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17/ENG06/042

MECHANICAL ENGINEERING

A 25KVA, 415V, threephase, 4 pole, 60Hz wire-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 0·8pf lagging

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

$$V_t = \frac{V_L}{\sqrt{3}} = \frac{415}{\sqrt{3}} = 239{\cdot}6V$$

$$X_s = 1{\cdot}5\Omega \; ; \; PF = 0{\cdot}8 \text{ lagging}; \; \therefore \theta = \cos^{-1}(-0{\cdot}8) = 143{\cdot}13°$$

$$I_a = \frac{S}{V_L\sqrt{3}} = \frac{25000}{415\sqrt{3}} = 34{\cdot}78A \angle 143{\cdot}13°$$

$$\therefore E_a = 239{\cdot}6 - j[(34{\cdot}78\angle 143{\cdot}13°)(1{\cdot}5)]$$

$$E_a = 270{\cdot}90 + j41{\cdot}74$$

$$E_a = 274{\cdot}098V \angle 8{\cdot}76°$$

(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 supplied by the machines.

$\therefore$ 20% increased $= 1 + 0{\cdot}2 = 1{\cdot}2$

$\delta = 8{\cdot}76°$

$E_a' = 1{\cdot}2 \times 274{\cdot}098 = 328{\cdot}92V$

$$\therefore \frac{V_t E_a}{X_s}\sin\delta = \frac{V_t E_a' \sin\delta'}{X_s} \; \therefore \sin\delta' = \frac{E_a}{E_a'}\sin\delta \rightarrow \frac{274{\cdot}098 \times \sin 8{\cdot}76}{328{\cdot}92V}$$

$$\sin\delta' = 0{\cdot}1269 \; \therefore \delta = \sin^{-1}(0{\cdot}1269)$$

$$\delta = 7{\cdot}29°$$

(1) $$I_A' = \frac{E_a' - V_t}{jX_s} = \frac{328{\cdot}92\angle 7{\cdot}29° - 239{\cdot}6\angle 0}{j1{\cdot}5} = 27{\cdot}82 - j57{\cdot}77$$

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

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

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 limit? Determine stator current I_A, power factor and reactive power Q

At max power $\delta = 90^\circ$

$$P_{max} = \frac{3E_a V_t}{X_s} = \frac{3 \times 274.098 \times 239.6}{1.5} = 131347.79\text{W} = 131.347\text{W}$$

$$I_{max} = \frac{E_a - V_t}{jX_s} = \frac{274.098\angle 90^\circ - 339.6\angle 0}{1.5j} = 242.71\text{A} \angle 41.16^\circ$$

Power factor $= \cos(41.16^\circ) = 0.7529$ leading

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

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

$= 114829.54\text{VAR}$

$= 114.829\text{kVAR}$