SOLUTION

(a) The unsaturated synchronous reactance of this generator is the same at any field current, so we will look at it at a field current of 380 A. The extrapolated air-gap voltage at this point is 18.3 kV, and the short-circuit current is 1240 A. Since this generator is Y-connected, the phase voltage is $V_\phi = 18.3\text{ kV}/\sqrt{3} = 10{,}566\text{ V}$ and the armature current is $I_A = 1240\text{ A}$. Therefore, the *unsaturated* synchronous reactance is

$$X_{Su} = \frac{10{,}566\text{ V}}{1240\text{ A}} = 8.52\ \Omega$$

The base impedance of this generator is

$$Z_{\text{base}} = \frac{3\,V_{\phi,\text{base}}{}^2}{S_{\text{base}}} = \frac{3(7044\text{ V})^2}{25{,}000{,}000\text{ VA}} = 5.95\ \Omega$$

Therefore, the per-unit unsaturated synchronous reactance is

$$X_{Su,\text{pu}} = \frac{8.52\ \Omega}{5.95\ \Omega} = 1.43$$

(b) The saturated synchronous reactance at a field current of 380 A can be found from the OCC and the SCC. The OCC voltage at I_F = 380 A is 14.1 kV, and the short-circuit current is 1240 A. Since this generator is Y-connected, the corresponding phase voltage is $V_\phi = 14.1\text{ kV}/\sqrt{3} = 8141\text{ V}$ and the armature current is $I_A = 1240\text{ A}$. Therefore, the *saturated* synchronous reactance is

$$X_S = \frac{8141\text{ V}}{1240\text{ A}} = 6.57\ \Omega$$

and the per-unit unsaturated synchronous reactance is

$$X_{S,\text{pu}} = \frac{8.52\ \Omega}{5.95\ \Omega} = 1.10$$

(c) The saturated synchronous reactance at a field current of 475 A can be found from the OCC and the SCC. The OCC voltage at I_F = 475 A is 15.2 kV, and the short-circuit current is 1550 A. Since this generator is Y-connected, the corresponding phase voltage is $V_\phi = 15.2\text{ kV}/\sqrt{3} = 8776\text{ V}$ and the armature current is $I_A = 1550\text{ A}$. Therefore, the *saturated* synchronous reactance is

$$X_S = \frac{8776\text{ V}}{1550\text{ A}} = 5.66\ \Omega$$

and the per-unit unsaturated synchronous reactance is

$$X_{S,\text{pu}} = \frac{5.66\ \Omega}{5.95\ \Omega} = 0.951$$

(d) The rated voltage of this generator is 12.2 kV, which requires a field current of 275 A. The rated line and armature current of this generator is

$$I_L = \frac{25\text{ MVA}}{\sqrt{3}(12.2\text{ kV})} = 1183\text{ A}$$

The field current required to produce a short-circuit current of 1183 A is about 365 A. Therefore, the short-circuit ratio of this generator is

$$\text{SCR} = \frac{275\text{ A}}{365\text{ A}} = 0.75$$

(e) The internal generated voltage of this generator at rated conditions would be calculated using the saturated synchronous reactance, which is about $X_S = 6.57\ \Omega$ if the field current is 380 A. Since the power factor is 0.9 lagging, the armature current is $\mathbf{I}_A = 1183\angle -25.8°\text{ A}$. The phase voltage is $V_\phi = 12{,}200 / \sqrt{3}\angle 0°\text{ V} = 7044\angle 0°\text{ V}$. Therefore,

$$\mathbf{E}_A = \mathbf{V}_\phi + R_A\mathbf{I}_A + jX_S\mathbf{I}_A$$

$$\mathbf{E}_A = 7044\angle 0° + (0.60\ \Omega)(1183\angle -25.8°\ \text{A}) + j(6.57\ \Omega)(1183\angle -25.8°\ \text{A})$$

$$\mathbf{E}_A = 12{,}930\angle 31.2°\ \text{V}$$

(f) If the internal generated voltage is 12,930 V per phase, the corresponding line value would be $(12{,}930\ \text{V})(\sqrt{3}) = 22{,}400\ \text{V}$. This would require a field current of about 470 A.