Name – Ikpeama John
Dept – Elect/Elect
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Electric Machines
EEE 326

A 25kVA, 415V, three phase, 4-pole, 60Hz, wye connected synchronous generator has a synchronous reactance of 1.5Ω/phase, and negligible stator machines 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.

b) The field excitation current I_f, 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.

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.

Solution

$S_r = 25kVA$ $V_L = 415V$

3ϕ, 4-Pole $\cos\theta$ (pf) $= 0.8$ lagging

(a) $E_a = V_t + jX_s\bar{I}_a + R_s\bar{I}_a$

$= V_t + jX_s\bar{I}_a$

$\cos\theta = 0.8$

$\theta = 36.87$

$V_L = 415$ $V_p = \frac{415}{\sqrt{3}}$

$= 239.6\angle 0$

$\bar{I}_a = \frac{S_r}{\sqrt{3} \times V_L} = \frac{25 \times 10^3}{\sqrt{3} \times 415} = 34.78\angle -36.87$

$$E_a = V_p + jX_s I_a$$
$$= 239.6 + 1.5\angle 90^\circ \times 34.98\angle -36.87$$
$$= 270.9 + j41.74$$
$$= 274.09\angle 8.76^\circ \text{ V}$$

(b) $E_1 \sin\delta_1 = E_2 \sin\delta_2$

$$\sin\delta_2 = \frac{E_1 \sin\delta_1}{E_2}$$
$$= \frac{274.1 \sin 8.76}{328.92}$$
$$\sin\delta_2 = 0.127$$
$$\delta_2 = 7.47^\circ$$

$$\bar{I}_a = \frac{E_a - V}{jX_s}$$

$$\bar{I}_A = \frac{E_{a_2} - V_t}{jX_s}$$

$$E_{a_2} = 1.2 \times E_a = 1.2 \times 274.1$$
$$= 328.92$$

$$\bar{I}_A = \frac{328.9\angle 7.47 - 239.6}{1.5\angle 90^\circ}$$

$$= 28.44 - j57.20$$

$$= 63.88\angle -63.6 \text{ A}.$$

(b)(ii) P.f = cos θ

= cos(−63.6)

= 0.4 lagging.

b(iii) $Q = \sqrt{3} \times V_L \times \overline{I}_L \times \sin\theta$

$= \sqrt{3} \times 415 \times 63.88 \times \sin 63.6$

$= 41128.41$

$= 41.1 \text{ KVAR}.$

(c) $\overline{I}_{A_3} = \dfrac{\Sigma a_3 - V}{jX_2}$

$= \dfrac{274.09\angle 90 - 239.6\angle 0}{1.5\angle 90^\circ}$

$= 182.72 + j\,159.73$

$\overline{I}_{A_3} = 242.7 \angle 41.2 \text{ A}.$

(c)(ii) $P.f = \cos\theta$

$= \cos(41.2)$

$= 0.75$ leading.

(c)(iii) $Q_2 = \sqrt{3} \times V_L \times \overline{I}_L \times \sin\theta$

$= \sqrt{3} \times 415 \times 242.7 \times \sin 41.2$

$= 114910.37$

$= 114.9 \text{ KVAR}.$