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EEE 326

A 25KVA, 415, Three Phase, 4-Pole 60Hz, Wye-Connected Synchronous generator has a synchronous reactance of 1.5 Ω/phase and negligible stator reactance. The generator is connected to an infinite bus (or constant voltage magnitude and constant frequency) of 415V and 60Hz.

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

$$E_a = V_t - jI_aX_s \quad ; \quad V_l = 415V, \quad S = 25KVA = 25000\,VA$$

$$V_t = V_l/\sqrt{3} = \frac{415}{\sqrt{3}} = 239.6V$$

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

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

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

$$E_a = 270.90 + j41.74$$

$$E_a = 274.0.98V \angle 8.76^\circ$$

b) The field excitation current I 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 applied by the machines

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

$$\delta = 8.76^\circ$$

$$E_a' = 1.2 \times 274.098 = 328.92V$$

$$\therefore \frac{V_t E_a \sin\delta}{X_s} = \frac{V_t E_a' \sin\delta'}{X_s} \quad \therefore \sin\delta' = \frac{E_a}{E_a'} \sin\delta$$

$$\Rightarrow \frac{274.098}{328.92V} \sin 8.76^\circ$$

$\sin\delta' = 0.1269 \quad \therefore \delta = \sin^{-1}(0.1269)$

$\delta' = 7.29°$

i) $I_a' = \dfrac{E_a' - V_t}{jX_s} = \dfrac{328.92\angle 7.29° - 239.6\angle 0}{j1.5}$

$= \dfrac{328.92\angle 7.29° - 239.6\angle 0}{j1.5} = 27.82 - j57.77$

ii) Power factor $= \cos(-64.28°) = 0.434$ lagging

iii) $Q = 3V_t I_a \sin\theta = 3 \times 239.6 \times 64.13 \times \sin(64.28) = 41529.65$ VAR

c) With the field excitation current I_f as in part (a), the input power from the prime mover is increased very slowly. what is the ~~Steady~~ Steady State limit? Determine Stator current I_a, Power factor and reactive Power Q.

At max power $\delta = 90°$

$P_{max} = \dfrac{3E_a V_t}{X_s} = \dfrac{3 \times 274.098 \times 239.6}{1.5} = 131347.76 KW = 131.347 KW$

$I_{max} = \dfrac{E_a - V_t}{jX_s} = \dfrac{274.098\angle 90° - 239.6\angle 0}{1.5j} = 249.71A\angle 41.16°$

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

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

$= 3 \times 239.6 \times 242.71 \times 0.6582 = 114929.54$ VAR

$\Rightarrow 114.829$ KVAR