Terminal voltage of the generator:

\[ V_a = \text{Terminal voltage} = E_a - r I_a - j X_s I_a \]

\[ I_a = \text{load current} \]
\[ X_s = (X_{st} + X_e) \]

Example 6.2

\[ V_a = 1.0 \quad X_s = 1.6 \quad r = 0.004 \quad I_a = 1 \angle -60^\circ \]

\[ E_a = 1.0 + 1 \angle -60^\circ \left[ 0.004 + j 1.6 \right] = 2.517 \angle 18.45^\circ \]

\[ S_m = \text{Angle between } V_a \text{ and } E_a \]

Now, if \( V_a = 0 \) [due to a short circuit]

Fault current \[ |I_{af}| = \left| \frac{E_a}{R + jX_s} \right| = 1.573 \angle -89.86^\circ \]

Power Delivered by Generator:

For round rotor (non-salient):

\[ S_G = \text{Complex power} = V_a I_a^* \]

\[ Z_G = R + jX_s \]
if \( R \ll X_s \)

\[
S_g = V_a \left( \frac{E_a - V_a}{jX_s} \right)^* 
\]

We need to use eqn 4.34 and 4.36 from the text.

\[
P_g = \frac{|E_a| \cdot |V_a|}{X_s} \sin \delta_m 
\]

\[
Q_g = \frac{|V_a| \left( |E_a| \cos \delta_m - |V_a| \right)}{X_s} 
\]

For salient pole generator:

Too complex, beyond the scope of this class.

Synchronous Generator connected to an infinite bus:

For an infinite bus,

\( V_{oo} = \text{Ideal Voltage Source} \)

Need to match 4 things to synchronize a generator:

(a) \( \left[ I_f g = \frac{f_{oo}}{|E_a| \cos \delta + j|E_a| \sin \delta} - V_a \right] \)

(b) Phase sequence

(c) Phase

(d) \( |V_a| = |E_a| = |V_{oo}| \)
During this condition, the generator is floating.

To increase the power flow from the generator, we need to increase the input mechanical power.

\[
\text{Mechanical power} \uparrow \Rightarrow \delta_m \uparrow
\]

where,

\[
\delta_m = L_{Ea} - L_{V_0}
\]

\( |E_a| \) will remain unchanged.

\[
I_a = \frac{E_a - V_{00}}{jX_s}
\]

We can change \( |E_a| \) (field excitation) to increase \( |E_a| \) this time, we are not changing the input mechanical power.

\[
P_o = \text{Power supplied by the generator} = \text{Input Mechanical power}
\]

\[
= \frac{|E_a| |V_0| \sin \delta_m}{X_s}
\]

So, if \( |E_a| \uparrow \Rightarrow \delta_m \downarrow \)
Synchronous condenser: \( \Rightarrow \) Generator working as a motor. 
Current flow from \( V_{oo} \) to \( E_a \), \( S_m = -V_e \)

\[ E_a \sin S_m \]

\[ E_{a1}, E_{a2}, E_{a3} \]

\[ I_{a1}, I_{a2}, I_{a3}, X_s \]

\[ \Theta = \text{angle between} \ I_a \ \text{and} \ V_{oo} \]