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~~[illegible]~~ EEE 326

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A 25kVA, 415V, three-phase, 4-pole, 60Hz - wye-connected synchronous generator has a synchronous reactance of 1.5Ω/phase and negligible stator resistance. The generator is connected to an infinite bus (of constant voltage magnitude and constant frequency) at 415V and 60Hz.

a) Determine the excitation voltage, E_a when the machine is delivering rated kVA at 0.8 PF lagging

$$E_a = V_\phi - jI_a X_s \quad \therefore V_L = 415V;\ S = 25kVA = 25000VA$$

$$V_\phi = \frac{V_L}{\sqrt{3}} = \frac{415}{\sqrt{3}} = 239.6V$$

$$X_s = 1.5\Omega;\ PF = 0.8 \text{ lagging} \therefore \theta = \cos^{-1}(-0.8) = 143.13^\circ$$

$$I_a = \frac{S}{V_L\sqrt{3}} = \frac{25000}{415\cdot\sqrt{3}} = 34.78A \angle 143.13^\circ$$

$$\therefore E_a = 239.6 - j[(34.78\angle 143.13^\circ)(1.5)]$$

$$E_a = 270.9 + j41.74$$

$$E_a = 274.098V \angle 8.76^\circ$$

(b) The field excitation current I_f is increased by 20% without changing the power input from the prime mover. Find the stator current I_a, power factor and reactive power Q supplied by the machine.

$$\therefore 20\% \text{ increase} = 1 + 0.2 = 1.2$$

$$\delta = 8.76^\circ$$

$$E_a' = 1.2 \times 274.078 = 328.92V$$

$$\therefore V_\phi E_a \sin\delta = V_\phi E_a' \sin\delta' \quad \therefore \sin\delta' = \frac{E_a \sin\delta}{E_a'} \Rightarrow \frac{274.08 \times \sin 8.76^\circ}{328.92V}$$

$$\sin\delta' = 0.1267 \quad \therefore \delta' = \sin^{-1}(0.1267)$$

$$\delta' = 7.29^\circ$$

(i) $$I_A' = \frac{E_a' - V_\phi}{jX_s} = \frac{328.92\angle 7.29 - 239.6\angle 0}{j1.5} = 27.82 - j57.77$$

$$I_A' = 64.134\angle -64.28^\circ$$

(ii) Power factor $= \cos(-64.28^\circ) = 0.434$ lagging.

h) $Q = 3 V_t I_a \sin\theta = 3 \times 239.6 \times 64.13 \times \sin(64.28) = 41529.65 \text{ VAR}$

i) With the field excitation current as in part (c), the input power from the prime mover is increased very slowly. What is the steady state limit? Determine stator current, power factor and reactive power at max power.

At max power $\delta = 90°$

$$P_{max} = \frac{3 E_a V_t}{X_s} = \frac{3 \times 274.098 \times 239.6}{1.5} = 131347.76 \text{ W} = 131.347 \text{ kW}$$

$$I_{amax} = \frac{E_a - V_t}{j X_s} = \frac{274.098\angle 90° - 239.6\angle 0}{1.5j} = 242.71\angle 41.16°$$

Power factor $= \cos(41.16°) = 0.7529$ leading

$Q_{max} = 3 V_t I_{amax} \sin(41.16°)$

$3 \times 239.6 \times 242.71 \times 0.6582 = 114829.54 \text{ VAR} = 114.829 \text{ kVAR}$