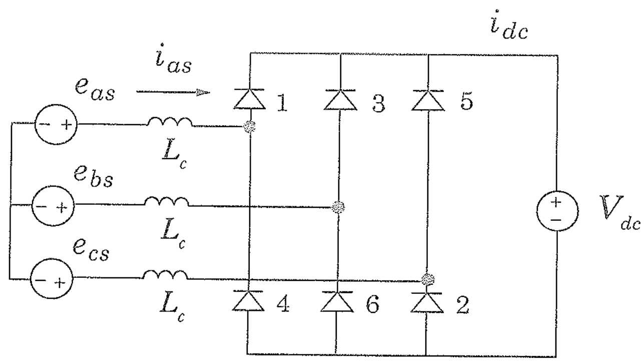
PE-3
August 2012 QE

$\left(33\frac{1}{3}\right)$ 1. A three-phase full-bridge rectifier is connected to an ideal voltage source (V_{dc}).

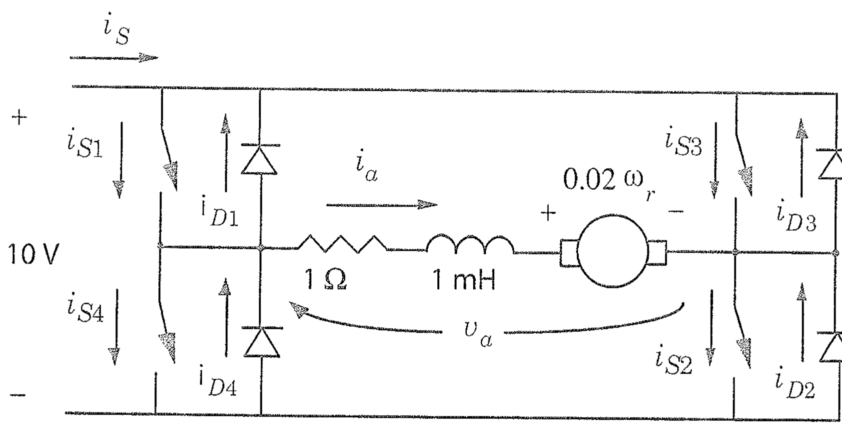


Let $e_{as} = E\cos\theta_e$, $e_{bs} = E\cos\left(\theta_e - \frac{2\pi}{3}\right)$, $e_{cs} = E\cos\left(\theta_e + \frac{2\pi}{3}\right)$ where $\theta_e = \omega_e t$.

(a) Assume valves 1 and 2 are on with all others off and that $i_{as}(0) = 0$. Express $i_{as}(\theta_e)$.

(b) Derive an expression (inequality) that defines the value of θ_e at which valve 3 begins to conduct (start of 1,2,3 inverval). You do NOT have to solve for θ_e.

$\left(33\frac{1}{3}\right)$ 2. Consider the four-quadrant chopper drive shown below. Assume all switches and diodes are ideal



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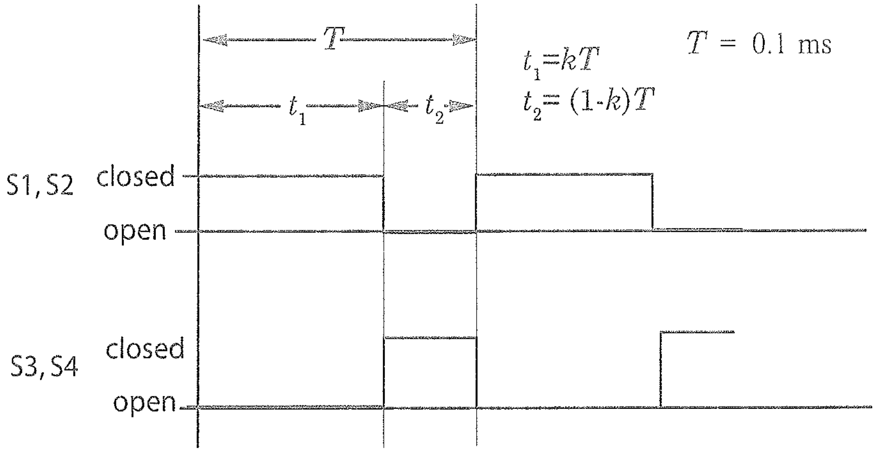
Assume steady-state operation.

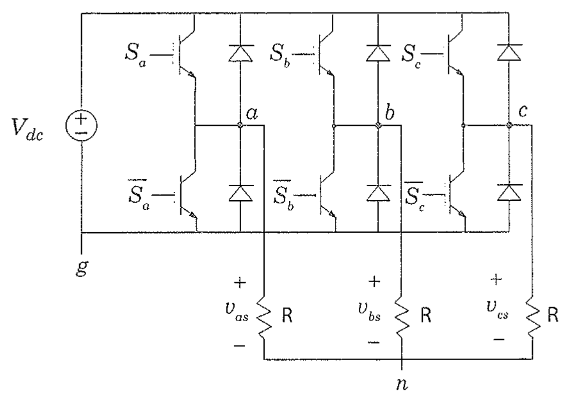


(a) If $k = 0.75$ and $\omega_r = 200$ rad/s, establish average T_e.

(b) If the current at the beginning of the t_1 interval is I_1, express $i_a(t)$ for this interval. Approximate the peak-to-peak armature current ripple ($I_2 - I_1$). Assume $T \ll L_{AA}/r_a$.

Hint: $e^{-x} \approx 1 - x$ for $x \ll 1$.

$\left(33\frac{1}{3}\right)$ 3. Consider the full-bridge inverter



The transformation to the stationary reference frame may be expressed

$$\begin{bmatrix} v_q^s \\ v_d^s \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} v_{ag} - v_{ng} \\ v_{bg} - v_{ng} \\ v_{cg} - v_{ng} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} v_{ag} \\ v_{bg} \\ v_{cg} \end{bmatrix}$$

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(a) Establish the value of v_q^s and v_d^s for each switching state. Assume $V_{dc} = \frac{3}{2}$ V.

Switching State	(S_a, S_b, S_c)	v_q^s	v_d^s
I	(000)		
II	(001)		
III	(010)		
IV	(011)		
V	(100)		
VI	(101)		
VII	(110)		
VIII	(111)		

(b) Consider an ideal three phase set $v_{an} = E\cos\theta_e$, $v_{bn} = E\cos\left(\theta_e - \frac{2\pi}{3}\right)$, $v_{cn} = E\cos\left(\theta_e + \frac{2\pi}{3}\right)$ where $\theta_e = \omega_e t$. Sketch the corresponding trajectory in the qs-ds plane. Superimpose and label (I through VIII) the achievable qs-ds voltages from (a) and describe how space vector modulation is used to approximate the ideal trajectory.