PMAC Drives: Induced EMF, Per-Phase Equivalent Circuit, Control

- Induced EMF in Stator Windings under Balanced Sinusoidal Steady State
- Induced EMF in the Stator Windings due to Rotating rotor-flux distribution
- Induced EMF in the Stator Windings due to Rotating stator-current space vector
- Net induced EMF in the stator windings
- Per-Phase Equivalent Circuit
- Controller and Power Processing Unit
- Hysteresis current control

Induced EMF in Stator Windings under Balanced Sinusoidal Steady State

1. $\vec{B}_r(t)$ rotates with an instantaneous speed of $\omega_m(t)$. This rotating flux-density distribution cuts the stator windings to induce a back-emf.

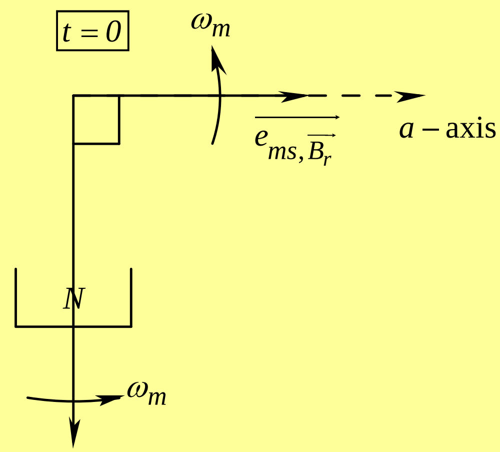
2. The rotating flux-density distribution due to rotating $\vec{i}_s(t)$ space vector induces an emf in the stator windings.

Induced EMF in the Stator Windings due to Rotating $\overrightarrow{B_r}$ $(\overrightarrow{e_{ms,\overrightarrow{B_r}}})$

$$\overrightarrow{e_{ms}}(t) = j\omega(\frac{3}{2}\pi r \ell \frac{N_s}{2})\overrightarrow{B_{ms}}(t)$$

with substitutions in the current case:

$$\overrightarrow{e_{ms,\overrightarrow{B_r}}}(t) = j\omega_m(\frac{3}{2}\pi r \ell \frac{N_s}{2})\overrightarrow{B_r}(t)$$



Voltage Constant:

$$k_E\left[\frac{V}{rad/s}\right] = k_T\left[\frac{Nm}{A}\right] = \pi\, r\, \ell\, \frac{N_s}{2}\hat{B}_r$$

$$\overrightarrow{e_{ms,\overrightarrow{B_r}}}(t) = j\frac{3}{2}k_E\omega_m\angle\theta_m(t) = \frac{3}{2}k_E\omega_m\angle(\theta_m(t)+90^{o})$$

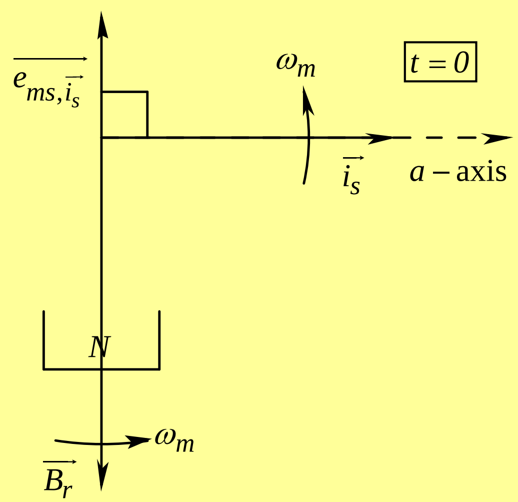
Induced EMF in the Stator Windings due to Rotating $\vec{i_s}$ $(\overrightarrow{e_{ms,\vec{i_s}}})$

$$\overrightarrow{e_{ms}}(t) = j\omega L_m \overrightarrow{i_{ms}}(t)$$

with substitutions:

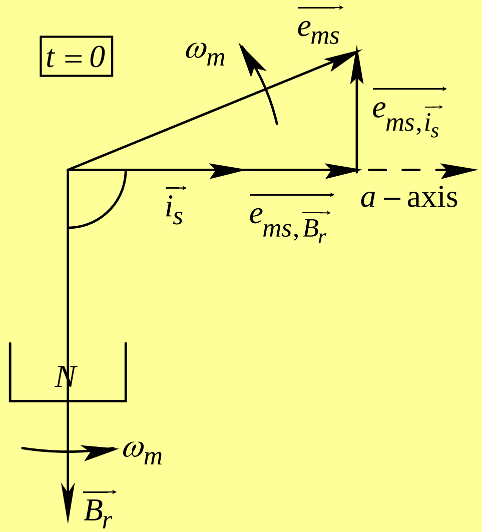
$$\overrightarrow{e_{s,\vec{i_s}}}(t) = j\omega_m L_m \vec{i_s}(t)$$

$$= \omega_m L_m \hat{I}_s \angle(\underbrace{\theta_m(t) + 90^o}_{\theta_{i_s}(t)} + 90^o)$$

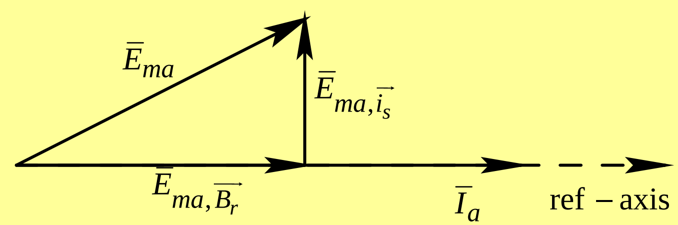


L_m : Magnetizing inductance

Net induced EMF in the stator windings $\left(\overrightarrow{e_{ms}}(t) \right)$



Space vector diagram



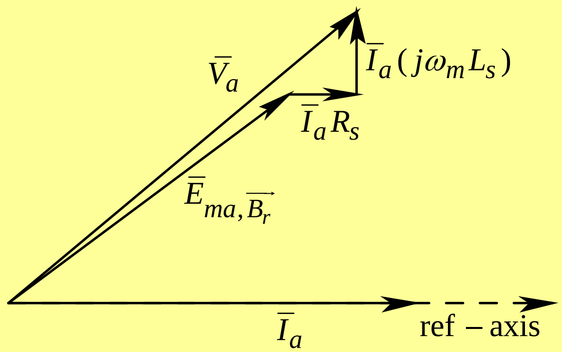
Phasor diagram for phase-*a*

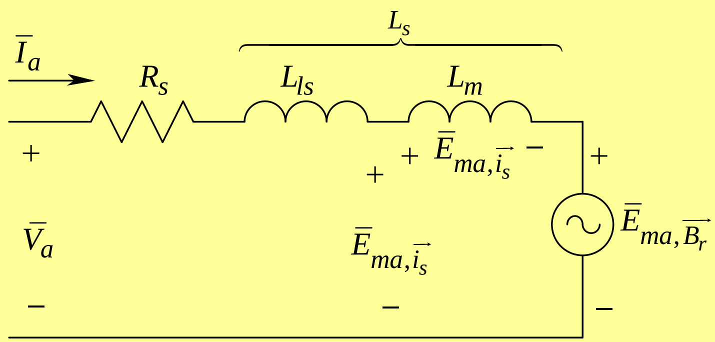
$$\overrightarrow{e_{ms}}(t) = \overrightarrow{e_{ms}}_{,\vec{B}_r}(t) + \overrightarrow{e_{ms}}_{,\vec{i}_s}(t)$$

$$\overrightarrow{e_{ms}}(t) = \frac{3}{2} k_E \omega_m \angle(\theta_m(t) + 90^{o}) \quad + \quad j\omega_m L_m \vec{i}_s(t)$$

$$\bar{E}_{ma} = k_E \omega_m \angle(\theta_m(t) + 90^{o}) + j\frac{2}{3}\omega_m L_m \bar{I}_a$$

Per-Phase Equivalent Circuit





$$\hat{E}_{a,\vec{B}_r} = \frac{2}{3}\hat{E}_{ms,\vec{B}_r} = k_E\,\omega_m = \hat{E}_{fa}$$

$$L_s = L_{\ell s} + L_m$$

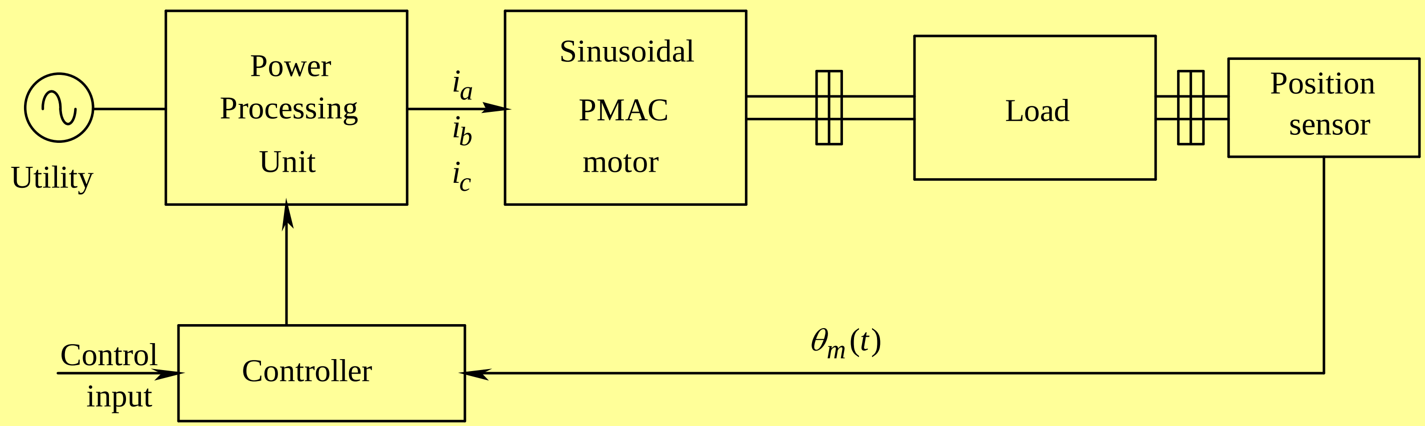
$$\bar{V}_a = \bar{E}_{fa} + j\omega_m L_s \bar{I}_a + R_s \bar{I}_a$$

R_s can often be ignored

L_m : Magnetizing inductance

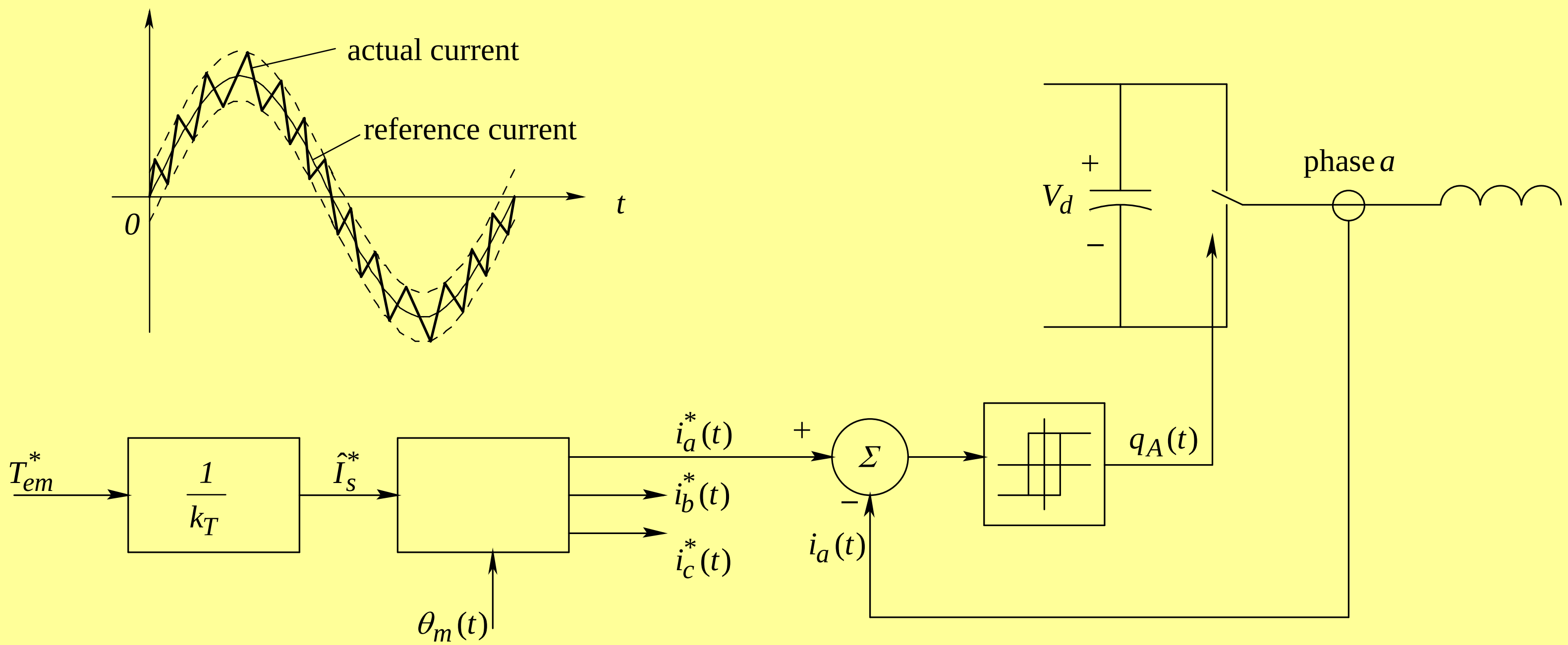
L_{ls} : Stator leakage inductance

Controller and Power Processing Unit



- Controller determines desired phase currents based on desired torque and motor position

Hysteresis current control



Summary

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