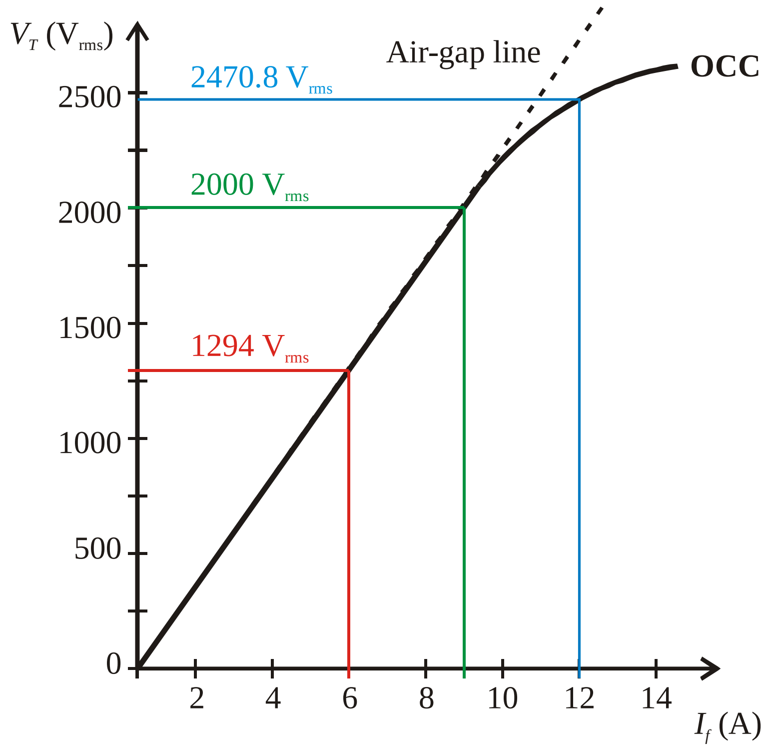
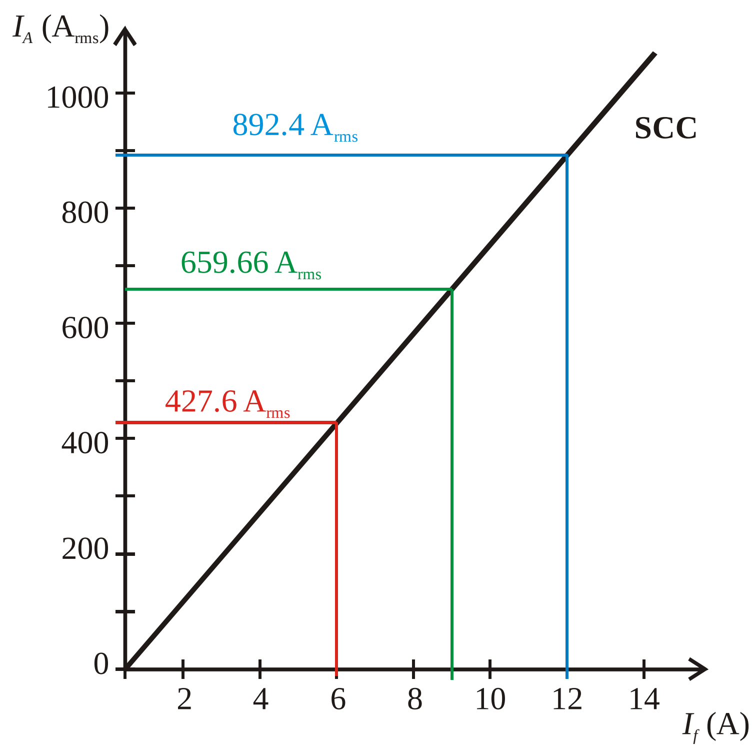
Example- A 1 MVA, 2.3 kVrms, 3-phase, Y-connected, 6-pole, 60 Hz, synchronous generator has the following open-circuit and short-circuit characteristics. The rated field current is 12 A. If a dc voltage of 12 V is applied to two terminals, a dc current of 20 A flows when the generator is at rest.





a) What mechanical speed of rotation is required?

From (4-34), $f_e = \dfrac{n_m P}{120} \quad \Rightarrow \quad n_m = \dfrac{120\, f_e}{P} = \dfrac{120(60)}{6} = 1200 \text{ RPM}$

b) What is the armature resistance?

Since generator is Y-connected, $R_{\text{terminal}} = 2R_A = \dfrac{V_{\text{dc}}}{I_{\text{dc}}} = \dfrac{12}{20} = 0.6\,\Omega$

$\Rightarrow R_A = 0.3\,\Omega$

c) At a field current of 6 A, what is the open-circuit phase voltage, short-circuit line current, and synchronous reactance & inductance?

From the OCC, $V_T = 1294$ V_{rms} at $I_f = 6$ A, for a Y-connection, then

$$V_{\phi,\text{OC}} = \frac{1294}{\sqrt{3}} = 747.1 \text{ V}_{\text{rms}}$$

From the SCC, $I_{A,\text{SC}} = 427.6$ A_{rms} at $I_f = 6$ A.

$$\sqrt{R_A^2 + X_S^2} = \frac{V_{\phi,\text{OC}}}{I_{A,\text{SC}}} = \frac{747.1}{427.6} = 1.7472$$

$$X_S^2 = 1.7472^2 - R_A^2 = (1.7472)^2 - 0.3^2 = 2.9627$$

$$X_S = \sqrt{2.9627} = 1.72\,\Omega$$

$$L_S = X_s / \omega = 1.72/(120\pi) = 4.57 \text{ mH}$$

d) Repeat c) for a field current of 9 A.

From OCC, $V_T = 2000$ V_{rms} at $I_f = 9$ A, for a Y-connection, then

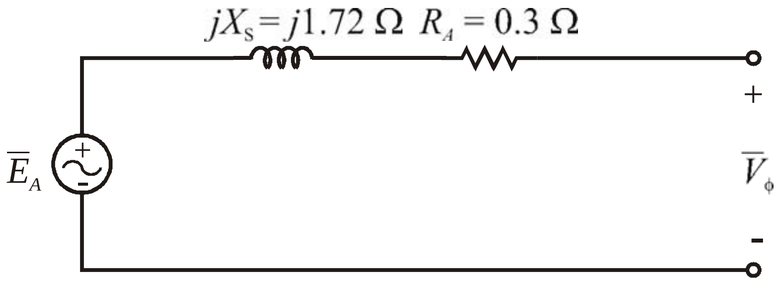
$$V_{\phi,\text{OC}} = \frac{2000}{\sqrt{3}} = 1154.7 \text{ V}_{\text{rms}}$$

From the SCC, $I_A = 659.66$ A_{rms} at $I_f = 9$ A.

$$\sqrt{R_A^2 + X_S^2} = \frac{V_{\phi,\text{OC}}}{I_{A,\text{SC}}} = \frac{1154.7}{659.66} = 1.75 \quad \Rightarrow \quad X_S^2 = 1.75^2 - 0.3^2 = 2.974$$

$X_S = 1.725\,\Omega$ and $L_S = X_s / \omega = 4.57 \text{ mH}$

$\Rightarrow$ Essentially no change in X_S (within measurement error)



Air-gap line equivalent circuit per phase

e) Repeat c) for a field current of 12 A.

From OCC, $V_T = 2470.8\ \text{V}_{\text{rms}}$ at $I_f = 12$ A, for a Y-connection, then

$$V_{\phi,\text{OC}} = \frac{2470.833}{\sqrt{3}} = 1426.5363\ \text{V}_{\text{rms}}$$

From the SCC, $I_A = 892.4\ \text{A}_{\text{rms}}$ at $I_f = 12$ A.

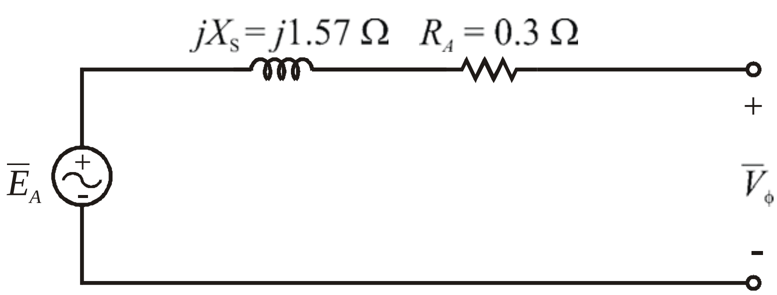
$$\sqrt{R_A^2 + X_S^2} = \frac{V_{\phi,\text{OC}}}{I_{A,\text{SC}}} = \frac{1426.5}{892.4} = 1.5985$$

$$X_S^2 = 1.5985^2 - 0.3^2 = 2.465$$

$$X_S = \sqrt{2.465} = 1.57\ \Omega$$

$$L_S = \frac{X_s}{\omega} = \frac{1.57}{2\pi(60)} = 4.165\ \text{mH}$$

⇒ ~9% change in X_S, the open-circuit voltage is leaving the air-gap line as the core saturates.



Equivalent circuit per phase for rated field current