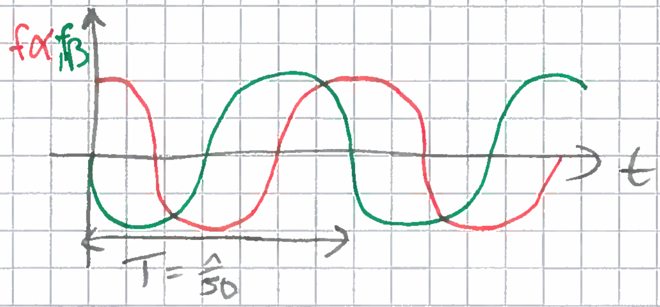
Re-exam 22th Feb 13

Problem 1:

1) $\bar{f} = e^{-j\omega_e t} = \cos(\omega_e t) - j\sin(\omega_e t)$

$f_\alpha = Re(\bar{f}) = \cos(\omega_e t)$

$f_\beta = Im(\bar{f}) = -\sin(\omega_e t)$

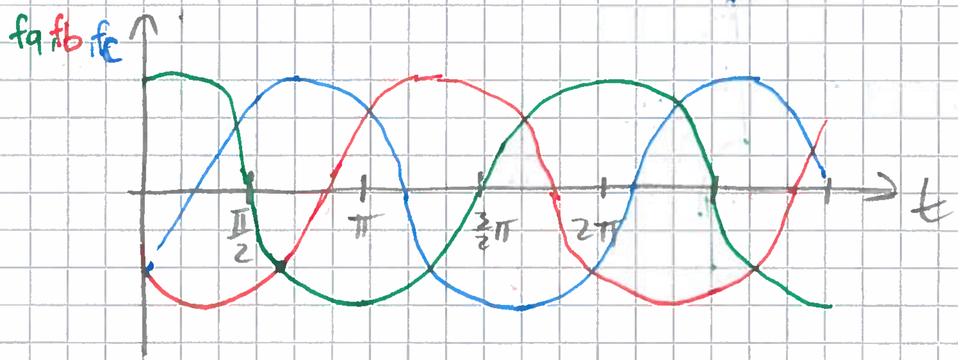


2) $f_{a0} = Re\left(\frac{\bar{f}}{e^{j0°}}\right) = Re\left(e^{-j\omega_e t}\right) = \cos(\omega_e t)$

$f_{b0} = Re\left(\frac{\bar{f}}{e^{j120°}}\right) = Re\left(e^{-j(\omega_e t + 120°)}\right) = \cos(\omega_e t + 120°)$

$f_{c0} = Re\left(\frac{\bar{f}}{e^{j120°}}\right) = Re\left(e^{-j(\omega_e t - 120°)}\right) = \cos(\omega_e t - 120°)$

In balanced systems: $f_a = f_{a0}$
$f_b = f_{b0}$
$f_c = f_{c0}$



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3.) $\cancel{\bar{V}_{\alpha\beta} = \bar{V}_{dq}\, e^{j\theta}}$

$\Leftrightarrow \cancel{\bar{V}_{dq} = \frac{\bar{V}_{\alpha\beta}}{e^{j\theta}}} =$ $\qquad \theta = 2\pi 50$

$\cancel{f_d = Re\left(\frac{f}{e^{j\theta}}\right)}$

$$f_d = Re\left(\frac{\bar{f}}{e^{j\theta}}\right) = Re\left(\frac{e^{-j\theta}}{e^{j\theta}}\right) = Re\left(e^{-j2\theta}\right)$$

$$= \cos(2\theta) = \cos(2\pi 100$$

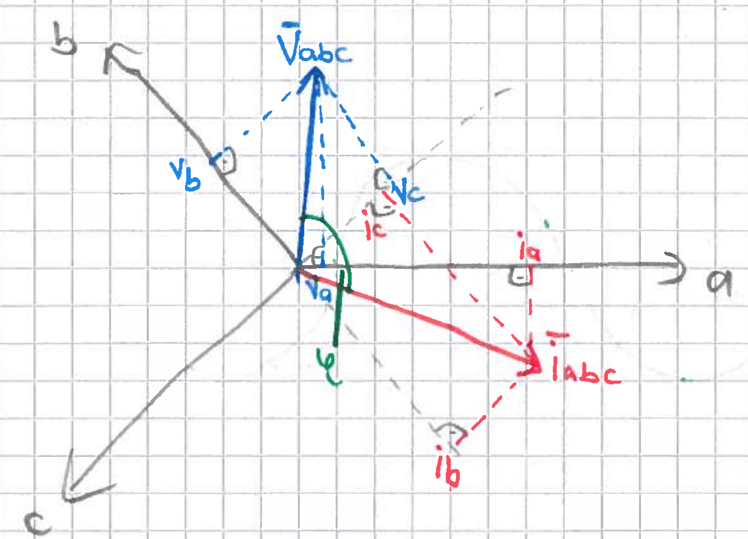
$$f_q = Re\left(\frac{\bar{f}}{e^{j(\theta+90°)}}\right) = Re\left(\frac{e^{-j\theta}}{e^{j(\theta+90°)}}\right) = Re\left(e^{-j(2\theta+90°)}\right)$$

$$= \cos(2\theta + 90°)$$

$$= -\sin(2\theta)$$

$$= -\sin(2\pi 100\, t)$$

4.)



if current $i_a = I_{pn}\cos(\omega_e t - \varphi)$ and the parameters of the RL-circuit are identical, then:

$i_b = I_{pn}\cos(\omega_e t - \frac{2\pi}{3} - \varphi)$

$i_c = I_{pn}\cos(\omega_e t + \frac{2\pi}{3} - \varphi)$

③

Power: $\bar{f}_{\alpha\beta} = \bar{f}_{dq}\, e^{j\theta}$ and $\bar{f}^{*}_{\alpha\beta} = \bar{f}^{*}_{dq}\, e^{-j\theta}$

$$p = v_a i_a + v_b i_b + v_c i_c$$
$$= \frac{3}{2}\left(v_d i_d + v_q i_q + \underbrace{\cancel{v_0 i_0}}_{=0}\right)$$

Balanced system, since same RL parameters → hence $v_0 = 0$, $i_0 = 0$

$$= \frac{3}{2} Re\left[(v_d + j v_q)(i_d + j i_q)^{*}\right]$$
$$= \frac{3}{2} Re\left[(v_d + j v_q)(i_d - j i_q)\right]$$
$$= \frac{3}{2} Re\left[(v_d + j v_q)\cdot e^{j\theta}\cdot(i_d - j i_q)\, e^{-j\theta}\right]$$
$$= \frac{3}{2} Re\left[\underbrace{\bar{v}_{dq}\cdot e^{j\theta}}_{\bar{v}_{\alpha\beta}} \cdot \underbrace{\bar{i}^{*}_{dq}\cdot e^{-j\theta}}_{\bar{i}^{*}_{\alpha\beta}}\right]$$
$$= \frac{3}{2} Re\left[(v_\alpha + j v_\beta)\cdot(i_\alpha - j i_\beta)\right]$$
$$= \frac{3}{2} Re\left[v_\alpha i_\alpha + v_\beta i_\beta + j(v_\beta i_\alpha - v_\alpha i_\beta)\right]$$
$$= \frac{3}{2}\left(v_\alpha i_\alpha + v_\beta i_\beta\right)$$

Problem 2:

1) By vector projection of the L_q and L_d values on the ~~certain~~ repective stator axes ~~→ eq equation~~

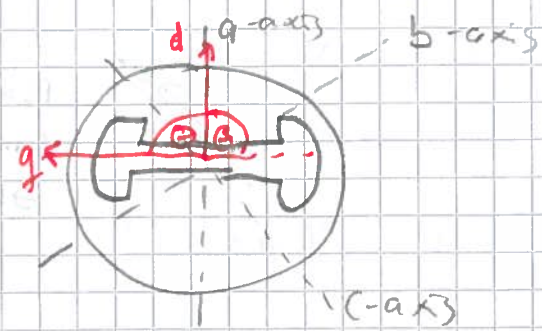
2)
$$M_{bs\,cs} = L_{aad}\, Re\left(\frac{e^{j\theta}}{e^{j120°}}\right) Re\left(\frac{e^{j\theta}}{e^{j-120°}}\right) + L_{aaq}\, Re\left(\frac{e^{j(\theta+90°)}}{e^{j120°}}\right) Re\left(\frac{e^{j(\theta+90°)}}{e^{j-120°}}\right)$$
$$= L_{aad} \cos(\theta - 120°)\cos(\theta + 120°) + L_{aaq} \sin(\theta - 120°)\sin(\theta + 120°)$$

with $L_{aad} = L_1 + L_2$, $L_{aaq} = L_1 - L_2$

$$= L_1\left(\cos(\theta - 120°)\cos(\theta + 120°) + \sin(\theta - 120°)\sin(\theta + 120°)\right)$$
$$+ L_2\left(\cos(\theta - 120°)\cos(\theta + 120°) - \sin(\theta - 120°)\sin(\theta + 120°)\right)$$
$$= L_1 \cdot \cos(\theta - 120° - (\theta + 120°)) + L_2 \cos(\theta - 120° + \theta + 1\ldots$$
$$= \ldots$$

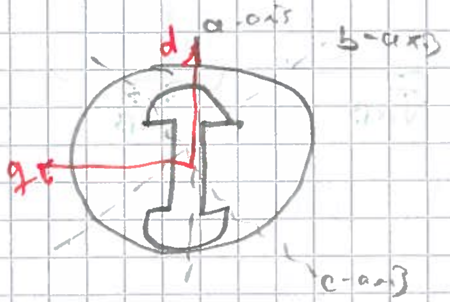
(4) Max. value if $M_{bscs} = -\frac{1}{2}L_1 - L_2$

$\Rightarrow$ obtained if $\Theta = -90°$ and $\Theta = 90°$



Min. value if $M_{bscs} = -\frac{1}{2}L_1 + L_2$

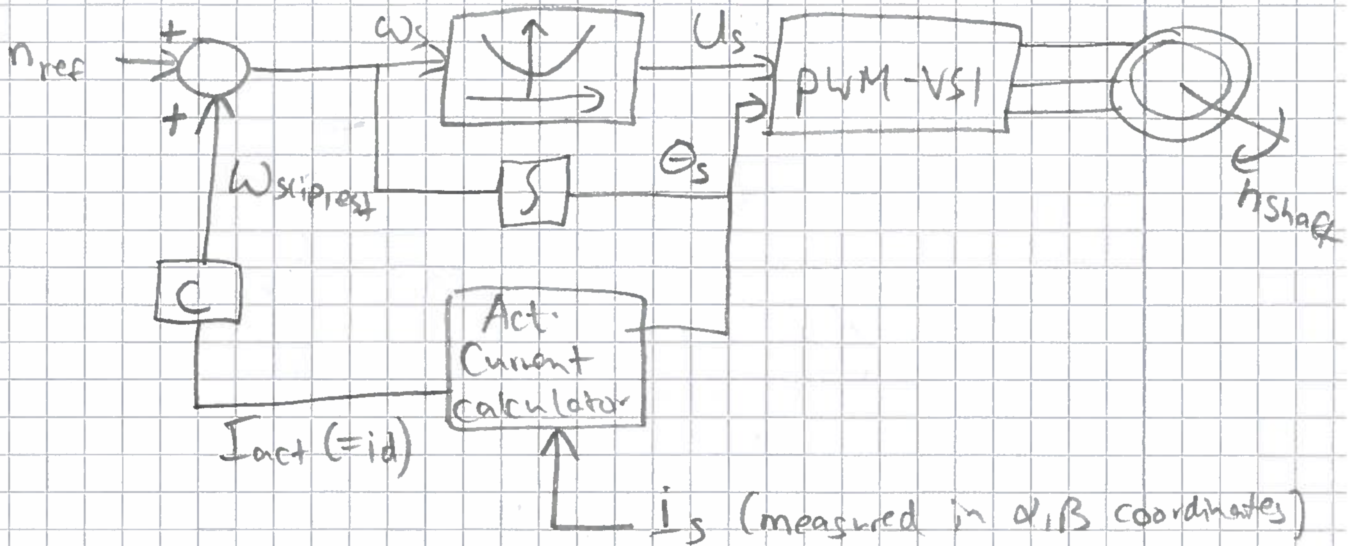
$\Rightarrow$ obtained if $\Theta = 0°$ and $\Theta = 180°$



3.) see „20 Jan 12" problem 2, ex. 6 !

4.) No, because the zero component of the current is only related to the leakage flux which will not affect the torque !

(5) Problem 3:



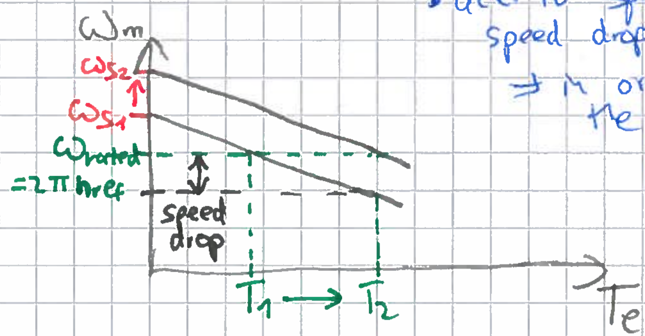
- Targets: • constant shaft speed for any load torque!
  • constant stator flux for high torque production capability

→ Target 2 obtained by adapt the stator voltage U_s for any frequency in oder to:

$$|\bar{\lambda}_s| = \left|\frac{\bar{U}_s}{\omega_s}\right| = ¢ \quad (\text{assuming } r_s = 0)$$

→ Target ~~2~~ 1 obtained by adapting the stator frequency at load changes in oder to keep $n_{mech} = ¢$

• acc. to speed-torque-characteristic the speed drops at increasing torque
⇒ in order to compensate this, increase the stator frequency and hence the synchronous speed



• obtained by following constraints: $T_e \sim \omega_{slip}$

$T_e \sim i_{sd}$

$\Rightarrow \omega_{slip} \sim i_{sd}$

→ measure stator current
→ calculate active part of it
→ use $\omega_{slip} - i_{sd}$ relationship with rated values to calculate an estimated slip that is added to the reference speed in order to calculate the supplied frequency

⑥

Steady state:

- at no load there is no estimated slip because $i_{sd} = 0$
  → motor runs at syn. speed which is then the rated speed
- at load the slip is estimated and added to the reference speed
  → syn. speed acc. to the required ref. speed

Dynamics

- sudden load step will force the speed to drop
  → but $i_{sd} \sim T_e$ increases which will increase the estimated slip
  → hence, the syn. speed is adapted after a while (depends on PI controller of the system) in order have the reference speed again which is normally not exactly the ref. speed but with an error $< 2\%$ (due to non-exact rated values)

2.)

- Rated speed as reference speed
- Rated voltage and rated frequency for calculating the supplied voltage depending on the stator frequency
- Rated active current (hence rated current + power factor) for calculating the estimated slip

(- Rated power in order to calculate rated torque for checking the model)