EE 458/533 – Power Electronics Controls
Homework 6

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1 Modeling the Digital Controller

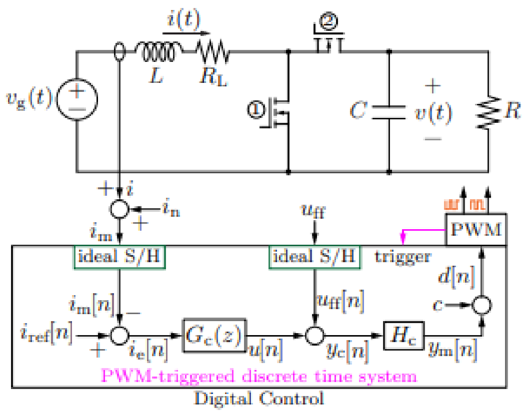


Figure 1: Feed Forward Boost Converter

1.1 Discretize the controller

$$K_i = \omega_{cg} R_L$$

$$K_p = \omega_{cg} L$$

$$G(s) = \frac{d(s)}{e(s)} = K_p + \frac{K_i}{s}$$

$$\begin{aligned}
G(z) = \left.\frac{d(s)}{e(s)}\right|_{s=\frac{2}{T_{samp}}\frac{1-z^{-1}}{1+z^{-1}}} &= K_p + \frac{K_i}{\frac{2}{T_{samp}} \cdot \frac{1-z^{-1}}{1+z^{-1}}} \\
&= K_p + \frac{K_i}{\frac{2}{T_{samp}} \cdot \frac{(1-1/z)}{(1+1/z)}} \\
&= K_p + \frac{K_i}{\frac{2}{T_{samp}} \cdot \frac{(z-1)/z}{(z+1)/z}} \\
&= K_p + \frac{K_i}{\frac{2}{T_{samp}} \cdot \frac{z-1}{z+1}}
\end{aligned}$$

$$G(z) = K_p + \frac{K_i T_{samp}\,(z+1)}{2(z-1)}$$

$$G(z) = \frac{2K_p(z-1) + K_i T_{samp}\,(z+1)}{2(z-1)}$$

$$G(z) = \frac{2K_p z - 2K_p + K_i T_{samp} z + K_i T_{samp}}{2(z-1)}$$

$$G(z) = \frac{(2K_p z + K_i T_{samp}) z - 2K_p + K_i T_{samp}}{2(z-1)}$$

1.2 PLECS Model

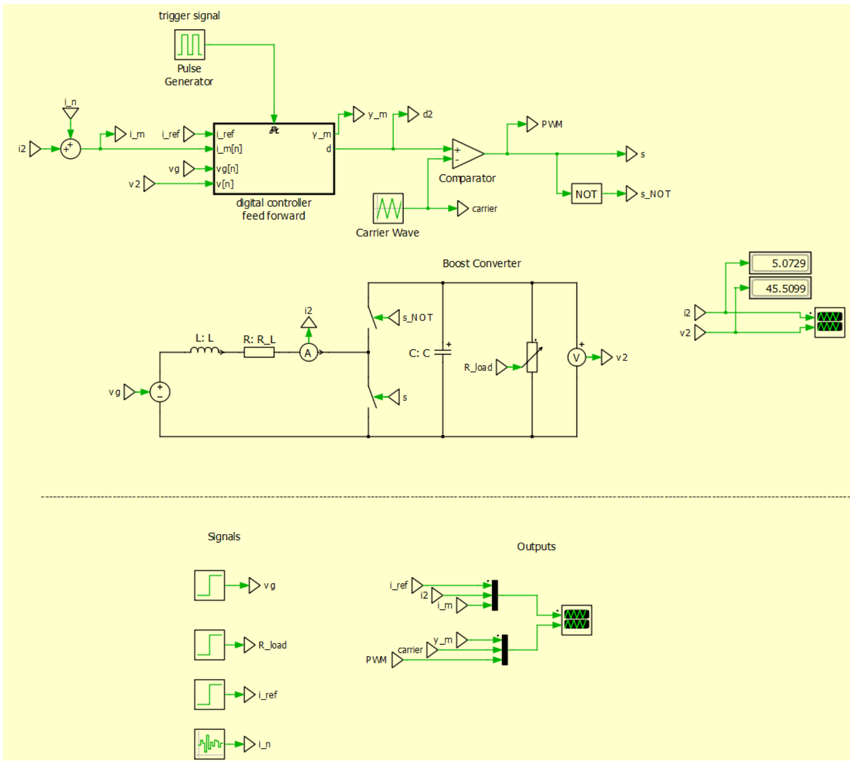


Figure 2: Boost Converter Top Level View

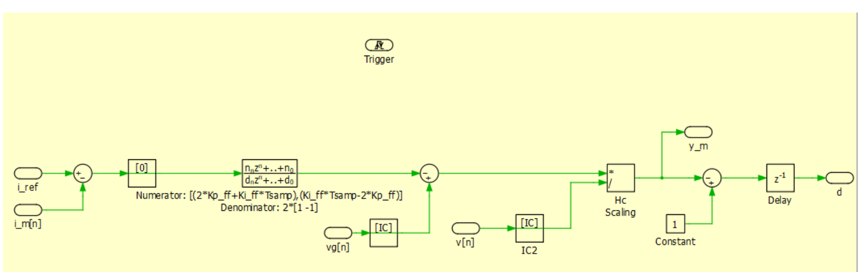


Figure 3: Digital Controller

1.3 Digital Controller PWM Response

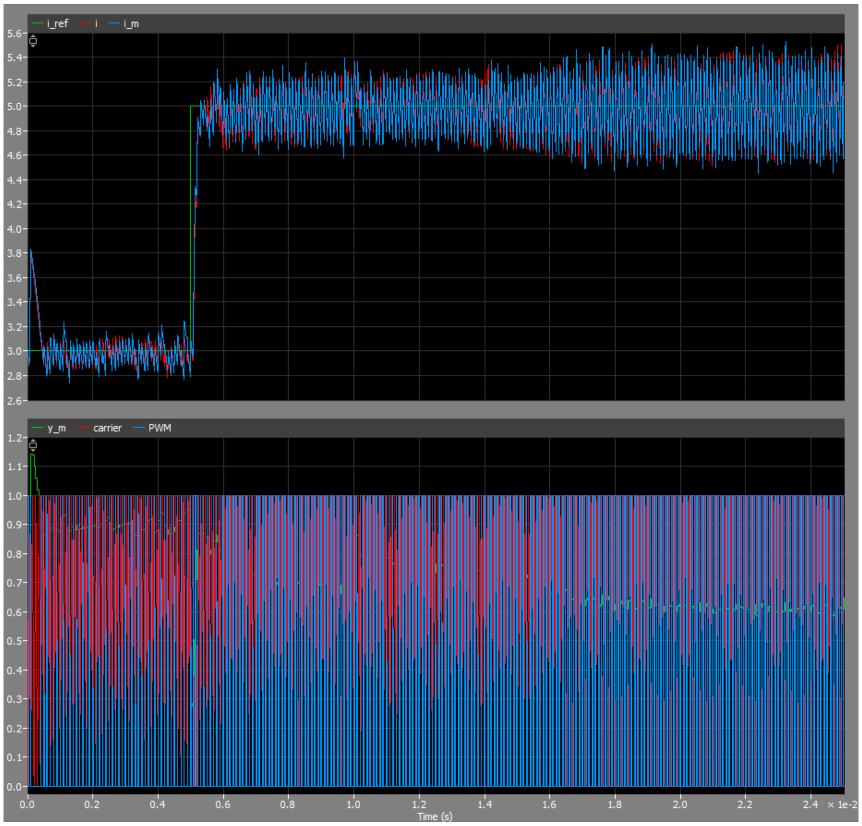


Figure 4: Feed Forward [[iref, i, i_m], [y_m, carrier, PWM]]

2 4-Pole Machine

Part i)
Clarification, each coil sees two times the respective back emf. So coil A sees $2e_a$, coil B sees $2e_b$, and coil C sees $2e_c$.

notation).

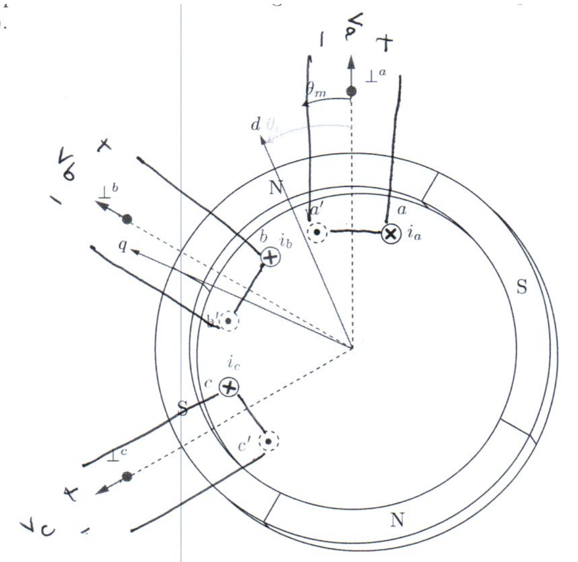


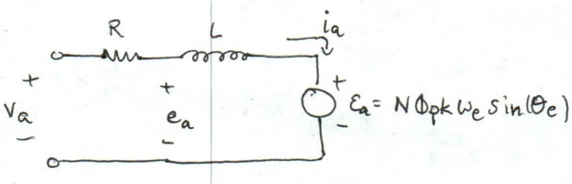
Figure 2: Magnetic ring with two pole pairs.

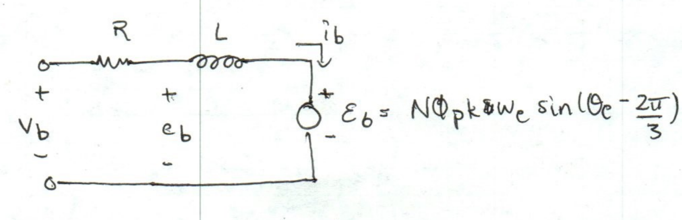
Flux linkage λ must come out of paper for CCW direction

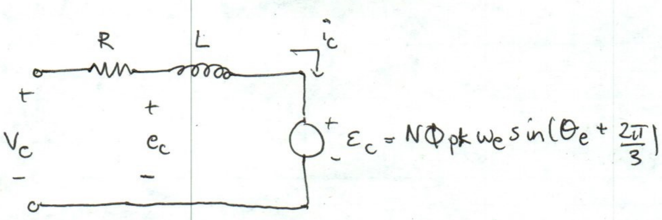
coil a: $-\frac{d}{dt}\lambda_a = -N\Phi_{pk}\omega_e \sin\theta_e - L\frac{d}{dt}i_a$

coil b: $-\frac{d}{dt}\lambda_b = -N\Phi_{pk}\omega_e \sin(\theta_e - \frac{2\pi}{3}) - L\frac{d}{dt}i_b$

coil c: $-\frac{d}{dt}\lambda_c = -N\Phi_{pk}\omega_e \sin(\theta_e + \frac{2\pi}{3}) - L\frac{d}{dt}i_c$



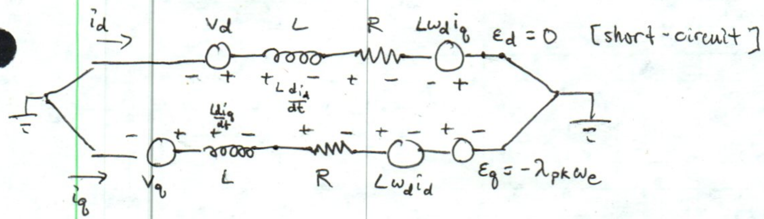




$$x_{dq} = \frac{2}{3}\Gamma_{dq}(\theta_d)\, x_{a,b,c}$$

c.) $$V_d = L\frac{d}{dt}i_d - L\omega_d i_q + R i_d + \mathcal{E}_d$$

$$V_q = L\frac{d}{dt}i_q + L\omega_d i_d + R i_q + \mathcal{E}_q$$



[power mechanical]

d.) $$P = -\frac{3}{2}N\Phi_{pk}\frac{p}{2}\omega_m i_q$$

P : power mechanical

p : poles

[torque] $$\tau = \frac{P}{\omega_m} = -\frac{3}{2}N\Phi_{pk}\frac{p}{2} i_q$$

e.) $\tau \propto -i_q$ Excite negative q-axis current

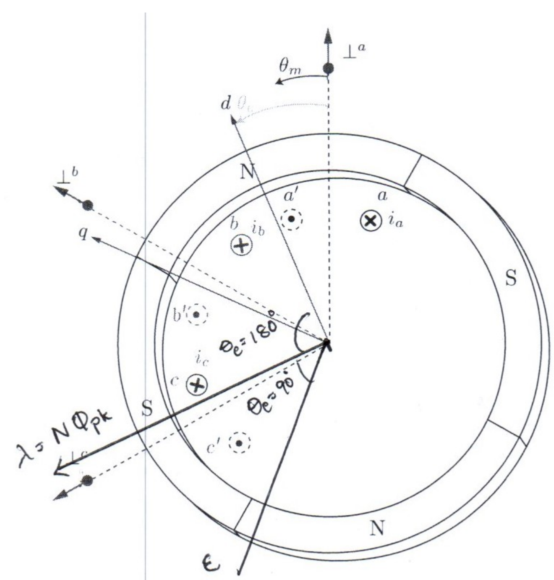


Figure 2: Magnetic ring with two pole pairs.

g.) For positive torque, must excite negative q axis current.

$\mathcal{E}$ leads 90° (CCW) rotor flux ($\lambda = N\Phi_{pk}$)

(h) Complete the table by filling the black spaces. CCW denotes counter-clockwise rotation of the rotor. Along which axis (d- or q-) should you excite a current and is the excited current positive, negative or zero, to ensure positive torque and hence positive power ($\omega_m > 0$ indicates counter-clockwise rotation). Assume q axis leads d axis and all angles are measured with respect to $\perp_a$ (as in class notation).

Orientation	Machine rotation	$i_d^\star(+,-,0)$	$i_q^\star(+,-,0)$
$\theta_d(t) = \theta_e(t) + \pi/2$	CCW	-	0
$\theta_d(t) = \theta_e(t) + \pi$	CCW	0	+
$\theta_d(t) = \theta_e(t) + 3\pi/2$	CCW	+	0
$\theta_d(t) = \theta_e(t)$	CW	0	+

(i) Now add the coils for the a,b and c phases for $180° < \theta_m < 360°$ and show the connection of those with the existing coils in Fig. 2 so that the back-emfs of these two coils add up. With these new coils, compare the power developed with the one you obtained in (d)

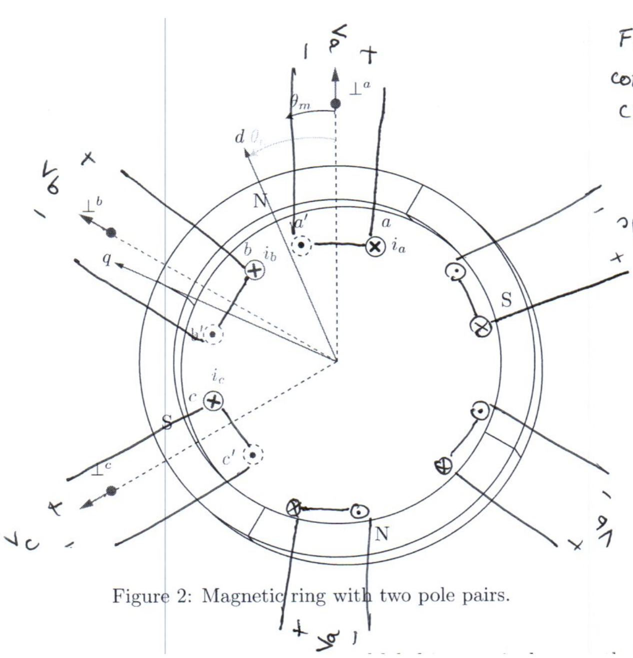
By superposition, the sum of the back emf seen at the coils is $2e_a$.

$$P = \underbrace{-\frac{3}{2} N\Phi_{pk}}_{2x} \frac{P}{2} \omega_m i_q$$

Power with coils from $0 < \theta_m < 360°$ is twice as large power from $0 < \theta_m < 180°$.

notation).

Flux linkage λ must come out of paper for CCW direction



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