

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.

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

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

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

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

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

$$E_a = 270.90 + j41.74$$

$$E_a = 274.098V \angle 8.76^\circ$$

(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.

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

$$\delta = 8.76^\circ$$

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

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

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

$$\delta' = 7.29^\circ$$

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

$$I_a' = 64.13A \angle -64.28^\circ$$

$$\text{Power factor} = \cos(-64.28^\circ) = 0.434 \text{ lagging}$$

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

(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 $\delta = 90^\circ$.

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

$$X_s = 1.5$$

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

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

$$Q_{\max} = 3 V_t I_a^{\max} \sin(41.16^\circ)$$

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