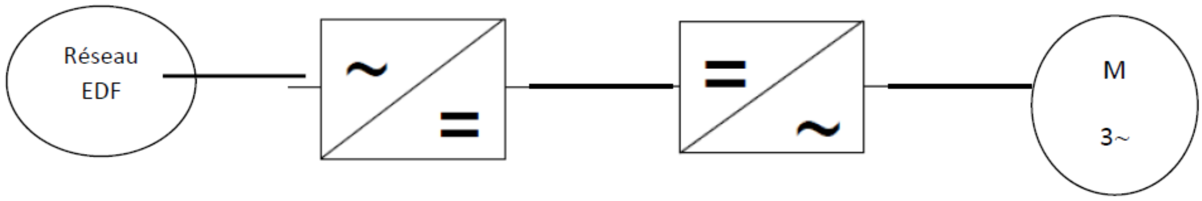
Fig.2. Phasor diagram of PMSM

CORRECTION:

Exercise: Speed variation and vector control

I- Preliminary Issues

1) Make a constitution schematic of an AC speed variator.



2) Explain the principle of scalar control of induction machine.

Son principe est de maintenir V/f=constant ce qui revient à garder le flux constant. Le contrôle du couple se fait par action sur le glissement. En effet, d'après le modèle établi en régime permanent, le couple maximum s'écrit :

$$C_{max} = \frac{3p}{2N'_r}\left(\frac{V_s}{\omega_s}\right)^2$$

On constate donc que le couple est directement proportionnel au carré du rapport de la tension sur la fréquence statorique. Cette quantité est proportionnelle au flux. Pour s'en convaincre, il suffit de partir de la relation de Faraday pour une spire supposée sans résistance (on la trempe dans l'hélium liquide) :

$$v = \frac{d\phi}{dt}$$

Si le flux est alternatif sinusoïdal, en l'exprimant à l'aide d'une grandeur complexe, on obtient :

$$\underline{\phi} = \Phi_{max} \cdot e^{j\omega t + \phi}$$

La formule de Faraday s'écrit alors :

$$\underline{V} = \frac{d\underline{\phi}}{dt} = j\omega \cdot \Phi_{max} \cdot e^{j\omega t + \phi} = j\omega\underline{\phi}$$

et donc, en prenant les modules des expressions complexes :

$$V = \omega \cdot \phi \Rightarrow \phi = \frac{V}{\omega}$$

En maintenant V/f=constant et en faisant varier la fréquence statorique, on déplace la courbe du couple électromagnétique (en régime quasi-statique) de la machine asynchrone comme le montre la figure 5.47 de la page 231.

En fait, garder le rapport constant revient à garder le flux constant. Quand la tension atteint sa valeur maximale, on commence alors à faire décroître ce rapport ce qui provoque une diminution du couple que peut produire la machine. On est en régime de « défluxage ». Ce régime permet de dépasser la vitesse nominale de la machine, on l'appelle donc aussi régime de survitesse.

À basse vitesse, la chute de tension ohmique ne peut pas être négligée. On compense alors en ajoutant un terme de tension V0 (figure 6.1).

Le schéma de commande de la figure 6.1 présente la manière de réguler la vitesse de la machine en reconstituant la pulsation statorique à partir de la vitesse et de la pulsation rotorique. Cette dernière, qui est l'image du couple de la machine est issue du régulateur de vitesse. Si la machine est chargée, la vitesse a tendance à baisser, le régulateur va fournir plus de couple (donc plus de glissement) afin d'assurer cet équilibre. La pulsation statorique est donc modifiée pour garder cet équilibre. La tension est calculée de manière à garantir le mode de contrôle en V/f de la machine.

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2) Which mathematic transformations are necessary for machines vector control?

Clarke–Park transformations and inverse transformations

3) List the advantages and disadvantages of machines vector control.

commande vectorielle
modèle régime transitoire + précise et rapide + contrôle du couple à l'arrêt - chére (capteur de position du rotor/stator ou estimateur de vitesse, DSP, ...
contrôle des grandeurs en amplitude et en *phase*

4) Knowing that for a PMSM the torque equation becomes:

$\boldsymbol{T_e} = \left(\frac{3}{2}\right) \boldsymbol{p} \, \emptyset \, \boldsymbol{i_q}$ with $\boldsymbol{p}$ number of pole pairs, $\emptyset$ flux linkage and $\boldsymbol{i_q}$ Torque-producing component of stator current,

What is the condition to make vector control possible?

- id has to be along the rotor flux.
- Vector control is only possible when precise knowledge of the instantaneous rotor flux is available.