A 200-MVA, 12-kV, 0.85-PF-lagging, 50-Hz, 20-pole, Y-connected water turbine generator has a per-unit synchronous reactance of 0.9 and a per-unit armature resistance of 0.1. This generator is operating in parallel with a large power system (infinite bus).

(a) What is the speed of rotation of this generator's shaft?

(b) What is the magnitude of the internal generated voltage E_A at rated conditions?

(c) What is the torque angle of the generator at rated conditions?

(d) What are the values of the generator's synchronous reactance and armature resistance in ohms?

(e) If the field current is held constant, what is the maximum power possible out of this generator? How much reserve power or torque does this generator have at full load?

(f) At the absolute maximum power possible, how much reactive power will this generator be supplying or consuming? Sketch the corresponding phasor diagram. (Assume I_F is still unchanged.)

Homework 11

(a) $n = \frac{120f}{P} = \frac{120 \times 50}{20} = 300$ r/min

(b) $\dot{V}_\phi = 1.0\angle 0^\circ$ pu , $\dot{I}_A = 1.0\angle -31.79^\circ$ pu

$\dot{E}_A = \dot{V}_\phi + R_A \dot{I}_A + jX_s \dot{I}_A$

$= 1\angle 0^\circ + (0.1)(1.0\angle -31.79^\circ) + j(0.9)(1\angle -31.79^\circ)$

$= 1.714\angle 24.55^\circ$ pu

$\dot{E}_A = 1.714\angle 24.55^\circ \times \frac{12\times10^3}{\sqrt{3}} = 11874\angle 24.55^\circ$

(c) $\delta = 24.55^\circ$

(d) $Z_{base} = \frac{3V_{\phi\,base}^2}{S_{base}} = \frac{3\times\left(\frac{12\times10^3}{\sqrt{3}}\right)^3}{200\times10^6} = 0.72$

$R_A = 0.1\times0.72 = 0.072\,\Omega$

$X_s = 0.9\times0.072 = 0.648\,\Omega$

(e) $P_{max} = \frac{3V_\phi E_A}{X_s}\sin\delta$

$= \frac{3\,\frac{12\times10^3}{\sqrt{3}}\times 11874}{0.648}\sin 90^\circ$

$= 380$ MW

$P = 200M\times0.85 = 170$ MW

$\frac{170}{380}\times100\% = 44.74\%$

(f) $\dot{E}_A = \dot{V}_\phi + R_A\dot{I}_A + jX_s\dot{I}_A$

$\dot{I}_A = \frac{\dot{E}_A - \dot{V}_\phi}{R_A + jX_s}$

$= \frac{11874\angle 90^\circ - \frac{12\times10^3}{\sqrt{3}}\angle 0^\circ}{0.072 + j0.648}$

$= 21085\angle 36.60^\circ$

$Q = 3V_\phi I_A \sin\theta$

$= 3\times\frac{12\times10^3}{\sqrt{3}}\times 21085\times\sin(-36.60^\circ)$

$= -261M$

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