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17/ENG06/045
MECHANICAL ENGINEERING
EEE 326

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

$E_a = V_t - j I_a X_s$; $V_L = 415V$, $S = 25kVA = 25000\,VA$

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

$X_s = 1.5\Omega$; 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 $= 1 + 0.2 = 1.2$

$\delta = 8.76°$

~~$E_a' = 239.6 - j[(34.78\angle 143.13°)(1.5)]$~~

~~$E_a = 270.90 + j41.74$~~

~~$E_a = 274.098V \angle 8.76°$~~

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

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

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

$\delta' = 7.29°$

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

$I_A' = 64.13A \angle -64.28°$

(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 if 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 $\delta = 90°$

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

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

Power factor = cos(41.16°) = 0.7529 leading

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

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