Emnekode	: MAS409
Kandidatnr.	: 505
Dato	: 22.05.19
Ark nr.	: 1 av 4

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a. $P = \sqrt{3} \cdot V_{LL,rms} \cdot I_{rms} \cdot \cos\varphi$

$10000\,W = \sqrt{3} \cdot V_{LL,rms} \cdot \frac{3}{2} \cdot \frac{1}{\sqrt{2}} \cdot 30A \cdot 0{,}85$

$\Downarrow$

$V_{LL,rms} = \underline{\underline{213{,}46V}}$

b. Diagram 2 is correct. The inductance in the motor gives a positive contribution to the phase angle of the current.

c. $\vec{B}_{net} = \mu_0 \cdot \frac{N_s}{2 \cdot l_g} \cdot \vec{i} = 4\pi \cdot 10^{-7} \cdot \frac{90}{2 \cdot 0{,}0015} \cdot \frac{3}{2} \cdot 30\angle 120^\circ = \underline{\underline{1{,}6965\angle 120^\circ}}$

d. Number 2 is correct. Magnitude of $B_{bb'}$ is twice that of $B_{aa'}$ and $B_{cc'}$ and both $B_{aa'}$ and $B_{cc'}$ are negative.

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2 a Referencing V_{d-} to 0V(N) and V_{d+} to 400V gives a voltage on A of 400V when $v_{ctrl} > v_{tri}$ and 0V if not.

~~$k_A = \frac{400V \cdot 0{,}7 \cdot 0{,}35 \cdot 10^{-4} \cdot T}{400V \cdot T} = 0{,}7$~~

~~The average voltage $\overline{v_{aN}} = 400V \cdot 0{,}7 = 280V$~~

$$k_A = \frac{V_{d+} \cdot 0{,}7 + V_{d-} \cdot (1-0{,}7)}{V_d} = \frac{400 \cdot 0{,}7 + 0 \cdot 0{,}3}{400} = \underline{\underline{0{,}7}}$$

$$\overline{v_{aN}} = V_d \cdot k_A = 400V \cdot 0{,}7 = \underline{\underline{280V}}$$

b $\overline{v_{bN}} = V_d \cdot (1-0{,}7) = 400 \cdot 0{,}3 = \underline{\underline{120V}}$

$\overline{v_o} = \overline{v_{aN}} - \overline{v_{bN}} = 280V - 120V = \underline{\underline{160V}}$

c. $\overline{v_o} - \overline{i_o} \cdot R_a - E_a = 0$

⇓

$$\frac{\overline{v_o} - E_a}{R_a} = \overline{i_o} = \frac{160V - 40V}{0{,}30\Omega} = \underline{\underline{400A}}$$

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2 d $V_d - \bar{V}_0 = L_a \cdot \frac{\Delta i_{o,ripple}}{\Delta t}$

$400V - 160V = 0{,}005H \cdot \frac{\Delta i_{o,ripple}}{0{,}7 \cdot 0{,}5 \cdot 10^{-4} s}$

$\Downarrow$

$\Delta i_{o,ripple} = \frac{400-160}{0{,}005} \cdot 0{,}7 \cdot 0{,}5 \cdot 10^{-4} = \underline{\underline{1{,}68A}}$

e bipolar switching, thus $f_{tri} = f_{out}$.

$f_{tri} = \frac{1}{0{,}5 \cdot 10^{-4}} = 20000 = \underline{\underline{20kHz}}$

$f_{out} = 20kHz$

3 a $\bar{V}_{ph} = \frac{\bar{V}_{LL}}{\sqrt{3}} = \frac{460}{\sqrt{3}} = \underline{\underline{265{,}58V}}$

$\bar{V}_{TH} = \frac{j \cdot 18\Omega}{0{,}58\Omega + j \cdot 0{,}32\Omega + j \cdot 18\Omega} \cdot 265{,}58 = \underline{\underline{260{,}81V}}$ (eq 16)

$Z_{TH} = \frac{j\,18\Omega \cdot (0{,}58\Omega + j \cdot 0{,}32\Omega)}{0{,}58\Omega + j\,0{,}32\Omega + j\,18\Omega} = \underline{\underline{0{,}6505\angle 30{,}70^\circ\ \Omega}}$

$R_{TH} = Re(Z_{TH}) = 0{,}5594\Omega$ $X_{TH} = Im(Z_{TH}) = 0{,}3321\Omega$

$n_{sync} = \frac{60 \cdot 60}{\frac{4}{2}} = 1800\ rpm$

$n_n = n_{sync} \cdot (1-s) = 1800 \cdot \frac{100-3{,}5}{100} = \underline{\underline{1737\ rpm}}$

$\tau_{ind} = \tau_{load} = \frac{3 \cdot \frac{0{,}07}{0{,}035} \cdot 260{,}81^2}{1800 \cdot \frac{2\pi}{60} \cdot \left(\left(0{,}5594 + \frac{0{,}07}{0{,}035}\right)^2 + (0{,}3321 + 0{,}386)^2 \right)} = \underline{\underline{306{,}43Nm}}$ (eq. 18)

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3 b

$$\tau_{max} = \frac{3 \cdot 260{,}81^2}{2 \cdot 1800 \cdot \frac{2\pi}{60} \cdot (0{,}5594 + \sqrt{0{,}5594^2 + (0{,}3321 + 0{,}386)^2})}$$

$$= \underline{\underline{368{,}33\,Nm}} \quad (eq\,(10))$$

$$s_{\tau_{max}} = \frac{0{,}07}{\sqrt{0{,}5594^2 + (0{,}3321 + 0{,}386)^2}} = \underline{\underline{0{,}077}} \quad (eq\,(9))$$

$$n_{\tau_{max}} = n_{sync} \cdot (1 - 0{,}077) = \underline{\underline{1661{,}4\,rpm}}$$

c. The starting torque occurs when

$$n_m = 0 \Rightarrow s_{start} = \underline{\underline{1}}$$

$$\tau_{ind(s=1)} = \tau_{start} = \frac{3 \cdot 0{,}07 \cdot 260{,}81^2}{1800 \cdot \frac{2\pi}{60} \cdot ((0{,}5594 + 0{,}07)^2 + (0{,}3321 + 0{,}386)^2)} \quad (eq\,(8))$$

$$\tau_{start} = \underline{\underline{83{,}71\,Nm}}$$

d The motor corresponds with Nema class A due to a low start-up torque and a high torque close to synchronous speed.
A high R_2 increases the starting torque (torque at high slip). This corresponds with rotor 1. Our motor with a low stating torque corresponds with rotor 2.
The double cage rotor (3) achieves both high starting torque and nominal torque.
Rotor 1 - class D / Rotor 2 - Class A / Rotor 3 - Class C