

بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِیْمِ



King Saud University

College of Engineering

Electrical Engineering Department

Course Id : EE 340

Term : 271 (1427/1428)

Midterm Exam (1) : Tuesday 07/11/1427 – 28/11/2006

Time Allowed: 30 Minutes

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Section # : 1180



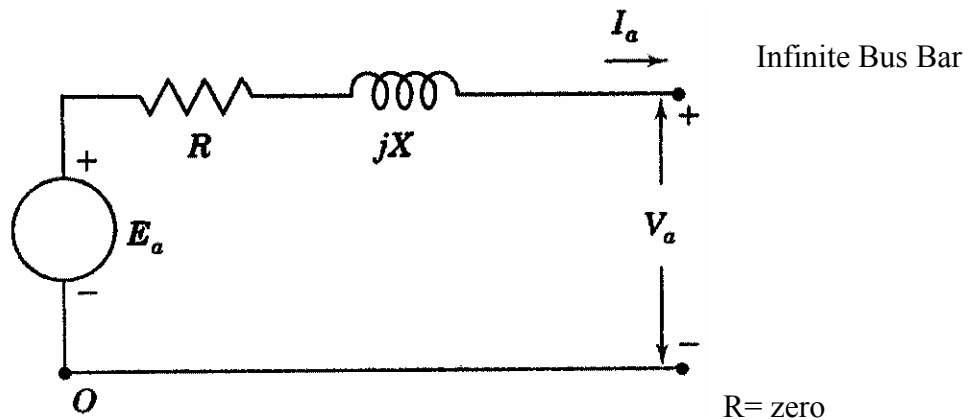
SOLUTION TO THE MAKEUP EXAM

Question : (20 Marks)

A three-phase, cylindrical rotor type synchronous generator, has negligible losses and synchronous reactance of 2.1Ω per phase. It is operated on an infinite bus having a voltage of 15 kV ((Assume as a reference.) and delivers 90 MVA at 0.8 power-factor lagging.

1. Determine :
 - a. The line current (2 points)
 - b. Generator internal voltage E (2 points)
 - c. Generator power angle δ . (2 points)
2. If the field current of the machine is reduced by 10%, while the mechanical power input to the machine is maintained constant, determine:
 - a. The new value of δ , (6-points)
 - b. The reactive power delivered to the system. (8-points).

Solution:



$$(a) : \text{Rated gen. current} = \frac{90 \cdot 10^6}{\sqrt{3} \cdot 15 \cdot 10^3} = 3,464.1 \angle -36.87^\circ \text{ Amp.}$$

$$V_a \angle 0^\circ = E_a \angle \delta - I_a \angle \theta * X \angle 90^\circ \quad (\text{all per phase quantities})$$

$$E_a \angle \delta = \frac{15 \cdot 10^3}{\sqrt{3}} \angle 0^\circ + 3,464.1 \angle -36.87^\circ * 2.1 \angle 90^\circ = 14,266.05 \angle 24.08^\circ$$

(b)

As the field current is reduced by 10%, then the induced e.m.f. of the generator get reduced by the same value (i.e. 10%) with new power angle, the system will have new operating condition. It was stated in the problem that the machine input is maintained constant

- The objective of this question is to show the relation of power with the values of voltages.

- It is worth mentioning that it has had direct relation to Q. whereas the mechanical input to the generator has direct relation to the P.

$$|E_a| = 0.9 * 3464.1 = 12,839.44 \angle \delta_{new}$$

$$S = P + jQ \quad P = 90 * 0.8 = 72 \text{ MW (constant)}$$

$$S = V I_a^*$$

$$I_a = \frac{|E_a| \angle \delta - |V| \angle 0}{jX} \quad \Rightarrow I_a^* = \frac{|E_a| \angle -\delta - |V| \angle 0}{-jX}$$

$$S = |V| \frac{|E_a| \angle -\delta - |V| \angle 0}{-jX}$$

P = Real Part of S

$$P = \frac{|V| |E_a|}{X} \sin \delta = 72 \text{ MW} \quad \dots\dots\dots(1)$$

$$Q = \frac{|V|}{X} (|E_a| \cos \delta - |V|) \quad \dots\dots\dots(2)$$

$$\sin \delta = \frac{72 * 2.1}{3 * 8.660 * 12.839.44} = 0.4555 \Rightarrow \sin^{-1}(0.4555) = 26.955$$

$$\therefore \delta = 26.96$$

Another way: Since the output power is the same, and |V| constant; then from equation (1), one can get:

$$P = \frac{|V| |E_{a1}|}{X} \sin \delta_1 = \frac{|V| |E_{a2}|}{X} \sin \delta_2 \quad \text{from which}$$

$$\sin \delta_2 = \frac{\sin \delta_1 * 1}{0.9} = \frac{\sin(24.08)}{0.9} = 0.4533 \Rightarrow \delta_2 = 26.955^\circ, \text{ substitute in (2)}$$

$$Q_{new} = \frac{8660}{2.1} ((12,839.44) * \cos 26.96 - 8660) = 11,479,831 \text{ var s}$$

$$Q_{3\text{-phase}} = 3 * 11,479,831 = 34,439,493 = 34.4 * 10^6$$