Solution Prob 9(a) Power Systems

i) $P_{load} = 500\text{ MW} = 5\text{ pu}$

$Q_{load} = 0 = 0\text{ pu}$

$$5 + j0 = -V\angle\theta \cdot I_L^*$$

$$= -V\angle\theta \left(\frac{V\angle\theta - 1}{.1j}\right)^* = -V\angle\theta\left(\frac{V\angle{-\theta} - 1}{-.1j}\right)$$

$$= \frac{V^2 - V\angle\theta}{.1j} = -10j\left(V^2 - V\cos\theta - V\sin\theta j\right)$$

$$= -10V^2 j + 10V\cos\theta j - 10V\sin\theta$$

So $P = -10V\sin\theta$ or $5 = -10V\sin\theta$

$Q = 10V(\cos\theta - V)$ So $V = \cos\theta$

Then $-.5 = V\sin\theta$ or $-.5 = \cos\theta\sin\theta$

Answer $\theta = -\pi/4$ or $-45°$

Then $V = .707$

ii) $I_{gen} = \dfrac{1 - V\angle\theta}{.1j}$

$$P_{gen} + jQ_{gen} = 1\left(I_L\right)^* = 1\left(\frac{1 - V\angle\theta}{-.1j}\right)$$

$$= \frac{1 - .707\left(\cos(+45°) + j\sin(+45°)\right)}{-.1j}$$

Prob 9a Solution

ii cont)

$$P_{gen} + jQ_{gen} = 10j(1 - .5 - .5j)$$

$$= 10j(.5 - .5j) = 5 + 5j$$

So $P_{gen} = 5$ or $P_{gen} = 500$ MW

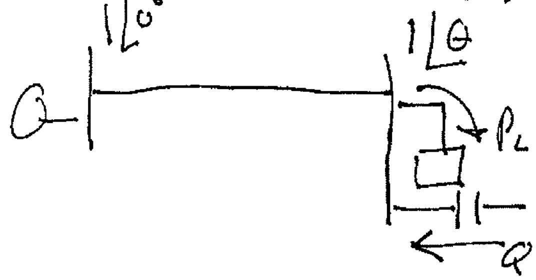
$Q_{gen} = 5$ $\quad$ $Q_{gen} = 500$ MVAR

iii) if $Q_{LOAD} = 0$ Then $Q_{gen} = Q_{Line} = 5pu = 500$ MVAR

also $I_L = \dfrac{1 - V\angle\theta}{.1j} = -10j(1 - .5 + .5j)$

$$= -10j + 5j + 5 = 5 - 5j$$

Then $Q_{Line} = (I_L)^2 X = (25 + 25).1 = 50(.1) = 5pu$

iv) 

let I_L = net current into Bus from load + cap.

$$I_L = \frac{1\angle\theta - 1}{.1j} = -10j(1\angle\theta - 1)$$

$$P_{net} + jQ_{net} = -1\angle\theta\left(\frac{1\angle\theta - 1}{.1j}\right)^* = \frac{1 - 1\angle\theta}{.1j}$$

$$= -10j(1 - 1\angle\theta)$$

Prob 9a Solution Cont.

iv) continued

$$P_{net} + jQ_{net} = -10j\left(1 - \left(\cos\theta + j\sin\theta\right)\right)$$

$$= -10j\left(1 - \cos\theta - j\sin\theta\right)$$

$$= -10j + 10j\cos\theta - 10\sin\theta$$

$P_{net} = 5 = -10\sin\theta$, $\sin\theta = -.5$, $\theta = -30^\circ$

$Q_{net} = -10 + 10\cos\theta = -10 + 10(.866) = -1.339$

Then the capacitor must inject 1.339 pu var

or 133.9 MVAR

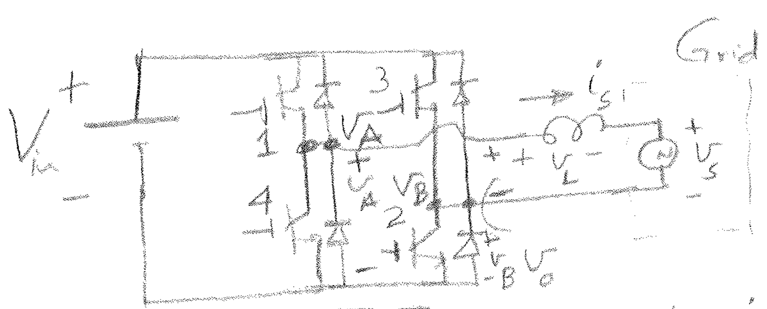
into the bus.

Solution of

November 10, 2012 **Problem 9(b)** <u>Power Electronics</u>

(2 pts) In a photovoltaic system, the voltage of the PV panel is first boosted to $250V$ across a capacitor. An inverter is used to interface this input dc voltage $V_{in} = 250V$ to the single-phase ac grid, whose sinusoidal voltage is $\bar{V}_s = 120\angle 0^0 V(rms)$ at 60 Hz. The power supplied to the grid is $500W$ at a unity power factor (assuming the ripple in the ac-side current to be negligible). At this operating condition, the inductor L_s between the inverter and the ac grid is such that the voltage drop across this inductor is $V_L = 5V(rms)$. Assume ideal components and the switching frequency to be much higher than 60 Hz.

Draw the inverter circuit consisting of IGBTs and diodes, label the IGBTs from one to four, and then calculate and draw the duty-ratios of the four IGBTs as a function of ωt. Label your graphs.



@ unity PF $\quad P = V_s I_s = 500W \quad \therefore I_s = \frac{500}{120} = 4.167\angle 0^\circ A$

$\bar{V}_L = j\omega L_s \bar{I}_s = 5.0\angle 90^\circ$

$\therefore \bar{V}_o = \bar{V}_s + \bar{V}_L = 120\angle 0 + 5.0\angle 90^\circ \simeq 120.1\angle 2.4^\circ V$

$\therefore v_o = 169.85 \cos(\omega t + 2.4^\circ)$

$\bar{v}_A = \frac{V_{in}}{2} + \frac{v_o}{2}, \quad \bar{v}_B = \frac{V_{in}}{2} - \frac{v_o}{2}$

$\therefore \bar{v}_A = 125 + 84.92 \cos(\omega t + 2.4^\circ) V$

$\bar{v}_B = 125 - 84.92 \cos(\omega t + 2.4^\circ)$

$\therefore d_1 = \bar{v}_A / V_{in} = \frac{1}{2} + \frac{84.92}{250}\cos(\omega t + 2.4^\circ) \simeq 0.5 + 0.34\cos(\omega t + 2.4^\circ)$

$d_3 = \bar{v}_B / V_{in} \simeq 0.5 - 0.34\cos(\omega t + 2.4^\circ); \quad d_2 = 1 - d_3 = d_1$

and $d_4 = 1 - d_1 = d_3$