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EEE326 MECH ENG

A 25KVA, 415v, three-phase, 4-pole, 60Hz, wye connected synchronous generator has a synchronous reactance of 1.5Ω/phase and negligible stator reactance. The generator is connected to an infinite bus (of 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

$$E_a = V_t - jI_aX_s \qquad \therefore V_L = 415V,\ S = 25KVA = 25000VA$$

$$V_t = \frac{V_L}{\sqrt{3}} = \frac{415}{\sqrt{3}} = 239.6v$$

$X_s = 1.5Ω \quad \therefore PF = 0.8$ lagging $\therefore \theta = Cos^{-1}(-0.8) = 143.13°$

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

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

$$E_a = 270.90 + j41.74$$

$$E_a = 274.098V \angle 8.76°$$

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 applied by the machines

$\therefore$ 20% increase $= 1 + 0.2 = 1.2$

$\delta = 8.76°$

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

$$\therefore \frac{V_t E_a \sin\delta}{X_s} = \frac{V_t E_a' \sin\delta'}{X_s} \quad \therefore \sin\delta' = \frac{E_a}{E_a'}\sin\delta \Rightarrow \frac{274.098}{328.92V} \times \sin 8.76°$$

$$\sin\delta' = 0.1269 \quad \therefore \delta = \sin^{-1}(0.129)$$

$$\delta' = 7.29°$$

i) $$I_a' = \frac{E_a' - V_t}{jX_s} = \frac{328.92\angle 7.29° - 239.6\angle 0}{j1.5} = 27.82 - j57.77.$$

$I_A = 69.13A \angle -64.28°$

a) Power factor $= \cos(-64.28°) = 0.439$ Leading

b) $Q = 3V_t I_a \sin\theta = 3 \times 239.6 \times 69.13 \times \sin(64.28) = 41589.65$ 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 state load? Determine stator current I_A, power factor and reactive power Q.

At max power, $\delta = 90°$

$$P_{max} = \frac{3E_f V_t}{X_s} = \frac{3 \times 274.098 \times 239.6}{1.5} = 181347.76\,W = 131.347\,kW$$

$$I_{max} = \frac{E_f - V_t}{jX_s} = \frac{274.098 \angle 90° - 239.6 \angle 0°}{1.5j} = 84.71A \angle 41.16°$$

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

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

$= 3 \times 239.6 \times 342.71 \times 0.6582 = 114827.54$ VAR $= 114.827$ KVAR