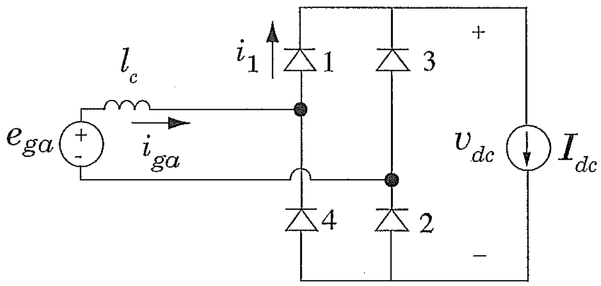
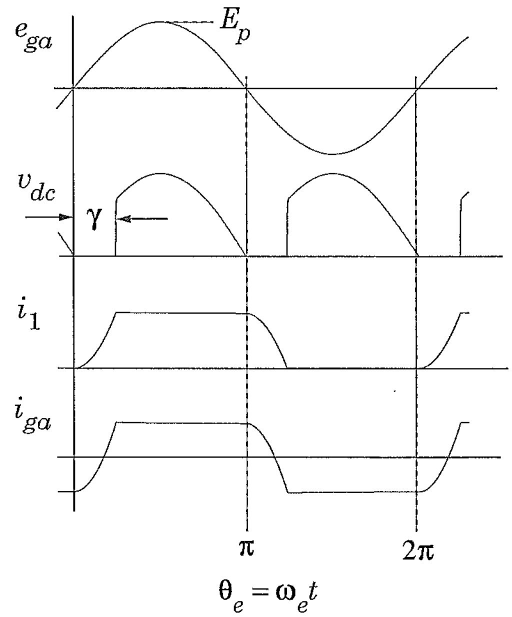
PE-3
August 2014 QE

1. Consider the single-phase full-bridge rectifier



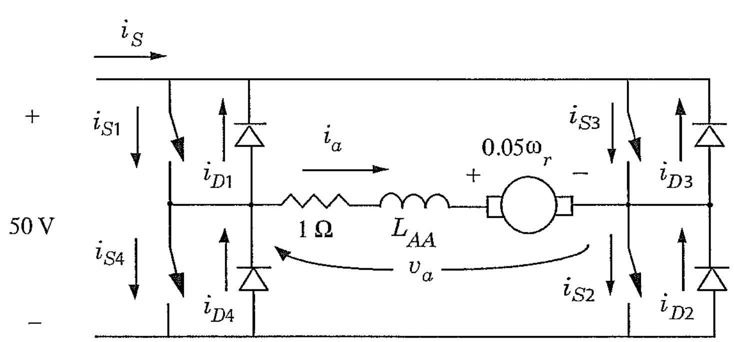


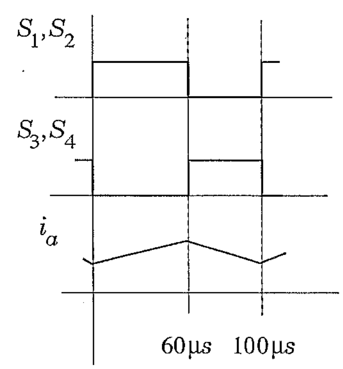
Assume the dc current I_{dc} is constant.

(a) Derive an expression for commutation angle γ in terms of E_p, ω_e, I_{dc}, and l_c.

(b) Derive an expression for the average dc voltage in terms of E_p and γ.

2. Consider the four-quadrant dc motor drive system



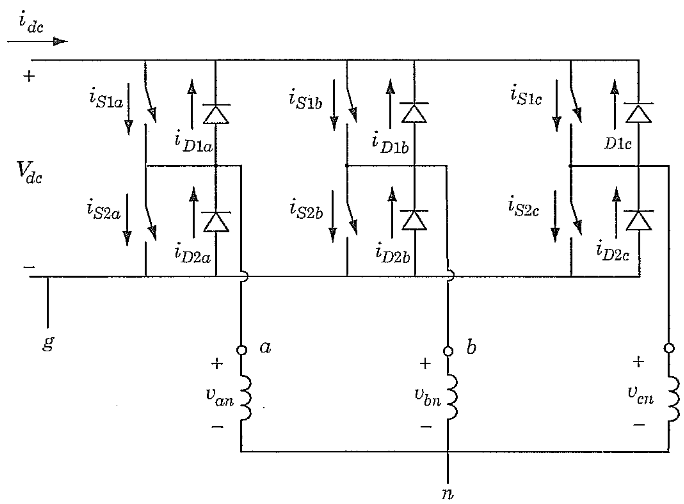


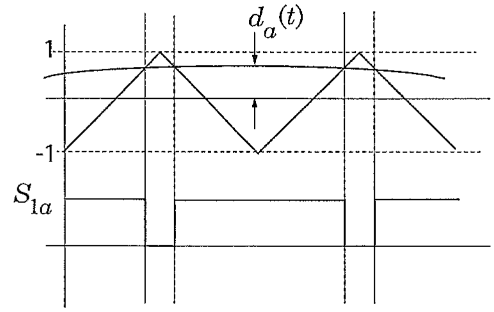
Assume switches and diodes are ideal.

(a) If $\omega_r = 100$ rad/s, establish average T_e.

(b) Suppose the minimum value of steady-state $i_a(t) = 4$ A, the maximum value of steady-state $i_a(t) = 6$ A, and $T \ll \tau$. Sketch steady-state $i_{S1}(t)$, $i_{D1}(t)$, and $i_S(t)$ for $0 < t < 100$ μs and approximate their average values.

3. Consider the three-phase drive system





(a) Assume S_{2a} is closed when S_{1a} is open and vice versa. A sine-triangle modulation strategy is used wherein the modulating (triangle) frequency is much larger than fundamental frequency ω_e. The duty cycle for each phase is

$$d_a(t) = d\cos\omega_e t \qquad d_b(t) = d\cos(\omega_e t - \tfrac{2\pi}{3}) \qquad d_c(t) = d\cos(\omega_e t + \tfrac{2\pi}{3}).$$

Express the "fast" or "moving" averages $\hat{v}_{ag}(t)$, $\hat{v}_{bg}(t)$, and $\hat{v}_{cg}(t)$ in terms of d, V_{dc}, and ω_e. Then, derive an expression for $\hat{v}_{an}(t)$. Assume the zero-sequence component of v_{an}, v_{bn}, and v_{cn} is zero.

(b) The duty cycle for each phase is

$$d_a = d\cos\theta_e - d_3\cos 3\theta_e \qquad d_b = d\cos(\theta_e - \tfrac{2\pi}{3}) - d_3\cos 3\theta_e \qquad d_c = d\cos(\theta_e + \tfrac{2\pi}{3}) - d_3\cos 3\theta_e.$$

Express $\hat{v}_{an}(t)$ in terms of d, d_3, and V_{dc}. What is the rationale for including third-harmonic injection d_3? If $d_3 = d/6$, what is the maximum value of d for which your expression for $\hat{v}_{an}(t)$ is valid?

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