A 25-MVA, 12.2-kV, 0.9-PF-lagging, three-phase, two-pole, Y-connected, 60-Hz synchronous generator was tested by the open-circuit test, and its air-gap voltage was extrapolated with the following results:

Open-circuit test

Field current, A	275	320	365	380	475	570
Line voltage, kV	12.2	13.0	13.8	14.1	15.2	16.0
Extrapolated air-gap voltage, kV	13.3	15.4	17.5	18.3	22.8	27.4

The short-circuit test was then performed with the following results:

Short-circuit test

Field current, A	275	320	365	380	475	570
Armature current, A	890	1040	1190	1240	1550	1885

The armature resistance is 0.6 Ω per phase.

(a) Find the unsaturated synchronous reactance of this generator in ohms per phase and in per-unit.

(b) Find the approximate saturated synchronous reactance X_S at a field current of 380 A. Express the answer both in ohms per phase and in per-unit.

(c) Find the approximate saturated synchronous reactance at a field current of 475 A. Express the answer both in ohms per phase and in per-unit.

(d) Find the short-circuit ratio for this generator.

(e) What is the internal generated voltage of this generator at rated conditions?

(f) What field current is required to achieve rated voltage at rated load?

Homework 9

(a) Phrase voltage : $V_{a\phi} = \frac{12.2}{\sqrt{3}} = 7.044\,kV$

$V_{a\phi-ag} = \frac{13.3}{\sqrt{3}} = 7.679\,kV$

$X_{su} = \frac{V_{a\phi-ag}}{I_{a,sc}} = \frac{7.679\times10^3}{890} = 8.628\,\Omega$

$Z_{base} = \frac{3V_{\phi,base}^2}{S} = \frac{3\times(7044)^2}{25\times10^6} = 5.954\,\Omega$

$\Downarrow$

$X_{su,pu} = \frac{8.628}{5.954} = 1.449$

(b) $X_s = \frac{V_{a\phi}'}{I_a'} = \frac{\frac{14.1\times10^3}{\sqrt{3}}}{1240} = 6.505\,\Omega$

per-unit : $X_{s,pu}' = \frac{6.505}{5.954} = 1.0925$

(c) $X_s = \frac{V_{a\phi}''}{I_a''} = \frac{\frac{15.2\times10^3}{\sqrt{3}}}{1550} = 5.662\,\Omega$

per-unit : $X_{s,pu}'' = \frac{5.662}{5.954} = 0.9509$

(d) O-C test : $12.2kV \rightarrow 275A$

$I_L = \frac{25\times10^6}{\sqrt{3}\times(12.2\times10^3)} = 1183A \Rightarrow SCR = \frac{275}{365} = 0.75$

S-C test : $1183A \rightarrow 365A$

(e) $\cos^{-1}(0.9) = 25.84°$, lagging

$\therefore I_a = 1183\angle -25.84°$

$V_{a\phi} = 7.044kV\angle 0°$

$E_A = V_{a\phi} + I_A(R_A + jX_s)$

$= 7044\angle 0° + 1183\angle -25.84°(0.6 + j6.505)$

$= 12868\angle 30.94°$

(f) Line voltage: $12868 \times \sqrt{3} = 22288\,V$

I_a: $22.288\,kV \longrightarrow 475\,A$